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APPENDICES

1 INTRODUCTION

SLR Consulting Australia Pty Ltd (SLR) has been commissioned by the SKM-AECOM Joint Venture (JV) to prepare an assessment of the noise and vibration aspects of the construction phase for BaT (Bus and Train) project (BaT project) for inclusion in the Environmental Impact Statement (EIS).

The BaT project 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. An overview of the major work sites proposed as part of the Reference Project is shown in **Figure 3.**

1.1 Terms of Reference

Objective: Development is planned, designed, constructed and operated to protect the environmental values of the acoustic environment.

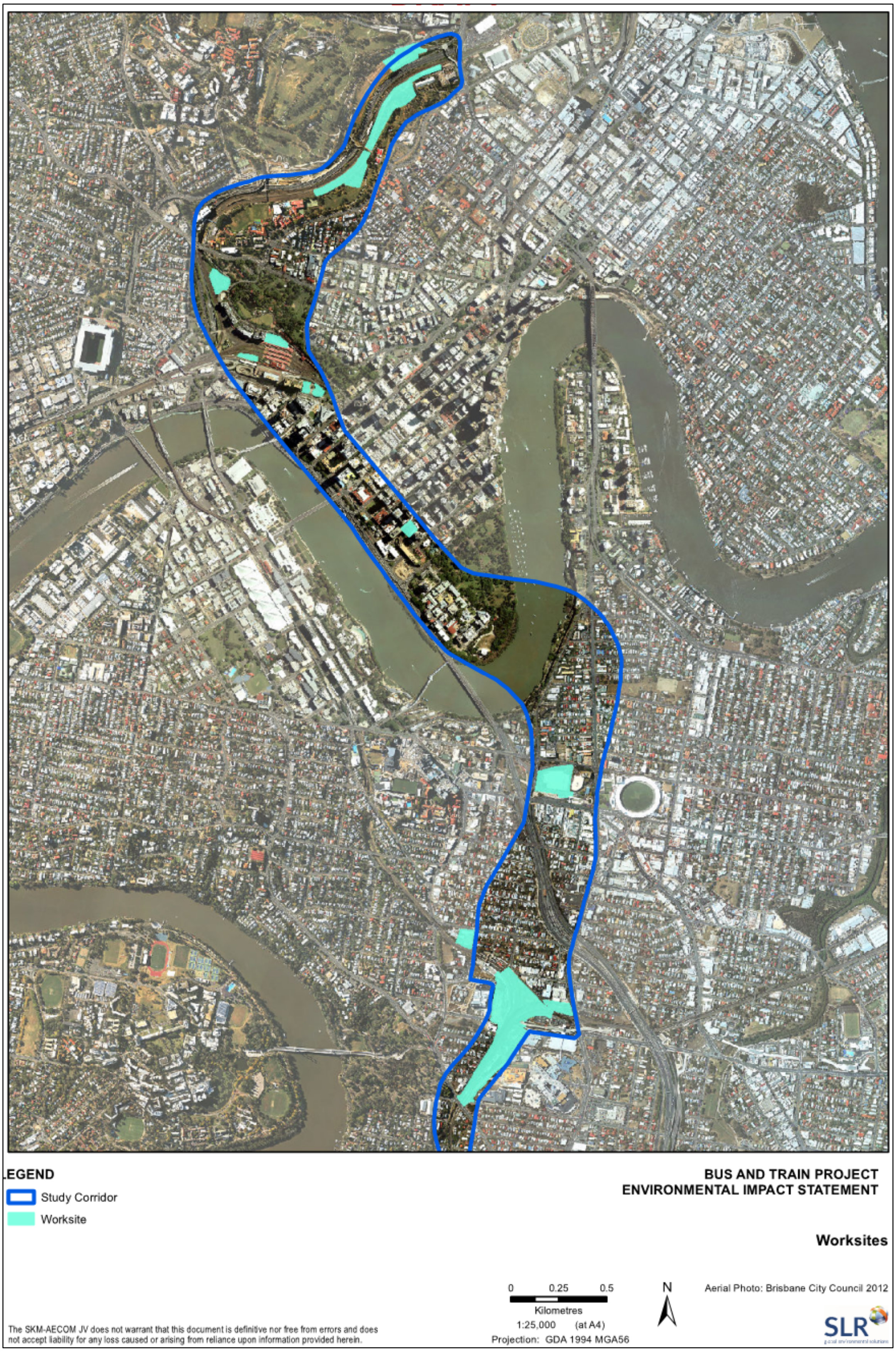
- Fully describe the characteristics of the noise and vibration sources that would be emitted when carrying out the activity (point source and general emissions). Describe noise and vibration emissions that may occur during construction, commissioning, upset conditions, and operation.
- Predict the impacts of the noise emissions and vibration from the construction and operation of the project on the environmental values of the receiving environment, with reference to sensitive receptors, using recognised quality assured methods. Discuss separately the key project components likely to present an impact on noise and vibration for the construction and operation phases of the project.
- Taking into account the practices and procedures that would be used to avoid or minimise impacts, the impact prediction must address the:
    - activity's consistency with the objectives
    - cumulative impact of the noise with other known emissions of noise associated with existing development and possible future development (as described by approved plans)
    - potential impacts of any low-frequency (<200 Hz) noise emissions
    - potential vibration impacts on sensitive receptors and transport-related infrastructure.
- Describe how the proposed activity, and in particular, the key project components described above, would be managed to be consistent with best practice environmental management for the activity. Where a government plan is relevant to the activity, or the site where the activity is proposed, describe the activity's consistency with that plan.
- Describe how the achievement of the objectives would be monitored and audited, and how corrective actions would be managed.

1.2 Report Objectives

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

- Address the acoustical requirements detailed in the Terms of Reference (see **Section 1.1**) in relation to the construction phase of the BaT project.
- Identify sensitive locations in relation to construction noise and vibration and 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 BaT 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.

Figure 3 BaT Project Major Worksites Overview



2 NOISE AND VIBRATION TERMINOLOGY

2.1 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 LP are commonly used to represent Sound Pressure Level. The symbol LA represents A-weighted Sound Pressure Level. The noise level descriptors that have been utilised within this report are illustrated in **Figure 4** and described below**.**

LAmax 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 4 Graphical Display of Typical Noise Indices

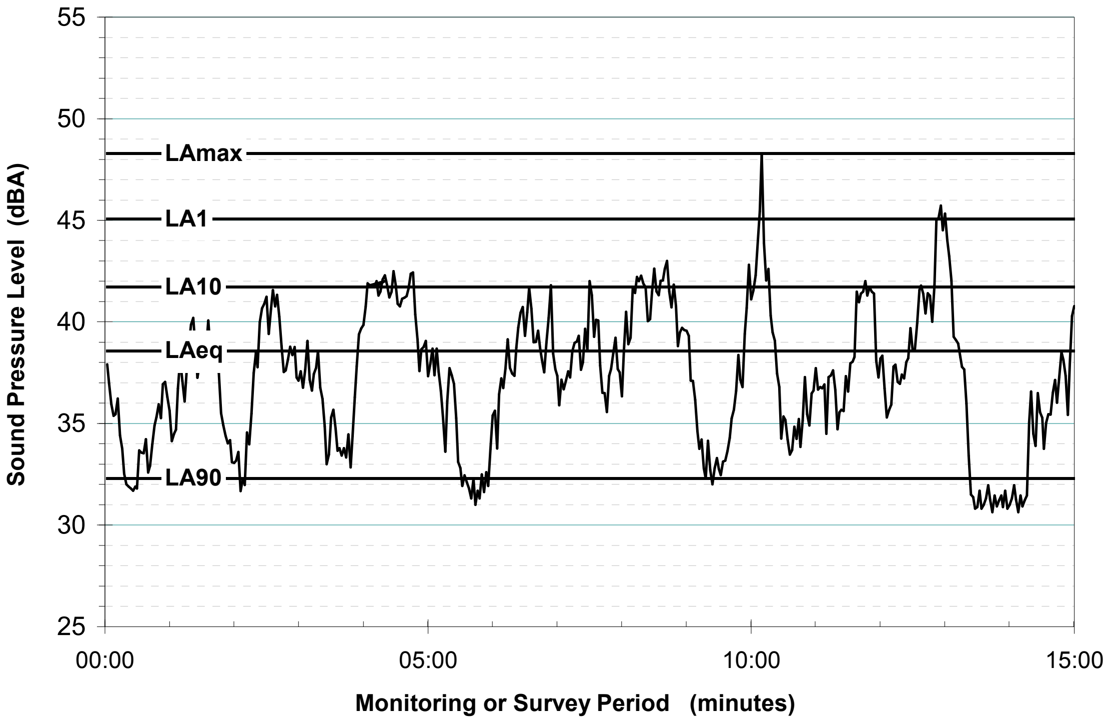


Table 22 presents examples of typical noise levels.

Table 22 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.

2.2 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).

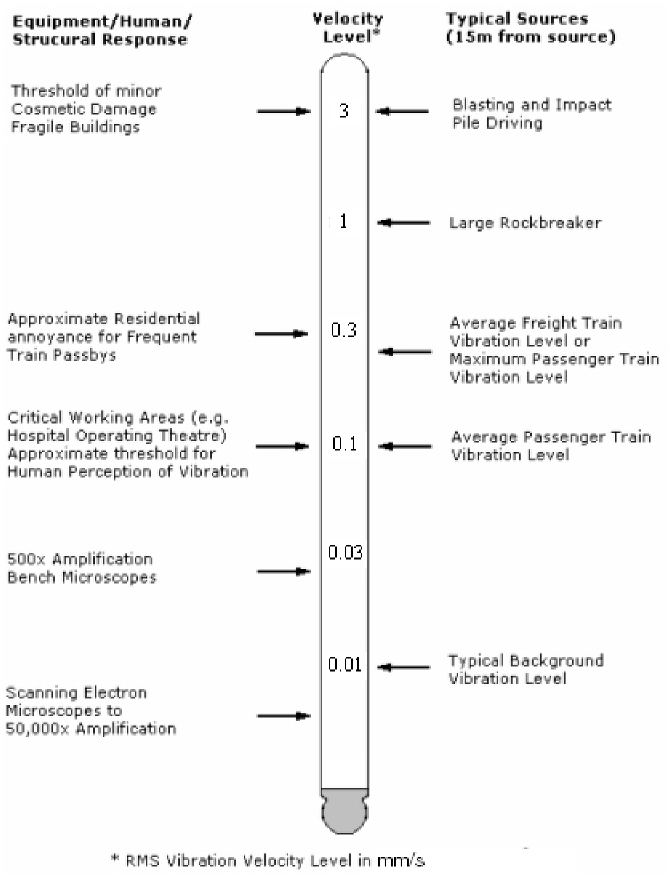
As with noise, decibel units can also be used, in which case the reference level should always be stated. Usually, the vibration velocity level is expressed in dB_V (ref 10^{-9} m/s). The character of vibration emissions can be continuous, intermittent or impulsive.

As for noise, the vibration can be described with the same level descriptors as presented and explained in **Section 2.1**. The corresponding vibration descriptors are V_{max}, V_1, V_{10}, V_{eq}, V_{90}.

Figure 5 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 5 Typical Vibration Levels



2.3 Ground-Borne Noise

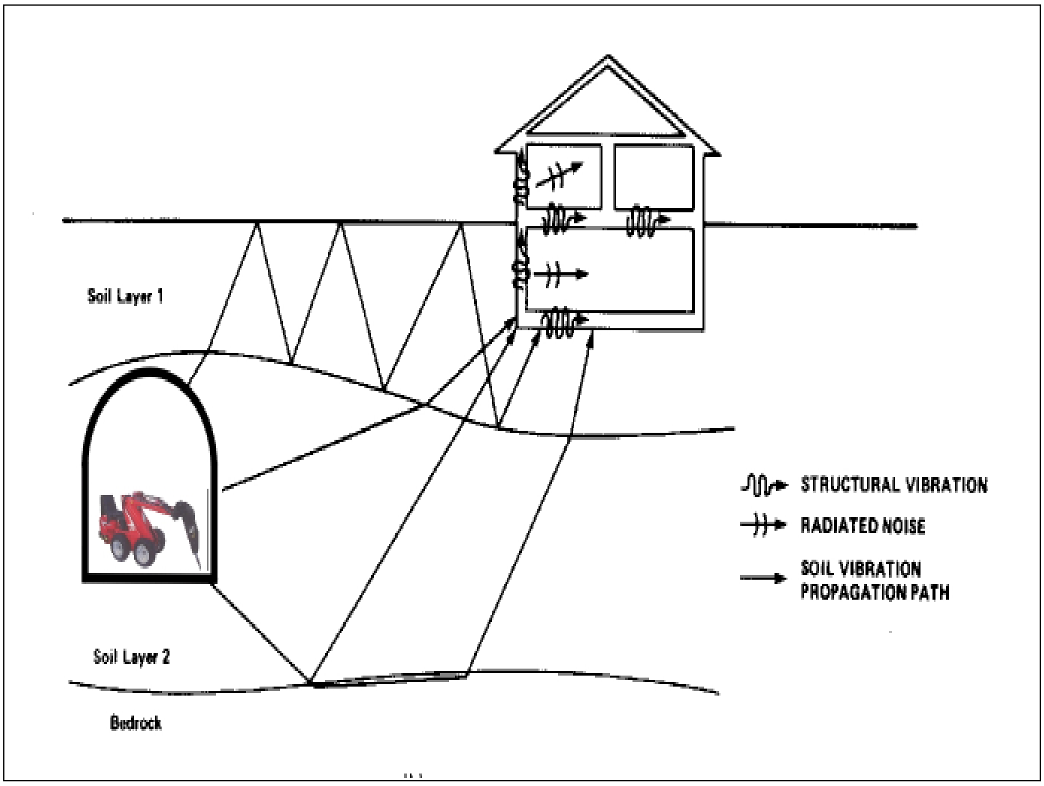
Noise that propagates through a structure as vibration and is radiated by vibrating wall, ceiling and floor surfaces is termed "ground-borne noise", "regenerated noise", or sometimes "structure-borne noise". Ground-borne noise originates as vibration and propagates between the source and receiver through 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 (e.g. rockbreakers), and building services plant (e.g. 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 6 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 6 Vibration and Ground-borne Noise Transmission Paths



3 IMPACT ASSESSMENT GOALS

3.1 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.

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.

3.1.1 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 or bus operations for this project. The acoustic quality objectives will be considered for assessing the ventilation and mechanical plant noise associated with the new rail and ventilation stations as these will be permanent long-term noise sources.

3.1.2 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.

3.2 Construction Noise Impact Assessment Goals

3.2.1 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 23**.

Table 23 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 BaT project would require approval to operate outside of the regulated hours.

3.2.2 Assessment Philosophy for Extended Construction Works

It is anticipated that the BaT project would involve the operation of certain noise sources on worksites (e.g. 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 goals for long-term construction noise sources should reflect the noise environment that is considered acceptable for normal functioning of adjoining areas.

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

- Sleep disturbance criteria contained in the World Health Organisation’s Night Noise Guidelines for Europe (2009).
- 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 specific noise goals for sleep disturbance and recommended noise levels for various building functions are discussed in the following sections.

Appropriate noise goals for relatively short term construction noise sources such as surface track construction (refer to **Section 3.2.3**), ground-borne noise from driven tunnelling (refer to **Section 3.2.4**) and airblast over-pressure from blasting (refer to **Section 3.2.5**) is also discussed.

The existing ambient noise levels measured as part of this assessment (refer to **Section 4.1**) have also been taken into account in nominating these construction noise goals.

Sleep Preservation

The World Health Organisation’s (WHO) *Night Noise Guidelines for Europe 2009* presents the findings of a WHO working group responsible for preparing guidelines for exposure to noise during sleep, and is an extension to WHO’s *Guideline for Community Noise (1999).*

Night Noise Guidelines for Europe 2009 states the following in relation to the 30 dBA L_{Aeq} for continuous noise and 45 dBA L_{Amax} for non-continuous noise (both internal) levels stated in *Guideline for Community Noise (1999)*:

It should also be borne in mind that the 1999 guidelines are based on studies carried out up to 1995 (and a few meta-analyses some years later). Important new studies (Passchier-Vermeer et al., 2002; Basner et al., 2004) have become available since then, together with new insights into normal and disturbed sleep.

Comparing the above statement with the recommendations, it is clear that new information has made more precise statements possible. The thresholds are now known to be lower than 45 dBA L_{Amax} for a number of effects.

From Table 5.1 “Summary of Effects and Threshold Levels for Effects Where Sufficient Evidence is Available” (in *Night Noise Guidelines for Europe 2009*), the threshold level for non-continuous noise events is (now) 42 dBA L_{Amax}.

SLR understands that the Department of Environment and Heritage Protection (EHP) currently recommends the use of 42 dBA L_{Amax} (internal) as the appropriate limit to avoid sleep disturbance for non-continuous noise sources.

Functional Noise Levels for Various Building Uses

The maximum recommended internal noise levels specified in AS 2107 are shown in **Table 24** 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 24 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 (e.g. 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.

3.2.3 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 construction noise levels from the BaT project surface track upgrades occurring over a relatively short term period (i.e. in the order of two to three days), such as that typically experienced during a weekend track possession (ie temporary closure).

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

QR 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} 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.

QR Planning Levels

Queensland Rail's Code of Practice outlines the "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}.

3.2.4 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 24**) are recommended as guidance for the purpose of assessing ground-borne noise levels within buildings during the construction phase of the BaT 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 25.**

Table 25 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 $L_{pA,LF}$.

The Ecoaccess ALFN guideline also gives advice regarding assessment of infrasound. However, the construction works associated with the BaT project 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 EcoAccess ALFN guideline) by 5 dBA.

3.2.5 Airblast Overpressure from Blasting

Noise criteria for blasting events can be found in the Act and EHP's EcoAccess Noise and Vibration from Blasting (Ecoaccess Blasting) and the United States Bureau of Mines (USBM) Report of Investigation RI 8507. These criteria are summarised in **Table 26**.

Table 26 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 (i.e. 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 BaT project. 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 132 dB Linear peak in line with the cosmetic damage limits from USBM and the criteria from recent large tunnelling projects in Brisbane.

3.2.6 Construction Road Traffic Noise

Where the construction phase of the BaT project 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 27** is recommended.

Table 27 Construction Road Traffic Noise Goal

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

3.2.7 Construction Noise Goals Summary

A summary of applicable noise goals at noise sensitive receptors associated with the construction phase of the BaT project is shown in **Table 28.**

Table 28 Construction Noise Goals

Construction Noise				Blasting [1] Airblast	Surface Track Worksites Queensland Rail Code of Practice	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 ($L_{Aeq,adj,15min}$) Maximum Design Level according to AS 2107 **Non-Steady State** ($L_{A10,adj,15min}$) Maximum Design Level according to AS 2107 + 10 dBA	35 dBA $L_{Aeq,adj(15min)}$	42 dBA L_{Amax}	25 dBA $L_{pA.LF}$	132 dB Linear Peak	87 dBA L_{Amax} 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 WHO. Internal noise level in bedroom
3: Low frequency assessment in accordance with EHP's 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 BaT 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 and background noise environment throughout the study area (see **Section 4.1.4**). 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 (e.g. 50 dBA L_{A10} internal noise level for intermittent noise sources at residences in inner-city locations).

3.3 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.

3.3.1 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 29**

Table 29 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 29 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 (i.e. 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 (e.g. 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 (i.e. below which the probability of “adverse comment” is low) from AS 2670.2 are shown in (for generally sinusoidal vibration).

Table 30 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 (e.g. 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 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 (e.g. 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.

3.3.2 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 (i.e. plants, hanging pictures, blinds, etc) is approximately 0.5 mm/s and audible rattling of loose objects (i.e. 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 (i.e. by sound pressure waves, which may be thought of as vibration in the air).

In any premises, day-to-day activities (e.g., 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 31**. Also included in **Table 31** are the estimated equivalent vibration velocity criteria, based on evenly distributed vibration energy within each of the specified frequency ranges.

Table 31 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.

3.3.3 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 32** 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 32** should be halved.

Table 32 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 32** 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.

3.3.4 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 (i.e. compaction), construction equipment, tunnelling, road and rail traffic and industrial machinery.

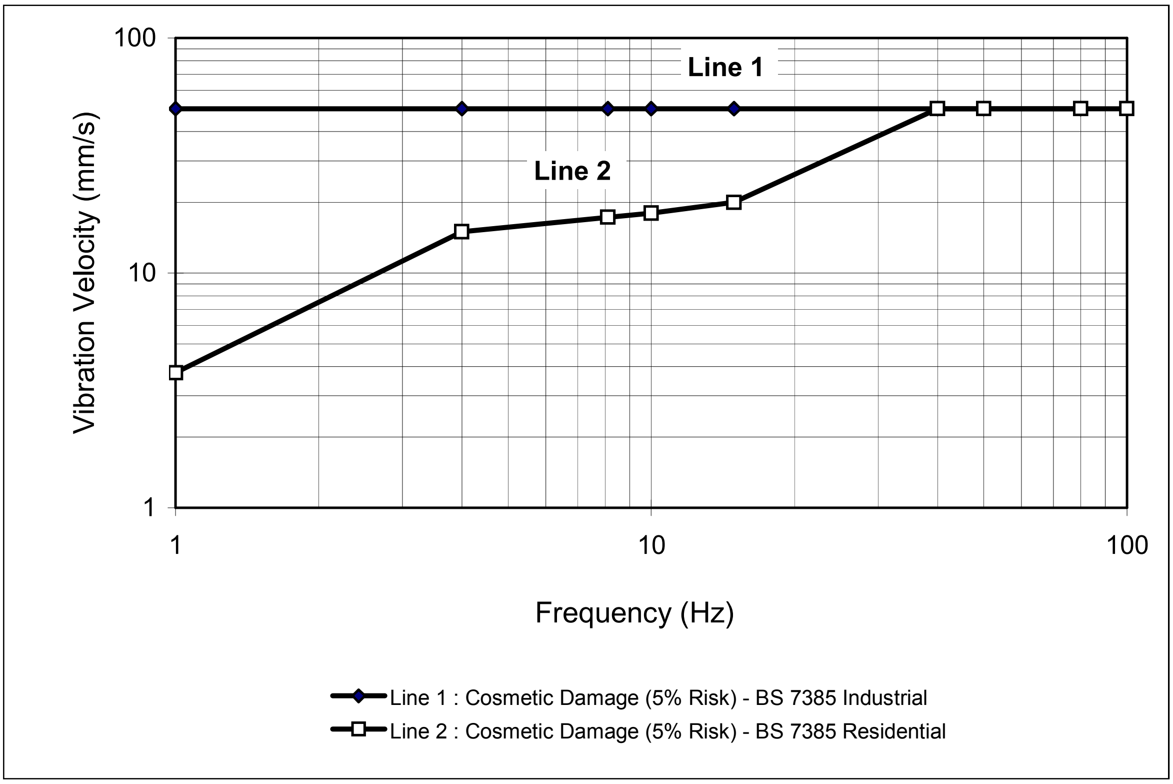
As the strain imposed on a building at foundation level is proportional to the peak particle velocity but is inversely proportional to the propagation velocity of the shear or compression waves in the ground, this quantity (i.e. peak particle velocity) has been found to be the best single descriptor 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 33** and graphically in **Figure 7**.

