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Cross River Rail

Environmental Impact Statement

Construction Noise and Vibration

PART A

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SKM-Aurecon Joint Venture

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Cross River Rail

Environmental Impact Statement

Construction Noise and Vibration

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EXECUTIVE SUMMARY

1 INTRODUCTION

SLR Consulting Australia Pty Ltd (SLR Consulting) has been commissioned by the SKM-Aurecon CRR Joint Venture (CRR JV) to prepare an assessment of the noise and vibration aspects of the construction phase for Cross River Rail (CRR) for inclusion in the Environmental Impact Statement (EIS).

CRR is a major project for the City of Brisbane, South East Queensland and the State of Queensland. It will provide a new north-south rail line in Brisbane's inner city that includes a new river crossing and inner city train stations. From the existing southern rail network, it will pass under the central business district (CBD) of Brisbane and connect with the existing northern rail network via the Exhibition loop. The project will include a tunnel under the Brisbane River and four new underground stations as well as upgrades to existing train stations.

Please note that all table and figure numbers in this executive summary have been kept the same as the corresponding tables and figures in the main body of the text for ease of reference.

1.1 Terms of Reference

The specific requirements of the Terms of Reference in relation to operational noise and vibration impacts associated with the project are reproduced below.

- Description of Environmental Values
  - Describing the existing noise and vibration environment.
  - Conducting additional baseline noise and vibration monitoring at representative sites in accordance with the Department of Environment and Resource Management's (DERM) Noise Measurement Manual.
  - Identifying sensitive noise and vibration receptors adjacent to more significant project components (e.g. proposed tunnel alignment, station and tunnel portal locations).
  - Nominating appropriate performance indicators and standards with reference to the Environmental Protection (Noise) Policy 2008 (EPP(Noise)) and DERM's EcoAccess Guideline Planning for Noise Control, where appropriate.
- Potential Impacts and Mitigation Measures – Construction
  - Assess the levels of noise and vibration generated, including noise and vibration generated by tunnelling works, equipment, surface construction sites spoil haulage management, placement and management, construction vehicle movements and ancillary activities, with noise contours, assessed against current typical background levels, using modelling where appropriate.
  - Assess the impact of noise, including low frequency noise (noise with components below 200Hz) and vibration at all potentially sensitive receivers within and around the study corridor, including low frequency re-radiated noise within sensitive premises due to tunnel construction compared with the performance indicators and standards nominated above.
  - Assess potential effects of ground vibration on nearby surface buildings structure.
  - Identification of properties at significant risk of noise and vibration impacts for pre-construction building conditions.
  - Assess vibration impacts on transport-related infrastructure.

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- By adopting a hierarchical impact mitigation methodology develop proposals to minimise or eliminate these effects, including details of any screening, lining, enclosing or bunding of facilities, alternative construction methods or timing schedules for construction and operations that would minimise environmental harm and environmental nuisance from noise and vibration.

1.2 Objectives

The objectives of this report in relation to the project description are to:

- Address the acoustical requirements detailed in the project's Terms of Reference in relation to the construction phase of the project.
- Evaluate the construction noise and vibration impacts at sensitive locations in terms of planning levels identified in the EPP(Noise) and other standards and Guidelines.
- Define noise and vibration goals by which construction noise and vibration impacts at sensitive locations may be evaluated.
- Evaluate and assess the extent of resulting impacts and the scope for the reduction of these impacts through reasonable and feasible mitigation strategies.
- Recommend appropriate mitigation measures.

2 IMPACT ASSESSMENT GOALS

2.1 Community Values Relating to Noise and Vibration

The EPP(Noise) defines the values to be protected as the qualities of the acoustic environment that are conducive to:

a. Protecting the health and biodiversity of ecosystems.

b. Human health and wellbeing, including by ensuring a suitable acoustic environment for individuals to do any of the following-

   - Sleep
   - Study or learn
   - Be involved in recreation, including relaxation and conversation

c. Protecting the amenity of the community.

2.2 Noise Impact Assessment Goals

The Environmental Protection Act 1994 (The Act), Section 440R requires that a builder or building contractor not carry out building work on a building site in a way that makes or causes audible noise to be made from the building work:

a. On a Sunday or public holiday, at any time; or

b. On a Saturday or business day, before 6.30 am or after 6.30 pm.

This project would involve some instances where construction activity is required to be undertaken on a 24 hour basis and that would likely be audible outside the regulated construction hours. Accordingly, the project would require approval to operate outside the regulated hours.

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There are no established noise goals in Queensland for the assessment of impacts associated with long-term construction noise sources, especially at night. It is suggested that assessment goals for long-term construction noise sources should reflect the noise environment that is considered acceptable for normal functioning of adjoining developments (eg residential, healthcare, educational and commercial office uses).

Thus, the potential impacts of long-term construction noise sources have been assessed by comparison with the following noise goals:

1. Sleep disturbance criteria contained in Brisbane City Council's Noise Impact Assessment Planning Scheme Policy (NIAPSP) and DERM's Ecoaccess Guideline Planning for Noise Control (Ecoaccess PNC).
2. Recommended internal noise levels for various building uses specified in AS/NZS 2107: 2000 Acoustics – Recommended design sound levels and reverberation times for building interiors (AS 2107) for daytime construction.

The applicable noise goals for the typically short term ground-borne noise from driven tunnelling with Tunnel Boring Machine (potentially impacts for up to a week during TBM passby) are the sleep disturbance criteria (as above) and also the low frequency criteria according to the DERM Draft Ecoaccess Guideline Assessment of Low Frequency Noise (Ecoaccess ALFN).

A summary of applicable noise goals at noise sensitive receptors associated with the construction phase of the project is shown in **Table 8**.

Table 8 Summary of Construction Noise Goals

Construction Noise				**Blasting[1] Airblast**	**Surface Track Worksites Queensland Rail CoP**	**Construction Road Traffic**
Monday to Saturday	**Monday to Saturday (6.30pm to 6.30am); Sundays and Public Holidays**					
(6.30am – 6.30pm)	**Sleep Disturbance[2]**		**Low Frequency $L_{pA.LF}$[3]**			
	Continuous	**Intermittent**				
Steady State ($L_{Aeq,adj}$) Maximum Design Level according to AS 2107 **Non-Steady State** ($L_{A10,adj}$) Maximum Design Level according to AS 2107 + 10 dBA	35 dBA $L_{Aeq,adj(1hour)}$ (AS1055.2 Appendix A R1-R3 Categories) 40 dBA $L_{Aeq,adj(1hour)}$ (AS1055.2 Appendix A R4-R6 Categories)	45 dBA $L_{Amax,adj}$ (AS1055.2 Appendix A R1-R3 Categories) 50 dBA $L_{Amax,adj}$ (AS1055.2 Appendix A R4-R6 Categories)	25 dBA $L_{pA.LF}$	130 dB Linear Peak	87 dBA $L_{Amax,adj}$ 65 dBA $L_{Aeq,adj(24hour)}$	$\leq$ 2 dBA change in existing $L_{A10(1hour)}$, $L_{A10(12hour)}$ and $L_{A10(18hour)}$

Note 1: Blasting should generally only be permitted during the hours of 7 am to 6 pm, Monday to Saturdays
2: Sleep disturbance in accordance with AS2107 and BCC NIAPSP. Internal noise level in bedroom
3: Low frequency assessment in accordance with DERM EcoAccess ALFN. The A-weighted 1/3rd octave band data for indoors is summed to yield the A-weighted noise level in the frequency range 10 Hz to 160 Hz. The resulting level is called $L_{pA,LF}$.

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2.3 Vibration Impact Assessment Goals

Given a sufficiently high vibration level, potential adverse effects of vibration in buildings generated by construction activities can be divided into the following main categories of effect:

- Human comfort.
- Integrity of building contents.
- Integrity of building services.
- Cosmetic damage.

Vibration criteria are also differentiated between short transient vibrations, such as those induced by blasting (of the order of one to two seconds), and more sustained vibrations such as those associated with tunnel boring, roadheading or rockhammering. The risk of human discomfort is generally lower for short duration vibrations compared to sustained vibration. The risk of cosmetic building damage is also lower for short duration vibrations compared to continuous vibrations of the same magnitude. This is because short duration vibrations will be less likely to fully 'excite' resonant vibration responses in a building structure.

A summary of applicable vibration goals at sensitive receptors associated with the construction phase of the project is shown in **Table 16**.

Table 16 Construction Vibration Goals

Receiver Type	Cosmetic Damage		Human Comfort (mm/s PPV)		Sensitive Building Contents (mm/s PPV)
	Continuous Vibration (mm/s PPV)	Transient (Blasting[1]) Vibration (mm/s PPV)	Day	Night	
Residential	5	25 (> 35 Hz) 10 (< 35 Hz)	According to AS 2670 refer to **Table 10**	0.5 [2]	-
Commercial	5	25 (> 35 Hz) 10 (< 35 Hz)	According to AS 2670 refer to **Table 10**	-	0.5[3]
Heritage Listed	2	2	-	-	-

Note 1: Blasting should generally only be permitted during the hours of 7 am to 6 pm, Monday to Saturdays.
2: Residential sleep disturbance
3: Equipment specific vibration criteria is required for highly sensitive equipment (ie electron microscopes, MRI systems or similar), as part of future site-specific detailed investigations.

3 EXISITING NOISE AND VIBRATION ENVIRONMENT

3.1 Noise

Ambient noise monitoring was conducted at twenty (20) residential and special use (ie educational or medical) locations spaced at representative intervals along the study corridor. Both operator-attended and unattended ambient noise measurements have been conducted in order to document the existing noise environment with confidence. The measured ambient noise levels have been used (in part) to determine applicable project noise goals.

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The unattended ambient noise measurements were carried out to determine the Rating Background Levels (RBL) for the daytime (7.00 am to 6.00 pm), evening (6.00 pm to 10.00 pm) and night-time (10.00 pm to 7.00 am) periods at each location. The RBL is the median of the 90th percentile background (L_{A90}) noise levels in each assessment period (day, evening and night) over the duration of the monitoring (as defined in DERM's *Ecoaccess Guideline Planning for Noise Control*). **Table 18** presents the determined RBL for each measurement location.

Table 18 Measured Rating Background Levels

Monitoring Location	Rating Background Levels (RBL), LA90 (dBA)		
	Day	Evening	Night
1 1/19 Chalk St, Lutwych	54	45	38
2 28 Bridge St, Albion	49	45	38
3 St Josephs College, Spring Hill	50	48	40
4 Brisbane Girls Grammar, Spring Hill	61	60	46
5 St Andrews War Memorial Hospital, Spring Hill	55	53	51
6 Parkland Cres, Brisbane City	54	50	47
7 191 George St, Brisbane City	58	57	54
8 QUT Gardens Point, Brisbane City	49	48	46
9 58 Leopard St, Woolloongabba	53	50	46
10 143 Park Rd, Woolloongabba	43	39[1]	34
11 Dutton Park State School, Dutton Park	44	40	35
12 19 Dutton St, Dutton Park	43	42	37
13 4 Fenton St, Fairfield	39	38	34
14 17 Lagonda St, Annerley	42	41	39
15 Yeronga State High School, Yeronga	43[2]	41[2]	36[2]
16 3 Cardross St, Yeerongpilly	42	37	33
17 1223 Ipswich Mwy, Moorooka	53	48	46
18 2/59 Brooke St, Rocklea	50	43	42
19 Nyanda State High School, Salisbury	54	50	46
20 14 Bellevue Ave, Salisbury	45	45	44

Note 1: Has been adjusted for elevated noise levels due to insect noise.
Note 2: Background noise level representative of only one day of noise data, due to vandalism of the noise logger.

On review of the measured ambient noise levels, the statistical noise plots (**Appendix B**), the 1/3 octave band attended measurements and operator notes during attended measurements, only one location (143 Park Rd) evidenced the presence of atypical insect noise. The short periods (around 6.00 pm) dominated by insect noise at 143 Park Rd were excluded when determining the RBL in **Table 18** to generate a conservatively low (ie no insects present) background noise level.

It is expected that there would be periods during the year when ambient and background noise levels along the Project could be higher than those shown in **Table 18** due to the presence of insect noise.

It should be noted that the Brisbane Girls Grammar school has high ambient noise levels and is representative of a location close to a Motorway (Inner City Bypass) with no existing traffic noise barriers.

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High noise levels have also been monitored at St Andrew Hospital and 191 George Street. These are representative of typical inner city locations with high density road traffic, pedestrian activity and nearby building mechanical services noise.

Monitoring locations 10 through to 16 show lower ambient noise levels, representative of the locations with more suburban characteristics - ie larger distances from receivers to dominant noise sources. For most locations, including these suburban locations (somewhat) distant to major roads, road traffic noise still dominates background noise levels.

Furthermore, monitoring locations 1, 6, 9, 17 and 19 are near major connector roads and show higher ambient noise levels accordingly.

3.2 Vibration

Unlike noise, existing ambient vibration levels at residences and other sensitive buildings are not particularly relevant in the assessment of potential vibration issues. This is primarily because vibration impacts are assessed based on absolute criteria rather than criteria that are expressed relative to an existing ambient level. Never-the-less, existing vibration levels along the study corridor were measured to compare (if required) with vibration levels during the construction phase of the Project.

Ambient vibration monitoring was conducted at eleven (11) residential and special use (ie educational/research or medical facilities) locations along the study corridor.

The unattended ambient vibration measurements were used to determine the Average Minimum Background Level (V_{90}), Average Maximum Level (V_{10}) and Maximum Level (V_1) for the daytime (7.00 am to 6.00 pm), evening (6.00 pm to 10.00 pm) and night-time (10.00 pm to 7.00 am) periods at each location. **Table 20** contains the determined vibration levels for each measurement location. Graphs showing the peak particle velocity measured at each monitoring location during the monitoring period are presented in **Appendix D**.

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Table 20 Measured Existing Ambient Vibration

Monitoring Location	Average Minimum Background Vibration V_{90} (mm/s) [1]			Average Maximum Vibration V_{10} (mm/s) [2]			Maximum Vibration V_1 (mm/s) [3]		
	Day	Evening	Night	Day	Evening	Night	Day	Evening	Night
1 – Wooloowin (residence)	0.07	0.04	0.02	0.66	0.20	0.14	2.31	0.82	0.49
2 – Spring Hill (hospital)	0.04	0.04	0.04	0.05	0.05	0.05	0.08	0.05	0.05
3 – Spring Hill (office)	0.03	0.03	0.02	0.08	0.05	0.04	0.17	0.08	0.06
4 – Brisbane City (university)	0.04	0.04	0.03	0.06	0.05	0.04	0.07	0.07	0.06
5 – Brisbane City (residence)	0.02	-	-	0.02	-	-	0.03	-	-
6 – Kangaroo Point (residence)	0.01	0.01	0.01	0.04	0.14	0.02	0.16	0.57	0.16
7 – Woolloongabba (residence)	0.04	0.04	0.04	0.06	0.10	0.05	0.19	0.49	0.10
8 – Dutton Park (residence)	0.03	0.03	0.03	0.04	0.04	0.03	0.31	0.04	0.04
9 – Fairfield (residence)	0.04	0.06	0.04	0.70	0.84	0.23	2.69	1.61	0.71
10 – Fairfield (residence)	0.04	0.04	0.04	0.05	0.05	0.04	0.11	0.08	0.13
11 – Rocklea (residence)	0.10	0.04	0.03	0.30	0.22	0.21	1.50	0.50	0.35

Note 1: The V_{90} is the vibration velocity exceeded 90% of a given measurement period and is representative of the average minimum background vibration.

Note 2: The V_{10} is the vibration velocity exceeded 10% of a given measurement period and is utilised normally to characterise average maximum vibration.

Note 3: The V_1 is the vibration velocity exceeded for 1% of a given measurement period. This parameter is sometimes used to represent the maximum vibration in a given period. The absolute maximum peak particle velocity can be higher than this V1 as can be seen in **Appendix D**.

The background vibration level (V_{90}) varies between 0.01 mm/s to 0.1 mm/s during daytime and evening. During the night-time, the background vibration level (V_{90}) varies between 0.01 mm/s to 0.04 mm/s. Maximum vibration levels (V_1) for the residential monitoring locations were in the range of 0.11 mm/s to 2.69 mm/s during daytime and evening. During night-time, vibration levels (V_1) of 0.04 mm/s to 0.71 were measured.

It can be noted that high vibration levels have been monitored at locations 1, 9 and 11 which are on timber floors in residential dwellings. This shows that normal activities (ie closing doors, drawers and cupboards, walking, moving and sitting on furniture etc) in these residential dwellings with light-weight (timber) floors generate vibration levels significantly above the vibration goals presented in **Section 2.3**.

For receivers containing vibration sensitive equipment (locations 3 and 5), background vibration levels (V_{90}) of 0.02 mm/s to 0.03 mm/s and maximum vibration levels (V_1) of 0.03 mm/s to 0.17 mm/s, were measured.

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4 IDENTIFICATION OF NOISE SENSITIVE BUILDINGS

Apart from the residential dwellings that are in the vicinity of the CRR alignment, other noise/vibration sensitive receivers have been identified. These have been considered in this report when assessing the potential for impacts arising from airborne or ground-borne noise and vibration.

These include the following types of facilities:

- Medical Facilities
- Child Care and Educational
- Places of Worship
- Heritage
- Commercial
- Hotel

5 TUNNELLING WORKSITE NOISE AND VIBRATION ASSESSMENT

5.1 Noise Modelling

In order to quantify noise emissions from construction, a three-dimensional computer noise model was prepared for the major construction sites. The modelling was undertaken using the CONCAWE industrial noise algorithm as implemented in SoundPLAN acoustic modelling software. The model for these sites includes source noise emission levels, ground topography, location of sources and receivers, acoustic shielding provided by intervening ground topography and buildings, air absorption and ground effects.

The output from the SoundPLAN noise model is a predicted noise level external to the receiver building of interest. In order to compare the relevant internal noise goals with the external predicted noise levels, the internal goals were adjusted (ie increased) to an equivalent external free-field noise level. The adjustment was determined by the type of facade through which noise transmission would occur. For CRR, the facade adjustment methodology applied was consistent with the methodology contained in Ecoaccess PNC including:

- For residential type receivers, a +10 dBA inside to outside adjustment for windows partially open (7 dBA in the free-field).
- For commercial type receivers, a +20 dBA inside to outside adjustment for single glazed closed windows (17 dBA in the free-field).

For proposed CRR worksites there are negligible existing barriers between the site and noise sensitive receivers. Therefore it is anticipated that the construction of minor noise barriers to fully enclosed structures would result in the following reductions in noise levels:

- Minor noise barrier (acoustic hoarding indicative height 3 m) – 5 dBA to 10 dBA reduction.
- Major noise barrier (acoustic hoarding indicative height 6 m) – 10 dBA to 15 dBA reduction.
- Acoustic Enclosure – 15 dBA to 25 dBA reduction (based on the medium performance transmission loss data in **Table 24**).

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Correctly designed and constructed barriers (of solid construction using appropriate materials, such as 25 mm timber without gaps) would be expected to result in reductions at the upper end of the range provided. For the calculations at nearby receivers 'mid-range' noise reductions of 8 dBA, 13 dBA and 20 dBA have been assumed for the minor, major barriers and acoustic enclosure respectively.

5.2 TBM Launch Sites - Noise and Vibration Assessment

Assessment of the TBM launch sites at the Southern Portal, Yeerongpilly, and Woolloongabba Station, Woolloongabba, is contained in this section. Generally these sites will be constructed using 'cut and cover' methodology.

It is proposed to utilise the Woolloongabba Station worksite as the major spoil removal facility for the TBM drives north to the Northern Portal worksite and the Southern portal worksite as the major spoil removal facility for the TBM drives north to the Woolloongabba Station worksite.

Woolloongabba Station

The nearest noise and/or vibration sensitive receivers to the Woolloongabba Station TBM launch site are identified in **Table 32**.

Table 32 Nearest Sensitive Receivers – Woolloongabba Station

Work Site/Excavation	Receiver Area	Location Relative to Works (m)
Woolloongabba Station	A – Vulture Street Residential	125
	B – Vulture Street Commercial	60
	C – Vulture Street Residential	25
	D - St Nicholas Cathedral	25
	E – Main Street Commercial	150
	F – Main Street Commercial	150
	G – Vulture Street Commercial	15
	H – Stanley Street Commercial	60
	I – St Josephs Primary School	180

Scenarios were developed for Woolloongabba Station TBM launch site construction being representative of activities having potentially the greatest (ie worst case) noise impact on the surrounding receivers. Worst case scenarios have been developed based on all plant items, as proposed by the Project design team including haul trucks where applicable, operating simultaneously. These scenarios are:

- Scenario 1 – Demolition of Goprint building:
  - Duration ~ 6 weeks
  - Dominant noise sources include rockbreakers (4 off) and excavators.
  - Daytime construction only.
- Scenario 2 – Installation of perimeter piles:
  - Duration ~ 7 weeks
  - Dominant noise sources include piling rigs (4 off)
  - Daytime construction only

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- Scenario 3 – Shaft excavation in hard rock and spoil removal:
  - Duration ~ 7 weeks
  - Dominant noise sources include jumbo drill rigs (3 off), excavators and front end loaders
  - Potentially 24 hour per day construction if acoustic enclosure is in place
- Scenario 4 - TBM support operations including on-site spoil movements:
  - Duration ~ 61 weeks
  - Dominant noise sources include tunnel ventilation, front end loaders and haul trucks
  - 24 hour per day construction with night-time works carried out inside an acoustic enclosure

A scenario assessing the noise emission associated with the construction of an acoustic enclosure or construction of station infrastructure at the surface has not been included on the basis that noise levels during these stages are typically lower than levels experienced during the three stages described above, particularly if the structure is prefabricated and only assembled at the site.

For all construction scenarios, typical construction noise levels with 3 m acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 34**. An assessment of noise goal compliance is also provided in **Table 34** with indicative noise level reductions based on 6 m acoustic hoarding for all scenarios and works carried out inside an acoustic enclosure for Scenario 2 and 3. Note a “dash” (-) in the tables indicates compliance, and “n/a” not applicable for the assessment period.

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Table 34 Woolloongabba Station Predicted Worst Case Construction Noise Levels

Receiver Area	Scenario	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)		
					3 m Hoarding	6 m Hoarding	Enclosure
A – Vulture St Residential	1	Day	LA10,adj – 62	68 – 72	10	5	n/a
	2	Day	LA10,adj – 62	65 – 70	8	3	n/a
	3	Day	LA10,adj – 62	71 – 77	15	10	3
	4	Day	LAeq,adj – 52	59 – 65	13	8	1
	3	Night	LAmax,adj – 57	76 – 71	14	9	2
	4	Night	LAeq,adj – 47	58 – 64	17	12	5
B – Vulture St Commercial	1	Day	LA10,adj – 72	78 – 80	8	3	n/a
	2	Day	LA10,adj – 72	73 – 76	4	-	n/a
	3	Day	LA10,adj – 72	81 – 82	10	5	-
	4	Day	LAeq,adj – 62	70 – 72	10	5	-
C – Vulture St Residential	1	Day	LA10,adj – 62	67 – 77	15	10	n/a
	2	Day	LA10,adj – 62	57 - 73	11	6	n/a
	3	Day	LA10,adj – 62	65 – 74	12	7	-
	4	Day	LAeq,adj – 52	57 – 65	13	8	1
	3	Night	LAmax,adj – 57	60 – 72	15	10	3
	4	Night	LAeq,adj – 47	52 – 62	15	10	3
D - St Nicholas Cathedral	1	Any	LA10,adj – 57	75 – 77	20	15	n/a
	2	Any	LA10,adj – 57	70 - 73	16	11	n/a
	3	Any	LA10,adj – 57	74 – 76	19	14	7
	4	Any	LAeq,adj – 47	63 – 65	18	13	6
E – Main St Commercial	1	Day	LA10,adj – 72	48 – 67	-	-	n/a
	2	Day	LA10,adj – 72	45 – 61	-	-	n/a
	3	Day	LA10,adj – 72	44 – 64	-	-	-
	4	Day	LAeq,adj – 62	50 – 54	-	-	-
F – Main St Commercial	1	Day	LA10,adj – 72	47 – 58	-	-	n/a
	2	Day	LA10,adj – 72	43 - 56	-	-	n/a
	3	Day	LA10,adj – 72	46 – 59	-	-	-
	4	Day	LAeq,adj – 62	36 – 47	-	-	-
G – Vulture St Commercial	1	Day	LA10,adj – 72	68 – 77	5	-	n/a
	2	Day	LA10,adj – 72	47 – 72	-	-	n/a
	3	Day	LA10,adj – 72	63 – 74	2	-	-
	4	Day	LAeq,adj – 62	58 – 62	-	-	-
H – Stanley St Commercial	1	Day	LA10,adj – 72	64 - 76	4	-	n/a
	2	Day	LA10,adj – 72	59 – 73	1	-	
	3	Day	LA10,adj – 72	72 – 78	6	1	-
	4	Day	LAeq,adj – 62	62 – 68	6	1	-
I – St Josephs	1	Day	LA10,adj – 62	46 – 62	-	-	n/a

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Receiver Area	Scenario	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)		
					3 m Hoarding	6 m Hoarding	Enclosure
Primary School	2	Day	LA10,adj – 62	45 – 56	-	-	n/a
	3	Day	LA10,adj – 62	45 – 57	-	-	-
	4	Day	LAeq,adj – 52	40 – 54	2	-	-

Note 1 – LA10,adj and LAmax,adj (night-time) assessment parameters applicable for non-steady state and intermittent noise sources. LAeq,adj assessment parameter applicable to steady state noise sources.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Predicted ground-borne noise and vibration impacts for the excavation of the Woolloongabba Station shaft are presented in **Table 38**.

Table 38 Woolloongabba Station Predicted Ground-borne Noise and Vibration Levels

Receiver Area	Period	Noise and Vibration Goals		Predicted Ground-borne Noise and Vibration Levels (Rockbreaking)	
		Vibration PPV (mm/s)	Ground-borne Noise (dBA)[1]	Ground-borne Vibration (mm/s)	Ground-borne Noise (dBA)
A – Vulture Street Residential	Day	5	LA10,adj – 55	0.04	34
	Night	0.5	LAmax,adj – 50	0.04	39
B – Vulture Street Commercial	Day	5	LA10,adj – 65	0.07	43
C – Vulture Street Residential	Day	5	LA10,adj – 55	0.02	30
	Night	0.5	LAmax,adj – 50	0.02	35
D - St Nicholas Cathedral (Heritage Listed)	Day	2	LA10,adj – 50	0.02	29
E – Main Street Commercial	Day	5	LA10,adj – 65	0.01	24
F – Main Street Commercial	Day	5	LA10,adj – 65	0.01	24
G – Vulture Street Commercial	Day	5	LA10,adj – 65	0.03	33
H – Stanley Street Commercial	Day	5	LA10,adj – 65	0.08	44
I – St Josephs Church & School (Heritage Listed)	Day	2	LA10,adj – 50	0.01	25

Note 1: Dominant construction noise during shaft excavation likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameters are most relevant. For the ground-borne noise all noise levels are internal levels.

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The predicted noise levels for site establishment works including demolition of the existing GoPrint building at the Woolloongabba Station site indicate exceedances of up to 15 dBA of the noise goal for daytime operations at the nearest residential receivers along Vulture Street. Higher exceedances are expected at St Nicholas Cathedral due to the lower noise goal. Similar exceedances are predicted during the pile installation works (ie Scenario 2) which are anticipated to occur over a seven week period.

The predicted noise levels for shaft excavation and spoil storage (ie Scenario 3) occurring inside a medium performance acoustic enclosure at the Woolloongabba Station site indicate exceedances of up to 3 dBA during the day and 3 dBA during the night-time period at the nearest residential receivers. The predicted noise levels indicate that a minor (eg 1 mm thick metal cladding rather than 0.62 mm thick cladding) upgrade on the medium performance acoustic enclosure would be required to achieve compliance with the daytime and night-time noise goals.

Longer term activities at this site associate with the TBM support activities (ie Scenario 4) are also predicted to exceed the night-time residential noise goal at the nearest receivers. A further 5 dBA reduction in noise emission could be achieved through the following mitigation measures:

- High performance acoustic enclosure over the site.
- Quietest available mobile plant operating at the site.
- Temporary tunnel ventilation noise sources to be located down in the shaft with appropriate ducting to the surface. Silencers may be required depending on the type of ventilation used.
- Acoustic louvres at enclosure ventilation points.

With the above mitigation measures in place combined with careful management of all heavy vehicle movements on the site, compliance with the noise goals during all time periods could be achieved at the Woolloongabba Station site with the exception of initial demolition works which cannot be reasonably and feasibly mitigated to achieve compliance with the daytime noise goal.

The predicted gound-borne noise and vibration levels in **Table 38** indicate compliance with the relevant goals primarily due to the Woolloongabba Station worksite being bordered by existing roads and therefore set back from sensitive receivers.

The use of drill and blast as an excavation technique at Woolloongabba Station would be limited to a 12 kg MIC to comply with the 2 mm/s PPV vibration goal at St Nicholas Cathedral. An MIC limit of 12 kg indicates that blasting of the station shaft could be carried out with minimal risk of impact. Therefore, blasting would be a suitable excavation technique for this location.

Southern Portal

The nearest noise and/or vibration sensitive receivers to the Southern Portal site are identified in **Table 39**.

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Table 39 Nearest Sensitive Receivers – Southern Portal

Work Site/Excavation	Receiver Area	Location Relative to Works (m)
Southern Portal	A – St Fabien's Church	20
	B – Tees Street Residential	30
	C – Wilkie Street Residential	30
	D – Livingstone Street Residential	35
	E – Fairfield Road Residential	50
	F – Cardross Street Residential	80

Assessment of ground-borne noise and vibration associated with tunnel boring the initial section adjacent to the Southern Portal is covered in the assessment of mechanical tunnel excavation.

Scenarios were developed for Southern Portal construction works being representative of activities having potentially the greatest (ie worst case) noise impact on the surrounding receivers. Worst case scenarios have been developed based on all plant items, as proposed by the Project design team including haul trucks where applicable, operating simultaneously. These scenarios are:

- Scenario 1 – Demolition of existing buildings:
  - Duration ~ 6 weeks
  - Dominant noise sources include rockbreakers and excavators
  - Daytime construction only
- Scenario 2 – Pile installation along cut and cover and section of the trough:
  - Duration ~ 6 weeks
  - Dominant noise sources include piling rigs (3 off)
  - Mostly daytime construction and potentially weekend work during track possessions
- Scenario 3 - TBM support including spoil removal:
  - Duration ~ 68 weeks
  - Dominant noise sources include spoil trucks, front end loaders and tunnel ventilation
  - 24 hour per day construction with night-time works carried out inside an acoustic enclosure
- Scenario 4 – Night-time truck (eg spoil, delivery etc) movements within the site near the entrance:
  - Duration ~ 125 weeks
  - Dominant noise sources include trucks prior to exiting the site at Lucy Road
  - 24 hour per day movements through the site

For all construction scenarios, typical construction noise levels with 3 m acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 41**. An assessment of noise goal compliance is also provided in **Table 41** with indicative noise level reductions based on 6 m acoustic hoarding for all scenarios and works carried out inside an acoustic enclosure for Scenario 2 and 3. Note a "dash" (-) in the tables indicates compliance, and "n/a" not applicable for the assessment period.

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Table 41 Southern Portal Predicted Worst Case Construction Noise Levels

Receiver Area	Scenario	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dB)	Noise Goal Exceedance with level of Noise Mitigation (dBA)		
					3 m Hoarding	6 m Hoarding	Enclosure
A – St Fabien's Church	1	Day	LA10,adj – 57	76 – 86	29	24	n/a
	2	Day	LA10,adj – 57	67 – 70	13	8	n/a
	3	Day	LAeq,adj – 47	47 – 51	4	-	-
B – Tees Street Residential	1	Day	LA10,adj – 57	73 – 86	29	24	n/a
	2	Day	LA10,adj – 57	58 – 72	15	11	n/a
	3	Day	LAeq,adj – 47	42 – 52	5	-	-
	2	Night	LAmax,adj – 52	51 – 68	16	11	n/a
	3	Night	LAeq,adj – 42	42 – 52	10	5	-
	4	Night	LAmax,adj – 52	31 – 34	-	-	n/a
C – Wilkie Street Residential	1	Day	LA10,adj – 57	69 – 84	27	22	n/a
	2	Day	LA10,adj – 57	56 – 69	12	7	n/a
	3	Day	LAeq,adj – 47	40 – 62	15	10	3
	2	Night	LAmax,adj – 52	52 – 63	11	6	n/a
	3	Night	LAeq,adj – 42	40 – 62	20	15	8
	4	Night	LAmax,adj – 52	24 – 37	-	-	n/a
D – Livingstone Street Residential	1	Day	LA10,adj – 57	52 – 76	19	14	n/a
	2	Day	LA10,adj – 57	41 – 62	5	-	n/a
	3	Day	LAeq,adj – 47	44 – 61	14	9	2
	2	Night	LAmax,adj – 52	40 – 48	-	-	n/a
	3	Night	LAeq,adj – 42	44 – 61	19	14	7
	4	Night	LAmax,adj – 52	31 - 53	1	-	n/a
E – Fairfield Road Residential	1	Day	LA10,adj – 62	69 – 76	14	9	n/a
	2	Day	LA10,adj – 62	62 – 72	10	5	n/a
	3	Day	LAeq,adj – 52	47 – 53	1	-	-
	2	Night	LAmax,adj – 57	58 – 70	13	8	n/a
	3	Night	LAeq,adj – 47	47 – 53	6	1	-
F – Cardross Street Residential	1	Day	LA10,adj – 57	61 – 68	11	6	n/a
	2	Day	LA10,adj – 57	48 – 62	5	-	n/a
	3	Day	LAeq,adj – 47	36 – 47	-	-	-
	2	Night	LAmax,adj – 52	43 – 58	6	1	n/a
	3	Night	LAeq,adj – 42	36 – 47	5	-	-

Note 1 – LA10,adj and LAmax,adj (night-time) assessment parameters applicable for non-steady state and intermittent noise sources. LAeq,adj assessment parameter applicable to steady state or continuous (night-time) noise sources.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

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The predicted noise levels for site establishment works including demolition of Wilkie Street and adjacent residences at the Southern Portal site indicate exceedances of up to 29 dBA of the noise goal for the daytime period. The large noise goal exceedances result from the use of rockbreakers in close proximity to receivers. It is anticipated that rockbreakers would be used intermittently during the six week site clearing phase of the Project.

It is recommended that demolition of residences nearest to the railway line occur first so that the buildings closest to the resumption extents act as a barrier for residences located beyond the property impact area, particularly if large rockbreakers are required to break up concrete slabs and/or footings.

It is understood that short-term night-time work would be required during earthworks immediately adjacent to the operational rail line. The predicted night-time noise levels for Scenario 2 reflect this activity, which indicate that exceedances of up to 16 dBA would be anticipated with just 3 m acoustic hoarding as noise mitigation. Where practicable, it is recommended that these works be carried out during weekend rail possessions and preferably during the daytime only. If night-time construction work is required, consideration should be given to the early installation of part of if not the entire acoustic enclosure to provide significant noise attenuation.

The predicted noise levels for spoil removal (during TBM operation) at the Southern Portal site indicate exceedances of up to 20 dBA during the night-time period at the nearest residential receivers. The predicted noise levels indicate that a high performance acoustic enclosure would be required to comply with the night-time noise goals.

The results of the SoundPLAN noise modelling for this site indicate that a hierarchy of noise controls would be required in order for the site to operate continuously whilst maintaining full compliance with the noise goals for the duration of the project. The hierarchy of controls would likely be in the form of:

- Where practicable, relocate plant inside the cut and cover tunnel.
- Selection and maintenance of quietest available plant.
- Mitigating each acoustically significant item of plant required to operate within the enclosure (eg residential grade mufflers on all front end loaders).
- Subsequent to the above measures, detailed design of a high performance acoustic enclosure, which may include double skin walls and roof lined with sound absorptive material, minimising openings and fitting acoustic louvres to ventilation openings. Access and ventilation openings should be constructed on the western facade of the enclosure away from residences.
- If necessary, mitigating noise at individually affected receivers through property treatments (eg mechanical ventilation, glazing upgrades etc).

Spoil movements within the site during the night-time period achieve compliance with the sleep disturbance noise goal as a result of the shielding being afforded by the existing warehouses at the site in combination with a 4 m high acoustic hoarding adjacent to the site entrance at Lucy Street.

The movement of trucks within the worksite should be designed to limit (as much as possible) the need for reversing activity and noise from reversing alarms. Where issues with reversing alarms occur, consideration should be given to the use of broadband “buzzer” reversing alarms and/or alarms which actively vary their volume according to the ambient noise levels during activation - rather than constant volume (tonal) “beeping” alarms.

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With the above mitigation measures in place combined with careful management of all heavy vehicle movements on the site, compliance with the noise goals during all time periods could be achieved at the Southern Portal site with the exception of initial demolition works and work requiring a rail possession which cannot be reasonably and feasibly mitigated to achieve compliance with the daytime noise goal.

Cumulative construction noise impacts from the Yeerongpilly Transit Oriented Development (TOD) site have not been assessed as the construction programs for both projects are yet to be finalised. Nonetheless, should the projects coincide it would be anticipated that cumulative construction noise impacts (daytime only) would be mostly limited to receivers located on the western side of the rail corridor north of the Yeerongpilly TOD site (ie Ortive Street). A large number of noise sensitive receivers located on the eastern side of the rail corridor would be shielded to the TOD worksite by the CRR acoustic enclosure. If required, mitigation of cumulative construction noise from the two projects should be considered during the detailed design stage.

Regarding construction noise impacts of the Project onto the Yeerongpilly TOD, predicted noise levels have not been assessed as the TOD masterplan for the entire site is yet to be finalised. Construction noise emission levels for future ground floor receivers at the TOD site can be interpreted from the noise contours presented in **Appendix G**.

Tunnel Portals – Noise and Vibration Assessment

Assessment of construction impacts associated with the Southern Portal was covered in the TBM Launch Sites section of this executive summary.

Northern Portal

The nearest noise and/or vibration sensitive receivers to the Northern Portal site are identified in **Table 45**.

Table 45 Nearest Sensitive Receivers – Northern Portal

Work Site/Excavation	Receiver Area	Location Relative to Works (m)
Northern Portal	A – Gregory Terrace Residential	230
	B – St Josephs College	150
	C – Centenary Aquatic Centre	25
	D – Gregory Terrace Residential	130
	E – Gregory Terrace Commercial	150
	F – Gregory Terrace Residential	170
	G – Bowen Bridge Road Commercial	20

Assessment of ground-borne noise and vibration associated with roadheading the initial section of Northern Portal is covered in the assessment of mechanical tunnel excavation.

Scenarios were developed for Northern Portal construction works being representative of activities having potentially the greatest (ie worst case) noise impact on the surrounding receivers. Worst case scenarios have been developed based on all plant items, as proposed by the Project design team including haul trucks where applicable, operating simultaneously. These scenarios are:

- Scenario 1 - Site establishment:
  - Duration ~ 4 weeks

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- Dominant noise sources include excavators and front end loaders
- Daytime construction only
- Scenario 2 - Trough excavation and spoil removal:
  - Duration ~ 5 weeks
  - Dominant noise sources include jumbo drill rigs and excavators
  - Daytime construction only
- Scenario 3 - TBM disassembly:
  - Duration ~ 15 weeks
  - Dominant noise sources include cranes and heavy vehicles
  - Daytime construction only

For all construction scenarios, typical construction noise levels with 3 m acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 47**. An assessment of noise goal compliance is also provided in **Table 47** with indicative noise level reductions based on 6 m acoustic hoarding for all scenarios and works carried out inside the cut and cover structure for Scenario 3. Note a "dash" (-) in the tables indicates compliance, and "n/a" not applicable for the assessment period.

Table 47 Northern Portal Predicted Worst Case Construction Noise Levels

Receiver Area	Scenario	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)		
					3 m Hoarding	6 m Hoarding	Enclosure
A – Gregory Terrace Residential	1	Day	$L_{A10,adj}$ – 57	56 – 59	2	-	n/a
	2	Day	$L_{A10,adj}$ – 57	54 – 58	1	-	n/a
	3	Day	$L_{A10,adj}$ – 57	48 – 54	-	-	-
B – St Josephs College	1	Day	$L_{A10,adj}$ – 62	48 – 62	-	-	n/a
	2	Day	$L_{A10,adj}$ – 62	48 – 60	-	-	n/a
	3	Day	$L_{A10,adj}$ – 62	44 – 57	-	-	-
C – Centenary Aquatic Centre	1	Day	$L_{A10,adj}$ – 72	64 – 83	11	6	n/a
	2	Day	$L_{A10,adj}$ – 72	67 – 74	2	-	n/a
	3	Day	$L_{A10,adj}$ – 72	66 – 72	-	-	-
D – Gregory Terrace Residential	1	Day	$L_{A10,adj}$ – 57	59 – 64	7	2	n/a
	2	Day	$L_{A10,adj}$ – 57	59 – 64	7	2	n/a
	3	Day	$L_{A10,adj}$ – 57	53 – 61	4	-	-
E – Gregory Terrace Commercial	1	Day	$L_{A10,adj}$ – 72	46 – 58	-	-	n/a
	2	Day	$L_{A10,adj}$ – 72	49 – 61	-	-	n/a
	3	Day	$L_{A10,adj}$ – 72	47 – 58	-	-	-
F – Gregory Terrace Residential	1	Day	$L_{A10,adj}$ – 62	47 – 56	-	-	n/a
	2	Day	$L_{A10,adj}$ – 62	50 – 60	-	-	n/a
	3	Day	$L_{A10,adj}$ – 62	45 – 57	-	-	-

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Receiver Area	Scenario	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)		
					3 m Hoarding	6 m Hoarding	Enclosure
G – Bowen Bridge Road Commercial	1	Day	LA10,adj – 72	54 – 72	-	-	n/a
	2	Day	LA10,adj – 72	57 – 70	-	-	-
	3	Day	LA10,adj – 72	53 – 61	-	-	-

Note 1 – LA10,adj and LAmax,adj (night-time) assessment parameters applicable for non-steady state and intermittent noise sources.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

The predicted noise levels for the three construction scenarios at the Northern Portal site indicate relatively small exceedances of the relevant noise goals at the nearest residential receivers due to the buffer distance between the worksite and residences. Higher noise goal exceedances are expected at commercial receivers located on the western side of Gregory Terrace.

The predicted noise levels in **Table 47** suggest that increasing the proposed 3 m acoustic hoarding along the eastern boundary to a 6 m acoustic hoarding should achieve compliance with the noise goals at all sensitive receivers except for the Centenary Aquatic Centre (6 dBA exceedance) and the nearest Gregory Terrace residences (marginal 2 dBA exceedance). Impacts to these receivers could be managed through use of quietest available construction plant and consultation. Regarding Scenario 2 impacts, as the excavation plant progress deeper into the portal structure, construction noise emission levels at Gregory Terrace (residential receivers) would be anticipated to approach compliance with the noise goal.

The movement of trucks within the worksite should be designed to limit (as much as practicable) the need for reversing and consequent reversing alarm noise. Where issues with reversing alarms occur, consideration should be given to the use of broadband "buzzer" reversing alarms and/or alarms which actively vary their volume according to the ambient noise levels during activation - rather than constant volume (tonal) "beeping" alarms.

Station Construction Noise and Vibration Assessment

Roma Street Station

The nearest noise and/or vibration sensitive receivers to the Roma Street Station site are identified in **Table 50**.

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Table 50 Nearest Sensitive Receivers – Roma Street Station

Work Site/Excavation	Receiver Area	Location Relative to Works (m)
Roma Street Station	A – Wickham Terrace Commercial	150
	B – St Alban Liberal Catholic Church	125
	C – Wickham Terrace Residential	120
	D – Wickham Terrace Commercial	140
	E – Brisbane Private Hospital	130
	F – Brisbane Dental Educational	100
	G – Turbot Street Commercial	40
	H – Roma Street Station Commercial[1]	10
	I – Holiday Inn Residential	50
	J - Parkland Crescent Residential	150

Note 1 – Receiver includes Brisbane Transit Centre and Roma Street Station platforms of which the southern building is heritage listed.

Scenarios were developed for Roma Street Station construction works being representative of activities having potentially the greatest (ie worst case) noise impact on the surrounding receivers. Worst case scenarios have been developed based on all plant items, as proposed by the Project design team including haul trucks where applicable, operating simultaneously. These scenarios are:

- Scenario 1 – Site establishment including demolition:
  - North shaft duration ~ 6 weeks
  - Central shaft duration ~ 10 weeks
  - South shaft duration ~ 6 weeks
  - Dominant noise sources include excavators and cranes
  - Mostly daytime construction works with potential for night-time work to avoid impact on existing rail operations
- Scenario 2 – Piling of access shafts:
  - North shaft duration ~ 8 weeks
  - Central shaft duration ~ 6 weeks
  - South shaft duration ~ 4 weeks
  - Dominant noise sources include piling rigs
  - Mostly daytime construction works with potential for night-time work to avoid impact on existing rail operations
- Scenario 3 – Shaft excavation:
  - North shaft duration ~ 12 weeks
  - Central shaft duration ~ 20 weeks
  - South shaft duration ~ 10 weeks
  - Dominant noise sources include jumbo drill rigs, excavators and front end loaders
  - 24 hour per day construction with night-time works carried out inside an acoustic enclosure at the south shaft

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For all construction scenarios, typical construction noise levels with 3 m acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 52**. An assessment of noise goal compliance is also provided in **Table 52** with indicative noise level reductions based on 6 m acoustic hoarding for all scenarios and works carried out inside an acoustic enclosure (southern worksite only) for Scenario 3. Note a “dash” (-) in the tables indicates compliance, and “n/a” not applicable for the assessment period.

Table 52 Roma Street Station Predicted Worst Case Construction Noise Levels

Receiver Area	Scenario	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)		
					3 m Hoarding	6 m Hoarding	Enclosure
A – Wickham Terrace Commercial	1	Day	LA10,adj – 72	49 – 51	-	-	n/a
	2	Day	LA10,adj – 72	51 – 52	-	-	n/a
	3	Day	LA10,adj – 72	48 – 50	-	-	-
B – St Alban Liberal Catholic Church	1	Day	LA10,adj – 57	46 – 50	-	-	n/a
	2	Day	LA10,adj – 57	49 – 52	-	-	n/a
	3	Any	LA10,adj – 57	45 – 49	-	-	-
C – Wickham Terrace Residential	1	Day	LA10,adj – 62	47 – 57	-	-	n/a
	2	Day	LA10,adj – 62	49 – 58	-	-	n/a
	3	Day	LA10,adj – 62	46 – 57	-	-	-
	1	Night	LAmax,adj – 57	52 – 62	5	-	n/a
	2	Night	LAmax,adj – 57	54 - 63	6	1	n/a
	3	Night	LAmax,adj – 57	51 – 62	5	-	-
D – Wickham Terrace Commercial	1	Day	LA10,adj – 72	46 – 57	-	-	n/a
	2	Day	LA10,adj – 72	45 – 64	-	-	n/a
	3	Day	LA10,adj – 72	44 – 57	-	-	-
E – Brisbane Private Hospital	1	Any	LA10,adj – 67	46 – 55	-	-	n/a
	2	Any	LA10,adj – 67	48 – 56	-	-	n/a
	3	Any	LA10,adj – 67	45 – 55	-	-	-
F – Brisbane Dental Educational	1	Day	LA10,adj – 62	45 – 54	-	-	n/a
	2	Day	LA10,adj – 62	45 – 55	-	-	n/a
	3	Day	LA10,adj – 62	44 – 53	-	-	-
G – Turbot Street Commercial	1	Day	LA10,adj – 72	51 – 70	-	-	n/a
	2	Day	LA10,adj – 72	54 – 72	-	-	n/a
	3	Day	LA10,adj – 72	54 – 71	-	-	-
H – Roma Street Station Commercial	1	Day	LA10,adj – 65	62 - 79	14	9	n/a
	2	Day	LA10,adj – 65	64 - 77	12	7	n/a
	3	Day	LA10,adj – 65	63 - 76	11	6	-
I – Holiday Inn Residential	1	Day	LA10,adj – 62	62 – 72	12	7	n/a
	2	Day	LA10,adj – 62	63 – 72	10	5	n/a
	3	Day	LA10,adj – 62	62 – 71	9	4	-
	1	Night	LAmax,adj – 57	67 – 77	20	15	n/a

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Receiver Area	Scenario	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)		
					3 m Hoarding	6 m Hoarding	Enclosure
	2	Night	LAmax,adj – 57	68 – 77	20	15	n/a
	3	Night	LAmax,adj – 57	67 – 76	19	14	7
J – Parkland Crescent Residential	1	Day	LA10,adj – 62	52 – 58	-	-	n/a
	2	Day	LA10,adj – 62	54 – 58	-	-	n/a
	3	Day	LA10,adj – 62	52 – 57	-	-	-
	1	Night	LAmax,adj – 57	57 – 63	6	1	n/a
	2	Night	LAmax,adj – 57	59 – 63	6	1	n/a
	3	Night	LAmax,adj – 57	57 – 62	5	-	-

Note 1 – LA10,adj and LAmax,adj (night-time) assessment parameters applicable for non-steady state and intermittent noise sources. LAeq,adj assessment parameter applicable to steady state or continuous (night-time) noise sources.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Predicted ground-borne noise and vibration impacts for the excavation of Roma Street Station access shafts are presented in **Table 55**.

Table 55 Roma Street Station Predicted Ground-borne Noise and Vibration Levels

Receiver Area	Period	Noise and Vibration Goals		Predicted Ground-borne Noise and Vibration Levels (Rockbreaking)	
		Vibration PPV (mm/s)	Ground-borne Noise (dBA)[1]	Ground-borne Vibration (mm/s)	Ground-borne Noise (dBA)
A – Wickham Terrace Commercial	Day	5	LA10,adj – 65	0.02	26
B – St Alban Liberal Catholic Church	Day	2	LA10,adj – 50	0.03	28
C – Wickham Terrace Residential	Day	5	LA10,adj – 55	0.04	29
	Night	0.5	LAmax,adj – 50	0.04	34
D – Wickham Terrace Commercial	Day	5	LA10,adj – 65	0.03	27
E – Brisbane Private Hospital	Any	5	LA10,adj – 60	0.02	24
F – Brisbane Dental Educational	Day	5	LA10,adj – 55	0.04	29
G – Turbot Street Commercial	Day	5	LA10,adj – 65	0.14	39
H – Roma Street Station Commercial	Day	5	LA10,adj – 65	0.37	47
H – Old Train Station Heritage Listed	Day	5	LA10,adj – 65	0.53	49
I – Holiday Inn	Day	5	LA10,adj – 55	0.14	39

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Receiver Area	Period	Noise and Vibration Goals		Predicted Ground-borne Noise and Vibration Levels (Rockbreaking)	
		Vibration PPV (mm/s)	Ground-borne Noise (dBA)[1]	Ground-borne Vibration (mm/s)	Ground-borne Noise (dBA)
Residential	Night	0.5	LAmax,adj – 50	0.14	44
J – Parkland Crescent Residential	Day	5	LA10,adj – 55	0.03	26
	Night	0.5	LAmax,adj – 50	0.03	31

Note 1: Dominant construction noise during shaft excavation likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameters are most relevant. For the ground-borne noise all noise levels are internal levels.

The predicted construction noise emission levels for Roma Street Station works exceed the noise goals for only a small number of receivers during the daytime and night-time period. The highest predicted noise goal exceedances occur at the Roma Street Station and the Holiday Inn. Consequently, consideration would need to be given to increasing the height of the temporary acoustic hoardings around the three work sites to achieve compliance with the daytime noise goals. A high performance acoustic enclosure would be required to achieve compliance with the external noise goal for the night-time period at the Holiday Inn.

The predicted construction noise levels indicate that with provision for 6 m hoarding around each site (where practicable), night-time construction noise levels would be within 1 dBA of the sleep disturbance noise goal and therefore unlikely to interfere with people's sleep. Further to this, it is likely that facade noise reductions for residential buildings located within the CBD are substantially higher than the 10 dBA (refer to **Section 8.1**) assumed for this assessment.

To assist with the interpretation of impacts associated with the construction of CRR, it is important that assessment goals are consistent across the project. However, in the case of CRR construction works required in the City precinct (ie Roma Street Station and Albert Street Station), it may prove onerous to apply absolute noise goals in acoustic environments characterised by relatively constant high ambient noise levels. For example, ambient night-time noise levels measured over a week at monitoring location 6 (ie Parkland Crescent) ranged between 75 to 80 dBA LAmax and 59 to 63 dBA LAeq. Comparison of predicted night-time construction noise levels in **Table 52** with a medium performance acoustic enclosure (eg residential receiver I-Holiday Inn LAmax,adj – 64 dBA) indicates that worst case CRR construction noise levels would be below the range of existing night-time ambient (LAmax) noise levels.

Further, the existing City landscape is scattered with high-rise building construction worksites that operate on a daily basis in accordance with Section 440R of the Act (ie with no daytime noise limits) presumably over extended periods of time (eg greater than 12 months). It is likely that noise sensitive receivers in the vicinity of Roma Street Station worksites would associate initial CRR construction work involving site establishment, demolition and piling, with typical high-rise building construction works, particularly at the major southern worksite adjacent the Station precinct. Where the CRR construction differs from typical inner city high-rise construction work is the subsequent long-term underground excavation of Station caverns by roadheaders. The long-term phases would primarily occur below surface and/or within an acoustic enclosure to minimise any noise impacts. The excavation of the station cavern is assessed in the roadheader tunnelling works **Section 9.2.2**.

Predicted gound-borne noise and vibration levels in **Table 55** from rockbreaking excavation of the shafts indicate compliance with the relevant goals.

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Assuming airblast overpressure can be sufficiently mitigated at the site (eg blast mat, enclosure etc) drill and blast excavation at Roma Street Station could be constrained by low MICs estimated to be 0.5 kg, controlled by the heritage listed station building shown in **Figure 13** .

Should drill and blast be required for this site, the following management measures would be required:

- Use of latest available blasting technology (eg Penetrating Cone Fracture (PCF)).
- Pre-blasting condition survey of adjacent buildings.
- Appropriate attention to blast design and commence blasting with a low MIC to develop a site law (ie blast design model) based on measurement data from the site.
- Monitoring the blast emissions.

Albert Street Station

The nearest noise and/or vibration sensitive receivers to the Albert Street Station site are identified in **Table 56**.

Table 56 Nearest Sensitive Receivers – Albert Street Station

Work Site/Excavation	Receiver Area	Location Relative to Works (m)
Albert Street Station	A - Queensland University of Technology	270
	B – Parliament House	260
	C – Alice Street Commercial	170
	D – Alice Street Residential	25
	E – Albert Street Commercial	25
	F – Albert Street Commercial	20
	G – Albert Street Residential	25
	H – Albert Street Residential	5
	I – Charlotte Street Commercial	5
	J – Mary Street Residential	20
	K – Albert Street Commercial	20
	L – Margaret Street Commercial	45
	M – Alice Street Residential	25

Scenarios were developed for Albert Street Station construction works being representative of activities having potentially the greatest (ie worst case) noise impact on the surrounding receivers. Worst case scenarios have been developed based on all plant items, as proposed by the Project design team including haul trucks where applicable, operating simultaneously. These scenarios are:

- Scenario 1 – Demolition of existing buildings:
  - North shaft duration ~ 10 weeks
  - South shaft duration ~ 20 weeks
  - Dominant noise sources include rockbreakers, excavators and spoil trucks
  - Mostly daytime construction works noting that the night-time period in the CBD currently experience higher noise levels than suburban areas and as such it would seem “reasonable” for construction (eg spoil removal) to extend into the night-time period

EXECUTIVE SUMMARY

- Scenario 2 - Piling around shaft perimeter:
  - North shaft duration ~ 10 weeks
  - South shaft duration ~ 4 weeks
  - Dominant noise sources include piling rigs
  - Mostly daytime construction works noting that the night-time period in the CBD currently experience higher noise levels than suburban areas and as such it would seem “reasonable” for construction to extend into the night-time period
- Scenario 3 - Shaft excavation within an acoustic enclosure:
  - North shaft duration ~ 20 weeks
  - South shaft duration ~ 10 weeks
  - Dominant noise sources include jumbo drill rigs, excavators and front end loaders
  - 24 hour per day construction with works carried out inside acoustic enclosures at the north and south shafts

For all construction scenarios, typical construction noise levels with 3 m acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 58**. An assessment of noise goal compliance is also provided in **Table 58** with indicative noise level reductions based on 6 m acoustic hoarding for all scenarios and works carried out inside an acoustic enclosure for Scenario 3. Note a “dash” (-) in the tables indicates compliance, and “n/a” not applicable for the assessment period.

Table 58 Albert Street Station Predicted Worst Case Construction Noise Levels

Receiver Area	Scenario	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)		
					3 m Hoarding	6 m Hoarding	Enclosure
A - QUT	1	Day	LA10,adj – 62	58 – 63	1	-	n/a
	2	Day	LA10,adj – 62	52 – 54	-	-	n/a
	3	Day	LA10,adj – 62	53 – 58	-	-	-
B – Parliament House	1	Day	LA10,adj – 72	60 – 63	-	-	n/a
	2	Day	LA10,adj – 72	51 – 54	-	-	n/a
	3	Day	LA10,adj – 72	55 – 58	-	-	-
C – Alice Street Commercial	1	Day	LA10,adj – 72	52 – 55	-	-	n/a
	2	Day	LA10,adj – 72	47 – 49	-	-	n/a
	3	Day	LA10,adj – 72	45 – 48	-	-	-
D – Alice Street Residential	1	Day	LA10,adj – 62	61 – 85	23	18	n/a
	2	Day	LA10,adj – 62	64 – 78	16	11	n/a
	3	Day	LA10,adj – 62	55 – 79	17	12	5
	1	Night	LAmax,adj – 57	66 - 90	33	28	n/a
	2	Night	LAmax,adj – 57	69 – 83	26	21	n/a
	3	Night	LAmax,adj – 57	60 – 84	27	22	15
E – Albert Street	1	Day	LA10,adj – 72	78 – 80	8	3	n/a

EXECUTIVE SUMMARY

Receiver Area	Scenario	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)		
					3 m Hoarding	6 m Hoarding	Enclosure
	2	Day	LA10,adj – 72	68 – 72	-	-	n/a
	3	Day	LA10,adj – 72	71 – 77	5	-	-
F – Albert Street Commercial	1	Day	LA10,adj – 72	84 – 85	13	8	n/a
	2	Day	LA10,adj – 72	74 - 77	5	-	n/a
	3	Day	LA10,adj – 72	79 – 81	9	4	-
G – Albert Street Residential	1	Day	LA10,adj – 62	59 – 84	22	17	n/a
	2	Day	LA10,adj – 62	54 – 75	13	8	n/a
	3	Day	LA10,adj – 62	60 – 79	17	12	5
	1	Night	LAmax,adj – 57	64 - 89	32	27	n/a
	2	Night	LAmax,adj – 57	59 – 80	23	18	n/a
	3	Night	LAmax,adj – 57	65 – 84	27	22	15
H – Albert Street Residential	1	Day	LA10,adj – 62	81 – 89	27	22	n/a
	2	Day	LA10,adj – 62	72 – 74	12	7	n/a
	3	Day	LA10,adj – 62	76 – 79	17	12	5
	1	Night	LAmax,adj – 57	86 - 94	37	32	n/a
	2	Night	LAmax,adj – 57	77 – 79	22	17	n/a
	3	Night	LAmax,adj – 57	81 – 84	27	22	15
I – Charlotte Street Commercial	1	Day	LA10,adj – 72	82 – 85	13	8	n/a
	2	Day	LA10,adj – 72	76 – 79	7	2	n/a
	3	Day	LA10,adj – 72	79 – 82	10	5	-
J – Mary Street Residential	1	Day	LA10,adj – 62	69 – 84	22	17	n/a
	2	Day	LA10,adj – 62	62 – 83	21	16	n/a
	3	Day	LA10,adj – 62	62 – 82	20	15	8
	1	Night	LAmax,adj – 57	74 - 89	32	27	n/a
	2	Night	LAmax,adj – 57	67 – 88	31	26	n/a
	3	Night	LAmax,adj – 57	67 – 87	30	25	18
K – Albert Street Commercial	1	Day	LA10,adj – 72	69 – 75	3	-	n/a
	2	Day	LA10,adj – 72	62 – 68	-	-	n/a
	3	Day	LA10,adj – 72	62 – 77	5	-	-
L – Margaret Street Commercial	1	Day	LA10,adj – 72	56 – 74	2	-	n/a
	2	Day	LA10,adj – 72	49 – 67	-	-	n/a
	3	Day	LA10,adj – 72	51 – 68	-	-	-
M – Alice Street Residential	1	Day	LA10,adj – 62	56 - 84	22	17	n/a
	2	Day	LA10,adj – 62	48 – 76	14	9	n/a
	3	Day	LA10,adj – 62	49 – 77	15	10	3
	1	Night	LAmax,adj – 57	61 – 89	32	27	n/a
	2	Night	LAmax,adj – 57	53 – 81	24	19	n/a
	3	Night	LAmax,adj – 57	54 - 82	25	20	13

EXECUTIVE SUMMARY

Note 1 – LA10,adj and LAmax,adj (night-time) assessment parameters applicable for non-steady state and intermittent noise sources. LAeq,adj assessment parameter applicable to steady state or continuous (night-time) noise sources.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Predicted ground-borne noise and vibration impacts for the excavation of Albert Street Station access shafts are presented in **Table 61**. Exceedances are shown in bold red.