Table 33 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 7 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 33** should not be reduced for fatigue considerations.

Nevertheless, the standard states that the guide values in **Table 33** 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 33** may need to be reduced by up to 50%.

It is noteworthy that additional to the guide values nominated in **Table 33**, 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 34**.

Table 34 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)

For assessment of vibration impacts relating to cosmetic damage from the construction stage of the BaT project, it is recommended not to exceed the guide values from BS 7385. BS 7385 also states that minor damage is possible at vibration magnitudes which are greater than twice those given in **Table 33**, and major damage to a building structure may occur at values greater than four times the values in **Table 33**.

3.3.5 Vibrations from Blasting

Vibration criteria for blasting events can be found in the Act, EHP's *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), Department of Transport and Main Roads (DTMR) Technical Standard MRTS51 and BS 7385. The blasting vibration criteria are summarised in **Table 35**.

Table 35 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)
BS 7385	50 mm/s PCPV at 4 Hz and above for reinforced or framed structures and heavy commercial buildings (such as those in the vicinity of the Roma St and George St worksites

Note 1: Peak Particle Velocity (PPV), Peak Component Particle Velocity (PCPV). Refer to BS 7385 for definitions of PPV and PCPV.

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 BaT project. 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).

Blasting is only proposed at the Roma Street station and George Street station worksites. Given the nature of the structures surrounding these sites as well as the extent of experience gained from blasting at other major construction sites in Brisbane, it is proposed that the cosmetic damage guide values from BS 7385 be adopted for the assessment of the BaT project for all non-heritage structures.

With regards to heritage structures, BS 7385 states that a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive. Notwithstanding this and the other heritage specific criteria outlined in **Table 35**, it is proposed that the blasting vibration assessment for heritage structures be assessed against a guide value of 10 mm/s. This is consistent with the most stringent criterion from the Act and is also in line with limits adopted for a recent blasting project successfully carried out (i.e. no cosmetic damage) in the CBD adjacent to a heritage building. Pre- and post-construction building condition surveys for all heritage structures in the vicinity of the Roma Street and George Street blasting worksites would also assist with the preservation of these structures.

3.3.6 Construction Vibration Goals Summary

A summary of applicable vibration goals at sensitive receptors associated with the construction phase of the BaT project is shown in **Table 36**.

Table 36 Construction Vibration Goals

Receiver Type	Cosmetic Damage			Human Comfort (mm/s PPV)		Sensitive Building Contents (mm/s PPV)
	Continuous Vibration (mm/s PPV)	Transient Vibration (mm/s PPV)	Blasting Vibration (mm/s PPV) [1]	Day	Night	
Residential	According to BS7385 (refer to Table 33) reduced by 50%	According to BS7385 (refer to Table 33)	50[2]	According to AS2670 (refer to Table 30)	0.5[3]	-
Commercial	According to BS7385 (refer to Table 33) reduced by 50%	According to BS7385 (refer to Table 33)	50	According to AS2670 (refer to Table 30)	-	0.5[4]
Heritage Structures	2		10	-	-	-

Note 1: Blasting should generally only be permitted during the hours of 7 am to 6 pm, Monday to Saturdays.

Note 2: All residential receivers in the vicinity of BaT project blasting sites are regarded as reinforced or framed structures (i.e. BS 7385 Line 1 - refer to Table 33)

Note 3: Residential sleep disturbance

Note 4: Equipment specific vibration criteria is required for highly sensitive equipment (i.e. electron microscopes, MRI systems or similar), as part of future site-specific detailed investigations.

4 EXISTING ENVIRONMENT

4.1 Noise

This section presents the results of the ambient monitoring surveys carried out for the BaT project. Ambient noise monitoring was conducted at 18 residential and special use (i.e. educational or medical) locations evenly spaced along the study corridor. The data for 11 of these locations were taken from a previous project where monitoring was conducted in May 2010. These locations were considered representative of the current BaT project. Both attended and unattended ambient noise measurements have been conducted at an additional seven (7) locations 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. The only exceptions to this program were:
  - Location 9 (803 Stanley Street) where only one (1) full day was possible due to logger malfunction and access restrictions.
  - Location 17 (Parkland Boulevard Building 3) and Location 18 (Floor 27, 21 Mary Street) where monitoring was carried out over a 48 hour period for the purpose of quantifying facade noise reductions of the nearest residential buildings to the Roma Street Station and George Street Station worksites respectively.
- Attended 15 minute noise measurements 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 undertaken in 2010, was performed between 7 May and 28 May 2010 for at least seven (7) days at each monitoring location. These locations are highlighted green in **Figure 8**.

Noise monitoring at the additional seven (7) locations was undertaken between 11 March and 1 May 2014. These locations are highlighted orange in **Figure 8**.

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 SVAN 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 are 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 SLM's were checked for calibration before and after each set of noise measurements using a Brüel & Kjær 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.

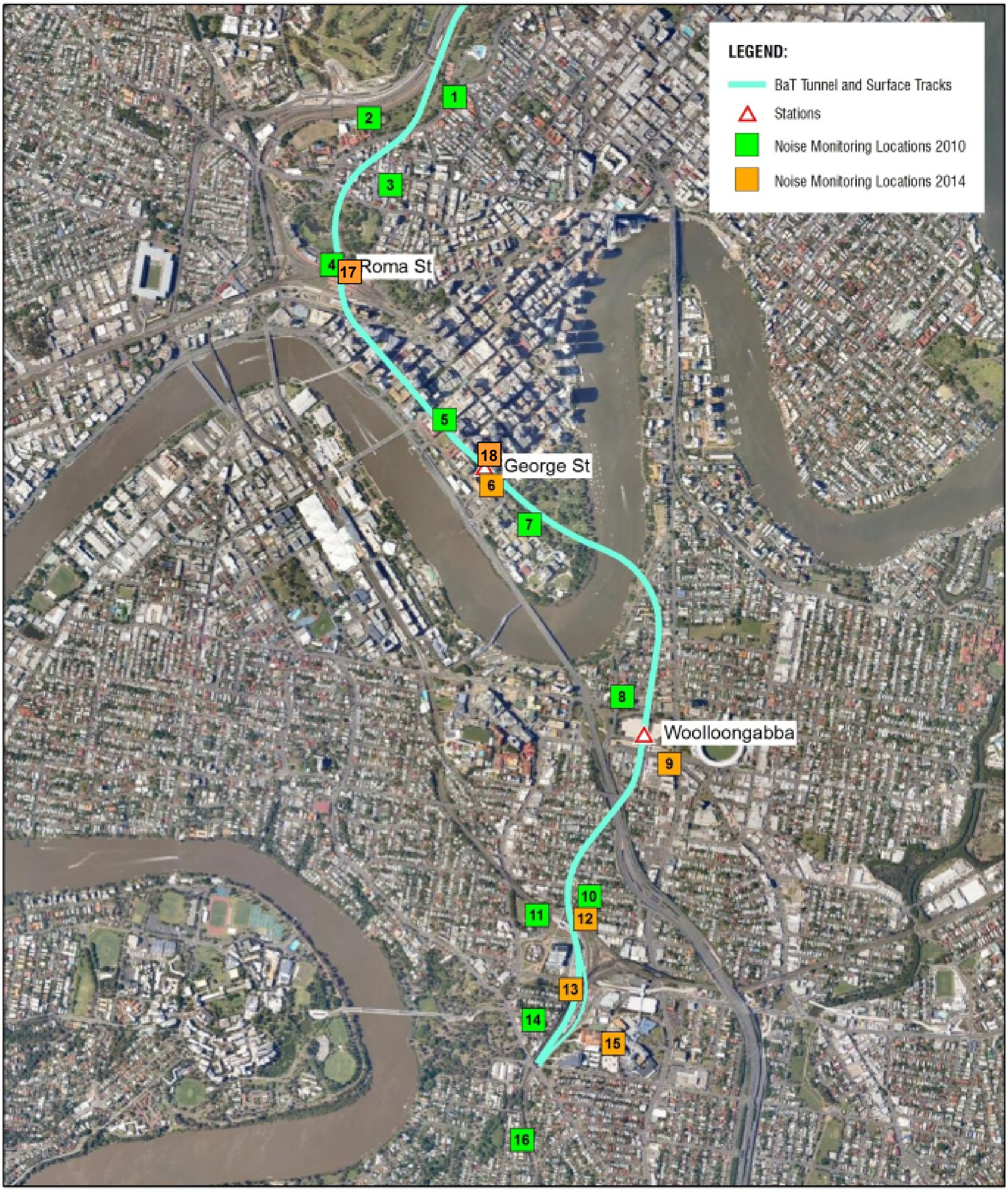
4.1.3 Noise Monitoring Locations

Noise monitoring locations have been selected to be representative of residential areas as well as special receivers (i.e. Educational and Health Care Facilities) along the corridor that may be potentially affected by the BaT project. 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 8**.

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

Figure 8 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 37** contains the determined RBL for each measurement location.

Table 37 Measured Rating Background Levels

Monitoring Location		Rating Background Levels (RBL), LA90 (dBA)		
		Day	Evening	Night
1	St Josephs College	50	48	40
2	Brisbane Girls Grammar	61	60	46
3	St Andrews War Memorial Hospital	55	53	51
4	Parkland Cres	54	50	47
5	191 George St	58	57	54
6	40 George Street, The Mansions	59	55	51
7	QUT Gardens Point	49	48	46
8	58 Leopard St	53	50	46
9	803 Stanley St [1]	58	57	51
10	143 Park Rd	43	39	34
11	Dutton Park State School	44	40	35
12	26 Elliot St	46	44	40
13	68 Railway Tce, Leukaemia Centre	47	45	41
14	19 Dutton St	43	42	37
15	Princess Alexandra Hospital	54	54	53
16	4 Fenton St	39	38	34
17	Parkland Boulevard (Level 3 conference meeting room, Building 3) [2]	RBL: 53 (30) LAeq: 61 (37)	RBL: 50 (27) LAeq: 58 (35)	RBL: 44 (<24) [3] LAeq: 55 (31)
18	21 Mary Street (Level 27 unit 1) [2]	RBL: 56 (33 – Living room) LAeq: 58 (34)	RBL: 55 (-) [4] LAeq: 56 (-) [4]	RBL: 53 (27 - Bedroom) LAeq: 56 (30)

Note 1: RBL based on only one (1) full day of data due to logger malfunction and access restrictions.

Note 2: Levels in brackets were measured inside the building.

Note 3: Actual noise level was below the instrument noise floor of 24 dBA.

Note 4: Evening period data not available due to logger malfunction at 21 Mary Street.

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 Station. 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.

On review of the measured ambient noise levels, the statistical noise plots (**Appendix B**), the 1/3 octave attended measurements and operator notes in **Table 38**, only one location (143 Park Rd) showed 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 37** to generate a conservatively low (i.e. no insects present) background noise level.

It is expected that there would be periods during the year when ambient noise levels along the BaT project could be higher than those shown in **Table 37** 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 noise barriers.

High noise levels have also been monitored at St Andrew Hospital, Parkland Boulevard, 21 Mary Street, 191 George Street, 40 George Street, 803 Stanley Street and PA Hospital. These are representative of typical inner city locations with high density of road and rail traffic, pedestrian activity and nearby mechanical noise. Noise levels measured on the balcony of 21 Mary Street were primarily dominated by rooftop mechanical plant from surrounding buildings.

Monitoring locations 10 through to 16 (with the exception of 15, the PA Hospital) show lower ambient noise levels, representative of locations with more suburban characteristics - i.e. larger distances from receivers to dominant noise sources. For most locations, including these suburban locations (somewhat) distant to major roads, road and rail traffic noise still dominates background noise levels.

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 (i.e. three (3) 15 minute attended measurements were taken at each location). The results of these measurements are summarised in **Table 38.**

Table 38 Attended Ambient Measurement Results – Day, Evening and Night-Time Periods

Monitoring Location	Date	Time (start of 15 min period)	Measured Noise Level (dBA)				Dominant Noise Sources/Comments
			LA90	LAeq	LA10	LA1	
1.	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.
2.	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.
3.	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.

Monitoring Location	Date	Time (start of 15 min period)	Measured Noise Level (dBA)				Dominant Noise Sources/Comments
			LA90	LAeq	LA10	LA1	
							Ventilation noise. Road cleaner passed by.
4.	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.
5.	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.
6.	14/03/14	11:27	51	53	55	60	Traffic from George street dominant. Pedestrian crossing noise intermittent with occasional heavy vehicle passby.
	20/03/14	18:34	56	62	65	70	Traffic from George street dominant. Pedestrian crossing noise intermittent.
	21/03/14	00:04	49	58	50	68	Humming from air conditioning vents dominant with intermittent car passbys.
7.	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.
8.	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.
	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.
9.	21/03/14	14:09	65	71	73	76	Road traffic noise dominant. A/C units in neighbouring apartments audible.
	20/03/14	19:05	61	68	71	73	Road traffic noise dominant.

Monitoring Location	Date	Time (start of 15 min period)	Measured Noise Level (dBA)				Dominant Noise Sources/Comments
			LA90	LAeq	LA10	LA1	
							Pedestrian crossing alarms. A/C units in neighbouring apartments audible.
	21/03/14	00:45	54	57	61	65	Intermittent road traffic, dominant when present. A/C units in neighbouring apartments audible. A TV set from neighbouring apartment just audible.
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.	01/04/14	15:30	50	64	67	80	Train squeal intermittent; train horn = max; frequent train pass-bys; train movements (pass-bys on various tracks, accelerating and decelerating) dominant; intermittent local traffic; neighbour mowing and people talking nearby for few min up to 59dB; motorway noise audible
	26/03/14	20:10	47	64	68	77	Passenger and freight train passby dominant noise source. Distant road traffic, insect noise.
	27/03/14	00:15	42	60	58	74	Insect noise and distant road traffic noise dominant. Intermittent rail passbys.
13.	11/03/14	15:00	55	62	66	73	Road traffic noise dominant most of the time. Plane flyover, train passby, intermittent bird chipping, intermittent nearby construction generator.
	20/03/14	20:42	47	57	57	70	Road traffic and rail traffic noise dominant. Insect noise clearly audible.
	21/03/14	2:00	47	49	50	56	Insect noise dominant
14.	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

Monitoring Location	Date	Time (start of 15 min period)	Measured Noise Level (dBA)				Dominant Noise Sources/Comments
			LA90	LAeq	LA10	LA1	
	20/05/10	21:29	39	47	45	61	Road traffic noise intermittent. Insect noise (low noise level) 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.
15.	14/03/14	11:27	51	53	55	60	Humming of air-conditioning vents dominant, intermittent banging noise and hospital traffic audible.
	26/03/14	19:41	52	53	54	55	Humming of air-conditioning vents dominant, distant aircraft, train passby and noise from a nearby closing roller door.
	26/03/14	23:53	51	51	51	52	Humming of air-conditioning vents dominant, distant road traffic just audible and train passby.
16.	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	00:01	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.
17[1].	29/04/14	13:06	55 (31)	59 (35)	61 (36)	81 (50)	Noise environment dominated by rail operations at Roma Street Station
	29/04/14	19:45	51 (31)	59 (36)	61 (39)	69 (45)	Noise environment dominated by rail operations at Roma Street Station
	29/04/14	22:03	(26)	(30)	(33)	(38)	Noise environment dominated by rail operations at Roma Street Station
18[1].	29/04/14	15:30	63 (33)	63 (40)	64 (40)	66 (44)	Noise environment dominated by rooftop mechanical plant and traffic noise
	29/04/14	20:30	61 (31)	62 (32)	62 (33)	64 (36)	Noise environment dominated by rooftop mechanical plant and traffic noise
	29/04/14	23:15	(30)	(31)	(32)	(34)	Noise environment dominated by rooftop mechanical plant

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)

Note 1: Levels in brackets were measured inside the building.

The attended measurements and observations summarised in **Table 38**, 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 one (1) monitoring locations (Location 10, 143 Park Rd) 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.

Monitoring location 5 (191 George Street) 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 representative of CBD living.

4.2 Vibration

Unlike noise, existing ambient vibration levels at residences and other sensitive buildings are not significant 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. Existing vibration levels along the study corridor were measured to (if required) compare with future vibration levels with the BaT project in operation.

This section presents the results of the ambient vibration monitoring surveys carried out for the BaT project. The data for eight (8) of these locations were taken from a previous project where monitoring was conducted in May 2010. These locations were considered representative of the current BaT project. Ambient vibration measurements have been conducted at an additional two (2) locations in order to accurately document the existing vibration environment.

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 and 25 May 2010 and 12 and 20 March 2014, 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.

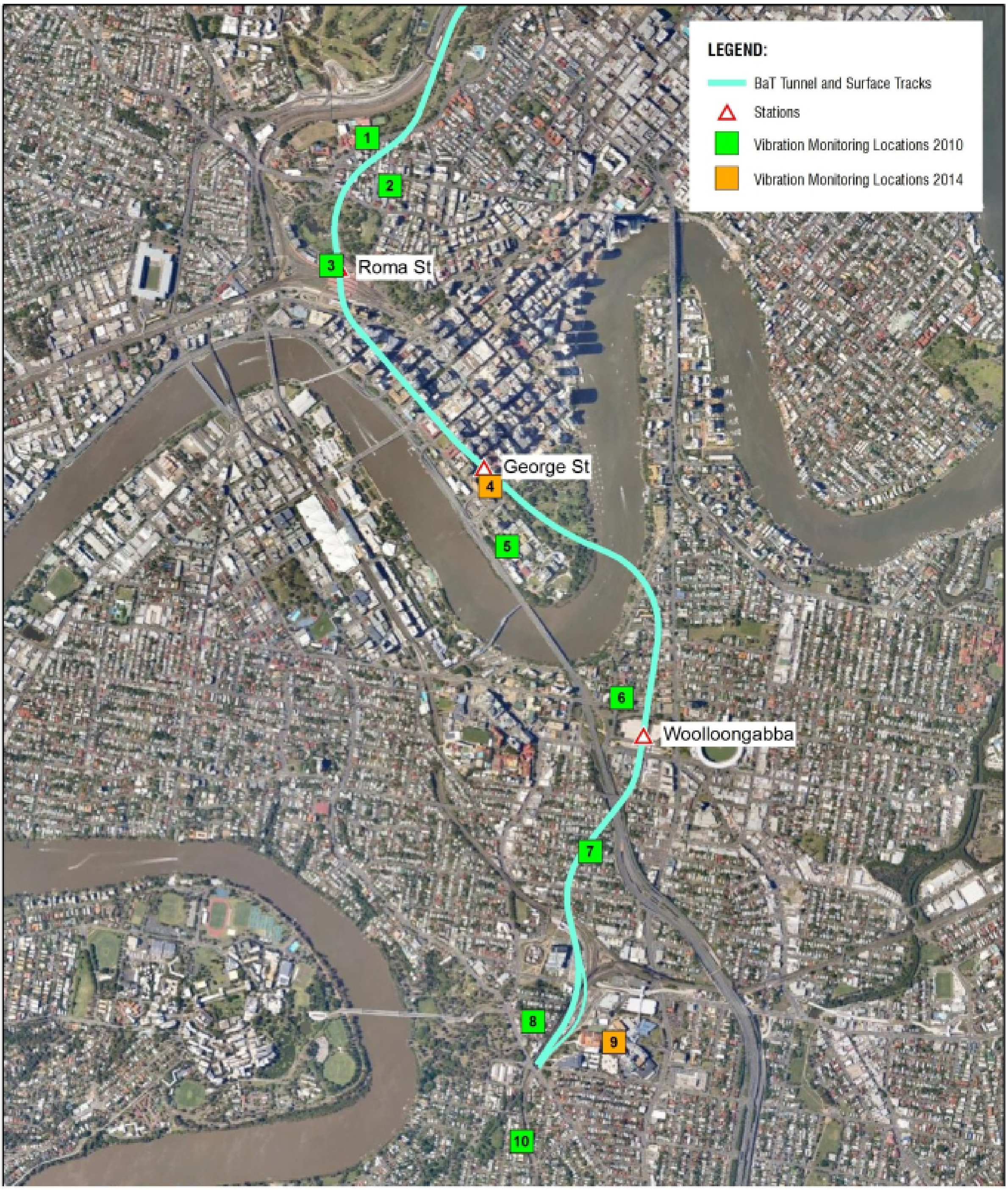
4.2.3 Vibration Monitoring Locations

Vibration monitoring locations have been selected to be representative of residential areas as well as special receivers (i.e. educational/research or health care facilities) along the corridor that may be potentially affected by the BaT project. 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 9**, with locations monitored in 2010 highlighted green and locations monitored in 2014 highlighted orange.

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

Figure 9 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 39** contains the determined vibration levels for each measurement location. Graphs showing the peak particle velocity (mm/s) measured at each monitoring location during the monitoring period are presented in **Appendix D**.

Table 39 Measured Existing Ambient Vibration

Monitoring Location[1]	Average Minimum Background Vibration V_{90} (mm/s) [2]			Average Maximum Vibration V_{10} (mm/s) [3]			Maximum Vibration V_1 (mm/s) [4]		
	Day	**Evening**	**Night**	**Day**	**Evening**	**Night**	**Day**	**Evening**	**Night**
1	0.04	0.04	0.04	0.05	0.05	0.05	0.08	0.05	0.05
2	0.03	0.03	0.02	0.08	0.05	0.04	0.17	0.08	0.06
3	0.04	0.04	0.03	0.06	0.05	0.04	0.07	0.07	0.06
4	0.08	-	-	0.09	-	-	0.10	-	-
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	0.13	0.11	0.11	0.79	0.53	0.13	2.50	1.53	0.36
10	0.04	0.06	0.04	0.70	0.84	0.23	2.69	1.61	0.71

Note 1: All monitoring locations are residential excluding locations 2 to 5.

Note 2: The V90 is the vibration velocity exceeded 90% of a given measurement period and is representative of the average minimum background vibration.

Note 3: The V10 is the vibration velocity exceeded 10% of a given measurement period and is utilised normally to characterise average maximum vibration.

Note 4: The V1 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 is higher than this V1 as can be seen in **Appendix D**.

The background vibration level (V_{90}) for all sites varies between 0.01 mm/s to 0.13 mm/s during daytime and evening. During the night-time, the background vibration level (V_{90}) varies between 0.01 mm/s to 0.11 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 mm/s 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 residential locations 6, 7 and 10 which are on floors in residential dwellings. This shows that normal activities (i.e. closing doors, drawers and cupboards, walking, moving and sitting on furniture etc) in these residential dwelling generated vibration levels above the vibration goals presented in **Section 3.3**.

For receivers with vibration sensitive equipment locations 3 (St Andrews Hospital), location 5 (QUT) and location 9 (PA Hospital), background vibration levels (V_{90}) of 0.02 mm/s to 0.06 mm/s and maximum vibration levels (V_1) of 0.03 mm/s to 2.69 mm/s, were measured. It can be noted that the monitoring location just outside the MRI room at the PA Hospital registered significantly higher vibration levels than at QUT and St Andrews Hospital.

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 has classified all buildings within a corridor extending approximately 100 m either side of the nearest BaT 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 40.**

Table 40 Major Plant Schedule and Source Sound Power Level Estimates for Tunnelling Worksites

Site	LAmax Sound Power Level (dBA)	Dutton Park Rail Works	PA Hospital Site	Boggo Road Site	Woolloongabba Station	George St Station	Roma St Station	North Connection Site	Exhibition Line Rail works	Gilchrist Avenue Site
TBM	See **Section 6.6.1**	-	-	1	-	-	-	-	-	-
Roadheader	See **Section 6.6.1**	-	1	1	2	2	2	1	-	-
Jumbo	118	-	1	1	2	2	2	1	-	-
Piling Rigs	118	1	1	2	2	2	2	2	-	1
150t Cranes	113	1	1	1	1	1	1	1	1	1
60-100t Cranes	110	2	1	1	2	2	2	2	1	2
3.5 Cu.M FEL	112	1		1	2	2	2	2	1	2
5 Cu.M FEL	115	2	3	2	2	2	2	2	2	2
Excavator 5t	110	2	1	1	1	1	1	1	2	1
Excavator 20t	112	2	1	1	1	1	1	1	2	1
Excavator 35t	114/125[1]	2	1	2	2	2	2	2	2	2
Scissor. Lift	106	3	1	2	4	4	4	2	3	2
Temp Vent	105	1	1	4	2	2	2	1	1	4
Shaft Hoist	100	-	1	1	1	1	1	-	-	-
Shaft Lift	100	-	1	1	1	1	1	-	-	-
Compressor	103	1	2	2	2	2	2	2	1	1
Generator	100	1	2	2	2	2	2	2	1	1
Pump	100	1	1	2	4	4	4	2	1	1
Spoil truck	110	Required at all sites at various stages and varying numbers (refer to **Section 10** 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 the BaT project 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 (i.e. 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 (e.g. 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 41**.

Table 41 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 (e.g. hisses, scrapes, whines) than low-pitched noises (e.g. 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 42**.

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 EHP licensing requirements for fixed stationary noise sources. For this reason, a general indicative sound power level is not listed.

Table 42 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 43**.

Table 43 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 43** in reducing the types of internal noise sources shown in **Table 42** has been calculated. The results of these calculations are presented in **Table 45**.

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 44.**

Table 44 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 43.**

‘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 43** 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 45**. These estimates account for the spectral characteristics of sources (refer **Table 42**), enclosure constructions (refer **Table 43)**, and associated internal reverberant characteristics (refer **Table 44**).

Table 45 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 45** 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).

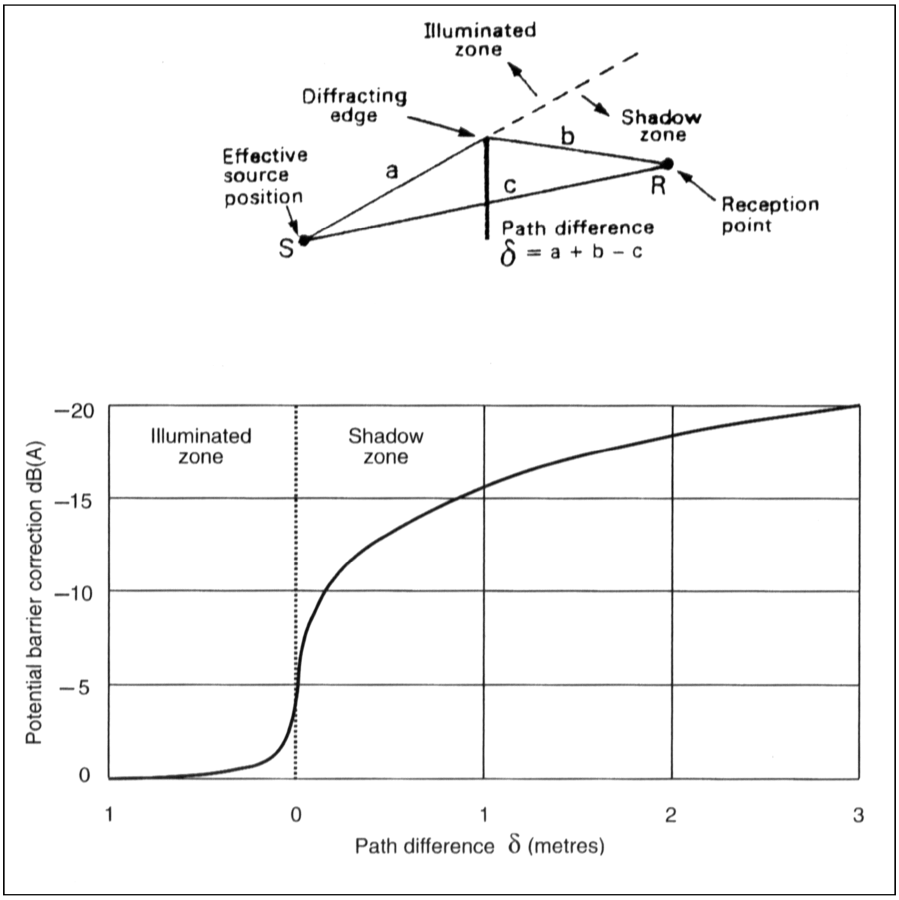
It can also be seen from **Table 45** that the effective noise reduction can vary as much as 10 dBA depending on the frequency content of the plant item. Plant emissions that are dominated by high frequency noises, such as rockbreaking, will benefit most from an acoustic enclosure.

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 10**.

Figure 10 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 2.4 m to 3.0 m high. In general, the dwellings near construction areas for this project are either highset or Queenslander buildings. This gives a nominal receptor height of 3 m 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 4 m. For a front-end loader or excavator, the effective source height may be in the range of 2 to 3 m.

Thus it can be seen that for many construction noise sources typical barriers in the range of 2.4 m to 3.0 m 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 6 m 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 7 dBA for single detached dwellings that rely predominantly on natural ventilation through windows, and 22 dBA for modern residential apartments with close-fitting sliding windows that would normally be equipped with air conditioning. For single detached 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 5 to 10 dBA higher than the nominal assumed value of 25 dBA (facade corrected) 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 and airblast overpressure levels have been obtained from the ICI Explosives Blasting Guide (ICI Explosives, 1995) for free face blasts (assumes a downward spiral blast technique creating a free face for blasts).

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 significantly lower than 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. Formulas to predict PCF have been sourced from RockTek Limited 2000 “RocKracker® / PCF® General Overview”.

The relationship, for 5 %[1] exceedance peak vibration and airblast overpressure levels, are:

Conventional Blasting

V (mm/s) = $1869 \times (Q^{0.5}/R)^{1.6}$ (ICI – conventional blasting)

Lp (dB Linear Peak) = $155.7 - 24 \times \log(R/Q^{0.33})$ (ICI – conventional blasting)

PCF Blasting

V (mm/s) = $1090 \times (Q^{0.5}/R)^{1.39}$ (RockTek – PCF blasting)

Lp (dB Linear Peak) = $140.8 - 24 \times \log(R/Q^{0.33})$ (RockTek – PCF blasting)

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

The conventional airblast overpressure formula assumes airblast mitigated with fully confined blast holes and application of blast matt or similar. The airblast overpressure for the PCF blast can be further attenuated if required through canopy, barrier or shroud.

Charge sizes per blasthole for PCF technology typically range from 10 grams to 300 grams. Minimum practical MIC for conventional blasting is from around 1 kg.

Table 46 shows the indicative permissible blast sizes that would result in a ground vibration velocity level of 10 mm/s at the building foundations. A vibration goal of 10 mm/s is proposed for blasting near heritage-listed buildings, refer to vibration goals in **Section 2.3.5**.

Table 47 shows the indicative permissible blast sizes that would result in a ground vibration velocity level of 50 mm/s at the building foundations. A level of 50 mm/s would be applicable to commercial and residential buildings.

Table 48 shows the indicative permissible blast sizes that would result in airblast overpressure of 132 dBL Peak.

Table 46 Indicative Permissible Maximum Instantaneous Charge (MIC) to Achieve 10 mm/s PPV near Heritage Structures – Conventional Blasting

Data Source	Indicative Permissible Charge weight (kg) Versus Distance					
	Exceedance	5m	10m	20m	30m	40m
Conventional Blasting (ICI formula)	5%	0.04	0.14	0.6	1.3	2.3
PCF Blasting (RockTek)	5%	0.03	0.1	0.5	1.0	1.9

Note: Charge sizes per blasthole for PCF technology typically range from 10 grams to 300 grams. Minimum practical MIC for conventional blasting is from around 1 kg.

[1] A 5% exceedance level has been applied as a reasonable upper limit to assess against the absolute ground vibration criteria of 50 mm/s (or 10 mm/s for heritage structures).

Table 47 Indicative Permissible Maximum Instantaneous Charge (MIC) to Achieve 50 mm/s PPV near Commercial and Residential Buildings

Data Source	Indicative Permissible Charge weight (kg) Versus Distance					
	Exceedance	**5m**	**10m**	**20m**	**30m**	**40m**
General ICI formula	5%	0.3	1.1	4.3	9.7	17
PCF Blasting (RockTek)	5%	0.3	1.2	4.7	10	19

Note: Charge sizes per blasthole for PCF technology typically range from 10 grams to 300 grams. Minimum practical MIC for conventional blasting is from around 1 kg.

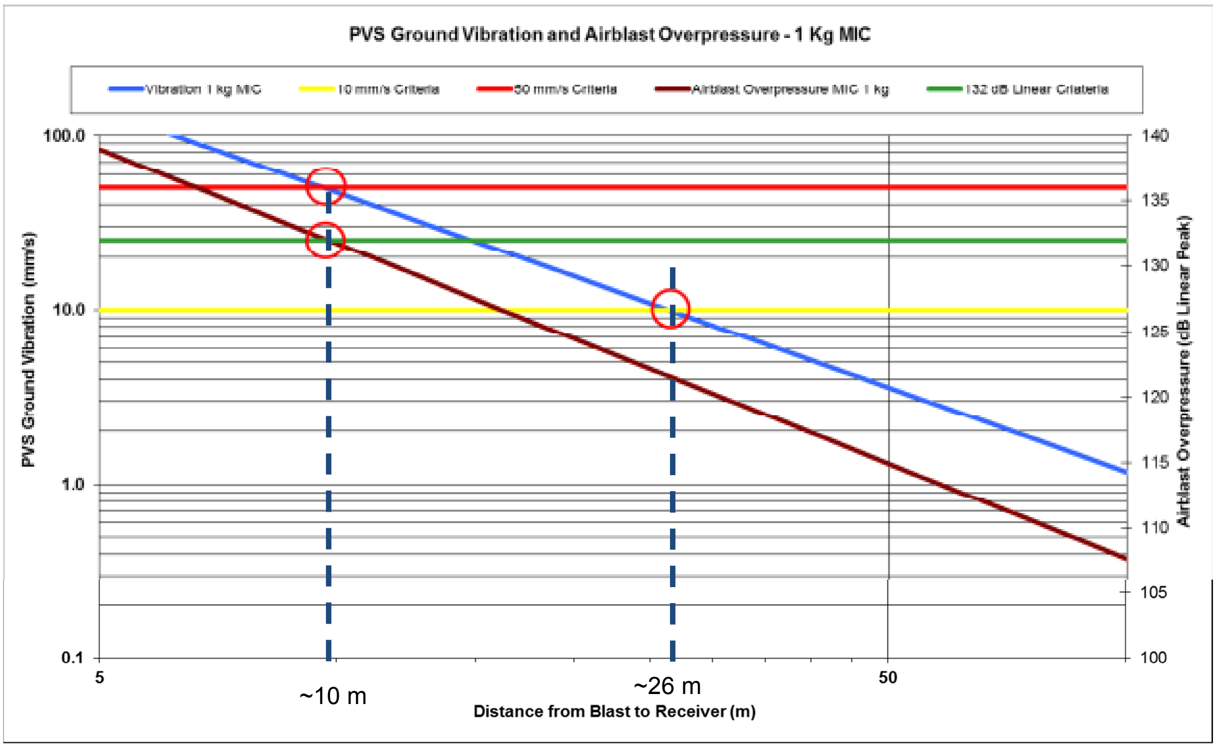
Table 48 Indicative Permissible Maximum Instantaneous Charge (MIC) to Achieve 132 dBL Peak Airblast near Commercial and Residential Buildings

Data Source	Indicative Permissible Charge weight (kg) Versus Distance					
	Exceedance	**5m**	**10m**	**20m**	**30m**	**40m**
General ICI formula	5%	0.1	1.1	8.7	29	70
PCF Blasting (RockTek)	5%	9.9	79	>100	>100	>100

Note: Charge sizes per blasthole for PCF technology typically range from 10 grams to 300 grams. Minimum practical MIC for conventional blasting is from around 1 kg.

The predicted ground vibration and airblast overpressure versus distance for a conventional blast with maximum instantaneous charge of 1 kg is shown as an example in **Figure 11**. This example shows that at distances less than approximately 10 m (26 m for heritage buildings), the PCF blasting technique or similar with lower blast emission will likely be required.

Figure 11 Predicted Ground Vibration and Airblast Overpressure (1 kg MIC) Vs Distance



6.5.3 Mechanical Tunnel Excavation

The BaT project tunnel is proposed to be constructed by a Tunnel Boring Machine (TBM). The TBM for the BaT tunnel is approximately 15.4 m in diameter.

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 (i.e. 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 larger (15 m diameter) TBM generate approximately 1.9 dB higher ground-borne noise and vibration. The likely ground-borne vibration levels for Underground Bus and Train TBMs are presented in **Table 49**.

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 49.** The frequency content of the ground-borne vibration associated with TBMs, roadheaders, rockbreaking and blasting is normally concentrated below 100 Hz.

Table 49 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**
15 m diameter hard rock TBM		6.02	2.89	1.38	0.90	0.66	0.52
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 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 (i.e. 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 BaT project study.

Also as stated in **Section 6.5.3**, it is assumed that the ground-borne noise from the larger (15 m diameter) TBM generate approximately 1.9 dBA higher 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 50**. The airblast overpressure is also included for reference (not taking into account any reduction due to acoustic enclosures).

Table 50 Indicative Ground-borne Noise Levels for Mechanical Tunnel Excavation Methods

Operation		Ground-borne Noise Levels (dBA L_{Aeq})[1] Versus Distance					
		5m	**10m**	**20m**	**30m**	**40m**	**50m**
15 m diameter hard rock TBM		72	63	54	49	45	42
Roadheading		57	48	39	34	30	27
Rockbreaking		67	58	50	45	40	37
Drilling (small percussive rig)		58	49	40	36	31	29
		Airblast Overpressure (dB Linear Peak)[2] Versus Distance					
Blasting ICI 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

BaT project worksites shown in **Figure 3** will be located at Dutton Park (Southern Connection, principal worksite and site offices), Boggo Road (TBM launch site), the former GoPrint site on land bounded by Stanley Street, Leopard Street and Vulture Street Woolloongabba (Woolloongabba Station), George Street (George Street Station), Roma Street (Roma Station) and Victoria Park (Northern Connection, TBM extraction shaft).

A satellite worksite for car parking, lay-down and storage purposes is proposed at the Roma Street Parklands as well as a site office at the former Dutton Park Special School off Park Road. 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 TBM and roadheaders will operate on 24 hour 7 days a week 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 BaT project construction works has been conducted for all relevant periods.

7.1 Southern Connection and Boggo Road TBM Launch Site

During the BaT project's construction phase, the Southern Connection construction site would be used for the following purposes:

- Cut and cover construction of the rail tunnels between the TBM launch shaft and the southern portals.
- Pipe jacking to provide ground stabilisation between the TBM launch shaft and Park Road Railway Station.
- TBM launch site and associated facilities for tunnel construction.
- Spoil removal from behind the TBM.
- Tunnel fitout including rail systems.
- General construction site.

7.2 Woolloongabba Station

The location of the Woolloongabba Station construction site (at the former GoPrint site) is between Vulture Street, Leopard Street and Stanley Street, Woolloongabba. Construction of the station involves excavation of a deep shaft (approximately 32 m deep) by means of rock-hammer and roadheader for the station cavern (approximately 200 m in length). The station cavern is required before the TBM pass-through.

The Woolloongabba Station worksite will also serve as a depot for the George Street Station worksite due to area constraints at the latter.

7.3 George Street Station

The location of the George Street Station construction site is on the corner of George Street and Mary Street. Construction of the station involves excavation of a deep shaft (approximately 52 m deep) by means of rock-hammer, drill and blast and roadheader for the station cavern (approximately 200 m in length). The station cavern is required before the TBM pass-through.

The George Street Station worksite will require occupation of two lanes of George Street.

7.4 Roma Street Station

The location of the Roma Street Station construction site is between Roma Street Station and Parkland Boulevard. Construction of the station involves excavation of a deep shaft (approximately 40 m deep) by means of rock-hammer, drill and blast and roadheader for the station cavern (approximately 200 m in length). The station cavern is required before the TBM pass-through.

7.5 Northern Connection (TBM Extraction Site)

During the BaT project's construction phase, the northern connection construction site, located south of the rail corridor at Victoria Park, would be used for the following purposes:

- Shaft excavation required for TBM extraction.
- Cut and cover transition, busway and rail connection works.
- Tunnel fitout including rail systems.
- Busway bridge over the ICB and busway ramp to the ICB west-bound lanes.
- General construction site.

8 IMPACT ASSESSMENT OF WORK SITES

8.1 Noise Modelling Methodology

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 ISO 9613:2 industrial noise algorithm as implemented in SoundPLAN acoustic modelling software. The ISO 9613:2 predicts noise emission under typical worst case weather consisting of a moderate temperature inversion or equivalent down wind conditions of 1 to 5 m/s.

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 (i.e. increased) to an external free-field noise level. The adjustment was determined by the type of facade through which noise transmission would occur. For the BaT project, the facade adjustment methodology applied to the assessment takes into consideration the type of receivers buildings present across the study area. In summary:

- For residential type receivers in standard suburban-type dwellings, a +10 dBA inside to outside adjustment for windows partially open (7 dBA in the free-field).
- For residential type receivers in high-rise apartment buildings, such as those in the vicinity of the George Street Station worksite, a +25 dBA inside to outside adjustment for windows closed (22 dBA in the free-field). An inside to outside facade adjustment noise level of 25 dBA is consistent with the findings of the measurements carried out at BaT project monitoring Location 17 (Parkland Boulevard) and Location 18 (21 Mary Street). The facade noise reduction measurement results (presented in **Table 37** and **Table 38**) identified an adjustment level of 26 dBA for the bedroom and 23 dBA for the living room.
- For commercial type receivers, a +25 dBA inside to outside adjustment for single glazed closed windows (22 dBA in the free-field). As discussed above, this is consistent with the findings of the facade noise reduction measurements carried out in the CBD.

The plant likely used at the major work sites would typically be a subset of that presented in **Table 40** for tunnelling worksites assessed in **Sections 8.2** to **8.6** and **Table 41** for surface rail track worksites assessed in **Section 8.7**.

TBM launch site activities representative of the typical noise emissions expected to occur during the BaT 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 site and associated facilities for tunnel construction.
- Spoil removal from behind the TBM and removal by heavy vehicle.
- Tunnel fit out including railway and busway systems.

Station site activities representative of the typical noise emissions expected to occur during the BaT 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 the proposed BaT 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 shed: 15 dBA to 25 dBA reduction (based on the medium performance transmission loss data in **Table 45**).

Correctly designed and constructed barriers (of solid construction using appropriate materials, such as 25 mm thick 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 (e.g. 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, piling and initial excavation phases of the works.

The indicative acoustic shed construction would consist of metal cladding with internal insulation faced with sisalation on the walls and ceiling. Where increased noise insulation is required this can be achieved by upgrading the acoustic shed 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, the following colour codes have been used:

- Pink — Residential
- Blue — Commercial
- Yellow — Hospital
- Orange — Educational
- Yellow with red boundary — Church or Place of Worship
- Green — Park

8.2 Southern Connection and TBM Launch Site - Noise and Vibration Assessment

Assessment of the TBM launch site and the Southern Connection, at Dutton Park, is covered in this section. This section also covers the assessment of the small section of pipe jacking (micro TBM) undertaken to support the TBM excavation under the railway tracks adjacent to the Park Road Railway Station. It is proposed to utilise the Southern Connection worksite as the major spoil removal facility for the TBM drive north to the Northern Connection worksite.

8.2.1 Nearest Sensitive Receivers

The nearest noise and/or vibration sensitive receivers to the Southern Connection site are identified in **Table 51** with the receiver areas illustrated in **Figure 12**.

Figure 12 Southern Connection Receiver Areas

Table 51 Nearest Sensitive Receivers – Southern Connection

Work Site/Excavation	Receiver Area	Distance to Worksite Boundary
Southern Connection	A - Railway Terrace Commercial	10 m
	B - Railway Terrace (Pound St to Rawnsley St)	14 m
	C - ESA Village (Leukaemia Centre)	< 10 m
	D - Ecosciences Building	20 m
	E - Police Station & Gaol	145 m
	F - Dutton Park Primary School	130 m
	G - Merton Rd to Elliott St Residential	20 m
	H - Burke St Commercial	12 m
	I – Metropolitan line service (MLS) commercial and PA Busway Station	10 m
	J - PA Hospital	20 m
	K - Rusk St & Cornwall St Residential	75 m
	L – PA Early Education Centre	55 m

8.2.2 Site Specific Construction Noise Goals

With reference to the BaT project noise goals and the ambient noise survey results summarised in **Section 3.2.7** and **Section 4.1.4** respectively, the site specific construction noise goals are presented in **Table 52**.