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Table 61 Albert Street Station Predicted Ground-borne Noise and Vibration Levels

Receiver Area	Period	Noise and Vibration Goals		Predicted Ground-borne Noise and Vibration Levels (Rockbreaking)	
		Vibration PPV (mm/s)	Ground-borne Noise (dBA)[1]	Ground-borne Vibration (mm/s)	Ground-borne Noise (dBA)
A - Queensland University of Technology (Heritage Listed)	Day	5	LA10,adj – 55	0.01	23
B – Parliament House (Heritage Listed)	Day	2	LA10,adj – 65	0.01	24
C – Queensland Club (Heritage Listed)	Day	5	LA10,adj – 65	0.02	29
D – Alice Street Residential	Day	5	LA10,adj – 55	0.57	55
	Night	0.5	LAmax,adj – 50	0.57	**60**
E – Albert Street Commercial	Day	5	LA10,adj – 65	0.23	48
F – Albert Street Commercial	Day	5	LA10,adj – 65	0.31	50
G – Albert Street Residential	Day	5	LA10,adj – 55	0.19	46
	Night	0.5	LAmax,adj – 50	0.19	**51**
H – Albert Street Residential	Day	5	LA10,adj – 55	0.25	49
	Night	0.5	LAmax,adj – 50	0.25	**54**
I – Charlotte Street Commercial	Day	5	LA10,adj – 65	0.67	56
J – Mary Street Residential	Day	5	LA10,adj – 55	1.56	**63**
	Night	0.5	LAmax,adj – 50	1.56	**68**
K – Albert Street Commercial I	Day	5	LA10,adj – 65	0.59	55
L – Margaret Street Commercial	Day	5	LA10,adj – 65	0.23	48
M – Alice Street Residentia	Day	5	LA10,adj – 55	0.29	50
	Night	0.5	LAmax,adj – 50	0.29	**55**

Note 1: Dominant construction noise during shaft excavation likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameters are most relevant. For the ground-borne noise all noise levels are internal levels.

The predicted noise levels for site establishment works including demolition of the existing buildings at the two Albert Street Station worksites indicate exceedances of up to 27 dBA of the noise goal for daytime operations and up to 37 dBA above the night-time noise goal at the nearest residential receivers. A noise goal exceedance of this order would be unacceptable during the night-time period, and since an acoustic enclosure would not be feasible during the site establishment and piling activities, these works would need to be restricted to the daytime period.

EXECUTIVE SUMMARY

Once excavation of the station shafts has progressed far enough to allow for installation of the acoustic enclosures, noise emission levels from the site would decrease significantly. A high performance acoustic enclosure with double skin walls, roof lined with sound absorptive material, minimised openings and acoustic louvres fitted to ventilation openings would be required in combination with the quietest available construction plant.

It should be noted that facade noise reductions for residential receiver buildings located within the CBD would likely perform significantly better than the 10 dBA (refer to **Section 8.1**) assumed for this assessment and that this may alter (reduce) the mitigation solutions recommended in this report.

Similar to Roma Street Station, predicted CRR construction noise levels should be considered with respect to existing ambient noise levels in the vicinity of the two Albert Street Station worksites. Ambient night-time noise levels measured over a week at monitoring location 7 (ie 191 George Street) ranged between 70 to 78 dBA L_{Amax} and 58 to 68 dBA L_{Aeq}. Comparison of predicted night-time construction noise levels in **Table 58** with a medium performance acoustic enclosure (eg residential receiver J-Mary Street $L_{Amax,adj}$ – 75 dBA) indicates that worst case CRR construction noise levels would be within the range of existing night-time ambient noise levels.

The ground-borne noise levels presented in **Table 61** for rockbreaking during excavation of Albert Street Station shafts are predicted to exceed the night-time noise goals for several residential receivers and for one residential receiver during the daytime period. The Mary Street residential receiver would be located less than 10 m from the northern shaft and approximately 13 m slant distance from the inferred rock level. Exceedance of the daytime internal noise goal of 55 dBA L_{A10} would be anticipated until rockbreaking had progressed beyond approximately 20 m slant distance from the receiver building.

As a guide, propagation of ground-borne noise levels in buildings attenuates by approximately 2 dB per floor for the first 4 floors and by approximately 1 dB per floor thereafter. On this basis, receivers located on the first 5 floors of the building may require temporary relocation until a slant distance of approximately 20 m has been reached.

Assuming airblast overpressure can be sufficiently mitigated at the worksite (eg blast mat, enclosure etc), drill and blast excavation at both Albert Street Station shafts would be constrained by low MICs estimated to be:

- North shaft – 1.0 kg to comply with the vibration goal at Mary Street residences.
- South shaft – 4.3 kg to comply with the vibration goal at Alice Street residences.

Should drill and blast be required for this worksite, the following management measures would be required:

- Use of latest available blasting technology (eg PCF).
- Pre-blasting condition survey of adjacent buildings.
- Appropriate attention to blast design and commence blasting with a low MIC to develop a site law (ie blast design model) based on measurement data from the site.
- Monitoring the blast emissions.

It is anticipated that the initial stages of shaft excavation would be carried out by rockbreaker due to the close proximity of sensitive receiver buildings. The point at which drill and blast excavation could be safely and efficiently carried out within the shaft would be determined as part of detailed investigations for the site. Acoustically, exposure to a short-term blast event would be preferred to long term rockbreaking where ground-borne noise impacts have been identified.

EXECUTIVE SUMMARY

Boggo Road Station

The nearest noise and/or vibration sensitive receivers to the Boggo Road Station site are identified in **Table 62**.

Table 62 Nearest Sensitive Receivers – Boggo Road Station

Work Site/Excavation	Receiver Area	Location Relative to Works (m)
Boggo Road Station	A – Ecoscience Building commercial	5
	B – Rawnsley Street Residential	15
	C – Maldon Street Commercial	45
	D – Maldon Street Residential	40
	E – Grantham Street Commercial	35
	F – Annerley Road Residential	75
	G – Boggo Road Police Station	90
	H – Dutton Park Primary School	40
	I – Boggo Road Gaol	15 (from buildings), 5 (from wall)
	J – Leukemia Support Village	100

Scenarios were developed for Boggo Road Station construction works being representative of activities having potentially the greatest (ie worst case) noise impact on the surrounding receivers. Worst case scenarios have been developed based on all plant items, as proposed by the Project design team including haul trucks where applicable, operating simultaneously. These scenarios are:

- Scenario 1 – Installation of piles:
  - North entrance duration ~ 12 weeks
  - South entrance duration ~ 12 weeks
  - Platform box (ie middle section) ~ 9 weeks
  - Dominant noise sources include piling rigs, excavators and front end loaders
  - Daytime construction only
- Scenario 2 - Excavation to slab level and deck construction:
  - Excavation 1 m below capping beam duration ~ 3 weeks
  - Construction of top slab duration ~ 12 weeks
  - Dominant noise sources include jumbo drill rig, excavators, concrete trucks and front end loaders
  - Daytime construction only
- Scenario 3 – North and south shaft excavation:
  - Duration ~ 25 weeks
  - Dominant noise sources include jumbo drill rigs, excavators, front end loaders and spoil trucks
  - 24 hour per day construction with night-time works carried out inside an acoustic enclosure (spoil trucks daytime only)

EXECUTIVE SUMMARY

A scenario assessing the impact associated with construction of station infrastructure at the surface has not been included on the basis that noise levels during this phase are typically lower than levels experienced during the three stages described above, particularly if the structure is prefabricated and only assembled at the site. Further, the building of station infrastructure would be similar in nature to the construction of the acoustic enclosures.

For all construction scenarios, typical construction noise levels with 3 m acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 64**. An assessment of noise goal compliance is also provided in **Table 64** with indicative noise level reductions based on 6 m acoustic hoarding for all scenarios and works carried out inside an acoustic enclosure for Scenario 3. Note a "dash" (-) in the tables indicates compliance, and "n/a" not applicable for the assessment period.

Table 64 Boggo Road Station Predicted Worst Case Construction Noise Levels

Receiver Area	Scenario	Period	Noise Goal (dBA)[1]	Predicted Noise Level[1] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)		
					3 m Hoarding	6 m Hoarding	Enclosure
A – Ecoscience Building commercial	1	Day	LA10,adj – 72	76 - 80	8	3	n/a
	2	Day	LA10,adj – 72	70 – 81	9	4	n/a
	3	Day	LA10,adj – 72	62 – 72	-	-	-
B – Rawnsley Street Residential	1	Day	LA10,adj – 57	64 – 76	19	14	n/a
	2	Day	LA10,adj – 57	61 – 73	16	11	n/a
	3	Day	LA10,adj – 57	59 – 67	10	5	-
	3	Night	LAmax,adj – 52	64 – 72	20	15	8
C – Maldon Street Commercial	1	Day	LA10,adj – 72	49 – 67	-	-	n/a
	2	Day	LA10,adj – 72	45 – 65	-	-	n/a
	3	Day	LA10,adj – 72	40 – 60	-	-	-
D – Maldon Street Residential	1	Day	LA10,adj – 62	63 - 66	4	-	n/a
	2	Day	LA10,adj – 62	57 – 60	-	-	n/a
	3	Day	LA10,adj – 62	55 – 58	-	-	-
	3	Night	LAmax,adj – 52	60 – 63	11	6	-
E – Grantham Street Commercial	1	Day	LA10,adj – 72	58 – 63	-	-	n/a
	2	Day	LA10,adj – 72	55 – 58	-	-	n/a
	3	Day	LA10,adj – 72	49 – 55	-	-	-
F – Annerley Road Residential	1	Day	LA10,adj – 62	52 – 58	1	-	n/a
	2	Day	LA10,adj – 62	55 – 58	-	-	n/a
	3	Day	LA10,adj – 62	48 – 51	-	-	-
	3	Night	LAmax,adj – 52	53 – 56	4	-	-
G – Boggo Road Police Station	1	Day	LA10,adj – 72	57 – 62	-	-	n/a
	2	Any	LA10,adj – 72	59 – 64	-	-	n/a
	3	Any	LA10,adj – 72	42 – 50	-	-	-
H – Dutton Park	1	Day	LA10,adj – 62	61 – 69	7	2	n/a

EXECUTIVE SUMMARY

Receiver Area	Scenario	Period	Noise Goal (dBA)[1]	Predicted Noise Level[1] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)		
					3 m Hoarding	6 m Hoarding	Enclosure
	2	Day	LA10,adj – 62	60 – 65	3	-	n/a
	3	Day	LA10,adj – 62	44 – 56	-	-	-
I – Boggo Road Gaol	1	Day	LA10,adj – 72	69 – 76	4	-	n/a
	2	Day	LA10,adj – 72	71 – 79	7	2	n/a
	3	Day	LA10,adj – 72	59 – 73	1	-	-
J – Leukemia Support Village	1	Day	LA10,adj – 57	67 – 72	15	10	n/a
	2	Day	LA10,adj – 57	68 – 71	14	9	n/a
	3	Day	LA10,adj – 57	60 – 65	8	3	-
	3	Night	LAmax,adj – 52	65 – 70	18	13	6

Note 1 – LA10,adj and LAmax,adj (night-time) assessment parameters applicable for non-steady state and intermittent noise sources. LAeq,adj assessment parameter applicable to steady state or continuous (night-time) noise sources.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Predicted ground-borne noise and vibration impacts for the excavation of Boggo Road Station access shafts are presented in **Table 67**. Exceedances are shown in bold red.

Table 67 Boggo Road Station Predicted Ground-borne Noise and Vibration Levels

Receiver Area	Period	Noise and Vibration Goals		Predicted Ground-borne Noise and Vibration Levels (Rockbreaking)	
		Vibration PPV (mm/s)	Ground-borne Noise (dBA)[1]	Ground-borne Vibration (mm/s)	Ground-borne Noise (dBA)
A – Ecoscience Building commercial	Day	5	LA10,adj – 65	0.48	54
A – Ecoscience Building TEM	Day	0.02	LA10,adj – 65	**0.11**	42
B – Rawnsley Street Residential	Day	5	LA10,adj – 55	0.06	37
	Night	0.5	LAmax,adj – 50	0.06	42
C – Maldon Street Commercial	Day	5	LA10,adj – 65	0.03	32
D – Maldon Street Residential	Day	5	LA10,adj – 55	0.03	32
	Night	0.5	LAmax,adj – 50	0.03	37
E – Grantham Street Commercial	Day	5	LA10,adj – 65	0.03	32
F – Annerley Road Residential	Day	5	LA10,adj – 55	0.02	29
	Night	0.5	LAmax,adj – 50	0.02	34
G – Boggo Road Police Station	Day	5	LA10,adj – 65	0.04	33
H – Dutton Park Primary School	Day	5	LA10,adj – 55	0.13	43
I – Boggo Road Gaol (Heritage	Day	2	LA10,adj – 65	1.23	50

EXECUTIVE SUMMARY

Receiver Area	Period	Noise and Vibration Goals		Predicted Ground-borne Noise and Vibration Levels (Rockbreaking)	
		Vibration PPV (mm/s)	Ground-borne Noise (dBA)[1]	Ground-borne Vibration (mm/s)	Ground-borne Noise (dBA)
Listed)					
J – Leukemia Support Village	Day	5	LA10,adj – 55	0.03	32
	Night	0.5	LAmax,adj – 50	0.03	37

Note 1: Dominant construction noise during shaft excavation likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameters are most relevant. For the ground-borne noise all noise levels are internal levels.

The predicted noise levels for pile installation works at the Boggo Road Station worksite indicate exceedances of up to 19 dBA of the noise goal for daytime operations at the nearest residential receivers in Rawnsley Street.

The predicted noise levels for the initial stages of excavation (ie prior to installation of the top slab) at the Boggo Road Station worksite indicate exceedances of up to 16 dBA during the day at the nearest residential receivers.

The predicted noise levels for the south entry shaft excavation once the acoustic enclosure is in place (ie Scenario 3) indicate that a high performance acoustic enclosure would be required to comply with the daytime and night-time noise goals at the nearest residential receivers in Rawnsley Street and the Leukemia Support Village. No acoustic enclosure is predicted to be required for the north entry shaft excavation.

The movement of trucks within the worksite should be designed to limit (as much as practicable) the need for reversing activities and consequent reversing alarm noise. Where issues with reversing alarms occur, consideration should be given to the use of broadband "buzzer" reversing alarms and/or alarms which actively vary their volume according to the ambient noise levels during activation - rather than constant volume (tonal) "beeping" alarms.

Predicted gound-borne noise and vibration levels in **Table 67** from rockbreaking indicate compliance with the relevant goals for all sensitive receivers with the exception of the transmission electron microscope (TEM) located at the Eco-science precinct building. Further, the estimated blast MIC limits for Boggo Road Station, presented in **Table 67**, indicate that the allowable MIC for the worksite would be controlled by the TEM.

As rockbreaking and/or drill and blasting would be required for this site, the following management measures would be required:

- Scheduling rockbreaking and blasts outside of typical TEM operating times. If this is not practicable without impacting on normal (Eco-science precinct) TEM operations, a special arrangement would need to be established so that blasting can be scheduled at a specific time.
- Appropriate attention to blast design and commence blasting with a low MIC to develop a site law (ie blast design model) based on measurement data from the site.
- Monitoring of the blast emissions.

If blasting could be scheduled outside of TEM operating times, the MICs would then be limited by the heritage-listed Boggo Road Gaol (ie MIC of 0.2 kg). Consequently, blasting may not be feasible for the southern shaft nearest Boggo Road Gaol until the shaft has deepened sufficiently to allow for efficient blasting.

EXECUTIVE SUMMARY

Vibration levels for bored piling adjacent the heritage-listed Boggo Road Gaol are predicted to be below 2 mm/s based on data obtained from measurements carried out on the Northern Busway project adjacent to the Royal Brisbane and Womens Hospital. Notwithstanding this, it is recommended that vibration measurements be carried out during the commencement of bored piling at the site to determine the risk of exceeding the TEM vibration limit when piling in close proximity to the Eco-science precinct building.

Cumulative construction noise impacts from the Boggo Road Urban Village development have not been assessed as the construction program for both projects is unknown. Taking into consideration the close proximity of both projects to noise sensitive receivers, cumulative construction noise impacts would be likely. Coincident construction works would need to be reviewed during the detailed design stage with consultation between all stakeholders to determine all practicable measures to minimise impacts.

Southern Ventilation Shaft Construction Noise and Vibration Assessment

The nearest noise and/or vibration sensitive receivers to the Southern Ventilation Shaft worksite are identified in **Table 68**.

Table 68 Nearest Sensitive Receivers – Southern Ventilation Shaft

Work Site/Excavation	Receiver Area	Location Relative to Works (m)
Southern Ventilation Shaft	A – Railway Road Residential	15
	B – Sunbeam Street Residential	50
	C – Baptist Union of QLD Church	60
	D – Railway Road Commercial	15
	E – Venner Road Residential	15
	F – Fairfield Road Residential	30
	G – Byrnes Street Commercial	25
	H – Fairfield Road Residential	40
	I – Love Street Residential	90

Scenarios were developed for the Southern Ventilation Shaft construction works being representative of activities having potentially the greatest (ie worst case) noise impact on the surrounding receivers. Worst case scenarios have been developed based on all plant items, as proposed by the Project design team including haul trucks where applicable, operating simultaneously. These scenarios are:

- Scenario 1 - Site establishment:
  - Duration ~ 6 weeks
  - Dominant noise sources include an excavator and front end loader
  - Daytime construction only
- Scenario 2 – Piling of access shaft:
  - Duration ~ 5 weeks
  - Dominant noise sources include a piling rig, excavator and front end loader
  - Daytime construction only
- Scenario 3 – Shaft excavation:
  - Duration ~ 12 weeks

EXECUTIVE SUMMARY

- Dominant noise sources include excavators and front end loaders
- Daytime construction only

A scenario assessing the impact associated with construction of the ventilation building at the surface has not been included on the basis that noise levels during this phase are typically lower than levels experienced during the three stages described above.

For all construction scenarios, typical construction noise levels with 3 m acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 70**. An assessment of noise goal compliance is also provided in **Table 70** with indicative noise level reductions based on 6 m acoustic hoarding for all scenarios. Note a "dash" (-) in the tables indicates compliance with the relevant noise goal.

Table 70 Southern Ventilation Shaft Predicted Worst Case Noise Levels

Receiver Area	Scenario	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
					3 m Hoarding	6 m Hoarding
A – Railway Road Residential	1	Day	LA10,adj – 62	59 – 67	5	-
	2	Day	LA10,adj – 62	67 – 74	12	7
	3	Day	LA10,adj – 62	64 – 73	11	6
B – Sunbeam Street Residential	1	Day	LA10,adj – 62	62 – 67	5	-
	2	Day	LA10,adj – 62	72 – 75	13	8
	3	Day	LA10,adj – 62	68 – 73	11	6
C – Baptist Union of QLD Church	1	Day	LA10,adj – 57	63 – 66	9	4
	2	Day	LA10,adj – 57	70 – 73	16	11
	3	Day	LA10,adj – 57	67 – 70	13	8
D – Railway Road Commercial	1	Day	LA10,adj – 72	67 – 70	-	-
	2	Day	LA10,adj – 72	75 – 78	6	1
	3	Day	LA10,adj – 72	70 – 73	1	-
E – Venner Road Residential	1	Day	LA10,adj – 62	58 – 71	9	4
	2	Day	LA10,adj – 62	66 – 76	14	9
	3	Day	LA10,adj – 62	61 – 73	11	6
F – Fairfield Road Residential	1	Day	LA10,adj – 62	49 – 69	7	2
	2	Day	LA10,adj – 62	53 – 73	11	6
	3	Day	LA10,adj – 62	52 – 71	9	4
G – Byrnes Street Commercial	1	Day	LA10,adj – 72	64 – 70	-	-
	2	Day	LA10,adj – 72	68 – 75	3	-
	3	Day	LA10,adj – 72	65 – 74	2	-
H – Fairfield Road Residential	1	Day	LA10,adj – 62	54 – 67	5	-
	2	Day	LA10,adj – 62	60 – 74	12	7
	3	Day	LA10,adj – 62	56 – 71	9	4

EXECUTIVE SUMMARY

Receiver Area	Scenario	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
					3 m Hoarding	6 m Hoarding
I – Love Street Residential	1	Day	LA10,adj – 62	49 – 61	-	-
	2	Day	LA10,adj – 62	55 – 68	6	1
	3	Day	LA10,adj – 62	54 – 65	3	-

Note 1 – LA10,adj and LAmax,adj (night-time) assessment parameters applicable for non-steady state and intermittent noise sources.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Predicted permissible MIC blast charges to achieve compliance with the relevant goals for airblast overpressure and ground vibration for the excavation of the Southern Ventilation Shaft are presented in **Table 73**. As the shaft is anticipated to remain open during the excavation phase ground-borne noise impacts would likely be insignificant compared with airborne noise from the site.

Table 73 Southern Ventilation Shaft Predicted Blasting Vibration & Noise Levels – Shaft Excavation

Receiver Area	Slant Distance to Inferred Rock Level (m)	Vibration Goal PPV (mm/s) Blasting	Noise Goal (dB Linear Peak) Blasting	Maximum Allowed Blast MIC to meet the Vibration Goal	Maximum Allowed Blast MIC to meet the Airblast Overpressure Goal
A – Railway Road Residential	50	10	130	14.9 kg	11.3kg
B – Sunbeam Street Residential	65	10	130	25 kg	25 kg
C – Baptist Union of QLD Church	80	10	130	38 kg	46 kg
D – Railway Road Commercial	22	10	130	3 kg	0.9 kg
E – Venner Road Residential	34	10	130	7 kg	4 kg
F – Fairfield Road Residential	43	10	130	11 kg	7 kg
G – Byrnes Street Commercial	39	10	130	9 kg	5 kg
H – Fairfield Road Residential	65	10	130	25 kg	25 kg
I – Love Street Residential	115	10	130	78 kg	136 kg

Note 1: Inferred rock level at approximately 5 m depth (ie depth at where blasting and/or rockbreaking will be required).

The predicted noise levels for the three modelled scenarios at the Southern Ventilation worksite indicate significant exceedances of the relevant daytime construction noise goals due to the close proximity of sensitive receivers.

EXECUTIVE SUMMARY

Increasing the proposed 3 m perimeter acoustic hoarding to 6 m acoustic hoarding will reduce the construction noise emission levels, however several noise goal exceedances would still be expected. Since mitigating piling rig noise within an enclosure is not practicable, it is recommended that an additional piling rig be utilised at the site to expedite the works thereby reducing the exposure period. An additional (acoustically identical) piling rig operating at the site would increase the overall noise level by a marginal 3 dBA but would halve the duration.

The predicted worst case shaft excavation noise levels have been modelled on the basis of the excavation plant operating close to existing ground level. During this phase of the work, construction noise emission levels would progressively decrease over time as the excavation plant progressed deeper into the shaft.

For the proposed CRR construction commencement year (ie 2016), road traffic noise levels from Fairfield Road were predicted at residences adjacent to Fairfield Road, Railway Road and Sunbeam Street, nearest to the Southern Ventilation Shaft worksite, for comparison with the predicted CRR construction noise levels. The road traffic noise predictions were carried out using the UK Department of Transport “Calculation of Road Traffic Noise” (CORTN 1998) methodology.

Fairfield Road traffic noise levels for 2016 are predicted to be in the order of 64 dBA to 74 dBA L_{A10} during the am and pm peak periods (ie 7 am to 9 am and 4 pm to 6 pm respectively) and 62 dBA to 72 dBA L_{A10} during the daytime off peak period (ie 9 am to 4 pm). Comparison with predicted worst case daytime construction noise levels indicates that at times road traffic noise from Fairfield Road would be higher and potentially dominate the acoustic environment in the vicinity of the Southern Ventilation Shaft worksite for the receivers closest to Fairfield Road.

The estimated blast MIC limits for the Southern Ventilation Shaft indicate that a maximum MIC of 0.9 kg would be permitted to achieve compliance with the airblast overpressure goal of 130 dB Linear Peak at the commercial receiver at location D (ie Railway Road). Assuming the airblast overpressure can be mitigated (eg blast mat, enclosing etc), a maximum MIC of 3 kg would be permitted to achieve compliance with the vibration goal of 10 mm/s PPV. With appropriately mitigated airblast overpressure, blasting would be a suitable excavation technique for this site.

Surface Rail Track Worksite Noise and Vibration Assessment

Mayne Yard

The nearest sensitive receivers to the Mayne Yard and viaduct sites are identified in **Table 74**.

Table 74 Nearest Sensitive Receivers – Mayne Yard

Work Site	Receiver Area	Location Relative to Works (m)
Mayne Yard	A – Residential West	300
	B – Residential East	180

Scenarios were developed for CRR construction works at Mayne Yard being representative of activities having potentially the greatest noise impact on the surrounding receivers. These scenarios are:

- Scenario 1 – Piling for viaduct piers.
- Scenario 2 – Viaduct construction.

EXECUTIVE SUMMARY

For all construction scenarios, typical construction noise levels without acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 75**. An assessment of noise goal compliance is also provided in **Table 75** with indicative noise level reductions based on 3 m acoustic hoarding for all scenarios. Note a “dash” (-) in the tables indicates compliance with the relevant noise goal.

Table 75 Mayne Yard Predicted Worst Case Noise Levels

Receiver Area	Scenario	Noise Goal (dBA) [1]	Predicted Noise Level (dBA) [2]	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				None	3 m Hoarding
A – Residential	1	LAeq(24hour) – 62	48 - 50	-	-
	1	LAmax,adj – 84	56 – 59	-	-
	2	LAeq(24hour) – 62	44 – 46	-	-
	2	LAmax,adj – 84	52 – 54	-	-
B – Residential	1	LAeq(24hour) – 62	48 – 52	-	-
	1	LAmax,adj – 84	56 – 60	-	-
	2	LAeq(24hour) – 62	44 – 46	-	-
	2	LAmax,adj – 84	52 – 54	-	-

Note 1 – Noise goal based on Queensland Rail’s Code of Practice planning levels adjusted to a free-field level.
Note 2 – Predicted noise levels without acoustic hoarding.

The predicted noise levels for the two modelled scenarios associated with the Mayne Yard viaduct construction works indicate compliance with the Queensland Rail planning levels without specific noise mitigation measures in place. Given that Mayne Yard is mostly offset from the operational “through tracks” (ie track possessions not required for construction works), if night-time piling construction works are required at Mayne Yard, reasonable and practicable mitigation measures should be considered to comply with the 57 dBA LAmax sleep disturbance noise goal applicable to other elements of the project. Examples of mitigation measures include:

- Selection of quietest available plant and techniques.
- Careful orientation of piling plant to take advantage of intervening structures.
- Noise monitoring at the commencement of construction works to refine noise mitigation measures.

At a distance in excess of 180 m to the nearest residential receiver, vibration impacts from CRR construction works would not be anticipated.

Clapham Yard

The nearest sensitive receivers to the Clapham Yard site are identified in **Table 77**.

Table 77 Nearest Sensitive Receivers – Clapham Yard

Work Site	Receiver Area	Location Relative to Works (m)
Clapham Yard	A – Residential East	100
	B – Residential West	250

EXECUTIVE SUMMARY

Scenarios were developed for CRR construction works at Clapham Yard being representative of activities having potentially the greatest noise impact on the surrounding receivers. These scenarios are:

- Scenario 1 – Earthworks.
- Scenario 2 – Track construction.
- Scenario 3 – Single track flyover construction.

For all construction scenarios, typical construction noise levels without acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 78**. An assessment of noise goal compliance is also provided in **Table 78** with indicative noise level reductions based on 3 m acoustic hoarding for all scenarios. Note a "dash" (-) in the tables indicates compliance with the relevant noise goal.

Table 78 Clapham Yard Predicted Worst Case Noise Levels

Receiver Area	Scenario	Noise Goal (dBA)[1]	Predicted Noise Level (dBA)[2]	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				None	3 m Hoarding
A – Residential	1	LAeq(24hour) – 62	48 – 56	-	-
	1	LAmax,adj – 84	56 – 64	-	-
	2	LAeq(24hour) – 62	55 – 62	-	-
	2	LAmax,adj – 84	63 – 71	-	-
	3	LAeq(24hour) – 62	58 – 70	8	-
	3	LAmax,adj – 84	66 – 78	-	-
B – Residential	1	LAeq(24hour) – 62	50 - 53	-	-
	1	LAmax,adj – 84	58 – 61	-	-
	2	LAeq(24hour) – 62	45 – 51	-	-
	2	LAmax,adj – 84	53 – 59	-	-
	3	LAeq(24hour) – 62	48 – 51	-	-
	3	LAmax,adj – 84	56 – 59	-	-

Note 1 – Noise goal based on Queensland Rail's Code of Practice planning levels adjusted to a free-field level.
Note 2 – Predicted noise levels without acoustic hoarding.

The predicted noise levels for the two modelled scenarios associated with the Clapham Yard construction works (ie Scenario 1 and 2) indicate compliance with the Queensland Rail noise goals without specific noise mitigation measures in place. Construction of the single track flyover (ie Scenario 3) is predicted to exceed the 62 dBA LAeq(24hour) planning level with no noise mitigation measures in place. 3 m high acoustic hoarding adjacent to the west of the piling work area is predicted to be an effective method of achieving compliance with the noise goal.

It is understood that the majority of the work at Clapham Yard could be staged in a way to avoid construction work outside normal daytime hours. Given that Clapham Yard is mostly offset from the operational "through tracks", if night-time construction works are required at Clapham Yard, all reasonable and practicable mitigation measures would be required to comply with the 57 dBA LAmax sleep disturbance noise goal applicable to other elements of the project. Examples of mitigation measures include:

- Selection of quietest available plant and techniques.

EXECUTIVE SUMMARY

- Careful orientation of piling plant to take advantage of intervening structures.
- Noise monitoring at the commencement of construction works to refine noise mitigation measures.

Construction noise levels from works occurring on the three-track bridge over Moolabin Creek have not been specifically assessed for Clapham Yard as they are anticipated to be less than the levels associated with the viaduct construction. The assessment of viaduct construction noise presented in **Table 78** would be representative of noise emission from the Moolabin Creek rail bridge works.

At a distance in excess of 100 m to the nearest residential receiver, vibration impacts from CRR construction works, including vibratory rollers and rockbreakers (if required), would not be anticipated.

Station Construction/Upgrades

Exhibition Station Replacement (including O'Connell Terrace Road Bridge)

The nearest sensitive receivers to the Exhibition Station site are identified in **Table 81**.

Table 81 Nearest Sensitive Receivers – Exhibition Station

Work Site	Receiver Area	Location Relative to Major Worksite (m)
Exhibition Station	A – Residential North-east	60
	B – Residential North-west	220
	C – Royal Brisbane & Women's Hospital (RBWH)	300
	D – RNA Showgrounds	10

Scenarios were developed for CRR construction works at the Exhibition Station worksite being representative of activities having potentially the greatest noise impact on the surrounding receivers. These scenarios are:

- Scenario 1 – Piling for O'Connell Terrace bridge piers.
- Scenario 2 – Station construction.

For all construction scenarios, typical construction noise levels without acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 82**. An assessment of noise goal compliance is also provided in **Table 82** with indicative noise level reductions based on 3 m acoustic hoarding for all scenarios. Note a "dash" (-) in the tables indicates compliance with the relevant noise goal.

EXECUTIVE SUMMARY

Table 82 Exhibition Station Construction Predicted Worst Case Noise Levels

Receiver Area	Scenario	Noise Goal (dBA)[1]	Predicted Noise Level (dBA) [2]	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				None	3 m Hoarding
A – Residential	1	LAeq(24hour) – 62	49 – 72	10	2
	1	LAmax,adj – 84	57 – 80	-	-
	2	LAeq(24hour) – 62	39 – 57	-	-
	2	LAmax,adj – 84	47 – 65	-	-
B – Residential	1	LAeq(24hour) – 62	35 – 54	-	-
	1	LAmax,adj – 84	43 – 62	-	-
	2	LAeq(24hour) – 62	38 – 52	-	-
	2	LAmax,adj – 84	46 – 60	-	-
C – RBWH	1	LAeq(24hour) – 62	51 – 54	-	-
	1	LAmax,adj – 84	57 – 60	-	-
	2	LAeq(24hour) – 62	51 – 53	-	-
	2	LAmax,adj – 84	59 – 61	-	-

Note 1 – Noise goal based on Queensland Rail's Code of Practice planning levels adjusted to a free-field level.
Note 2 – Predicted noise levels without acoustic hoarding.

The predicted noise levels for the two modelled scenarios associated with the Exhibition Station construction works indicate compliance with the Queensland Rail planning levels with the exception of the nearest residences to the east of the site in Tufton Street. Acoustic hoarding in the order of 4 m in height around the piling worksite would likely result in compliance with the adopted noise goal based on the marginal exceedance in **Table 82**.

Night-time construction works at Exhibition Station should be avoided insofar as possible.

Cumulative construction noise impacts from the RNA Showgrounds redevelopment have not been assessed as the construction program for both projects is unknown. Taking into consideration the extent of both projects in this area, CRR construction works would be relatively short in duration compared with the RNA redevelopment. Mitigation of cumulative construction noise would need to be addressed during the detailed design stage through consultation with all stakeholders if the projects coincided.

Predicted vibration levels at the nearest heritage-listed building within the RNA Showgrounds are below the cosmetic damage goal of 2 mm/s. Where vibration-intensive construction works are required to occur within 10 m of RNA Showground heritage structures, pre-construction condition surveys and monitoring during construction would be recommended.

Yeerongpilly Station Replacement

The nearest sensitive receivers to the Yeerongpilly Station worksite are identified in **Table 84**.

EXECUTIVE SUMMARY

Table 84 Nearest Sensitive Receivers – Yeerongpilly Station

Work Site	Receiver Area	Location Relative to Works (m)
Yeerongpilly Station	A – Residential East	35
	B – Residential West	300

A noise model scenario was developed for CRR construction works at Yeerongpilly Station being representative of activities having potentially the greatest noise impact on the surrounding receivers. The scenario was:

- Scenario 1 – Station construction.

The typical construction noise levels without acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 85**. An assessment of noise goal compliance is also provided in **Table 85** with indicative noise level reductions based on 3 m acoustic hoarding. Note a "dash" (-) in the tables indicates compliance with the relevant noise goal.

Table 85 Yeerongpilly Station Predicted Worst Case Construction Noise Levels

Receiver Area	Scenario	Noise Goal (dBA)[1]	Predicted Noise Level (dBA)[2]	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				None	3 m Hoarding
A – Residential	1	LAeq(24hour) – 62	49 – 65	3	-
	1	LAmax,adj – 84	57 – 73	-	-
B – Residential	1	LAeq(24hour) – 62	31 – 40	-	-
	1	LAmax,adj – 84	39 – 48	-	-

Note 1 – Noise goal based on Queensland Rail's Code of Practice planning levels adjusted to a free-field level.
Note 2 – Predicted noise levels without acoustic hoarding.

The predicted noise levels for the two modelled scenarios associated with the Yeerongpilly Station construction works indicate compliance with the QR planning levels with the exception of the nearest residences to the east of the site in Livingstone Street. A 3 m high acoustic hoarding along the eastern boundary of the worksite would likely result in compliance with the adopted noise goal based on the marginal exceedance of 3 dBA.

Given that Yeerongpilly Station construction site would be remote from the realigned operational track, if night-time construction works are required at Yeerongpilly Station, all reasonable and practicable noise mitigation measures would be required to minimise exceedance of the 57 dBA LAmax sleep disturbance goal. Retaining part of or the entire acoustic shed at Yeerongpilly Station for the station construction phase would be highly beneficial to the acoustic amenity of the area.

At a distance in excess of 35 m to the nearest residential receiver, vibration impacts from CRR construction works would not be anticipated at this site.

Moorooka Station Upgrade

The nearest sensitive receivers to the Moorooka Station worksite are identified in **Table 86**.

EXECUTIVE SUMMARY

Table 86 Nearest Sensitive Receivers – Moorooka Station

Work Site	Receiver Area	Location Relative to Works (m)
Moorooka Station	A – Residential East	130
	B – Residential West	500

A noise model scenario was developed for CRR construction works at Moorooka Station being representative of activities having potentially the greatest noise impact on the surrounding receivers. The scenario was:

- Scenario 1 – Station construction.

The typical construction noise levels without acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 87**. An assessment of noise goal compliance is also provided in **Table 87** with indicative noise level reductions based on 3 m acoustic hoarding. Note a "dash" (-) in the tables indicates compliance with the relevant noise goal.

Table 87 Moorooka Station Predicted Worst Case Construction Noise Levels

Receiver Area	Scenario	Noise Goal (dBA)[1]	Predicted Noise Level (dBA) [2]	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				None	3 m Hoarding
A – Residential	1	LAeq(24hour) – 62	47 – 63	1	-
	1	LAmax,adj – 84	55 – 71	-	-
B – Residential	1	LAeq(24hour) – 62	27 – 37	-	-
	1	LAmax,adj – 84	35 – 45	-	-

Note 1 – Noise goal based on Queensland Rail's Code of Practice planning levels adjusted to a free-field level.
Note 2 – Predicted noise levels without acoustic hoarding.

The predicted noise levels for the modelled scenario of CRR upgrade works at Moorooka Station indicate compliance with the Queensland Rail planning levels with the exception of a marginal 1 dBA exceedance at the nearest residences east of the worksite. Every effort would be made to use the quietest available equipment and optimise the use of plant to ensure that the worst case noise levels presented in **Table 87** do not eventuate.

At a distance in excess of 130 m to the nearest residential receiver, vibration impacts from minor CRR construction works would not be anticipated.

Rocklea Station Upgrade

The nearest sensitive receivers to the Rocklea Station worksite are identified in **Table 88**.

Table 88 Nearest Sensitive Receivers – Rocklea Station

Work Site	Receiver Area	Location Relative to Works (m)
Rocklea Station	A – Residential West	40
	B – Residential East	170

EXECUTIVE SUMMARY

A noise model scenario was developed for CRR construction works at Rocklea Station being representative of activities having potentially the greatest noise impact on the surrounding receivers. The scenario was:

- Scenario 1 – Station construction.

The typical construction noise levels without acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 89**. An assessment of noise goal compliance is also provided in **Table 89** with indicative noise level reductions based on 3 m acoustic hoarding. Note a "dash" (-) in the tables indicates compliance with the relevant noise goal.

Table 89 Rocklea Station Predicted Worst Case Construction Noise Levels

Receiver Area	Scenario	Noise Goal (dBA)[1]	Predicted Noise Level (dBA)[2]	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				None	3 m Hoarding
A – Residential	1	LAeq(24hour) – 62	47 – 73	11	3
	1	LAmax,adj – 84	55 – 81	-	-
B – Residential	1	LAeq(24hour) – 62	46 – 54	-	-
	1	LAmax,adj – 84	54 – 62	-	-

Note 1 – Noise goal based on Queensland Rail's Code of Practice planning levels adjusted to a free-field level.
Note 2 – Predicted noise levels without acoustic hoarding.

The predicted noise levels for the modelled scenario of upgrade works at Rocklea Station indicate compliance with the Queensland Rail planning levels with the exception of the nearest residences to the west of the site on Brooke Street. Acoustic hoarding in the order of 4 m in height along the western boundary of the worksite would likely result in compliance with the adopted noise goal based on the marginal exceedance in **Table 89**.

At a distance in excess of 40 m to the nearest residential receiver, vibration impacts from minor CRR construction works would not be anticipated.

The current reference design of Rocklea Station indicates that a 10 m buffer zone would be maintained between rockbreaking and sensitive structures. Where rockbreakers are required to be used within 10 m of Queensland Rail heritage structures, pre-construction condition surveys and monitoring during construction would be recommended.

Surface Roads (Remote from Major Worksites)

Ipswich Motorway On-Ramp

The nearest sensitive receivers to the Ipswich Motorway on-ramp worksite are identified in **Table 90**.

Table 90 Nearest Sensitive Receivers – Ipswich Motorway On-ramp

Work Site	Receiver Area	Location Relative to Works (m)
Ipswich Motorway On-ramp	A – Residential South	50
	B – Residential North-East	350

EXECUTIVE SUMMARY

As the Ipswich on-ramp worksite is outside the rail corridor, QR's CoP noise goals applied to other surface worksites (within rail corridors) would not be relevant. Further, it is acknowledged that under certain "safety" and/or "traffic flow" circumstances, numerical noise limits are typically not applied to road construction works, particularly where the works are required within the road reserve of major roads (eg Ipswich Motorway).

It is not considered that numerical noise goals be proposed for these works given that:

- These works would be short term in nature.
- They would be undertaken throughout the day unless "worker safety" or "traffic flow" considerations meant that DTMR mandated night-time works (which was one of the CG's noise goal exclusions for the Legacy Way Conditions of Approval).

Although temporary disruption to normal amenity of the nearest residential receivers is an inevitable consequence of roadworks of this nature, it is imperative that all practicable noise management measures be employed with particular focus on community engagement.

With regards to potential vibration impacts, at a distance in excess of 50 m to the nearest residential receiver, vibration impacts from the Ipswich On-ramp works would not be anticipated.

Other Minor Roadworks

The following roadworks, also not directly connected to a major construction worksite, would be required to accommodate the Project:

- Beaudesert Road and Musgrave Road intersection upgrade.
- Realignment and truncation of Dollis Street involving the construction of two large cul-de-sacs either side of Riawena Road overpass.
- Beaudesert Road and Lillian Avenue intersection upgrade including:
  - New signalised intersection.
  - Conversion of Tranmore Street to two-way traffic flow.
  - Realignment of Lillian Avenue east of the Beaudesert Road intersection.
  - Realignment (including raising) of Beaudesert Service Road connecting to Lillian Avenue.
- Realignment of Heaton Street under the existing span of Beaudesert Road overpass.
- Realignment of Fairlie Terrace under the existing span of Beaudesert Road overpass.
- New traffic signals at Gladstone Street and Muriel Avenue intersection.

It is anticipated that construction noise and vibration emissions from these relatively short term roadworks (eg like those that occur regularly throughout Queensland), would be temporary in nature and, with the exception of the Gladstone Street and Muriel Avenue intersection works and realignment of Heaton Street, are remote from residential receivers. Therefore taking into account the nature and short term duration of these works, no further noise and vibration assessment has been carried out.

EXECUTIVE SUMMARY

Surface Trackwork Construction Noise

Trackwork required for CRR would include the use of typical Queensland Rail rollingstock for delivery of both rail and concrete sleepers to site, specialised plant including switch tampers, mainline tampers, ballast regulators, rail grinder, overhead wiring plant etc. Due to the large extent of CRR surface track, it is not practical to identify all noise sensitive receivers potentially affected by surface track construction noise within (narrow) operational rail corridors. Consequently, construction noise levels from activities/plant listed in **Table 22** have been calculated in **Table 91** for various setback distances. The calculated noise emission levels in **Table 91** assume "line-of-sight" exposure and do not take into consideration the potential mitigating effects of topographical shielding.

It should be noted that work associated with construction of new rail track or the upgrading of existing rail track is relatively short in duration, particularly because the work is often confined to shut down periods (eg night-time, weekend, Christmas holidays etc) which is standard Queensland Rail practice to minimise disruption to rail services.

Table 91 Surface Track Construction Plant Noise Emissions

Plant Item	Sound Power Level (dBA)	Noise Level at Setback Distance				
		10 m	25 m	50 m	100 m	250 m
Flat bed truck with crane	110	82	74	68	62	54
Ballast truck (rail)	110	82	74	68	62	54
Ballast truck (road)	110	82	74	68	62	54
Speed swing (360)	114	86	78	72	66	58
Locomotive	111	83	75	69	63	55
Ballast regulator	122	94	86	80	74	66
Tamper	115	87	79	73	67	59
Hand held compactor	114	86	78	72	66	58
CWR welding plant	93	65	57	51	45	37
Cherry Picker	104	76	68	62	56	48
Wiring equipment	111	83	75	69	63	55
Engineers train	111	83	75	69	63	55

As indicated by the construction noise levels in **Table 91**, high noise levels (potentially in excess of Queensland Rail's 87 dBA L_{Amax} planning level) may result from CRR trackwork over small setback distances. In addition to limiting, where practicable, the duration of track construction works near any sensitive receiver, all reasonable and feasible noise mitigation measures would need to be applied consistent with the measure listed in Queensland Rail's CoP.

IMPACT ASSESSMENT OF MECHANICAL TUNNEL EXCAVATION

Approximately 9.2 km of driven tunnelling will be required for the CRR tunnels. The tunnels will mainly be constructed using Tunnel Boring Machines (TBM), which account for approximately 8 km of the tunnelling. The underground stations at Woolloongabba, Albert Street and Roma Street will be excavated by a combination of cut and cover and roadheader. Approximately 200 m of the tunnel near the Northern Portal, after the extraction point for the TBMs, will be excavated by roadheader. The TBMs tunnelling north are proposed to be launched north of the proposed Woolloongabba Station.

EXECUTIVE SUMMARY

TBM Tunnelling Works

The receivers nearest to the tunnels have been identified and the corresponding ground-borne vibration and noise levels have been predicted.

Regarding vibration, sleep disturbance may result if the vibration levels from a continuous source are higher than 0.5 mm/s which is predicted to be the case for many residences above the CRR tunnels. It should be noted that the 0.5 mm/s night-time vibration goal for this project is conservatively low and some people may be comfortable with higher levels.

Worst-case predictions indicate that it is likely that ground-borne noise from the TBM will be noticeable in many buildings above the tunnel alignment and may result in sleep disturbance.

It should be noted that these exceedances will only occur during a relatively short period (less than 1 week for each TBM passby).

The following management strategies are proposed to minimise the impact of the TBM tunnelling works:

- Ground-borne noise and vibration monitoring to be undertaken at the commencement of tunnelling to confirm that the source data utilised for this assessment is applicable to this project (including the low frequency noise assessment inputs and findings).
- Comprehensive advance notice as well as educating the public of intended tunnelling activities in the localities near the tunnel alignment. Part of the consultation process should include information regarding the monitoring program which may require involvement from residences located above the tunnel alignment. A thorough education program will assist to allay fears of the tunnelling process.
- Conduct building condition surveys in accordance with Brisbane City Council requirements where it is considered there may be potential risk for cosmetic (superficial) building damage from TBM excavation.
- Relocation of residents particularly impacted by ground-borne noise from TBM tunnelling may be required.

Roadheader Tunnelling Works

The receivers nearest to any roadheading works associated with the cross passages, Northern Portal and Station caverns have been identified and corresponding ground-borne noise and vibration predicted.

It should be noted that the roadheaders generate lower ground-borne noise and vibration levels compared to the TBMs.

All residential receivers comply with the night-time vibration goal of 0.5 mm/s Peak Particle Velocity during the tunnelling works for the cross passages. All receivers also comply with the relevant cosmetic damage vibration goals.

There are 22 exceedances of the night-time ground-borne noise goal for residential receivers above or close to the cross passages (13 of these are within a marginal 2 dBA exceedance). It should be noted that the ground-borne noise and vibration from excavation of cross passages will be short duration (2 to 3 days) works. All commercial receivers comply with the relevant 45 dBA (office spaces) and 50 dBA (retail) ground-borne noise goals.

EXECUTIVE SUMMARY

All residential receivers comply with the ground-borne noise and vibration goals during the roadheader tunnelling works at the portal and station locations. Levels at all commercial receivers comply with the relevant 45 dBA (office spaces) and 50 dBA (retail) ground-borne noise goals.

There are predicted exceedances of the ground-borne noise and vibration goals for five hotels near Albert Street Station. It should however be noted that the predicted levels are for ground floor and the ground-borne noise and vibration levels attenuate by approximately 2 dB per floor for the first 4 floors and by approximately 1 dB per floor thereafter. This results in exceedances of the ground-borne noise and vibration goals only for hotel rooms on the Ground Floor and Floor 1.

LOW FREQUENCY NOISE ASSESSMENT

The low frequency noise assessment based on the DERM Ecoaccess ALFN Guideline includes an assessment of annoyance due to infrasound (dBG) and low frequency noise ($L_{pA,LF}$). The assessment indicates that annoyance limits will likely be exceeded during driven CRR tunnelling works for offset distances less than approximately 100 m.

The recommended noise and vibration management plan should cover mitigation of the potential for low frequency noise impacts, with the following recommendations as a minimum:

- A comprehensive notification and education program to assist in allaying unfounded fears regarding tunnelling. Part of the education process should include an indication of tunnelling progress and subsequent likely (temporary) exposure periods.
- Infrasound and low frequency noise measurements in accordance with the ALFN guideline at the commencement of tunnelling operations and in the event of a “low frequency” noise complaint (where required).
- An option for temporary relocation of people pending the outcome of an assessment of the impact against the EIS goals and ALFN Guideline.

CONSTRUCTION TRAFFIC NOISE AND VIBRATION ASSESSMENT

The effect of construction-related heavy vehicle traffic on the noise emission from roadways has been assessed by calculating how the additional truck traffic would alter the $L_{A10(12hour)}$ level of noise emission from roadways using the CoRTN prediction algorithms. For the purpose of this analysis, the $L_{A10(12hour)}$ is the average L_{A10} traffic noise level between the hours of 6:30 am and 6:30 pm. For Woolloongabba Station and the Southern Portal worksites the change in road traffic noise levels was assessed over the following time periods to cover the 24 tunnelling operations from these sites:

- $L_{A10(18hour)}$ for between 6 am and 12 midnight.
- $L_{A10(1hour)}$ for the peak number of heavy vehicle movements during any hour between 12 midnight and 6 am.

On a given roadway, the essential modelling inputs that the additional construction traffic will alter are the percentage of heavy vehicles and total vehicle numbers utilising that roadway. For the assessment of typical construction truck volumes, the peak daily frequencies have been adopted as being representative of total truck movements. This assessment is summarised in **Table 101**.

For this analysis the existing annual average daily traffic (AADT) road traffic predictions on all roads have been obtained from traffic information supplied by the CRR JV.

Table 101 Effect of Construction Truck Movements on Traffic Noise Levels along Spoil Routes

EXECUTIVE SUMMARY

Worksite	Road Segment	Change in Road Traffic Noise Level due to CRR
Tunnel Worksites		
Northern Portal	Gregory Terrace to Bowen Bridge Road	L_{A10}(12hr) +0.3
Roma Street Station	Roma Street adjacent existing Station	L_{A10}(12hr) +0.3
Albert Street Station	Alice Street west of Albert Street	L_{A10}(12hr) +0.3
Woolloongabba Station	Ipswich Road south of Stanley Street	L_{A10}(18hr) +0.3
		L_{A10}(1hr) +0.8
Boggo Road Station	Annerley Road south of Boggo Road	L_{A10}(12hr) 0
Southern Ventilation Shaft	Fairfield Road south of Brougham Street	L_{A10}(12hr) 0
Southern Portal	Lucy Street[2]	L_{A10}(18hr) +1.5
	Ipswich Road south of Lucy Street	L_{A10}(18hr) +0.2
		L_{A10}(1hr) +0.5
Surface Worksites		
O'Connell Terrace	Bowen Bridge Road north of O'Connell Tce	L_{A10}(12hr) 0
Mayne Stabling Yard	Inner City Bypass	L_{A10}(12hr) 0
Clapham Stabling Yard	Fairfield Road south of Chale Street	L_{A10}(12hr) +0.2

Note 1 – No traffic data available for Cardross Street.
Note 2 – Road adjacent to industrial/commercial receivers only.

From **Table 101** it can be seen that spoil traffic would not increase average traffic noise levels on spoil routes that pass residential receivers by more than 0.3 dBA for existing road corridors between 6:30 am and 6:30 pm. For Woolloongabba Station, an increase in road traffic noise level of 0.8 dBA was predicted for the (12 midnight to 6 am) night-time peak. At the Southern Portal an increase of up to 0.5 dBA was predicted for the $L_{A10(1hour)}$ night-time peak for residential receivers adjacent to Ipswich Road. A 1.5 dBA increase is predicted for Lucy Street however this is not impacting on residential receivers. It is generally recognised in acoustics that changes in noise levels of 2 dBA or less are undetectable to the human ear and therefore negligible.

Fully loaded trucks travelling on properly maintained public roadways would not generate significant levels of ground vibration (ie able to be clearly felt) at buildings adjacent to spoil routes.

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APPENDICES

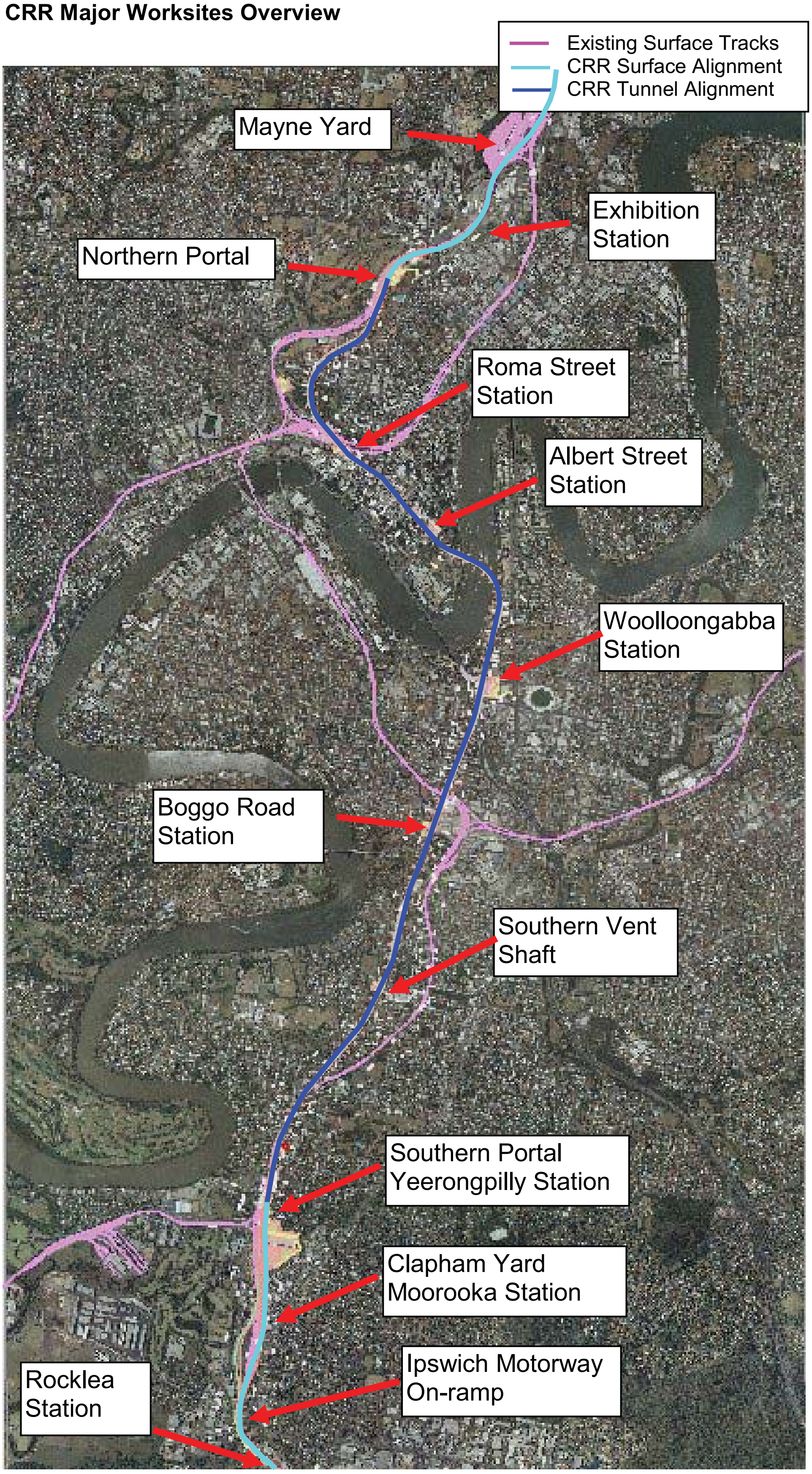
1 INTRODUCTION

SLR Consulting Australia Pty Ltd (SLR Consulting) has been commissioned by the SKM-Aurecon CRR Joint Venture (CRR JV) to prepare an assessment of the noise and vibration aspects of the construction phase for Cross River Rail (CRR) for inclusion in the Environmental Impact Statement (EIS).

CRR is a major project for the City of Brisbane, South East Queensland and the State of Queensland. It will provide a new north-south rail line in Brisbane's inner city that includes a new river crossing and inner city train stations. From the existing southern rail network, it will pass under the central business district (CBD) of Brisbane and connect with the existing northern rail network via the Exhibition loop. CRR will include a tunnel under the Brisbane River and new and upgraded train stations.

An overview of the major work sites for proposed as part of the Reference Project is shown in **Figure 9**.

Figure 9 CRR Major Worksites Overview



1.1 Terms of Reference

The specific requirements of the Terms of Reference in relation to the construction noise and vibration impacts associated with the project are reproduced below.

3.8.1 Description of Environmental Values

This section should describe the existing noise and vibration environment that may be affected by the project in the context of environmental values as defined by the Environmental Protection (Noise) Policy 2008 (EPP(Noise)). DERM's Noise Measurement Manual should be considered and references should be made to the DERM's EcoAccess Guidelines Noise and Vibration from Blasting and Planning for Noise Control, as appropriate.

Likely sensitive noise receptors adjacent to more significant project components (e.g. proposed station and major worksite locations) should be identified and typical background noise and vibration levels estimated based on surveys at representative sites. The potential sensitivity of such receptors should be discussed and performance indicators and standards nominated.