Table 52 Southern Connection 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 $L_{Aeq,adj(15min)}$) [1]	Intermittent (dBA L_{Amax}) [1]
A - Railway Terrace Commercial	67	77	-	-
B - Railway Terrace Residential	47	57	42	49
C - ESA Village (Leukaemia Centre) Residential	62	72	57	64
D - Ecosciences Building Commercial	67	77	-	-
E - Police Station & Gaol Commercial	62[2]	72[2]	-	-
F - Dutton Park Primary School	52	62	-	-
G - Merton Rd to Elliott St Residential	47	57	42	49
H - Burke St Commercial	67	77	-	-
I - MLS	67	77	-	-
J - PA Hospital	62[3]	72[3]	57	64
K - Rusk St & Cornwall St Residential	47	57	42	49
L – PA Early Education Centre	52	62	-	-

Note 1 – Noise goal has been adjusted to represent external free-field levels.
Note 2 – Noise goal relevant at all times.
Note 3 - Based on AS2107 category “wards” for medical buildings and applicable to all time periods.

8.2.3 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 Connection is presented in **Section 9.2.2**. However, assessment of the pipe jacking activity (micro TBM) under Park Road Railway Station is presented in this section.

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

- Scenario 1 – Site Establishment and removal of existing railway infrastructure:
  - Duration ~ 3 months
  - Dominant noise sources include rockbreakers, excavators and spoil trucks
  - Daytime construction only
- Scenario 2 – Pile installation along cut and cover tunnel sections, excavation of the TBM launch shaft and excavation of the pipe jacking retrieval shaft adjacent to Quarry Street:
  - Duration ~ 4 months
  - Dominant noise sources include piling rigs, rockbreakers and spoil trucks
  - Mostly daytime construction and potentially weekend work during track possessions

- Scenario 3 – Night-time pipe jacking activities:
  - Duration ~ 3 months
  - Dominant noise sources include bentonite plant, generator, front end loader and cranes
    - Pipe jacking construction activities required 24/7
- Scenario 4 - TBM assembly and acoustic shed construction:
  - Duration ~ 3 months
  - Dominant noise sources include delivery trucks, cranes and front end loaders
- Scenario 5 – Night-time TBM operations including spoil loading inside the acoustic shed and spoil removal from site by haul trucks:
  - Duration ~ 17 months
  - Dominant noise sources include spoil trucks entering and leaving the acoustic shed on the southern side of the railway corridor
  - 24 hour per day movements through the site
- Scenario 6 – Night-time TBM operations based on steady state noise sources inside the acoustic shed (e.g. tunnel ventilation and conveyor system noise):
  - Duration ~ 17 months
  - Dominant noise sources include the spoil conveyor to the loadout hopper and tunnel ventilation fans
  - 24 hour per day activities

For all construction scenarios, typical construction noise levels with either 3 m acoustic hoarding surrounding the site or existing railway noise barriers have been predicted at the nearest noise sensitive receivers and are presented in **Table 53** to **Table 58**. 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 area near the TBM shaft and an acoustic enclosure on the southern side of the rail corridor for Scenario 5 and Scenario 6. 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 F**.

Predicted ground-borne noise and vibration impacts for the Southern Connection are presented in **Table 59**. All predicted ground-borne noise and vibration levels have been based on the shortest distance between the excavation source and the receiver building.

Table 53 Southern Connection Predicted Worst Case Noise Levels – Scenario 1: Site Establishment and Removal of Existing Railway Infrastructure

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 Terrace Commercial	Day	$L_{A10,adj}$ – 77	57 - 54	-	-
B - Railway Terrace Residential	Day	$L_{A10,adj}$ – 57	65 - 57	8	3
C - ESA Leukaemia Village Residential	Day	$L_{A10,adj}$ – 72	69 - 60	-	-
D - Ecosciences Building Commercial	Day	$L_{A10,adj}$ – 77	74 - 57	-	-
E - Police Station & Gaol Commercial	Day	$L_{A10,adj}$ – 72	52 - 42	-	-

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
F - Dutton Park Primary School	Day	LA10,adj – 62	47 - 43	-	-
G - Merton Rd to Elliott St Residential	Day	LA10,adj – 57	61 - 44	4	-
H - Burke St Commercial	Day	LA10,adj – 77	61 - 52	-	-
I - MLS	Day	LA10,adj – 77	63 - 53	-	-
J - PA Hospital	Day	LA10,adj – 72	72 - 40	-	-
K - Rusk St & Cornwall St Residential	Day	LA10,adj – 57	44 - 40	-	-
L – PA Early Education Centre	Day	LA10,adj – 62	57 - 57	-	-

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 54 Southern Connection Predicted Worst Case Noise Levels – Scenario 2: Piling, TBM Launch Shaft and Pipe Jacking Retrieval 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 Terrace Commercial	Day	LA10,adj – 77	57 - 54	-	-
B - Railway Terrace Residential	Day	LA10,adj – 57	66 - 58	9	4
C - ESA Leukaemia Village Residential	Day	LA10,adj – 72	74 - 66	2	-
D - Ecosciences Building Commercial	Day	LA10,adj – 77	73 - 59	-	-
E - Police Station & Gaol Commercial	Day	LA10,adj – 72	53 - 48	-	-
F - Dutton Park Primary School	Day	LA10,adj – 62	54 - 50	-	-
G - Merton Rd to Elliott St Residential	Day	LA10,adj – 57	73 - 59	16	11
H - Burke St Commercial	Day	LA10,adj – 77	64 - 55	-	-
I - MLS	Day	LA10,adj – 77	65 - 57	-	-
J - PA Hospital	Day	LA10,adj – 72	69 - 45	-	-
K - Rusk St & Cornwall St Residential	Day	LA10,adj – 57	48 - 46	-	-
L – PA Early Education Centre	Day	LA10,adj – 62	58 - 57	-	-

Note 1 – Dominant construction noise during piling and excavation 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 55 Southern Connection Predicted Worst Case Noise Levels – Scenario 3: Night-time Pipe Jacking Activities

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 – Low Performance
B - Railway Tce Residential	Night	LAeq,adj – 42	23 - 17	-	-	-
C - ESA Leukaemia Village Residential	Night	LAeq,adj – 57	31 - 24	-	-	-
G - Merton Rd to Elliott St Residential	Night	LAeq,adj – 42	33 - 23	-	-	-
J - PA Hospital	Night	LAeq,adj – 57	29 - 16	-	-	-
K - Rusk St & Cornwall St Residential	Night	LAeq,adj – 42	14 - 9	-	-	-

Note 1 – Construction noise from pipe jacking activities would be steady state. Therefore the LAeq,adj assessment parameter is most relevant.

Note 2 – Predicted noise levels assume that steady state noise sources associated with the pipe jacking activity are located at the base of the TBM launch shaft, with no cover over the shaft, and include 3 m acoustic hoarding between noise sources and receivers (i.e. around the worksite boundary).

Table 56 Southern Connection Predicted Worst Case Noise Levels – Scenario 4: TBM Assembly and Acoustic Shed Construction

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 Terrace Commercial	Day	LA10,adj – 77	50 - 47	-	-
B - Railway Terrace Residential	Day	LA10,adj – 57	58 - 51	1	-
C - ESA Leukaemia Village Residential	Day	LA10,adj – 72	62 - 57	-	-
D - Ecosciences Building Commercial	Day	LA10,adj – 77	68 - 49	-	-
E - Police Station & Gaol Commercial	Day	LA10,adj – 72	46 - 37	-	-
F - Dutton Park Primary School	Day	LA10,adj – 62	43 - 38	-	-
G - Merton Rd to Elliott St Residential	Day	LA10,adj – 57	54 - 41	-	-
H - Burke St Commercial	Day	LA10,adj – 77	56 - 49	-	-
I - MLS	Day	LA10,adj – 77	61 - 49	-	-
J - PA Hospital	Day	LA10,adj – 72	64 - 37	-	-
K - Rusk St & Cornwall St Residential	Day	LA10,adj – 57	40 - 35	-	-
L – PA Early Education Centre	Day	LA10,adj – 62	54 - 51	-	-

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 57 Southern Connection Predicted Worst Case Noise Levels – Scenario 5: Night-time TBM Support including Spoil Truck Movements

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 – Low Performance
B - Railway Tce Residential	Night	LAmax – 49	55 - 48	6	6	3[3]
C - ESA Leukaemia Village Residential	Night	LAmax – 64	61 - 53	-	-	-
G - Merton Rd to Elliott St Residential	Night	LAmax – 49	50 - 36	1	-	-
J - PA Hospital	Night	LAmax – 64	65 - 32	1	-	-
K - Rusk St & Cornwall St Residential	Night	LAmax – 49	39 - 29	-	-	-

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

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

Note 3 – Noise goal exceedance due to spoil truck movements outside of the acoustic enclosure.

Table 58 Southern Connection Predicted Worst Case Noise Levels – Scenario 6: Night-time TBM Support Steady State Noise Sources

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 – Low Performance
B - Railway Tce Residential	Night	LAeq,adj – 42	46 - 41	4	-	-
C - ESA Leukaemia Village Residential	Night	LAeq,adj – 57	57 - 43	-	-	-
G - Merton Rd to Elliott St Residential	Night	LAeq,adj – 42	49 - 31	7	2	-
J - PA Hospital	Night	LAeq,adj – 57	56 - 26	-	-	-
K - Rusk St & Cornwall St Residential	Night	LAeq,adj – 42	33 - 25	-	-	-

Note 1 – Construction noise from spoil conveyor and tunnel ventilation would be steady state. 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 59 Southern Connection Predicted Ground-borne Noise and Vibration Levels – TBM Launch Shaft Excavation, Pipe Jacking Activities and Cut and Cover Tunnel Excavation

Receiver Area	Period	Construction Sources Noise and Vibration Goals			Predicted Ground-borne Vibration Level (mm/s)		Predicted Ground-borne Noise Level (dBA)	
		Vibration PPV (mm/s)	Internal Ground-borne Noise (dBA)		Rockbreaking[3]	Pipe Jacking (Micro TBM)	Rockbreaking[3]	Pipe Jacking (Micro TBM)
			Continuous[1]	Intermittent[2]				
A - Railway Tce Commercial	Day	10	LAeq,adj – 45	LA10,adj – 55	0.02	<0.01	24	<25
B - Railway Tce Residential	Day	10	LAeq,adj – 40	LA10,adj – 50	0.27	<0.01	45	<25
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.27	<0.01	**50 (8)**	<25
C - ESA Village (Leukaemia Centre) Residential	Day	25	LAeq,adj – 40	LA10,adj – 50	0.49	<0.01	**52 (2)**	<25
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.49	<0.01	**57 (15)**	<25
D - Ecosciences Commercial	Day	25	LAeq,adj – 45	LA10,adj – 55	0.29	0.06	50	<25
D – Ecosciences TEM	24/7	0.02	n/a	n/a	**0.05 (0.03)**	<0.01	n/a	n/a
G - Merton Rd to Elliott St Residential	Day	10	LAeq,adj – 40	LA10,adj – 50	2.7	0.17[5]	37[4]	35[5]
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.06	0.17[5]	42	35[5]
H - Burke St Commercial	Day	25	LAeq,adj – 45	LA10,adj – 55	0.05	0.03	37	<25
I - MLS & PA Busway Station Commercial	Day	25	LAeq,adj – 45	LA10,adj – 55	0.07	<0.01	39	<25
J - PA Hospital	Day	25	LAeq,adj – 40	LA10,adj – 50	0.06	<0.01	37	<25
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.06	<0.01	42	<25

Note 1: Dominant construction noise during pipe jacking likely to be steady state and continuous. Therefore the LAeq,adj assessment parameter is most relevant.

Note 2: Dominant construction noise during cut and cover tunnel excavation (i.e. rockbreaking) likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax (night-time) assessment parameter is most relevant.

Note 3: Assessment assumes that the cut and cover sections of the Down and Up track tunnels would be top down constructed (i.e. carried out below a ground slab.)

Note 4: Predicted from the cut and cover tunnel excavation site as the TBM launch shaft and pipe jacking retrieval pit will be open and therefore airborne noise from rockbreaking at these locations would be more significant than ground-borne noise.

Note 5: Worst case ground-borne vibration and noise levels predicted at the nearest residential receiver on Quarry Street based on the final stages of each pipe jacking drive (i.e just before reaching the retrieval shaft). All other residential receivers on Merton Road to Elliott Street will experience significantly lower levels.

Discussion

Air-borne Noise

Based on typical worst case construction noise levels with either 3 m acoustic hoarding surrounding the site or existing railway noise barriers, the following is noted:

- The predicted noise levels for site establishment works including demolition of existing structures within the rail corridor indicate exceedances of up to 8 dBA of the daytime noise goal for the nearest residential receivers adjacent to Railway Terrace and Merton Street to Elliott Street. The predicted noise goal exceedances result from the use of rockbreakers in close proximity to receivers. It is anticipated that rockbreakers would be used only intermittently during the initial site clearing phase of the BaT project.
- A similar exceedance of the noise goal is anticipated during the operation of piling rigs at the cut and cover areas and excavation of the TBM launch shaft. The notable exceedance during Scenario 2 is associated with excavation of the pipe jacking retrieval shaft adjacent to Quarry Road. With 3 m acoustic hoarding around these works, the daytime noise goal is predicted to be exceeded by up to 16 dBA during operation a rockbreaker. It should be noted that noise emission levels associated with the shaft excavation would decrease significantly as the shaft progresses downwards. Notwithstanding this, it is recommended that excavation of the pipe jacking retrieval shaft be carried out during the daytime period only.
- Predicted noise emission levels associated with night-time pipe jacking activities (i.e. operation of the slurry separation unit, centrifuge, jacks, generator etc) comply with the night-time noise goals for steady state noise sources at all noise sensitive receiver locations.
- A marginal 1 dBA exceedance of the daytime noise goal is predicted for the residential receivers adjacent to Railway Terrace during the assembly stage of the TBM. It is anticipated that the majority of noise intensive activities associated with this stage would occur within the TBM launch shaft and mined tunnel underneath the existing rail corridor.
- Predicted noise emission levels based on night-time spoil removal during TBM operation indicate an exceedance of the night-time noise goal (for intermittent noise sources) of up to 6 dBA. The predicted noise goal exceedance for residences adjacent to Railway Terrace is attributed to spoil truck movements within the site. Given the length of the on-site journey required by spoil trucks to access the spoil load out shed (i.e. via O'Keefe Street) it is not practicable to contain this activity within the proposed acoustic shed. Consequently it will be important to consider all reasonable and feasible noise mitigation measures to minimise night-time spoil truck impacts to nearby residential receivers including:
  - Erecting a noise barrier (approximately 3 to 4 m high) along the north-west side of the on-site spoil route adjacent to the rail track; or
  - Increasing the height of the existing rail noise barrier along Railway Terrace (height and extent of upgrade to be confirmed during detailed design); and
  - Use of quietest available spoil trucks.

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.

The assessment of steady state noise sources associated with long-term construction activities within the spoil load out facility indicated compliance with the night-time noise goal for all sensitive receivers with the provision of a low performance acoustic shed.

With all practicable noise mitigation measures in place combined with careful management of all heavy vehicle movements on the site, airborne noise impacts should be minimal during the construction phase of the Southern Connection.

Ground-borne Noise & Vibration

The predicted ground-borne noise and vibration levels are summarised as follows:

- The ground-borne noise levels presented in **Table 59** for rockbreaking under the existing rail tracks between the TBM launch shaft site and the tunnel portal indicate an exceedance of the night-time noise goal for the Leukaemia Centre (up to 15 dBA) and the nearest Railway Terrace residential receivers (up to 8 dBA). A marginal 2 dBA exceedance of the daytime noise goal has also been predicted for the Leukaemia Centre. The minimum offset distance between the rockbreaker and receiver building required to achieve compliance with the night-time ground-borne noise goal and the length of tunnel predicted to exceed the ground-borne noise goal have been calculated as follows:
    - Leukaemia Centre night-time (42 dBA LAmax): 95 m from the building and 125 m of cut and cover tunnel predicted to exceed the night-time ground-borne noise goal.
    - Railway Terrace night-time (42 dBA LAmax): 95 m from the receiver building and 60 m of cut and cover tunnel predicted to exceed the night-time ground-borne noise goal.
- On the basis of the predicted exceedances of the night-time ground-borne noise goal, it is recommended that rockbreaking of the cut and cover sections of tunnel within the exceedance ranges listed above be carried out only during the daytime period.
- The predicted ground-borne noise and vibration from the Pipe Jacking (micro TBM) under the Park Road Railway Station tracks comply with the ground-borne noise and vibration goals at all locations.
- An investigation of the Ecosciences TEM vibration isolation system has not been carried out for the BaT project. Based on the predicted marginal exceedance of the TEM criterion in **Table 59** during rockbreaking, it is anticipated that an effective vibration isolation system would prevent interference to the operation of the TEM. It is recommended that the performance of the Ecosciences TEM vibration isolation system be checked prior to commencement of vibration intensive construction works at the TBM launch shaft site. If this system is found to be inadequate and the findings of vibration trials confirm the need to mitigate vibration interference to the TEM, then the vibration isolation system would require upgrading.
- All predicted daytime construction vibration levels are well below the guide values, judged to result in a minimal risk of cosmetic damage, as provided in BS 7385 for buildings surrounding the worksites.

SLR understands that the Translational Research Institute (TRI) laboratory located within the PA Hospital grounds includes a basement rodent holding facility. Medical and specialist research facilities holding rodents are sensitive to noise and vibration, however specific industry guidelines on these aspects is limited within Australia. Following a review of the literature, SLR believes the following criteria are likely to be acceptable in line with Section 3.3.4 of the Victorian Government Department of Primary Industries Code of Practice for the Housing and Care of Laboratory Mice, Rats, Guinea Pigs and Rabbits and the 2008 US National Institutes of Health (NIH) Design Requirements Manual for Biomedical Laboratories and Animal Research Facilities:

- Noise levels of L_{AmaxF} 55dB during construction.
- Floor vibration levels of 0.1 mm/s or less when measured as a peak vector sum over a minimum 1 second period, in accordance with ISO 2631 series or other recognised Australian equivalent standard.

Excessive noise and vibration can create a range of issues in mice (and rats) including but not limited to disturbance of natural sleep-wake cycles and breeding / reproduction rates, induction of an array of behavioural and physiological changes, and physical injuries from startle reactions.

For basement locations (as is the case for the TRI laboratory), airborne noise from the construction of the BaT project is unlikely to be an issue, however ground vibration and regenerated noise may be of concern.

At the TRI facility, ground-borne construction noise emissions from the BaT project are predicted to be L_{AmaxF} 42 dBA or less, which is in compliance with the above recommended noise limits. Construction vibration from the BaT project is also estimated (at 0.06mm/s) to be below the above criteria.

Additionally, we note that noise levels experienced by the rodents within TRI facility are (and will continue to be) typically higher than the above values during normal activities, and they generally include door closing/slamming, normal speech, spray hoses (cleaning and maintenance), bench activities, cage feedstocking, cage ventilation systems and radios / public address systems. Higher vibration levels experienced by the rodents may also arise from general footfall / walking, doorstrikes and manual handling of cages, feedstock and heavy items within the building floorplate.

On this basis, we expect noise and vibration emissions from the BaT project to be acceptable to the mice holding facilities. Regardless, it is recommended that noise and vibration monitoring is undertaken when construction activity is closest to the TRI laboratory to ensure ongoing noise and vibration levels are compliant with the criteria recommended.

8.3 Woolloongabba Station

8.3.1 Nearest Sensitive Receivers

The nearest noise and/or vibration sensitive receivers to the Woolloongabba Station work site are identified in **Table 60** with the receiver areas illustrated in **Figure 13**.

Figure 13 Woolloongabba Station Receiver Areas

Table 60 Nearest Sensitive Receivers – Woolloongabba Station

Work Site/Excavation	Receiver Area	Distance to Worksite Boundary
Woolloongabba Station	A - Allen St Residential	250 m
	B - Vulture St Residential	25 m
	C - Vulture St Commercial	10 m
	D - St Nicholas Cathedral	25 m
	E - Main St Residential	85 m
	F - Main St Commercial	10 m
	G - Stanley St Commercial	60 m
	H - Busway Station	10 m
	I – Stanley St Residential	100 m
	J – St Joseph's Church & School	160 m

8.3.2 Site Specific Construction Noise Goals

With reference to the BaT project noise goals and the ambient noise survey results summarised in **Section 3.2.7** and **Section 4.1.4** respectively, the site specific construction noise goals are presented in **Table 61**.

Table 61 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 $L_{Aeq,adj(15min)}$) [1]	Intermittent (dBA L_{Amax} [1])
A - Allen St Residential	67	77	57	64
B - Vulture St Residential	52	62	42	49
C - Vulture St Commercial	67	77	-	-
D - St Nicholas Cathedral	47[2]	57[2]	-	-
E - Main St Residential	67	77	57	64
F - Main St Commercial	67	77	-	-
G - Stanley St Commercial	67	77	-	-
H - Busway Station	n/a[3]	n/a[3]	-	-
I – Stanley St Residential	67	77	57	64
J – St Joseph's School	52	62	-	-

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

Note 2 – Noise goal based on AS2107 and is relevant at all times.

Note 3 – No internal waiting area spaces therefore AS2107 airborne noise criteria not applicable.

8.3.3 Assessment at the Nearest Noise and/or Vibration Sensitive Receivers

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

- Scenario 1 – Demolition of Goprint building:
  - Duration ~ 2 months
  - Dominant noise sources include rockbreakers, excavators and spoil trucks.
  - Daytime construction only.
- Scenario 2 – Installation of perimeter piles:
  - Duration ~ 2 months
  - Dominant noise sources include piling rigs
  - Daytime construction only
- Scenario 3 – Initial shaft excavation in hard rock and spoil removal:
  - Duration ~ 5 months
  - Dominant noise sources include rockbreakers, excavators, front end loaders and spoil trucks
  - Daytime construction only until acoustic enclosure constructed

- Scenario 4 – Night-time shaft and cavern excavation including rockbreakers and on-site spoil movements:
  - Duration ~ 15 months inclusive of station shaft and cavern excavation and therefore the initial stage of the station shaft excavation (i.e. typically the worst case stage of this scenario) would be significantly less in duration.
  - Dominant noise sources include rockbreakers, excavators, front end loaders and spoil 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 shed 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 four 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 62** to **Table 65**. 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 4. 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 proposed noise mitigation, and are presented in **Appendix F**.

Predicted ground-borne noise and vibration impacts for the excavation of the Woolloongabba Station shaft are presented in **Table 66**. All predicted ground-borne noise and vibration levels have been based on the shortest distance between the excavation source and the receiver building, that is the distance from the receiver building to existing rock level for shaft excavation and the top of station cavern for roadheading.

Table 62 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 - Allen St Residential	Day	$L_{A10,adj}$ – 77	56 - 54	-	-
B - Vulture St Residential	Day	$L_{A10,adj}$ – 62	65 - 54	3	-
C - Vulture St Commercial	Day	$L_{A10,adj}$ – 77	71 - 49	-	-
D - St Nicholas Cathedral	24/7	$L_{A10,adj}$ – 57	65 - 62	8	3
E - Main St Residential	Day	$L_{A10,adj}$ – 77	52 - 49	-	-
F - Main St Commercial	Day	$L_{A10,adj}$ – 77	65 - 44	-	-
G - Stanley St Commercial	Day	$L_{A10,adj}$ – 77	70 - 49	-	-
I – Stanley St Residential	Day	$L_{A10,adj}$ – 77	63 - 57	-	-
J – St Joseph’s School	Day	$L_{A10,adj}$ – 62	61 - 46	-	-

Note 1 – Dominant construction noise during Goprint building demolition 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 63 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 - Allen St Residential	Day	LA10,adj – 77	52 - 49	-	-
B - Vulture St Residential	Day	LA10,adj – 62	62 - 53	-	-
C - Vulture St Commercial	Day	LA10,adj – 77	70 - 47	-	-
D - St Nicholas Cathedral	24/7	LA10,adj – 57	61 - 58	4	-
E - Main St Residential	Day	LA10,adj – 77	54 - 51	-	-
F - Main St Commercial	Day	LA10,adj – 77	63 - 49	-	-
G - Stanley St Commercial	Day	LA10,adj – 77	66 - 51	-	-
I – Stanley St Residential	Day	LA10,adj – 77	60 - 59	-	-
J – St Joseph's School	Day	LA10,adj – 62	57 - 46	-	-

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 64 Woolloongabba Station Predicted Worst Case Noise Levels – Scenario 3 Initial 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 - Allen St Residential	Day	LA10,adj – 77	56 - 53	-	-
B - Vulture St Residential	Day	LA10,adj – 62	65 - 52	3	-
C - Vulture St Commercial	Day	LA10,adj – 77	75 - 45	-	-
D - St Nicholas Cathedral	24/7	LA10,adj – 57	65 - 62	8	3
E - Main St Residential	Day	LA10,adj – 77	56 - 53	-	-
F - Main St Commercial	Day	LA10,adj – 77	66 - 45	-	-
G - Stanley St Commercial	Day	LA10,adj – 77	69 - 49	-	-
I – Stanley St Residential	Day	LA10,adj – 77	65 - 59	-	-
J – St Joseph's School	Day	LA10,adj – 62	61 - 44	-	-

Note 1 – Dominant construction noise during initial 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 65 Woolloongabba Station Predicted Worst Case Noise Levels – Scenario 4 Night-time Shaft and Cavern 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 – Low Performance
A - Allen St Residential	Night	LAmax – 64	52 - 50	-	-	-
B - Vulture St Residential	Night	LAmax – 49	58 - 48	9	4	1[3]
E - Main St Residential	Night	LAmax – 64	52 - 49	-	-	-
I - Stanley St Residential	Night	LAmax – 64	67 - 59	3	-	-

Note 1 – Dominant construction noise during night-time shaft excavation likely to be non-steady state. Therefore the LAmax assessment parameter is most relevant.

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

Note 3 – Noise goal exceedance due to spoil truck movements outside of the acoustic enclosure.

Table 66 Woolloongabba Station Predicted Ground-borne Noise and Vibration Levels – Station Shaft and Cavern Excavation

Receiver Area	Period	Construction Sources Noise and Vibration Goals			Predicted Ground-borne Vibration Level (mm/s)		Predicted Ground-borne Noise Level (dBA)	
		Vibration PPV (mm/s)	Internal Ground-borne Noise (dBA)					
			Continuous[1]	Intermittent[2]	Rockbreaking	Roadheading	Rockbreaking	Roadheading
A - Allen St Residential	Day	10	LAeq,adj – 45	LA10,adj – 55	0.01	0.01	20	6
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.01	0.01	25	6
B - Vulture St Residential	Day	10	LAeq,adj – 45	LA10,adj – 55	0.02	0.01	28	15
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.02	0.01	33	15
C – Vulture St Commercial	Day	25	LAeq,adj – 45	LA10,adj – 55	0.05	0.06	36	28
D - St Nicholas Cathedral (Heritage Listed)	24/7	2	LAeq,adj – 40	LA10,adj – 50	0.05	0.17	37	39
E - Main St Residential	Day	10	LAeq,adj – 45	LA10,adj – 55	0.03	0.04	32	26
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.03	0.04	37	26
F – Main St Commercial	Day	25	LAeq,adj – 45	LA10,adj – 55	0.11	0.07	42	30
G – Stanley St Commercial	Day	25	LAeq,adj – 45	LA10,adj – 55	0.06	0.15	37	37
H – Busway Station	Day	25	n/a	n/a	0.39	0.26	n/a	n/a
I - Stanley St Residential	Day	25	LAeq,adj – 45	LA10,adj – 55	0.03	0.03	32	20
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.03	0.03	37	20
I – St Josephs Church & School (Heritage Listed)	Day	2	LAeq,adj – 45	LA10,adj – 55	0.02	0.02	27	16

Note 1: Dominant construction noise during cavern excavation (i.e. roadheading) likely to be steady state. Therefore the LAeq,adj assessment parameter is most relevant.

Note 2: Dominant construction noise during shaft excavation (i.e. rockbreaking) likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax (night-time) assessment parameters are most relevant.

Discussion

Air-borne Noise

The predicted noise levels for site establishment works including demolition of the existing GoPrint building at the Woolloongabba Station site indicate exceedances of the daytime noise goal of up to 3 dBA at the nearest residential receivers along Vulture Street with 3 m high acoustic hoarding around the site. Similar exceedances are predicted during the initial station shaft excavation (i.e. Scenario 3).

Higher exceedances are predicted for Scenario 1 to 3 at St Nicholas Cathedral due to the lower daytime noise goal. The assessment has assumed a 7 dBA outside to inside construction noise reduction through the facade. It is recommended that facade noise measurements be carried out prior to the commencement of construction works at the site to determine the actual acoustic performance of the facade as it is likely that to be achieving higher than 7 dBA being situation adjacent to Vulture Street. Subsequent to the findings of the facade noise measurements, temporary (or permanent) upgrades to the facade (e.g. double glazing, acoustic seals around doors etc) would need to be considered in tandem with respite periods during services.

Activities associated with night-time excavation and spoil removal from the site (i.e. Scenario 4) are also predicted to exceed the night-time residential noise goal at the nearest receivers. Even with the provision of a low performance acoustic shed, a marginal 1 dBA night-time sleep disturbance noise goal is predicted as a result of spoil truck movements through the site, which only a small distance of this on-site journey would occur inside the acoustic shed.

With all practicable noise mitigation measures in place combined with careful management of all heavy vehicle movements on the site, noise impacts associated with the construction phase of the Woolloongabba Station for the BaT project should be largely avoided.

Ground-borne Noise & Vibration

The predicted ground-borne noise and vibration levels in **Table 66** 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.

8.4 George Street Station

8.4.1 Nearest Sensitive Receivers

The nearest noise and/or vibration sensitive receivers to the George Street Station site are identified in **Table 67** with the receiver areas illustrated in **Figure 14**.

Figure 14 George Street Station Receiver Areas

Table 67 Nearest Sensitive Receivers – George Street Station

Work Site/Excavation	Receiver Area	Distance to Worksite Boundary
George Street Station	A - QUT	300 m
	B - Parliament	190 m
	C - 41 George St Commercial	< 10 m
	D - 103 George St Residential	65 m
	E - Alice St Commercial	115 m
	F - City Botanic Gardens	170 m
	G - 21 Mary St Residential	20 m
	H - 21 Mary St Commercial	25 m
	I - Brisbane Synagogue (Margaret Street)	20 m

8.4.2 Site Specific Construction Noise Goals

With reference to the BaT project noise goals and the ambient noise survey results summarised in **Section 3.2.7** and **Section 4.1.4** respectively, the site specific construction noise goals are presented in **Table 68**.

Table 68 George 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 $L_{Aeq,adj(15min)}$) [1]	Intermittent (dBA L_{Amax}) [1]
A - QUT	52[2]	62[2]	-	-
B - Parliament	67	77	-	-
C - 41 George St Commercial	67	77	-	-
D - 103 George St Residential	67	77	57	64
E - Alice St Commercial	67	77	-	-
F - City Botanic Gardens	Ensure an area of the park that preserves the amenity of the existing park			
G - 21 Mary St Residential	67	77	57	64
H - 21 Mary St Commercial	67	77	-	-
I - Brisbane Synagogue	47[2]	57[2]	-	-

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

8.4.3 Assessment at the Nearest Noise and/or Vibration Sensitive Receivers

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

- Scenario 1 – Site establishment including demolition of existing buildings:
  - Duration ~ 3 months
  - Dominant noise sources include rockbreakers, excavators, spoil trucks and cranes
  - Mostly daytime construction works with potential for night-time work to avoid impact on existing road operations
- Scenario 2 – Piling of station access shaft (Mary Street staging):
  - Duration ~ 1 month
  - Dominant noise sources include piling rigs
  - Mostly daytime construction works with potential for night-time work to avoid impact on existing road operations
- Scenario 3 – Initial station access shaft excavation:
  - Duration ~ 5 months
  - Dominant noise sources include rockbreakers, excavators, front end loaders and spoil trucks
  - Daytime construction only until acoustic enclosure constructed
- Scenario 4 – Night-time shaft excavation including rockbreakers and on-site spoil movements:
  - Duration ~ 18 months inclusive of station shaft and cavern excavation and therefore the initial stage of the station shaft excavation (i.e. typically the worst case stage of this scenario) would be significantly less in duration.
  - Dominant noise sources include rockbreakers, excavators, front end loaders and spoil trucks
  - 24 hour per day construction with night-time works carried out inside an 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 69** 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 and works carried out inside an acoustic enclosure for Scenario 4. 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 F**.

Predicted ground-borne noise and vibration impacts for the excavation of the George Street Station access shaft and cavern is presented in **Table 73**. All predicted ground-borne noise and vibration levels have been based on the shortest distance between the excavation source and the receiver building, that is the distance from the receiver building to existing rock level for shaft excavation and the top of station cavern for roadheading. Where exceedances of the ground-borne noise and vibration goals have been predicted based on the shortest source to receiver distance, predictions have also been carried out for increasing source to receiver distances to reflect increasing excavation depths.

Predicted ground-borne vibration and airblast overpressure impacts associated with blasting for the George Street Station access shaft are presented in **Table 74**.

Table 69 George 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	$L_{A10,adj}$ – 62	48 - 34	-	-
B - Parliament	Day	$L_{A10,adj}$ – 77	51 - 44	-	-
C - 41 George St Commercial	Day	$L_{A10,adj}$ – 77	76 - 49	-	-
D - 103 George St Residential	Day	$L_{A10,adj}$ – 77	63 - 60	-	-
E - Alice St Commercial	Day	$L_{A10,adj}$ – 77	53 - 52	-	-
F - City Botanic Gardens	Day	n/a	51 - 51	-	-
G - 21 Mary St Residential	Day	$L_{A10,adj}$ – 77	84 - 70	7	7[3]
H - 21 Mary St Commercial	Day	$L_{A10,adj}$ – 77	86 - 58	9	9[3]
I – Brisbane Synagogue	Any	$L_{A10,adj}$ – 57	51 - 61	4	-

Note 1 – Dominant construction noise during site establishment likely to be non-steady state and intermittent. Therefore the $L_{A10,adj}$ and $L_{Amax,adj}$ (night-time) assessment parameters are most relevant.

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

Note 3 – Negligible effect from increasing the 3 m noise barrier to 6 m due to the height and position of the receiver.

Table 70 George Street Station Predicted Worst Case Noise Levels – Scenario 2 Piling for Station Shaft

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	47 - 34	-	-
B - Parliament	Day	LA10,adj – 77	50 - 41	-	-
C - 41 George St Commercial	Day	LA10,adj – 77	76 - 46	-	-
D - 103 George St Residential	Day	LA10,adj – 77	60 - 55	-	-
E - Alice St Commercial	Day	LA10,adj – 77	52 - 50	-	-
F - City Botanic Gardens	Day	n/a	50 - 50	-	-
G - 21 Mary St Residential	Day	LA10,adj – 77	75 - 65	-	-
H - 21 Mary St Commercial	Day	LA10,adj – 77	82 - 64	5	5[3]
I – Brisbane Synagogue	Day	LA10,adj – 57	51 - 60	3	-

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.

Note 3 – Negligible effect from increasing the 3 m noise barrier to 6 m due to the height and position of the receiver.

Table 71 George Street Station Predicted Worst Case Noise Levels – Scenario 3 Initial 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 - QUT	Day	LA10,adj – 62	50 - 35	-	-
B - Parliament	Day	LA10,adj – 77	56 - 45	-	-
C - 41 George St Commercial	Day	LA10,adj – 77	80 - 51	3	3[3]
D - 103 George St Residential	Day	LA10,adj – 77	64 - 60	-	-
E - Alice St Commercial	Day	LA10,adj – 77	59 - 56	-	-
F - City Botanic Gardens	Day	n/a	55 - 55	-	-
G - 21 Mary St Residential	Day	LA10,adj – 77	82 - 71	5	5[3]
H - 21 Mary St Commercial	Day	LA10,adj – 77	89 - 70	12	12[3]
I - Brisbane Synagogue	Day	LA10,adj – 57	50 - 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.

Note 3 – Negligible effect from increasing the 3 m noise barrier to 6 m due to the height and position of the receiver.

Table 72 George Street Station Predicted Worst Case Noise Levels – Scenario 4 Night-time 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 – Medium Performance
D - 103 George St Residential	Night	LAmax – 64	60 - 55	-	-	-
G - 21 Mary St Residential	Night	LAmax – 64	84 - 71	20	20	-

Note 1 – Dominant construction noise during night-time shaft excavation likely to be non-steady state. Therefore the LAmax assessment parameter is most relevant.

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

Table 73 George Street Station Predicted Ground-borne Noise and Vibration Levels – Station Shaft and Cavern Excavation

Receiver Area	Period	Construction Sources Noise and Vibration Goals			Predicted Ground-borne Vibration Level (mm/s)		Predicted Ground-borne Noise Level (dBA)		
		Continuous Vibration PPV (mm/s)	Internal Ground-borne Noise (dBA)						
			Continuous[1]	Intermittent[2]	Rockbreaking	Roadheading	Rockbreaking	Roadheading	Drilling
A - QUT (heritage)	Day	2	LAeq,adj – 45	LA10,adj – 55	0.01	0.01	23	12	14
B - Parliament House (heritage)	Day	2	LAeq,adj – 45	LA10,adj – 55	0.02	0.02	28	19	20
C – 41 George St Commercial: Source @ RL10	Day	25	LAeq,adj – 45	LA10,adj – 55	10.5	0.16	**78 (23)** [3]	39	**68 (13)** [3]
C – 41 George St Commercial: Source @ RL0	Day	-	-	LA10,adj – 55	1.38	-	**62 (7)** [3]	-	53
C – 41 George St Commercial: Source @ RL-10	Day	-	-	LA10,adj – 55	-	-	55	-	-
C – 80 George St (heritage): Source @ RL10	Day	2	LAeq,adj – 45	LA10,adj – 55	**2.13 (0.13)** [3]	0.14	**63 (8)** [3]	36	**56 (1)** [3]
C – 80 George St (heritage): Source @ RL0	Day	2	-	LA10,adj – 55	0.98	-	**57 (2)** [3]	-	50
C – 80 George St (heritage): Source @ RL-10	Day	-	-	LA10,adj – 55	-	-	52	-	**-**
D – 103 George St Residential	Day	25	LAeq,adj – 45	LA10,adj – 55	0.14	0.15	42	35	34

Receiver Area	Period	Construction Sources Noise and Vibration Goals			Predicted Ground-borne Vibration Level (mm/s)		Predicted Ground-borne Noise Level (dBA)		
		Continuous Vibration PPV (mm/s)	Internal Ground-borne Noise (dBA) Continuous[1]	Internal Ground-borne Noise (dBA) Intermittent[2]	Rockbreaking	Roadheading	Rockbreaking	Roadheading	Drilling
D – 103 George St Residential: Source @ RL10	Night	0.5	LAeq,adj – 35	LAmax – 42	0.14	0.15	**47 (5)** [3]	35	39
D – 103 George St Residential: Source @ RL0	Night	-	-	LAmax – 42	-	-	**47 (5)** [3]	**-**	-
D – 103 George St Residential: Source @ RL-10	Night	-	-	LAmax – 42	-	-	**46 (4)** [3]	**-**	-
E – Queensland Club (heritage)	Day	2	LAeq,adj – 45	LA10,adj – 55	0.05	0.16	35	38	40
G – 21 Mary St Residential: Source @ RL10	Day	25	LAeq,adj – 45	LA10,adj – 55	6.43	0.06	**64 (9)** [3]	27	55
G – 21 Mary St Residential: Source @ RL0	Day	-	-	LA10,adj – 55	0.57	-	51	-	42
G – 21 Mary St Residential: Source @ RL-10	Day	-	-	LA10,adj – 55	**-**	-	44	-	**-**
G – 21 Mary St Residential: Source @ RL10	Night	0.5	LAeq,adj – 35	LAmax – 42	**6.43 (5.93)** [3]	0.06	**69 (27)** [3]	27	**60 (18)** [3]
G – 21 Mary St Residential: Source @ RL0	Night	0.5	-	LAmax – 42	**0.57 (0.07)** [3]	-	**56 (14)** [3]	-	**47 (5)** [3]
G – 21 Mary St Residential: Source @ RL-10	Night	-	-	LAmax – 42	0.21	-	**49 (7)** [3]	-	41
H – 21 Mary St Commercial: Source @ RL10	Day	25	LAeq,adj – 45	LA10,adj – 55	19.62	0.17	**83 (28)** [3]	39	**73 (18)** [3]

Receiver Area	Period	Construction Sources Noise and Vibration Goals			Predicted Ground-borne Vibration Level (mm/s)		Predicted Ground-borne Noise Level (dBA)		
		Continuous Vibration PPV (mm/s)	Internal Ground-borne Noise (dBA)		Rockbreaking	Roadheading	Rockbreaking	Roadheading	Drilling
			Continuous[1]	Intermittent[2]					
H – 21 Mary St Commercial: Source @ RL0	Day	-	-	LA10,adj – 55	-	-	**64 (9)** [3]	-	55
H – 21 Mary St Commercial: Source @ RL-10	Day	-	-	LA10,adj – 55	-	-	**56 (1)** [3]	-	-
I – Brisbane Synagogue (heritage): Source @ RL10	Day	2	LAeq,adj – 40	LA10,adj – 50	0.76	0.15	**55 (5)** [3]	38	48
I – Brisbane Synagogue (heritage): Source @ RL0	Day	-	-	LA10,adj – 50	-	-	**54 (4)** [3]	-	-
I – Brisbane Synagogue (heritage): Source @ RL-10	Day	-	-	LA10,adj – 50	-	-	**51 (1)** [3]	-	-

Note 1: Dominant construction noise during cavern excavation (i.e. roadheading) likely to be steady state. Therefore the LAeq,adj assessment parameter is most relevant.

Note 2: Dominant construction noise during shaft excavation (i.e. rockbreaking) likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax (night-time) assessment parameters are most relevant.

Note 3: Exceedances of noise or vibration goal shown in ( ).

Table 74 George Street Station Predicted Ground-borne Vibration and Airblast Overpressure Levels – Blasting of Station Shaft

Receiver Area	Period	Blasting Criteria		Maximum Allowed Blast MIC to meet Noise & Vibration Goal (kg)			
				Conventional Blasting		PCF Blasting[1]	
		Vibration PPV (mm/s)	Airblast Overpressure (dBL Peak)	Vibration	Airblast Overpressure	Vibration	Airblast Overpressure
A - QUT (heritage)	Day	10	132	>100	>100	>100	>100
B – Parliament House (heritage)	Day	10	132	>100	>100	>100	>100
C – George St Commercial	Day	50	132	0.18	0.08	0.20	5.57
C – George St Heritage	Day	10	132	0.17	1.36	0.14	99
D – George Street Residential	Day	50	132	33	>100	36	>100
E – Queensland Club (heritage)	Day	50	132	>100	>100	>100	>100
G – Mary Street Residential	Day	50	132	0.31	0.17	0.34	12
H – Mary Street Commercial	Day	50	132	0.16	0.06	0.17	4.46
I – Brisbane Synagogue (heritage)	Day	10	132	0.58	8.72	0.47	>100

Note 1: A PCF cartridge mass as little as 10 grams may be practicable.

Discussion

Air-borne Noise

The predicted noise levels for site establishment works including demolition of the existing buildings at the George Street Station worksite indicate exceedances of up to 7 dBA of the daytime noise goal at the high-rise residential apartment building at 21 Mary Street adjacent to the site. Similar noise goal exceedances are predicted during initial shaft excavation works at this site.

Once excavation of the station shaft has progressed far enough to allow for installation of the acoustic enclosure, noise emission levels from the site would decrease significantly. The airborne construction noise assessment has indicated that a medium performance acoustic shed (refer to the typical construction type in **Table 45**) will be required to achieve compliance with the airborne noise goals during the night-time period.

It is noteworthy that 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 (i.e. with no noise limits) over extended periods of time (e.g. greater than 12 months). It is likely that noise sensitive receivers in the vicinity of the George Street Station worksite would associate initial BaT project construction work involving site establishment, demolition and piling, with typical high-rise building construction works. Where BaT project 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 shed to minimise any noise impacts.

Ground-borne Noise & Vibration from Mechanical Excavation

The ground-borne noise levels presented in **Table 73** for rockbreaking during excavation of the George Street Station shaft is predicted to significantly exceed the daytime and night-time noise goals for the residential receiver building located along the north-east boundary of the site (i.e. 21 Mary Street, Day: 9 dBA and Night: 27 dBA) as well as during the night-time period for 103 George Street (i.e. Night: 5 dBA).

The daytime noise goal applicable to the commercial receiver buildings on the north-east (i.e. 21 Mary Street: 23 dBA) and south-east (i.e. 41 George Street: 28 dBA) boundary of the site is also predicted to be significantly exceeded during rockbreaking of the station shaft.

A 6 dBA exceedance of the night-time noise goal and a marginal 1 dBA exceedance of the daytime noise goal are predicted inside 103 George Street (residential receiver building) during roadheading of the station cavern.