3.8.2 Potential Impacts and Mitigation Measures – Construction

The EIS should describe the impacts of noise and vibration generated during the construction phase of the project, especially associated with major worksites. Noise and vibration impact analysis should include

- *an hierarchical impact mitigation methodology*

- *the levels of noise and vibration generated, including noise and vibration generated by tunnelling works, equipment, surface construction sites spoil haulage management, placement and management, construction vehicle movements and ancillary activities, with noise contours, assessed against current typical background levels, using modelling where appropriate*

- *the impact of noise, including low frequency noise (noise with components below 200Hz) and vibration at all potentially sensitive receivers within and around the study corridor, including low frequency re-radiated noise within sensitive premises due to tunnel construction compared with the performance indicators and standards nominated above*

- *potential effects of ground vibration on nearby surface buildings structure*

- *identification of properties at significant risk of noise and vibration impacts for pre-construction building conditions*

- *vibration impacts on transport-related infrastructure*

- *proposals to minimise or eliminate these effects, including details of any screening, lining, enclosing or bunding of facilities, alternative construction methods or timing schedules for construction and operations that would minimise environmental harm and environmental nuisance from noise and vibration.*

This assessment is to be inclusive of noise and vibration impacts to or on critical or sensitive places and determine the ground vibration effects on equipment within health care facilities.

1.2 Objectives

The objectives of this report in relation to the Project description are to:

- Address the acoustical requirements detailed in the Terms of Reference in relation to the construction phase of the Project.
- Identify sensitive locations in relation to construction noise and vibration.
- Define noise and vibration criteria by which construction noise and vibration impacts at sensitive locations may be evaluated.
- Describe noise and vibration levels associated with the Project.
- Evaluate the extent of resulting impacts and the scope for the reduction of these impacts through reasonable and feasible mitigation strategies.
- Recommend appropriate mitigation measures and noise and vibration performance requirements in order to protect community values and sensitive locations.

2 IMPACT ASSESSMENT GOALS

2.1 Community Values Relating to Noise and Vibration

The EPP(Noise) defines the values to be protected as the qualities of the acoustic environment that are conducive to:

c. Protecting the health and biodiversity of ecosystems.

d. Human health and wellbeing, including by ensuring a suitable acoustic environment for individuals to do any of the following-

   - Sleep
   - Study or learn
   - Be involved in recreation, including relaxation and conversation

e. Protecting the amenity of the community.

Sleep

A person's ability to sleep is perhaps the most important value that can be impacted by noise and/or vibration. Noise and vibration effects on sleep are generally referred to as sleep disturbance.

Education and Work

The needs for education and work in relation to the acoustic environment relate to the need to be able to communicate effectively either face-to-face or by telephone, and the ability to think or focus on auditory information without undue intrusion from other sources of noise.

Recreation

Recreation is an important aspect of a healthy lifestyle. Recreation may include time spent both indoors and outdoors. In terms of acoustic function, recreation may involve communication with others in verbal conversation or simple enjoyment of an outdoor or indoor soundscape.

2.1.1 Acoustic Quality Objectives

The EPP(Noise) includes long term acoustic quality objectives. It is intended that the acoustic quality objectives be progressively achieved as part of achieving the purpose of the EPP(Noise) policy over the long term. Due to construction noise being time limited and not permanent, it is not considered appropriate to assess construction noise against the long term acoustic quality objectives. Furthermore, the EPP(Noise) states that it is not applicable for assessing noise mentioned in the reprint No 8 (2009) of the Environmental Protection Act 1994 (the Act), Schedule 1, Part 1 which refers to safety and transportation noise. Therefore, the acoustic quality objectives are also not considered applicable for assessing the operational noise associated with rail operations for this project. The acoustic quality objectives will be considered for assessing the ventilation and mechanical plant noise associated with the new stations as these will be permanent long-term noise sources.

2.1.2 Evaluating Impacts

The impact of a project on community values relating to noise and vibration is normally evaluated using statutory regulations and policies which describe acceptable levels of noise and vibration from various sources.

For types of noise for which specific levels are not listed in statutory regulations or policies, it is common to refer to relevant Australian or internationally recognised standards that define acceptable levels of noise and vibration in various human and structural contexts. Such standards can serve an advisory function to regulatory organisations and may be adopted by statutory authorities for the purpose of defining regulatory levels.

2.2 Construction Noise Impact Assessment Goals

2.2.1 Standard Statutory Construction Noise Regulations

State and Local Government noise policies and regulations do not specify noise limits for construction activity.

The Act, Section 440R states the following for building works:

1. *A person must not carry out building work in a way that makes an audible noise—*

   (a) on a business day or Saturday, before 6.30a.m. or after 6.30p.m; or

   (b) on any other day, at any time.

2. *The reference in subsection (1) to a person carrying out building work—*

   (a) includes a person carrying out building work under an owner-builder permit; and

   (b) otherwise does not include a person carrying out building work at premises used by the person only for residential purposes.

Thus, construction activity between the hours of 6.30 am to 6.30 pm Monday to Saturday, excluding public holidays is not normally subject to numerical noise limits (other than those which apply to blasting), providing the machinery being used is in good working condition. This regulation is summarised in **Table 1**.

Table 1 Standard Noise Regulations for Construction Activity

Day	Operating Constraint
Monday to Saturday	6.30 am – 6.30 pm – no numerical noise limits
Sunday, Public Holidays and all other times	Construction must be inaudible at noise sensitive locations

This project would involve some instances where construction activity would be required to be undertaken on a 24 hour basis and that would likely be audible outside of the regulated construction hours. Accordingly, the project would require approval to operate outside of the regulated hours

2.2.2 Assessment Philosophy for Extended Construction Works

It is anticipated that the project would involve the operation of certain noise sources on worksites (eg temporary ventilation and spoil extraction to surface from tunnelling) on a 24 hour per day basis, seven days per week over periods extending beyond a year. Thus, as these construction noise sources would be present for an extended period of time, it is recommended that numerical noise goals be utilised to limit the adverse impacts on the community for both the day and night period. Based on experience from other similar projects, it is also unlikely that these sources could be made completely inaudible at night.

There are no established noise criteria in Queensland for the assessment of impacts associated with long-term construction noise sources, especially at night. It is suggested that assessment criteria for long-term construction noise sources should reflect the noise environment that is considered acceptable for normal functioning of adjoining developments.

Thus, the potential impacts of long-term construction noise sources should be assessed by comparison with appropriate noise goals for:

1. Sleep disturbance criteria contained in Brisbane City Council's Noise Impact Assessment Planning Scheme Policy (NIAPSP) and Queensland Department of Environmental Resources Management (DERM) Ecoaccess Guideline Planning for Noise Control (Ecoaccess PNC).
2. Recommended internal noise levels for various building uses specified in AS/NZS 2107: 2000 Acoustics – Recommended design sound levels and reverberation times for building interiors (AS 2107).

The NIAPSP and Ecoaccess PNC also include 'background noise creep' criteria. Background noise creep requires consideration where a locality is subject to various (continuous) noise sources from on-going development. However in this instance, as the proposed construction works are not permanent, it would be unreasonable to apply a 'background creep' criterion to the construction phase of this project.

The specific noise goals for sleep disturbance, recommended noise levels for various building functions and comparison with existing ambient background noise levels are discussed in the following sections.

Appropriate noise goals for relatively short term construction noise sources such as surface track construction (refer to **Section 2.2.3**), ground-borne noise from driven tunnelling (refer to **Section 2.2.4**) and airblast over-pressure from blasting (refer to **Section 2.2.5**) is also discussed.

Sleep Preservation

Both BCC NIAPSP and DERM Ecoaccess PNC recommend maximum internal noise levels in sleeping areas to avoid sleep disturbance. The recommended maximum levels from these two policies are summarised in **Table 2**.

Table 2 Regulatory Guidelines for Avoidance of Noise-induced Sleep Disturbance

Guideline	Recommended Maximum Internal LAmax	Recommended Maximum Number of Occurrences per Night
BCC NIAPSP		
AS1055.1 Appendix A R1-R3 Categories AS1055.1 Appendix A R4-R6 Categories	45 dBA 50 dBA	"must not regularly exceed" "must not regularly exceed"
DERM Ecoaccess PNC	"Approximately 45 dBA"	"no more than 10 to 15"

The "R-category" descriptions in AS1055.1 are somewhat subjective. R1 and R2 are described as "Areas with negligible to low density transportation and R3 is described as "Areas with medium density transportation or some commerce or industry" whereas R4 is described as "Areas with dense transportation or with some commerce or industry" and R5 to R6 are described as "Areas with very dense to extremely dense transportation or in commercial districts or bordering industrial districts to within predominantly industrial districts".

The NIAPSP approach to assessing sleep disturbance is preferred as it includes some recognition that sleep disturbance is a function of the background noise level in addition to the level of the intrusive sound.

Acceptable levels of steady or near-steady ("quasi-steady") noise for sleeping environments are recommended in Australian Standard AS 2107. These are detailed in the section below.

Functional Noise Levels for Various Building Uses

The maximum recommended internal noise levels specified in AS 2107 are shown in **Table 3** for a selection of building uses that may be relevant to building uses near construction works or tunnelling with Tunnel Boring Machines (TBM) and Roadheaders.

Table 3 Example Noise Design Levels from AS 2107

Type of Building Occupancy		Recommended Design Sound Level $L_{Aeq,adj(15 minute)}$ (dBA)	
		Satisfactory	Maximum
Residential buildings (sleeping areas)	near major roads	30	40
	near minor roads	30	35
Residential buildings (living areas)	near major roads	35	45
	near minor roads	30	40
Hospitals	wards	35	40
	operating theatres, nurses stations consulting rooms and the like	40	45
Place of Worship (with speech amplification)		35	40
School music rooms		40	45
School teaching area		35	45
School library		40	50
School Gymnasium		45	55
Commercial buildings – office space		40	45
Commercial Buildings – retail space		45	50

The stated scope of AS 2107 applies to noise that is steady or quasi-steady in nature. In practice, the design levels from AS 2107 are widely used by Councils (eg Brisbane City Council NIAPSP) and the Department of Transport and Main Roads as design goals in relation to daytime and night-time traffic noise which demonstrates some fluctuations in noise level. Brisbane City Council also uses AS 2107 for the assessment of mechanical plant noise intrusion into new residential developments. Further, AS 2107 is also applicable to steady or quasi-steady state construction noise levels. A measurement period of between 15 minutes and 1 hour is normally used to evaluate the LAeq parameter. Thus the proposed use of AS 2107 maximum design levels for the assessment of relatively steady plant noise emanating from construction sites and tunnelling has some similarities to the utilisation of AS 2107 in contemporary assessments of traffic noise and of mechanical plant noise intrusion into dwellings.

Due to the extended construction works, the above maximum design levels according to AS 2107 are proposed as appropriate construction noise goals for steady state construction noise during the daytime period (6.30 am to 6.30 pm on Monday to Saturday). To assess non-steady state construction noise, the $L_{A10(15minute)}$ parameter with a tolerance of 10 dB above the maximum design levels according to AS 2107 is proposed during the daytime period (6.30 am to 6.30 pm on Monday to Saturday).

For night-time steady state construction noise, the maximum design levels according to AS 2107 are proposed as appropriate night-time noise goals.

Comparison with Existing Noise Environment

The use of existing background noise levels for the assessment of noise impacts is a common impact assessment practice. The DERM Ecoaccess PNC refer to the short term Specific (Intrusive) Noise Levels (SNL) noise criteria presented in **Table 4**.

Table 4 Intrusive 'Background Plus' Noise Criteria

Criterion	Noise Limit
Specific (Intrusive) Noise Levels (Ecoaccess PNC)	RBL[1] + 3 dBA $L_{Aeq(1hour)}$

Note 1: Measured Rating Background Level LA90 according to DERM Ecoaccess PNC. This is representative of the average minimum background noise level.

Adjustments are normally made to the source levels as per AS1055.1-1997 in order to account for the increased subjective loudness associated with noises that are particularly tonal or impulsive.

The DERM Ecoaccess PNC is normally applicable for long term industrial (operational) noise emissions during day, even and night-time assessed external to the dwelling. The purpose of this section is to propose applicable noise goals for assessment of long term construction noise emissions during extended work hours (night-time). During the night-time period, the primary objective would be to protect the internal noise amenity of surrounding residences and it is therefore proposed that the above internal noise goals according to AS 2107 take president over these external noise goals.

2.2.3 Surface Trackwork Construction Noise Goals

Consistent with State and Local Government noise policies and regulations, Queensland Rail do not specify noise limits for construction activity. Queensland Rail does prescribe "Planning Levels" within the *Code of Practice – Railway Noise Management* (Queensland Rail Code of Practice) which is applied to the long term operation of the rail network. The Queensland Rail Code of Practice is used as a guide in deciding a reasonable level of noise from day to day operation of the network. The Queensland Rail Code of Practice planning noise levels have been adopted herein as a guide to assessing the impact of relatively short term construction noise levels from CRR surface track worksites

The Queensland Rail Code of Practice refers to the following noise metrics and planning noise levels.

Operational Noise Metrics

The two primary noise metrics used to describe railway noise emissions in accordance with the Queensland Rail Code of Practice are:

- **Single Event Maximum Level** Queensland DERM and Queensland Rail have reached agreement on the definition of single event maximum level as being the *"arithmetic average of the 15 highest maximum noise levels in the 24 hour period"*. For construction noise sources, the $L_{Amax,adj}$ would be applicable.
- **$L_{Aeq(24hour)}$** "Equivalent Continuous Noise Level", sometimes referred to as the "energy-averaged noise level". The $L_{Aeq(24hour)}$ may be likened to a "noise dose", representing the cumulative effect of all construction noise events occurring in one day.

Operational Planning Levels

Queensland Rail's Code of Practice outlines the operational "planning levels" applicable to this project.

The Planning Levels are:

- 65 dBA, assessed as the $L_{Aeq(24hour)}$.
- 87 dBA, assessed as the $L_{Amax,adj}$.

The Queensland Rail planning levels refer to an assessment location one metre in front of the facade of an affected noise sensitive building. For consistency with the noise assessment for tunnelling worksites, the planning levels are corrected to a free field assessment location (ie adjusted by –3 dBA).

2.2.4 Ground-borne (Regenerated) Noise from Tunnelling

Vibration generated by tunnelling can sometimes be heard in nearby buildings as a low frequency "rumbling" sound. The potential for this to occur may be enhanced where the tunnel alignment is passing near or directly beneath a building.

The maximum design levels listed in AS 2107 (see **Table 3**) are recommended as guidance for the purpose of assessing ground-borne noise levels within buildings during the construction phase of the project.

Furthermore, to assess the possible low frequency impacts from tunnelling the DERM EcoAccess Draft Guideline Assessment of Low Frequency Noise (Ecoaccess ALFN) gives recommended noise criteria as shown in **Table 5**

Table 5 Low Frequency Noise Criteria.

Type of Space	$L_{pA,LF}$ [1] (dBA)
Dwelling, evening and night	20
Dwelling, day	25
Classroom, office etc	30
Rooms within commercial enterprises	35

Note 1: The A-weighted 1/3rd octave band data for indoors is summed to yield the A-weighted noise level in the frequency range 10 Hz to 160 Hz. The resulting level is called LpA,LF.

The Ecoaccess ALFN guideline also gives advice regarding assessment of infrasound. However, the construction works associated with the CRR is not anticipated to generate any infrasound (based on past experience of tunnelling projects) and therefore will not require a specific assessment.

It should be noted that the driven tunnelling is a distinctly short-term construction noise source of approximately one to two weeks duration at each sensitive receiver location. For this reason, it is considered appropriate to apply a relaxation on the low frequency criterion (in the draft Ecoacces ALFN guideline) by 5 dBA.

2.2.5 Airblast Overpressure from Blasting

Noise criteria for blasting events can be found in the Act and the DERM EcoAccess Noise, Vibration from Blasting (Ecoaccess Blasting) and the United States Bureau of Mines (USBM) Report of Investigation RI 8507. These criteria are summarised in **Table 6**

Table 6 Blasting Airblast Noise Criteria

Reference	Airblast Overpressure	Comment
The Act	115 dBZ[1] peak for 4 out of any 5 consecutive blasts 120 dBZ peak for any blast	Takes into account both building damage and human comfort
Ecoaccess Blasting	115 dB Linear peak for 9 out of any 10 consecutive blasts 120 dB Linear peak for any blast	Takes into account both building damage and human comfort
USBM	130 dB Linear, when measured by a system having low frequency limit of 6 Hz or lower 132 dB Linear, when measured by a system having low frequency limit of 2 Hz or lower	Only building damage

Note 1: dBZ is a frequency weighting of flat frequency response between 10 Hz and 20 kHz (±1.5dB). The dBZ response sometimes replaces the traditionally used dB Linear response as it does not define the frequency range over which the meter will be linear. However, with a SLM Type 1, the difference in measured level will be negligible.

The US criteria are cosmetic damage limits based on the relationship between the level of airblast and the probability of window breakage, and include a significant safety margin. It has been well documented that windows are the elements of residential buildings most at risk to damage from airblast from blasting.

The Coordinator General has applied airblast criteria in line with the cosmetic damage limits in USBM RI 8507 for the past three large tunnelling projects in Brisbane (ie CLEM 7, Airport Link and Northern Link).

The Ecoaccess Blasting guideline also give advice that blasting should generally only be permitted during the hours 9 am to 3 pm, Monday to Friday, and from 9 am to 1 pm on Saturdays. Blasting should not generally take place on Sunday or public holidays. Limiting blasting to between the hours recommended in the Ecoaccess Blasting guideline is likely to be impractical for the proposed CRR. The principle of limiting the hours of blasting to the “least sensitive” times of the day, however, is a valid one. Therefore, blasting is proposed to be limited to the times 7am to 6 pm each day (e.g. “daytime” as defined in the Ecoaccess guidelines).

For the impact assessment of airblast overpressure from blasting, it is recommended not to exceed 130 dB Linear peak.

2.2.6 Construction Road Traffic Noise

Where the construction phase of CRR is adding heavy vehicles to the existing road network, it is appropriate to consider the incremental change in noise levels due to the changes in traffic volume.

A change of up to 3 dBA in the level of a dynamic noise, such as passing vehicles is difficult for most people to detect, whilst a 3 dBA to 5 dBA change corresponds to a small but noticeable change in loudness. A 10 dBA change corresponds to an approximate doubling or halving in loudness.

It is acknowledged that people are likely to notice increased traffic based on visual clues and perception of vehicle pass-by frequency before they will objectively notice an increase in the average noise level.

For assessment purposes it is common to set the threshold of significance in relation to changes in the noise emission level from roads at 2 dBA.

For the impact assessment of construction traffic noise the noise goal in **Table 7** is recommended.

Table 7 Construction Road Traffic Noise Goal

Type of Road	Goal
Existing Roads	≤ 2 dBA change in existing $L_{A10(1hour)}$, $L_{A10(12hour)}$ and $L_{A10(18hour)}$

2.2.7 Construction Noise Goals Summary

A summary of applicable noise goals at noise sensitive receptors associated with the construction phase of the project is shown in **Table 8.**

Table 8 Construction Noise Goals

Construction Noise				**Blasting [1] Airblast**	**Surface Track Worksites Queensland Rail CoP**	**Construction Road Traffic**
Monday to Saturday (6.30am – 6.30pm)	**Monday to Saturday (6.30pm to 6.30am); Sundays and Public Holidays**					
	Sleep Disturbance [2]		**Low Frequency $L_{pA.LF}$ [3]**			
	Continuous	**Intermittent**				
Steady State ($L_{Aeq,adj}$) Maximum Design Level according to AS 2107 **Non-Steady State** ($L_{A10,adj}$) Maximum Design Level according to AS 2107 + 10 dBA	35 dBA $L_{Aeq,adj(1hour)}$ (AS1055.2 Appendix A R1-R3 Categories) 40 dBA $L_{Aeq,adj(1hour)}$ (AS1055.2 Appendix A R4-R6 Categories)	45 dBA $L_{Amax,adj}$ (AS1055.2 Appendix A R1-R3 Categories) 50 dBA $L_{Amax,adj}$ (AS1055.2 Appendix A R4-R6 Categories)	25 dBA $L_{pA.LF}$	130 dB Linear Peak	87 dBA $L_{Amax,adj}$ 65 dBA $L_{Aeq,adj(24hour)}$	≤ 2 dBA change in existing $L_{A10(1hour)}$, $L_{A10(12hour)}$ and $L_{A10(18hour)}$

Note 1: Blasting should generally only be permitted during the hours of 7 am to 6 pm, Monday to Saturdays
2: Sleep disturbance in accordance with AS2107 and BCC NIAPSP. Internal noise level in bedroom
3: Low frequency assessment in accordance with DERM EcoAccess ALFN. The A-weighted 1/3rd octave band data for indoors is summed to yield the A-weighted noise level in the frequency range 10 Hz to 160 Hz. The resulting level is called $L_{pA,LF}$.

Although specific noise goals for the evening period (6.30 pm to 10.00 pm) have not been proposed for the Project, it is acknowledged that the evening period is normally associated with an ambient noise environment with acoustic amenity in-between that for the daytime and night-time periods. This is supported by the measurements of the existing ambient background noise environment throughout the study area (see **Table 18**). It would therefore be reasonable to adapt noise goals for the evening period of noise levels in-between those proposed for the daytime and night-time periods (eg 50 dBA L_{A10} internal noise level for intermittent noise sources at residences in inner-city locations).

2.3 Construction Vibration Impact Assessment Goals

Given a sufficiently high vibration level, potential adverse effects of vibration in buildings generated by construction activities can be divided into the following main categories:

- Human comfort.
- Effects of vibration on building contents.
- Safe vibration levels for common services.
- Cosmetic damage.

Vibration criteria are also differentiated between short transient vibrations, such as those induced by blasting (of the order of one to two seconds), and more sustained vibrations such as those associated with tunnel boring, roadheading or rockhammering. The risk of human discomfort is generally lower for short duration vibrations. The risk of cosmetic building damage is also lower for short duration vibrations compared to continuous vibrations of the same magnitude. This is because short duration vibrations will be less likely to fully ‘excite’ resonant vibration responses in a building structure.

2.3.1 Human Comfort

Humans are far more sensitive to vibration than is commonly realised. They can detect and possibly even be annoyed at vibration levels which are well below those causing any risk of damage to a building or its contents.

Human Subjective Response to Vibration

The actual perception of motion or vibration may not, in itself, be disturbing or annoying. An individual’s response to that perception, and whether the vibration is “normal” or “abnormal”, depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as “normal” in a car, bus or train is considerably higher than what is perceived as “normal” in a shop, office or dwelling.

Human tactile perception of random motion, as distinct from human comfort considerations, was investigated by Diekmann and subsequently updated in German Standard DIN 4150 Part 2 1975. On this basis, the resulting degrees of perception for humans are suggested by the continuous vibration level categories given in **Table 9**

Table 9 Vibration Levels and Human Perception of Motion

Approximate Vibration Level	Degree of Perception
0.10 mm/s	Not felt
0.15 mm/s	Threshold of perception
0.35 mm/s	Barely noticeable
1 mm/s	Noticeable
2.2 mm/s	Easily noticeable
6 mm/s	Strongly noticeable
14 mm/s	Very strongly noticeable

Note: These approximate vibration levels (in floors of building) are for vibration having frequency content in the range of 8 Hz to 80 Hz.

Table 9 suggests that people will just be able to feel continuous floor vibration at levels of about 0.15 mm/s and that the motion becomes “noticeable” at a level of approximately 1 mm/s.

Human Comfort Vibration Goals

Guidance in relation to assessing the potential human disturbance from ground-borne vibration inside buildings and structures is contained in Australian Standard AS 2670.2-1990 *“Evaluation of Human Exposure to whole-body vibration Part 2 Continuous and shock induced vibrations in buildings (1 Hz to 80 Hz)”.*

The AS 2670.2 gives guidance to satisfactory vibration velocity levels based on the RMS or “root mean squared” vibration levels. The RMS vibration level can be converted to peak vibration level by applying the appropriate “crest” factor (ie ratio of the peak level to RMS level) to obtain a “peak” vibration level. Crest factors will vary from 1.4 for construction activities of a sinusoidal nature (eg continuous vibratory rolling and rotating plant) up to 4 or more for intermittent activities such as rockbreaking and blasting.

Satisfactory magnitudes of peak vibration velocity (ie below which the probability of “adverse comment” is low) from AS 2670.2 are shown in **Table 10** (for generally sinusoidal vibration).

Table 10 Satisfactory Level or Peak Vibration Velocity (8 Hz to 80 Hz)

Type of Space Occupancy	Time of Day	Satisfactory Peak Vibration Levels in mm/s Over the Frequency Range 8 Hz to 80 Hz			
		Continuous or Intermittent Vibration		Transient Vibration Excitation with Several Occurrences per Day	
		Vertical	Horizontal	Vertical	Horizontal
Critical working areas (eg some hospital operating theatres, some precision laboratories, etc)	Day Night	0.14	0.4	0.14	0.4
Residential	Day Night	0.3 to 0.6 0.2	0.8 to 1.5 0.6	4 to 13 0.2 to 3	13 to 36 0.6 to 8.4
Offices	Day Night	0.6	1.7	8 to 18	24 to 52

As can be seen from the last two columns of **Table 10** situations can exist where vibration magnitudes above those generally corresponding to a low probability of reaction, particularly for temporary disturbances and infrequent and intermittent events such as those associated with blasting, can be tolerated. With close cooperation and liaison with the occupants of the potentially affected properties, significantly higher levels of short-term vibration could be tolerated by many people for construction projects. In many instances there is a trade-off between the magnitude and duration of construction related vibration (eg rockbreaking versus blasting).

Sleep Preservation

It is difficult to define the level of vibration that would disturb sleep at night, as there is not a significant body of research that specifically investigates this issue. In practice, vibration in buildings that is considered to be disturbing is often perceived as structure-borne regenerated noise, noise generated by rattling objects or through visual cues such as movement of wall hangings, rather than through tactile perception only. Often it is these effects that may make falling asleep difficult rather than actually disturbing a person out of a sleep state.

Nevertheless it is important to make an estimate of the threshold of vibration levels that may produce effects that disturb sleep, to identify geographical areas where specific attention may need to be directed in respect of night-time vibration.

For this purpose a vibration guide level of 0.5 mm/s (peak) has been estimated. This estimate is based on consideration of vibration levels commonly associated with the on-set of movement and rattling of building contents, vibration guide values based on human perception nominated in AS2670-1990, and the qualitative perception scale for continuous vibration outlined in German Standard DIN 4150 Part 2-1975.

The actual night-time response of individuals to vibration is difficult to predict and is usually altered by their level of understanding of the causes of vibration and the likely (or unlikely) effects, and their awareness of the project construction methods and timeframe. Some people may be comfortable with much higher levels of night vibration than the 0.5 mm/s estimate. It is important therefore that public consultation and education is conducted before and during tunnelling, combined with early vibration monitoring, to confirm actual vibration levels that are likely to avoid night-time sleep disturbance associated with tunnelling vibration.

2.3.2 Effects of Vibration on Building Contents

Over the frequency range typical of vibration in buildings from construction and excavation activities, industrial vibration, road and rail traffic (approximately 8 Hz to possibly 100 Hz), the threshold for visible movement of susceptible building contents (ie plants, hanging pictures, blinds, etc) is approximately 0.5 mm/s and audible rattling of loose objects (ie crockery) generally does not occur until levels of about 0.9 mm/s are reached.

For delicately balanced objects, rattling may sometimes occur at lower vibration levels. Window rattling may also be excited acoustically (ie by sound pressure waves, which may be thought of as vibration in the air).

In any premises, day-to-day activities (eg, footfalls, doors closing, etc) will cause levels of vibration in floors and walls that exceed 1 mm/s (sometimes by quite considerable margins), and therefore visible movement and rattling are often observed. In most instances however, such movement is considered normal, and vibration levels of even much greater magnitude do not result in damage to the objects or building contents.

Potentially vibration-susceptible building contents include sensitive instrumentation, computers and other electronic equipment, although such items are not usually kept in residences (apart from personal computers which are considerably more robust). Typical maximum floor vibration levels for satisfactory operation of such sensitive items are:

- 0.5 mm/s to 2 mm/s — -Precision balances
  -Some optical microscopes
- 1 mm/s to 5 mm/s — -Large computer disk drives
  -Sensitive electronic instrumentation

Very short duration vibration events, for example vibration from infrequent impulsive vibration, could be permitted to cause somewhat higher levels, depending on vibration frequency content and on the specific susceptibility of particular objects and their location.

The actual levels of vibration induced by a source outside a building are a function of the particular ground conditions, the foundation/footing interaction, location of the receiver within the building and the nature of the building and its floor.

At the Eco-science precinct a Transmission Electron Microscope (TEM) has been identified to be located in the basement. A technical paper received from the tenant for this specific TEM (JEOL type JEM-1400) gives a vibration deflection tolerance as presented in **Table 11**. Also included in **Table 11** are the estimated equivalent vibration velocity criteria, based on evenly distributed vibration energy within each of the specified frequency ranges.

Table 11 Floor Vibration Tolerance for JEM-1400

Frequency Range	Vibration Displacement (μm)		Vibration Velocity (mm/s)	
	Vertical	Horizontal	Vertical	Horizontal
3 Hz or less	2	0.6	0.019 mm/s	0.006
3 Hz to 10 Hz	0.5	0.5	0.02	0.02
10 Hz or higher	1	0.2	0.3	0.06

Note: It should be noted that normally the horizontal vibration is significantly lower in buildings than the vertical vibration, especially at basement and lower floor levels. The very strict horizontal vibration criteria indicate that the JEOL vibration criteria could be based on actually measured floor vibrations at a successful installation site rather than based on forced vibrations until disturbances are noticed in the equipment.

2.3.3 Safe Vibration Levels for Common Services

Vibration due to the construction process has the potential to effect services such as buried pipes, electrical and telecommunication cables.

German Standard DIN 4150-3 1999 *"Structural Vibration – Part 3: Effects of vibration on structures"* provides guidance on safe vibration levels for buried pipe work. The levels assume "current technology" as special considerations must be applied for systems associated with older structures such as might occur in the vicinity of Heritage Listed buildings. **Table 12** details the DIN 4150-3 limits for short-term vibration. The levels apply at the wall of the pipe. For long-term vibration the guideline levels presented in **Table 12** should be halved.

Table 12 DIN 4150 Part 3 – Damage to Buried Pipes – Guidelines for Short-term Vibration

Pipe Material	Peak Wall Vibration Velocity
Steel (including welded pipes)	100 mm/s
Clay, concrete, reinforced concrete, prestressed concrete, metal with or without flange (other than steel)	80 mm/s
Masonry, plastic	50 mm/s

Note: For gas and water supply pipes within 2 m of buildings, the levels given in **Table 12** should be applied. Consideration must also be given to pipe junctions with the building structure as potential significant changes in mechanical loads on the pipe must be considered.

Recommended vibration goals for electrical cables and telecommunication services such as fibre optic cables range from between 50 mm/s and 100 mm/s.

It is noted however that although the cables may sustain these vibration levels, the services they are connected to, such as transformers and switch blocks, may not. It is recommended that should such equipment be encountered during the construction process an individual vibration assessment should be carried out.

2.3.4 Cosmetic Damage

In terms of relevant vibration damage criteria, *British Standard 7385: Part 2-1993 Evaluation and measurement for vibration in buildings Part 2* is a definitive standard against which the likelihood of building damage from ground vibration can be assessed.

Although there is a lack of reliable data on the threshold of vibration-induced damage in buildings both in countries where national standards already exist and in the UK, BS 7385: Part 2 has been developed from an extensive review of UK data, relevant national and international documents and other published data. The standard sets guide values for building vibration based on the lowest vibration levels above which damage has been credibly demonstrated. These levels are judged to give a minimum risk of vibration-induced damage, where minimal risk for a named effect is usually taken as a 95% probability of no effect.

Sources of vibration which are considered in the standard include blasting, demolition, piling, ground treatments (ie compaction), construction equipment, tunnelling, road and rail traffic and industrial machinery.

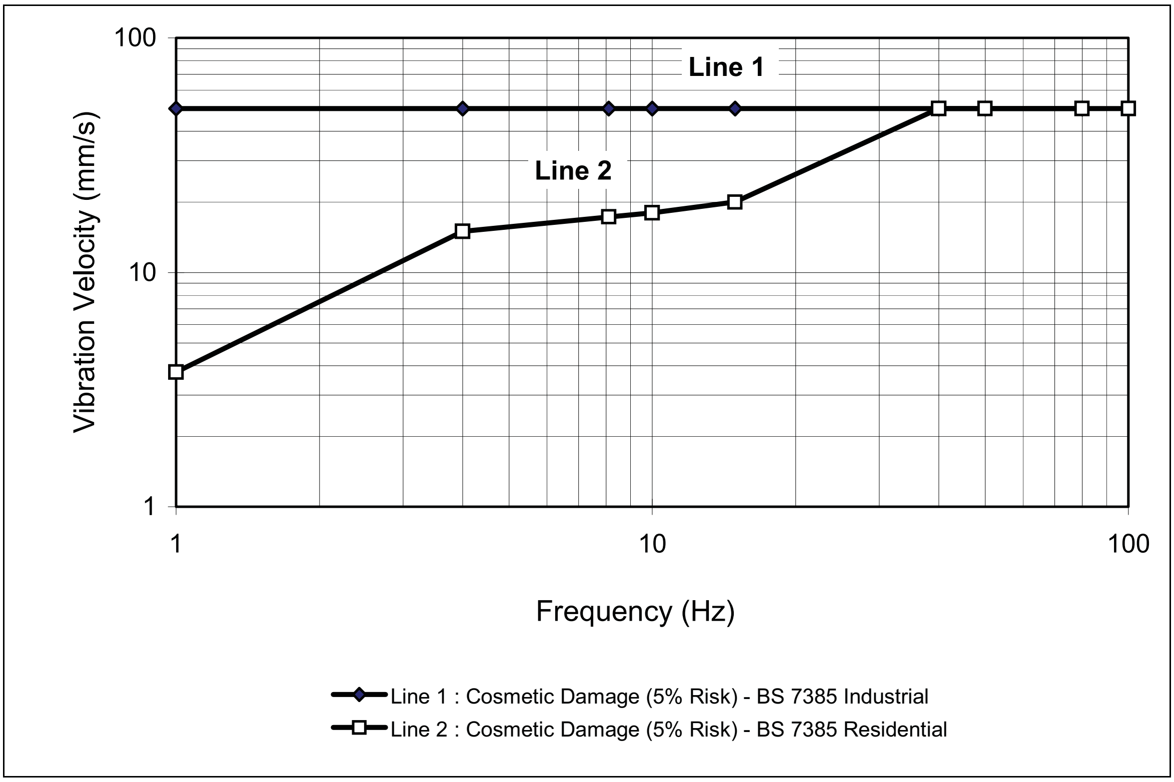
As the strain imposed on a building at foundation level is proportional to the peak particle velocity but is inversely proportional to the propagation velocity of the shear or compression waves in the ground, this quantity (ie peak particle velocity) has been found to be the best single descriptor for correlating with case history data on the occurrence of vibration-induced damage.

The guide values from this standard for transient vibration judged to result in a minimal risk of cosmetic damage to residential buildings and industrial buildings are presented numerically in **Table 13** and graphically in **Figure 1**.

Table 13 BS 7385 – Transient Vibration Guide Values for Cosmetic Damage

Line	Type of Building	Peak Component Particle Velocity in Frequency Range of Predominant Pulse	
		4 Hz to 15 Hz	**15 Hz and above**
1	Reinforced or framed structures Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Non-reinforced or light framed structures Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

Figure 1 Graph of Transient Vibration Guide Values for Cosmetic Damage



In the lower frequency region where strains associated with a given vibration velocity magnitude are higher, the guide values for the building types corresponding to Line 2 are reduced. Below a frequency of 4 Hz where a high displacement is associated with the relatively low peak component particle velocity value, a maximum displacement of 0.6 mm (zero to peak) is recommended. This displacement is equivalent to a vibration velocity of 3.7 mm/s at 1 Hz.

Fatigue considerations are also addressed in the standard and it is concluded that unless calculation indicates that the magnitude and number of low reversals is significant (in respect of the fatigue life of building materials) then the guide values in **Table 13** should not be reduced for fatigue considerations.

Nevertheless, the standard states that the guide values in **Table 13** relate predominantly to transient vibration which does not give rise to resonant responses in structures, and to low-rise buildings. Where the dynamic loading caused by continuous vibration is such to give rise to dynamic magnification due to resonance, especially at the lower frequencies where lower guide values apply, then the guide values in **Table 13** may need to be reduced by up to 50%.

It is noteworthy that additional to the guide values nominated in **Table 13**, the Standard states that:

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

Also that:

> *"A building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive."*

The Department of Transport and Main Roads (DTMR) Technical Standard MRTS51 give ground vibration limits as presented in **Table 14**.

Table 14 Ground Vibration Criteria for Construction Activities – MRTS51

Type of Receptor	Ground Vibration, mm/s PPV[1]
Historical buildings, monuments and buildings of special value or significance.	2 mm/s PPV
Houses and low rise residential buildings, commercial buildings not included below	5 mm/s PPV
Commercial and industrial buildings or structures of reinforced concrete or steel construction including bridges.	5 mm/s PPV

Note 1: Peak Particle Velocity (PPV)

Based on the above discussion, a cosmetic damage criterion of 5 mm/s PPV is proposed

2.3.5 Vibrations from Blasting

Vibration criteria for blasting events can be found in the Act, the DERM *EcoAccess Noise and Vibration from Blasting* (Ecoaccess Blasting), Part 6 of the Brisbane City Council Local Law 5 - *Permits and Licences* (BCC Local Law 5) and Department of Transport and Main Roads (DTMR) Technical Standard MRTS51. The blasting vibration criteria are summarised in **Table 15**.

Table 15 Blasting Vibration Criteria

Reference	Ground Vibration, mm/s PPV[1]
The Act	25 mm/s PPV (> 35 Hz)
	10 mm/s PPV (≤ 35 Hz)
Ecoaccess Blasting	5 mm/s PPV for 9 out of any 10 consecutive blasts
	not exceed 10 mm/s PPV for any blast
BCC Local Law 5	2 mm/s PPV (Historical buildings, monuments or ruin)
	10 mm/s PPV (Visibly damaged or cracked buildings or structures)
	20 mm/s PPV (Structurally sound buildings or structures)
	50 mm/s PPV (Reinforced concrete or steel buildings or structures)
DTMR MRTS51	2 mm/s PPV (Historical buildings, monuments and buildings of special value)
	10 mm/s PPV (Houses and low rise residential buildings, commercial buildings not included below)
	25 mm/s PPV (Commercial and industrial buildings or structures of reinforced concrete or steel construction including bridges)

Note 1: Peak Particle Velocity (PPV)

BCC Local Law 5 gives advice for provision of formal notification of intention to blast 24 hours in advance and to perform pre- and post-construction building condition surveys for all buildings where the anticipated ground vibration level will be 10 mm/s peak particle velocity or greater.

The Ecoaccess Blasting guideline also give advice that blasting should generally only be permitted during the hours 9 am to 3 pm, Monday to Friday, and from 9 am to 1 pm on Saturdays. Blasting should not generally take place on Sunday or public holidays. Limiting blasting to between the hours recommended in the Ecoaccess Blasting guideline is likely to be impractical for the proposed CRR. The principle of limiting the hours of blasting to the “least sensitive” times of the day, however, is a valid one. Therefore, blasting is proposed to be limited to the times 7am to 6 pm each day (e.g. “daytime” as defined in the Ecoaccess guidelines).

2.3.6 Construction Vibration Goals Summary

A summary of applicable vibration goals at sensitive receptors associated with the construction phase of the project is shown in **Table 16**.

Table 16 Construction Vibration Goals

Receiver Type	Cosmetic Damage		Human Comfort (mm/s PPV)		Sensitive Building Contents (mm/s PPV)
	Continuous Vibration (mm/s PPV)	Transient (Blasting[1]) Vibration (mm/s PPV)	Day	Night	
Residential	5	25 (> 35 Hz) 10 (< 35 Hz)	According to AS 2670 refer to **Table 10**	0.5 [2]	-
Commercial	5	25 (> 35 Hz) 10 (< 35 Hz)	According to AS 2670 refer to **Table 10**	-	0.5[3]
Heritage Listed	2	2	-	-	-

Note 1: Blasting should generally only be permitted during the hours of 7 am to 6 pm, Monday to Saturdays.
2: Residential sleep disturbance
3: Equipment specific vibration criteria is required for highly sensitive equipment (ie electron microscopes, MRI systems or similar), as part of future site-specific detailed investigations.

3 NOISE AND VIBRATION TERMINOLOGY

3.1 Noise

The terms “sound” and “noise” are almost interchangeable, except that in common usage “noise” is often used to refer to unwanted sound. Sound (or noise) consists of minute fluctuations in atmospheric pressure capable of evoking the sense of hearing. The human ear responds to changes in sound pressure over a very wide range. The loudest sound pressure to which the human ear responds is ten million times greater than the softest. The decibel (abbreviated as dB) scale reduces this ratio to a more manageable size by the use of logarithms.

The symbols SPL, L or L_P are commonly used to represent Sound Pressure Level. The symbol L_A represents A-weighted Sound Pressure Level. The noise level descriptors that have been utilised within this report are illustrated in **Figure 2** and described below**.**

L_{Amax} The maximum A-weighted noise level associated with a sampling period.

LA1 The A-weighted noise level exceeded for 1% of a given measurement period. This parameter is often used to represent the typical maximum noise level in a given period.

LA10 The A-weighted noise level exceeded 10% of a given measurement period and is utilised normally to characterise average maximum noise levels.

LAeq The A-weighted average noise level. It is defined as the steady noise level that contains the same amount of acoustical energy as a given time-varying noise over the same measurement period.

LA90 The A-weighted noise level exceeded 90% of a given measurement period and is representative of the average minimum background noise level (in the absence of the source under consideration), or simply the "background" level.

Figure 2 Graphical Display of Typical Noise Indices

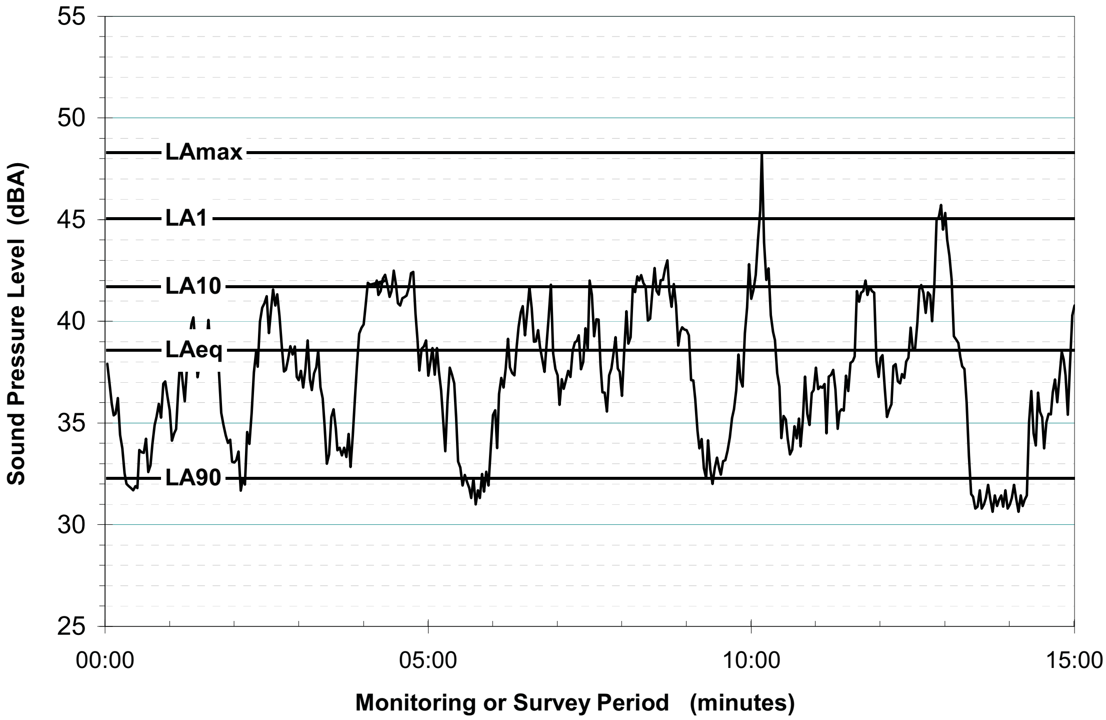


Table 17 presents examples of typical noise levels.

Table 17 Typical Noise Levels

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

When dealing with numerous days of statistical noise data, it is sometimes necessary to define the typical noise levels at a given location for a particular time of day. A standardised method is available for determining these representative levels. This method produces a level representing the “average minimum” background (L_{A90}) noise level over the relevant daytime, evening and night-time periods, and is referred to as the Rating Background Level (RBL).

A change of up to 3 dBA in the level of a sound is difficult for most people to detect, whilst a 3 dBA to 5 dBA change corresponds to a small but noticeable change in loudness. A 10 dBA change corresponds to an approximate doubling or halving in loudness.

3.2 Vibration

Vibration is the term used to describe the oscillating or transient motions in physical bodies. This motion can be described in terms of vibration displacement, vibration velocity or vibration acceleration. Most assessments of human response to vibration or the risk of damage to buildings use measurements of vibration velocity. These may be expressed in terms of “peak” velocity or “rms” velocity. The former is the maximum instantaneous velocity, without any averaging, and is sometimes referred to as “peak particle velocity”, or PPV. The latter incorporates “root mean squared” averaging over some defined time period.

Vibration measurements may be carried out in a single axis or alternatively as triaxial measurements. Where triaxial measurements are used, the axes are commonly designated vertical, longitudinal (aligned toward the source) and transverse. The common units for velocity are millimetres per second (mm/s).

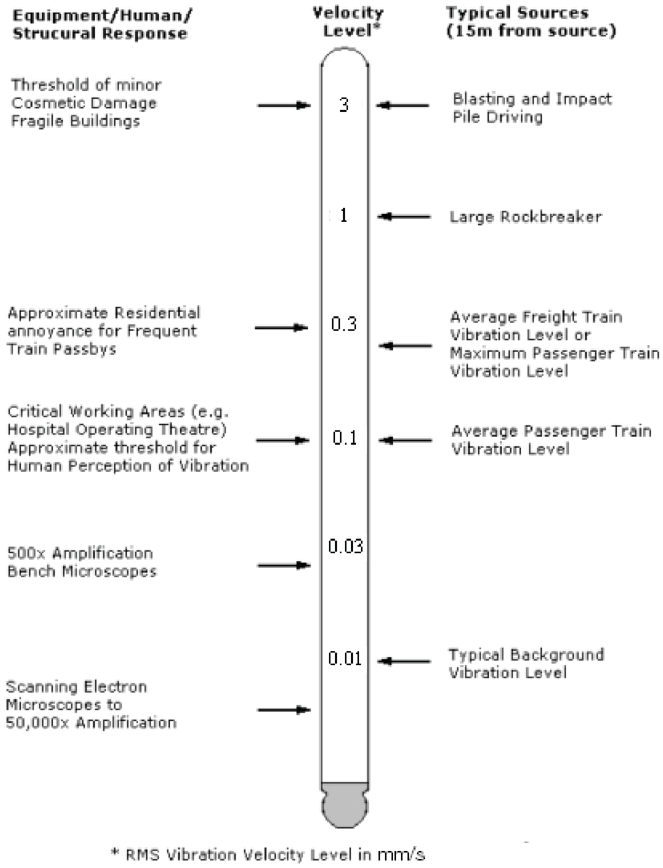
As with noise, decibel units can also be used, in which case the reference level should always be stated. Usually, the vibration velocity level is expressed in dB_V (ref 10^{-9} m/s). The character of vibration emissions can be continuous, intermittent or impulsive.

As for noise, the vibration can be described with the same level descriptors as presented and explained in **Section 3.1**. The corresponding vibration descriptors are V_{max}, V_1, V_{10}, V_{eq}, V_{90}.

Figure 3 gives examples of typical vibration levels associated with surface and underground railway projects together with the approximate sensitivities of buildings, people and precision equipment. The vibration levels are expressed in terms of the vibration velocity (in mm/s).

Vibration and sound are intimately related. Vibrating objects can generate (radiate) sound and, conversely, sound waves (particularly lower frequencies) can also cause objects to vibrate.

Figure 3 Typical Vibration Levels



3.3 Ground-Borne Noise

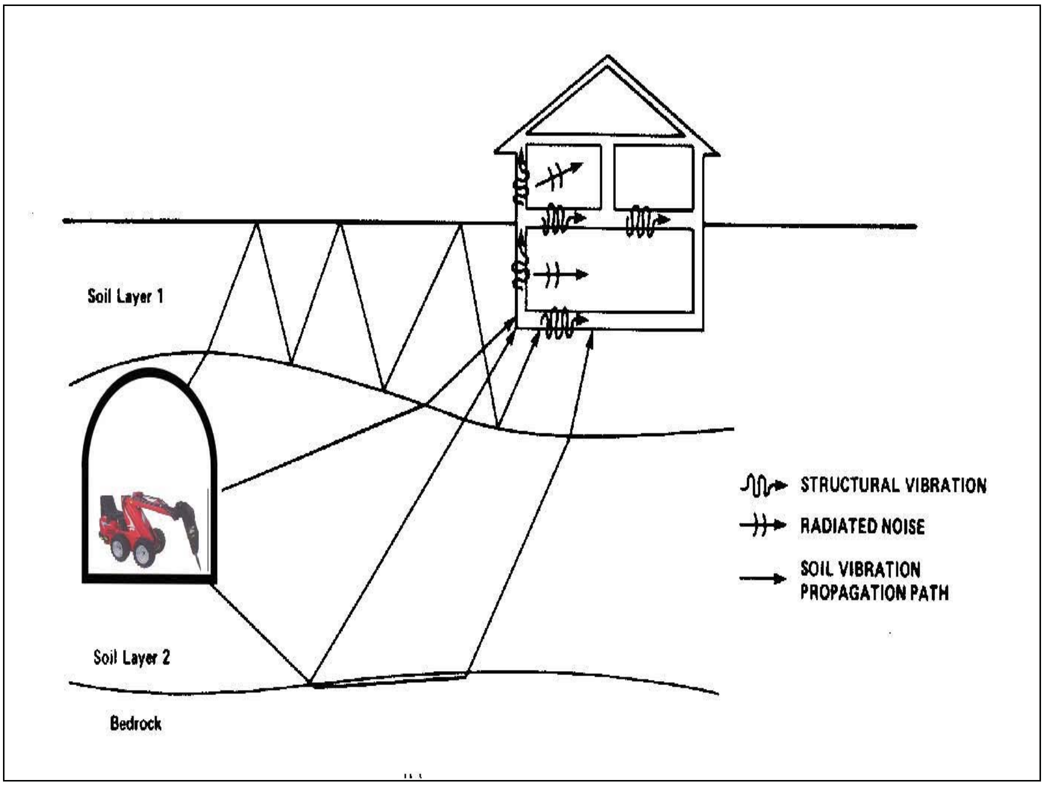
Noise that propagates through a structure as vibration and is radiated by vibrating wall, ceiling and floor surfaces is termed “ground-borne noise”, “regenerated noise”, or sometimes “structure-borne noise”. Ground-borne noise originates as vibration and propagates between the source and receiver through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

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

For surface rail operations, the airborne noise will be significantly higher than the ground-borne noise for most situations. It is only if the airborne noise is highly attenuated by very effective noise barriers that the ground-borne noise component may become dominant. This rare situation has not been identified next to the existing surface rail tracks throughout the study corridor.

Figure 4 presents the various paths by which vibration and ground-borne noise may be transmitted between a source and receiver for construction activities occurring within a tunnel.

Figure 4 Vibration and Ground-borne Noise Transmission Paths



4 EXISTING ENVIRONMENT

4.1 Noise

This section presents the results of the ambient monitoring surveys carried out for the project. Ambient noise monitoring was conducted at twenty (20) residential and special use (ie educational or health care) locations evenly spaced along the study corridor. Both attended and unattended ambient noise measurements have been conducted in order to accurately document the existing noise environment. The measured ambient noise levels have been used in part to determine applicable project noise goals.

4.1.1 Noise Monitoring Methodology

In order to determine the existing ambient noise environment along the study corridor, information about the existing ambient noise environment has been obtained from the following sources:

- Unattended continuous noise measurement of sound pressure levels at the selected monitoring locations over a seven (7) day period.
- Attended 15 minute noise measurement of sound pressure levels at the selected monitoring locations during the daytime (7 am to 6 pm), evening (6 pm to 10 pm) and night-time (10 pm to 7 am) periods.

The noise monitoring was performed between 7 May and 28 May 2010 for at least seven (7) days at each monitoring location (except at Yeronga State High School where the noise logger was vandalised after 1 day monitoring).

4.1.2 Instrumentation

The ambient noise monitoring was undertaken using Acoustic Research Laboratories Type EL-316 and SVAN Type 957 Environmental Noise Loggers programmed to record various statistical noise levels over consecutive 15 minute intervals.

Each logger was checked for calibration before and after the survey with a Rion NC-73 Sound Level Calibrator and no significant drift (greater than 0.5 dBA) in calibration was detected.

ARL EL-316 and SVAN 957 Noise Loggers are NATA certified Type 1 meters. It is common practice to use Type 1 (or 2) noise loggers for measuring ambient noise levels in accordance with the Australian Standard AS 1055.1 *Acoustics – Description and measurement of environmental noise*. The noise floor of EL-316 loggers is approximately 20-22 dBA and the SVAN 957 loggers is approximately 10 – 15 dBA.

Attended measurements were undertaken using Precision Sound Level Meters (SLM); a Rion NA-27, a SVAN Type 948 and a Brüel & Kjær Type 2250. All the SLMs were Type 1 Sound Level Meters. The noise floors of the SLMs are approximately 10 dBA. The used SLM was checked for calibration before and after each set of noise measurements using a Rion NC-73 Sound Level Calibrator and no significant drift (greater than 0.5 dBA) in calibration signal level was observed.

All items of acoustic instrumentation employed during the noise monitoring were set to ‘Fast’ response in accordance with the relevant Australian Standards and the Queensland Department of Environment and Resource Management (DERM) *Noise Measurement Manual*. All items of acoustic instrumentation employed during the noise measurement surveys were designed to comply with AS IEC 61672.2-2004 *Electroacoustics-Sound level meters–Specifications* and carry current calibration certificates.

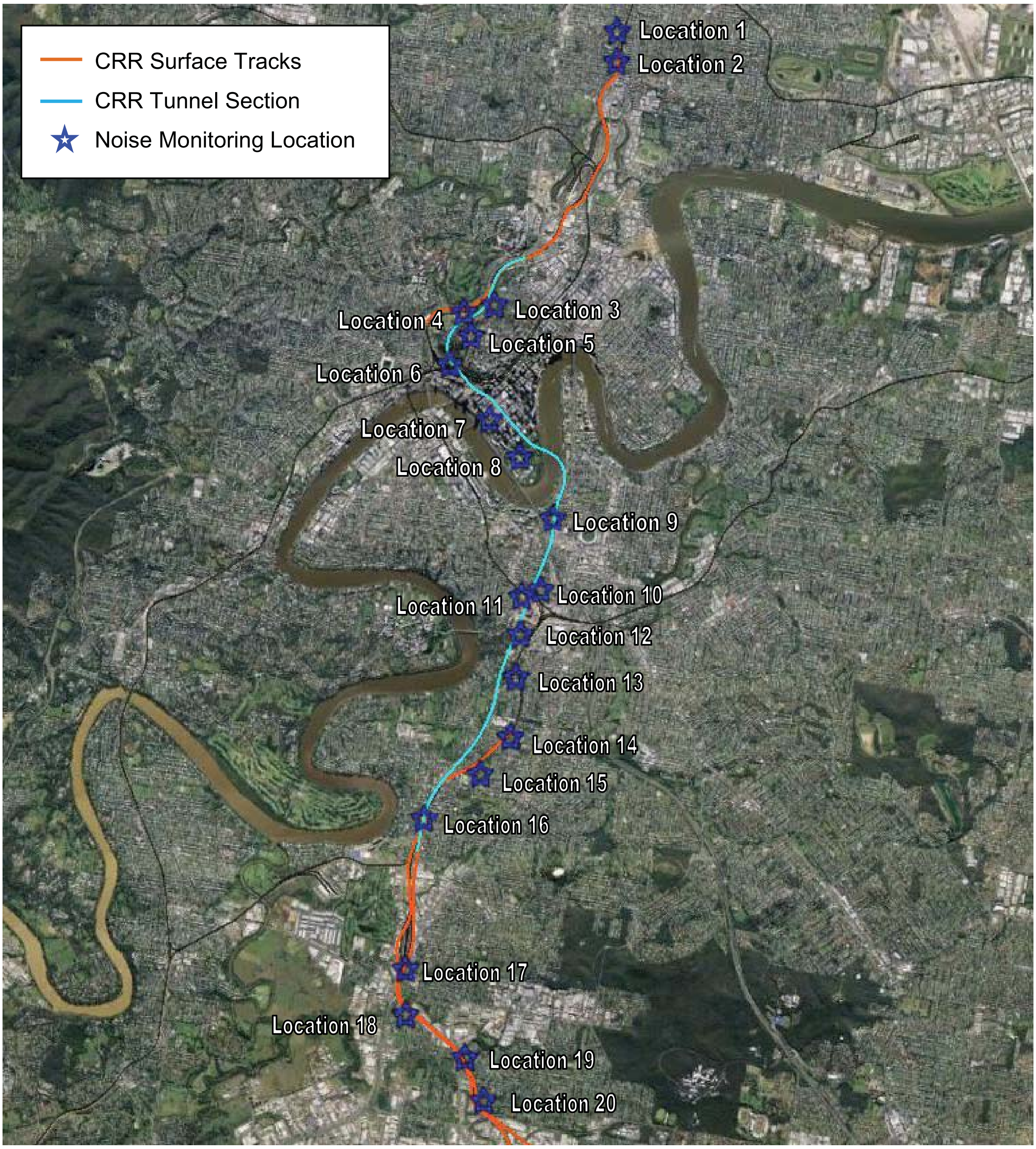
4.1.3 Noise Monitoring Locations

Noise monitoring locations have been selected to be representative of residential areas as well as special receivers (ie Educational and Health Care Facilities) along the corridor that may be potentially affected by the CRR. Noise monitoring locations have been selected to provide spatial coverage of the areas with sensitive receivers along the length of the study corridor.

An overview of the selected monitoring locations is shown in **Figure 5**.

The details of the selected noise monitoring locations are summarised in **Appendix A**.

Figure 5 Overview of Noise Monitoring Locations



4.1.4 Noise Monitoring Results

Unattended Logging

The unattended ambient noise measurements were used to determine the Rating Background Levels (RBL) for the daytime (7.00 am to 6.00 pm), evening (6.00 pm to 10.00 pm) and night-time (10.00 pm to 7.00 am) periods at each location. The RBL is the median of the 90th percentile background (L_{A90}) noise levels in each assessment period (day, evening and night) over the duration of the monitoring (as defined in the *Ecoaccess PNC*). **Table 18** contains the determined RBL for each measurement location.

Table 18 Measured Rating Background Levels

Monitoring Location	Rating Background Levels (RBL), L_{A90} (dBA)		
	Day	Evening	Night
1 1/19 Chalk St	54	45	38
2 28 Bridge St	49	45	38
3 St Josephs College	50	48	40
4 Brisbane Girls Grammar	61	60	46
5 St Andrew War Memorial Hospital	55	53	51
6 Parkland Cres	54	50	47
7 191 George St	58	57	54
8 QUT Gardens Point	49	48	46
9 58 Leopard St	53	50	46
10 143 Park Rd	43	39[1]	34
11 Dutton Park State School	44	40	35
12 19 Dutton St	43	42	37
13 4 Fenton St	39	38	34
14 17 Lagonda St	42	41	39
15 Yeronga State High School	43[2]	41[2]	36[2]
16 3 Cardross St	42	37	33
17 1223 Ipswich Mwy	53	48	46
18 2/59 Brook St	50	43	42
19 Nyanda State High School	54	50	46
20 14 Bellevue Ave	45	45	44

Note 1: Has been adjusted for elevated noise levels due to insect noise.
Note 2: Background noise level representative of only one day of noise data, due to vandalism of the noise logger.

On review of the measured ambient noise levels, the statistical noise plots (refer to **Appendix B**), the 1/3 octave attended measurements and operator notes in **Table 19**, only one location (143 Park Rd) showed the presence of atypical insect noise. The short periods dominated by insect noise at 143 Park Rd was excluded when determining the RBL in **Table 18** to generate a conservatively low (ie no insects present) background noise level.

It is expected that there would be periods during the year when ambient and background noise levels along the project could be higher than those shown in **Table 18** due to the presence of insect noise.

Graphs showing the statistical noise levels measured at the monitoring locations over the whole monitoring period are presented in **Appendix B** for each 24-hour period. The graphs show various statistical noise levels, including the background (L_{A90}) noise level at each site.

15 minute weather data during noise monitoring periods was sourced from the Bureau of Meteorology (Brisbane Airport, Brisbane and Archerfield Met Stations). The weather conditions during the monitoring periods were generally fine. Some rainfall was recorded during the monitoring period and these periods have been excluded from the measurement results. The weather conditions during the remainder of the monitoring period are considered to be suitable for obtaining ambient noise measurements.

It should be noted that the Brisbane Girls Grammar school has high ambient noise levels and is representative of a location close to a Motorway (Inner City Bypass) with no existing noise barriers.

High noise levels have also been monitored at St Andrew Hospital and 191 George St which are representative of typical inner city locations with high density of road traffic, pedestrians and ventilation noise.

Monitoring locations 10 through to 16 are showing lower ambient noise levels representative of the more suburban locations with larger distances to dominant noise sources. For most locations, including these suburban locations (somewhat) distant to major roads, road traffic noise is dominant.

Furthermore, monitoring locations 1, 6, 9, 17 and 19 are near major connector roads and show higher ambient noise levels accordingly.

Attended Ambient Noise Measurements

Attended ambient noise measurements were also conducted at each site to confirm background noise levels and to observe typical noise sources associated with the ambient noise environment during the daytime, evening and night-time periods. The attended ambient noise measurements were conducted for one (1) 15 minute period during each of the daytime (7.00 am to 6.00 pm), evening (6.00 pm to 10.00 pm) and night-time (10.00 pm to 7.00 am) periods at each location (ie three (3) 15 minute attended measurements were taken at each location). The results of these measurements are summarised in **Table 19.**

Table 19 Attended Ambient Measurement Results – Day, Evening and Night-Time Periods

Location	Date	Time (start of 15 min period)	Measured Noise Level (dBA)				Dominant Noise Sources/Comments
			LA90	LAeq	LA10	LA1	
1.	24/05/10	16:34	57	67	70	77	Road traffic noise frequent to constant ~ 70 dBA. Train passby noise. Domestic noises occasionally. Some birds just audible.
	24/05/10	19:52	48	62	66	70	Road traffic noise dominant (intermittent to frequent) ~ 58-65 dBA. Train passby noise ~ 60+ dBA. Some low level insect noise. Plane pass-over.
	25/05/10	06:16	55	67	71	76	Road traffic noise dominant (intermittent to frequent) ~ 60+ dBA. Train passby noise. Plane pass-over. Nearby reverse beep few minutes.
2.	20/05/10	15:45	53	63	66	75	Road traffic noise dominant. Birds chirping intermittently. Train passby noise. A few concrete truck passby.
	24/05/10	20:15	46	64	62	75	Road traffic noise dominant first few minutes ~ 60-70 dBA. Traffic and electrical (power-lines on train tracks) hum just audible in background. Train passby noise ~ 63-66 dBA. Some insects. Dog barking loudly most of measurement ~60-90 dBA.
	21/05/10	01:52	39	47	48	58	Some insect noise. Intermittent road traffic noise.
3.	19/05/10	15:20	54	63	66	71	Road traffic noise dominant. Children talking nearby.
	20/05/10	18:30	51	62	66	69	Road traffic noise dominant. Distant railway noise.
	21/05/10	01:20	38	49	50	63	Intermittent road traffic noise dominant.

Location	Date	Time (start of 15 min period)	Measured Noise Level (dBA)				Dominant Noise Sources/Comments
			LA90	LAeq	LA10	LA1	
4.	17/05/10	17:35	65	67	68	73	Road traffic noise dominant. Train passby noise.
	20/05/10	18:55	63	68	68	81	Road traffic noise dominant. Train passby noise. Occasional siren from inside the gymnasium just audible.
	21/05/10	00:55	47	58	61	67	Road traffic noise dominant, though intermittent. Distant low level ventilation/construction noise. Some low level insect noise.
5.	10/05/10	17:20	57	60	63	67	Road traffic noise dominant. Various city noises.
	12/05/10	18:40	54	57	59	79	Road traffic noise dominant. Low level noise from ventilation at car park some distance away.
	13/05/10	00:35	51	53	54	60	Road traffic noise dominant. Ventilation noise. Road cleaner passed by.
6.	18/05/10	15:30	55	63	66	74	Road traffic noise. Some low level noise from ventilation. Train passby noise including warning horn and wheel squeal. Ambulance siren.
	20/05/10	21:20	51	62	65	73	Train passby noise including warning horn and wheel squeal. Some road traffic noise and ventilation noise.
	21/05/10	00:30	48	51	54	58	Low noise levels from distant road cleaner, ventilation and insects. One distant low level train passby including some wheel squeal. Some bird noise and road traffic noise.
7.	25/05/10	11:49	68	69	70	71	Ventilation noise constant. Some clangs and bangs from alley-way. Road traffic noise just audible in background.
	20/05/10	20:50	58	60	62	65	Ventilation noise dominant. Live music started playing at the Irish Murphy’s at 9.00 pm. Plane pass-over. Patron noises. Intermittent road traffic noise.
	26/05/10	01:30	54	55	56	58	Ventilation noise constant and dominant noise source. Road traffic noise intermittent. Pedestrians talking occasionally.
8.	07/05/10	15:55	51	56	57	64	Distant road traffic noise. People talking loudly most of the time.
	13/05/10	18:45	50	56	58	66	Pedestrian noise dominant most of the time. Some low level insect noise. Distant road traffic noise. Occasionally bird noise. Ambulance siren.
	13/05/10	01:15	47	48	48	50	Distant ventilation noise. Some low level insect noise and road traffic noise.
9.	25/05/10	08:13	54	57	59	75	Noises from children playing dominant ~57-64 dBA. Hum from road traffic noise constant ~ 54 dBA. Various vehicle and domestic noises intermittent.

Location	Date	Time (start of 15 min period)	Measured Noise Level (dBA)				Dominant Noise Sources/Comments
			LA90	LAeq	LA10	LA1	
	18/05/10	18:10	52	56	58	70	Road traffic noise dominant. Domestic noises intermittent. Ambulance siren.
	26/05/10	00:55	46	49	51	55	Road traffic noise dominant. Low level ventilation noise.
10.	25/05/10	08:49	44	57	61	67	Road traffic noise dominant. Plane pass-over intermittent. Train passby noise ~ 48-55 dBA. Some bird noise.
	25/05/10	18:55	42	52	56	60	Road traffic noise dominant most of the time. Significant contribution from insect noise. Train passby noise.
	26/05/10	00:20	37`	44	48	55	Distant road traffic noise dominant. Sporadic local road traffic. Freight train passby.
11.	18/05/10	14:10	45	57	61	70	Distant road traffic noise. Train passby noise including warning horn and wheel squeal. Plane pass-over. Occasional bird noise. Some noises from children playing/talking.
	20/05/10	20:15	42	51	52	63	Distant road traffic noise. Plane pass-over. Train passby noise. Pedestrians occasionally passing by.
	20/05/10	22:20	37	49	43	66	Stationary train with auxiliary units operating at station for a few minutes and train passby noise dominant. Plane pass-over.
12.	25/05/10	09:17	44	54	56	66	Plane pass-over. Birds intermittent ~ 54-58 dBA. Constant low level road traffic noise. Some domestic noises. Train passby noise ~ 48-54 dBA
	20/05/10	21:29	39	47	45	61	Road traffic noise intermittent. Insect noise constant in background. Occasional domestic noises. Train passby noise including warning horn and pass-bys ~46-49 dBA. Plane pass-over.
	20:/05/10	23:50	39	42	43	51	Distant road traffic noise. Train passby noise. Distant low-level ventilation/industrial and construction noise.
13.	07/05/10	16:53	45	55	58	64	Road traffic noise dominant. Train passby noise ~ 55-65 dBA. Some bird noise. Plane pass-over. Some domestic noises.
	17/05/10	20:55	39	50	52	62	Train passby noise ~ 48-64 dBA. Insects just audible. Road traffic noise intermittent. Plane pass-over. Occasional domestic noises/wildlife in trees.
	18/05/10	00:001	34	49	51	62	Road traffic noise intermittent. Insects just audible in background. Train passby noise ~ 40-66 dBA. Wildlife in trees occasionally. Helicopter pass-over.

Location	Date	Time (start of 15 min period)	Measured Noise Level (dBA)				Dominant Noise Sources/Comments
			LA90	LAeq	LA10	LA1	
14.	07/05/10	15:26	46	53	51	66	Train passby noise. Road traffic noise. Birds chirping occasionally.
	17/05/10	20:31	39	53	51	67	Intermittent noise from bats and possums in trees ~ 50dBA. 'Hum' noise from pool pump constant ~ 39 dBA. Train passby noise ~ 48-75 dBA. Local traffic just audible in background.
	17/05/10	23:30	38	55	57	68	Intermittent noise from bats and possums in trees. 'Hum' noise from pool pump constant ~ 39 dBA. Train passby noise ~ 60-73 dBA.
15.	18/05/10	13:10	45	57	57	69	Noises from children playing dominant. Freight and passenger train passby noise. Distant road traffic noise. Plane pass-over. Bird noise intermittent.
	20/05/10	19:40	43	50	54	60	Intermittent road traffic noise. Insect noise dominant. Aircraft pass-over. Some rail traffic. Some domestic noises.
	20/05/10	22:50	34	44	48	56	Insect noise in background. Road traffic noise intermittent. Train passby noise. Helicopter pass-over.
16.	11/05/10	08:23	44	51	53	60	Road traffic noise dominant ~ 45-50 dBA. Low level intermittent bird noise. Train passby noise ~ 50-62 dBA. Talking nearby.
	17/05/10	20:03	37	46	47	59	Local traffic noise occasional. Some road traffic noise from main road. Domestic noises. Train passby noise ~ 48-60 dBA
	18/05/10	0:30	31	47	49	60	Train passby noise ~ 56-60 dBA. Intermittent domestic noises nearby. Road traffic noise quiet and intermittent. Bats and possums in trees occasionally.
17.	17/05/10	15:20	56	61	63	70	Road traffic noise dominant. Some domestic noises. Train passby noise. Helicopter pass-over.
	24/05/10	18:08	53	60	63	70	Road traffic noise dominant (frequent to constant0. Train passby noise ~62-73 dBA. Insect noise audible most of the time. Some domestic noises. Plane pass-over.
	20/05/10	23:15	43	53	56	66	Road traffic noise dominant, though intermittent. Some insect noise. Train passby noise.
18.	10/05/10	16:11	54	58	61	67	Road traffic noise intermittent ~ 60-67 dBA. Train passby noise ~ 60-67 dBA. Domestic noises intermittent. Some birds. Generator noise constant in background.

Location	Date	Time (start of 15 min period)	Measured Noise Level (dBA)				Dominant Noise Sources/Comments
			LA90	LAeq	LA10	LA1	
	17/05/10	19:36	45	54	55	66	Road traffic noise constantly intermittent in background. Vehicle pass-bys ~ 60+ dBA. Train passby noise. Occasional domestic noises. Insects in background.
	18/05/10	01:51	40	45	48	54	Road traffic noise intermittent ~ 38-40 dBA. Talking at train station fairly loud. Low level insects noise in background. Domestic noises.
19.	11/05/10	09:04	56	61	63	71	Noise from announcements in hall intermittent first few minutes ~ 70 dBA. Road traffic noise, frequent ~ 58-65 dBA. Intermittent bird noise. Plane pass-over.
	17/05/10	19:11	51	58	59	70	Road traffic noise dominant ~ 54 dBA. Insect noise just audible. Train passby noise. Some talking in distance occasionally.
	18/05/10	01:03	45	49	51	55	Intermittent road traffic noise. Low level insects noise in background. Bats and possums in trees occasionally. Distant industrial noises.
20.	19/05/10	15:28	50	55	58	65	Road traffic noise constant. Domestic noises intermittent. Plane pass-over just audible. Train passby noise ~60+ dBA
	17/05/10	18:46	48	52	54	60	Road traffic noise dominant, constantly ~ 48 dBA. Occasional domestic noises. Train passby noise.
	18/05/10	01:23	44	48	50	53	Road traffic noise 'hum' constant ~ 45-50 dBA. Bats and possums in trees occasionally.

Note: Daytime (7.00 am to 6.00 pm), evening (6.00 pm to 10.00 pm) and night-time (10.00 pm to 7.00 am)

The attended measurements and observations summarised in **Table 19,** show that railway noise and/or road traffic noise is dominant at the majority of monitoring locations during daytime and evenings. The night-time period was dominated by road traffic noise at most locations, though it was mostly a distant traffic noise.

Only two monitoring locations (143 Park Rd and Yeronga State High School) had the ambient background environment dominated by insect noise during the evening period. Insect noise has been adjusted for where necessary at 143 Park Rd. The noise logger at Yeronga State High School was vandalised, and as such noise logger data is only available for one (1) 24 hour period. The available noise data did not show adverse interference by insect noise.

At monitoring location 1 and 2 there were increased levels of road traffic during the daytime for the monitoring period due to concrete trucks associated with the Airport Link Project. The increased number of truck pass-bys during daytime will not significantly affect the measured RBL during daytime.

Monitoring location 7 was located in an alley next to Irish Murphy's and was more representative of a commercial location than a residential location. The noise environment was dominated by ventilation noise, patron noise and music. As such, noise levels obtained at this location are assumed to be slightly higher than expected for the city residential area (where ventilation noise, music and patron noise is less prevalent), but never-the-less is somewhat representative of CBD living.

4.2 Vibration

This section presents the results of the ambient vibration monitoring surveys carried out for the project. Ambient vibration monitoring was conducted at 11 residential and special use (ie educational/research or health care facilities) locations along the study corridor.

4.2.1 Vibration Monitoring Methodology

In order to determine the existing ambient vibration environment along the study corridor, 24 hour unattended vibration measurements were conducted at each selected site.

The vibration monitoring was performed between 7 May and 20 July 2010, for a period of at least 24 hours at each monitoring location.

4.2.2 Instrumentation

The vibration measurements were conducted using Instantel Minimate Plus vibration loggers with one triaxial (transverse, vertical and longitudinal) geophone installed inside the building at the monitoring locations. The vibration loggers were programmed to record Peak Particle Velocity (PPV) in mm/s every 60 seconds over the monitoring period.

The vibration instrumentation employed during the vibration measurement surveys carry current calibration certificates by an ISO 17025 accredited laboratory.

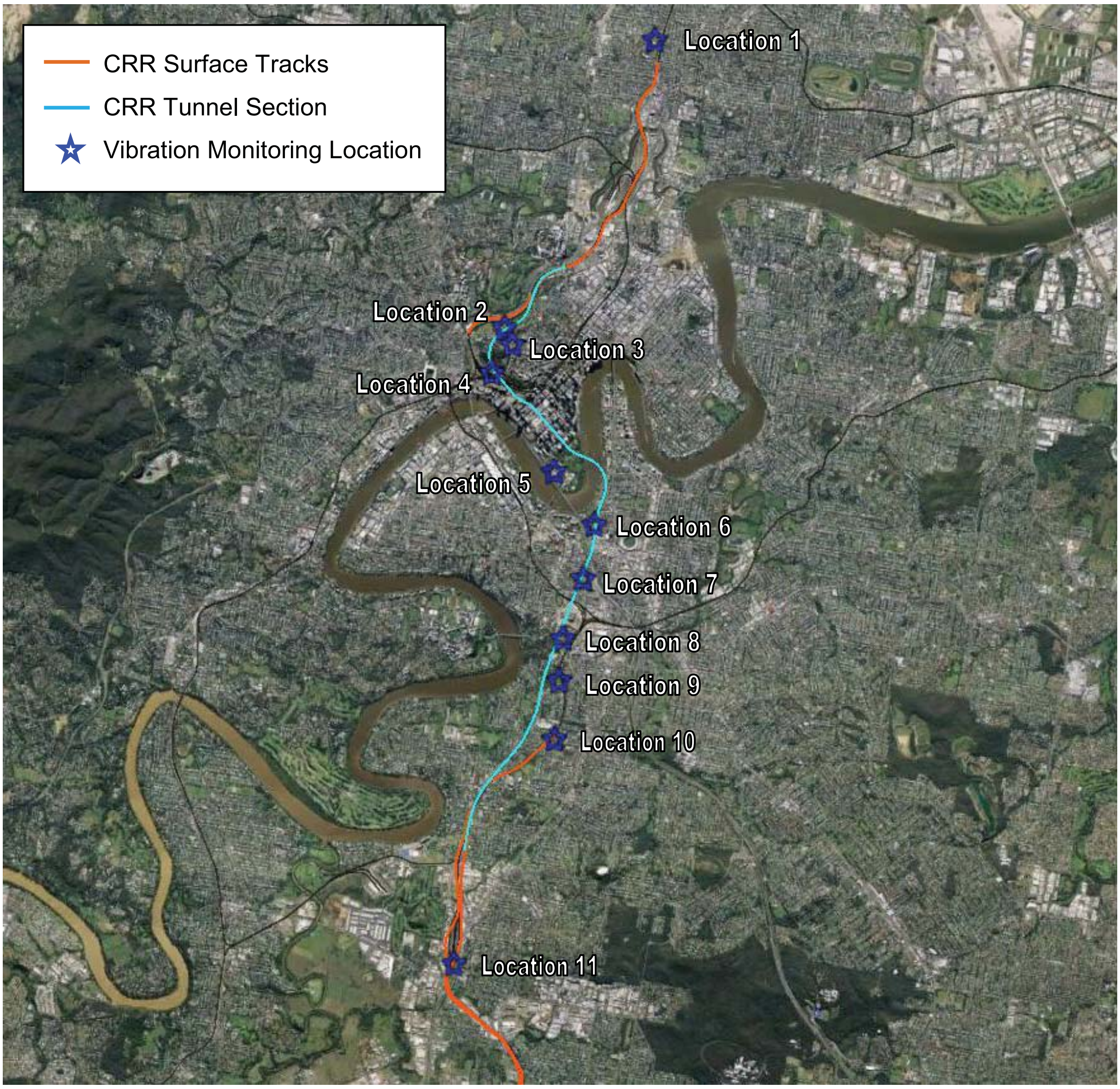
4.2.3 Vibration Monitoring Locations

Vibration monitoring locations have been selected to be representative of residential areas as well as special receivers (ie educational/research or health care facilities) along the corridor that may be potentially affected by the CRR. Vibration monitoring locations have been selected to provide spatial coverage of the areas having sensitive receivers within the whole study corridor.

An overview of the selected vibration monitoring locations is shown in **Figure 6**.

The details of the selected vibration monitoring locations are summarised in **Appendix C**.

Figure 6 Overview of Vibration Monitoring Locations



4.2.4 Vibration Monitoring Results

The unattended ambient vibration measurements were used to determine the Average Minimum Background Level (V_{90}), Average Maximum Level (V_{10}) and Maximum Level (V_1) for the daytime (7.00 am to 6.00 pm), evening (6.00 pm to 10.00 pm) and night-time (10.00 pm to 7.00 am) periods at each location. **Table 20** contains the determined vibration levels for each measurement location. Graphs showing the peak particle velocity measured at each monitoring location during the monitoring period are presented in **Appendix D**.

Table 20 Measured Ambient Background Vibration

Monitoring Location	Average Minimum Background Vibration V90 (mm/s) [1]			Average Maximum Vibration V10 (mm/s) [2]			Maximum Vibration V1 (mm/s) [3]		
	Day	Evening	Night	Day	Evening	Night	Day	Evening	Night
1	0.07	0.04	0.02	0.66	0.20	0.14	2.31	0.82	0.49

Monitoring Location	Average Minimum Background Vibration V90 (mm/s) [1]			Average Maximum Vibration V10 (mm/s) [2]			Maximum Vibration V1 (mm/s) [3]		
	Day	Evening	Night	Day	Evening	Night	Day	Evening	Night
2	0.04	0.04	0.04	0.05	0.05	0.05	0.08	0.05	0.05
3	0.03	0.03	0.02	0.08	0.05	0.04	0.17	0.08	0.06
4	0.04	0.04	0.03	0.06	0.05	0.04	0.07	0.07	0.06
5	0.02	-	-	0.02	-	-	0.03	-	-
6	0.01	0.01	0.01	0.04	0.14	0.02	0.16	0.57	0.16
7	0.04	0.04	0.04	0.06	0.10	0.05	0.19	0.49	0.10
8	0.03	0.03	0.03	0.04	0.04	0.03	0.31	0.04	0.04
9	0.04	0.06	0.04	0.70	0.84	0.23	2.69	1.61	0.71
10	0.04	0.04	0.04	0.05	0.05	0.04	0.11	0.08	0.13
11	0.10	0.04	0.03	0.30	0.22	0.21	1.50	0.50	0.35

Note 1: The V_{90} is the vibration velocity exceeded 90% of a given measurement period and is representative of the average minimum background vibration.

Note 2: The V_{10} is the vibration velocity exceeded 10% of a given measurement period and is utilised normally to characterise average maximum vibration.

Note 3: The V_1 is the vibration velocity exceeded for 1% of a given measurement period. This parameter is sometimes used to represent the maximum vibration in a given period. The absolute maximum peak particle velocity can be higher than this V_1 as can be seen in **Appendix D**.

The background vibration level (V_{90}) varies between 0.01 mm/s to 0.1 mm/s during daytime and evening. During the night-time, the background vibration level (V_{90}) varies between 0.01 mm/s to 0.04 mm/s. Maximum vibration levels (V_1) for the residential monitoring locations were in the range of 0.11 mm/s to 2.69 mm/s during daytime and evening. During night-time, vibration levels (V_1) of 0.04 mm/s to 0.71 were measured. The average maximum levels (V_{10}) for the residential monitoring locations ranged 0.04 mm/s to 0.84 mm/s during daytime and evening.

It can be noted that high vibration levels have been monitored at locations 1, 9 and 11 which are on wooden floors. This shows that normal activities (ie closing doors and cupboards, walking etc) in these residential dwellings with light-weight (wooden) floors generate vibration levels significantly above the vibration goals presented in **Section 2.3**.

For receivers with vibration sensitive equipment locations 3 (St Andrews Hospital) and location 5 (QUT), background vibration levels (V_{90}) of 0.02 mm/s to 0.03 mm/s and maximum vibration levels (V_1) of 0.03 mm/s to 0.17 mm/s, were measured.

5 IDENTIFICATION OF NOISE AND VIBRATION SENSITIVE RECEIVERS

The sensitivity of occupants to noise and vibration varies according to the nature of the occupancy and the activities performed within the affected premises. For example, recording studios are more sensitive to vibration and ground-borne noise than residential premises, which in turn are more sensitive than typical commercial premises.

The sensitivity may also depend on the existing noise and vibration environment. For example, the AS/NZS 2107:2000 *"Recommended Design Sound Levels and Reverberation Times for Building Interiors"* recommend higher acceptable noise levels in urban areas compared with suburban areas.

Following receipt of the Reference Design, SLR Consulting has classified all buildings within a corridor extending approximately 100 m either side of the nearest CRR track alignment or any construction site. Each building was classified into the following receiver categories:

- Residential
- Commercial
- Educational
- Health Care
- Place of Worship
- Heritage Item
- Industrial

In the noise and vibration modelling presented in this report, all residential receivers are considered to be of a sensitive nature. Commercial receivers are generally less sensitive to noise and vibration compared to residential receivers.

Appendix E presents details of non-residential noise and vibration sensitive receivers that are situated along the length of the alignment.

6 NOISE AND VIBRATION DATA

6.1 Machinery Noise

6.1.1 Tunnelling Worksites

A wide range of mechanical plant items are anticipated for the construction phase of the project. The specific size and selection of these plant items are not yet known, however typical items of plant have been nominated based on observations of similar tunnelling activities at existing worksites in the Brisbane region and on indicative sizing of materials handling equipment that would be required to transport the spoil at the anticipated rates of tunnel excavation. Indicative source sound power levels have been obtained from AS 2436:2010 *Guide to noise and vibration control on construction, demolition and maintenance sites*.

A summary of these plant items including number of plant required at each worksite and indicative sound power level are summarised in **Table 21.**

Table 21 Major Plant Schedule and Source Sound Power Level Estimates for Tunnelling Worksites

Plant Item	LAmax Sound Power Level (dBA)	North Portal	Roma Street North	Roma Street Central	Roma Street South	Roma Street Satellite	Albert Street North	Albert Street South	Woolloongabba Station	Boggo Road Station	Ventilation Shaft	Floodgate Building	Yeerongpilly Portal Site
Jumbo Drill Rig	118	3			3			3	3				3
Piling Rig	118	2	1	1	2		1	2	4	4	1	1	1
150t Crane	113	1			1			1	2	1	1	1	1
60-100t Crane	110	2	1	1	2		1	2	4	4	1	1	1
3.5 m^3 FEL	112		2	2	2		2	2	2	2	1	1	2
3.5 m^3 FEL	115	5			4			4	4	4	1	1	4
5t Excavator	110	2	1	1	1	1	1	1	2	2	1	1	2
20t Excavator	112	3	1	1	1		1	1	2	2			3
35t Excavator	114/125[1]	3	2	2	2		2	2	4	4	1	1	3
Scissor Lift	106	3	1	1	3		1	3	4	4	2	1	3
Temp Ventilation	105	2	1	1	2		1	2	4	4	1	1	2
Shaft Hoist	100	1	1	1	1		1	1	2	2	1		
Shaft Lift	100	1	1	1	1		1	1	2	2	1	1	
Compressor	103	2			2			2	2				2
Generator	100	2	1	1	2	1	1	2	2	1	1	1	2
Pump	100	2	1	1	2		1	2	2	1	1	1	2
Spoil Truck	110	Required at all sites at various stages and varying numbers (refer to **Section 9.4** for volumes accessing each site)											

Note 1 – SWL of 125 dBA with rockbreaker attachment, including a +5 dBA adjustment for impulsiveness.

6.1.2 Surface Track Worksites

Noise from CRR surface track construction works will generally depend upon the number of plant items and equipment operating at any one time and on their precise location relative to noise sensitive receivers. A receiver will therefore experience a range of values representing “minimum” and “maximum” construction noise emissions depending upon:

- The location of the particular construction activity (ie if the plant of interest were as close as possible or further away from the receiver of interest).
- The likelihood of the various items of equipment of interest operating simultaneously.

While noise from diesel-powered mobile plant will generally form the major part of noise emissions over the construction phase, the highest noise levels are expected to occur during the use of specialised track laying plant (eg ballast regulator, tamper etc).

The specific size and selection of surface track construction plant items are not yet known, however typical items of plant have been nominated based on typical Queensland Rail track construction and maintenance plant. A summary of these plant items along with indicative sound power levels are summarised in **Table 22**.

Table 22 Surface Track Construction Plant

Plant Item	Sound Power Level (LAmax dBA)
Dozer (D8)	111
Vibratory Roller	110
Front End Loader	115
Excavator (inc sleeper bars)	114
Flat bed truck with crane (Hiab)	110
Ballast truck (rail)	110
Ballast truck (road)	110
Speed swing (360)	114
Locomotive	111
Ballast regulator	122
Tamper	115
Hand held compactor	114
CWR welding plant	93
Cherry Picker	104
Wiring equipment	111
Engineers train	111

6.2 Acoustic Properties and Enclosure Materials

Sound power refers to the total rate of sound generation of a given item of plant. This quantity is independent of the distance from the plant item (analogous to the wattage power of a light-bulb) and allows direct comparison of the relative acoustic ‘size’ of different plant items. From this data, the sound pressure level (or noise level) at any offset distance from the plant can be calculated (analogous to the light intensity from a light-bulb – the greater the distance, the less intense).

It is proposed to enclose night-time noise sources within large acoustic enclosures in noise-sensitive areas to allow spoil accumulation on a 24 hour basis. In general, any enclosure is more effective at containing high-pitched noises (eg hisses, scrapes, whines) than low-pitched noises (eg thuds, deep exhaust notes). Therefore, to understand how effectively an acoustic enclosure will contain machinery noise, estimates are needed of both the frequency spectrum (or pitch) of noise sources and the frequency-dependent (or pitch-dependent) sound transmission characteristics of the acoustic enclosure.

Typical spectral shape data for representative types of noise sources that may be used within worksite acoustic enclosures are summarised in **Table 23**.

Ventilation plant will also be a major item of plant that would operate at all worksites on a 24 hour basis. Sound power levels have not been listed for this plant since no indicative selections of construction ventilation plant have yet been determined. Further, the acoustic specification for this plant would normally be determined by site-specific acoustic constraints in accordance with the standard DERM licensing requirements for fixed stationary noise sources. For this reason, a general indicative sound power level is not listed.

Table 23 Indicative Spectral Sound Power Distribution for Plant Located within Acoustic Enclosures

Plant Type	Octave A-weighted Sound Power Levels Relative to Overall A-weighted Power Level (dB)							
	63 Hz	**125 Hz**	**250 Hz**	**500 Hz**	**1 kHz**	**2 kHz**	**4 kHz**	**8 kHz**
Air Compressor	-27	-10	-6	-6	-9	-9	-14	-20
Diesel Powered Mobile Plant	-27	-20	-9	-7	-5	-6	-14	-24
Electric Conveyor Drive	-35	-22	-13	-9	-2	-12	-16	-32
Rock Drill	-23	-18	-15	-8	-6	-5	-7	-14

The amount by which acoustic energy is reduced as it passes through a material is known as the transmission-loss of the material. As discussed in the previous section, the transmission-loss is generally greater for high-pitched sounds than for low-pitched sounds.

Transmission Loss spectra for examples of possible enclosure construction materials are detailed in **Table 24**.

Table 24 Indicative Transmission Loss Spectra for Representative Enclosure Constructions

Material Description	Transmission Loss in Octave Bands (dB)							
	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
1 - Low Performance Option 0.62 mm metal cladding	3	8	14	20	23	26	27	35
2 - Medium Performance Option 0.62 mm metal cladding lined with 50 mm fibreglass[1]	5 (est)	10	15	22	32	37	43	43
3 - High performance Option 0.62 mm metal cladding, 110 mm airspace, 50 mm fibreglass blanket in airspace, internal lining of 18 kg/m^2 porous-faced fibre-board[2]	15 (est)	20	29	43	46	57	63	63

Note 1 - Report No. 3668/159/4517B-5-83 in accordance with AS1276-1979 – Louis A. Challis & Associates Pty Ltd
Note 2 - Report No. 3798-1-82 – Louis A. Challis & Associates Pty Ltd

The effectiveness of the enclosure materials listed in **Table 24** in reducing the types of internal noise sources shown in **Table 23** has been calculated. The results of these calculations are presented in **Table 26**.

Factors that maximise the effectiveness of an acoustic enclosure include the minimisation or avoidance of gaps or holes, effective mechanical isolation of the enclosure from pieces of machinery inside, and most importantly, the inclusion of sound absorption on internal surfaces of the enclosure.

An enclosure that has hard (non-absorptive) internal surfaces will cause what is described as reverberant build-up within the enclosure. This is noise that is reflected within the enclosure rather than being dissipated in acoustically absorptive materials (such as glass-fibre of poly-fibre linings - loose spoil also exhibits acoustical absorption). The more reverberant build-up of noise within the enclosure, the less effective the enclosure is in controlling noise because the inside noise level effectively increases.

The actual degree of absorption within the proposed enclosures is difficult to predict without an enclosure design and without information relating to the sound absorption of spoil.

For indicative purposes the reverberant corrections described by Bies and Hansen have been utilised. These corrections are reproduced in **Table 25.**

Table 25 Correction Factors for Internal Acoustic Conditions

Enclosure Internal Acoustic Conditions	Reverberant Corrections in Octave Bands (dB)							
	63 Hz	125 Hz	250 Hz	500 Hz	1 Hz	2 Hz	4 Hz	8 Hz
Live (bare metal)	18	16	15	14	12	13	15	16
Average (absorptive lining of enclosure)	13	11	9	7	5	4	3	3
Dead (absorptive lining of all surfaces)	11	9	6	5	3	2	1	1

'Live' internal conditions would occur if all internal surfaces were hard, such as bare metal. This would occur for the Option 1 enclosure construction in **Table 24.**

'Average' internal conditions would occur if all internal surfaces of the enclosure were faced with a sound-absorptive material. Enclosure construction Options 2 and 3 in **Table 24** would achieve this. It is considered unlikely that acoustically 'dead' conditions would be achievable.

The effective noise reductions that would be achieved by alternative enclosure designs are summarised in **Table 26**. These estimates account for the spectral characteristics of sources (refer **Table 23**), enclosure constructions (refer **Table 24)**, and associated internal reverberant characteristics (refer **Table 25**).

Table 26 Effective Noise Reductions Achieved by an Acoustic Enclosure

Plant Type	Effective Noise Reduction (dBA)		
	1 - Low Performance enclosure	2 - Medium Performance enclosure	3 - High Performance enclosure
Air compressor	0	7	18
Diesel powered mobile plant	4	12	24
Electric conveyor drive	7	16	28
Rock drill	4	12	23

It can be seen in **Table 26** that a simple metal enclosure would achieve no overall noise level reduction for a noise source such as a compressor that has a noise emission dominated by low frequency components. Overall, a bare metal enclosure should not be regarded as an effective noise control.

Substantial improvements in the effectiveness of an acoustic enclosure can be achieved by adding an acoustically absorptive internal lining (refer Option 2). A further substantial improvement can be achieved by effectively creating a double layer construction for walls and ceiling elements (refer Option 3).

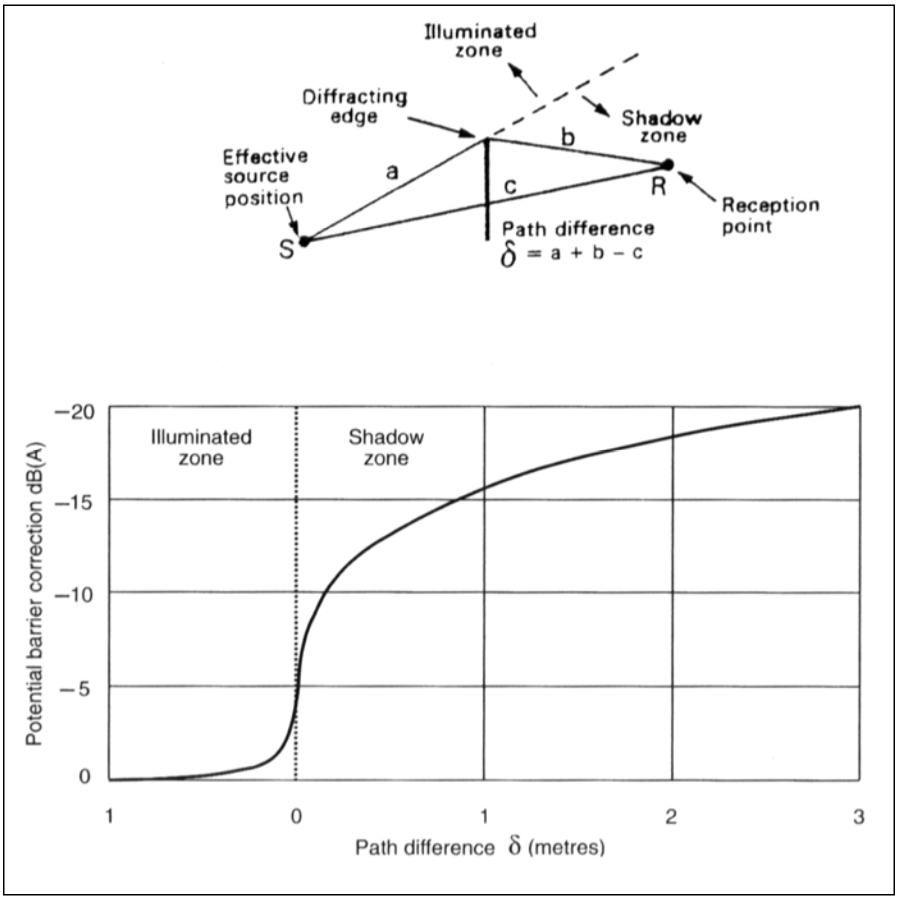
It can also be seen from **Table 26** that the effective noise reduction can vary as much as 10 dBA depending on the frequency content of the plant item. Plant emissions that are dominated by high frequency noises, such as rockbreaking, will benefit most from an acoustic enclosure.

6.3 Indicative Effectiveness of Noise Barriers

The effectiveness of noise barriers typically ranges from 5 dBA if line-of-sight between the noise source and receiver location is just obscured, up to around 15 dBA where the barrier provides optimal blocking of the sound transmission path.

The actual degree of attenuation will depend on the frequency spectrum of the noise and the length of the diffracted noise path compared with the direct noise path. For a noise spectrum dominated by sound in the range of 300 to 500 Hz, the relationship between the barrier attenuation and geometrical parameters is illustrated on **Figure 7**.

Figure 7 Geometric Dependency of Barrier Attenuation



For this project it is very difficult to generalise about the degree of barrier shielding that would likely result from the erection of noise barriers near construction sites. Construction site barriers are typically in the range of 2.4m to 3.0m high. In general, the dwellings near construction areas for this project are either highset or Queenslander buildings. This gives a nominal receptor height of 3m or higher.

The effective height of noise sources will vary depending on the type of machinery in use and the exhaust height. For a pile-boring rig as an example, this height may be around 3 to 4m. For a front-end loader or excavator, the effective source height may be in the range of 2 to 3m.

Thus it can be seen that for many construction noise sources typical barriers in the range of 2.4m to 3.0m high would not obscure line-of-sight and would therefore not produce significant attenuation. The height of temporary barriers may therefore need to be 5 to 6m high in many instances to provide noise reductions.

6.4 Indicative Effectiveness of Upgrading Building Facades

The following analysis of potential construction noise impacts in residential buildings is based on the assumption that the noise level difference outside a dwelling to inside a habitable room is a nominal 10 dBA for older type dwellings that rely predominantly on natural ventilation through windows, and 20 dBA for modern residential apartments with close-fitting sliding windows that would normally be equipped with air conditioning. For older dwellings it would be possible to increase the inside/outside noise level difference by 10 to 20 dBA.

This type of improvement would require a combination of the following physical changes to windows facing construction sites:

- Retrofitting or replacing window seals,
- Closing windows,
- Fitting a secondary sliding window system, or alternatively replacing the existing window system.

Installation of ceiling fans and/or an air-conditioner system (window-mounted or split-type) and/or silenced fresh air ventilators may be appropriate to compensate for the loss of thermal comfort and natural ventilation that may occur if windows were kept closed.

For modern residential units, inside/outside noise level differences of up to 10 dBA higher than the nominal assumed value of 20 dBA may already be achieved if facades have already been design for control of traffic noise.

To give an exact prediction of possible gains in inside/outside noise level differences requires specific knowledge about the construction of individual dwellings. This could be achieved within the context of a detailed noise management plan.

6.5 Vibration

6.5.1 General Considerations

Different excavation methods generate different patterns of vibration. Conventional blasting can produce very short periods of vibration associated with each blast per shift. This could mean one blast each 12 hours during blasting operations. Blasting would normally be complimented by rockbreaking to trim the excavation envelope.

The milder form of blasting known as Penetrating Cone Fracture or PCF blasting (also referred to as Gas Blasting) does not require the same degree of evacuation as conventional blasting. In theory, PCF blasting could be undertaken to achieve smaller, more frequent blasts.

Rockbreaking normally involves periods of operation interrupted by manoeuvring and clearing by an excavator. Tunnel boring machines and roadheaders, on the other hand, generate relatively constant vibration levels during sustained periods of operation.

The vibration levels generated at the surface of the ground during surface or tunnel excavation is a function of many variables, including the excavation method, advance rate, depth below surface, ground (rock) hardness and the structure of surface strata. With limited strata information available before construction, it is difficult to predict exactly what vibration levels may be experienced. In this circumstance, it is usual to collate the highest vibration levels recorded for a range of extraction methods in similar circumstances. A consequence of this approach is that actual vibration levels may be lower than the predicted levels.

6.5.2 Drill and Blast

Vibration levels from blasting do not represent a constant vibration source. To a greater degree than mechanical excavation methods, the design of a blast can be controlled to ensure that vibration levels remain within specified bounds. The extraction rate of advance is therefore dependent on the size and design of blasts.

Indicative blast vibration levels associated with tunnelling have been sourced from measurements carried out during the trial blasting for Brisbane Rail Tunnel Duplication (Heggies Q02-R1, 1990). These trials were conducted at the Creek Street tunnel portals that were excavated in hard rock. Vibration transducers were located on the foundations of nearby buildings, including the Incholm Building on Wickham Terrace and All-Saints Anglican Church on Anne Street. The correlation obtained from this study is:

Vibration, V (mm/s) = $14655 \times \{Q^{0.5}/R\}^{2.27}$ (Heggies Q02-R1, 1990)

Where R = distance (m) and Q = maximum instantaneous charge (kg).

A second estimate of blast vibration levels has been obtained from the ICI Explosives Blasting Guide (ICI Explosives, 1995) for tunnel blasts. The prediction formula from this guide would suggest higher vibration levels than the data from the Brisbane Rail Tunnel Duplication project. This relationship, for 80 percentile peak vibration levels, is:

V (mm/s) = $608 \times \{Q^{0.5}/R\}^{1.6}$ (ICI Tunnelling).

Table 27 shows the indicative permissible blast sizes that would result in a ground vibration velocity level of 2 mm/s at the building foundations. A vibration goal of 2 mm/s is proposed for blasting near heritage-listed buildings, refer to vibration goals in **Section 2.3.5**.

Table 28 shows the indicative permissible blast sizes that would result in a ground vibration velocity level of 5 mm/s at the building foundations. A level of 5 mm/s would typically relate to commercial buildings containing sensitive equipment. Based on the normal frequency spectra associated with blasting, vibrations are likely to contain dominant frequencies above 3 Hz.

Table 27 Indicative Permissible Maximum Instantaneous Charge (MIC) to Achieve 2 mm/s PPV Near Heritage Structures – Conventional Blasting

Data Source	Indicative Permissible Charge weight (kg) Versus Distance					
	Exceedance	5m	10m	20m	30m	40m
General ICI Tunnelling formula	20%	0.02	0.08	0.3	0.7	1.3
Queensland Rail Rail Tunnel trial blasts	20%	0.01	0.04	0.15	0.35	0.6

Table 28 Indicative Permissible Maximum Instantaneous Charge (MIC) to Achieve 5 mm/s PPV Near Buildings with Sensitive Equipment – Conventional Blasting

Data Source	Indicative Permissible Charge weight (kg) Versus Distance					
	Exceedance	5m	10m	20m	30m	40m
General ICI Tunnelling formula	20%	0.06	0.25	1.0	2.2	4.0
Queensland Rail Rail Tunnel trial blasts	20%	0.02	0.09	0.35	0.8	1.4

Table 29 shows indicative permissible blast sizes that would result in a ground vibration velocity level of 10 mm/s PPV. This level would relate to residential dwellings and other buildings not containing highly sensitive equipment.

A 20% exceedance level has been reported for consistency with the blasting criteria in the EP Act.

Table 29 Indicative Permissible Maximum Instantaneous Charge (MIC) to achieve 10 mm/s PPV Near Residential Dwellings and other Buildings – Conventional Blasting

Data Source	Indicative Permissible Charge weight (kg) Versus Distance					
	Exceedance	**5m**	**10m**	**20m**	**30m**	**40m**
General ICI Tunnelling formula	20%	0.05	0.6	2.3	5.3	9.4
Queensland Rail Rail Tunnel trial blasts	20%	0.04	0.16	0.65	1.4	2.6

In recent years, Penetrating Cone Fracture (PCF) blasting technology has been developed for rock excavation where vibration (and/or airblast) constraints are critical. In suitable rock formations the more efficient fracture mechanism employed by PCF allows vibration levels to be approximately half that of conventional explosives for the same volume of broken rock (or alternatively double the extraction for comparable vibration levels).

The PCF technique also dramatically reduces flyrock issues and airblast. PCF may therefore have advantages where blasting is required close to the surface (eg excavation of tunnelling access shafts at worksites) as well as for tunnel blasting beneath sensitive areas.

Charge sizes per blasthole for PCF technology typically range from 10 grams to 300 grams. Minimum charge sizes for conventional blasting are upwards of 120 grams per blasthole.

The ICI Explosives Blasting Guide (ICI Explosives, 1995) for tunnel blasts also gives a formula to predict the airblast overpressure. This relationship, for 80 percentile airblast overpressure, is:

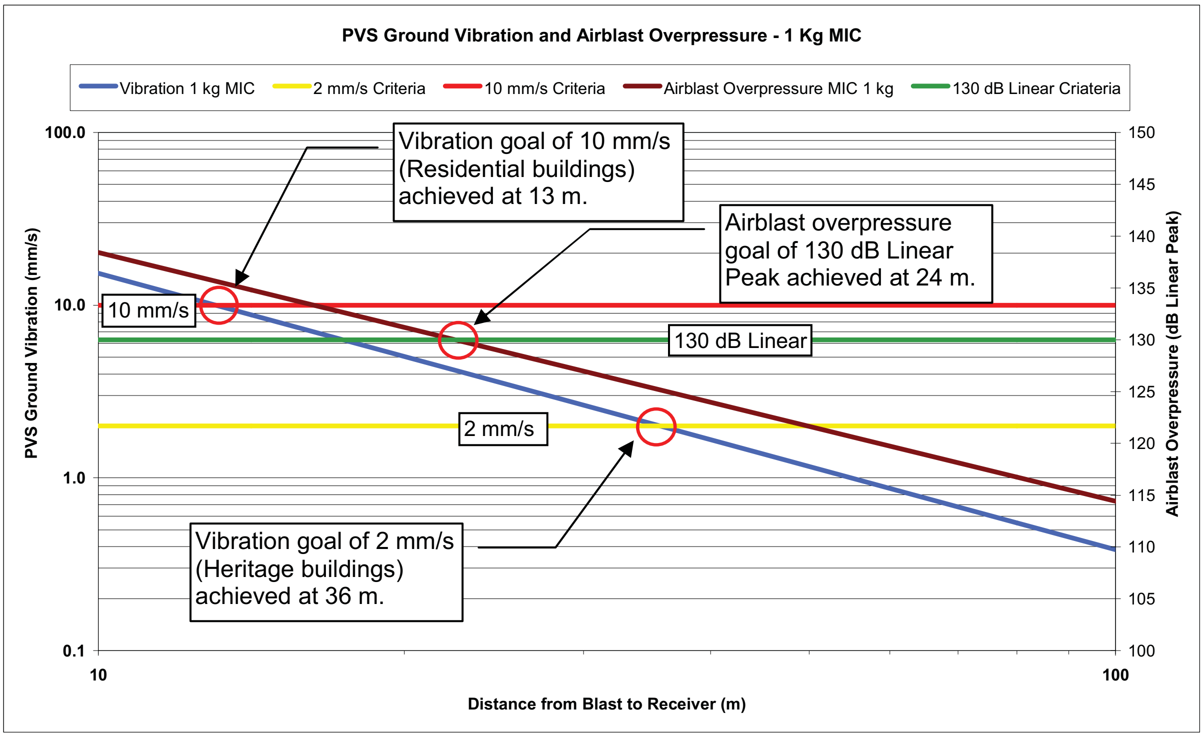
$$P \text{ (dB Linear Peak)} = 2640 \times \{Q^{0.33}/R\}^{1.2} \quad \text{(ICI Tunnelling).}$$

Where R = distance (m) and Q = maximum instantaneous charge (kg).

The prediction formula above assumes a fully confined blasthole.

The predicted ground vibration and airblast overpressure versus distance for a blast with maximum instantaneous charge of 1 kg is shown as an example in **Figure 8**. This example shows that for a blast size of 1 kg MIC the vibration cosmetic damage criterion for heritage buildings (2 mm/s) is most stringent (ie longest offset distance to achieve criterion). The residential vibration cosmetic damage criterion and airblast overpressure criterion being achieved at a shorter offset distance.

Figure 8 Predicted Ground Vibration and Airblast Overpressure (1 kg MIC) Vs Distance



6.5.3 Mechanical Tunnel Excavation

The two single track tunnels for the CRR are proposed to be constructed by Tunnel Boring Machines (TBMs). The TBMs for the CRR tunnels are approximately 7 m in diameter. These TBMs are significantly smaller in diameter than those previously employed in Brisbane for the road tunnels. Due to a smaller drilling surface, the CRR TBMs are predicted to generate less ground-borne vibration and noise (compared to the road tunnel TBMs).

Measurements of ground-borne vibration from TBMs and roadheaders during the construction of CLEM7 have been used to verify the source levels used for the EIS's of the previous road tunnels in Brisbane (which were based on international data). The measurements showed lower ground-borne vibration levels than previously predicted for the TBMs and higher for the roadheaders.

It was also found that the ground-borne noise levels at the Government Land Centre Building with footings constructed directly into the bedrock had approximately 5 dBA higher ground-borne noise levels than expected. The ground-borne noise and vibration predictions have therefore been updated to include a 5 dB increase where the buildings are likely to have footings connected directly into the bedrock (ie all buildings within the CBD and some large buildings outside the CBD).

It has been assumed that the ground-borne noise and vibration from the TBM is related to the surface area of the TBM drill head as $10\log(A_2/A_1)$. This means that the smaller (7 m diameter) TBMs generate approximately 4.7 dB less ground-borne noise and vibration. The likely ground-borne vibration levels for CRR TBMs are presented in **Table 30**.

The typical maximum levels of ground-borne vibration from heavy rockbreaking conventional drill and blast (as a function of charge sizes) operations are also listed in **Table 30.** The frequency content of the ground-borne vibration associated with TBMs, roadheaders, rockbreaking and blasting is normally concentrated below 100 Hz.

Table 30 Indicative Maximum Ground Vibration Levels for Mechanical Tunnel Excavation Methods

Data Source		Peak Particle Velocity (mm/s) Versus Distance					
		5m	10m	20m	30m	40m	50m
7 m diameter hard rock TBM		2.8	1.35	0.64	0.42	0.31	0.24
Heavy Roadheading		1.1	0.43	0.17	0.09	0.06	0.05
Heavy Rockbreaking		4.5	1.3	0.4	0.2	0.14	0.1
Blasting ICI tunnelling formula	5 kg Maximum Instantaneous Charge	168	55	18	10	6	4
	1 kg Maximum Instantaneous Charge	46	15	5	2.6	1.7	1.2
	0.2 kg Maximum Instantaneous Charge	13	4.2	1.4	0.7	0.5	0.3

Note: The values in the table are ground-borne vibration level expected for buildings not directly connected on the bedrock. Ground-borne vibration level in the CBD is expected to be approximately 5 dB (ie a multiplying factor of 1.8 for vibration velocity) higher due to most buildings are likely to have footings founded directly into the underlying bedrock.

6.6 Ground-borne Noise

Ground-borne noise refers to noise that is first transmitted to the ground by machinery as vibration which then travels to a sensitive location (such as a house) through the ground and foundations, where the walls, floor and ceiling then radiate this vibration as audible noise.

Ground-borne noise levels are more difficult to predict than noise that is transmitted through the air only. This is because the transmission of ground-borne noise depends on the ground strata, coupling between the ground and buildings and internal acoustical characteristics of buildings.

6.6.1 Mechanical Tunnel Excavation

Measurements of ground-borne noise from TBMs during the construction of CLEM7 have been used to verify the source levels used for the EIS's of the previous road tunnels in Brisbane (which were based on international data).

As discussed in **Section 6.5.3** the CLEM7 measurements resulted in a 5 dB increase for buildings that are likely to have footings connected directly into the bedrock (ie all buildings within the CBD and some large buildings outside the CBD). Ground-borne noise levels from the road tunnel EIS's for typical residential properties (not founded in the bedrock) have been maintained for TBMs, roadheaders and rockbreakers for the CRR study.

Also as stated in **Section 6.5.3**, it is assumed that the ground-borne noise from the smaller (7 m diameter) TBMs generate approximately 4.7 dBA less ground-borne noise compared to the (12 m diameter) TBMs used for the previous road tunnels in Brisbane.

A summary of ground-borne noise levels anticipated from mechanical tunnel excavation methods is presented in **Table 31**. The airblast overpressure is also included for reference (not taking into account any reduction due to acoustic enclosures).

Table 31 Indicative Ground-borne Noise Levels for Mechanical Tunnel Excavation Methods

Operation		Ground-borne Noise Levels (dBA LAeq)[1] Versus Distance					
		5m	10m	20m	30m	40m	50m
7 m diameter hard rock TBM		65	56	52	42	38	35
Roadheading		57	48	39	34	30	27
Rockbreaking		67	58	50	45	40	37
		Airblast Overpressure (dB Linear Peak)[2] Versus Distance					
Blasting ICI tunnelling formula	5 kg Maximum Instantaneous Charge	151	144	137	133	130	127
	1 kg Maximum Instantaneous Charge	146	138	131	127	124	124
	0.2 kg Maximum Instantaneous Charge	140	133	126	122	118	93

Note 1: The values in the table are ground-borne noise levels expected for buildings not directly connected in the bedrock. Ground-borne noise level in the CBD is expected to be approximately 5 dBA higher due to most buildings are likely to have footings founded directly into the underlying bedrock.

Note 2: Predicted values for airblast overpressure assumes fully confined blasthole.

7 CONSTRUCTION SITE DESCRIPTIONS

Major CRR tunnelling worksites shown in **Figure 9** are located at Victoria Park (Northern Portal), Roma Street Station, Albert Street (Albert Street Station), Vulture Street at Woolloongabba (Woolloongabba Station - TBM launch site), Boggo Road (Boggo Road Station, Fairfield Road (southern ventilation building) and Yeerongpilly Station (Southern Portal – TBM launch site).

Major surface track construction sites (also shown in **Figure 9**) would be located at Mayne Yard, Clapham Yard, Exhibition Station (RNA showgrounds), Yeerongpilly Station, Moorooka Station, Rocklea Station and the Ipswich Motorway on ramp at Rocklea. Significant noise generating construction activities will involve demolition of existing buildings, excavation using rockbreakers and other construction plant, earthworks, removal of spoil and station construction.

Satellite worksites are proposed at the following locations across the Project:

- Salisbury including:
  - At track bifurcation south of Riawena Road – material stockpile area
  - South of Salisbury Station – early material storage area
  - North of Salisbury Station – long term material storage area
  - Opposite Fairlie Terrace – prefabrication area for footbridge
  - Off Annie Street – use of sheds as site offices
- Rocklea including:
  - Adjacent Rocklea Station (3 off) – construction material laydown
  - Off Fairfield Road – construction material storage area
- Moorooka off Ipswich Road – construction material storage area
- Clapham Yard (2 off) opposite rail yard – material storage area
- Roma Street Parklands – office, store, workshop and carpark
- Bowen Hills including:
  - RNA Showgrounds (2 off) – construction material storage area

- Near Clem 7 portal (2 off) – construction material storage area
- Mayne Yard – construction material storage area

As these sites would be primarily utilised as material laydown areas, it is anticipated that construction noise and vibration emissions from these sites would be of a temporary nature and therefore no further noise and vibration assessment has been carried out. Consideration should be given to providing acoustic hoarding at satellite worksites adjacent to residential receivers where acoustically significant works are required for prolonged periods of time.

The following roadworks, which are not directly connected to a major construction worksite, would be required to accommodate the Project:

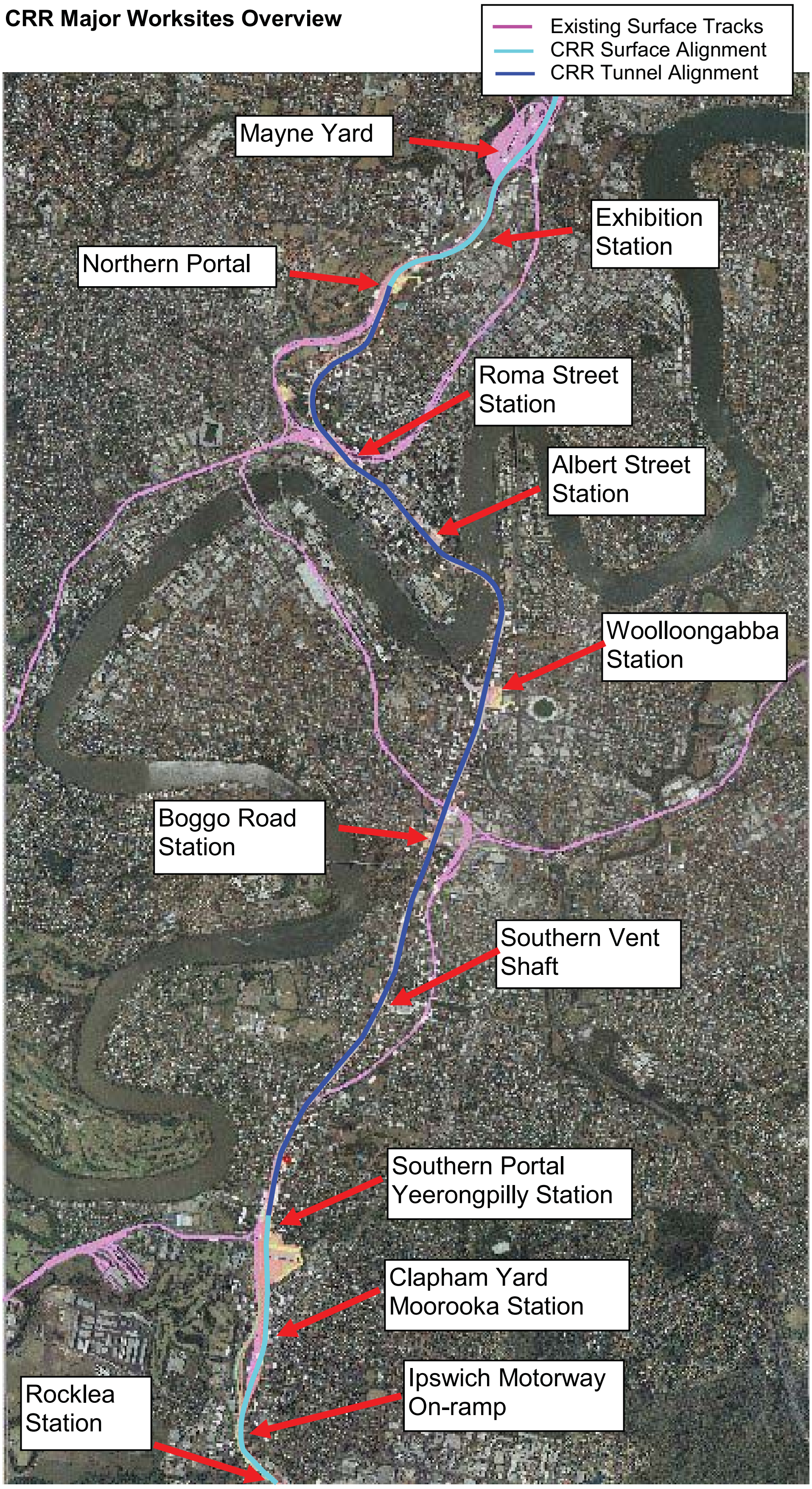
- Beaudesert Road and Musgrave Road intersection upgrade.
- Realignment and truncation of Dollis Street involving the construction of two large cul-de-sacs either side of Riawena Road overpass.
- Beaudesert Road and Lillian Avenue intersection upgrade including:
  - New signalised intersection.
  - Conversion of Tranmore Street to two-way traffic flow.
  - Realignment of Lillian Avenue east of the Beaudesert Road intersection.
  - Realignment (including raising) of Beaudesert Service Road connecting to Lillian Avenue.
- Realignment of Heaton Street under the existing span of Beaudesert Road overpass.
- Realignment of Fairlie Terrace under the existing span of Beaudesert Road overpass.
- New traffic signals at Gladstone Street and Muriel Avenue intersection.