A marginal exceedance of the 2 mm/s vibration goal for heritage structures is predicted for Harris Terrace (i.e. C - George Street heritage) during the initial stages of heavy rockbreaking of the station shaft. It is noteworthy that BS 7385 states that a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive. Notwithstanding this, it is recommended that a building condition survey be carried out at Harris Terrace prior to the commencement of construction works at the George Street site. Vibration monitoring at Harris Terrace is also recommended during (at least) the initial stages of shaft excavation.

Based on the predicted vibration levels in **Table 73**, it is recommended that a survey of potentially sensitive building contents (e.g. sensitive computer systems, instruments etc) be carried out inside the adjacent Mary Street and George Street buildings prior to the commencement of shaft excavation works. If vibration sensitive equipment is identified and temporary relocation is not feasible, further predictive modelling would be required to determine specific vibration mitigation measures.

Notwithstanding the worst-case predicted ground-borne noise and vibration impacts summarised above, further predictions were carried out for the two buildings adjacent to the George Street Station shaft worksite (i.e. 21 Mary Street and 41 George Street). These predictions were carried out for the purpose of taking into consideration the effect of increased shaft depth (i.e. as shaft excavation progresses downwards) or by interrupting the direct transmission path of vibrations by creating cut-off trenches in the rock between the rockbreaking / drilling location and the foundations of the two adjacent buildings. Based on these two scenarios, the findings are summarised as follows:

- Ground-borne noise levels from blast hole drilling are predicted to comply with the noise goal during the daytime for the commercial receivers at 41 George Street and 21 Mary Street and the residential floors of 21 Mary Street.
- Ground-borne noise levels from rockbreaking are predicted to exceed the noise goal during the daytime for the commercial receivers at 41 George Street (i.e. by 7 dBA) and 21 Mary Street (i.e. by 9 dBA).
- Ground-borne noise levels from blast hole drilling are predicted to exceed the noise goal during the night-time for the closest residential floor of 21 Mary Street by 5 dBA. Based on a 2 dBA ground-borne noise level attenuation per floor, the first three residential floors of 21 Mary Street are predicted to exceed the internal ground-borne noise goal.
- Ground-borne noise levels from rockbreaking are predicted to exceed the noise goal during the night-time for the closest residential floor of 21 Mary Street by 14 dBA.

Given the predicted regenerated noise and vibration exceedances, in particular at 21 Mary Street and 41 George Street, it is strongly recommended that:

- Rockbreaking be restricted to the daytime period until measurement results achieve compliance with the ground-borne noise goals or affected residents have been temporarily relocated.
- Ground-borne noise and vibration measurement trials are carried out for rockbreaking during the detailed design stage of the BaT project to accurately determine the extent of the impact and to allow sufficient time to develop an appropriate management strategy.
- Preference is given to drill and blast for the station shaft excavation and subject to the findings of ground-borne noise trials at the site, drilling of blast holes may also need to be restricted during the night-time period.

Drill and Blast

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. Furthermore, the predicted ground-borne noise levels in **Table 73** indicate that drilling of blast holes results in a better environmental outcome compared with rockbreaking the entire station shaft.

Considerable exceedances of the internal noise goals are still predicted to occur within the commercial and residential levels of the adjacent Mary Street building as well as the adjacent George Street commercial building. Should drill and blast be required for this worksite, the following management measures would be required to deal with these exceedances:

- Restricting drilling to the daytime period until measurement results achieve compliance with the ground-borne noise goals or affected residents have been temporarily relocated.
- Investigate the benefits from making deep vertical cuts into the rock using rock saws or diamond wire (e.g. blind hole cutting) along the boundaries of the shaft shared with adjacent buildings. The cuts would increase the propagation path of the vibration emitted from the drilling (as well as for blasting).
- Use of latest available blasting technology (e.g. PCF, double decking etc).

- Pre-blasting condition survey of adjacent buildings.
- Appropriate attention to blast design and commence blasting with a low MIC to develop a site law (i.e. blast design model) based on measurement data from the site.
- Monitoring of the blast emissions.

8.5 Roma Street Station

8.5.1 Nearest Sensitive Receivers

The nearest noise and/or vibration sensitive receivers to the Roma Street Station site are identified in **Table 75** with the receiver areas illustrated in **Figure 15**.

Figure 15 Roma Street Station Receiver Areas

Table 75 Nearest Sensitive Receivers – Roma Street Station

Work Site/Excavation	Receiver Area	Distance to Worksite Boundary
Roma Street Station	A - Wickham Terrace Residential	95 m
	B - Wickham Terrace Commercial	100 m
	C - Memorial Hospital	270 m
	D - St Alban Catholic Church	95 m
	E - Brisbane Private Hospital	140 m
	F - Dentist School	300 m
	G - Roma St Residential (Traders Hotel)	120 m
	H - Roma St Station [1]	10 m
	I - Parkland Boulevard Residential	< 10 m
	J - Parkland Boulevard Commercial	< 10 m
	K - Roma St Parkland	< 10 m

Note 1 – Receiver includes the Roma Street Station southern building which is heritage listed.

8.5.2 Site Specific Construction Noise Goals

With reference to the BaT project noise goals and the ambient noise survey results summarised in **Section 3.2.7** and **Section 4.1.4** respectively, the site specific construction noise goals are presented in **Table 76**.

Table 76 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 $L_{Aeq,adj(15min)}$) [1]	Intermittent (dBA L_{Amax}) [1]
A - Wickham Terrace Residential	52	62	42	49
B - Wickham Terrace Commercial	67	77	-	-
C - Memorial Hospital	62[2]	72[2]	57	64
D - St Alban Catholic Church	47[3]	57[3]	-	-
E - Brisbane Private Hospital	62[2]	72[2]	57	64
F - Dentist School	52	62	-	-
G - Roma St Residential (Traders Hotel)	67	77	57	64
H - Roma St Station	n/a[4]	n/a[4]	-	-
I - Parkland Boulevard Residential	67	77	57	64
J - Parkland Boulevard Commercial	67	77	-	-
K - Roma St Parkland	Ensure an area of the park that preserves the amenity of the existing park			

Note 1 – Noise goal has been adjusted to represent external free-field levels.
Note 2 - Based on AS2107 category “wards” for medical buildings. 25 dBA façade adjustment to an external noise goal
Note 3 - Monday to Saturday 6:30 am to 6:30 pm goals relevant at all times.
Note 4 - No internal waiting area spaces on ground level therefore AS2107 airborne noise criteria not applicable.

8.5.3 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 (i.e. worst case) noise impact on the surrounding receivers. Worst case scenarios have been developed based on all plant items, as proposed by the BaT project design team including spoil trucks where applicable, operating simultaneously. These scenarios are:

- Scenario 1 – Site establishment including removal of Roma Street Station infrastructure:
  - Duration ~ 3 months
  - Dominant noise sources include rockbreakers, excavators, spoil trucks and cranes
  - Mostly daytime construction works with potential for night-time work to avoid impact on existing rail operations
- Scenario 2 – Piling of station access shaft:
  - Duration ~ 1 month
  - Dominant noise sources include piling rigs
  - Daytime construction only
- Scenario 3 – Initial station access shaft excavation:
  - Duration ~ 5 months
  - Dominant noise sources include rockbreakers, excavators, front end loaders and spoil trucks
  - Daytime construction only until acoustic enclosure constructed

- Scenario 4 – Night-time shaft excavation including rockbreakers and on-site spoil movements:
  - Duration ~ 17 months inclusive of station shaft and cavern excavation and therefore the initial stage of the station shaft excavation (i.e. typically the worst case stage of this scenario) would be significantly less in duration.
  - Dominant noise sources include rockbreakers, excavators, front end loaders and spoil trucks
  - 24 hour per day construction with night-time works carried out inside an 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 77** to **Table 80**. 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 4. 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 F**.

Predicted ground-borne noise and vibration impacts for the excavation of Roma Street Station access shaft and station cavern are presented in **Table 81**. All predicted ground-borne noise and vibration levels have been based on the shortest distance between the excavation source and the receiver building, that is the distance from the receiver building to existing rock level for shaft excavation and the top of station cavern for roadheading. Where exceedances of the ground-borne noise and vibration goals have been predicted based on the shortest source to receiver distance, predictions have also been carried out for increasing source to receiver distances to reflect increasing excavation depths.

Predicted ground-borne vibration and airblast overpressure impacts associated with blasting for the Roma Street Station access shaft are presented in **Table 82**.

Table 77 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 Residential	Day	$L_{A10,adj}$ – 62	54 - 46	-	-
B - Wickham Terrace Commercial	Day	$L_{A10,adj}$ – 77	51 - 47	-	-
C - Memorial Hospital	24/7	$L_{A10,adj}$ – 72	50 - 47	-	-
D - St Alban Catholic Church	24/7	$L_{A10,adj}$ – 57	50 - 47	-	-
E - Brisbane Private Hospital	24/7	$L_{A10,adj}$ – 72	50 - 43	-	-
F - Dentist School	Day	$L_{A10,adj}$ – 62	38 - 33	-	-
G - Roma St Residential (Traders Hotel)	Day	$L_{A10,adj}$ – 77	52 - 41	-	-
I - Parkland Boulevard Residential	Day	$L_{A10,adj}$ – 77	81 - 77	4	4[3]
J - Parkland Boulevard Commercial	Day	$L_{A10,adj}$ – 77	79 - 76	2	2[3]
K - Roma St Parkland	Day	n/a	61 - 58	-	-

Note 1 – Dominant construction noise during site establishment likely to be non-steady state and intermittent. Therefore the $L_{A10,adj}$ and $L_{Amax,adj}$ (night-time) assessment parameters are most relevant.

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

Note 3 – Negligible effect from increasing the 3 m noise barrier to 6 m due to the height and position of the receiver.

Table 78 Roma Street Station Predicted Noise Levels – Scenario 2 Piling Station Access Shaft

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 Residential	Day	LA10,adj – 62	56 - 47	-	-
B - Wickham Terrace Commercial	Day	LA10,adj – 77	54 - 51	-	-
C - Memorial Hospital	24/7	LA10,adj – 72	52 - 49	-	-
D - St Alban Catholic Church	24/7	LA10,adj – 57	54 - 51	-	-
E - Brisbane Private Hospital	24/7	LA10,adj – 72	53 - 47	-	-
F - Dentist School	Day	LA10,adj – 62	41 - 38	-	-
G - Roma St Residential (Traders Hotel)	Day	LA10,adj – 77	54 - 40	-	-
I - Parkland Boulevard Residential	Day	LA10,adj – 77	87 - 75	10	10[3]
J - Parkland Boulevard Commercial	Day	LA10,adj – 77	80 - 77	3	3[3]
K - Roma St Parkland	Day	n/a	59 - 56	-	-

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.

Note 3 – Negligible effect from increasing the 3 m noise barrier to 6 m due to the height and position of the receiver.

Table 79 Roma Street Station Predicted Noise Levels – Scenario 3 Initial 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 - Wickham Terrace Residential	Day	LA10,adj – 62	58 - 44	-	-
B - Wickham Terrace Commercial	Day	LA10,adj – 77	56 - 50	-	-
C - Memorial Hospital	24/7	LA10,adj – 72	55 - 55	-	-
D - St Alban Catholic Church	24/7	LA10,adj – 57	54 - 54	-	-
E - Brisbane Private Hospital	24/7	LA10,adj – 72	55 - 46	-	-
F - Dentist School	Day	LA10,adj – 62	39 - 36	-	-
G - Roma St Residential (Traders Hotel)	Day	LA10,adj – 77	57 - 42	-	-
I - Parkland Boulevard Residential	Day	LA10,adj – 77	86 - 80	9	9[3]
J - Parkland Boulevard Commercial	Day	LA10,adj – 77	84 - 80	7	7[3]
K - Roma St Parkland	Day	n/a	60 - 60	-	-

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.

Note 3 – Negligible effect from increasing the 3 m noise barrier to 6 m due to the height and position of the receiver.

Table 80 Roma Street Station Predicted Noise Levels – Scenario 4 Night-time 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 - High Performance
A - Wickham Tce Residential	Night	LAmax – 49	55 - 40	6	1	-
C - Memorial Hospital	Night	LAmax – 64	45 - 45	-	-	-
E - Brisbane Private Hospital	Night	LAmax – 64	47 - 44	-	-	-
G - Roma St Residential (Traders Hotel)	Night	LAmax – 64	55 - 42	-	-	-
I - Parkland Boulevard Residential	Night	LAmax – 64	83 - 80	19	19	-

Note 1 – Dominant construction noise during night-time shaft excavation likely to be non-steady state. Therefore the LAmax assessment parameter is most relevant.

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

Table 81 Roma Street Station Predicted Ground-borne Noise and Vibration Levels – Station Shaft and Cavern Excavation

Receiver Area	Period	Construction Sources Noise and Vibration Goals			Predicted Ground-borne Vibration Level (mm/s)		Predicted Ground-borne Noise Level (dBA)		
		Continuous Vibration PPV (mm/s)	Internal Ground-borne Noise (dBA) Continuous[1]	Internal Ground-borne Noise (dBA) Intermittent[2]	Rockbreaking	Roadheading	Rockbreaking	Roadheading	Drilling
A – Wickham Tce Residential	Day	10	LAeq,adj – 45	LA10,adj – 55	0.02	0.02	31	15	22
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.02	0.02	36	15	27
B – Wickham Tce Commercial	Day	10	LAeq,adj – 45	LA10,adj – 55	0.02	0.02	30	15	22
C – Memorial Hospital	Day	2	LAeq,adj – 40	LA10,adj – 50	0.01	0.01	21	10	13
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.01	0.01	26	10	18
D – St Alban Church	24/7	10	LAeq,adj – 40	LA10,adj – 50	0.02	0.02	31	15	22
E – Brisbane Private Hospital	Day	25	LAeq,adj – 40	LA10,adj – 50	0.01	0.01	24	10	16
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.01	0.01	29	10	21
F – Brisbane Dental Educational	Day	25	LAeq,adj – 45	LA10,adj – 55	0.00	0.01	18	5	10
G – Traders Hotel Residential	Day	25	LAeq,adj – 45	LA10,adj – 55	0.02	0.02	28	18	20
	Night	0.5	LAeq,adj – 35	LAmax – 42	0.02	0.02	33	18	25
H – Old Train Station Heritage	Day	2	n/a	n/a	0.06	0.24	n/a	n/a	n/a
I – Parkland Blvd Residential: Source @ RL19	Day	25	LAeq,adj – 45	LA10,adj – 55	4.31	0.16	**68 (13)** [3]	36	**59 (4)** [3]
I – Parkland Blvd Residential: Source @ RL10	Day	n/a	n/a	LA10,adj – 55	n/a	n/a	**56 (1)** [3]	n/a	47
I – Parkland Blvd Residential: Source @ RL1	Day	n/a	n/a	LA10,adj – 55	n/a	n/a	50	n/a	41
I – Parkland Blvd Residential: Source @ RL19	Night	0.5	LAeq,adj – 35	LAmax – 42	**4.31 (3.81)** [3]	0.16	**73 (31)** [3]	**36 (1)** [3,4]	**64 (22)** [3]

Receiver Area	Period	Construction Sources Noise and Vibration Goals			Predicted Ground-borne Vibration Level (mm/s)		Predicted Ground-borne Noise Level (dBA)		
		Continuous Vibration PPV (mm/s)	Internal Ground-borne Noise (dBA)		Rockbreaking	Roadheading	Rockbreaking	Roadheading	Drilling
			Continuous[1]	Intermittent[2]					
I – Parkland Blvd Residential: Source @ RL10	Night	0.5	n/a	LAmax – 42	**0.87 (0.37)**	n/a	**61 (19)** [3]	n/a	**52 (10)** [3]
I – Parkland Blvd Residential: Source @ RL1	Night	0.5	n/a	LAmax – 42	0.39	n/a	**55 (13)** [3]	n/a	**46 (4)** [3]
J – Parkland Blvd Commercial: Source @ RL19	Day	25	LAeq,adj – 45	LA10,adj – 55	6.74	0.25	**74 (19)** [3]	42	**65 (10)** [3]
J – Parkland Blvd Commercial: Source @ RL10	Day	5	n/a	LA10,adj – 55	1.36	n/a	**62 (7)** [3]	n/a	53
J – Parkland Blvd Commercial: Source @ RL1	Day	n/a	n/a	LA10,adj – 55	n/a	n/a	**56 (1)** [3]	n/a	n/a

Note 1: Dominant construction noise during cavern excavation (i.e. roadheading) likely to be steady state. Therefore the LAeq,adj assessment parameter is most relevant.

Note 2: Dominant construction noise during shaft excavation (i.e. rockbreaking) likely to be non-steady state and intermittent. Therefore the LA10,adj and LAmax (night-time) assessment parameters are most relevant.

Note 3: Exceedances of noise or vibration goal shown in ( ).

Note 4: Compliance with the ground-borne noise goal predicted from RL 0 and below (i.e. after approximately the top 2 m of rock roadheaded from the station cavern).

Table 82 Roma Street Station Predicted Ground-borne Vibration and Airblast Overpressure Levels – Blasting of Station Shaft

Receiver Area	Period	Blasting Criteria		Maximum Allowed Blast MIC to meet Noise & Vibration Goal (kg)			
				Conventional Blasting		PCF Blasting[1]	
		Vibration PPV (mm/s)	Airblast Overpressure (dBL Peak)	Vibration	Airblast Overpressure	Vibration	Airblast Overpressure
A – Wickham Tce Residential	Day	50	132	>100	>100	>100	>100
B – Wickham Tce Commercial	Day	50	132	>100	>100	>100	>100
C – Memorial Hospital	Day	10	132	>100	>100	>100	>100
D – St Alban Church	Day	50	132	>100	>100	>100	>100
E – Brisbane Private Hospital	Day	50	132	>100	>100	>100	>100
F – Brisbane Dental Educational	Day	50	132	>100	>100	>100	>100
G – Traders Hotel Residential	Day	50	132	>100	>100	>100	>100
H – Old Train Station Heritage	Day	10	132	11	>100	9.27	>100
I – Parkland Boulevard Residential	Day	50	132	0.31	0.17	0.34	12
J – Parkland Boulevard Commercial	Day	50	132	0.31	0.17	0.34	12

Note 1: A PCF cartridge mass as little as 10 grams may be practicable.

Discussion

Air-borne Noise

For worst-case construction Scenarios 1 to 3, the predicted noise emission levels for Roma Street Station works exceed the noise goals at the Parkland Boulevard building adjacent to the site. The highest noise goal exceedance (i.e. of up to 10 dBA), based on Scenarios 1 to 3, is predicted to occur during the operation of the bored piling rigs adjacent to the Parkland Boulevard receiver building. A similar exceedance of the noise goal is anticipated during the operation of rockbreakers, particularly during the initial stages of the shaft excavation prior to the construction of acoustic enclosure over the shaft.

Given the height of the receiver building and its proximity to the worksite, increasing the 3 m high acoustic barrier around the site would have a negligible effect on construction noise emission levels at the Parkland Boulevard receiver building. The airborne noise assessment has therefore identified the requirement of a high performance acoustic shed over the Roma Street Station worksite.

Ground-borne Noise & Vibration from Mechanical Excavation

The ground-borne noise levels presented in **Table 81** for rockbreaking during excavation of the Roma Street Station shaft is predicted to significantly exceed the daytime noise goals for both the commercial receivers (i.e. by up to 19 dBA) and residential receivers (i.e. by up to 13 dBA) inside the adjacent Parkland Boulevard receiver building. The night-time noise goal for the residential receivers in this building is also predicted to be significantly exceeded as a result of ground-borne noise from rockbreaking. The predicted ground-borne noise levels in **Table 81** are based on a large rockbreaker, however it is anticipated that even a relatively small rockbreaker would exceed the internal noise goals for the Parkland Boulevard 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 all levels of the apartment building would be impacted during the night-time period.

A marginal 1 dBA exceedance of the night-time noise goal is predicted inside the Parkland Boulevard apartment building during roadheading of the station cavern.

The close proximity of the Parkland Boulevard receiver building to the rockbreaking required for the BaT project is the reason for the predicted exceedance, in **Table 81**, of the vibration criteria for the night-time period. Notwithstanding this, it is noteworthy that the predicted construction vibration levels at the Parkland Boulevard apartment building is well below the guide values, judged to result in a minimal risk of cosmetic damage, as provided in BS 7385 for heavy reinforced buildings such as the Parkland Boulevard building.

Further to the worst-case predicted ground-borne noise and vibration impacts summarised above, predictions were carried out for the Parkland Boulevard building taking into consideration the effect of increased shaft depth (i.e. as shaft excavation progresses downwards) or by interrupting the direct transmission path of vibrations by creating cut-off trenches in the rock between the rockbreaking / drilling location and the foundations of the Parkland Boulevard building. Based on these two scenarios, the findings are summarised as follows:

- Ground-borne noise levels from blast hole drilling are predicted to comply with the noise goal during the daytime for both the commercial receiver floor and the closest residential floor.
- Ground-borne noise levels from rockbreaking are predicted to exceed the noise goal during the daytime for both the commercial receiver floor (i.e. by 7 dBA) and the closest residential floor by a marginal 1 dBA. Based on a 2 dBA ground-borne noise level attenuation per floor, only the first residential floor of the Parkland Boulevard building is predicted to exceed the internal ground-borne noise goal during the daytime period.

- Ground-borne noise levels from blast hole drilling are predicted to exceed the noise goal during the night-time for the closest residential floor by 10 dBA. Based on a 2 dBA ground-borne noise level attenuation per floor, the first five residential floors of the Parkland Boulevard building are predicted to exceed the internal ground-borne noise goal.
- Ground-borne noise levels from rockbreaking are predicted to exceed the noise goal during the night-time for the closest residential floor by 19 dBA.

Given the predicted regenerated noise and vibration exceedances for the Parkland Boulevard apartment building adjacent the site, it is strongly recommended that:

- Rockbreaking be restricted to the daytime period until measurement results achieve compliance with the ground-borne noise goals or affected residents have been temporarily relocated.
- Ground-borne noise and vibration measurement trials are carried out for rockbreaking during the detailed design stage of the BaT project to accurately determine the extent of the impact and to allow sufficient time to develop an appropriate management strategy.
- Preference is given to drill and blast for the station shaft excavation and subject to the findings of ground-borne noise trials at the site, drilling of blast holes may also need to be restricted during the night-time period.

Drill and Blast

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 provided appropriate building damage limits are achieved.

Although to a lesser extent of impact compared with rockbreaking, ground-borne noise from blast hole drilling is also predicted to exceed the daytime noise goals for both the commercial and residential receivers inside the adjacent Parkland Boulevard receiver building. The night-time noise goal for the residential receivers in this building is also predicted to be significantly exceeded as a result of ground-borne noise from drilling.