It is anticipated that construction noise and vibration emissions from these relatively short term roadworks (eg like those that occur regularly throughout Queensland), would be temporary in nature and, with the exception of the Gladstone Street and Muriel Avenue intersection works and realignment of Heaton Street, are remote from residential receivers. Therefore taking into account the nature and short term duration of these works, no further noise and vibration assessment has been carried out.

The TBMs and roadheaders operate on 24/7 basis (noting that usually one day a week is devoted to maintenance) hence spoil handling and support facilities such as segment handling are required through the night-time and generally carried out below ground or within acoustic enclosures.

At this stage of the construction planning it is anticipated that night-time construction works would be required at most worksites at some stage during the construction phase. Accordingly the following assessment of CRR construction works has been conducted for all relevant periods.

Figure 9 CRR Major Worksites Overview



7.1 TBM Launch Sites

During the CRR construction phase the Woolloongabba Station and Southern Portal construction sites would be used for the following purposes:

- TBM launch site and associated facilities for tunnel construction.
- Spoil removal from behind the TBMs at Woolloongabba Station.
- Tunnel fitout including rail systems.
- General construction site.

7.1.1 Woolloongabba Station

The location of the Woolloongabba Station construction site is between Vulture Street, Main Street and Stanley Street, Woolloongabba. The TBM launch and future station construction site is shown in **Figure 10**. The site will serve two TBM dual tunnels to the north with associated launch and spoil handling facilities over a central shaft. The overall launch box and launch areas are constructed using cut and cover techniques. Existing commercial/industrial buildings on the site will be demolished prior to launch site excavation.

7.1.2 Southern Portal

The location of the Southern Portal site is adjacent to Yeerongpilly Station (refer to **Figure 11**). Construction of the Southern Portal would involve realignment of Wilkie Street, earthworks, retaining wall construction and cut and cover near the portal wall.

7.2 Tunnel Portals

Refer to **Section 7.1.2** for the Southern Portal description.

7.2.1 Northern Portal

During the CRR construction phase the northern construction site would be used for the following purposes:

- Roadheader launch site and associated facilities for TBM retrieval.
- Spoil removal from behind the roadheader
- Tunnel fitout including rail systems
- General construction site

The Northern Portal site would be located adjacent to the Centenary Aquatic Centre at Spring Hill and is shown in **Figure 12**. The site will serve roadheaded tunnels to the south-west with associated launch and spoil handling facilities adjacent the tunnel portal. The TBM retrieval shaft and roadheader launch area is constructed using cut and cover techniques.

7.3 Station Construction Sites

In conjunction with the CRR station located at the Woolloongabba TBM launch site, stations are proposed to be located at Exhibition Station (upgrade of existing station), Roma Street Station, Albert Street Station, Boggo Road Station, Yeerongpilly Station (upgrade of existing station), Moorooka Station (upgrade of existing station) and Rocklea Station (upgrade of existing station).

Key station site activities representative of the typical noise emissions expected to occur during the project are:

- Demolition of existing buildings, site establishment including spoil handling facilities.
- Vertical excavation using rockbreakers and other construction plant.
- Spoil removal from on site storage areas by heavy vehicle.
- Station construction, fitout and commissioning.

7.3.1 Exhibition Station

Exhibition Station is located within the RNA showgrounds adjacent O'Connell Terrace (refer to **Figure 19**). The station would be a non-conventional structure due to the staging complication of building the main structure in two halves adjacent to live tracks. Some demolition of existing structures would be required during the initial stages.

Upgrading of the bridge structure over the railway line at O'Connell Terrace, including pedestrian access to the station, would be included as part of the Exhibition Station construction works.

7.3.2 Roma Street Station

CRR construction at Roma Street Station would be located within three distinct worksites shown in **Figure 13**. The main access shaft and associated site offices/facilities would be located at the southern end of the station. Demolition, piling and shaft excavation would be required at the three worksites.

7.3.3 Albert Street Station

The two distinct worksites for the Albert Street Station are displayed in **Figure 14**. Both the Alice Street and Mary Street worksites require substantial demolition of existing buildings prior to site establishment. Temporary traffic diversions would also be necessary at various stages during the construction phase.

7.3.4 Boggo Road Station

The Boggo Road Station worksite is located between Boggo Road and Peter Doherty Street and is bordered to the west by Boggo Gaol and to the east by the Eco-science precinct building (refer to **Figure 15**). The station cavern would be accessed through the main hatch adjacent to Peter Doherty Street, for top-down construction.

Worksite facilities would be located adjacent to Rawnsley Street residences with acoustic hoarding separating the site from receivers.

7.3.5 Yeerongpilly Station

A new station structure would be constructed just south of the Southern Portal adjacent to the realigned Wilkie Street to cater for CRR rail traffic. The location of the site is shown in **Figure 20**. The new station would be constructed mostly off-line away from the live tracks.

7.3.6 Moorooka Station

As part of CRR, the existing Moorooka Station, shown in **Figure 21**, would require minor upgrading to access arrangements to cater for CRR rail traffic. The Station site is on the eastern boundary of the Clapham Rail Yard and is bordered to the east by commercial buildings along Ipswich Road.

7.3.7 Rocklea Station

As part of CRR, the existing Rocklea Station, shown in **Figure 22**, would undergo a relatively minor upgraded including the installation of a longer footbridge with lift and access stairs to cater for future CRR rail traffic. Upgrades to existing platforms would not require alteration to platform heights or geometry.

7.4 Southern Ventilation Building

The southern ventilation building is located adjacent to Fairfield Road and Railway Road, Fairfield (refer to **Figure 16**). Construction activities will include site preparation, vertical excavation to the shaft, mechanical plant and building construction. The main excavation area is rectangular shaped typically 30 m x 25 m with the site compound area located immediately south of the shaft.

The Southern Ventilation Shaft would be sunk ahead of the TBM drives.

8 IMPACT ASSESSMENT OF WORK SITES

8.1 Noise Modelling

In order to quantify noise emissions from construction, a three-dimensional computer noise model was prepared for the major construction sites. This was undertaken using the CONCAWE industrial noise algorithm as implemented in SoundPLAN acoustic modelling software. The model for these sites includes source noise emission levels, ground topography, location of sources and receivers, acoustic shielding provided by intervening ground topography, air absorption and ground effects.

The output from the SoundPLAN noise model is a predicted noise level external to the receiver building of interest. In order to compare the relevant internal noise goals with the external predicted noise levels, the internal goals were adjusted (ie increased) to an external free-field noise level. The adjustment was determined by the type of facade through which noise transmission would occur. For CRR, the facade adjustment methodology applied was consistent with the methodology contained in Ecoaccess PNC including:

- For residential type receivers, a +10 dBA inside to outside adjustment for windows partially open (7 dBA in the free-field).
- For commercial type receivers, a +20 dBA inside to outside adjustment for single glazed closed windows (17 dBA in the free-field).

The plant likely used at the major work sites would typically be a subset of that presented in **Table 21** for tunnelling worksites assessed in **Section 8.2** and **Table 22** for surface rail track worksites assessed in **Section 8.3**.

TBM and roadheader launch sites activities representative of the typical noise emissions expected to occur during the project are:

- Demolition of existing buildings, site establishment including spoil handling facilities.
- Installation of perimeter retaining walls using piling, precast concrete segments etc.
- Initial excavation using excavators, rockbreakers and other construction plant.
- TBM/Roadheader site and associated facilities for tunnel construction.
- Spoil removal from behind the TBM/Roadheader and removal by heavy vehicle.
- Tunnel fit out including rail systems.

Station site activities representative of the typical noise emissions expected to occur during the project are:

- Demolition of existing buildings, site establishment including spoil handling facilities.
- Installation of perimeter retaining walls using piling
- Excavation using excavators, rockbreakers drill and blast and other construction plant.
- Spoil removal by heavy vehicle.
- Station construction, fitout and commissioning.

For proposed CRR worksites there are negligible existing barriers between the site and noise sensitive receivers. Therefore it is anticipated that the construction of minor noise barriers to fully enclosed structures would result in the following reductions in noise levels:

- Minor noise barrier (acoustic hoarding indicative height 3 m) 5 dBA to 10 dBA reduction.
- Major noise barrier (acoustic hoarding indicative height 6 m) 10 dBA to 15 dBA reduction.
- Acoustic Enclosure 15 dBA to 25 dBA reduction (based on the medium performance transmission loss data in **Table 24**).

Correctly designed and constructed barriers (of solid construction using appropriate materials, such as 25 mm timber without gaps) would be expected to result in reductions at the upper end of the range provided. For the calculations at nearby receivers 'mid-range' noise reductions of 8 dBA, 13 dBA and 20 dBA have been assumed for the minor, major barriers and acoustic enclosure respectively.

The (acoustic hoarding) noise barriers are effective for receivers at or near ground level (eg outdoor eating areas), they will however not attenuate noise at elevated receivers "overlooking" the construction sites. It is also noted the use of noise barriers, and in particular acoustic enclosures, is often not feasible prior to completion of the demolition and piling phases of the works.

The indicative acoustic enclosure construction would consist of metal cladding with internal insulation faced with sisalation on the walls and roof. Where increased noise insulation is required this can be achieved by upgrading the enclosure elements by using, for example, double skin with infill similar to that used on Airport Link.

In the following report sections assessing the construction noise impacts, aerials showing the construction site and nearest receivers are presented. For these construction site and receiver plans shown in **Figure 10** to **Figure 16**, the following colour codes have been used:

- Blue Residential
- Orange Commercial
- Red Hospital
- Green Educational
- Purple/Pink Church or Place of Worship

8.2 Tunnelling Worksite Noise and Vibration Assessment

8.2.1 TBM Launch Sites - Noise and Vibration Assessment

Assessment of the TBM launch sites at the Southern Portal, Yeerongpilly, and Woolloongabba Station, Woolloongabba, is contained in this section. Generally these sites will be constructed using 'cut and cover' methodology.

It is proposed to utilise the Woolloongabba Station worksite as the major spoil removal facility for the TBM drives north to the Northern Portal worksite and the Southern portal worksite as the major spoil removal facility for the TBM drives north to the Woolloongabba Station worksite.

Woolloongabba Station

Nearest Sensitive Receivers

The nearest noise and/or vibration sensitive receivers to the Woolloongabba Station TBM launch site are identified in **Table 32** with the receiver areas illustrated in **Figure 10**.

Figure 10 Woolloongabba Station Construction Site and Receiver Areas

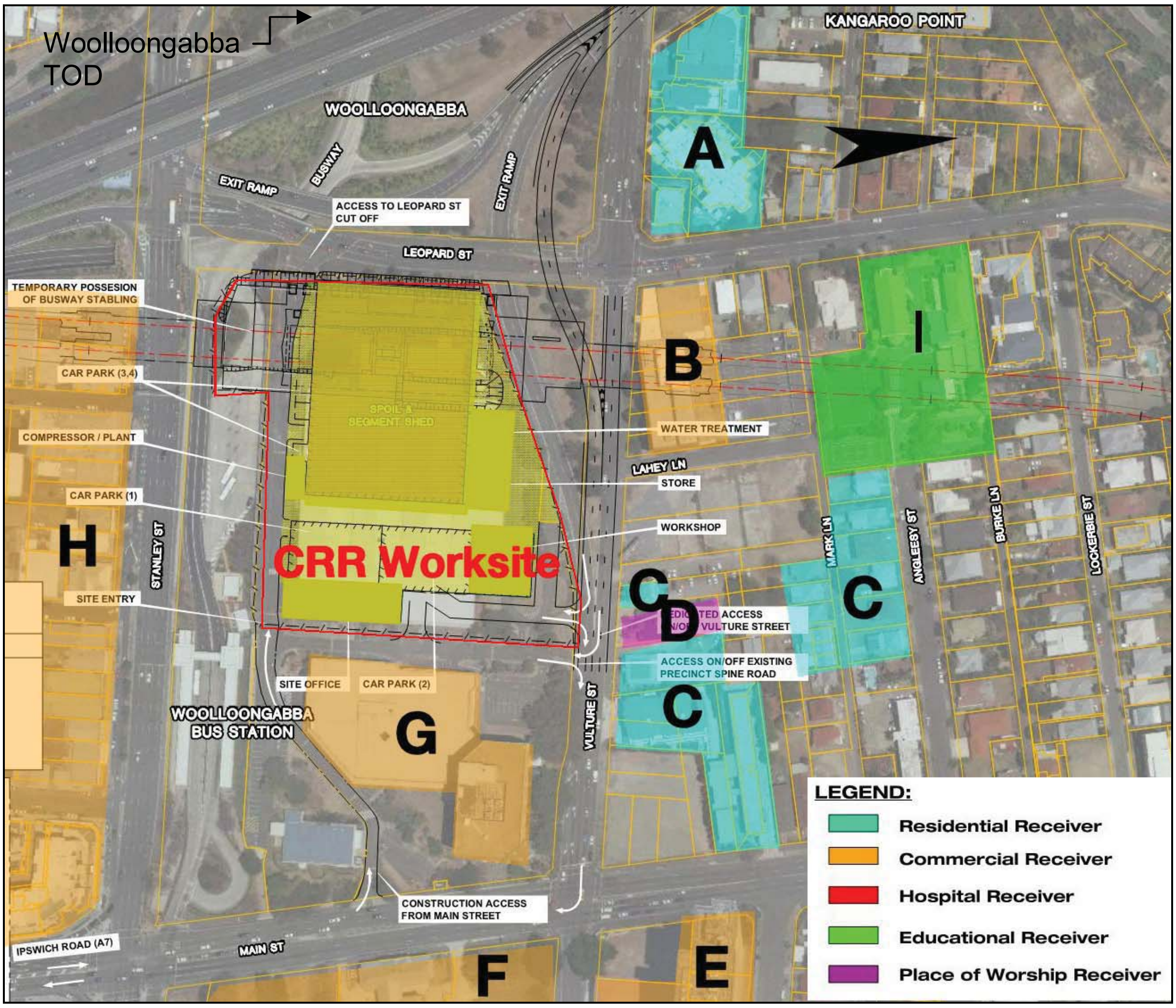


Table 32 Nearest Sensitive Receivers – Woolloongabba Station

Work Site/Excavation	Receiver Area	Location Relative to Works (m)
Woolloongabba Station	A – Vulture Street Residential	125
	B – Vulture Street Commercial	60
	C – Vulture Street Residential	25
	D - St Nicholas Cathedral	25
	E – Main Street Commercial	150
	F – Main Street Commercial	150
	G – Vulture Street Commercial	15
	H – Stanley Street Commercial	60
	I – St Josephs Primary School	180

Site Specific Construction Noise Goals

With reference to the CRR noise goals and the ambient noise survey results summarised in **Section 2.2.7** and **Section 4.1.4** respectively, the site specific construction noise goals are presented in **Table 33**.

Table 33 Woolloongabba Station Construction Noise Goals

Receiver Location/Type	Monday to Saturday 6:30 am to 6:30 pm		Monday to Saturday 6:30 pm to 6:30 am, Sundays and Public Holidays	
	Steady State (dBA $L_{Aeq,adj}$)	Non-Steady State (dBA $L_{A10,adj}$)	Continuous (dBA $L_{Aeq,adj(1hour)}$) [1]	Intermittent (dBA $L_{Amax,adj}$) [1]
A – Vulture Street Residential	52	62	47[2]	57
B – Vulture Street Commercial	62	72	-	-
C – Vulture Street Residential	52	62	47[2]	57
D - St Nicholas Cathedral	47[3]	57[3]	-	-
E – Main Street Commercial	62	72	-	-
F – Main Street Commercial	62	72	-	-
G – Vulture Street Commercial	62	72	-	-
H – Stanley Street Commercial	62	72	-	-
I – St Josephs Primary School	52	62	-	-

Note 1 – Noise goal has been adjusted to represent external free-field levels.
Note 2 – Based on LAeq,adj(1hour) 40 dBA Sleep Disturbance goal.
Note 3 – Noise goal relevant at all times.

Assessment at the Nearest Noise and/or Vibration Sensitive Receivers

Scenarios were developed for Woolloongabba Station TBM launch site construction being representative of activities having potentially the greatest (ie worst case) noise impact on the surrounding receivers. Worst case scenarios have been developed based on all plant items, as proposed by the Project design team (refer to **Appendix F** for plant deployment details) including haul trucks where applicable, operating simultaneously. These scenarios are:

- Scenario 1 – Demolition of Goprint building:
  - Duration ~ 6 weeks
  - Dominant noise sources include rockbreakers (4 off) and excavators.
  - Daytime construction only.
- Scenario 2 – Installation of perimeter piles:
  - Duration ~ 7 weeks
  - Dominant noise sources include piling rigs (4 off)
  - Daytime construction only
- Scenario 3 – Shaft excavation in hard rock and spoil removal:
  - Duration ~ 7 weeks
  - Dominant noise sources include jumbo drill rigs (3 off), excavators and front end loaders
  - Potentially 24 hour per day construction if acoustic enclosure is in place
- Scenario 4 - TBM support operations including on-site spoil movements:
  - Duration ~ 61 weeks
  - Dominant noise sources include tunnel ventilation, front end loaders and haul trucks
  - 24 hour per day construction with night-time works carried out inside an acoustic enclosure

A scenario assessing the noise emission associated with the construction of an acoustic enclosure or construction of station infrastructure at the surface has not been included on the basis that noise levels during these stages are typically lower than levels experienced during the three stages described above, particularly if the structure is prefabricated and only assembled at the site.

For all construction scenarios, typical construction noise levels with 3 m acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 34** to **Table 37**. An assessment of noise goal compliance is also provided with indicative noise level reductions based on 6 m acoustic hoarding for all scenarios and works carried out inside an acoustic enclosure for Scenario 2 and 3. Note a “dash” (-) in the tables indicates compliance, and “n/a” not applicable for the assessment period.

Noise contours have also been predicted for the three scenarios with the proposed noise mitigation, and are presented in **Appendix G**.

Predicted ground-borne noise and vibration impacts for the excavation of the Woolloongabba Station shaft are presented in **Table 38**.

Assessment of ground-borne noise and vibration associated with roadheading the station cavern is presented in **Section 9.2.2**.

Table 34 Woolloongabba Station Predicted Worst Case Noise Levels – Scenario 1 Goprint Demolition

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level (dBA)[2]	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				3 m Hoarding	6 m Hoarding
A – Vulture Street Residential	Day	LA10,adj – 62	68 – 72	10	5
B – Vulture Street Commercial	Day	LA10,adj – 72	78 – 80	8	3
C – Vulture Street Residential	Day	LA10,adj – 62	69 – 77	15	10
D - St Nicholas Cathedral	Any	LA10,adj – 57	75 – 77	20	15
E – Main Street Commercial	Day	LA10,adj – 72	48 – 67	-	-
F – Main Street Commercial	Day	LA10,adj – 72	47 – 58	-	-
G – Vulture Street Commercial	Day	LA10,adj – 72	68 – 77	5	-
H – Stanley Street Commercial	Day	LA10,adj – 72	64 - 76	4	-
I – St Josephs School	Day	LA10,adj – 62	46 – 62	-	-

Note 1 – Dominant construction noise during Goprint building demolition likely to be non-steady state. Therefore the LA10,adj assessment parameter is most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 35 Woolloongabba Station Predicted Worst Case Noise Levels – Scenario 2 Pile Installation

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				3 m Hoarding	6 m Hoarding
A – Vulture Street Residential	Day	LA10,adj – 62	65 – 70	8	3
B – Vulture Street Commercial	Day	LA10,adj – 72	73 – 76	4	-
C – Vulture Street Residential	Day	LA10,adj – 62	57 – 73	11	6
D - St Nicholas Cathedral	Any	LA10,adj – 57	70 – 73	16	11
E – Main Street Commercial	Day	LA10,adj – 72	45 – 61	-	-
F – Main Street Commercial	Day	LA10,adj – 72	43 – 56	-	-
G – Vulture Street Commercial	Day	LA10,adj – 72	47 – 72	-	-
H – Stanley Street Commercial	Day	LA10,adj – 72	59 – 73	1	-
I – St Josephs School	Day	LA10,adj – 62	45 – 56	-	-

Note 1 – Dominant construction noise during pile installation likely to be non-steady state. Therefore the LA10,adj assessment parameter is most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 36 Woolloongabba Station Predicted Worst Case Noise Levels – Scenario 3 Shaft Excavation

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)		
				3 m Hoarding	6 m Hoarding	Enclosure
A – Vulture Street Residential	Day	LA10,adj – 62	71 – 77	15	10	3
	Night	LAmax,adj – 57	66 – 71	14	9	2
B – Vulture Street Commercial	Day	LA10,adj – 72	81 – 82	10	5	-
C – Vulture Street Residential	Day	LA10,adj – 62	65 – 74	12	7	-
	Night	LAmax,adj – 57	60 – 72	15	10	3
D - St Nicholas Cathedral	Any	LA10,adj – 57	74 – 76	19	14	7
E – Main Street Commercial	Day	LA10,adj – 72	44 – 64	-	-	-
F – Main Street Commercial	Day	LA10,adj – 72	46 – 59	-	-	-
G – Vulture Street Commercial	Day	LA10,adj – 72	63 – 74	2	-	-
H – Stanley Street Commercial	Day	LA10,adj – 72	72 - 78	6	1	-
I – St Josephs School	Day	LA10,adj – 62	45 – 57	-	-	-

Note 1 – Dominant construction noise during shaft excavation likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameters are most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 37 Woolloongabba Station Predicted Worst Case Noise Levels – Scenario 4 Tunnelling Support

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)		
				3 m Hoarding	6 m Hoarding	Enclosure
A – Vulture Street Residential	Day	LAeq,adj – 52	59 – 65	13	8	1
	Night	LAeq,adj – 47	58 – 64	17	12	5
B – Vulture Street Commercial	Day	LAeq,adj – 62	70 – 72	10	5	-
C – Vulture Street Residential	Day	LAeq,adj – 52	57 – 65	13	8	1
	Night	LAeq,adj – 47	52 – 62	15	10	3
D - St Nicholas Cathedral	Any	LAeq,adj – 47	63 – 65	18	13	6
E – Main Street Commercial	Day	LAeq,adj – 62	50 – 54	-	-	-
F – Main Street Commercial	Day	LAeq,adj – 62	36 – 47	-	-	-
G – Vulture Street Commercial	Day	LAeq,adj – 62	58 – 62	-	-	-
H – Stanley Street Commercial	Day	LAeq,adj – 62	62 - 68	6	1	-
I – St Josephs School	Day	LAeq,adj – 52	40 - 54	2	-	-

Note 1 – Dominant construction noise during long term TBM support operations (ie spoil removal, ventilation etc) likely to be steady state and continuous. Therefore the LAeq,adj assessment parameter is most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 38 Woolloongabba Station Predicted Ground-borne Noise and Vibration Levels – Shaft Excavation

Receiver Area	Period	Noise and Vibration Goals				Predicted Ground-borne Noise and Vibration Levels (Rockbreaking)		Maximum Allowed Blast MIC (kg) to meet Noise & Vibration Goal	
		Blasting Criterion[1]		Construction Sources					
		Vibration PPV (mm/s)	Airblast Overpressure (dB Linear Peak)	Vibration PPV (mm/s)	Ground-borne Noise (dBA)[2]	Ground-borne Vibration (mm/s)	Ground-borne Noise (dBA)	Vibration	Airblast Overpressure
A – Vulture Street Residential	Day	10	130	5	LA10,adj – 55	0.04	34	43 kg	56 kg
	Night	n/a	n/a	0.5	LAmax,adj – 50	0.04	39	n/a	n/a
B – Vulture Street Commercial	Day	10	130	5	LA10,adj – 65	0.07	43	22 kg	20 kg
C – Vulture Street Residential	Day	10	130	5	LA10,adj – 55	0.02	30	74 kg	126 kg
	Night	n/a	n/a	0.5	LAmax,adj – 50	0.02	35	n/a	n/a
D - St Nicholas Cathedral (Heritage Listed)	Day	2	130	2	LA10,adj – 50	0.02	29	12 kg	175 kg
E – Main Street Commercial	Day	10	130	5	LA10,adj – 65	0.01	24	446 kg	1852 kg
F – Main Street Commercial	Day	10	130	5	LA10,adj – 65	0.01	24	430 kg	1753 kg
G – Vulture Street Commercial	Day	10	130	5	LA10,adj – 65	0.03	33	100 kg	197 kg
H – Stanley Street Commercial	Day	10	130	5	LA10,adj – 65	0.08	44	18 kg	16 kg
I – St Josephs Church & School (Heritage Listed)	Day	2	130	2	LA10,adj – 50	0.01	25	23 kg	439 kg

Note 1: Blasting only during daytime.
2: Dominant construction noise during shaft excavation likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameters are most relevant. For the ground-borne noise all noise levels are internal levels.

Discussion

The predicted noise levels for site establishment works including demolition of the existing GoPrint building at the Woolloongabba Station site indicate exceedances of up to 15 dBA of the noise goal for daytime operations at the nearest residential receivers along Vulture Street. Higher exceedances are expected at St Nicholas Cathedral due to the lower noise goal. Similar exceedances are predicted during the pile installation works (ie Scenario 2) which are anticipated to occur over a seven week period.

The predicted noise levels for shaft excavation and spoil storage (ie Scenario 3) occurring inside a medium performance acoustic enclosure at the Woolloongabba Station site indicate exceedances of up to 3 dBA during the day and 3 dBA during the night-time period at the nearest residential receivers. The predicted noise levels indicate that a minor (eg 1 mm thick metal cladding rather than 0.62 mm thick cladding) upgrade on the medium performance acoustic enclosure would be required to achieve compliance with the daytime and night-time noise goals.

Longer term activities at this site associate with the TBM drives (ie Scenario 4) are also predicted to exceed the night-time residential noise goal at the nearest receivers. A further 5 dBA reduction in noise emission could be achieved through the following mitigation measures:

- High performance acoustic enclosure over the shaft.
- Quietest available mobile plant operating at the site.
- Temporary tunnel ventilation noise sources to be located down in the shaft with appropriate ducting to the surface. Silencers may be required depending on the type of ventilation used.
- Acoustic louvres at enclosure ventilation points.

Detailed design of a high performance acoustic enclosure will be required for the Woolloongabba site should include double skin walls and roof lined with sound absorptive material, minimised openings and fitted with acoustic louvres to ventilation openings. The acoustic enclosure could be constructed with a retractable/removable roof to allow for delivery of large TBM components.

With these mitigation measures in place combined with careful management of all heavy vehicle movements on the site, compliance with the noise goals during all time periods could be achieved at the Woolloongabba Station site with the exception of initial demolition works which cannot be reasonably and feasibly mitigated to achieve compliance with the daytime noise goal.

The predicted gound-borne noise and vibration levels in **Table 38** indicate compliance with the relevant goals primarily due to the Woolloongabba Station worksite being bordered by existing roads and therefore set back from sensitive receivers.

The estimated blast MIC limits for Woolloongabba Station indicate that blasting of the station shaft could be carried out with minimal risk of impact. Therefore, blasting would be a suitable excavation technique for this location.

Regarding construction noise impacts of the Project onto future urban development in Woolloongabba, predicted construction noise levels have not been assessed as building layouts are yet to be finalised. Construction noise emission levels for future ground floor receivers at these developments can be interpreted from the noise contours presented in **Appendix G**.

Southern Portal

Nearest Sensitive Receivers

The nearest noise and/or vibration sensitive receivers to the Southern Portal site are identified in **Table 39** with the receiver areas illustrated in **Figure 11**.

Figure 11 Southern Portal Construction Site and Receiver Areas

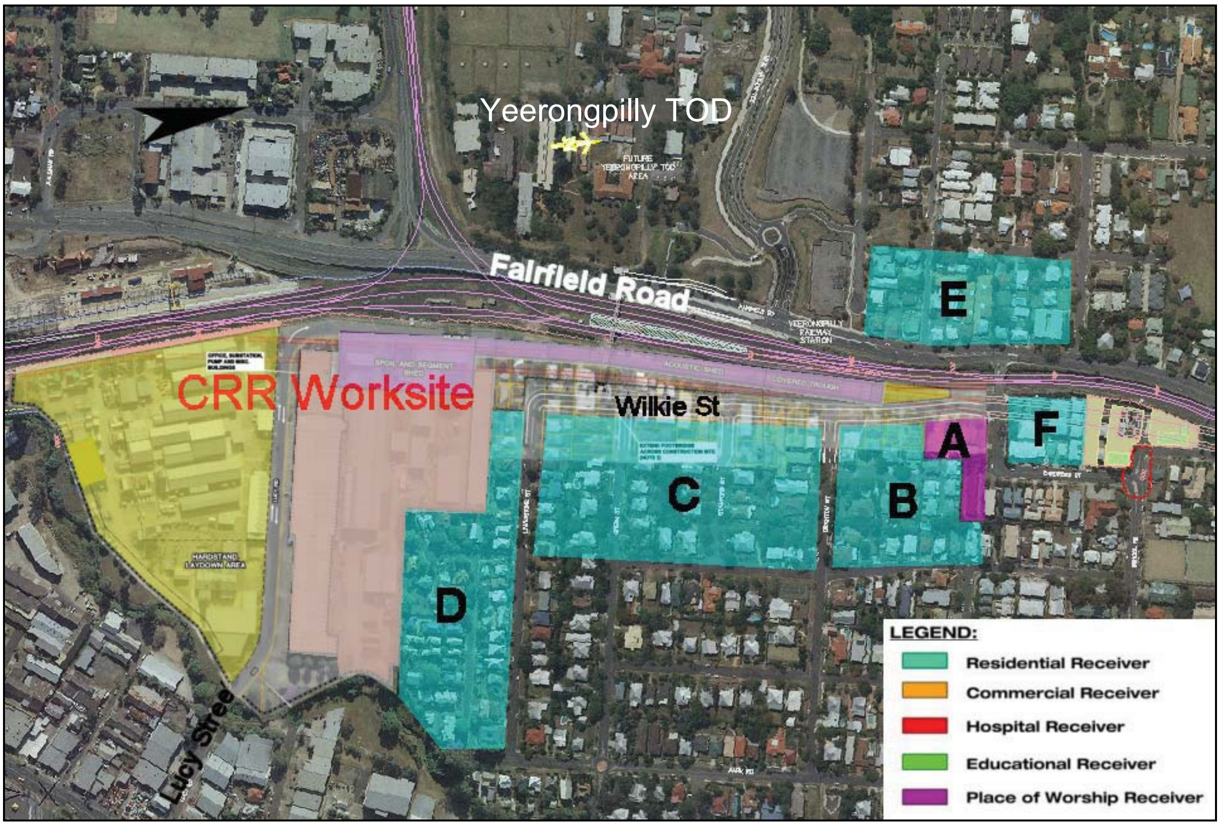


Table 39 Nearest Sensitive Receivers – Southern Portal

Work Site/Excavation	Receiver Area	Location Relative to Works (m)
Southern Portal	A – St Fabien's Church	20
	B – Tees Street Residential	30
	C – Wilkie Street Residential	30
	D – Livingstone Street Residential	35
	E – Fairfield Road Residential	50
	F – Cardross Street Residential	80

Site Specific Construction Noise Goals

With reference to the CRR project noise goals and the ambient noise survey results summarised in **Section 2.2.7** and **Section 4.1.4** respectively, the site specific construction noise goals are presented in **Table 40**.

Table 40 Southern Portal Construction Noise Goals

Receiver Location/Type	Monday to Saturday 6:30 am to 6:30 pm		Monday to Saturday 6:30 pm to 6:30 am, Sundays and Public Holidays	
	Steady State (dBA $L_{Aeq,adj}$)	Non-Steady State (dBA $L_{A10,adj}$)	Continuous (dBA $L_{Aeq,adj(1hour)}$) [1]	Intermittent (dBA $L_{Amax,adj}$) [1]
A – St Fabien's Church	47[2]	57[2]	-	-
B – Tees Street Residential	47	57	42	52
C – Wilkie Street Residential	47	57	42	52
D – Livingstone Street Residential	47	57	42	52
E – Fairfield Road Residential	52	62	47	57
F – Cardross Street Residential	47	57	42	52

Note 1 – Noise goal has been adjusted to represent external free-field levels.
Note 2 – Noise goal relevant at all times.

Assessment at the Nearest Noise Sensitive Receivers

Assessment of ground-borne noise and vibration associated with tunnel boring the initial section adjacent to the Southern Portal is presented in **Section 9.2.2**.

Scenarios were developed for Southern Portal construction works being representative of activities having potentially the greatest (ie worst case) noise impact on the surrounding receivers. Worst case scenarios have been developed based on all plant items, as proposed by the Project design team (refer to **Appendix F** for plant deployment details) including haul trucks where applicable, operating simultaneously. These scenarios are:

- Scenario 1 – Demolition of existing buildings:
  - Duration ~ 6 weeks
  - Dominant noise sources include rockbreakers and excavators
  - Daytime construction only
- Scenario 2 – Pile installation along cut and cover and section of the trough:
  - Duration ~ 6 weeks
  - Dominant noise sources include piling rigs (3 off)
  - Mostly daytime construction and potentially weekend work during track possessions
- Scenario 3 - TBM support including spoil removal:
  - Duration ~ 68 weeks
  - Dominant noise sources include spoil trucks, front end loaders and tunnel ventilation
  - 24 hour per day construction with night-time works carried out inside an acoustic enclosure
- Scenario 4 – Night-time truck (eg spoil, delivery etc) movements within the site near the entrance:
  - Duration ~ 125 weeks
  - Dominant noise sources include trucks prior to exiting the site at Lucy Road
  - 24 hour per day movements through the site

For all construction scenarios, typical construction noise levels with 3 m acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 41** to **Table 43**. An assessment of noise goal compliance is also provided with indicative noise level reductions based on 6 m acoustic hoarding for all scenarios and works carried out inside an acoustic enclosure for Scenario 2 and 3. Note a “dash” (-) in the tables indicates compliance, and “n/a” not applicable for the assessment period.

Noise contours have also been predicted for the four scenarios with the standard 3 m perimeter acoustic hoarding, and are presented in **Appendix G**.

Table 41 Southern Portal Predicted Worst Case Noise Levels – Scenario 1 Demolition of Existing Buildings

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				3 m Hoarding	6 m Hoarding
A – St Fabien’s Church	Day	LA10,adj – 57	76 – 86	29	24
B – Tees Street Residential	Day	LA10,adj – 57	73 – 86	29	24
C – Wilkie Street Residential	Day	LA10,adj – 57	69 – 84	27	22
D – Livingstone Street Residential	Day	LA10,adj – 57	52 – 76	19	14
E – Fairfield Road Residential	Day	LA10,adj – 62	69 – 76	14	9
F – Cardross Street Residential	Day	LA10,adj – 57	61 – 68	11	6

Note 1 – Dominant construction noise during demolition works likely to be non-steady state. Therefore the LA10,adj assessment parameter is most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 42 Southern Portal Predicted Worst Case Noise Levels – Scenario 2 Pile Installation

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				3 m Hoarding	6 m Hoarding
A – St Fabien’s Church	Day	LA10,adj – 57	67 – 70	13	8
B – Tees Street Residential	Day	LA10,adj – 57	58 – 72	15	11
	Night	LAmax,adj – 52	51 – 68	16	11
C – Wilkie Street Residential	Day	LA10,adj – 57	56 – 69	12	7
	Night	LAmax,adj – 52	52 – 63	11	6
D – Livingstone Street Residential	Day	LA10,adj – 57	41 – 62	5	-
	Night	LAmax,adj – 52	40 – 48	-	-
E – Fairfield Road Residential	Day	LA10,adj – 62	62 – 72	10	5
	Night	LAmax,adj – 57	58 – 70	13	8
F – Cardross Street Residential	Day	LA10,adj – 57	48 – 62	5	-
	Night	LAmax,adj – 52	43 – 58	6	1

Note 1 – Dominant construction noise during pile installation works likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameters are most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 43 Southern Portal Predicted Worst Case Noise Levels – Scenario 3 TBM Support

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)		
				3 m Hoarding	6 m Hoarding	Enclosure
A – St Fabien's Church	Day	LAeq,adj – 47	47 – 51	4	-	-
B – Tees Street Residential	Day	LAeq,adj – 47	42 – 52	5	-	-
	Night	LAeq,adj – 42	42 – 52	10	5	-
C – Wilkie Street Residential	Day	LAeq,adj – 47	40 – 62	15	10	3
	Night	LAeq,adj – 42	40 – 62	20	15	8
D – Livingstone Street Residential	Day	LAeq,adj – 47	44 – 61	14	9	2
	Night	LAeq,adj – 42	44 – 61	19	14	7
E – Fairfield Road Residential	Day	LAeq,adj – 52	47 – 53	1	-	-
	Night	LAeq,adj – 47	47 – 53	6	1	-
F – Cardross Street Residential	Day	LAeq,adj – 47	36 – 47	-	-	-
	Night	LAeq,adj – 42	36 – 47	5	-	-

Note 1 – Dominant construction noise during long term TBM drives likely to be steady state and continuous. Therefore the LAeq,adj assessment parameter is most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 44 Southern Portal Predicted Worst Case Noise Levels – Scenario 4 On-site Spoil Trucks

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				3 m Hoarding	4 m Hoarding[3]
B – Tees Street Residential	Night	LAmax,adj – 52	31 – 34	-	-
C – Wilkie Street Residential	Night	LAmax,adj – 52	24 – 37	-	-
D – Livingstone Street Residential	Night	LAmax,adj – 52	31 - 53	1	-

Note 1 – Construction noise from spoil trucks would be intermittent. Therefore the LAmax,adj assessment parameter is most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Note 3 – Minimum height of acoustic hoarding adjacent to site entrance required to achieve compliance with the noise goal.

Discussion

The predicted noise levels for site establishment works including demolition of Wilkie Street and adjacent residences at the Southern Portal site indicate exceedances of up to 29 dBA of the noise goal for the daytime period. The large noise goal exceedances result from the use of rockbreakers in close proximity to receivers. It is anticipated that rockbreakers would be used intermittently during the six week site clearing phase of the Project.

It is recommended that demolition of residences nearest to the railway line occur first so that the buildings closest to the resumption extents act as a barrier for residences located beyond the property impact area, particularly if large rockbreakers are required to break up concrete slabs and/or footings.

It is understood that short-term night-time work would be required during pile installation works immediately adjacent to the operational rail line. The predicted night-time noise levels for Scenario 2 reflect this activity, which indicate that exceedances of up to 16 dBA would be anticipated with just 3 m acoustic hoarding as noise mitigation. Where practicable, it is recommended that these works be carried out during weekend rail possessions and preferably during the daytime only.

The predicted noise levels for spoil removal (during TBM operation) at the Southern Portal site indicate exceedances of up to 20 dBA during the night-time period at the nearest residential receivers. The predicted noise levels indicate that a high performance acoustic enclosure would be required to comply with the night-time noise goals.

The results of the SoundPLAN noise modelling for this site indicate that a hierarchy of noise controls would be required in order for the site to operate continuously whilst maintaining full compliance with the noise goals for the duration of the project. The hierarchy of controls would likely be in the form or:

- Where practicable to do so, relocate plant inside the cut and cover tunnel.
- Selection of quietest available plant.
- Mitigating each acoustically significant item of plant required to operate within the acoustic enclosure (eg residential grade mufflers on al front end loaders).
- Subsequent to the above measures, detailed design of a high performance acoustic enclosure, which may include double skin walls and ceiling lined with sound absorptive material, minimising openings and fitting acoustic louvres to ventilation openings. Access and ventilation openings should be constructed on the western facade of the enclosure away from the nearest residences to the east.
- If necessary, mitigating noise at individually affected receivers through property treatments (eg mechanical ventilation, glazing upgrades etc).

Spoil movements within the site during the night-time period achieve compliance with the sleep disturbance noise goal as a result of the shielding being afforded by the existing warehouses at the site in combination with 4 m high noise barrier adjacent to the site entrance at Lucy Street.

The movement of trucks within the worksite should be designed to limit (as much as possible) the need for reversing and therefore reversing alarms. Where issues with reversing alarms occur, consideration should be given to the use of broadband “buzzer” reversing alarms and/or alarms which actively vary their volume according to the ambient noise levels during activation - rather than constant volume (tonal) “beeping” alarms.

With the above mitigation measures in place combined with careful management of all heavy vehicle movements on the site, compliance with the noise goals during all time periods could be achieved at the Southern Portal site with the exception of initial demolition works and work requiring a rail possession which cannot be reasonably and feasibly mitigated to achieve compliance with the daytime noise goal.

Cumulative construction noise impacts from the Yeerongpilly Transit Oriented Development (TOD) site west of the rail corridor and Southern Portal worksite has not been assessed as the construction programs for both projects are yet to be finalised. Nonetheless, should the projects coincide it would be anticipated that cumulative construction noise impacts (daytime only) would be mostly limited to receivers located on the western side of the rail corridor north of the Yeerongpilly TOD site (ie Ortive Street). A large number of noise sensitive receivers located on the eastern side of the rail corridor would be shielded to the TOD worksite by the CRR acoustic enclosure. If required, mitigation of cumulative construction noise from the two projects should be considered during the detailed design stage.

Regarding construction noise impacts of the Project onto the Yeerongpilly TOD west of the rail corridor, predicted noise levels have not been assessed as the TOD masterplan for the entire site is yet to be finalised. Construction noise emission levels for future ground floor receivers at the TOD site can be interpreted from the noise contours presented in **Appendix G**.

8.2.2 Tunnel Portals – Noise and Vibration Assessment

Assessment of the CRR tunnel portal at Spring Hill (ie Northern Portal), is contained in this section. Assessment of construction impacts associated with the Southern Portal was covered in **Section 8.2.1** of this report.

Northern Portal

Nearest Sensitive Receivers

The nearest noise and/or vibration sensitive receivers to the Northern Portal site are identified in **Table 45** with the receiver areas illustrated in **Figure 12**.

Figure 12 Northern Portal Construction Worksite and Receiver Areas

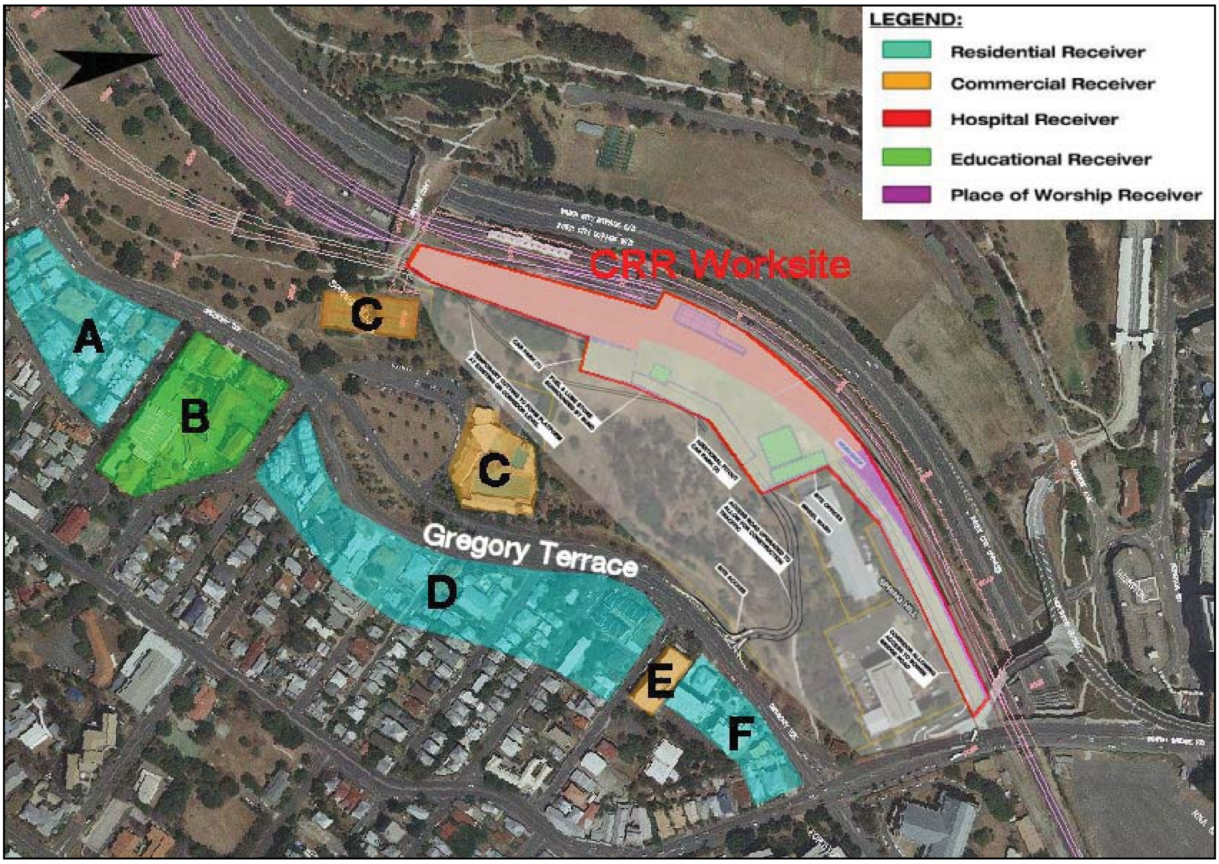


Table 45 Nearest Sensitive Receivers – Northern Portal

Work Site/Excavation	Receiver Area	Location Relative to Works (m)
Northern Portal	A – Gregory Terrace Residential	230
	B – St Josephs College	150
	C – Centenary Aquatic Centre	25
	D – Gregory Terrace Residential	130
	E – Gregory Terrace Commercial	150
	F – Gregory Terrace Residential	170
	G – Bowen Bridge Road Commercial	20

Site Specific Construction Noise Goals

With reference to the CRR noise goals and the ambient noise survey results summarised in **Section 2.2.7** and **Section 4.1.4** respectively, the site specific construction noise goals are presented in **Table 46**.

Table 46 Northern Portal Construction Noise Goals

Receiver Location/Type	Monday to Saturday 6:30 am to 6:30 pm		Monday to Saturday 6:30 pm to 6:30 am, Sundays and Public Holidays	
	Steady State (dBA $L_{Aeq,adj}$)	Non-Steady State (dBA $L_{A10,adj}$)	Continuous (dBA $L_{Aeq,adj(1hour)}$) [1]	Intermittent (dBA $L_{Amax,adj}$) [1]
A – Gregory Terrace Residential	47	57	42	52
B – St Josephs College	52	62	-	-
C – Centenary Aquatic Centre	62	72	-	-
D – Gregory Terrace Residential	47	57	42	52
E – Gregory Terrace Commercial	62	72	-	-
F – Gregory Terrace Residential	52	62	47	57
G – Bowen Bridge Road Commercial	62	72	-	-

Note 1 – Noise goal has been adjusted to represent external free-field levels.

Assessment at the Nearest Noise Sensitive Receivers

Assessment of ground-borne noise and vibration associated with roadheading the initial section of Northern Portal is presented in **Section 9.2.2**.

Scenarios were developed for Northern Portal construction works being representative of activities having potentially the greatest (ie worst case) noise impact on the surrounding receivers. Worst case scenarios have been developed based on all plant items, as proposed by the Project design team (refer to **Appendix F** for plant deployment details) including haul trucks where applicable, operating simultaneously. These scenarios are:

- Scenario 1 - Site establishment:
  - Duration ~ 4 weeks
  - Dominant noise sources include excavators and front end loaders
  - Daytime construction only
- Scenario 2 - Trough excavation and spoil removal:
  - Duration ~ 5 weeks
  - Dominant noise sources include jumbo drill rigs and excavators
  - Daytime construction only
- Scenario 3 - TBM disassembly:
  - Duration ~ 15 weeks
  - Dominant noise sources include cranes and heavy vehicles
  - Daytime construction only

For all construction scenarios, typical construction noise levels with 3 m acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 47** to **Table 49**. An assessment of noise goal compliance is also provided with indicative noise level reductions based on 6 m acoustic hoarding for all scenarios and works carried out inside the cut and cover structure for Scenario 3. Note a "dash" (-) in the tables indicates compliance, and "n/a" not applicable for the assessment period.

Noise contours have also been predicted for the three scenarios including the proposed noise mitigation, and are presented in **Appendix G**.

Table 47 Northern Portal Predicted Worst Case Noise Levels – Scenario 1 Site Establishment

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				3 m Hoarding	6 m Hoarding
A – Gregory Terrace Residential	Day	$L_{A10,adj}$ – 57	56 – 59	2	-
B – St Josephs College	Day	$L_{A10,adj}$ – 62	48 – 62	-	-
C – Centenary Aquatic Centre	Day	$L_{A10,adj}$ – 72	64 – 83	11	6
D – Gregory Terrace Residential	Day	$L_{A10,adj}$ – 57	59 – 64	7	2
E – Gregory Terrace Commercial	Day	$L_{A10,adj}$ – 72	46 – 58	-	-
F – Gregory Terrace Residential	Day	$L_{A10,adj}$ – 62	47 – 56	-	-
G – Bowen Bridge Road Commercial	Day	$L_{A10,adj}$ – 72	54 – 72	-	-

Note 1 – Dominant construction noise during site establishment likely to be non-steady state. Therefore the $L_{A10,adj}$ assessment parameter is most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 48 Northern Portal Predicted Worst Case Noise Levels – Scenario 2 Trough Excavation and Cut and Cover

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				3 m Hoarding	6 m Hoarding
A – Gregory Terrace Residential	Day	LA10,adj – 57	54 – 58	1	-
B – St Josephs College	Day	LA10,adj – 62	48 – 60	-	-
C – Centenary Aquatic Centre	Day	LA10,adj – 72	67 – 74	2	-
D – Gregory Terrace Residential	Day	LA10,adj – 57	59 – 64	7	2
E – Gregory Terrace Commercial	Day	LA10,adj – 72	49 – 61	-	-
F – Gregory Terrace Residential	Day	LA10,adj – 62	50 – 60	-	-
G – Bowen Bridge Road Commercial	Day	LA10,adj – 72	57 – 70	-	-

Note 1 – Dominant construction noise during trough excavation likely to be non-steady state. Therefore the LA10,adj assessment parameter is most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 49 Northern Portal Predicted Worst Case Noise Levels – Scenario 3 TBM Disassembly

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)		
				3 m Hoarding	6 m Hoarding	Enclosure
A – Gregory Terrace Residential	Day	LA10,adj – 57	48 – 54	-	-	-
B – St Josephs College	Day	LA10,adj – 62	44 – 57	-	-	-
C – Centenary Aquatic Centre	Day	LA10,adj – 72	66 – 72	-	-	-
D – Gregory Terrace Residential	Day	LA10,adj – 57	53 – 61	4	-	-
E – Gregory Terrace Commercial	Day	LA10,adj – 72	47 – 58	-	-	-
F – Gregory Terrace Residential	Day	LA10,adj – 62	45 – 57	-	-	-
G – Bowen Bridge Road Commercial	Day	LA10,adj – 72	53 – 61	-	-	-

Note 1 – Dominant construction noise during TBM disassembly likely to be non-steady state. Therefore the LA10,adj assessment parameter is most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Discussion

The predicted worst case noise levels for the three construction scenarios at the Northern Portal site indicate relatively small exceedances of the relevant noise goals at the nearest residential receivers due to the buffer between the worksite and residences. Higher noise goal exceedances are expected at commercial receivers located on the western side of Gregory Terrace.

The predicted noise levels in **Table 47** to **Table 49** suggest that increasing the proposed 3 m acoustic hoarding along the eastern boundary to a 6 m acoustic hoarding should achieve compliance with the noise goals at all sensitive receivers except for the Centenary Aquatic Centre (6 dBA exceedance) and the nearest Gregory Terrace residences (marginal 2 dBA exceedance). Impacts to these receivers could be managed through use of quietest available construction plant and consultation. Regarding Scenario 2 impacts, as the excavation plant progress deeper into the trough structure, construction noise emission levels at Gregory Terrace (residential receivers) would be anticipated to approach compliance with the noise goal.

The movement of trucks within the worksite should be designed to limit (as much as practicable) the need for reversing and therefore reversing alarms. Where issues with reversing alarms occur, consideration should be given to the use of broadband “buzzer” reversing alarms and/or alarms which actively vary their volume according to the ambient noise levels during activation - rather than constant volume (tonal) “beeping” alarms.

8.2.3 Station Construction – Noise and Vibration Assessment

Assessment of the CRR underground stations at Roma Street (existing surface railway station), Albert Street and Boggo Road, is contained in this section. Construction noise impacts for Woolloongabba Station have been covered in **Section 8.2.1** relating to TBM launch sites.

Roma Street Station

Nearest Sensitive Receivers

The nearest noise and/or vibration sensitive receivers to the Roma Street Station site are identified in **Table 50** with the receiver areas illustrated in **Figure 13**.

Figure 13 Roma Street Station Construction Site and Receiver Areas

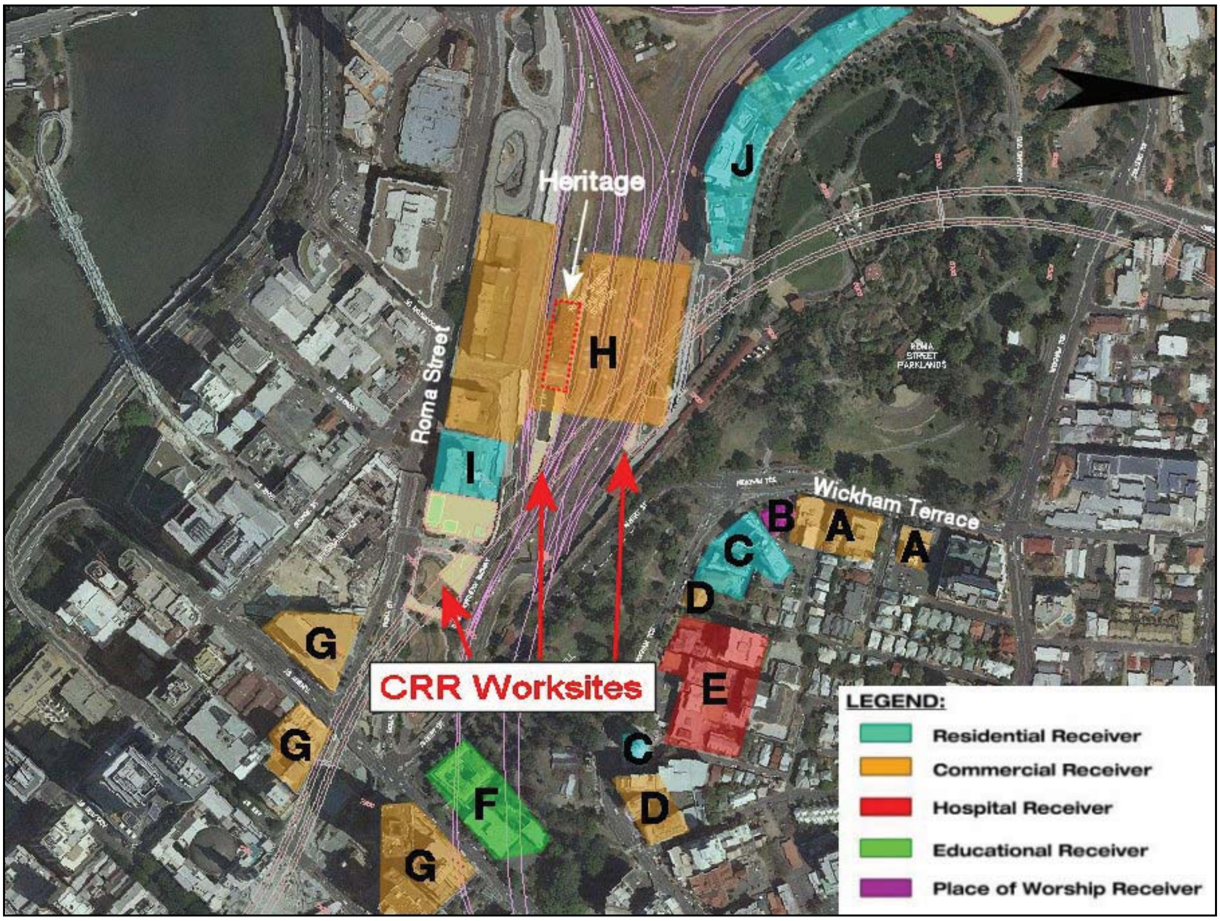


Table 50 Nearest Sensitive Receivers – Roma Street Station

Work Site/Excavation	Receiver Area	Location Relative to Works (m)
Roma Street Station	A – Wickham Terrace Commercial	150
	B – St Alban Liberal Catholic Church	125
	C – Wickham Terrace Residential	120
	D – Wickham Terrace Commercial	140
	E – Brisbane Private Hospital	130
	F – Brisbane Dental Educational	100
	G – Turbot Street Commercial	40
	H – Roma Street Station Commercial[1]	10
	I – Holiday Inn Residential	50
	J - Parkland Crescent Residential	150

Note 1 – Receiver includes Brisbane Transit Centre and Roma Street Station platforms of which the southern building is heritage listed.

Site Specific Construction Noise Goals

With reference to the CRR project noise goals and the ambient noise survey results summarised in **Section 2.2.7** and **Section 4.1.4** respectively, the site specific construction noise goals are presented in **Table 51**.

Table 51 Roma Street Station Construction Noise Goals

Receiver Location/Type	Monday to Saturday 6:30 am to 6:30 pm		Monday to Saturday 6:30 pm to 6:30 am, Sundays and Public Holidays	
	Steady State (dBA $L_{Aeq,adj}$)	Non-Steady State (dBA $L_{A10,adj}$)	Continuous (dBA $L_{Aeq,adj(1hour)}$) [1]	Intermittent (dBA $L_{Amax,adj}$) [1]
A – Wickham Terrace Commercial	62	72		
B – St Alban Liberal Catholic Church	47[2]	57[2]	-	-
C – Wickham Terrace Residential	52	62	47	57
D – Wickham Terrace Commercial	62	72	-	-
E – Brisbane Private Hospital	57[3]	67[3]	-	-
F – Brisbane Dental Educational	52	62	-	-
G – Turbot Street Commercial	62	72	-	-
H – Roma Street Station Commercial (external areas)	55[4]	65[4]	-	-
I – Holiday Inn Residential	52	62	47	57
J – Parkland Crescent Residential	52	62	47	57

Note 1 – Noise goal has been adjusted to represent external free-field levels.
Note 2 - Monday to Saturday 6:30 am to 6:30 pm goals relevant at all times.
Note 3 - Based on AS2107 category “wards” for medical buildings. Applies to all time periods. 20 dBA façade adjustment to an external noise goal.
Note 4 - Based on AS2107 category “waiting areas” for railway and bus terminals and is applied to external areas of the station. Applicable to all time periods.

Assessment at the Nearest Noise and/or Vibration Sensitive Receivers

Scenarios were developed for Roma Street Station construction works being representative of activities having potentially the greatest (ie worst case) noise impact on the surrounding receivers. Worst case scenarios have been developed based on all plant items, as proposed by the Project design team (refer to **Appendix F** for plant deployment details) including haul trucks where applicable, operating simultaneously. These scenarios are:

- Scenario 1 – Site establishment including demolition:
  - North shaft duration ~ 6 weeks
  - Central shaft duration ~ 10 weeks
  - South shaft duration ~ 6 weeks
  - Dominant noise sources include excavators and cranes
  - Mostly daytime construction works with potential for night-time work to avoid impact on existing rail operations
- Scenario 2 – Piling of access shafts:
  - North shaft duration ~ 8 weeks
  - Central shaft duration ~ 6 weeks

- South shaft duration ~ 4 weeks
- Dominant noise sources include piling rigs
- Mostly daytime construction works with potential for night-time work to avoid impact on existing rail operations

- Scenario 3 – Shaft excavation:
  - North shaft duration ~ 12 weeks
  - Central shaft duration ~ 20 weeks
  - South shaft duration ~ 10 weeks
  - Dominant noise sources include jumbo drill rigs, excavators and front end loaders
  - 24 hour per day construction with night-time works carried out inside an acoustic enclosure at the south shaft

For all construction scenarios, typical construction noise levels with 3 m acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 52** to **Table 54**. An assessment of noise goal compliance is also provided with indicative noise level reductions based on 6 m acoustic hoarding for all scenarios and works carried out inside an acoustic enclosure (southern worksite only) for Scenario 3. Note a “dash” (-) in the tables indicates compliance, and “n/a” not applicable for the assessment period.

Noise contours have also been predicted for the three scenarios with the proposed noise mitigation, and are presented in **Appendix G**.

Predicted ground-borne noise and vibration impacts for the excavation of Roma Street Station access shafts are presented in **Table 55**.

Assessment of ground-borne noise and vibration associated with roadheading the station cavern is presented in **Section 9.2.2**.

Table 52 Roma Street Station Predicted Noise Levels – Scenario 1 Site Establishment

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				3 m Hoarding	6 m Hoarding
A – Wickham Terrace Commercial	Day	$L_{A10,adj}$ – 72	49 – 51	-	-
B – St Alban Liberal Catholic Church	Day	$L_{A10,adj}$ – 57	46 – 50	-	-
C – Wickham Terrace Residential	Day	$L_{A10,adj}$ – 62	47 – 57	-	-
	Night	$L_{Amax,adj}$ – 57	52 – 62	5	-
D – Wickham Terrace Commercial	Day	$L_{A10,adj}$ – 72	46 – 57	-	-
E – Brisbane Private Hospital	Any	$L_{A10,adj}$ – 67	46 – 55	-	-
F – Brisbane Dental Educational	Day	$L_{A10,adj}$ – 62	45 – 54	-	-
G – Turbot Street Commercial	Day	$L_{A10,adj}$ – 72	51 – 70	-	-
H – Roma Street Station Commercial	Day	$L_{A10,adj}$ – 65	62 - 79	14	9

I – Holiday Inn Residential	Day	LA10,adj – 62	62 – 72	12	7
	Night	LAmax,adj – 57	67 – 77	20	15
J – Parkland Crescent Residential	Day	LA10,adj – 62	52 – 58	-	-
	Night	LAmax,adj – 57	57 – 63	6	1

Note 1 – Dominant construction noise during site establishment likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameters are most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 53 Roma Street Station Predicted Noise Levels – Scenario 2 Piling for Shafts

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				3 m Hoarding	6 m Hoarding
A – Wickham Terrace Commercial	Day	LA10,adj – 72	51 – 52	-	-
B – St Alban Liberal Catholic Church	Day	LA10,adj – 57	49 – 52	-	-
C – Wickham Terrace Residential	Day	LA10,adj – 62	49 – 58	-	-
	Night	LAmax,adj – 57	54 - 63	6	1
D – Wickham Terrace Commercial	Day	LA10,adj – 72	45 – 64	-	-
E – Brisbane Private Hospital	Any	LA10,adj – 67	48 – 56	-	-
F – Brisbane Dental Educational	Day	LA10,adj – 62	45 – 55	-	-
G – Turbot Street Commercial	Day	LA10,adj – 72	54 – 72	-	-
H – Roma Street Station Commercial	Day	LA10,adj – 65	64 - 77	12	7
I – Holiday Inn Residential	Day	LA10,adj – 62	63 – 72	10	5
	Night	LAmax,adj – 57	68 – 77	20	15
J – Parkland Crescent Residential	Day	LA10,adj – 62	54 – 58	-	-
	Night	LAmax,adj – 57	59 – 63	6	1

Note 1 – Dominant construction noise during piling likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameters are most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 54 Roma Street Station Predicted Noise Levels – Scenario 3 Shaft Excavation

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)		
				3 m Hoarding	6 m Hoarding	Enclosure
A – Wickham Terrace Commercial	Day	LA10,adj – 72	48 – 50	-	-	-
B – St Alban Liberal Catholic Church	Any	LA10,adj – 57	45 – 49	-	-	-
C – Wickham Terrace Residential	Day	LA10,adj – 62	46 – 57	-	-	-
	Night	LAmax,adj – 57	51 – 62	5	-	-

D – Wickham Terrace Commercial	Day	LA10,adj – 72	44 – 57	-	-	-
E – Brisbane Private Hospital	Any	LA10,adj – 67	45 – 55	-	-	-
F – Brisbane Dental Educational	Day	LA10,adj – 62	44 – 53	-	-	-
G – Turbot Street Commercial	Day	LA10,adj – 72	54 – 71	-	-	-
H – Roma Street Station Commercial	Day	LA10,adj – 65	63 - 76	11	6	-
I – Holiday Inn Residential	Day	LA10,adj – 62	62 – 71	9	4	-
	Night	LAmax,adj – 57	67 – 76	19	14	7
J – Parkland Crescent Residential	Day	LA10,adj – 62	52 – 57	-	-	-
	Night	LAmax,adj – 57	57 – 62	5	-	-

Note 1 – Dominant construction noise during shaft excavation likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameters are most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 55 Roma Street Station Predicted Ground-borne Noise and Vibration Levels – Shaft Excavation

Receiver Area	Period	Noise and Vibration Goals				Predicted Ground-borne Noise and Vibration Levels (Rockbreaking)		Maximum Allowed Blast MIC (kg) to meet Noise & Vibration Goal	
		Blasting Criterion[1]		Construction Sources					
		Vibration PPV (mm/s)	Airblast Overpressure (dB Linear Peak)	Vibration PPV (mm/s)	Ground-borne Noise (dBA)[2]	Ground-borne Vibration (mm/s)	Ground-borne Noise (dBA)	Vibration	Airblast Overpressure
A – Wickham Terrace Commercial	Day	10	130	5	LA10,adj – 65	0.02	26	151 kg	364 kg
B – St Alban Liberal Catholic Church	Day	10	130	2	LA10,adj – 50	0.03	28	107 kg	219 kg
C – Wickham Terrace Residential	Day	10	130	5	LA10,adj – 55	0.04	29	85 kg	154 kg
	Night	n/a	n/a	0.5	LAmax,adj – 50	0.04	34	n/a	n/a
D – Wickham Terrace Commercial	Day	2	130	5	LA10,adj – 65	0.03	27	115 kg	244 kg
E – Brisbane Private Hospital	Any	10	130	5	LA10,adj – 60	0.02	24	180 kg	476 kg
F – Brisbane Dental Educational	Day	10	130	5	LA10,adj – 55	0.04	29	85 kg	154 kg
G – Turbot Street Commercial	Day	10	130	5	LA10,adj – 65	0.14	39	18 kg	15 kg
H – Roma Street Station Commercial	Day	10	130	5	LA10,adj – 65	0.37	47		
H – Old Train Station Heritage Listed	Day	2	130	5	LA10,adj – 65	0.53	49	0.5 kg	1.4 kg
I – Holiday Inn Residential	Day	10	130	5	LA10,adj – 55	0.14	39	18 kg	15 kg
	Night	n/a	n/a	0.5	LAmax,adj – 50	0.14	44	n/a	n/a
J – Parkland Crescent Residential	Day	10	130	5	LA10,adj – 55	0.03	26	145 kg	344 kg
	Night	n/a	n/a	0.5	LAmax,adj – 50	0.03	31	n/a	n/a

Note 1: Blasting only during daytime.
2: Dominant construction noise during shaft excavation likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameters are most relevant. For the ground-borne noise all noise levels are internal levels.

Discussion

The predicted construction noise emission levels for Roma Street Station works exceed the noise goals for only a small number of receivers during the daytime and night-time period. The highest predicted noise goal exceedances during the three scenarios occur at the Roma Street Station and the Holiday Inn. Consequently, a high performance acoustic enclosure would be required to achieve compliance with the external noise goal at these receiver locations.

With the exception of the Holiday Inn, predicted construction noise levels in **Table 52** to **Table 54** indicate that with provision for 6 m acoustic hoarding around each site (where practicable), night-time construction noise levels would be within 1 dBA of the sleep disturbance noise goal and therefore unlikely to interfere with peoples sleep. Further to this, it is likely that facade noise reductions for residential buildings located within the CBD are substantially higher than the 10 dBA (refer to **Section 8.1**) assumed for this assessment.

To assist with the interpretation of impacts associated with the construction of CRR, it is important that assessment goals are consistent across the project. However, in the case of CRR construction works required in the City precinct (ie Roma Street Station and Albert Street Station), it may prove onerous to apply absolute noise goals in acoustic environments characterised by relatively constant high ambient noise levels. For example, ambient night-time noise levels measured over a week at monitoring location 6 (ie Parkland Crescent) ranged between 75 to 80 dBA L_{Amax} and 59 to 63 dBA L_{Aeq}. Comparison of predicted night-time construction noise levels in **Table 54** with a medium performance acoustic enclosure (eg residential receiver I-Holiday Inn $L_{Amax,adj}$ – 64 dBA) indicates that worst case CRR construction noise levels would be below the range of existing night-time ambient (L_{Amax}) noise levels.

Further, the existing City landscape is scattered with high-rise building construction worksites that operate on a daily basis in accordance with Section 440R of the Act (ie with no noise limits) presumably over extended periods of time (eg greater than 12 months). It is likely that noise sensitive receivers in the vicinity of Roma Street Station worksites would associate initial CRR construction work involving site establishment, demolition and piling, with typical high-rise building construction works, particularly at the major southern worksite adjacent the Station precinct. Where the CRR construction differs from typical inner city high-rise construction work is the subsequent long-term underground excavation of Station caverns by roadheaders. The long-term phases would primarily occur below surface and/or within an acoustic enclosure to minimise any noise impacts. The excavation of the station cavern is assessed in the roadheader tunnelling works **Section 9.2.2**.

Predicted gound-borne noise and vibration levels in **Table 55** from rockbreaking indicate compliance with the relevant goals.

Assuming airblast overpressure can be sufficiently mitigated at the site (eg blast mat, enclosure etc) drill and blast excavation at Roma Street Station would be highly constrained by low MICs estimated to be 0.5 kg (refer to **Table 55**), controlled by the heritage listed station building shown in **Figure 13** .

Should drill and blast be required for this site, the following management measures would be required:

- Use of latest available blasting technology (eg PCF).
- Pre-blasting condition survey of adjacent buildings.
- Appropriate attention to blast design and commence blasting with a low MIC to develop a site law (ie blast design model) based on measurement data from the site.
- Monitoring of the blast emissions.

Albert Street Station

Nearest Sensitive Receivers

The nearest noise and/or vibration sensitive receivers to the Albert Street Station site are identified in **Table 56** with the receiver areas illustrated in **Figure 14**.

Figure 14 Albert Street Station Construction Site and Receiver Areas

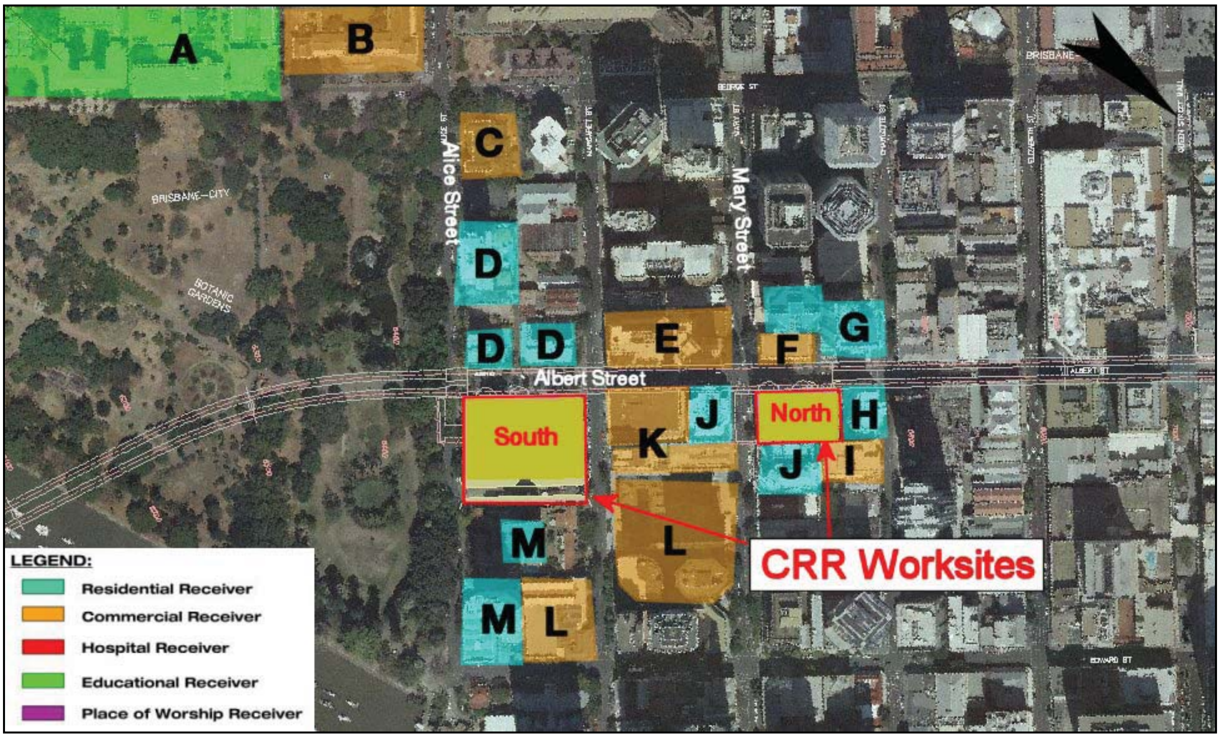


Table 56 Nearest Sensitive Receivers – Albert Street Station

Work Site/Excavation	Receiver Area	Location Relative to Works (m)
Albert Street Station	A - Queensland University of Technology	270
	B – Parliament House	260
	C – Alice Street Commercial	170
	D – Alice Street Residential	25
	E – Albert Street Commercial	25
	F – Albert Street Commercial	20
	G – Albert Street Residential	25
	H – Albert Street Residential	5
	I – Charlotte Street Commercial	5
	J – Mary Street Residential	20
	K – Albert Street Commercial	20
	L – Margaret Street Commercial	45
	M – Alice Street Residential	25

Site Specific Construction Noise Goals

With reference to the CRR project noise goals and the ambient noise survey results summarised in **Section 2.2.7** and **Section 4.1.4** respectively, the site specific construction noise goals are presented in **Table 57**.

Table 57 Albert Street Station Construction Noise Goals

Receiver Location/Type	Monday to Saturday 6:30 am to 6:30 pm		Monday to Saturday 6:30 pm to 6:30 am, Sundays and Public Holidays	
	Steady State (dBA $L_{Aeq,adj}$)	Non-Steady State (dBA $L_{A10,adj}$)	Continuous (dBA $L_{Aeq,adj(1hour)}$) [1]	Intermittent (dBA $L_{Amax,adj}$) [1]
A - Queensland University of Technology	52[2]	62[2]	-	-
B – Parliament House	62	72	-	-
C – Alice Street Commercial	62	72	-	-
D – Alice Street Residential	52	62	47	57
E – Albert Street Commercial	62	72	-	-
F – Albert Street Commercial	62	72	-	-
G – Albert Street Residential	52	62	47	57
H – Albert Street Residential	52	62	47	57
I – Charlotte Street Commercial	62	72	-	-
J – Mary Street Residential	52	62	47	57
K – Albert Street Commercial	62	72	-	-

Receiver Location/Type	Monday to Saturday 6:30 am to 6:30 pm		Monday to Saturday 6:30 pm to 6:30 am, Sundays and Public Holidays	
	Steady State (dBA $L_{Aeq,adj}$)	Non-Steady State (dBA $L_{A10,adj}$)	Continuous (dBA $L_{Aeq,adj(1hour)}$) [1]	Intermittent (dBA $L_{Amax,adj}$) [1]
L – Margaret Street Commercial	62	72	-	-
M – Alice Street Residential	52	62	47	57

Note 1 – Noise goal has been adjusted to represent external free-field levels.
Note 2 – Noise goal relevant at all times.

Assessment at the Nearest Noise and/or Vibration Sensitive Receivers

Scenarios were developed for Albert Street Station construction works being representative of activities having potentially the greatest (ie worst case) noise impact on the surrounding receivers. Worst case scenarios have been developed based on all plant items, as proposed by the Project design team (refer to **Appendix F** for plant deployment details) including haul trucks where applicable, operating simultaneously. These scenarios are:

- Scenario 1 – Demolition of existing buildings:
  - North shaft duration ~ 10 weeks
  - South shaft duration ~ 20 weeks
  - Dominant noise sources include rockbreakers, excavators and spoil trucks
  - Mostly daytime construction works noting that the night-time period in the CBD currently experience higher noise levels than suburban areas and as such it would seem “reasonable” for construction (eg spoil removal) to extend into the night-time period
- Scenario 2 - Piling around shaft perimeter:
  - North shaft duration ~ 10 weeks
  - South shaft duration ~ 4 weeks
  - Dominant noise sources include piling rigs
  - Mostly daytime construction works noting that the night-time period in the CBD currently experience higher noise levels than suburban areas and as such it would seem “reasonable” for construction (eg spoil removal) to extend into the night-time period
- Scenario 3 - Shaft excavation within an acoustic enclosure:
  - North shaft duration ~ 20 weeks
  - South shaft duration ~ 10 weeks
  - Dominant noise sources include jumbo drill rigs, excavators and front end loaders
  - 24 hour per day construction with night-time works carried out inside acoustic enclosures

For all construction scenarios, typical construction noise levels with 3 m acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 58** to **Table 60**. An assessment of noise goal compliance is also provided with indicative noise level reductions based on 6 m acoustic hoarding for all scenarios and works carried out inside an acoustic enclosure for Scenario 3. Note a “dash” (-) in the tables indicates compliance, and “n/a” not applicable for the assessment period.

Noise contours have also been predicted for the three scenarios with the proposed noise mitigation, and are presented in **Appendix G**.

Predicted ground-borne noise and vibration impacts for the excavation of Albert Street Station access shafts are presented in **Table 61**. Exceedances are shown in bold red.

Assessment of ground-borne noise and vibration associated with roadheading the station cavern is presented in **Section 9.2.2**.

Table 58 Albert Street Station Predicted Worst Case Noise Levels – Scenario 1 Demolition of Existing Buildings

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				3 m Hoarding	6 m Hoarding
A - QUT	Day	LA10,adj – 62	58 – 63	1	-
B – Parliament House	Day	LA10,adj – 72	60 – 63	-	-
C – Alice Street Commercial	Day	LA10,adj – 72	52 – 55	-	-
D – Alice Street Residential	Day	LA10,adj – 62	61 – 85	23	18
	Night	LAmax,adj – 57	66 - 90	33	28
E – Albert Street Commercial	Day	LA10,adj – 72	78 – 80	8	3
F – Albert Street Commercial	Day	LA10,adj – 72	84 – 85	13	8
G – Albert Street Residential	Day	LA10,adj – 62	59 – 84	22	17
	Night	LAmax,adj – 57	64 - 89	32	27
H – Albert Street Residential	Day	LA10,adj – 62	81 – 89	27	22
	Night	LAmax,adj – 57	86 - 94	37	32
I – Charlotte Street Commercial	Day	LA10,adj – 72	82 – 85	13	8
J – Mary Street Residential	Day	LA10,adj – 62	69 – 84	22	17
	Night	LAmax,adj – 57	74 - 89	32	27
K – Albert Street Commercial	Day	LA10,adj – 72	69 – 75	3	-
L – Margaret Street Commercial	Day	LA10,adj – 72	56 – 74	2	-
M – Alice Street Residential	Day	LA10,adj – 62	56 - 84	22	17
	Night	LAmax,adj – 57	61 – 89	32	27

Note 1 – Dominant construction noise during site establishment likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameters are most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 59 Albert Street Station Predicted Worst Case Noise Levels – Scenario 2 Piling for Shafts

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				3 m Hoarding	6 m Hoarding
A - QUT	Day	LA10,adj – 62	52 – 54	-	-
B – Parliament House	Day	LA10,adj – 72	51 – 54	-	-
C – Alice Street Commercial	Day	LA10,adj – 72	47 – 49	-	-
D – Alice Street	Day	LA10,adj – 62	64 – 78	16	11

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				3 m Hoarding	6 m Hoarding
Residential	Night	LAmax,adj – 57	69 – 83	26	21
E – Albert Street Commercial	Day	LA10,adj – 72	68 – 72	-	-
F – Albert Street Commercial	Day	LA10,adj – 72	74 - 77	5	-
G – Albert Street Residential	Day	LA10,adj – 62	54 – 75	13	8
	Night	LAmax,adj – 57	59 – 80	23	18
H – Albert Street Residential	Day	LA10,adj – 62	72 – 74	12	7
	Night	LAmax,adj – 57	77 – 79	22	17
I – Charlotte Street Commercial	Day	LA10,adj – 72	76 – 79	7	2
J – Mary Street Residential	Day	LA10,adj – 62	62 – 83	21	16
	Night	LAmax,adj – 57	67 – 88	31	26
K – Albert Street Commercial	Day	LA10,adj – 72	62 – 68	-	-
L – Margaret Street Commercial	Day	LA10,adj – 72	49 – 67	-	-
M – Alice Street Residential	Day	LA10,adj – 62	48 – 76	14	9
	Night	LAmax,adj – 57	53 – 81	24	19

Note 1 – Dominant construction noise during piling likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameters are most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 60 Albert Street Station Predicted Worst Case Noise Levels – Scenario 3 Shaft Excavation

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)		
				3 m Hoarding	6 m Hoarding	Enclosure
A - QUT	Day	LA10,adj – 62	53 – 58	-	-	-
B – Parliament House	Day	LA10,adj – 72	55 – 58	-	-	-
C – Alice Street Commercial	Day	LA10,adj – 72	45 – 48	-	-	-
D – Alice Street Residential	Day	LA10,adj – 62	55 – 79	17	12	5
	Night	LAmax,adj – 57	60 – 84	27	22	15
E – Albert Street Commercial	Day	LA10,adj – 72	71 – 77	5	-	-
F – Albert Street Commercial	Day	LA10,adj – 72	79 – 81	9	4	-
G – Albert Street Residential	Day	LA10,adj – 62	60 – 79	17	12	5
	Night	LAmax,adj – 57	65 – 84	27	22	15
H – Albert Street Residential	Day	LA10,adj – 62	76 – 79	17	12	5
	Night	LAmax,adj – 57	81 – 84	27	22	15
I – Charlotte Street Commercial	Day	LA10,adj – 72	79 – 82	10	5	-

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)		
				3 m Hoarding	6 m Hoarding	Enclosure
J – Mary Street Residential	Day	$L_{A10,adj}$ – 62	62 – 82	20	15	8
	Night	$L_{Amax,adj}$ – 57	67 – 87	30	25	18
K – Albert Street Commercial	Day	$L_{A10,adj}$ – 72	62 – 77	5	-	-
L – Margaret Street Commercial	Day	$L_{A10,adj}$ – 72	51 – 68	-	-	-
M – Alice Street Residential	Day	$L_{A10,adj}$ – 62	49 – 77	15	10	3
	Night	$L_{Amax,adj}$ – 57	54 - 82	25	20	13

Note 1 – Dominant construction noise during shaft excavation likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameters are most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 61 Albert Street Station Predicted Ground-borne Noise and Vibration Levels – Shaft Excavation

Receiver Area	Period	Noise and Vibration Goals				Predicted Ground-borne Noise and Vibration Levels (Rockbreaking)		Maximum Allowed Blast MIC (kg) to meet Noise & Vibration Goal	
		Blasting Criterion[1]		Construction Sources					
		Vibration PPV (mm/s)	Airblast Overpressure (dB Linear Peak)	Vibration PPV (mm/s)	Ground-borne Noise (dBA)[2]	Ground-borne Vibration (mm/s)	Ground-borne Noise (dBA)	Vibration	Airblast Overpressure
A - Queensland University of Technology (Heritage Listed)	Day	2	130	5	LA10,adj – 55	0.01	23	62 kg	1953 kg
B – Parliament House (Heritage Listed)	Day	2	130	2	LA10,adj – 65	0.01	24	60 kg	1850 kg
C – Queensland Club (Heritage Listed)	Day	2	130	5	LA10,adj – 65	0.02	29	24 kg	477 kg
D – Alice Street Residential	Day	10	130	5	LA10,adj – 55	0.57	55	3.4 kg	1.2 kg
	Night	n/a	n/a	0.5	LAmax,adj – 50	0.57	**60**	n/a	n/a
E – Albert Street Commercial	Day	10	130	5	LA10,adj – 65	0.23	48	10 kg	6 kg
F – Albert Street Commercial	Day	10	130	5	LA10,adj – 65	0.31	50	7 kg	3.5 kg
G – Albert Street Residential	Day	10	130	5	LA10,adj – 55	0.19	46	13 kg	9 kg
	Night	n/a	n/a	0.5	LAmax,adj – 50	0.19	**51**	n/a	n/a
H – Albert Street Residential	Day	10	130	5	LA10,adj – 55	0.25	49	9 kg	5 kg
	Night	n/a	n/a	0.5	LAmax,adj – 50	0.25	**54**	n/a	n/a
I – Charlotte Street Commercial	Day	10	130	5	LA10,adj – 65	0.67	56	2.8 kg	0.9 kg
J – Mary Street Residential	Day	10	130	5	LA10,adj – 55	1.56	**63**	1.0 kg	0.2 kg
	Night	n/a	n/a	0.5	LAmax,adj – 50	1.56	**68**	n/a	n/a
K – Albert Street Commercial I	Day	10	130	5	LA10,adj – 65	0.59	55	3.2 kg	1.1 kg

Receiver Area	Period	Noise and Vibration Goals				Predicted Ground-borne Noise and Vibration Levels (Rockbreaking)		Maximum Allowed Blast MIC (kg) to meet Noise & Vibration Goal	
		Blasting Criterion[1]		Construction Sources					
		Vibration PPV (mm/s)	Airblast Overpressure (dB Linear Peak)	Vibration PPV (mm/s)	Ground-borne Noise (dBA)[2]	Ground-borne Vibration (mm/s)	Ground-borne Noise (dBA)	Vibration	Airblast Overpressure
L – Margaret Street Commercial	Day	10	130	5	LA10,adj – 65	0.23	48	10 kg	6 kg
M – Alice Street Residentia	Day	10	130	5	LA10,adj – 55	0.29	50	8 kg	4 kg
	Night	n/a	n/a	0.5	LAmax,adj – 50	0.29	55	n/a	n/a

Note 1: Blasting only during daytime.
2: Dominant construction noise during shaft excavation likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameters are most relevant. For the ground-borne noise all noise levels are internal levels.

Discussion

The predicted noise levels for site establishment works including demolition of the existing buildings at the two Albert Street Station worksites indicate exceedances of up to 27 dBA of the noise goal for daytime operations and up to 37 dBA above the night-time noise goal at the nearest residential receivers. A noise goal exceedance of this order would be unacceptable during the night-time period, and since an acoustic enclosure would not be feasible during the site establishment and piling works these works would need to be restricted to the daytime period.

Once excavation of the station shafts has progressed far enough to allow for installation of the acoustic enclosures, noise emission levels from the site would decrease significantly. A high performance acoustic enclosure constructed with double skin walls and ceiling lined with sound absorptive material, minimised openings and fitted with acoustic louvres to ventilation openings would be required to achieve compliance with the noise goals.

It should be noted that facade noise reductions for residential receiver buildings located within the CBD would likely perform significantly better than the 10 dBA (refer to **Section 8.1**) assumed for this assessment and that this may alter the mitigation solutions recommended in this report.

Similar to Roma Street Station, predicted CRR construction noise levels should be considered with respect to existing ambient noise levels in the vicinity of the two Albert Street Station worksites. Ambient night-time noise levels measured over a week at monitoring location 7 (ie 191 George Street) ranged between 70 to 78 dBA L_{Amax} and 58 to 68 dBA L_{Aeq}. Comparison of predicted night-time construction noise levels in **Table 60** with a medium performance acoustic enclosure (eg residential receiver J-Mary Street $L_{Amax,adj}$ – 75 dBA) indicates that worst case CRR construction noise levels would be within the range of existing night-time ambient noise levels.

The ground-borne noise levels presented in **Table 61** for rockbreaking during excavation of Albert Street Station shafts are predicted to exceed the night-time noise goals for several residential receivers and one residential receiver during the daytime period. The Mary Street residential receiver would be located less than 10 m from the northern shaft and approximately 13 m slant distance from the inferred rock level. Exceedance of the daytime internal noise goal of 55 dBA L_{A10} would be anticipated until rockbreaking had progressed beyond approximately 20 m slant distance from the receiver building.

As a guide, ground-borne noise levels attenuate by approximately 2 dB per floor for the first 4 floors and by approximately 1 dB per floor thereafter. On this basis, receivers located on the first 5 floors of the building may require temporary relocation until a slant distance of approximately 20 m has been reached.

Assuming airblast overpressure can be sufficiently mitigated at the worksite (eg blast mat, enclosure etc), drill and blast excavation at both Albert Street Station shafts would be highly constrained by low MICs estimated to be:

- North shaft – 1.0 kg to comply with the vibration goal at Mary Street residences.
- South shaft – 4.3 kg to comply with the vibration goal at Alice Street residences.

Should drill and blast be required for this worksite, the following management measures would be required:

- Use of latest available blasting technology (eg PCF).
- Pre-blasting condition survey of adjacent buildings.
- Appropriate attention to blast design and commence blasting with a low MIC to develop a site law (ie blast design model) based on measurement data from the site.
- Monitoring of the blast emissions.

It is anticipated that the initial stages of shaft excavation would be carried out by rockbreaker due to the closeness of sensitive receiver buildings. The point at which drill and blast excavation could be safely and efficiently carried out within the shaft would be determined as part of detailed investigations for the site. Acoustically, exposure to a short-term blast event would be preferred to long term rockbreaking where ground-borne noise impacts have been identified.

Boggo Road Station

Nearest Sensitive Receivers

The nearest noise and/or vibration sensitive receivers to the Boggo Road Station site are identified in **Table 63** with the receiver areas illustrated in **Figure 15**.

Figure 15 Boggo Road Station Construction Site and Receiver Areas

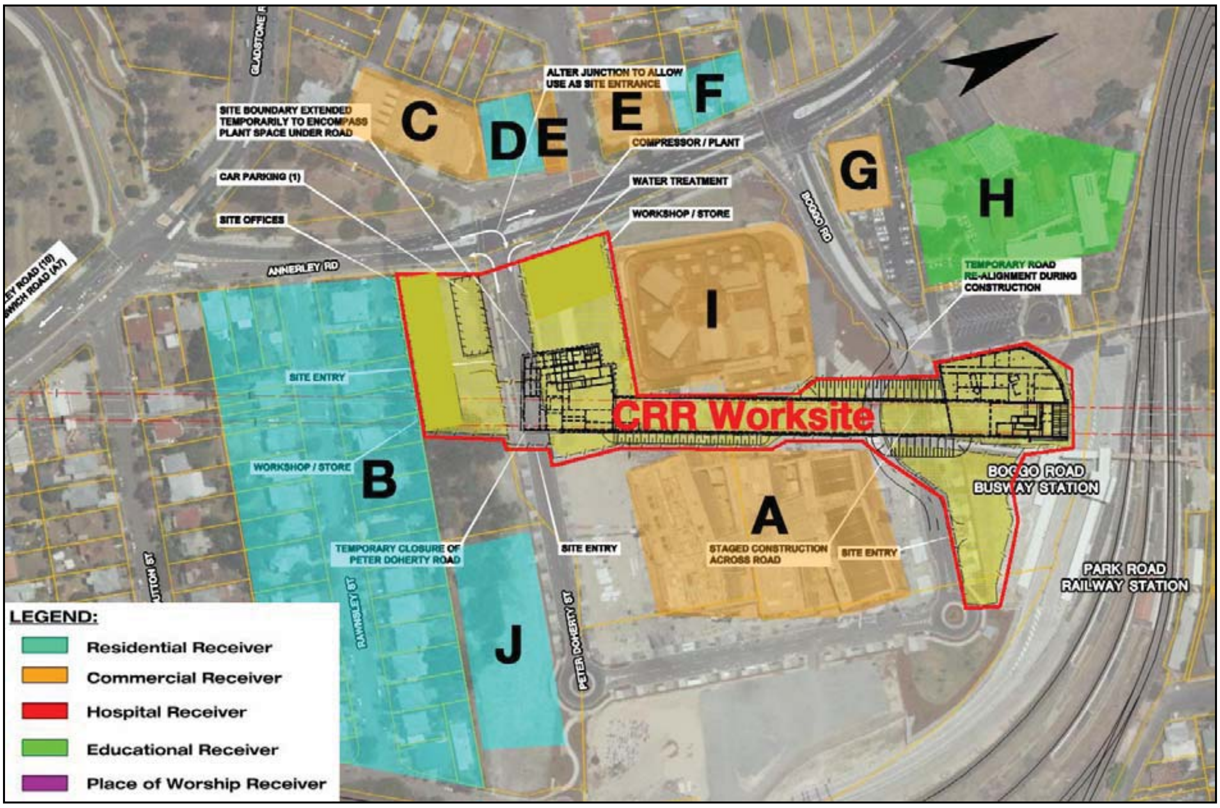


Table 62 Nearest Sensitive Receivers – Boggo Road Station

Work Site/Excavation	Receiver Area	Location Relative to Works (m)
Boggo Road Station	A – Ecoscience Building commercial	5
	B – Rawnsley Street Residential	15
	C – Maldon Street Commercial	45
	D – Maldon Street Residential	40
	E – Grantham Street Commercial	35
	F – Annerley Road Residential	75
	G – Boggo Road Police Station	90
	H – Dutton Park Primary School	40
	I – Boggo Road Gaol	15 (from buildings) 5 (from wall)
	J – Leukemia Support Village[1]	100

Note 1 – Future development for Boggo Road Urban Village.

Site Specific Construction Noise Goals

With reference to the CRR noise goals and the ambient noise survey results summarised in **Section 2.2.7** and **Section 4.1.4** respectively, the site specific construction noise goals are presented in **Table 63**.

Table 63 Boggo Road Station Construction Noise Goals

Receiver Location/Type	Monday to Saturday 6:30 am to 6:30 pm		Monday to Saturday 6:30 pm to 6:30 am, Sundays and Public Holidays	
	Steady State (dBA $L_{Aeq,adj}$)	Non-Steady State (dBA $L_{A10,adj}$)	Continuous (dBA $L_{Aeq,adj(1hour)}$) [1]	Intermittent (dBA $L_{Amax,adj}$) [1]
A – Ecoscience Building commercial	62	72	-	-
B – Rawnsley Street Residential	47	57	42	52
C – Maldon Street Commercial	62	72	-	-
D – Maldon Street Residential	52	62	42	52
E – Grantham Street Commercial	62	72	-	-
F – Annerley Road Residential	52	62	42	52
G – Boggo Road Police Station	62[2]	72[2]	-	-
H – Dutton Park Primary School	52	62	-	-
I – Boggo Road Gaol	62[3]	72[3]	-	-
J – Leukemia Support Village	47	57	42	52

Note 1 – Noise goal has been adjusted to represent external free-field levels.
Note 2 – Noise goal relevant at all times.
Note 3 – Noise goal based on museum (exhibition spaces) category in AS2107.

Assessment at the Nearest Noise and/or Vibration Sensitive Receivers

Scenarios were developed for Boggo Road Station construction works being representative of activities having potentially the greatest (ie worst case) noise impact on the surrounding receivers. Worst case scenarios have been developed based on all plant items, as proposed by the Project design team (refer to **Appendix F** for plant deployment details) including haul trucks where applicable, operating simultaneously. These scenarios are:

- Scenario 1 – Installation of piles:
  - North entrance duration ~ 12 weeks
  - South entrance duration ~ 12 weeks
  - Platform box (ie middle section) ~ 9 weeks
  - Dominant noise sources include piling rigs, excavators and front end loaders
  - Daytime construction only
- Scenario 2 - Excavation to slab level and deck construction:
  - Excavation 1 m below capping beam duration ~ 3 weeks
  - Construction of top slab duration ~ 12 weeks
  - Dominant noise sources include jumbo drill rig, excavators, concrete trucks and front end loaders
  - Daytime construction only
- Scenario 3 – North and south shaft excavation:
  - Duration ~ 25 weeks
  - Dominant noise sources include jumbo drill rigs, excavators, front end loaders and spoil trucks
  - 24 hour per day construction with night-time works carried out inside an acoustic enclosure (spoil trucks daytime only)

A scenario assessing the impact associated with construction of station infrastructure at the surface has not been included on the basis that noise levels during this phase are typically lower than levels experienced during the three stages described above, particularly if the structure is prefabricated and only assembled at the site. Further, the building of station infrastructure would be similar in nature to the construction of the acoustic enclosure.

For all construction scenarios, typical construction noise levels with 3 m acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 64** to **Table 66**. An assessment of noise goal compliance is also provided with indicative noise level reductions based on 6 m acoustic hoarding for all scenarios and works carried out inside an acoustic enclosure for Scenario 3. Note a “dash” (-) in the tables indicates compliance, and “n/a” not applicable for the assessment period.

Noise contours have also been predicted for the three scenarios with the proposed noise mitigation, and are presented in **Appendix G**.

Predicted ground-borne noise and vibration impacts for the excavation of Boggo Road Station access shafts are presented in **Table 67**. Exceedances are shown in bold red.

Assessment of ground-borne noise and vibration associated with roadheading the station cavern is presented in **Section 9.2.2**.

Table 64 Boggo Road Station Predicted Noise Levels – Scenario 1 Pile Installation

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				3 m Hoarding	6 m Hoarding
A – Ecoscience Building commercial	Day	LA10,adj – 72	76 - 80	8	3
B – Rawnsley Street Residential	Day	LA10,adj – 57	64 – 76	19	14
C – Maldon Street Commercial	Day	LA10,adj – 72	49 – 67	-	-
D – Maldon Street Residential	Day	LA10,adj – 62	63 - 66	4	-
E – Grantham Street Commercial	Day	LA10,adj – 72	58 – 63	-	-
F – Annerley Road Residential	Day	LA10,adj – 62	52 – 58	-	-
G – Boggo Road Police Station	Day	LA10,adj – 72	57 – 62	-	-
H – Dutton Park Primary School	Day	LA10,adj – 62	61 - 69	7	2
I – Boggo Road Gaol	Day	LA10,adj – 72	69 - 76	4	-
J – Leukemia Support Village	Day	LA10,adj – 57	67 – 72	15	10

Note 1 – Dominant construction noise during pile installation likely to be non-steady state. Therefore the LA10,adj assessment parameter is most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 65 Boggo Road Station Predicted Noise Levels – Scenario 2 Excavation to Slab Level

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				3 m Hoarding	6 m Hoarding
A – Ecoscience Building commercial	Day	LA10,adj – 72	70 – 81	9	4
B – Rawnsley Street Residential	Day	LA10,adj – 57	61 – 73	16	11
C – Maldon Street Commercial	Day	LA10,adj – 72	45 – 65	-	-
D – Maldon Street Residential	Day	LA10,adj – 62	57 – 60	-	-
E – Grantham Street Commercial	Day	LA10,adj – 72	55 – 58	-	-
F – Annerley Road Residential	Day	LA10,adj – 62	55 – 58	-	-
G – Boggo Road Police Station	Any	LA10,adj – 72	59 – 64	-	-
H – Dutton Park Primary School	Day	LA10,adj – 62	60 - 65	3	-
I – Boggo Road Gaol	Day	LA10,adj – 72	71 - 79	7	2

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				3 m Hoarding	6 m Hoarding
J – Leukemia Support Village	Day	LA10,adj – 57	68 – 71	14	9

Note 1 – Dominant construction noise during initial shaft excavation likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameters are most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 66 Boggo Road Station Predicted Noise Levels – Scenario 3 Shaft Excavation

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)		
				3 m Hoarding	6 m Hoarding	Enclosure
A – Ecoscience Building commercial	Day	LA10,adj – 72	62 – 72	-	-	-
B – Rawnsley Street Residential	Day	LA10,adj – 57	59 – 67	10	5	-
	Night	LAmax,adj – 52	64 – 72	20	15	8
C – Maldon Street Commercial	Day	LA10,adj – 72	40 – 60	-	-	-
D – Maldon Street Residential	Day	LA10,adj – 62	55 – 58	-	-	-
	Night	LAmax,adj – 52	60 – 63	11	6	-
E – Grantham Street Commercial	Day	LA10,adj – 72	49 – 55	-	-	-
F – Annerley Road Residential	Day	LA10,adj – 62	48 – 51	-	-	-
	Night	LAmax,adj – 52	53 – 56	4	-	-
G – Boggo Road Police Station	Any	LA10,adj – 72	42 – 50	-	-	-
H – Dutton Park Primary School	Day	LA10,adj – 62	44 – 56	-	-	-
I – Boggo Road Gaol	Day	LA10,adj – 72	59 – 73	1	-	-
J – Leukemia Support Village	Day	LA10,adj – 57	60 – 65	8	3	-
	Night	LAmax,adj – 52	65 – 70	18	13	6

Note 1: Dominant construction noise during shaft excavation likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameters are most relevant. For the airborne noise all noise levels are external free-field levels.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 67 Boggo Road Station Predicted Ground-borne Noise and Vibration Levels – Shaft Excavation (Worst Case)

Receiver Area	Period	Noise and Vibration Goals				Predicted Maximum Ground-borne Noise and Vibration Levels (Rockbreaking)		Maximum Allowed Blast MIC (kg) to meet Noise & Vibration Goal	
		Blasting Criterion[2]		Construction Sources					
		Vibration PPV (mm/s)	Airblast Overpressure (dBL Peak)	Vibration PPV (mm/s)	Ground-borne Noise (dBA)[1]	Ground-borne Vibration (mm/s)	Ground-borne Noise (dBA)	Vibration	Airblast Overpressure
A – Ecoscience Building Commercial	Day	10	130	5	LA10,adj – 65	0.48	54	4.1 kg	1.7 kg
A – Ecoscience TEM	Day	0.02	130	0.02	LA10,adj – 65	**0.11**	42	0.01 kg	25 kg
B – Rawnsley Street Residential	Day	10	130	5	LA10,adj – 55	0.06	37	25 kg	25 kg
	Night	n/a	n/a	0.5	LAmax,adj – 50	0.06	42	n/a	n/a
C – Maldon Street Commercial	Day	10	130	5	LA10,adj – 65	0.03	32	59 kg	90 kg
D – Maldon Street Residential	Day	10	130	5	LA10,adj – 55	0.03	32	54 kg	77 kg
	Night	n/a	n/a	0.5	LAmax,adj – 50	0.03	37	n/a	n/a
E – Grantham Street Commercial	Day	10	130	5	LA10,adj – 65	0.03	32	54 kg	77 kg
F – Annerley Road Residential	Day	10	130	5	LA10,adj – 55	0.02	29	85 kg	155 kg
	Night	n/a	n/a	0.5	LAmax,adj – 50	0.02	34	n/a	n/a
G – Boggo Road Police Station	Day	10	130	5	LA10,adj – 65	0.04	33	48 kg	66 kg
H – Dutton Park Primary School	Day	10	130	5	LA10,adj – 55	0.13	43	10 kg	6 kg
I – Boggo Road Gaol (Heritage Listed)	Day	2	130	2	LA10,adj – 65	1.23	50	0.2 kg	0.5 kg
J – Leukemia Support Village	Day	10	130	5	LA10,adj – 55	0.03	32	59 kg	90 kg
	Night	n/a	n/a	0.5	LAmax,adj – 50	0.03	37	n/a	n/a

Note 1: Dominant construction noise during shaft excavation likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax,adj (night-time) assessment parameters are most relevant. For the ground-borne noise all noise levels are internal levels.

2: Blasting only during daytime.

Discussion

The predicted noise levels for pile installation works at the Boggo Road Station site indicate exceedances of up to 19 dBA of the noise goal for daytime operations at the nearest residential receivers in Rawnsley Street.

The predicted noise levels in **Table 66** during the initial stages of excavation (ie prior to installation of the top slab) at the Boggo Road Station site indicate exceedances of up to 16 dBA during the day at the nearest residential receivers.

The predicted noise levels for the south entry shaft excavation once the acoustic enclosure is in place (ie Scenario 3) indicate that a high performance acoustic enclosure would be required to comply with the daytime and night-time noise goals at the nearest residential receivers in Rawnsley Street and the Leukemia Support Village. No acoustic enclosure is predicted to be required for the north entry shaft excavation.

The movement of trucks within the worksite should be designed to limit (as much as possible) the need for reversing and therefore reversing alarms. Where issues with reversing alarms occur, consideration should be given to the use of broadband “buzzer” reversing alarms and/or alarms which actively vary their volume according to the ambient noise levels during activation - rather than constant volume (tonal) “beeping” alarms.

Predicted gound-borne noise and vibration levels in **Table 67** from rockbreaking indicate compliance with the relevant goals for all sensitive receivers with the exception of the transmission electron microscope (TEM) located at the Eco-science precinct building.

The estimated blast MIC limits for Boggo Road Station, presented in **Table 67**, indicate that the allowable MIC for the worksite would be controlled by the TEM. Should drill and blasting be required for this site, the following management measures would be required:

- Scheduling blasts outside of typical TEM operating times. If this is not practicable without impacting on normal Eco-science precinct TEM operations, a special arrangement would need to be established so that blasting can be scheduled at a specific time.
- Appropriate attention to blast design and commence blasting with a low MIC to develop a site law (ie blast design model) based on measurement data from the site.
- Monitoring of the blast emissions.

Cumulative construction noise impacts from the Boggo Road Urban Village development have not been assessed as the construction program for both projects is unknown. Taking in to consideration the close proximity of both projects to noise sensitive receivers, cumulative construction noise impacts would be likely. Coincident construction works would need to be reviewed during the detailed design stage with consultation between all stakeholders to determine all practicable measures to minimise impacts.

Regarding construction noise impacts of the Project onto the Boggo Road Urban Village development, predicted noise levels have not been assessed as the masterplan for the entire site is yet to be finalised. Construction noise emission levels for future ground floor receivers at the development site can be interpreted from the noise contours presented in **Appendix G**.

If blasts could be scheduled outside of TEM operating times, the MICs would then be limited by the heritage listed Boggo Road Gaol (ie MIC of 0.2 kg). Consequently, blasting may not be feasible for the southern shaft nearest Boggo Road Gaol until the shaft has deepened sufficiently to allow for efficient blasting.

Vibration levels for bored piling adjacent the heritage listed Boggo Road Gaol are predicted to be below 2 mm/s based on data obtained from measurements carried out on the Northern Busway project adjacent to the Royal Brisbane and Womens Hospital. Notwithstanding this, it is recommended that vibration measurements be carried out during the commencement of bored piling at the site to determine the risk of exceeding the TEM vibration limit when piling in close proximity to the Eco-science precinct building.

8.2.4 Southern Ventilation Shaft Construction – Noise and Vibration Assessment

Assessment of the CRR Southern Ventilation Shaft at Fairfield Road, Fairfield, is contained in this section.

Nearest Sensitive Receivers

The nearest noise and/or vibration sensitive receivers to the Southern Ventilation Shaft worksite are identified in **Table 68** with the receiver areas illustrated in **Figure 16**.

Figure 16 Southern Ventilation Shaft Construction Worksite and Receiver Areas

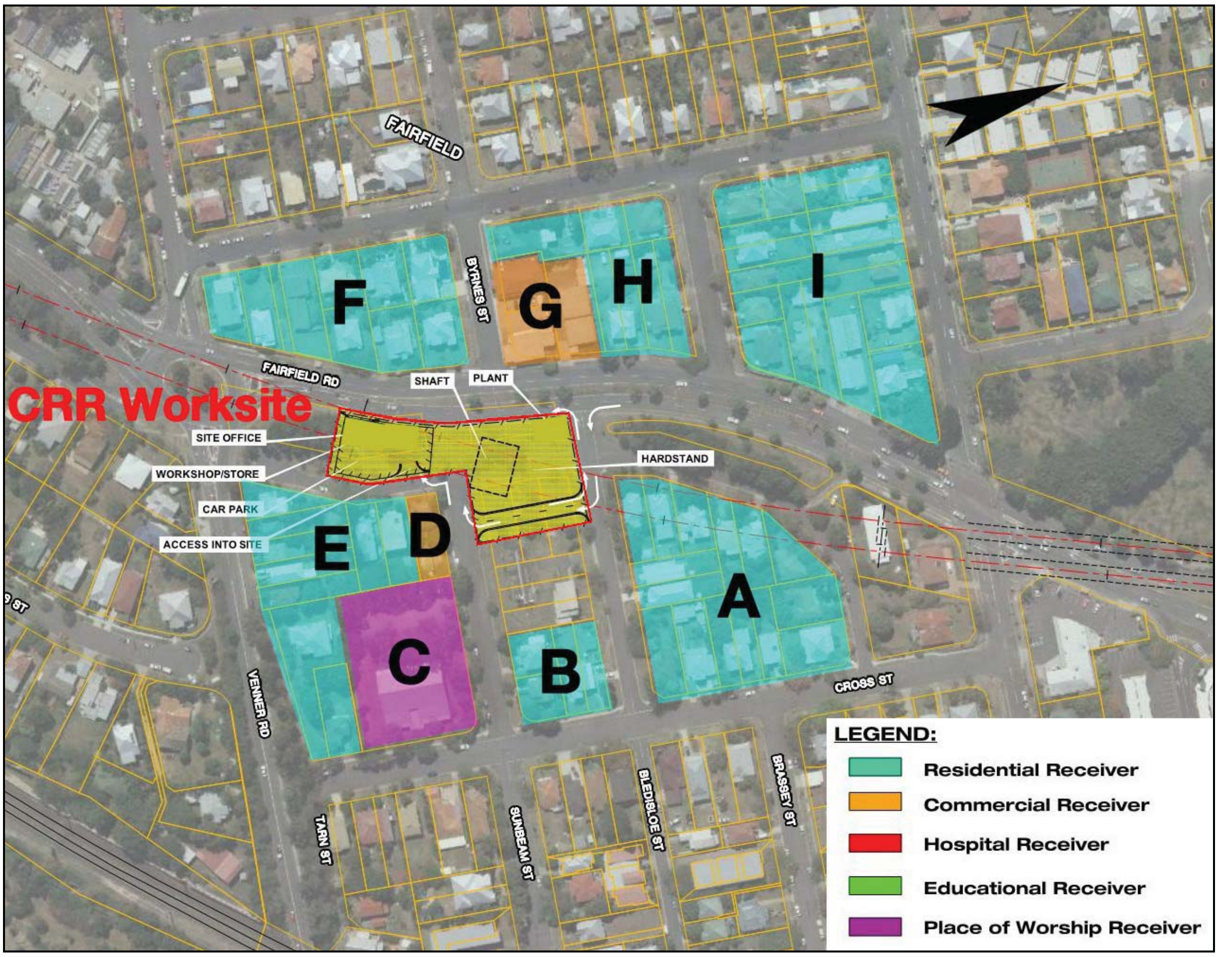


Table 68 Nearest Sensitive Receivers – Southern Ventilation Shaft

Work Site/Excavation	Receiver Area	Location Relative to Works (m)
Southern Ventilation Shaft	A – Railway Road Residential	15
	B – Sunbeam Street Residential	50
	C – Baptist Union of QLD Church	60
	D – Railway Road Commercial	15
	E – Venner Road Residential	15
	F – Fairfield Road Residential	30
	G – Byrnes Street Commercial	25
	H – Fairfield Road Residential	40
	I – Love Street Residential	90

Site Specific Construction Noise Goals

With reference to the CRR project noise goals and the ambient noise survey results summarised in **Section 2.2.7** and **Section 4.1.4** respectively, the site specific construction noise goals are presented in **Table 69**.

Table 69 Southern Ventilation Shaft Construction Noise Goals

Receiver Location/Type	Monday to Saturday 6:30 am to 6:30 pm		Monday to Saturday 6:30 pm to 6:30 am, Sundays and Public Holidays	
	Steady State (dBA $L_{Aeq,adj}$)	Non-Steady State (dBA $L_{A10,adj}$)	Continuous (dBA $L_{Aeq,adj(1hour)}$) [1]	Intermittent (dBA $L_{Amax,adj}$) [1]
A – Railway Road Residential	52	62	42	52
B – Sunbeam Street Residential	52	62	42	52
C – Baptist Union of QLD Church	47[2]	57[2]	-	-
D – Railway Road Commercial	62	72	-	-
E – Venner Road Residential	52	62	42	52
F – Fairfield Road Residential	52	62	42	52
G – Byrnes Street Commercial	62	72	-	-
H – Fairfield Road Residential	52	62	42	52
I – Love Street Residential	52	62	42	52

Note 1 – Noise goal has been adjusted to represent external free-field levels.
Note 2 – Noise goal relevant at all times.

Assessment at the Nearest Noise and/or Vibration Sensitive Receivers

Scenarios were developed for the Southern Ventilation Shaft construction works being representative of activities having potentially the greatest (ie worst case) noise impact on the surrounding receivers. Worst case scenarios have been developed based on all plant items, as proposed by the Project design team (refer to **Appendix F** for plant deployment details) including haul trucks where applicable, operating simultaneously. These scenarios are:

- Scenario 1 - Site establishment:
  - Duration ~ 6 weeks
  - Dominant noise sources include an excavator and front end loader
  - Daytime construction only
- Scenario 2 – Piling of access shaft:
  - Duration ~ 5 weeks
  - Dominant noise sources include a piling rig, excavator and front end loader
  - Daytime construction only
- Scenario 3 – Shaft excavation:
  - Duration ~ 12 weeks
  - Dominant noise sources include excavators and front end loaders
  - Daytime construction only

A scenario assessing the impact associated with construction of the ventilation building at the surface has not been included on the basis that noise levels during this phase are typically lower than levels experienced during the three stages described above.

For all construction scenarios, typical construction noise levels with 3 m acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 70** to **Table 72**. An assessment of noise goal compliance is also provided with indicative noise level reductions based on 6 m acoustic hoarding for all scenarios. Note a “dash” (-) in the tables indicates compliance with the relevant noise goal.

Noise contours have also been predicted for the three scenarios with the standard 3 m perimeter acoustic hoarding, and are presented in **Appendix G**.

Predicted permissible MIC blast charges to achieve compliance with the relevant goals for airblast overpressure and ground vibration for the excavation of the Southern Ventilation Shaft are presented in **Table 73**. As the shaft is anticipated to remain open during the excavation phase ground-borne noise impacts would likely be insignificant compared with airborne noise from the site.

Table 70 Southern Ventilation Shaft Predicted Worst Case Noise Levels – Scenario 1 Site Establishment

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				3 m Hoarding	6 m Hoarding
A – Railway Road Residential	Day	LA10,adj – 62	59 – 67	5	-
B – Sunbeam Street Residential	Day	LA10,adj – 62	62 – 67	5	-
C – Baptist Union of QLD Church	Day	LA10,adj – 57	63 – 66	9	4
D – Railway Road Commercial	Day	LA10,adj – 72	67 – 70	-	-
E – Venner Road Residential	Day	LA10,adj – 62	58 – 71	9	4
F – Fairfield Road Residential	Day	LA10,adj – 62	49 – 69	7	2
G – Byrnes Street Commercial	Day	LA10,adj – 72	64 – 70	-	-
H – Fairfield Road Residential	Day	LA10,adj – 62	54 – 67	5	-
I – Love Street Residential	Day	LA10,adj – 62	49 - 61	-	-

Note 1 – Dominant construction noise during site establishment likely to be non-steady state. Therefore the LA10,adj assessment parameter is most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 71 Southern Ventilation Shaft Predicted Worst Case Noise Levels – Scenario 2 Piling

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				3 m Hoarding	6 m Hoarding
A – Railway Road Residential	Day	LA10,adj – 62	67 – 74	12	7
B – Sunbeam Street Residential	Day	LA10,adj – 62	72 – 75	13	8
C – Baptist Union of QLD Church	Day	LA10,adj – 57	70 – 73	16	11
D – Railway Road Commercial	Day	LA10,adj – 72	75 – 78	6	1
E – Venner Road Residential	Day	LA10,adj – 62	66 – 76	14	9
F – Fairfield Road Residential	Day	LA10,adj – 62	53 – 73	11	6
G – Byrnes Street Commercial	Day	LA10,adj – 72	68 – 75	3	-
H – Fairfield Road Residential	Day	LA10,adj – 62	60 – 74	12	7
I – Love Street Residential	Day	LA10,adj – 62	55 - 68	6	1

Note 1 – Dominant construction noise during piling likely to be non-steady state. Therefore the LA10,adj assessment parameter is most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 72 Southern Ventilation Shaft Predicted Worst Case Noise Levels – Scenario 3 Shaft Excavation

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
				3 m Hoarding	6 m Hoarding
A – Railway Road Residential	Day	LA10,adj – 62	64 – 73	11	6
B – Sunbeam Street Residential	Day	LA10,adj – 62	68 – 73	11	6
C – Baptist Union of QLD Church	Day	LA10,adj – 57	67 – 70	13	8
D – Railway Road Commercial	Day	LA10,adj – 72	70 – 73	1	-
E – Venner Road Residential	Day	LA10,adj – 62	61 – 73	11	6
F – Fairfield Road Residential	Day	LA10,adj – 62	52 – 71	9	4
G – Byrnes Street Commercial	Day	LA10,adj – 72	65 – 74	2	-
H – Fairfield Road Residential	Day	LA10,adj – 62	56 – 71	9	4
I – Love Street Residential	Day	LA10,adj – 62	54 - 65	3	-

Note 1 – Dominant construction noise during shaft excavation likely to be non-steady state. Therefore the LA10,adj assessment parameter is most relevant.

Note 2 – Predicted noise levels include 3 m acoustic hoarding between noise sources and receivers.

Table 73 Southern Ventilation Shaft Predicted Blasting Vibration & Noise Levels – Shaft Excavation

Receiver Area	Slant Distance to Inferred Rock Level (m)	Vibration Goal PPV (mm/s) Blasting	Noise Goal (dB Linear Peak) Blasting	Maximum Allowed Blast MIC to meet the Vibration Goal	Maximum Allowed Blast MIC to meet the Airblast Overpressure Goal
A – Railway Road Residential	50	10	130	14.9 kg	11.3kg
B – Sunbeam Street Residential	65	10	130	25 kg	25 kg
C – Baptist Union of QLD Church	80	10	130	38 kg	46 kg
D – Railway Road Commercial	22	10	130	3 kg	0.9 kg
E – Venner Road Residential	34	10	130	7 kg	4 kg
F – Fairfield Road Residential	43	10	130	11 kg	7 kg
G – Byrnes Street Commercial	39	10	130	9 kg	5 kg
H – Fairfield Road Residential	65	10	130	25 kg	25 kg
I – Love Street Residential	115	10	130	78 kg	136 kg

Note 1: Inferred rock level at approximately 5 m depth (ie depth at where blasting and/or rockbreaking will be required).