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

- Restricting drilling to the daytime period until measurement results achieve compliance with the ground-borne noise goals or affected residents have been temporarily relocated.
- Investigate the benefits from making deep vertical cuts into the rock using rock saws or diamond wire (e.g. blind hole cutting) along the boundaries of the shaft shared with adjacent buildings. The cuts would increase the propagation path of the vibration emitted from the drilling (as well as for blasting).
- Use of latest available blasting technology (e.g. PCF, double decking etc).
- Pre-blasting condition survey of adjacent buildings.
- Appropriate attention to blast design and commence blasting with a low MIC to develop a site law (i.e. blast design model) based on measurement data from the site.
- Monitoring of the blast emissions.

8.6 Northern Connection (TBM Retrieval Site)

8.6.1 Nearest Sensitive Receivers

The nearest noise and/or vibration sensitive receivers to the Northern Connection site are identified in **Table 83** with the receiver areas illustrated in **Figure 16**.

Figure 16 Northern Connection Construction Worksite and Receiver Areas

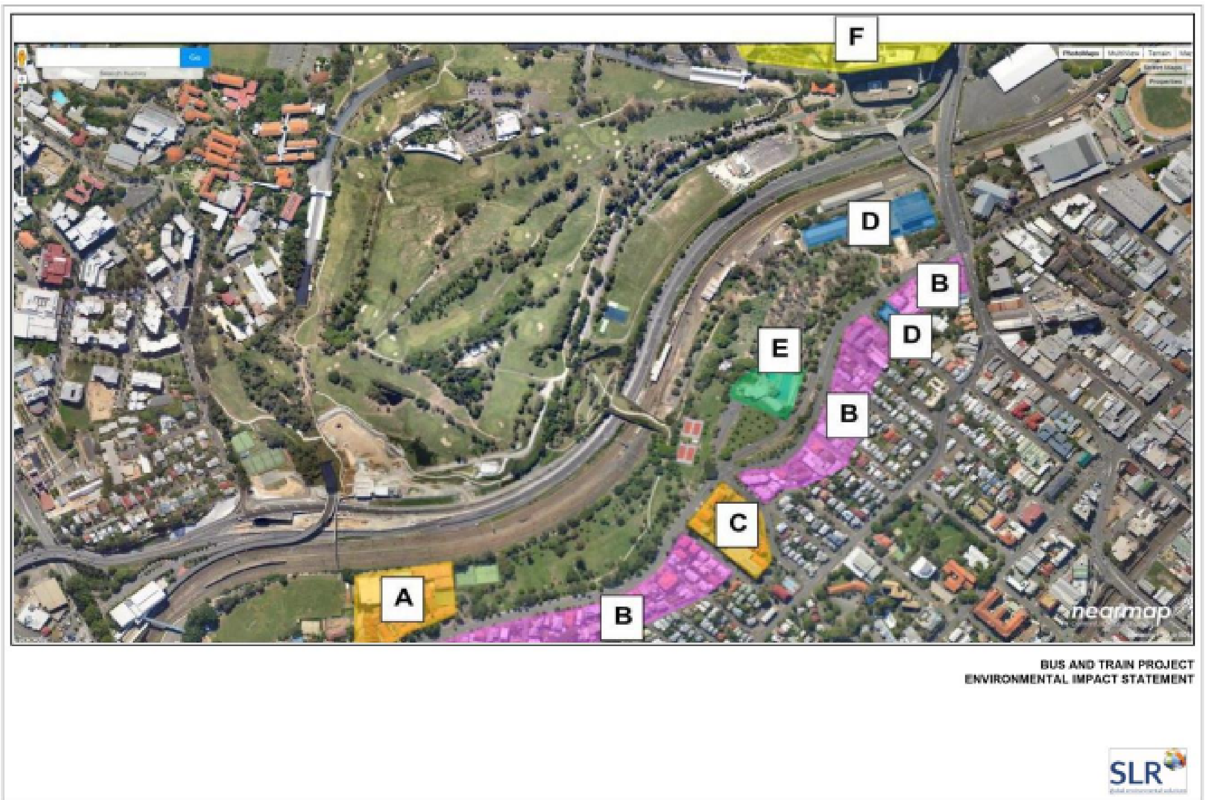


Table 83 Nearest Sensitive Receivers – Northern Connection

Work Site/Excavation	Receiver Area	Distance to Worksite Boundary
Northern Connection	A - Brisbane Girls Grammar School	230 m
	B - Gregory Tce Residential	85 m
	C - St Joseph's College	90 m
	D - Gregory Tce Commercial	160 m
	E - Centenary Pool	85 m
	F - Royal Children's Hospital	100 m

8.6.2 Site Specific Construction Noise Goals

With reference to the BaT project noise goals and the ambient noise survey results summarised in **Section 3.2.7** and **Section 4.1.4** respectively, the site specific construction noise goals are presented in **Table 84**.

Table 84 Northern Connection 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 - Brisbane Girls Grammar School	52	62	-	-
B - Gregory Tce Residential	47	57	42	49
C - St Joseph's College	52	62	-	-
D - Gregory Tce Commercial	67	77	-	-
E - Centenary Pool	67	77	-	-
F - Royal Childrens Hospital	62[2]	72[2]	57	64

Note 1 – Noise goal has been adjusted to represent external free-field levels.
Note 2 - Based on AS2107 category "wards" for medical buildings and applicable to all time periods.

8.6.3 Assessment at the Nearest Noise Sensitive Receivers

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

- Scenario 1 - Site establishment and construction of the ICB bridge:
  - Duration ~ 3 months
  - Dominant noise sources include cranes, trucks, excavators and front end loaders
  - Mostly daytime construction and potentially night-time / weekends for work required over the ICB
- Scenario 2 - Trough excavation and spoil removal:
  - Duration ~ 1 month
  - Dominant noise sources include rockbreakers, excavators and spoil trucks
  - Daytime construction only
- Scenario 3 – Completion of the transition structure:
  - Duration ~ 10 months
  - Dominant noise sources include concrete trucks, cranes and trucks
  - Daytime construction only
- Scenario 4 – TBM disassembly:
  - Duration ~ 1 month
  - Dominant noise sources include delivery trucks, cranes and power tools
  - Daytime construction only

For all construction scenarios, typical construction noise levels with 3 m acoustic hoarding around the boundary of the work site have been predicted at the nearest noise sensitive receivers and are presented in **Table 85** to **Table 88**. Where necessary, an assessment of noise goal compliance is also provided with indicative noise level reductions based on 6 m acoustic hoarding. 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 including the proposed noise mitigation, and are presented in **Appendix F**.

Table 85 Northern Connection Predicted Worst Case Noise Levels – Scenario 1 Site Establishment and ICB Bridge Construction

Receiver Area	Period	Noise Goal (dBA)[1]	Predicted Noise Level[2] (dBA)	Noise Goal Exceedance with level of Noise Mitigation (dBA)
				3 m Hoarding
A - Brisbane Girls Grammar School	Day	LA10,adj – 62	47 - 45	-
B - Gregory Tce Residential	Day	LA10,adj – 57	53 - 41	-
C - St Joseph's College	Day	LA10,adj – 62	49 - 40	-
D - Gregory Tce Commercial	Day	LA10,adj – 77	59 - 49	-
E - Centenary Pool	Day	LA10,adj – 77	58 - 54	-
F - Royal Childrens Hospital	Day	LA10,adj – 72	60 - 57	-

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 86 Northern Connection Predicted Worst Case Noise Levels – Scenario 2 Trough 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 - Brisbane Girls Grammar School	Day	LA10,adj – 62	58 - 56	-	-
B - Gregory Tce Residential	Day	LA10,adj – 57	61 - 39	4	-
C - St Joseph's College	Day	LA10,adj – 62	58 - 43	-	-
D - Gregory Tce Commercial	Day	LA10,adj – 77	53 - 44	-	-
E - Centenary Pool	Day	LA10,adj – 77	64 - 51	-	-
F - Royal Childrens Hospital	Day	LA10,adj – 72	51 - 48	-	-

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 87 Northern Connection Predicted Worst Case Noise Levels – Scenario 3 Completion of Transition Structure

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 - Brisbane Girls Grammar School	Day	LA10,adj – 62	56 - 55	-	-
B - Gregory Tce Residential	Day	LA10,adj – 57	59 - 35	2	-
C - St Joseph's College	Day	LA10,adj – 62	56 - 38	-	-
D - Gregory Tce Commercial	Day	LA10,adj – 77	50 - 41	-	-
E - Centenary Pool	Day	LA10,adj – 77	62 - 45	-	-
F - Royal Childrens Hospital	Day	LA10,adj – 72	50 - 44	-	-

Note 1 – Dominant construction noise during completion of the transition structure 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 88 Northern Connection Predicted Worst Case Noise Levels – Scenario 4 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
A - Brisbane Girls Grammar School	Day	LA10,adj – 62	50 - 49	-
B - Gregory Tce Residential	Day	LA10,adj – 57	54 - 35	-
C - St Joseph's College	Day	LA10,adj – 62	51 - 35	-
D - Gregory Tce Commercial	Day	LA10,adj – 77	50 - 39	-
E - Centenary Pool	Day	LA10,adj – 77	56 - 47	-
F - Royal Childrens Hospital	Day	LA10,adj – 72	47 - 43	-

Note 1 – Dominant construction noise during completion of the transition structure 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

Air-borne Noise

Careful planning of the construction footprint for the northern worksite has ensured a significant buffer between the worksite and sensitive receivers. This buffer together with the proposed 3 m high acoustic hoarding has resulted in the prediction of relatively minor exceedances of the daytime noise goals. The predicted noise levels in **Table 86** to **Table 87** indicate that increasing the proposed 3 m acoustic hoarding along the eastern boundary to up to 6 m should achieve compliance with the noise goals at all sensitive receivers.

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.

Ground-borne Noise & Vibration

As discussed for the airborne noise assessment, the worksite and in particular the location of vibration intensive activities, would occur at significant distances from vibration sensitive receivers. On this basis, prediction of ground-borne vibration and noise is not considered warranted for the Northern Connection.

8.7 Surface Track Construction Noise

Track work required for the BaT project 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.

The majority of rail track for the BaT project will be located within the tunnel and therefore potential airborne noise impacts from construction of the rail track will be limited to the southern and northern connections. In comparison to the long-term construction of the connections themselves and ongoing tunnelling support, installation of the surface track would be significantly shorter in duration. Also, where the BaT project rail tracks tie-in to the existing rail network, this work will likely involve weekend and/or night-time rail possessions to enable the works to be carried out safely.

For assessment of airborne noise impacts associated with surface track construction works carried out in isolation from the major BaT project worksite activities, it is relevant to apply QR's Code of Practice. The Code of Practice planning noise levels have been adopted as a guide to assessing the impact of relatively short term construction noise levels from the BaT project surface track upgrades:

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

Construction noise levels from activities/plant listed in **Table 41** have been calculated in **Table 89** for various setback distances with regards to the 87 dBA L_{Amax} planning noise level. The L_{Amax} parameter is more relevant than the $L_{Aeq(24hour)}$ parameter for assessing the typically transient (i.e. passby) noise associated with surface track construction work.

The calculated noise emission levels in **Table 89** do not take into consideration effects from topographical shielding.

Table 89 Surface Track Construction Plant Noise Emissions

Plant Item	Sound Power Level (dBA)	Distance to comply with 87 dBA LAmax (m)	Noise Level at Setback Distance				
			10 m	25 m	50 m	100 m	250 m
Flat bed truck with crane	110	6	82	74	68	62	54
Ballast truck (rail)	110	6	82	74	68	62	54
Ballast truck (road)	110	6	82	74	68	62	54
Speed swing (360)	114	9	86	78	72	66	58
Locomotive	111	7	83	75	69	63	55
Ballast regulator	122	23	94	86	80	74	66
Tamper	115	11	87	79	73	67	59
Hand held compactor	114	9	86	78	72	66	58
CWR welding plant	93	1	65	57	51	45	37
Cherry Picker	104	3	76	68	62	56	48
Wiring equipment	111	7	83	75	69	63	55
Engineers train	111	7	83	75	69	63	55

A "footprint" noise contour developed on the basis of typical Queensland Rail track work consisting of a subset of the plant listed in is provided in **Appendix G**. 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 89**, high noise levels (potentially in excess of Queensland Rail's 87 dBA LAmax planning level) may result from BaT track work 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 (e.g. 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 5 km of driven tunnelling will be required for the Project. The tunnel will mainly be constructed using a Tunnel Boring Machine (TBM). The underground stations at Woolloongabba, George Street and Roma Street will potentially be excavated by a combination of rockbreaking for the shaft and roadheader for the station caverns.

The TBM is proposed to be launched from the Southern Connection site. The TBM is proposed to be travelling 140 m per week on a 24 hour per day basis.

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 49.**

Predicted ground-borne vibration levels from TBM tunnelling works at the nearest receivers along the BaT tunnel alignment are presented in **Table 90**.

There are no exceedances of the cosmetic damage vibration goal, neither at any the residential/commercial nor at 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 exceed the ‘strongly noticeable’ level (> 2.0 mm/s PPV) only for a few commercial buildings in the CBD. It should be noted that these vibrations will only occur during a relatively short period (less than 1 week for the TBM passby).

Table 90 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 SD - Sleep Disturbance 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 TR = temporary relocation
Southern Connection to Woolloongabba Station	Residential Commercial Educational Worship Hotel	15 m – 133 m 29 m – 236 m 98 m – 178 m 114 m – 153 m 76 m	0.18 to **1.91** mm/s 0.10 to 1.00 mm/s 0.14 to 0.26 mm/s 0.16 to 0.22 mm/s 0.34 mm/s	EN, SD N TP TP BN	P, M, TR
Woolloongabba Station to George St Station	Residential Commercial Educational Worship Medical Hotel	31 m – 310 m 48 m – 294 m 100 m – 176 m 28 m – 311 m 311 m 45 m – 258 m	0.08 to **1.52** mm/s 0.08 to 0.55 mm/s 0.18 to 0.29 mm/s 0.08 to 0.96 mm/s 0.08 mm/s 0.1 to 0.**58** mm/s	EN, SD N BN N NF N, SD	P, M, TR
George St Station to Roma St Station	Residential Commercial Educational Worship Medical Hotel	26 m – 113 m 23 m – 313 m 70 m – 270 m 242 m – 279 m 233 m – 250 m 25 m – 306 m	0.39 to **1.87** mm/s 0.13 to 2.13 mm/s[1] 0.16 to 0.65 mm/s 0.15 to 0.17 mm/s 0.17 to 0.18 mm/s 0.14 to **1.97** mm/s	EN, SD SN N TP TP EN, SD	P, M, BCS, TR
Roma St Station to Northern Connection	Residential Commercial Educational Medical Hotel	29 m – 124 m 33 m – 103 m 29 m – 159 m 86 m 48 m – 119 m	0.09 to **0.90** mm/s 0.20 to 0.80 mm/s 0.07 to 0.44 mm/s 0.29 mm/s 0.10 to **0.54** mm/s	N, SD N BN BN N, SD	P, TR

Note: Ground-borne vibration goals based on BS 7385 (halved values) for cosmetic damage, 2 mm/s for Heritage sites and a residential (and hotel) sleep disturbance of 0.5 mm/s

Note: Exceedances shown in **bold**.

Note 1: No heritage listed structures exceeding the 2 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 50**.

Predicted ground-borne noise levels from TBM tunnel excavation at nearest sensitive receivers along the BaT tunnel alignment are presented in **Table 91**.

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

There are several 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 the 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.
- Temporary relocation of residences particularly impacted by ground-borne noise from TBM tunnelling may be required.

Table 91 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 TR = temporary relocation
Southern Connection to Woolloongabba Station	Residential	15 m – 133 m	29 dBA to **58** dBA	Very Low to High	P, M, TR
	Commercial	29 m – 236 m	21 dBA to 49 dBA	Very Low to High	
	Educational	98 m – 178 m	25 dBA to 33 dBA	Very Low	
	Worship	114 m – 153 m	27 dBA to 31 dBA	Very Low	
	Hotel	76 m	**36** dBA	Low	
Woolloongabba Station to George St Station	Residential	31 m – 310 m	18 dBA to **53** dBA	Very Low to High	P, M, TR
	Commercial	48 m – 294 m	19 dBA to 42 dBA	Very Low to Moderate	
	Educational	100 m – 176 m	29 dBA to 33 dBA	Very Low	
	Worship	28 m – 311 m	18 dBA to 49 dBA	Very Low to High	
	Medical	311 m	18 dBA	Very Low	
	Hotel	45 m – 258 m	21 dBA to **43** dBA	Very Low to Moderate	
George St Station to Roma St Station	Residential	26 m – 113 m	36 dBA to **55** dBA	Low to High	P, M, TR
	Commercial	23 m – 313 m	23 dBA to **57** dBA	Very Low to High	
	Educational	70 m – 270 m	25 dBA to 42 dBA	Very Low to Moderate	
	Worship	242 m – 279 m	24 dBA to 26 dBA	Very Low	
	Medical	233 m – 250 m	26 dBA to 27 dBA	Very Low	
	Hotel	25 m – 306 m	23 dBA to **56** dBA	Very Low to High	
Roma St Station to Northern Connection	Residential	29 m – 124 m	23 dBA to **49** dBA	Very Low to High	P, M, TR
	Commercial	33 m – 103 m	32 dBA to 47 dBA	Very Low to High	
	Educational	29 m – 159 m	20 dBA to 42 dBA	Very Low to High	
	Medical	86 m	35 dBA	Low	
	Hotel	48 m – 119 m	24 dBA to **42** dBA	Very Low to Moderate	

Note: Ground-borne noise goals: Commercial = 40 to 50 dBA, Residential night-time = 35 dBA and Educational = 45 dBA

Note: Exceedances shown in **bold**.

9.2 Low Frequency Noise Impacts

Low frequency noise ranges from approximately 20 Hz to 200 Hz. 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 (e.g. TBMs and roadheaders) may also be a source of low frequency noise. For BaT, 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.

Low frequency noise from the operation of the Project will be assessable in accordance with the EHP's draft guideline *Assessment of Low Frequency Noise* (EHP, 2013). The intent of this guideline is to accurately assess annoyance and discomfort to persons at noise sensitive places.

The draft guideline's assessment procedure involves a two-part screening test, following receipt of a low frequency noise-related complaint. To establish the potential of high levels of low frequency noise inside dwellings, the following methodology applies:

a. The overall sound pressure level inside residences should not exceed 55 dBZ; and, if (a) is true

b. The difference between the interior dBZ value and the interior dBA value exceeds 15 dB.

Where (b) is subsequently found to be true, the draft guideline states that there is a risk for low frequency noise impact and a detailed one third octave band analysis should be performed to establish impact.

For this assessment, the initial screening test has been undertaken to investigate if there is potential for low frequency noise impacts from the driven tunnelling associated with the BaT Project.

Ground-borne noise measurements for a 12 m diameter TBM used for the CLEM7 project have been used for the low frequency assessment. All measurement data have been adjusted to account for the BaT 15 m diameter TBM in accordance with an assumed 10 x log(Area) relationship (i.e. BaT TBM generate 1.9 dBA higher ground-borne noise emission).

CLEM7 TBM and roadheader measurement results, over slant distances of approximately 45 m and 20 m respectively (shown in **Table 92**), indicate that the 55 dBZ level will be exceeded when tunnelling at close distance (within approximately 180 m and 40 m from the TBM and roadheader respectively). The results in **Table 92** also indicate that the difference between the Linear and A-weighted sound pressure level is more than 15 dB indicating the ground-borne noise is of low frequency character.

Table 92 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	60 dB	63 dB	62 dB	69 dB	69 dB	59 dB	55 dB	53 dB	53 dB
TBM A-weighted SPL	-3 dBA	6 dBA	11 dBA	24 dBA	29 dBA	25 dBA	25 dBA	27 dBA	30 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	54 dB	51 dB	50 dB	47 dB	39 dB	32 dB	73 dB Linear		
TBM A-weighted SPL	35 dBA	35 dBA	37 dBA	36 dBA	30 dBA	25 dBA	43 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

The spectral data used for the low frequency 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 Project.

The EHP 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.

10 CONSTRUCTION HEAVY VEHICLE NOISE AND VIBRATION

The selection of a suitable destination for spoil from a large tunnelling project such as BaT is a complex process requiring consideration of many factors including potential impacts associated with noise and vibration from heavy vehicle movements. It is understood the JV have investigated five potential spoil destinations as part of this process including:

- A site accessed from Swanbank Road, Swanbank
- The existing quarry at Pine Mountain Road, Carindale
- Brisbane Airport site at the intersection of Sugarmill Road and Lomandra Drive
- A reclamation area at the Port of Brisbane
- A site at Larapinta (sand pits adjacent to the intersection of Paradise Road and the Logan Motorway)

At this stage, the quantitative assessment of noise and vibration impacts from spoil movements has been limited to the Pine Mountain Road, Swanbank Road and Brisbane Airport sites.

10.1 Spoil Trucks

Spoil from the TBM would be removed via a spoil conveyor behind the TBM in the tunnel out to the acoustic shed at the Southern Connection worksite. From this point, the spoil would likely be transferred by heavy vehicle to either:

- Scenario 1 – From 6:30 am to 6:30 pm to the existing quarry at Pine Mountain Road, Carindale, via a route along O'Keefe Street, Logan Road, Old Cleveland Road, Creek Road and Pine Mountain Road. From 6:30 pm to 6:30 am, spoil will be transferred to Swanbank via a route along O'Keefe Street, Ipswich Road, Ipswich Motorway, Cunningham Highway and Swanbank Road.
- Scenario 2 – All spoil transferred to Swanbank via a route along O'Keefe Street, Ipswich Road, Ipswich Motorway, Cunningham Highway and Swanbank Road.
- Scenario 3 – All spoil transferred to Brisbane Airport via a route along O'Keefe Street, Ipswich Road, Clem 7 tunnel, Airport Link tunnel, East-West Arterial Road, Airport Drive and Lomandra Drive.