Discussion

The predicted noise levels for the three modelled scenarios at the Southern Ventilation worksite indicate significant exceedances of the relevant daytime construction noise goals due to the close proximity of sensitive receivers.

Increasing the proposed 3 m perimeter acoustic hoarding to 6 m acoustic hoarding will reduce the construction noise emission levels, however several noise goal exceedances would still be expected. Since mitigating piling rig noise within an enclosure is not practicable, it is recommended that an additional piling rig be utilised at the site to expedite the works thereby reducing the exposure period. An additional (acoustically identical) piling rig operating at the site would increase the overall noise level by a marginal 3 dBA but would halve the duration.

The predicted worst case shaft excavation noise levels in **Table 72** have been modelled on the basis of the excavation plant operating close to existing ground level. During this phase of the work, construction noise emission levels would progressively decrease over time as the excavation plant progressed deeper into the shaft.

Further reductions in noise emission level may be achieved through the following mitigation measures:

- Quietest available mobile plant operating at the site.
- Temporary tunnel ventilation noise sources to be located either down in the shaft with appropriate ducting to the surface or within a dedicated enclosure at the surface.
- Drill and blast in place of the rockbreaking to expedite the works and minimise exposure to receivers of significantly high construction noise.

- Careful placement of fixed plant (eg compressors, gensets etc) at the site to maximise shielding or separation from sensitive receivers.

An acoustic enclosure over the shaft has not been considered as part of the construction methodology as the shaft excavation works would be completed within a relatively short timeframe (ie three months) and restricted to the daytime period.

For the proposed CRR construction commencement year (ie 2016), road traffic noise levels from Fairfield Road were predicted at residences adjacent to Fairfield Road, Railway Road and Sunbeam Street, nearest to the Southern Ventilation Shaft worksite, for comparison with the predicted CRR construction noise levels. The road traffic noise predictions were carried out using the UK Department of Transport "Calculation of Road Traffic Noise" (CORTN 1998) methodology. CORTN modelling incorporates inputs such as traffic volume and mix, road surface types, vehicle speed, road gradient, ground absorption and shielding from topography and physical noise barriers. Traffic volumes for year 2016 were provided by the project traffic engineers.

Fairfield Road traffic noise levels for 2016 are predicted to be in the order of 64 dBA to 74 dBA L_{A10} during the am and pm peak periods (ie 7 am to 9 am and 4 pm to 6 pm respectively) and 62 dBA to 72 dBA L_{A10} during the daytime off peak period (ie 9 am to 4 pm). Comparison with predicted worst case daytime construction noise levels indicates that at times road traffic noise from Fairfield Road would be higher and potentially dominate the acoustic environment in the vicinity of the Southern Ventilation Shaft worksite for the receivers closest to Fairfield Road.

The estimated blast MIC limits for the Southern Ventilation Shaft indicate that a maximum MIC of 0.9 kg would be permitted to achieve compliance with the airblast overpressure goal of 130 dB Linear Peak at the commercial receiver at location D (ie Railway Road). Assuming the airblast overpressure can be mitigated (eg blast mat, enclosing etc), a maximum MIC of 3 kg would be permitted to achieve compliance with the vibration goal of 10 mm/s PPV. With appropriately mitigated airblast overpressure, blasting would be a suitable excavation technique for this site.

8.3 Surface Rail Track Worksite Noise and Vibration Assessment

Assessment of CRR surface rail track construction works required north of the Northern Portal and south of the Southern Portal is contained in this section. The following assessment has been broken up into the following categories:

- Rail stabling yard.
- Station construction/upgrade.
- Surface structures.
- Surface track.

Due to the geographic location of the Eastern Bypass Viaduct and the Single Track Flyover, assessment of construction noise from these worksites has been included in the Mayne Yard and Clapham Yard assessments respectively.

8.3.1 Rail Stabling Yards

Mayne Yard

Nearest Sensitive Receivers

The nearest sensitive receivers to the Mayne Yard and viaduct sites are identified in **Table 74** with the receiver areas illustrated in **Figure 17**.

Figure 17 Mayne Yard Construction Site and Receiver Areas

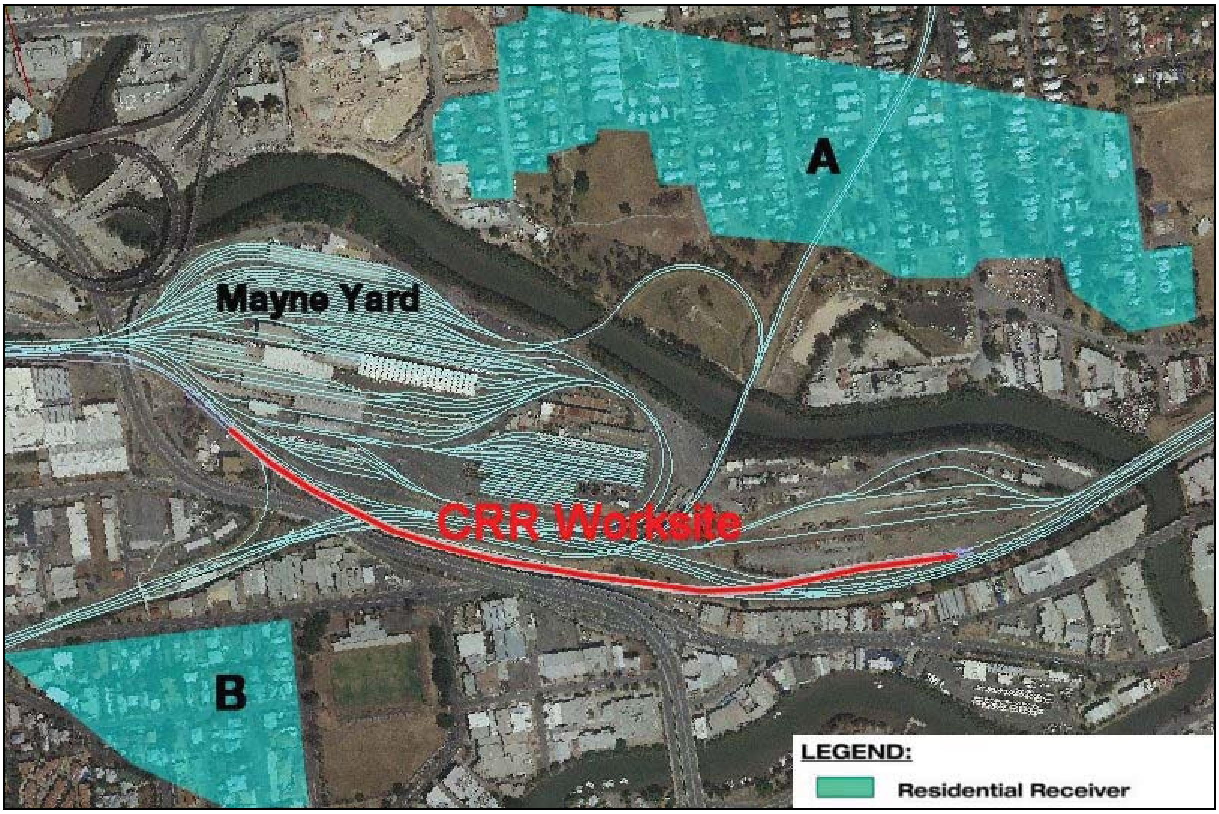


Table 74 Nearest Sensitive Receivers – Mayne Yard

Work Site	Receiver Area	Location Relative to Works (m)
Mayne Yard	A – Residential West	300
	B – Residential East	180

Assessment at the Nearest Sensitive Receivers

Scenarios were developed for CRR construction works at Mayne Yard being representative of activities having potentially the greatest noise impact on the surrounding receivers. These scenarios are:

- Scenario 1 – Piling for viaduct piers.
- Scenario 2 – Viaduct construction.

For all construction scenarios, typical construction noise levels without acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 75** and **Table 76**. An assessment of noise goal compliance is also provided in **Table 75** and **Table 76** with indicative noise level reductions based on 3 m acoustic hoarding for all scenarios. Note a “dash” (-) in the tables indicates compliance with the relevant noise goal.

Noise contours have also been predicted for the two scenarios without any form of noise mitigation, and are presented in **Appendix G**.

Table 75 Mayne Yard Predicted Noise Levels – Scenario 1 Viaduct Piles

Receiver Area	Noise Goal (dBA)[1]	Predicted Noise Level (dBA)[2]	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
			None	3 m Hoarding
A – Residential	LAeq(24hour) – 62	48 - 50	-	-
	LAmax,adj – 84	56 – 59	-	-
B - Residential	LAeq(24hour) – 62	48 – 52	-	-
	LAmax,adj – 84	56 – 60	-	-

Note 1 – Noise goal based on Queensland Rail's Code of Practice planning levels adjusted to a free-field level.
Note 2 – Predicted noise levels without acoustic hoarding.

Table 76 Mayne Yard Predicted Noise Levels – Scenario 2 Viaduct Construction

Receiver Area	Noise Goal (dBA)[1]	Predicted Noise Level (dBA)[2]	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
			None	3 m Hoarding
A – Residential	LAeq(24hour) – 62	44 – 46	-	-
	LAmax,adj – 84	52 – 54	-	-
B - Residential	LAeq(24hour) – 62	44 – 46	-	-
	LAmax,adj – 84	52 – 54	-	-

Note 1 – Noise goal based on Queensland Rail's Code of Practice planning levels adjusted to a free-field level.
Note 2 – Predicted noise levels without acoustic hoarding.

Discussion

The predicted noise levels for the two modelled scenarios associated with the Mayne Yard viaduct construction works indicate compliance with the Queensland Rail planning levels without specific noise mitigation measures in place. Given that Mayne Yard is mostly offset from the operational "through tracks" (ie track possessions not required for construction works), if night-time piling construction works are required at Mayne Yard, reasonable and practicable mitigation measures should be considered to comply with the 57 dBA LAmax sleep disturbance noise goal applicable to other elements of the project. Examples of mitigation measures include:

- Selection of quietest available plant and techniques.
- Careful orientation of piling plant to take advantage of intervening structures.
- Noise monitoring at the commencement of construction works to refine noise mitigation measures.

At a distance in excess of 180 m to the nearest residential receiver, vibration impacts from CRR construction works would not be anticipated.

Clapham Yard

Nearest Sensitive Receivers

The nearest sensitive receivers to the Clapham Yard site are identified in **Table 77** with the receiver areas illustrated in **Figure 18**.

Figure 18 Clapham Yard Construction Worksite and Receiver Areas

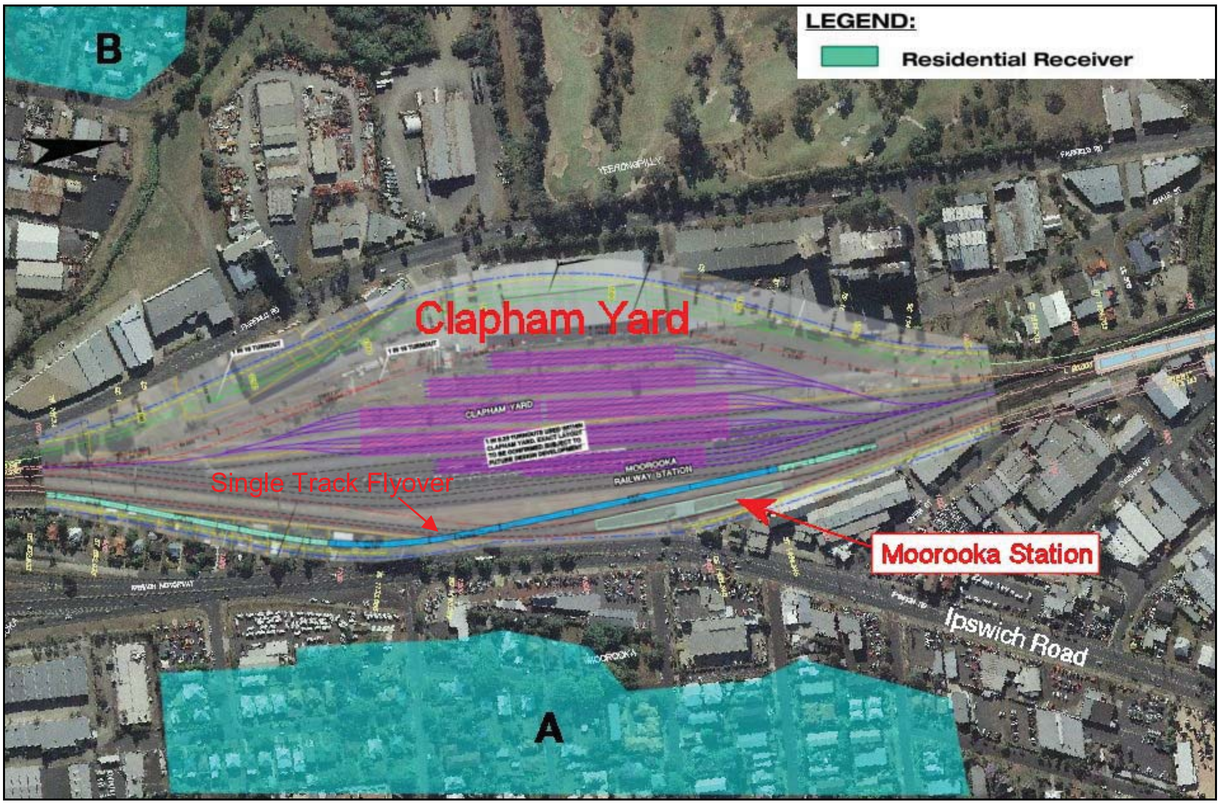


Table 77 Nearest Sensitive Receivers – Clapham Yard

Work Site	Receiver Area	Location Relative to Works (m)
Clapham Yard	A – Residential East	100
	B – Residential West	250

Assessment at the Nearest Sensitive Receivers

Scenarios were developed for CRR construction works at Clapham Yard being representative of activities having potentially the greatest noise impact on the surrounding receivers. These scenarios are:

- Scenario 1 – Earthworks.
- Scenario 2 – Track construction.
- Scenario 3 – Single track flyover construction.

For all construction scenarios, typical construction noise levels without acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 78** to **Table 81**. An assessment of noise goal compliance is also provided in **Table 78** to **Table 81** with indicative noise level reductions based on 3 m acoustic hoarding for all scenarios. Note a "dash" (-) in the tables indicates compliance with the relevant noise goal.

Noise contours have also been predicted for the three scenarios without any form of noise mitigation, and are presented in **Appendix G**.

Table 78 Clapham Yard Predicted Worst Case Noise Levels – Scenario 1 Earthworks

Receiver Area	Noise Goal (dBA) [1]	Predicted Noise Level (dBA) [2]	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
			None	3 m Hoarding
A – Residential	LAeq(24hour) – 62	48 – 56	-	-
	LAmax,adj – 84	56 – 64	-	-
B - Residential	LAeq(24hour) – 62	50 - 53	-	-
	LAmax,adj – 84	58 – 61	-	-

Note 1 – Noise goal based on Queensland Rail's Code of Practice planning levels adjusted to a free-field level.
Note 2 – Predicted noise levels without acoustic hoarding.

Table 79 Clapham Yard Predicted Worst Case Noise Levels – Scenario 2 Track Construction

Receiver Area	Noise Goal (dBA) [1]	Predicted Noise Level (dBA) [2]	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
			None	3 m Hoarding
A – Residential	LAeq(24hour) – 62	55 – 62	-	-
	LAmax,adj – 84	63 – 71	-	-
B - Residential	LAeq(24hour) – 62	45 – 51	-	-
	LAmax,adj – 84	53 – 59	-	-

Note 1 – Noise goal based on Queensland Rail's Code of Practice planning levels adjusted to a free-field level.
Note 2 – Predicted noise levels without acoustic hoarding.

Table 80 Clapham Yard Predicted Worst Case Noise Levels – Scenario 3 Flyover Construction

Receiver Area	Noise Goal (dBA) [1]	Predicted Noise Level (dBA) [2]	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
			None	3 m Hoarding
A – Residential	LAeq(24hour) – 62	58 – 70	8	-
	LAmax,adj – 84	66 – 78	-	-
B - Residential	LAeq(24hour) – 62	48 – 51	-	-
	LAmax,adj – 84	56 – 59	-	-

Note 1 – Noise goal based on Queensland Rail's Code of Practice planning levels adjusted to a free-field level.
Note 2 – Predicted noise levels without acoustic hoarding.

Discussion

The predicted noise levels for the two modelled scenarios associated with the Clapham Yard construction works (ie Scenario 1 and 2) indicate compliance with the Queensland Rail noise goals without specific noise mitigation measures in place. Construction of the single track flyover (ie Scenario 3) is predicted to exceed the 62 dBA LAeq(24hour) planning level with no noise mitigation measures in place. 3 m high acoustic hoarding adjacent to the west of the piling work area is predicted to be an effective method of achieving compliance with the noise goal.

It is understood that the majority of the work at Clapham Yard could be staged in a way to avoid construction work outside of normal daytime hours. Given that Clapham Yard is mostly offset from the operational "through tracks", if night-time construction works are required at Clapham Yard, all reasonable and practicable mitigation measures would be required to comply with the 57 dBA LAmax sleep disturbance criterion applicable to other elements of the project. Examples of mitigation measures include:

- Selection of quietest available plant and techniques.

- Careful orientation of piling plant to take advantage of intervening structures.
- Noise monitoring at the commencement of construction works to refine noise mitigation measures.

Construction noise from works occurring on the rail bridge over Moolabin Creek has not been specifically assessed for Clapham Yard as they are anticipated to be less than the impacts associated with Clapham Yard and Yeerongpilly Station construction. The assessment of construction noise for the flyover adjacent Clapham Yard (presented in **Table 78**) would be representative of noise emissions from the Moolabin Creek rail bridge works.

At a distance in excess of 100 m to the nearest residential receiver, vibration impacts from CRR construction works including vibratory rollers and rockbreakers (if required) would not be anticipated.

8.3.2 Station Construction/Upgrades

Exhibition Station Replacement (including O'Connell Terrace Road Bridge)

Nearest Sensitive Receivers

The nearest sensitive receivers to the Exhibition Station site are identified in **Table 81** with the receiver areas illustrated in **Figure 19**.

Figure 19 Exhibition Station Construction Worksite and Receiver Areas

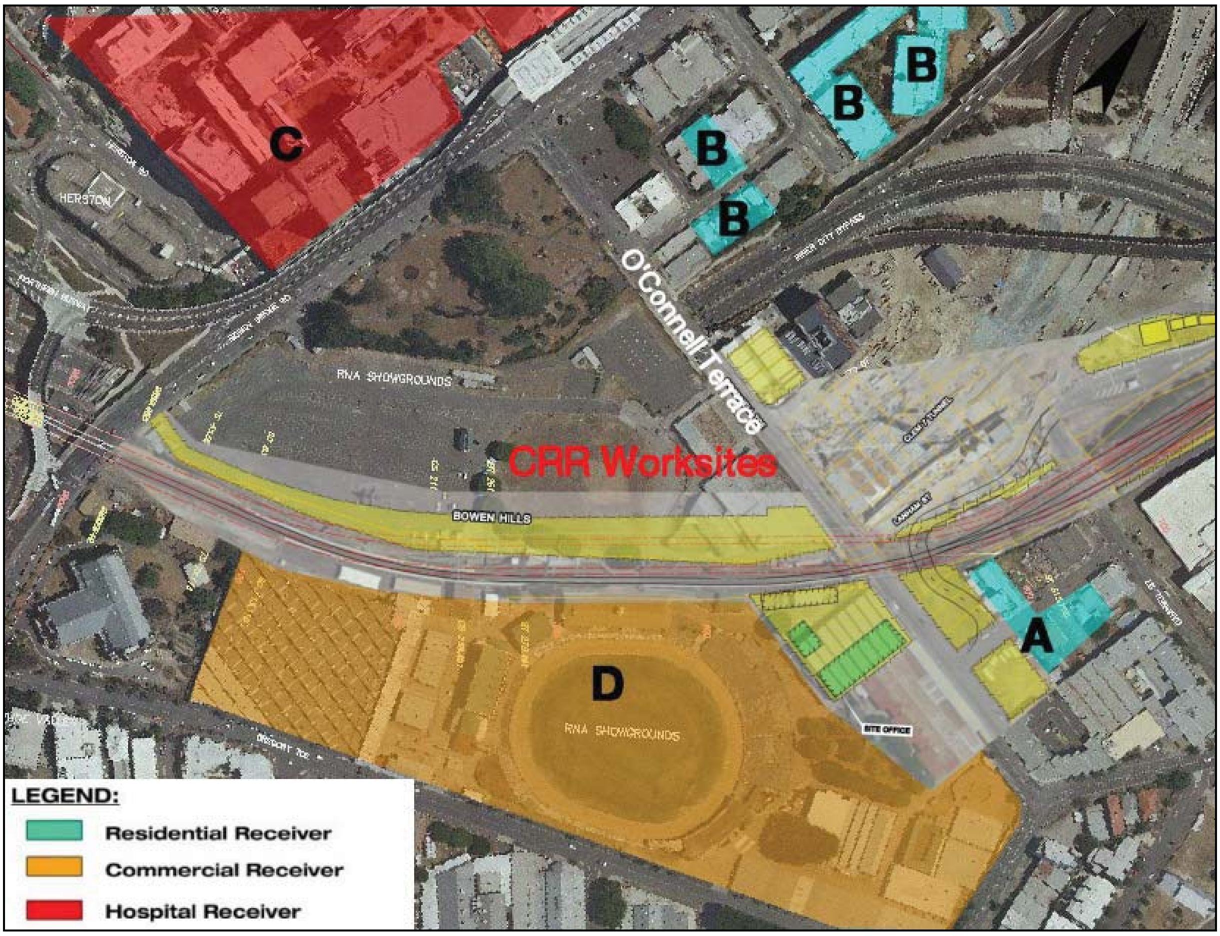


Table 81 Nearest Sensitive Receivers – Exhibition Station

Work Site	Receiver Area	Location Relative to Major Worksite (m)
Exhibition Station	A – Residential North-east	60
	B – Residential North-west	220
	C – Royal Brisbane & Women's Hospital (RBWH)	300
	D – RNA Showgrounds	10

Assessment at the Nearest Sensitive Receivers

Scenarios were developed for CRR construction works at the Exhibition Station site being representative of activities having potentially the greatest noise impact on the surrounding receivers. These scenarios are:

- Scenario 1 – Piling for O'Connell Terrace bridge piers.
- Scenario 2 – Station construction.

For all construction scenarios, typical construction noise levels without acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 82** and **Table 83**. An assessment of noise goal compliance is also provided in **Table 82** and **Table 83** with indicative noise level reductions based on 3 m acoustic hoarding for all scenarios. Note a "dash" (-) in the tables indicates compliance with the relevant noise goal.

Noise contours have also been predicted for the two scenarios without any form of noise mitigation, and are presented in **Appendix G**.

Table 82 Exhibition Station Predicted Worst Case Noise Levels – Scenario 1 O'Connell Terrace Piling

Receiver Area	Noise Goal (dBA) [1]	Predicted Noise Level (dBA) [2]	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
			None	3 m Hoarding
A – Residential	LAeq(24hour) – 62	49 – 72	10	2
	LAmax,adj – 84	57 – 80	-	-
B - Residential	LAeq(24hour) – 62	35 – 54	-	-
	LAmax,adj – 84	43 – 62	-	-
C - RBWH	LAeq(24hour) – 62	51 – 54	-	-
	LAmax,adj – 84	57 – 60	-	-

Note 1 – Noise goal based on Queensland Rail's Code of Practice planning levels adjusted to a free-field level.
Note 2 – Predicted noise levels without acoustic hoarding.

Table 83 Exhibition Station Predicted Worst Case Noise Levels – Scenario 2 Station Construction

Receiver Area	Noise Goal (dBA) [1]	Predicted Noise Level (dBA) [2]	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
			None	3 m Hoarding
A – Residential	LAeq(24hour) – 62	39 – 57	-	-
	LAmax,adj – 84	47 – 65	-	-
B - Residential	LAeq(24hour) – 62	38 – 52	-	-
	LAmax,adj – 84	46 – 60	-	-
C - RBWH	LAeq(24hour) – 62	51 – 53	-	-
	LAmax,adj – 84	59 – 61	-	-

Note 1 – Noise goal based on Queensland Rail's Code of Practice planning levels adjusted to a free-field level.

Note 2 – Predicted noise levels without acoustic hoarding.

Maximum vibration levels at the nearest buildings within the RNA Showgrounds of 1.3 mm/s from station construction works has been predicted based on offset distances of greater than 10 m.

Discussion

The predicted noise levels for the two modelled scenarios associated with the Exhibition Station construction works indicate compliance with the Queensland Rail planning levels with the exception of the nearest residences to the east of the site in Tufton Street. Acoustic hoarding in the order of 4 m in height around the piling worksite would likely result in compliance with the adopted noise goal based on the marginal exceedance in **Table 82**.

Night-time construction works at Exhibition Station should be avoided insofar as possible.

Cumulative construction noise impacts from the RNA showgrounds redevelopment have not been assessed as the construction program for both projects is unknown. Taking into consideration the extent of both projects in this area, CRR construction works would be relatively short in duration compared with the RNA redevelopment. Mitigation of cumulative construction noise would need to be addressed during the detailed design stage through consultation with all stakeholders if the projects coincided.

Regarding construction noise impacts of the Project onto future urban development in and around the RNA Showground precinct, predicted construction noise levels have not been assessed as building layouts are yet to be finalised. Construction noise emission levels for future ground floor receivers at these developments can be interpreted from the noise contours presented in **Appendix G**.

Predicted vibration levels at the nearest heritage listed building within the RNA Showgrounds are below the cosmetic damage goal of 2 mm/s. Where vibration intensive construction works are required to occur within 10 m of RNA Showground heritage structures, pre-construction condition surveys and monitoring during construction would be recommended.

Yeerongpilly Station Replacement

Nearest Sensitive Receivers

The nearest sensitive receivers to the Yeerongpilly Station worksite are identified in **Table 84** with the receiver areas illustrated in **Figure 20**.

Figure 20 Yeerongpilly Station Construction Site and Receiver Areas

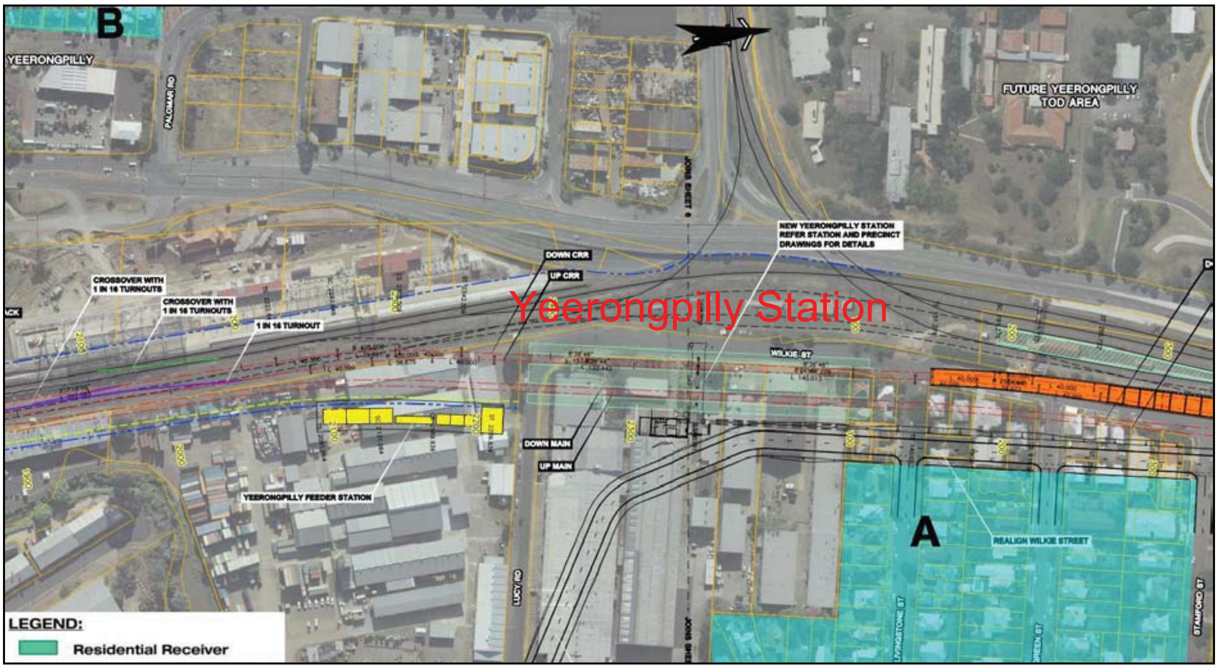


Table 84 Nearest Sensitive Receivers – Yeerongpilly Station

Work Site	Receiver Area	Location Relative to Works (m)
Yeerongpilly Station	A – Residential North-east	35
	B – Residential South-west	300

Assessment at the Nearest Sensitive Receivers

A noise model scenario was developed for CRR construction works at Yeerongpilly Station being representative of activities having potentially the greatest noise impact on the surrounding receivers. The scenario was:

- Scenario 1 – Station construction.

The typical construction noise levels without acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 85**. An assessment of noise goal compliance is also provided in **Table 85** with indicative noise level reductions based on 3 m acoustic hoarding. Note a “dash” (-) in the tables indicates compliance with the relevant noise goal.

Noise contours have also been predicted for the modelled scenario without any form of noise mitigation, and is presented in **Appendix G**.

Table 85 Yeerongpilly Station Predicted Worst Case Construction Noise Levels

Receiver Area	Noise Goal (dBA)[1]	Predicted Noise Level (dBA)[2]	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
			None	3 m Hoarding
A – Residential	LAeq(24hour) – 62	49 – 65	3	-
	LAmax,adj – 84	57 – 73	-	-
B - Residential	LAeq(24hour) – 62	31 – 40	-	-
	LAmax,adj – 84	39 – 48	-	-

Note 1 – Noise goal based on Queensland Rail's Code of Practice planning levels adjusted to a free-field level.
Note 2 – Predicted noise levels without acoustic hoarding.

Discussion

The predicted noise levels for the two modelled scenarios associated with the Yeerongpilly Station construction works indicate compliance with the QR planning levels with the exception of the nearest residences to the east of the site in Livingstone Street. A 3 m high acoustic hoarding along the eastern boundary of the worksite would likely result in compliance with the adopted noise goal based on the marginal exceedance of 3 dBA in **Table 85**.

Given that Yeerongpilly Station construction site would be remote from the realigned operational track, if night-time construction works are required at Yeerongpilly Station, all reasonable and practicable noise mitigation measures would be required to minimise exceedance of the 57 dBA LAmax sleep disturbance goal. Retaining part of or the entire acoustic shed at Yeerongpilly Station for the station construction phase would be highly beneficial to the acoustic amenity of the area.

At a distance in excess of 35 m to the nearest residential receiver, vibration impacts from CRR construction works would not be anticipated at this site.

Moorooka Station Upgrade

Nearest Sensitive Receivers

The nearest sensitive receivers to the Moorooka Station worksite are identified in **Table 86** with the receiver areas illustrated in **Figure 21**.

Figure 21 Moorooka Station Construction Worksite and Receiver Areas

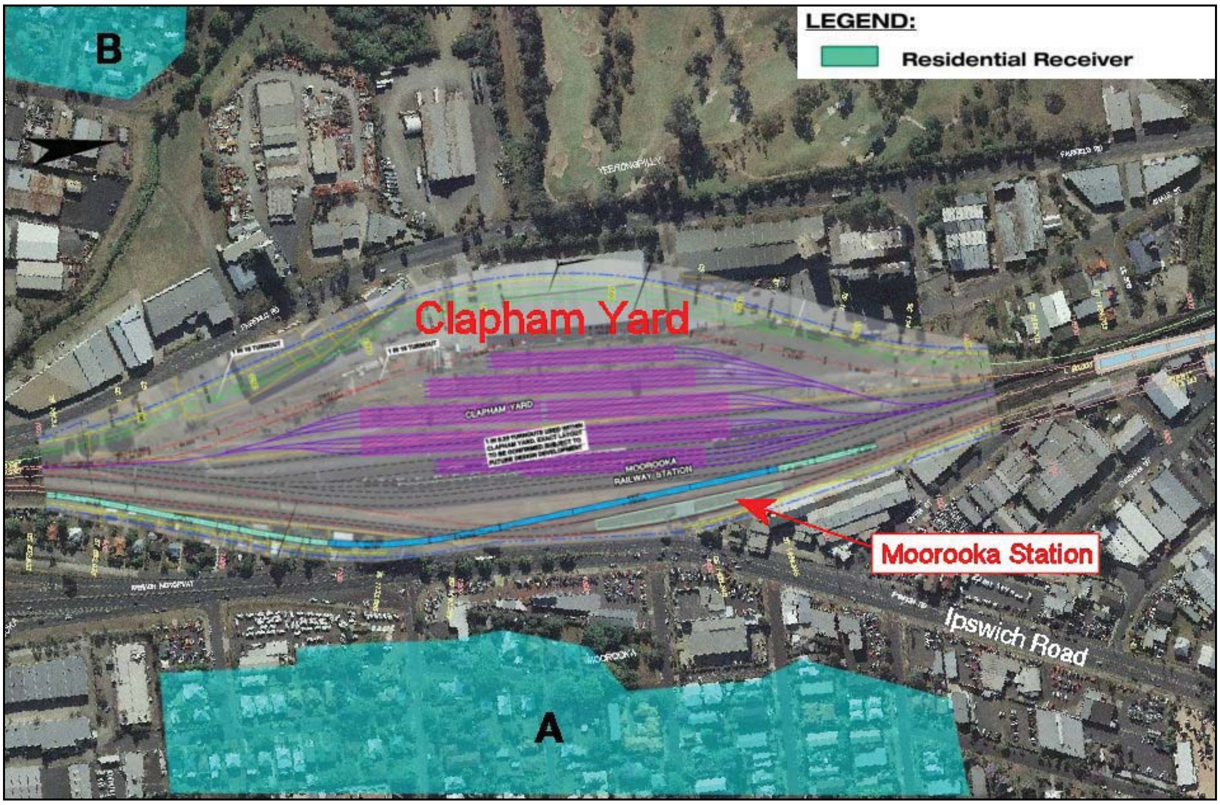


Table 86 Nearest Sensitive Receivers – Moorooka Station

Work Site	Receiver Area	Location Relative to Works (m)
Moorooka Station	A – Residential East	130
	B – Residential West	500

Assessment at the Nearest Sensitive Receivers

A noise model scenario was developed for CRR construction works at Moorooka Station being representative of activities having potentially the greatest noise impact on the surrounding receivers. The scenario was:

- Scenario 1 – Station construction.

The typical construction noise levels without acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 87**. An assessment of noise goal compliance is also provided in **Table 87** with indicative noise level reductions based on 3 m acoustic hoarding. Note a "dash" (-) in the tables indicates compliance with the relevant noise goal.

Noise contours have also been predicted for the modelled scenario without any form of noise mitigation, and is presented in **Appendix G**.

Table 87 Moorooka Station Predicted Worst Case Construction Noise Levels

Receiver Area	Noise Goal (dBA)[1]	Predicted Noise Level (dBA) [2]	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
			None	3 m Hoarding
A – Residential	LAeq(24hour) – 62	47 – 63	1	-
	LAmax,adj – 84	55 – 71	-	-
B - Residential	LAeq(24hour) – 62	27 – 37	-	-
	LAmax,adj – 84	35 – 45	-	-

Note 1 – Noise goal based on Queensland Rail's Code of Practice planning levels adjusted to a free-field level.
Note 2 – Predicted noise levels without acoustic hoarding.

Discussion

The predicted noise levels for the modelled scenario of CRR upgrade works at Moorooka Station indicate compliance with the Queensland Rail planning levels with the exception of a marginal 1 dBA noise goal exceedance at the nearest residences east of the worksite. Every effort would be made to use the quietest available equipment and optimise the use of plant to ensure that the worst case noise levels presented in **Table 87** do not eventuate.

At a distance in excess of 130 m to the nearest residential receiver, vibration impacts from minor CRR construction works would not be anticipated.

Rocklea Station Upgrade

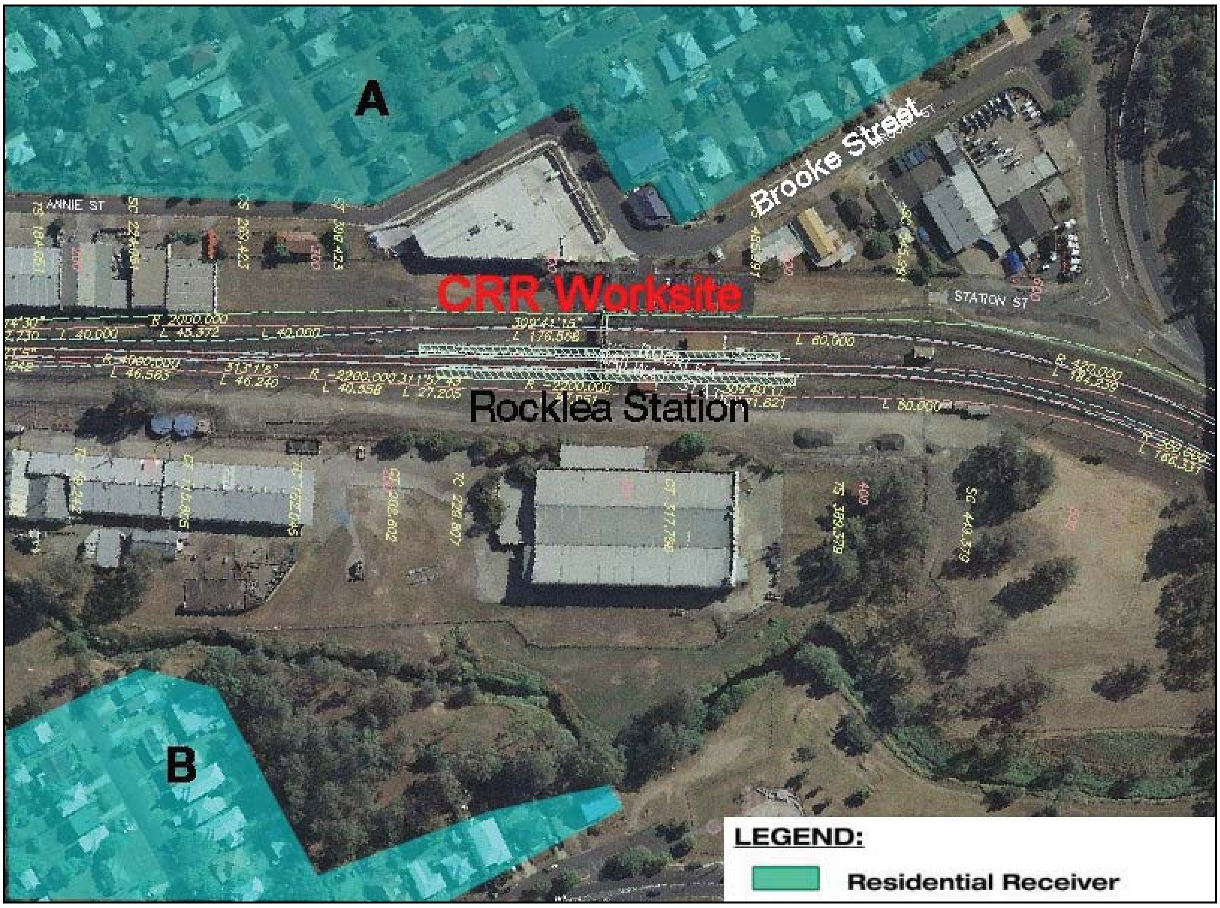
Nearest Sensitive Receivers

The nearest sensitive receivers to the Rocklea Station worksite are identified in **Table 88** with the receiver areas illustrated in **Figure 22**.

Table 88 Nearest Sensitive Receivers – Rocklea Station

Work Site	Receiver Area	Location Relative to Works (m)
Rocklea Station	A – Residential West	40
	B – Residential East	170

Figure 22 Rocklea Station Construction Worksite and Receiver Areas



Assessment at the Nearest Sensitive Receivers

A noise model scenario was developed for CRR construction works at Rocklea Station being representative of activities having potentially the greatest noise impact on the surrounding receivers. The scenario was:

- Scenario 1 – Station construction.

The typical construction noise levels without acoustic hoarding surrounding the site have been predicted at the nearest noise sensitive receivers (at ground floor level) and are presented in **Table 89**. An assessment of noise goal compliance is also provided in **Table 89** with indicative noise level reductions based on 3 m acoustic hoarding. Note a "dash" (-) in the tables indicates compliance with the relevant noise goal.

Noise contours have also been predicted for the modelled scenario without any form of noise mitigation, and is presented in **Appendix G**.

Table 89 Rocklea Station Predicted Noise Levels – Scenario 1 Station Construction

Receiver Area	Noise Goal (dBA)[1]	Predicted Noise Level (dBA)[2]	Noise Goal Exceedance with level of Noise Mitigation (dBA)	
			None	3 m Hoarding
A – Residential	LAeq(24hour) – 62	47 – 73	11	3
	LAmax,adj – 84	55 – 81	-	-
B - Residential	LAeq(24hour) – 62	46 – 54	-	-
	LAmax,adj – 84	54 – 62	-	-

Note 1 – Noise goal based on Queensland Rail's Code of Practice planning levels adjusted to a free-field level.
Note 2 – Predicted noise levels without acoustic hoarding.

Discussion

The predicted noise levels for the modelled scenario of upgrade works at Rocklea Station indicate compliance with the Queensland Rail planning levels with the exception of the nearest residences to the west of the site on Brooke Street. Acoustic hoarding in the order of 4 m in height along the western boundary of the worksite would likely result in compliance with the adopted noise goal based on the marginal exceedance in **Table 89**.

At a distance in excess of 40 m to the nearest residential receiver, vibration impacts from minor CRR construction works would not be anticipated.

The current reference design of Rocklea Station indicates that a 10 m buffer zone would be maintained between rockbreaking and sensitive structures. Where rockbreakers are required to be used within 10 m of Queensland Rail heritage structures, pre-construction condition surveys and monitoring during construction would be recommended.

8.3.3 Surface Structures

Ipswich Motorway On-Ramp

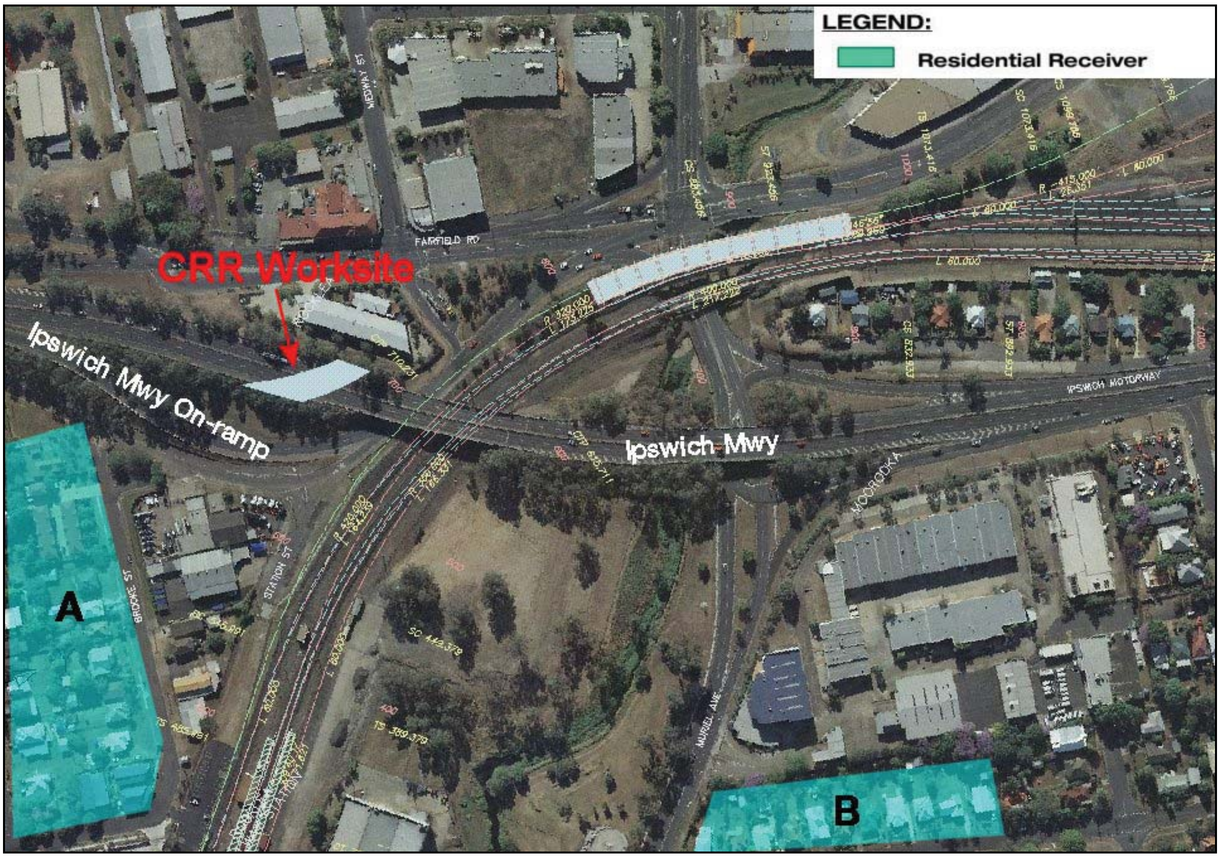
Nearest Sensitive Receivers

The nearest sensitive receivers to the Ipswich Motorway on-ramp worksite are identified in **Table 90** with the receiver areas illustrated in **Figure 23**.

Table 90 Nearest Sensitive Receivers – Ipswich Motorway On-ramp

Work Site	Receiver Area	Location Relative to Works (m)
Ipswich Motorway On-ramp	A – Residential South	50
	B – Residential North-east	350

Figure 23 Ipswich Motorway On-ramp Construction Worksite and Receiver Areas



Discussion

As the Ipswich On-ramp worksite is outside the rail corridor, the CoP noise goals applied to other surface worksites would not be relevant. Further, it is acknowledged that under certain circumstances numerical noise limits are often not applied to road construction works, particularly where the works are required within the road reserve of major roads (eg Ipswich Motorway), construction personnel and public safety is a priority and where disruption to major road networks can be avoided by careful scheduling of work hours. Conditions of this nature have been applied to existing major road projects including Northern Link and Airport Link. On this basis, numerical noise goals have not been proposed for the Ipswich On-ramp roadworks.

Although temporary disruption to normal amenity of the nearest residential receivers is an inevitable consequence of roadworks of this nature, it is imperative that all practicable noise management measures be employed with particular focus on community engagement.

With regards to potential vibration impacts, at a distance in excess of 50 m to the nearest residential receiver, vibration impacts from the Ipswich On-ramp works would not be anticipated.

8.3.4 Surface Trackwork Construction Noise

Trackwork required for CRR would include the use of typical Queensland Rail rollingstock for delivery of both rail and concrete sleepers to site, specialised plant including switch tampers, mainline tampers, ballast regulators, rail grinder, overhead wiring plant etc. Due to the large extent of CRR surface track, it is not practicable to identify all noise sensitive receivers potentially affected by surface track construction noise within (narrow) operational rail corridors. Consequently, construction noise levels from activities/plant listed in **Table 22** have been calculated in **Table 91** for various setback distances. The calculated noise emission levels in **Table 91** do not take into consideration effects from topographical shielding.

It should be noted that work associated with construction of new rail track or the upgrading of existing rail track is relatively short in duration particularly because the work is often confined to shut down periods (eg night-time, weekend, Christmas holidays etc) which is standard Queensland Rail practice to minimise disruption to rail services.

Table 91 Surface Track Construction Plant Noise Emissions

Plant Item	Sound Power Level (dBA)	Noise Level at Setback Distance				
		10 m	25 m	50 m	100 m	250 m
Flat bed truck with crane	110	82	74	68	62	54
Ballast truck (rail)	110	82	74	68	62	54
Ballast truck (road)	110	82	74	68	62	54
Speed swing (360)	114	86	78	72	66	58
Locomotive	111	83	75	69	63	55
Ballast regulator	122	94	86	80	74	66
Tamper	115	87	79	73	67	59
Hand held compactor	114	86	78	72	66	58
CWR welding plant	93	65	57	51	45	37
Cherry Picker	104	76	68	62	56	48
Wiring equipment	111	83	75	69	63	55
Engineers train	111	83	75	69	63	55

A “footprint” noise contour developed on the basis of typical Queensland Rail trackwork consisting of a subset of the plant listed in **Table 91** is provided in **Appendix H**. Similar noise emission levels would prevail across the surface track sections of the project during track construction.

As indicated by the construction noise levels in **Table 91**, high noise levels (potentially in excess of Queensland Rail’s 87 dBA LAmax planning level) may result from CRR trackwork over small setback distances. In addition to limiting, where practicable, the duration of track construction works near any sensitive receiver, all reasonable and feasible noise mitigation measures would need to be applied consistent with the measures listed in Queensland Rail’s CoP. These measures include:

- Locate mobile plant (compressors, generators, etc) as far as practicable away from neighbouring noise-sensitive places.
- Direct principal noise sources (eg exhausts) away from noise sensitive places as far as possible.
- Utilisation of quietest available equipment.
- Fitting of equipment with effective and properly maintained noise suppression equipment consistent with the requirements of the activity, where possible.

- Ensure equipment utilised is maintained and operated as per manufacturers' specifications.
- Minimise the use of warning devices to within operational health and safety constraints.
- Co-ordination of loading/unloading of material activities to be within standard daytime working hours wherever practicably possible.

Comprehensive advance notice would be provided to potentially affected receivers. Part of the consultation process should include information regarding the scheduled works, duration, monitoring regime etc.

9 IMPACT ASSESSMENT OF MECHANICAL TUNNEL EXCAVATION

Approximately 9.2 km of driven tunnelling will be required for the CRR tunnels. The tunnels will mainly be constructed using Tunnel Boring Machines (TBM), which account for approximately 8 km of the tunnelling. The underground stations at Woolloongabba, Albert Street and Roma Street will be excavated by a combination of cut and cover and roadheader. Approximately 200 m of the tunnel near the Northern Portal, after the extraction point for the TBMs, will be excavated by roadheader. The TBMs tunnelling north are proposed to be launched north of the proposed Woolloongabba Station.

TBM 1 and 2 are proposed to be launched from the Southern Portal site to the north separated by approximately 8 weeks. TBM 3 and 4 are proposed to be launched from north of the proposed Woolloongabba Station and travelling north separated by approximately 8 weeks. The TBMs are proposed to be travelling 100 m per week on a 24 hour per day basis.

After construction of the two tunnels, cross passages connecting the two tunnels will be constructed by roadheader excavation approximately every 240 m.

9.1 TBM Tunnelling Works

The following sections present the predicted ground-borne noise and vibration levels from the TBM tunnelling works.

9.1.1 Ground-borne Vibration

The nearest receivers from the tunnels have been identified and the corresponding ground-borne vibration levels have been predicted based on source levels in **Table 30**.

Predicted ground-borne vibration levels from TBM tunnelling works at the nearest receivers along the CRR tunnel alignment are presented in **Table 92**.

It can be seen that there are no exceedances of the cosmetic damage vibration goal, neither the residential nor the stricter cosmetic damage to heritage buildings vibration goal. In some locations, the predicted vibration levels from TBM tunnelling would extend beyond the theoretical threshold for human perception (0.15 mm/s PPV) and could be noticeable (0.5 to 1.0 mm/s PPV) and even 'easily noticeable' (1.0 to 2.0 mm/s PPV) for some people. Predicted vibration from TBM tunnelling would be below the 'strongly noticeable' level (> 2.0 mm/s PPV) at all residential properties. It should be noted that these exceedances will only occur during a relatively short period (less than 1 week for each TBM passby).

Table 92 Summary of TBM Ground-borne Vibration Levels along the Tunnel Alignment

Tunnel Section	Type of Building	Min Slant Distance to Tunnel Crown	Indicative Maximum Vibration Level	Possible Impact NF - Not felt TP - Threshold of perception BN - Barely noticeable N - Noticeable EN - Easily noticeable SN - Strongly noticeable VSN - Very strongly noticeable	Mitigation Options P = pre notification BCS = building condition survey BSS = building sensitive study M = monitoring
Southern Portal to Southern Ventilation Shaft	Residential Commercial Educational Worship Medical	13 m – 115 m 31 m – 80 m 76 m 21 m – 86 m 31 m	0.1 to 1.0 mm/s 0.1 to 0.4 mm/s 0.2 mm/s 0.1 to 0.6 mm/s 0.4 mm/s	N BN TP N BN	P, M
Dutton Park Cemetery	Cemetery	22.5 m – 45 m	0.5 to 1.0 mm/s		
Southern Ventilation Shaft to Boggo Rd Station	Residential Commercial Worship Heritage Medical	13 m – 114 m 13 m – 133 m 21 m – 59 m 85 m – 140 m 22.5 m – 38 m	0.1 to 1.0 mm/s 0.1 to 1.0 mm/s 0.2 to 0.6 mm/s 0.08 to 0.14 mm/s 0.3 to 0.6 mm/s	N N N TP N	P, M
Boggo Rd Station to Woolloongabba Station	Residential Commercial Educational Heritage Hotel	10 m – 92 m 26 m – 123 m 82 m – 110 m 56 m – 95 m 48 m	0.1 to 1.4 mm/s 0.1 to 0.5 mm/s 0.11 to 0.14 mm/s 0.1 to 0.2 mm/s 0.3 mm/s	EN BN TP TP BN	P, BSS, M
Woolloongabba Station to Albert St Station	Residential Commercial Educational Worship Medical Hotel	34 m – 200 m 25.5 m – 167 m 35 m – 233 m 36 m – 190 m 200 m 24 m – 153 m	0.1 to 0.4 mm/s 0.1 to 0.5 mm/s 0.1 to 0.4 mm/s 0.1 to 0.3 mm/s 0.1 mm/s 0.1 to 1.0 mm/s	N BN BN BN TP N	P, M

Tunnel Section	Type of Building	Min Slant Distance to Tunnel Crown	Indicative Maximum Vibration Level	Possible Impact NF - Not felt TP - Threshold of perception BN - Barely noticeable N - Noticeable EN - Easily noticeable SN - Strongly noticeable VSN - Very strongly noticeable	Mitigation Options P = pre notification BCS = building condition survey BSS = building sensitive study M = monitoring
Albert St Station to Roma St Station	Commercial	12 m – 177 m	0.1 to 2.0 mm/s	EN	P, M
	Educational	50 m – 153 m	0.1 to 0.4 mm/s	BN	
	Worship	49 m – 80 m	0.3 to 0.4 mm/s	BN	
	Heritage	28 m – 65 m	0.3 to 0.8 mm/s	N	
	Medical	26.5 m – 96 m	0.2 to 0.8 mm/s	N	
	Hotel	18 m – 141 m	0.1 to 1.3 mm/s	EN	
Roma St Station to Northern Portal	Residential	33 m – 120 m	0.1 to 0.4 mm/s	BN	P
	Commercial	45 m – 281 m	0.04 to 0.3 mm/s	BN	
	Educational	38 m – 135 m	0.1 to 0.3 mm/s	BN	
	Medical	136 m	0.1 mm/s	TP	
	Hotel	46 m – 107 m	0.1 to 0.3 mm/s	BN	

Note: Ground-borne vibration goals:
Cosmetic damage of 5 mm/s (2 mm/s for Heritage listed sites)
Residential (hotel) sleep disturbance of 0.5 mm/s

9.1.2 Ground-borne Noise

The nearest sensitive receivers from the tunnels have been identified and the corresponding ground-borne noise levels have been predicted based on source levels in **Table 31**.

Predicted ground-borne noise levels from TBM tunnel excavation at nearest sensitive receivers along the CRR tunnel alignment are presented in **Table 93**.

There are predicted exceedances of the night-time sleep disturbance criterion for residential receivers along the tunnel alignment as well as some daytime exceedance for commercial and place of worship. It should be noted that these exceedances will only occur during a relatively short period (less than 1 week for each TBM passby).

There are five hotels in the CBD that exceed the night-time ground-borne noise goal for up to ten days, however it should be noted that the noise predictions are for the ground floor and the noise level will be lower higher up in the buildings. As a guide, ground-borne noise levels attenuate by approximately 2 dB per floor for the first 4 floors and by approximately 1 dB per floor thereafter.

The following management strategies are proposed to minimise the impact of the TBM tunnelling works:

- Ground-borne noise and vibration monitoring to be undertaken at the commencement of tunnelling to confirm that the source data utilised for this assessment is applicable to this project (including the low frequency noise assessment inputs and findings).
- Comprehensive advance notice as well as educating the public of intended tunnelling activities in the localities near the tunnel alignment. Part of the consultation process should include information regarding the monitoring program which may require involvement from residences located above the tunnel alignment. A thorough education program will assist to allay fears of the tunnelling process.
- Conduct building condition surveys in accordance with Brisbane City Council requirements where it is considered there may be potential risk for cosmetic (superficial) building damage from TBM excavation.
- Relocation of residences particularly impacted by ground-borne noise from TBM tunnelling may be required.

Table 93 Summary of TBM Ground-borne Noise Levels along the Tunnel Alignment

Tunnel Section	Type of Building	Min Slant Distance to Tunnel Crown	Indicative Maximum Ground-borne Noise Level (dBA)	Possible Impact Very Low: <35 dBA Low: 35 – 40 dBA Moderate: 40 to 45 dBA High: > 45 dBA	Mitigation Options P = pre notification M = monitoring R = temporary relocation
Southern Portal to Southern Ventilation Shaft	Residential	13 m – 115 m	24 dBA to 53 dBA	Very Low to High	P, M, R
	Commercial	31 m – 80 m	29 dBA to 42 dBA	Very Low to Moderate	
	Educational	76 m	30 dBA	Very Low	
	Worship	21 m – 86 m	28 dBA to 47 dBA	Very Low to High	
	Medical	31 m	31 dBA to 42 dBA	Very Low to Moderate	
Southern Ventilation Shaft to Boggo Rd Station	Residential	13 m – 114 m	25 dBA to 53 dBA	Very Low to High	P, M, R
	Commercial	13 m – 133 m	25 dBA to 53 dBA	Very Low to High	
	Worship	21 m – 59 m	33 dBA to 47 dBA	Very Low to High	
	Heritage	85 m – 140 m	22 dBA to 28 dBA	Very Low	
	Medical	22.5 m – 38 m	39 dBA to 46 dBA	Low to High	
Boggo Rd Station to Woolloongabba Station	Residential	10 m – 92 m	27 dBA to 57 dBA	Very Low to High	P, M, R
	Commercial	26 m – 123 m	28 dBA to 44 dBA	Very Low to Moderate	
	Educational	82 m – 110 m	25 dBA to 29 dBA	Very Low	
	Heritage	56 m – 95 m	27 dBA to 34 dBA	Very Low	
	Hotel	48 m	36 dBA	Low	
Woolloongabba Station to Albert St Station	Residential	34 m – 200 m	17 dBA to 40 dBA	Very Low to Low	P, M, R
	Commercial	25.5 m – 167 m	19 dBA to 44 dBA	Very Low to Moderate	
	Educational	35 m – 233 m	20 dBA to 40 dBA	Very Low to Low	
	Worship	36 m – 190 m	18 dBA to 39 dBA	Very Low to Low	
	Medical	200 m	17 dBA	Very Low	
	Hotel	24 m – 153 m	21 dBA to 50 dBA	Very Low to High	

Tunnel Section	Type of Building	Min Slant Distance to Tunnel Crown	Indicative Maximum Ground-borne Noise Level (dBA)	Possible Impact Very Low: <35 dBA Low: 35 – 40 dBA Moderate: 40 to 45 dBA High: > 45 dBA	Mitigation Options P = pre notification M = monitoring R = temporary relocation
Albert St Station to Roma St Station	Commercial	12 m – 177 m	24 dBA to 59 dBA	Very Low to High	P, M, R
	Educational	50 m – 153 m	26 dBA to 40 dBA	Very Low to Low	
	Worship	49 m – 80 m	34 dBA to 40 dBA	Very Low to Low	
	Heritage	28 m – 65 m	37 dBA to 48 dBA	Very Low to High	
	Medical	26.5 m – 96 m	32 dBA to 49 dBA	Very Low to High	
	Hotel	18 m – 141 m	27 dBA to 54 dBA	Very Low to High	
Roma St Station to Northern Portal	Residential	33 m – 120 m	24 dBA to 41 dBA	Very Low to Moderate	P, M, R
	Commercial	45 m – 281 m	13 dBA to 37 dBA	Very Low to Low	
	Educational	38 m – 135 m	22 dBA to 39 dBA	Very Low to Low	
	Medical	136 m	22 dBA	Very Low	
	Hotel	46 m – 107 m	25 dBA to 36 dBA	Very Low to Low	

Note: Ground-borne noise goals:
Commercial of 40 to 50 dBA
Residential night-time of 35 dBA

9.2 Roadheader Tunnelling Works

The following sections present the predicted ground-borne noise and vibration levels from the roadheader tunnelling works associated with the cross-passages, stations and close to the portals.

The roadheader generates lower ground-borne noise and vibration levels compared to the TBMs as shown in **Table 30** and **Table 31**.

9.2.1 Ground-borne Noise and Vibration – Cross Passages

The nearest receivers from the cross passages between the tunnels have been identified and the corresponding ground-borne noise and vibration levels have been predicted.

There are no exceedances of the cosmetic damage vibration goal, neither the residential nor the stricter cosmetic damage to heritage buildings vibration goal. All residential receivers are complying with the night-time vibration perceptibility goal of 0.5 mm/s Peak Particle Velocity during the tunnelling works for the cross passages.

There are 22 exceedances of the night-time ground-borne noise goal for residential receivers above or close to the cross passages (13 of these are within a marginal 2 dBA exceedance). It should be noted that the ground-borne noise and vibration from excavation of cross passages will be short duration (2 to 3 days) works. All commercial receivers comply with the relevant 45 dBA (office spaces) and 50 dBA (retail) ground-borne noise goals.

9.2.2 Ground-borne Noise and Vibration – Stations and Portals

A short section adjacent to the Northern Portal (after the TBM recover site) as well as the station caverns (except at Boogo Road) are proposed to be constructed by roadheader tunnelling.

The nearest sensitive receivers from the sections next to the portals and at the underground stations have been identified and the corresponding predicted ground-borne vibration levels are presented in **Table 94** and ground-borne noise levels are presented in **Table 95**.

All residential receivers are complying with the ground-borne noise and vibration goals during the roadheader tunnelling works at the portal and station locations.

There are predicted exceedances of the ground-borne noise and vibration goals for two hotels (Carrington/Sunland and Oaks Festival Towers) near Albert Street Station. It should however be noted that the predicted levels are for ground floor and the ground-borne noise and vibration levels attenuate by approximately 2 dB per floor for the first 4 floors and by approximately 1 dB per floor thereafter. This results in exceedances of the ground-borne noise and vibration goals only for hotel rooms on the Ground Floor and Floor 1.

Table 94 Summary of Roadheader Ground-borne Vibration Levels

Tunnel Section	Type of Building	Min Slant Distance to Tunnel Crown	Indicative Maximum Vibration Level	Possible Impact NF - Not felt TP - Threshold of perception BN - Barely noticeable N - Noticeable EN - Easily noticeable SN - Strongly noticeable VSN - Very strongly noticeable	Mitigation P = pre notification BCS = building condition survey BSS = building sensitive study M = monitoring
Woolloongabba Station	Residential	47 m – 195 m	0.01 to 0.05 mm/s	NF	
	Commercial	21 m – 192 m	0.01 to 0.15 mm/s	TP	
	Educational	90 m – 149 m	0.01 to 0.02 mm/s	NF	
	Worship	115 m	0.02 mm/s	NF	
	Hotel	40 m	0.06 mm/s	NF	
Albert St Station	Commercial	27 m – 194 m	0.01 to 0.2 mm/s	TP	P, M
	Educational	33 m – 277 m	0.01 to 0.15 mm/s	TP	
	Hotel	8 m (24 m[1]) – 107 m	0.01 to 1.0 mm/s (0.2 mm/s[1])	N	
Roma St Station	Residential	114 m – 148 m	0.01 to 0.02 mm/s	NF	
	Commercial	51 m – 169 m	0.02 to 0.08 mm/s	NF	
	Heritage	62 m	0.04 mm/s	NF	
	Medical	137 m	0.02 mm/s	NF	
	Hotel	45.5 m – 78 m	0.05 to 0.1 mm/s	NF	
Northern Portal	Residential	109 m – 213 m	0.01 to 0.02 mm/s	NF	
	Commercial	136 m – 152 m	0.01 to 0.01 mm/s	NF	
	Educational	100 m – 120 m	0.01 to 0.02 mm/s	NF	
	Hotel	141 m – 150 m	0.01 to 0.01 mm/s	NF	

Note: Ground-borne vibration goals:
Cosmetic damage of 5 mm/s (2 mm/s for Heritage listed sites)
Residential (hotel) sleep disturbance of 0.5 mm/s

Note 1: Minimum distance of 8 m to lowest level underground parking, 24 m to ground floor (first occupied floor). Vibration levels on ground floor 0.2 mm/s barely noticeable.

Table 95 Summary of Roadheader Ground-borne Noise Levels

Tunnel Section	Type of Building	Min Slant Distance to Tunnel Crown	Indicative Maximum Ground-borne Noise Level (dBA)	Possible Impact Very Low: <35 dBA Low: 35 – 40 dBA Moderate: 40 to 45 dBA High: > 45 dBA	Mitigation P = pre notification M = monitoring R = temporary relocation
Woolloongabba Station	Residential	47 m – 195 m	<10 dBA to 28 dBA	Very Low	
	Commercial	21 m – 192 m	<10 dBA to 38 dBA	Low to Moderate	
	Educational	90 m – 149 m	13 dBA to 19 dBA	Very Low	
	Worship	115 m	16 dBA	Very Low	
	Hotel	40 m	30 dBA	Very Low	
Albert St Station	Commercial	27 m – 194 m	<10 dBA to 40 dBA	Very Low to Moderate	P, M, R
	Educational	33 m – 277 m	<10 dBA to 37 dBA	Very Low to Low	
	Hotel	(8 m[1]) 24 m – 107 m	22 dBA to 42 dBA	Very Low to Moderate	
Roma St Station	Residential	114 m – 148 m	13 dBA to 16 dBA	Very Low	
	Commercial	51 m – 169 m	16 dBA to 32 dBA	Very Low	
	Heritage	62 m	24 dBA	Very Low	
	Medical	137 m	19 dBA	Very Low	
	Hotel	45.5 m – 78 m	26 dBA to 33 dBA	Very Low	
Northern Portal	Residential	109 m – 213 m	<10 dBA to 17 dBA	Very Low	
	Commercial	136 m – 152 m	12 dBA to 14 dBA	Very Low	
	Educational	100 m – 120 m	15 dBA to 18 dBA	Very Low	
	Hotel	141 m – 150 m	12 dBA to 13 dBA	Very Low	

Note: Ground-borne noise goals:
Commercial of 40 to 50 dBA
Residential night-time of 35 dBA

Note 1: 8 m to lowest level underground parking, 24 m to ground floor (first occupied floor).

9.3 Low Frequency Noise Impacts

The frequency range of infrasound is normally taken to be below 20 Hz and audible noise from 20 Hz to 20,000 Hz. Contrary to this interpretation, noise at frequencies below 20 Hz can be audible, however tonality is lost below 16 – 18 Hz thus losing a key element of perception. Low frequency noise spans the infrasonic and audible ranges and may be considered as the range from about 10 Hz to 200 Hz.

Infrasound and low frequency noise may result from pumps, compressors, diesel engines, aircraft, shipping, combustion, air turbulence, wind and fans. Ground-borne or structure borne noise originating as vibration from tunnelling activities (eg TBMs and roadheaders) may also be a source of low frequency noise. For CRR, driven tunnelling is considered to be the only potentially significant source of low frequency noise. Other potential sources, such as compressors and diesel engines may be mitigated by means of enclosures, increasing separation distances, limiting use etc.

Guidance on the assessment of low frequency noise impacts can be sought from the Department of Environmental Resources Management (DERM) Ecoaccess Guideline *Assessment of Low Frequency Noise* (ALFN). The intent of these criteria is to accurately assess annoyance and discomfort to persons at noise sensitive places. The guideline assesses both infrasound – below 20 Hz (Part A) and low frequency noise – above 20 Hz (Part B).

The following is an assessment of low frequency noise impacts associated with the CRR.

9.3.1 Part A – Infrasound (<20 Hz)

The G-weighting function is used to determine annoyance due to infrasound. G-weighted noise levels below 85 to 90 dB(G) are not normally significant in terms of human perception and are not annoying. The average hearing threshold for single tones is usually about 95 to 100 dB(G).

Recommended infrasound limit values are:

- 85 dB(G) inside dwellings during the day, evening and night and inside classrooms and offices.
- 90 dB(G) for occupied rooms in commercial enterprises.

From ground-borne noise measurements of two 12 m diameter TBMs and roadheaders conducted within commercial type buildings (RNA pavilion and child care centre respectively) above the CLEM7 tunnel, the resultant one-third octave band spectrum for both TBM and roadheader was analysed to determine the G-weighted sound pressure levels. The analysis results are shown in **Table 96**.

Table 96 TBM and Roadheader G-weighted Sound Pressure Levels

Tunnelling Plant	12.5Hz	16Hz	20Hz	25Hz	31.5Hz	40Hz	50Hz	63Hz	80Hz	100Hz	Overall Level
Tunnel Boring Machine											
Measured TBM – CLEM7	58 dB	61 dB	60 dB	67 dB	67 dB	57 dB	53 dB	51 dB	51 dB	52 dB	
Factored to achieve CRR EIS Level[1]	73 dB	76 dB	75 dB	82 dB	82 dB	72 dB	68 dB	66 dB	66 dB	67 dB	
G-Weighting	4.0	7.7	9.0	3.7	-4.0	-12.0	-20.0	-28.0	-36.0	-44.0	
G-weighted TBM @ 10 m	77	84	84	86	78	60	48	38	30	23	**90 dBG**

Tunnelling Plant	12.5Hz	16Hz	20Hz	25Hz	31.5Hz	40Hz	50Hz	63Hz	80Hz	100Hz	Overall Level
Roadheader											
Measured Roadheader – CLEM7	55 dB	56 dB	57 dB	55 dB	55 dB	54 dB	53 dB	51 dB	51 dB	50 dB	
Factored to achieve CRR EIS Level[2]	72 dB	73 dB	74 dB	72 dB	72 dB	71 dB	70 dB	68 dB	68 dB	67 dB	
G-Weighting	4.0	7.7	9.0	3.7	-4.0	-12.0	-20.0	-28.0	-36.0	-44.0	
G-weighted Roadheader @ ~5m	76 dB	81 dB	83 dB	76 dB	68 dB	59 dB	50 dB	40 dB	32 dB	23 dB	**86 dBG**

Note 1 – Ground-borne noise level for a hard rock 7 m diameter TBM at 10 m taken to be LAeq 56 dBA (refer to **Table 31**).
Note 2 – Ground-borne noise level for a roadheader at 5 m taken to be LAeq 57 dBA (refer to **Table 31**).

From the measurements conducted during CLEM7 tunnelling, the results from the G-weighted sound pressure level analysis shown in **Table 96** indicates that recommended infrasound limits will be complied with during tunnelling works that occur approximately 5 m (roadheader) to 10 m (TBM) from sensitive receiver buildings including dwellings, classrooms and offices.

9.3.2 Part B – Low Frequency Noise (≥20 Hz)

Low frequency noise sources typically exhibit a spectrum that shows a general increase in sound pressure level with decrease in frequency. Annoyance due to low frequency noise can be high even though the actual measured level is relatively low and typically occurs in quiet environments such as residential and office spaces. This occurs as a result of the absence of high frequency components (which can have a masking effect) caused by transmission loss through the building envelope.

The main elements of the ALFN guideline assessment include:

- *The low frequency noise criterion adopted for initial screening inside home environments in terms of Linear, A-weighted and one-third octave band sound pressure levels in the range 20 to 200 Hz.*
- *The comparison of one-third octave band low frequency sound with the values for L_{HS} of the ISO median hearing threshold level for the best 10% of the aged population (55-60 years old) to initially establish auditory perception.*

Assessment Procedure

The ALFN guideline assessment procedure involves the following:

- Step 1 Initial Screening – *Where a noise immission occurs exhibiting an unbalanced frequency spectra, the overall sound pressure level inside residences should not exceed 50 dB Linear to avoid complaints of low frequency noise annoyance. If the dB Linear measurements exceeds the dBA measurement by more than 15 dB, a one-third octave band measurement in the frequency range 20 to 200 Hz should be carried out.*
- Step 2 Audibility Assessment – *The following checks should be made to establish whether the noise contains dominant low-frequency components:*
  - *Determine if $L_{LINeq} – L_{Aeq}$ > 15 dB*
  - *Compare measured one-third octave band levels with the L_{HS} values of the median hearing threshold level for the best 10% of the older population (55-60 Years old) to determine the degree of low frequency noise audibility.*
  - *Check for the existence of an amplitude-modulating component.*

- Step 3 Annoyance due to Tonal Noise – *Check if the sound pressure level in a particular one-third octave band is 5 dB or more above the levels in the two neighbouring bands.*
- Step 4 Annoyance due to Non-tonal Noise – *To establish annoyance for non-tonal noise in the frequency range 10 Hz to 160 Hz, A-weighting network corrections are applied to the one-third octave spectra measured indoors and the overall A-weighted value, called* $L_{pA,LF}$ *is assessed against a recommended limits (refer to* ***Section 2.2.2****).*

Step 1 – Initial Screening

The CLEM7 measurements were for a 12 m diameter TBM, all measurement data have been adjusted to account for the CRR 7 m diameter TBM in accordance with an assumed 10 x log(Area) relationship (ie CRR TBMs generate 4.7 dBA lower ground-borne noise emission).

CLEM7 TBM and roadheader measurement results, over slant distances of approximately 45 m and 20 m respectively (shown in **Table 97**), indicate that the 50 dB Linear level will be exceeded when tunnelling at close distance. The results in **Table 97** also indicate that the linear sound pressure level is more than 15 dB higher than the A-weighted sound pressure level.

Compliance with the 50 dB Linear level will likely be achieved at slant distances of approximately 170 m and 50 m or greater for the TBM and Roadheader respectively.

Table 97 Comparison of Linear and A-weighted TBM and Roadheader Sound Pressure Levels

Tunnelling Plant	12.5Hz	16Hz	20Hz	25Hz	31.5Hz	40Hz	50Hz	63Hz	80Hz
TBM Linear SPL	53 dB	57 dB	55 dB	62 dB	62 dB	53 dB	48 dB	46 dB	46 dB
TBM A-weighted SPL	-10 dBA	0 dBA	5 dBA	17 dBA	23 dBA	18 dBA	18 dBA	20 dBA	24 dBA
Roadheader Linear SPL	55 dB	56 dB	57 dB	55 dB	55 dB	54 dB	53 dB	51 dB	51 dB
Roadheader A-weighted SPL	-8 dBA	-1 dBA	7 dBA	10 dBA	16 dBA	19 dBA	23 dBA	25 dBA	29 dBA
	100Hz	**125Hz**	**160Hz**	**200Hz**	**315Hz**	**400Hz**	**Overall**		
TBM Linear SPL	47 dB	44 dB	44 dB	40 dB	32 dB	25 dB	67 dB Linear		
TBM A-weighted SPL	28 dBA	28 dBA	30 dBA	29 dBA	24 dBA	19 dBA	36 dBA		
Roadheader Linear SPL	50 dB	48 dB	48 dB	43 dB	38 dB	30 dB	64 dB Linear		
Roadheader A-weighted SPL	31 dBA	32 dBA	35 dBA	32 dBA	29 dBA	23 dBA	40 dBA		

Note – TBM data at slant distance of 45m; Roadheader data at slant distance of 20m

Step 2 – Audibility Assessment

It is recognised that ground-borne noise from driven tunnelling plant will be audible at times during construction and therefore steps 3 and 4 of the ALFN guideline are undertaken below.

Step 3 – Tonal Noise Assessment

The one-third octave band spectra from measurements of the CLEM7 TBMs and roadheaders do not exhibit tonality.

Step 4 – Annoyance due to Non-tonal Noise

The assessment results (A-weighted corrections) for annoyance due to non-tonal noise are presented in **Table 98**.

Table 98 A-weighted Corrected Noise Levels for TBM and Roadheader Annoyance

Tunnelling Plant	12.5Hz	16Hz	20Hz	25Hz	31.5Hz	40Hz	50Hz	63Hz	80Hz
TBM @ ~10 m	10 dBA	20 dBA	25 dBA	37 dBA	42 dBA	38 dBA	38 dBA	40 dBA	44 dBA
Roadheader @ ~5m	9 dBA	16 dBA	24 dBA	27 dBA	33 dBA	36 dBA	40 dBA	42 dBA	46 dBA
	100Hz	**125Hz**	**160Hz**	**$L_{pA,LF}$**					
TBM @ ~10 m	48 dBA	48 dBA	50 dBA	**55 dBA**					
Roadheader @ ~5m	48 dBA	49 dBA	52 dBA	**55 dBA**					

The A-weighted corrected one-third octave noise levels presented in **Table 98** for TBM and roadheader indicate that the recommended limits applicable to non-tonal low frequency noise will be exceeded for all receiver types when operating in close proximity.

At slant distances of approximately 100 m and 50 m (for TBM and roadheader respectively) or greater, compliance with the annoyance threshold (LpA,LF 25 dBA) would likely be achieved for dwellings during the evening and night-time period.

The spectral data used for the present assessment is based on a relatively small measurement sample. It is recommended that the low frequency noise assessment is updated based on measurements performed during the initial construction phase of the CRR.

The ALFN guideline includes a chapter on potential noise reduction measures which focus primarily on design such as incorporating silencers and enclosures near the source of low frequency noise. However, in the case of tunnelling operations, design modifications to the process itself and/or to the receiver environment are not practicable leaving very little options for mitigation. One option for avoiding annoyance from low frequency noise associated with tunnelling is to temporarily provide alternate accommodation (eg hotel room) for building occupants when the source is operating within a particular distance from the building.

9.3.3 Low Frequency Noise Summary

The above low frequency noise assessment based on the DERM Ecoaccess ALFN Guideline includes an assessment of annoyance due to infrasound (dBG) and low frequency noise ($L_{pA,LF}$). The assessment indicates that annoyance limits will likely be exceeded during driven tunnelling works for offset distances of approximately 100 m associated with the CRR.

The recommended noise and vibration management plan should cover the potential for low frequency noise impacts, with the following recommendations as a minimum:

- A comprehensive notification and education program to assist in allaying fears regarding tunnelling. Part of the education process should include an indication of tunnelling progress and subsequent likely (temporary) exposure periods.
- Infrasound and low frequency noise measurements in accordance with the ALFN guideline at the commencement of tunnelling operations and in the event of a “low frequency” noise complaint (where required).
- An option for temporary relocation of people pending the outcome of an assessment of the impact against the EIS goals and ALFN Guideline.

9.4 Construction Traffic

9.4.1 Proposed Activities

Spoil Removal

Spoil from the TBMs would be removed via a spoil conveyor behind the TBM in the tunnel out to the acoustic enclosures at the Woolloongabba Station and Southern Portal worksites. At which point the spoil would likely be transferred by heavy vehicle to a site in Swanbank via a route along Ipswich Road, Ipswich Motorway, Cunningham Highway and Redbank Plains Road. Since the proposed spoil destination route does not pass residential receiver locations after vehicles exit the Cunningham Highway, no further assessment of road traffic noise impact is required.

Spoil from the excavation of all other CRR worksites not required to be used as fill on the Project would be loaded into trucks during the daytime period and transported to Swanbank.

Anticipated average and peak frequencies of spoil trucks from each worksite are summarised in **Table 99**.

Table 99 Summary of Spoil Truck Movements

Worksite	Hours of Spoil Removal	Average Truck Movements per Day[1]	Peak Truck Movements per Day[1]
Tunnel Worksites			
Northern Portal	6:30 am to 6:30 pm Monday to Saturday	30	75
Roma Street Station	6:30 am to 6:30 pm Monday to Saturday	64	160
Albert Street Station	6:30 am to 6:30 pm Monday to Saturday	55	137
Woolloongabba Station	24 hours a day 7 days a week	86	214 (hourly peak = 9)
Boggo Road Station	6:30 am to 6:30 pm Monday to Saturday	36	89
Southern Ventilation Shaft	6:30 am to 6:30 pm Monday to Saturday	12	29
Southern Portal	24 hours a day 7 days a week	86	214 (hourly peak = 9)
Surface Worksites			
O'Connell Terrace	6:30 am to 6:30 pm Monday to Saturday	n/a	60[2]
Mayne Stabling Yard	6:30 am to 6:30 pm Monday to Saturday	n/a	143[2]
Clapham Stabling Yard	6:30 am to 6:30 pm Monday to Saturday	n/a	143[2]

Note 1 – Truck movements = 2 trips
Note 2 – Includes delivery vehicles.

Material Deliveries

Truck deliveries of materials and machinery would utilise the same local site access arrangements as for the spoil removal. These movements would occur during daytime working hours only, except where over-size regulations require transit at other times. Night-time deliveries have only been assessed for Woolloongabba Station and the Southern Portal sites (eg for delivery of precast tunnel segments).

Anticipated average and peak frequencies of delivery trucks are summarised in **Table 100**. With the exception of the sites directly servicing the TBM drives, it is unlikely that periods of peak material deliveries would coincide with periods of peak spoil removal.

Delivery vehicles for surface worksites are included with the volume for spoil truck movements in **Table 99**.

Table 100 Summary of Delivery Truck Movements

Worksite	Hours of Spoil Removal	Average Trucks per Day[1]	Peak Trucks per Day[1]
Northern Portal	6:30 am to 6:30 pm Monday to Saturday	8	20
Roma Street Station	6:30 am to 6:30 pm Monday to Saturday	12	27
Albert Street Station	6:30 am to 6:30 pm Monday to Saturday	9	21
Woolloongabba Station	24 hours a day 7 days a week	23	57
Boggo Road Station	6:30 am to 6:30 pm Monday to Saturday	10	24
Southern Ventilation Shaft	6:30 am to 6:30 pm Monday to Saturday	3	8
Southern Portal	24 hours a day 7 days a week	23	57

Note 1 – One-way volumes - total truck movements are double these values due to return trip.

9.4.2 Construction Traffic Noise Impacts

The effect of construction related heavy vehicle traffic on the noise emission from roadways has been assessed by calculating how the additional truck traffic would alter the $L_{A10(12hour)}$ level of noise emission from roadways using the CoRTN prediction algorithms. For the purpose of this analysis, the $L_{A10(12hour)}$ is the average L_{A10} traffic noise level between the hours of 6:30 am and 6:30 pm.

For Woolloongabba Station and the Southern Portal worksites the change in road traffic noise levels was assessed over the following time periods to cover the 24 tunnelling operations from these sites:

- $L_{A10(18hour)}$ for between 6 am and 12 midnight.
- $L_{A10(1hour)}$ for the peak number of heavy vehicle movements during any hour between 12 midnight and 6 am.

On a given roadway, the essential modelling inputs that the additional construction traffic will alter are the percentage of heavy vehicles and total vehicle numbers utilising that roadway. For the assessment of typical construction truck volumes, the peak daily frequencies have been adopted as being representative of total truck movements. This assessment is summarised in **Table 101**.

For this analysis the existing annual average daily traffic (AADT) road traffic predictions an all roads has been obtained from traffic information supplied by the CRR JV.

Table 101 Effect of Construction Truck Movements on Traffic Noise Levels along Spoil Routes

Worksite	**Road Segment**	**Change in Road Traffic Noise Level due to CRR (dBA)**	
		LA10(12hr)	**LA10(1hr)**
Tunnel Worksites			
Northern Portal	Gregory Terrace to Bowen Bridge Road	+0.3	n/a
Roma Street Station	Roma Street adjacent existing Station	+0.3	n/a
Albert Street Station	Alice Street west of Albert Street	+0.3	n/a
Woolloongabba Station	Ipswich Road south of Stanley Street	+0.3[1]	+0.8
Boggo Road Station	Annerley Road south of Boggo Road	0	n/a
Southern Ventilation Shaft	Fairfield Road south of Brougham Street	0	n/a
Southern Portal	Lucy Street[2]	+1.5[1]	n/a
	Ipswich Road south of Lucy Street	+0.2[1]	+0.5
Surface Worksites			
O'Connell Terrace	Bowen Bridge Road north of O'Connell Tce	0	n/a
Mayne Stabling Yard	Inner City Bypass	0	n/a
Clapham Stabling Yard	Fairfield Road south of Chale Street	+0.2	n/a

Note 1 – LA10(18hour).
Note 2 – Road adjacent to industrial/commercial receivers only.
Note 3 – Levels in brackets based on average truck movements

From **Table 101** it can be seen that spoil traffic would not increase average traffic noise levels on spoil routes that pass residential receivers by more than 0.3 dBA for existing road corridors between 6:30 am and 6:30 pm. For Woolloongabba Station, an increase in road traffic noise level of 0.8 dBA was predicted for the (12 midnight to 6 am) night-time peak. At the Southern Portal an increase of up to 0.5 dBA was predicted for the LA10(1hour) night-time peak for residential receivers adjacent to Ipswich Road. A 1.5 dBA increase is predicted for Lucy Street however this is not impacting on residential receivers. It is generally recognised in acoustics that changes in noise levels of 2 dBA or less are undetectable to the human ear and therefore negligible.

The absolute maximum noise levels associated with vehicle pass-bys would not be altered by CRR construction vehicles (see recommendation below for all CRR spoil trucks to be tested against ADR 28/01), however, the frequency of such events would increase.

Best practice noise management practices that should be incorporated into management of spoil removal as required by the General Environmental Duty under the Environmental Protection Act 1994 are discussed in the following section.

9.4.3 Truck Vibration Impacts

Fully loaded trucks travelling on properly maintained public roadways would not generate significant levels (ie able to be clearly felt) of ground vibration at buildings adjacent to spoil routes.

9.4.4 Mitigation

Recommended mitigation measures include:

- Best practice management over engine noise emissions by procurement and maintenance of a fleet that conforms to Australian Design Rule 28/01 for engine noise emissions, tested in accordance with the National Road Transport Commission document Stationary Exhaust Noise Test Procedures for In-Service Motor Vehicles.
- Adoption of airbag suspension throughout the fleet to minimise noise associated with empty trucks travelling over road irregularities.
- Satellite tracking and management of the position of the truck fleet to ensure that waiting queues are appropriate to space constraints, minimising noise from idling trucks.

10 OVERVIEW OF CONSTRUCTION NOISE AND VIBRATION MANAGEMENT

The extent of any construction noise and vibration impact would depend on the construction scenarios finally adopted. The equipment selected, the distances to residences and the duration of noisy activities may combine to have some noise and/or vibration impacts. Well considered construction planning can minimise the potential impacts.

The following typical noise control and impact mitigation measures are frequently required where surface construction compounds are situated near a sensitive receiver locality:

- Constant review of alternative construction methods aimed at reducing the extent of potential impacts.
- Selection of the quietest plant and equipment that can economically undertake the work, wherever possible.
- Regular maintenance of equipment to ensure that it remains in good working order.
- Where possible, avoid the coincidence of plant and equipment working simultaneously close together near sensitive receivers.
- Mobile plant such as excavators, front end loader and other diesel powered equipment to be fitted with residential class mufflers.
- Use localised noise screens/barriers for particular noisy operations such as pile boring, rockbreaking, blasting etc. An example of utilising the built environment to mitigate noise could be achieved at Wilkie Street during the demolition of existing buildings, whereby the last row of buildings to be removed could remain in place until the final stage of demolition.
- When residential dwellings are in close proximity to the work site, the use of barriers and/or acoustic enclosures would likely provide a significant reduction in impacts when carefully designed.
- Conduct pre- and post-construction building condition surveys where it is considered there may be potential for cosmetic (superficial) building damage from CRR construction activities (eg TBM, roadheader and drill and blast etc).
- Comprehensive advance notice as well as educating the public of intended tunnelling activities in the localities near the tunnel alignment. Part of the consultation process should include information regarding the monitoring program which may require involvement from residences located above the tunnel alignment. A thorough education program will assist to allay fears of the tunnelling process.
- Noise and vibration monitoring should be undertaken at the commencement of tunnelling to confirm that the source data utilised for this assessment is applicable to this project (including the low frequency noise assessment inputs and findings).

- Minimise night-time construction activities and spoil removal where possible.

Construction noise and vibration monitoring procedures would be developed to address the initial and ongoing monitoring of emissions from construction to assist in planning of excavation and construction works. This will be of particular importance where work activities are close (ie less than 100 m) to residences or other noise sensitive receivers.

Pre-condition surveys would likely be conducted for buildings and historical items in vibration sensitive zones prior to commencement of construction.

Ongoing spot checks of noise intensive plant and equipment would be undertaken. Construction noise and vibration levels would be monitored throughout the construction phase to verify compliance with the design goals. Monitoring would be undertaken at those locations where predictions indicate exceedance of the nominated project noise and vibration goals. Supplementary noise and/or vibration monitoring may also be conducted to identify issues of concern in response to any complaints.

As with all major construction projects in Brisbane, weekly inspections would be undertaken throughout the construction period by the project environment officers, site supervisor or project engineers. The inspections would ensure that appropriate noise and vibration controls are being implemented and are effective. It would also ensure that where necessary additional monitoring is undertaken as a result of changes to activities/construction methods and community complaints. Any issues identified during the weekly inspections would be documented in regular (typically monthly) monitoring reports.

A detailed monitoring program would be prepared closer to the commencement of construction as part of the tendering and detailed design processes. **Table 102** outlines a construction noise monitoring program and **Table 103** outlines a construction vibration monitoring program, both of which are recommended as a minimum for the Project.

Table 102 Construction Noise Monitoring Recommendations

Monitoring	Schedule	Locations	Procedures and Instrumentation
Operator Attended Noise Monitoring - Worksites	At the commencement of all noise intensive construction activities then typically once a week thereafter.	Typically at the nearest receiver in each direction to each site specific activity associated with: - Worksite activities (site prep works, day and night tunnelling). - Surface trackworks	Attended measurements to quantify and qualify construction noise emissions using a calibrated sound level meter capable of measuring L_{A90}, L_{Aeq}, L_{A10} and L_{A1} statistical noise levels in 15 minute intervals. One 15 minute sample per survey location is generally sufficient. Extraneous noise (eg cars, trains etc) should be excluded from the measurements. Sources contributing to the noise levels are to be noted.
Unattended Noise Monitoring - Worksites	On a continuous basis or as required. Regular (typically weekly or fortnightly) data downloads would be required.	Continuous noise logging to be undertaken at the nearest noise sensitive receiver adjacent to tunnel worksites taking into consideration extraneous noise sources such as major roads, train passby etc.	A calibrated noise logger capable of measuring L_{A90}, L_{Aeq}, L_{A10} and L_{A1} statistical noise levels in 15 minute intervals would be sufficient. Noise loggers are not typically used where extraneous noise is present. Therefore consideration should be given to using noise loggers capable of recording audio samples by means of preset trigger level exceedances to assist in identifying the source of the noise level exceedance.

Monitoring	Schedule	Locations	Procedures and Instrumentation
Plant Noise Audits	As required but generally limited to particularly noisy plant items such as piling rigs, hydraulic hammer, haul trucks etc.	On site, typically at 7 m from the item of plant (for surface equipment) in the direction of dominant noise emission. Closer to the source if other sources prevent measurement at this distance.	Attended measurements using a calibrated sound level meter capable of measuring L_{Aeq}, L_{A10}, L_{A1} and L_{Amax} statistical noise levels. Select the items of plant which appear to be the most dominant sources of noise. Measure noise emissions under conditions of maximum noise normally occurring for that source. For most noise sources, a one minute sample will be satisfactory, although sampling may be extended up to 15 minutes for sources varying greatly over time. The results of the plant noise audits would enhance the input data fed into the predictive modelling process. Equipment significantly exceeding the plant noise levels used in the predictive modelling should undergo inspection to identify appropriate noise control measures. Where noise control measures are not feasible, predictive modelling should be updated accordingly and additional mitigation measures adopted where required. Haul trucks to be checked against ADR 28/01 before commencing works and at 12 month intervals.
Regenerated Noise Monitoring	At the commencement of driven tunnelling works at each site.	10 receiver locations per working face of short-term operator attended regenerated noise measurements at varying slant distances from the working face.	A calibrated sound level meter capable of measuring L_{A90}, L_{Aeq}, L_{A10}, L_{A1} and L_{Amax} statistical noise levels and one-third octave noise levels in 15 minute intervals would be sufficient The results of the regenerated noise measurements would enhance the input data fed into the predictive modelling process.
Response to Complaints	Within a 24 hour period of receiving the complaint	As appropriate to address the particular complaint.	Attended or unattended measurements as appropriate to identify and measure the source in question.

Table 103 Construction Vibration Monitoring Recommendations

Monitoring	Schedule	Locations	Procedures and Instrumentation
Driven Tunnelling	A minimum of 1 vibration logger per working face for first 3 months for each tunnel section. After initial 3 months at each section, a minimum of 1 vibration logger for each tunnel section where: - exceedance of vibration goals are predicted. - complaints have been received (to be addressed within a 24 hour period).	Tunnel sections include: - 2 x mainline tunnels - 2 x portals At the nearest receiver to the cutting face where predictions indicate exceedances. As appropriate to address the particular complaint.	Operator attended measurements using a calibrated instrument capable of measuring peak particle velocity in 3 axes (ie vertical, longitudinal and transverse). The results of the vibration monitoring would enhance the reference data fed into the predictive modelling process.
Blasting	A minimum of 2 vibration and blast overpressure monitoring locations during each blast throughout the blasting phase of the project.	All efforts should be made to locate the monitors at the nearest receivers to the blast site. Monitoring should always be undertaken at a heritage listed structure if close to blasting	Measurements using a calibrated instrument capable of measuring peak particle velocity in 3 axes (ie vertical, longitudinal and transverse) and blast overpressure. The results of the blast monitoring would enhance the input data fed into the predictive modelling process.
Buffer Distance Tests for: - Worksite activities - Surface track works	At the commencement of all vibration intensive activities associated with each worksite and surface track works. To address complaints (within 24 hours) Where exceedances are predicted to occur.	At foundation of potentially affected structure	Attended measurements using a calibrated instrument capable of measuring peak particle velocity in 3 axes.

11 CONCLUSIONS

11.1 General

The analysis of noise and vibration impacts associated with the CRR construction phase has been prepared based on design parameters as supplied by the CRR EIS JV and Design Team. The analysis is intended to provide a practical and specific understanding of the potential impacts and the mitigation measures that may be necessary to mitigate impacts during the construction phase.

Due to the temporary nature of construction works, the potential noise and vibration impacts during the construction phase of a project are often less significant than the long-term operational impacts. Notwithstanding this, noise and vibration emissions are typically higher during the construction phase than during operations. Construction often requires the use of heavy machinery which can generate significant noise and vibration emissions at nearby buildings and receivers. For some equipment, there is limited opportunity to mitigate the noise and vibration levels in a cost-effective manner while still carrying out the intended works - and hence the potential impacts need to be effectively managed and minimised.

At any particular location, the potential noise and vibration impacts can vary greatly depending on factors such as the relative proximity of noise-sensitive receivers, the overall duration of the construction works, the intensity of the noise and vibration emissions, the time at which the construction works are undertaken and the character of the noise or vibration emissions.

It is anticipated that the construction methodology will evolve and be refined as detailed construction plans are developed for the project, with consequential implications for the design of mitigation strategies. It is therefore recommended that a detailed Construction Noise and Vibration Management Plan (or sub-plans) be prepared for the project as the detailed construction plans are developed.

11.2 Tunnelling Worksites

11.2.1 TBM Launch Sites

Woolloongabba Station

The assessment of construction noise and vibration impacts from the Woolloongabba Station and associated TBM launching operations indicated that for site establishment works (including demolition of the existing GoPrint building at the Woolloongabba Station site), exceedances by up to 15 dBA of the noise goal for daytime operations at the nearest residential receivers along Vulture Street may occur. Higher exceedances are expected at St Nicholas Cathedral due to the lower noise goal.

The predicted noise levels for shaft excavation and spoil storage at the Woolloongabba Station site indicate marginal exceedances of up to 3 dBA during the day and 3 dBA during the night-time period at the nearest residential receivers. The assessment indicated that a minor upgrade (eg 1 mm thick metal cladding rather than 0.62 mm thick cladding) on the medium performance acoustic enclosure in combination with quietest available mobile plant would be required to comply with the daytime and night-time noise goals.

Longer term activities at this site associate with the TBM support activities are also predicted to exceed the night-time residential noise goal at the nearest receivers. A further 5 dBA reduction in noise emission could be achieved through the following mitigation measures:

- Highest performance acoustic enclosure over the site.
- Quietest available mobile plant operating at the site.
- Temporary tunnel ventilation noise sources to be located down in the shaft with appropriate ducting to the surface. Silencers may be required depending on the type of ventilation used.
- Acoustic louvres at enclosure ventilation openings.

With the above mitigation measures in place, combined with careful management of all heavy vehicle movements on the site, compliance with the noise goals during all time periods could be achieved at the Woolloongabba Station site with the exception of initial demolition works which cannot be reasonably and feasibly mitigated to achieve compliance with the daytime noise goal.

It is noteworthy that existing night-time background noise levels in the vicinity of the Woolloongabba Station worksite are typical of a city environment (eg RBL of 46 dBA at Leopard Street). It would be expected that, at times, night-time construction noise originating from the high performance enclosure at Woolloongabba Station worksite would not be discernable to the majority of residential receivers surrounding the site as the night-time noise goal is 1 dBA above the RBL.

The use of drill and blast as an excavation technique at Woolloongabba Station would be limited to a 12 kg MIC to comply with the 2 mm/s PPV vibration limit at St Nicholas Cathedral. An MIC limit of 12 kg indicates that blasting of the station shaft could be carried out with minimal risk of impact. Therefore, blasting would be a suitable excavation technique for this location.

Southern Portal

The predicted noise levels for site establishment works including demolition of Wilkie Street and adjacent residences and the cut and cover of the Southern Portal indicate exceedances of up to 29 dBA of the noise goal for the daytime period. The large noise goal exceedances result from the use of rockbreakers in close proximity to receivers. It is anticipated that rockbreakers would be used intermittently during the six week site clearing phase of the Project.

It is recommended that demolition of residences nearest to the railway line occur first so that the buildings closest to the resumption extents act as a barrier for residences located beyond the property impact area, particularly if large rockbreakers are required to break up concrete slabs and/or footings.

It is understood that short-term night-time work would be required during pile installation works immediately adjacent to the operational rail line. The predicted noise levels during these works indicate that exceedances of up to 16 dBA would be anticipated with just 3 m acoustic hoarding as noise mitigation. Where practicable, it is recommended that these works be carried out during weekend rail possessions and preferably during the daytime only.

The predicted noise levels for spoil removal (during TBM operation) at the Southern Portal site indicate exceedances of up to 20 dBA during the night-time period at the nearest residential receivers. The predicted noise levels indicate that a high performance acoustic enclosure would be required to comply with the night-time noise goals.

The hierarchy of controls would likely be in the form of:

- Where practicable to do so, relocate plant inside the cut and cover tunnel.
- Selection of quietest available plant and equipment.
- Mitigating each acoustically significant item of plant required to operate within the enclosure (eg residential grade mufflers on all front end loaders).
- Subsequent to the above measures, detailed design of a high performance acoustic enclosure, which may include double skin walls and roof lined with sound absorptive material, minimising openings and acoustic louvres fitted to ventilation openings. Access and ventilation openings should be constructed on the western facade of the enclosure away from residences.
- If necessary, mitigating noise at individually affected receivers through property treatments (eg mechanical ventilation, glazing upgrades etc).

Spoil movements within the site during the night-time period achieve compliance with the sleep disturbance noise goal as a result of the shielding being afforded by the existing warehouses at the site in combination with 4 m high noise barrier adjacent to the site entrance at Lucy Street.

The movement of trucks within the worksite should be designed to limit (as much as possible) the need for reversing activities and consequent reversing alarm noise. Where issues with reversing alarms occur, consideration should be given to the use of broadband “buzzer” reversing alarms and/or alarms which actively vary their volume according to the ambient noise levels during activation - rather than constant volume (tonal) “beeping” alarms.

With the above mitigation measures in place, combined with careful management of all heavy vehicle movements on the site, compliance with the noise goals during all time periods could be achieved at the Southern Portal site with the exception of initial demolition works which cannot be reasonably and feasibly mitigated to achieve compliance with the daytime noise goal.

11.2.2 Tunnel Portal

Northern Portal

The predicted worst case noise levels for the Northern Portal site indicate relatively small exceedances of the relevant noise goals at the nearest residential receivers due to the buffer distance between the worksite and residences. Higher noise goal exceedances are expected at commercial receivers located on the western side of Gregory Terrace.

The predicted construction noise levels suggest that increasing the proposed 3 m acoustic hoarding along the eastern boundary to a 6 m acoustic hoarding should achieve compliance with the noise goals at all sensitive receivers except for the Centenary Aquatic Centre (6 dBA exceedance) and the nearest Gregory Terrace residences (marginal 2 dBA exceedance). Impacts to these receivers would be managed through use of quietest available construction plant and effective consultation with potentially affected receivers. Regarding Scenario 2 (ie cut and cover excavation) impacts, as the excavation plant progress deeper into the portal structure, construction noise emission levels at Gregory Terrace (residential receivers) could be anticipated to approach compliance with the noise goal.

11.2.3 Stations

Roma Street Station

The predicted construction noise emission levels for Roma Street Station works exceed the noise goals for only a small number of receivers during the daytime and night-time period. The highest predicted noise goal exceedances occur at the Roma Street Station and the Holiday Inn. Consequently, consideration would need to be given to increasing the height of the temporary acoustic hoardings around the three work sites to achieve compliance with the daytime noise goals. A high performance acoustic enclosure would be required to achieve compliance with the external noise goal for the night-time period at the Holiday Inn.

The predicted construction noise levels indicate that with provision for 6 m acoustic hoarding around each site (where practicable), night-time construction noise levels would be within 1 dBA of the sleep disturbance noise goal and therefore unlikely to interfere with people's sleep. Further to this, it is likely that facade noise reductions for residential buildings located within the CBD are substantially higher than the 10 dBA (refer to **Section 8.1**) assumed for this assessment.

To assist with the interpretation of impacts associated with the construction of CRR, it is important that assessment goals are consistent across the project. However, in the case CRR construction works required in the City precinct (ie Roma Street Station and Albert Street Station), it may prove onerous to apply absolute noise goals in acoustic environments characterised by relatively constant high ambient noise levels.

Further, the existing City landscape is scattered with high-rise building construction worksites that operate on a daily basis in accordance with Section 440R of the Act (ie with no noise limits) presumably over extended periods of time (eg greater than 12 months). It is likely that noise sensitive receivers in the vicinity of Roma Street Station worksites would associate initial CRR construction work involving site establishment, demolition and piling, with typical high-rise building construction works, particularly at the major southern worksite adjacent the Station precinct. Where the CRR construction differs from typical inner city high-rise construction work is the subsequent long-term underground excavation of Station caverns by roadheaders. The long-term phases would primarily occur below surface and/or within an acoustic enclosure to minimise any noise impacts.

Predicted gound-borne noise and vibration levels in **Table 55** from rockbreaking excavation of the shafts indicate compliance with the relevant goals.

Assuming airblast overpressure can be sufficiently mitigated at the site (eg blast mat, enclosure etc) drill and blast excavation at Roma Street Station could be constrained by low MICs estimated to be 0.5 kg, controlled by the heritage-listed station building.

Should drill and blast be adopted for this site, the following management measures would be required:

- Use of latest available blasting technology (eg PCF).
- Pre-blasting condition survey of adjacent buildings.
- Appropriate attention to blast design and commence blasting with a low MIC to develop a site law (ie blast design model) based on measurement data from the site.
- Monitoring the blast emissions.

Albert Street Station

The predicted noise levels for site establishment works including demolition of the existing buildings at the two Albert Street Station sites indicate exceedances of up to 27 dBA of the noise goal for daytime operations and up to 37 dBA above the night-time noise goal at the nearest residential receivers. A noise goal exceedance of this order would be unacceptable during the night-time period, and since an acoustic enclosure would not be feasible during the site establishment and piling activities, these works would need to be restricted to the daytime period.

Once excavation of the station shafts has progressed far enough to allow for installation of the acoustic enclosures, noise emission levels from the site would decrease significantly. A high performance acoustic enclosure with double skin walls, roof lined with sound absorptive material, minimised openings and acoustic louvres fitted to ventilation openings would be required in combination with use of the quietest available construction plant.

It should be noted that facade noise reductions for residential receiver buildings located within the CBD would likely perform significantly better than the 10 dBA assumed for this assessment (refer to **Section 8.1**) and that this may alter (reduce) the mitigation solutions recommended in this report.

Predicted CRR construction noise levels should be considered with respect to existing ambient noise levels in the vicinity of the two Albert Street Station worksites. Ambient night-time noise levels measured over a week at monitoring location 7 (ie 191 George Street) ranged between 70 to 78 dBA L_{Amax} and 58 to 68 dBA L_{Aeq}. Comparison of predicted night-time construction noise levels with a medium performance acoustic enclosure (eg residential receiver J-Mary Street $L_{Amax,adj}$ – 75 dBA) indicates that worst case CRR construction noise levels would be within the range of existing night-time ambient noise levels.

The ground-borne noise levels presented in **Table 61** for rockbreaking during excavation of Albert Street Station shafts are predicted to exceed the night-time noise goals for several residential receivers and one residential receiver during the daytime period. The Mary Street residential receiver would be located less than 10 m from the northern shaft and approximately 13 m slant distance from the inferred rock level. Exceedance of the daytime internal noise goal of 55 dBA L_{A10} would be anticipated until rockbreaking had progressed beyond approximately 20 m slant distance from the receiver building.

As a guide, propagation of ground-borne noise levels in buildings attenuates by approximately 2 dB per floor for the first 4 floors and by approximately 1 dB per floor thereafter. On this basis, receivers located on the first 5 floors of the building may require temporary relocation until a slant distance of approximately 20 m has been reached.

Assuming airblast overpressure can be sufficiently mitigated at the site (eg blast mat, enclosure etc), drill and blast excavation at both Albert Street Station shafts could be constrained by low MICs estimated to be:

- North shaft – 1.0 kg to comply with the vibration criterion at Mary Street residences.
- South shaft – 3.4 kg to comply with the vibration criterion at Alice Street residences.

Should drill and blast be adopted for this site, the following management measures would be required:

- Use of latest available blasting technology (eg PCF).
- Pre-blasting condition survey of adjacent buildings.
- Appropriate attention to blast design and commence blasting with a low MIC to develop a site law (ie blast design model) based on measurement data from the site.
- Monitoring the blast emissions.

It is anticipated that the initial stages of shaft excavation would be carried out by rockbreaker due to the close proximity of sensitive receiver buildings. The point at which drill and blast excavation could be safely and efficiently carried out within the shaft would be determined as part of detailed investigations for the site. Acoustically, exposure to a short-term blast event would be preferred to long term rockbreaking where ground-borne noise impacts have been identified.

Boggo Road Station

The predicted noise levels for pile installation works at the Boggo Road Station site indicate exceedances of up to 19 dBA of the noise goal for daytime operations at the nearest residential receivers in Rawnsley Street.

The predicted noise levels for the initial stages of excavation (ie prior to installation of the top slab) at the Boggo Road Station site indicate exceedances of up to 16 dBA during the day at the nearest residential receivers.

The predicted noise levels for the south entry shaft excavation once the acoustic enclosure is in place (ie Scenario 3) indicate that a high performance acoustic enclosure would be required to comply with the daytime and night-time noise goals at the nearest residential receivers in Rawnsley Street and the Leukemia Support Village. No acoustic enclosure is predicted to be required for the north entry shaft excavation.

The movement of trucks within the worksite should be designed to limit (as much as possible) the need for reversing activity and consequent reversing alarm noise. Where issues with reversing alarms occur, consideration should be given to the use of broadband “buzzer” reversing alarms and/or alarms which actively vary their volume according to the ambient noise levels during activation - rather than constant volume (tonal) “beeping” alarms.

Predicted gound-borne noise and vibration levels in **Table 67** from rockbreaking indicate compliance with the relevant goals for all sensitive receivers with the exception of the TEM located at the Eco-science precinct building. Further, the estimated blast MIC limits for Boggo Road Station, presented in **Table 67**, indicate that the allowable MIC for the worksite would be controlled by the TEM. As rockbreaking and/or drill and blasting would be required for this site, the following management measures would be required:

- Scheduling rockbreaking and blasts outside of typical TEM operating times. If this is not practicable without impacting on normal (Eco-science precinct) TEM operations, a special arrangement would need to be established so that blasting can be scheduled at a specific time.
- Appropriate attention to blast design and commence blasting with a low MIC to develop a site law (ie blast design model) based on measurement data from the site.

- Monitoring of the blast emissions.

If blasts could be scheduled outside TEM operating times, the MICs would then be limited by the heritage-listed Boggo Road Gaol (ie MIC of 0.2 kg). Consequently, blasting may not be feasible for the southern shaft nearest Boggo Road Gaol until the shaft has deepened sufficiently to allow for efficient blasting.

Vibration levels for bored piling adjacent the heritage listed Boggo Road Gaol are predicted to be below 2 mm/s based on data obtained from measurements carried out on the Northern Busway project adjacent to the Royal Brisbane and Womens Hospital. Notwithstanding this, it is recommended that vibration measurements be carried out during the commencement of bored piling at the site to determine the risk of exceeding the TEM vibration limit when piling in close proximity to the Eco-science precinct building.

11.2.4 Southern Ventilation Shaft

The predicted noise levels for the three modelled scenarios at the Southern Ventilation site indicate significant exceedances of the relevant daytime construction noise goals due to the close proximity of sensitive receivers.

Increasing the proposed 3 m perimeter acoustic hoarding to 6 m acoustic hoarding will reduce the construction noise emission levels, however several noise goal exceedances would still be expected. Since mitigating piling rig noise within an enclosure is not practicable, it is recommended that an additional piling rig be utilised at the site to expedite the works thereby reducing the exposure period. An additional (acoustically identical) piling rig operating at the site would increase the overall noise level by a marginal 3 dBA but would halve the duration.

The predicted worst case shaft excavation noise levels have been modelled on the basis of the excavation plant operating close to existing ground level. During this phase of the work, construction noise emission levels would progressively decrease over time as the excavation plant progressed deeper into the shaft.

Further reductions in noise emission level may be achieved through the following mitigation measures:

- Quietest available mobile plant operating at the site.
- Temporary tunnel ventilation noise sources to be located either down in the shaft with appropriate ducting to the surface or within a dedicated enclosure at the surface.
- Drill and blast in place of the rockbreaking to expedite the works and minimise exposure to receivers of prolonged significantly high construction noise.
- Careful placement of fixed plant (eg compressors, gensets etc) at the site to maximise shielding or separation from sensitive receivers.

An acoustic enclosure over the shaft has not been considered as part of the construction methodology as the shaft excavation works would be completed within a relatively short timeframe (ie three months) and restricted to the daytime period.

Fairfield Road traffic noise levels for 2016 are predicted to be in the order of 64 dBA to 74 dBA L_{A10} during the am and pm peak periods (ie 7 am to 9 am and 4 pm to 6 pm respectively) and 62 dBA to 72 dBA L_{A10} during the daytime off peak period (ie 9 am to 4 pm). Comparison with predicted worst case daytime construction noise levels indicates that at times road traffic noise from Fairfield Road would be higher and potentially dominate the acoustic environment in the vicinity of the Southern Ventilation Shaft worksite for the receivers closest to Fairfield Road.

The estimated blast MIC limits for the Southern Ventilation Shaft indicate that a maximum MIC of 0.9 kg would be permitted to achieve compliance with the airblast overpressure goal of 130 dB Linear Peak at the commercial receiver at location D (ie Railway Road). Assuming the airblast overpressure can be mitigated (eg blast mat, enclosing etc), a maximum MIC of 3 kg would be permitted to achieve compliance with the vibration goal of 10 mm/s PPV. With appropriately mitigated airblast overpressure, blasting would be a suitable excavation technique for this site.

11.3 Surface Track Worksites

11.3.1 Noise

CRR construction noise levels at surface track worksites are predicted to comply with the Queensland Rail CoP planning levels (with no specific mitigation) at Mayne Yard, Clapham Yard and Moorooka Station, due to the large buffer distance between the worksites and sensitive receivers. If night-time construction works are required at Mayne Yard (only for piling) or Clapham Yard, in areas where a track possession is not required, all reasonable and practicable mitigation measures would be required to comply with the 57 dBA LAmax sleep disturbance criterion applicable to other elements of the project.

At CRR surface track worksites where receivers are in close proximity, noise goal exceedances have been identified with 3 m acoustic hoarding. The exceedances include:

- Exhibition Station during piling of O’Connell Terrace (ie 2 dBA)
- Rocklea Station during station construction (ie 3 dBA)

Work associated with construction of new rail track or the upgrading of existing rail track is relatively short in duration, particularly because the work is often confined to shut down periods (eg night-time, weekend, Christmas holidays etc) which is standard Queensland Rail practice to minimise disruption to rail services.

Noise emission levels from typical rail construction plant have been provided for various setback distances for the CRR project. Significant short duration noise impacts would be expected from CRR trackwork for receivers at smaller setback distances. In addition to limiting, where practicable, the duration of track construction works near any sensitive receivers, all reasonable and feasible noise mitigation measures (consistent with the measures listed in Queensland Rail’s CoP – refer to **Section 8.3.4**) would need to be applied.

11.3.2 Vibration

During surface track construction activities, the major potential sources of vibration include rockbreakers and vibratory rollers. The majority of the surface track worksites do not require significant work and hence would not be anticipated to result in any impact on vibration sensitive receivers outside the rail corridor.

For the sites that require substantial work, including Clapham Yard, Exhibition Station and Mayne Yard viaduct, the location at which vibration intensive plant would likely be operating within these sites is far enough from sensitive residential receivers to avoid any impact. For example, substantial earthworks and compaction would be required at Clapham Yard with the nearest residential receivers located approximately 100 m to the east of the site. At this distance, compliance with both building damage and human comfort limits would be readily achieved during operation of vibratory rollers or rockbreakers.

For construction works in close proximity to heritage-listed buildings, including Exhibition Station, Yeerongpilly Station and Rocklea Station, a detailed investigation would be required to determine the risk of exceeding the 2 mm/s vibration goal. Notwithstanding this, the Reference Project at these sites results in offset distances to Queensland Rail heritage structures which would comply with the vibration goal of 2 mm/s.

11.4 Tunnelling Between Portals

11.4.1 TBM

The predicted ground-borne vibration levels result in no exceedances of the cosmetic damage vibration goal or the stricter cosmetic damage goal to heritage buildings. Exceedances of the night-time residential vibration goal are predicted. It should be noted that these exceedances would only occur during a relatively short period (less than 1 week for each TBM passby).

The maximum anticipated ground-borne noise levels occurring when the TBM is located below the receiver location have been predicted for residential and commercial receivers. The predicted maximum duration of levels exceeding the ground-borne noise goal for any residential receiver is seven days for each TBM passby. There are 5 hotels in the CBD where levels may exceed the night-time ground-borne noise goal for up to ten days; however it should be noted that the noise predictions are for the ground floor and noise levels will be lower higher up in the buildings.

The following management strategies are proposed to minimise the impact of the TBM tunnelling works:

- Ground-borne noise and vibration monitoring to be undertaken at the commencement of tunnelling to confirm that the source data utilised for this assessment is applicable to this project (including the low frequency noise assessment inputs and findings).
- Comprehensive advance notice as well as educating the public of intended tunnelling activities in the localities near the tunnel alignment. Part of the consultation process should include information regarding the monitoring program which may require involvement from residences located above the tunnel alignment. A thorough education program will assist to allay fears of the tunnelling process.
- Conduct building condition surveys in accordance with Brisbane City Council requirements where it is considered there may be potential risk for cosmetic (superficial) building damage from TBM excavation.
- Relocation of residents particularly impacted by ground-borne noise from TBM tunnelling may be required.

11.4.2 Roadheader

Ground-borne noise and vibration levels from roadheader tunnelling works associated with the cross-passages between the two tunnels, station caverns and close to the northern portal have been assessed. The roadheader generates lower ground-borne noise and vibration levels compared to the TBMs.

All residential receivers are complying with the ground-borne vibration goals during the roadheader tunnelling works.

There are 22 predicted exceedances of the night-time ground-borne noise goal for residential receivers above or close to the cross passages (13 of these are within a marginal 2 dBA exceedance). It should be noted that the ground-borne noise and vibration from excavation of cross passages will be short duration (2 to 3 days) works. All commercial receivers comply with the relevant 45 dBA (office spaces) and 50 dBA (retail) ground-borne noise goals.

Exceedances of the ground-borne noise and vibration goals for two hotels near Albert Street station have been predicted. It should, however, be noted that the predicted levels are for the ground floor and the ground-borne noise and vibration levels attenuate by approximately 2 dB per floor for the first 4 floors and by approximately 1 dB per floor thereafter. This results in exceedances of the ground-borne noise and vibration goals only for hotel rooms on the Ground Floor and Floor 1.

11.5 Low Frequency Noise Assessment

The low frequency noise assessment indicates that annoyance limits would likely be exceeded during driven tunnelling works for offset distances up to approximately 100 m associated with the CRR.

The recommended noise and vibration management plan should cover the potential for low frequency noise impacts, with the following recommendations as a minimum:

- A comprehensive notification and education program to assist in allaying fears regarding tunnelling. Part of the education process will include an indication of tunnelling progress and subsequent likely (temporary) exposure periods.
- Infrasound and low frequency noise measurements in accordance with the ALFN guideline at the commencement of tunnelling operations and in the event of a “low frequency” noise complaint (if required).
- An option for temporary relocation of people pending the outcome of an assessment of the impact against the EIS goals and ALFN Guideline.

11.6 Construction Traffic

The increase in road traffic noise due to CRR spoil traffic is predicted to be less than 2 dBA on all spoil roads at adjacent residential receiver locations. It is generally recognised in acoustics that changes in noise levels of 2 dBA or less are undetectable to the human ear and therefore negligible.

The absolute maximum noise levels associated with vehicle pass-bys would not be altered by CRR construction vehicles (see recommendation for all CRR spoil trucks to be tested against ADR 28/01), however, the frequency of such events would increase.

Best practice noise management practices should be incorporated into management of spoil removal as required by the General Environmental Duty under the Environmental Protection Act 1994.

12 REFERENCES

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13 CLOSURE

This report has been prepared by SLR Consulting with all reasonable skill, care and diligence, and taking account of the manpower and resources devoted to it by agreement with the client. Information reported herein is based on the interpretation of data collected and has been accepted in good faith as being accurate and valid.

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