Spoil from the excavation of all other BaT project worksites not required to be used as fill would be loaded into trucks during the daytime period (i.e. 6:30 am to 6:30 pm) and into the evening period until 10:00 pm, with the exception of the Woolloongabba worksite where 24 hour spoil removal is proposed. The spoil would be transported to Pine Mountain Road, Swanbank or Brisbane Airport consistent with the three scenarios outlined above for TBM spoil. Accordingly, the proposed spoil truck routes for all other worksites, based on Scenario 1 (i.e. daytime to Pine Mountain and after hours to Swanbank), are outlined below:

- Northern Connection – From 6:30 am to 10:00 pm, spoil will be transferred to Swanbank via a route along the ICB, Legacy Way, Western Freeway, Centenary Highway, Ipswich Motorway, Cunningham Highway and Swanbank Road.
- Roma Street Station:
  - From 6:30 am to 6:30 pm to the existing quarry at Pine Mountain Road, Carindale, via a route along Parkland Boulevard, Roma Street, Herschell Street, Riverside Expressway, Captain Cook Bridge, Vulture Street, Main Street, Ipswich Road, O'Keefe Street, Logan Road, Old Cleveland Road, Creek Road and Pine Mountain Road.
  - From 6:30 pm to 10:00 pm to Swanbank via a route along Parkland Boulevard, Roma Street, Upper Roma Street, Milton Road, Western Freeway, Centenary Highway, Ipswich Motorway, Cunningham Highway and Swanbank Road.
- George Street Station:
  - From 6:30 am to 6:30 pm to the existing quarry at Pine Mountain Road, Carindale, via a route along George Street, Alice Street, Captain Cook Bridge, Vulture Street, Main Street, Ipswich Road, O'Keefe Street, Logan Road, Old Cleveland Road, Creek Road and Pine Mountain Road.
  - From 6:30 pm to 10:00 pm to Swanbank via a route along George Street, Alice Street, Riverside Expressway, Milton Road, Western Freeway, Centenary Highway, Ipswich Motorway, Cunningham Highway and Swanbank Road.
- Woolloongabba Station:
  - From 6:30 am to 6:30 pm to the existing quarry at Pine Mountain Road, Carindale, via a route along Leopard Street, Vulture Street, Main Street, Ipswich Road, O'Keefe Street, Logan Road, Old Cleveland Road, Creek Road and Pine Mountain Road.
  - From 6:30 pm to 6:30 am to Swanbank via a route along Leopard Street, Vulture Street, Main Street, Ipswich Road, Ipswich Motorway, Cunningham Highway and Swanbank Road.
- Boggo Road TBM Launch Site:
  - From 6:30 am to 6:30 pm to the existing quarry at Pine Mountain Road, Carindale, via a route along either Peter Doherty Street or Joe Baker Street and Boggo Road, Annerley Road, Cornwall Street, Logan Road, Old Cleveland Road, Creek Road and Pine Mountain Road.
  - From 6:30 pm to 10:00 pm to Swanbank via a route along Peter Doherty Street, Annerley Road, Cornwall Street, Ipswich Road, Ipswich Motorway, Cunningham Highway and Swanbank Road.

Alternatively, if Scenario 2 or 3 are the preferred option then all spoil trucks would travel to Swanbank or Brisbane Airport during the allocated travel times.

Anticipated maximum spoil trucks from each worksite are summarised in **Table 93**.

Table 93 Summary of Maximum Spoil Truck Movements per Worksite

Worksite	Hours of Spoil Removal	Maximum One Way Truck Movements per Day
Northern Connection	6:30 am to 10:00 pm Monday to Saturday	27
Roma Street Station	6:30 am to 10:00 pm Monday to Saturday	52
George Street Station	6:30 am to 10:00 pm Monday to Saturday	46
Woolloongabba Station	24 hours a day 7 days a week	41 (night-time hourly peak = 2)
Boggo Road	6:30 am to 6:30 pm Monday to Saturday	57
Southern Connection	24 hours a day 7 days a week	249 (night-time hourly peak = 10)[1]

Note 1 – Includes both spoil and material delivery trucks

10.2 Material Delivery Trucks

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 and for delivery of precast concrete tunnel segments to the Southern Connection site.

With the exception of the Southern Connection site directly servicing the TBM drive, it is anticipated that periods of peak material deliveries would not coincide with periods of peak spoil removal. As peak spoil movements are significantly greater than peak material deliveries at all worksites, the assessment of potential noise impacts associated with heavy vehicle movements has been based on spoil truck movements except for the Southern Connection. The truck movements listed in **Table 93** for the Southern Connection worksite includes both spoil trucks and material delivery trucks.

10.3 Construction Heavy Vehicle 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 level of noise emission from roadways using the CoRTN prediction algorithms.

Based on Scenario 1, Scenario 2 and Scenario 3 spoil truck route options, the change in road traffic noise levels was assessed over the following time periods to cover the proposed spoil transfer times from each worksite:

- $L_{A10(12hour)}$ for between 6:30 am and 6:30 pm for Scenario 1.
- $L_{A10(18hour)}$ for between 6 am and 12 midnight for Scenario 2.
- $L_{A10(1hour)}$ for maximum heavy vehicle movements from Woolloongabba Station or the Southern Connection during any hour between 12 midnight and 6 am

For the purpose of this analysis, the $L_{A10(12hour)}$ and $L_{A10(18hour)}$ is the average L_{A10} traffic noise level between the hours of 6:30 am to 6:30 pm and 6:00 am to 12 midnight respectively.

It is noted that for Scenario 1, spoil trucks movements would be directed to Swanbank or Brisbane Airport between 6:30 pm and 10:00 pm. The change in road traffic noise level associated with spoil truck movements to Swanbank or Brisbane Airport during this 3.5 hour period has not been directly assessed as the impact (i.e. change in existing road traffic noise level) is anticipated to be less than that assessed for Scenario 2 or Scenario 3 using the $L_{A10(18hour)}$ assessment parameter.

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 this analysis, the existing annual average daily traffic (AADT) road traffic predictions an all roads has been obtained from traffic information supplied by the JV.

The assessment of noise impact associated with BaT project construction heavy vehicle traffic is summarised in **Table 94**. The assessment takes into consideration the cumulative effect of BaT project heavy vehicles from multiple worksites on the assessed road segments. Changes in noise level greater than the nominated 2 dBA goal are shown in **bold**.

Table 94 Effect of Construction Truck Movements on Traffic Noise Levels along Spoil Routes

Scenario	Road Segment	Worksite Traffic[1]	Change in Road Traffic Noise Level (dBA)		
			LA10(12hr)	LA10(18hr)	LA10(1hr)
Scenario 1 Pine Mountain 6:30 to 18:30 and Swanbank at all other times	ICB	NC	0.0	-	-
	Centenary Highway	NC	0.0	-	-
	Ipswich Motorway	NC	0.0	-	-
	Cunningham Highway	NC	0.0	-	-
	Swanbank Road	NC	0.2	-	-
	Herschell Street	RSS	0.3	-	-
	Riverside Express	RSS	0.0	-	-
	George Street	GSS	0.3	-	-
	Leopard Street	WS	0.1	-	-
	Vulture Street	WS, RSS, GSS	0.1	-	-
	Main Street	WS, RSS, GSS	0.1	-	-
	Ipswich Road	WS, RSS, GSS	0.1	-	-
	O’Keefe Street	SC	2.3	-	-
	O’Keefe Street	WS, RSS, GSS, SC	0.4	-	-
	Peter Doherty Street	BR	**3.5**	-	-
	Annerley Road	BR	0.2	-	-
	Cornwall Street	BR	0.3	-	-
	Logan Road	BR	0.3	-	-
	Old Cleveland Road	WS, RSS, GSS, SC, BR	0.2	-	-
	Creek Road	WS, RSS, GSS, SC, BR	0.3	-	-
	Pine Mountain Road	WS, RSS, GSS, SC, BR	0.5	-	-
Scenario 2 Swanbank	ICB	NP	-	0.0	-
	George Street	GSS	-	0.3	-
	Riverside Expressway	GSS	-	0.0	-
	Milton Road	RSS, GSS	-	0.0	-
	Centenary Highway	NC, RSS, GSS	-	0.0	-
	Leopard Street	WS	-	0.1	0.8
	Vulture Street	WS	-	0.2	0.8
	Main Street	WS	-	0.1	0.5
	Peter Doherty Street	BR	-	**3.0**	-
	Annerley Road	BR	-	0.2	-
	Cornwall Street	BR	-	0.2	-
	O’Keefe Street[2]	SC	-	2.1	-
	Ipswich Road	WS, SC, BR	-	0.1	0.3
	Ipswich Motorway	NC, RSS, GSS, WS, SC, BR	-	0.1	0.4
	Cunningham Highway	NC, RSS, GSS, WS, SC, BR	-	0.2	1.2
	Swanbank Road	NC, RSS, GSS, WS, SC, BR	-	1.0	**6.6**

Scenario	Road Segment	Worksite Traffic[1]	Change in Road Traffic Noise Level (dBA)		
Scenario 3 Brisbane Airport			**L_{A10}(12hr)**	**L_{A10}(18hr)**	**L_{A10}(1hr)**
	Peter Doherty Street	BR		**3.0**	
	Annerley Road	BR	-	0.2	-
	Cornwall Street	BR	-	0.2	-
	O'Keefe Street [2]	SC	-	2.1	-
	Ipswich Road	WS, SC, BR	-	0.1	0.3
	Leopard Street	WS	-	0.1	0.8
	Vulture Street	WS	-	0.2	0.8
	Main Street	WS	-	0.1	0.5
	George Street	GSS	-	0.3	-
	Riverside Expressway	GSS	-	0.0	-
	ICB	NC, RSS, GSS, WS	-	0.0	0.0
	East-West Arterial Road	NC,RSS,GSS,WS,SC,BR	-	0.2	0.2

Note 1 – Abbreviation code: NC = Northern Connection, RSS = Roma Street Station, GSS = George Street Station, WS = Woolloongabba Station, SC = Southern Connection and BR = Boggo Road.

Note 2 – West of Ipswich Road. O'Keefe Street west of Ipswich Road not assessed outside of daytime construction hours as there are no adjacent night-time sensitive receivers.

From **Table 94,** it can be seen that increases in road traffic noise levels of more than 2 dBA have been predicted for Peter Doherty Street and Swanbank Road. The reason for the predicted exceedances is outlined as follows:

- Forecast 2016 traffic volumes on Peter Doherty Street are low (i.e. 24 hour weekday average of 224 vehicles) and therefore the introduction of 57 heavy vehicle movements (i.e. approximately 5 truck passbys per hour) between 6:30 am and 6:30 pm will potentially be noticeable. Accordingly all practicable noise mitigation measures (refer to **Section 10.5**) will be required to minimise the predicted impact for the Leukaemia Centre and the proposed multi-storey residential developments adjacent to Peter Doherty Street.
- Forecast 2016 night-time hourly minimum traffic volumes on Swanbank Road are low (i.e. 1 hour night-time minimum of 9 vehicles) and therefore the introduction of (a maximum of) 16 heavy vehicle movements per hour during the night-time period will be noticeable. If Swanbank is selected as a destination for night-time spoil deliveries, then all practicable noise mitigation measures (refer to **Section 10.5**) will be required to minimise the predicted impact.

For all other assessed road segments, BaT project construction heavy vehicles are anticipated to result in increases to forecast 2016 road traffic noise levels of 2 dBA or less. 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.

It is noteworthy that absolute maximum noise levels associated with vehicle pass-bys would not be altered by BaT project construction vehicles, 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.

10.4 Construction Heavy Vehicle Vibration Impacts

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

10.5 Construction Heavy Vehicle Noise and Vibration Mitigation

Recommended construction heavy vehicle noise and vibration 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.
- Restricting spoil truck movements to and from the Boggo Road site via Joe Baker Street and Boggo Road which, unlike Peter Doherty Street, currently has no adjacent residential receivers. This would avoid exposing Peter Doherty Street to spoil truck noise. Furthermore, due to the height and access arrangements of the proposed residential apartment buildings adjacent to Peter Doherty Street, a temporary road traffic noise barrier along the southern side of Peter Doherty Street is not practicable.
- Where there are a relatively small number of impacted receivers, consideration should be given to providing property treatments to mitigate truck passby noise particularly for the night-time period.
- With regards to noise impacts associated with the processing of spoil at the destination locations, it is anticipated that noise impacts associated with this activity would be managed in accordance with the operating licence conditions or environmental management plan relevant to that site. Notwithstanding this, it is recommended that a detailed assessment of spoil handling and processing noise at the preferred destination site(s) be carried out as part of the detailed design stage of the BaT project.

11 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.

In addition to the site/activity specific mitigation measures detailed in the previous sections of this report, 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.

- 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 the Project construction activities (e.g. 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 should 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 (i.e. less than 100 m) to residences or other noise sensitive receivers.
- Pre-condition surveys should 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 should be undertaken. Construction noise and vibration levels should be monitored throughout the construction phase to verify compliance with the design goals. Monitoring should 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 should ensure that appropriate noise and vibration controls are being implemented and are effective. It should 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 should be prepared closer to the commencement of construction as part of the tendering and detailed design processes. **Table 95** outlines a construction noise monitoring program and **Table 96** outlines a construction vibration monitoring program, both of which are recommended as a minimum for the Project.

Table 95 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 (e.g. cars, trains etc) should be excluded from the measurements. Sources contributing to the noise levels are to be noted.

Monitoring	Schedule	Locations	Procedures and Instrumentation
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 LA90, LAeq, LA10 and LA1 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.
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 LAeq, LA10, LA1 and LAmax 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 LA90, LAeq, LA10, LA1 and LAmax 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 96 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 (i.e. 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 (i.e. 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.

12 CONCLUSIONS

12.1 General

The analysis of noise and vibration impacts associated with the BAT project construction phase has been prepared based on design parameters as supplied by the Project 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.

12.2 Construction Worksites

12.2.1 Southern Connection

Air-borne Noise

Based on typical worst case construction noise levels with either 3 m acoustic hoarding surrounding the site or existing railway noise barriers, the following is noted:

- The predicted noise levels for site establishment works including demolition of existing structures within the rail corridor indicate exceedances of up to 8 dBA of the daytime noise goal for the nearest residential receivers adjacent to Railway Terrace and Merton Street to Elliott Street. The predicted noise goal exceedances result from the use of rockbreakers in close proximity to receivers. It is anticipated that rockbreakers would be used only intermittently during the initial site clearing phase of the BaT project.
- A similar exceedance of the noise goal is anticipated during the operation of piling rigs at the cut and cover areas and excavation of the TBM launch shaft. The notable exceedance during Scenario 2 is associated with excavation of the pipe jacking retrieval shaft adjacent to Quarry Road. With 3 m acoustic hoarding around these works, the daytime noise goal is predicted to be exceeded by up to 16 dBA during operation of a rockbreaker. It should be noted that noise emission levels associated with the shaft excavation would decrease significantly as the shaft progresses downwards. Notwithstanding this, it is recommended that excavation of the pipe jacking retrieval shaft be carried out during the daytime period only.
- Predicted noise emission levels associated with night-time pipe jacking activities (i.e. operation of the slurry separation unit, centrifuge, jacks, generator etc) comply with the night-time noise goals for steady state noise sources at all noise sensitive receiver locations.
- A marginal 1 dBA exceedance of the daytime noise goal is predicted for the residential receivers adjacent to Railway Terrace during the assembly stage of the TBM. It is anticipated that the majority of noise intensive activities associated with this stage would occur within the TBM launch shaft and mined tunnel underneath the existing rail corridor.
- Predicted noise emission levels based on night-time spoil removal during TBM operation indicate an exceedance of the night-time noise goal (for intermittent noise sources) of up to 6 dBA. The predicted noise goal exceedance for residences adjacent to Railway Terrace is attributed to spoil truck movements within the site. Given the length of the on-site journey required by spoil trucks to access the spoil load out shed (i.e. via O'Keefe Street) it is not practicable to contain this activity within the proposed acoustic shed. Consequently it will be important to consider all reasonable and feasible noise mitigation measures to minimise night-time spoil truck impacts to nearby residential receivers including:
    - Erecting a noise barrier (approximately 3 to 4 m high) along the north-west side of the on-site spoil route adjacent to the rail track; or
    - Increasing the height of the existing rail noise barrier along Railway Terrace (height and extent of upgrade to be confirmed during detailed design); and
    - Use of quietest available spoil trucks.

The assessment of steady state noise sources associated with long-term construction activities within the spoil load out facility indicated compliance with the night-time noise goal for all sensitive receivers with the provision of a low performance acoustic shed.

With all practicable noise mitigation measures in place combined with careful management of all heavy vehicle movements on the site, airborne noise impacts should be minimal during the construction phase of the Southern Connection.

Ground-borne Noise & Vibration

The predicted ground-borne noise and vibration levels are summarised as follows:

- Predicted ground-borne noise levels for rockbreaking under the existing rail tracks between the TBM launch shaft site and the tunnel portal indicate an exceedance of the night-time noise goal for the Leukaemia Centre (i.e. up to 15 dBA) and the nearest Railway Terrace residential receivers (i.e. up to 8 dBA). A marginal 2 dBA exceedance of the daytime noise goal has also been predicted for the Leukaemia Centre. The minimum offset distance between the rockbreaker and receiver building required to achieve compliance with the night-time ground-borne noise goal and the length of tunnel predicted to exceed the ground-borne noise goal have been calculated as follows:
    - Leukaemia Centre night-time (42 dBA L_{Amax}): 95 m from the building and 125 m of cut and cover tunnel predicted to exceed the night-time ground-borne noise goal.
    - Railway Terrace night-time (42 dBA LAmax): 95 m from the receiver building and 60 m of cut and cover tunnel predicted to exceed the night-time ground-borne noise goal.
- On the basis of the predicted exceedances of the night-time ground-borne noise goal, it is recommended that rockbreaking of the cut and cover sections of tunnel within the exceedance ranges listed above be carried out only during the daytime period.
- The predicted ground-borne noise and vibration from the Pipe Jacking (micro TBM) under the Park Road Railway Station tracks comply with the ground-borne noise and vibration goals at all locations.
- An investigation of the Ecosciences TEM vibration isolation system has not been carried out for the BaT project. Based on the predicted marginal exceedance of the TEM criterion during rockbreaking and roadheading, it is anticipated that an effective vibration isolation system would prevent interference to the operation of the TEM. It is recommended that the performance of the Ecosciences TEM vibration isolation system be checked prior to commencement of vibration intensive construction works at the TBM launch shaft site. If this system is found to be inadequate and the findings of vibration trials confirm the need to mitigate vibration interference to the TEM, then the vibration isolation system would require upgrading
- All predicted daytime construction vibration levels are well below the guide values, judged to result in a minimal risk of cosmetic damage, as provided in BS 7385 for buildings surrounding the worksites.

12.2.2 Woolloongabba Station

Air-borne Noise

The predicted noise levels for site establishment works including demolition of the existing GoPrint building at the Woolloongabba Station site indicate exceedances of the daytime noise goal of up to 3 dBA at the nearest residential receivers along Vulture Street with 3 m high acoustic hoarding around the site.

Similar exceedances are predicted during the initial station shaft excavation. Higher exceedances are predicted for Scenario 1 to 3 at St Nicholas Cathedral due to the lower daytime noise goal. The assessment has assumed a 7 dBA outside to inside construction noise reduction through the facade. It is recommended that facade noise measurements be carried out prior to the commencement of construction works at the site to determine the actual acoustic performance of the facade as it is likely that to be achieving higher than 7 dBA being situation adjacent to Vulture Street. Subsequent to the findings of the facade noise measurements, temporary (or permanent) upgrades to the facade (e.g. double glazing, acoustic seals around doors etc) would need to be considered in tandem with respite periods during services.

Activities associated with night-time excavation and spoil removal from the site (i.e. Scenario 4) are also predicted to exceed the night-time residential noise goal at the nearest receivers. With the provision of a low performance acoustic shed, there is only a marginal 1 dBA predicted exceedence of the night-time sleep disturbance noise goal as a result of spoil truck movements through the site, where only a small distance of this on-site journey would occur inside the acoustic shed.

With all practicable noise mitigation measures in place combined with careful management of all heavy vehicle movements on the site, noise impacts associated with the construction phase of the Woolloongabba Station for the BaT project should be largely avoided.

Ground-borne Noise & Vibration

The predicted ground-borne noise and vibration levels 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.

12.2.3 George Street Station

Air-borne Noise

The predicted noise levels for site establishment works including demolition of the existing buildings at the George Street Station worksite indicate exceedances of up to 7 dBA of the daytime noise goal at the high-rise apartment building in Mary Street adjacent to the site (i.e. 21 Mary Street). Similar noise goal exceedances are predicted during initial shaft excavation works at this site.

Once excavation of the station shaft has progressed far enough to allow for installation of the acoustic enclosure, noise emission levels from the site would decrease significantly. The airborne construction noise assessment has indicated that a medium performance acoustic shed will be required to achieve compliance with the airborne noise goals during the night-time period.

It is noteworthy that 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 (i.e. with no noise limits) over extended periods of time (e.g. greater than 12 months). It is likely that noise sensitive receivers in the vicinity of the George Street Station worksite would associate initial BaT project construction work involving site establishment, demolition and piling, with typical high-rise building construction works. Where BaT project 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 shed to minimise any noise impacts.

Ground-borne Noise & Vibration from Mechanical Excavation

Ground-borne noise levels for rockbreaking during excavation of the George Street Station shaft is predicted to significantly exceed the daytime and night-time noise goals for the residential receiver building located along the north-east boundary of the site (i.e. 21 Mary Street, Day: 9 dBA and Night: 27 dBA) as well as during the night-time period for 103 George Street (i.e. Night: 5 dBA).

The daytime noise goal applicable to the commercial receiver buildings on the north-east (i.e. 21 Mary Street: 23 dBA) and south-east (i.e. 41 George Street: 28 dBA) boundary of the site is also predicted to be significantly exceeded during rockbreaking of the station shaft.

A 6 dBA exceedance of the night-time noise goal and a marginal 1 dBA exceedance of the daytime noise goal are predicted inside 103 George Street (residential receiver building) during roadheading of the station cavern.

A marginal exceedance of the 2 mm/s vibration goal for heritage structures is predicted for Harris Terrace (i.e. C - George Street heritage) during the initial stages of heavy rockbreaking of the station shaft. It is noteworthy that BS 7385 states that a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive. Notwithstanding this, it is recommended that a building condition survey be carried out at Harris Terrace prior to the commencement of construction works at the George Street site. Vibration monitoring at Harris Terrace is also recommended during (at least) the initial stages of shaft excavation.

Based on the predicted vibration levels, it is recommended that a survey of potentially sensitive building contents (e.g. sensitive computer systems, instruments etc) be carried out inside the adjacent Mary Street and George Street buildings prior to the commencement of shaft excavation works. If vibration sensitive equipment is identified and temporary relocation is not feasible, further predictive modelling would be required to determine specific vibration mitigation measures.

Given the predicted regenerated noise and vibration exceedances, in particular at 21 Mary Street and 41 George Street, it is strongly recommended that:

- Rockbreaking be restricted to the daytime period until measurement results achieve compliance with the ground-borne noise goals or affected residents have been temporarily relocated.
- Ground-borne noise and vibration measurement trials are carried out for rockbreaking during the detailed design stage of the BaT project to accurately determine the extent of the impact and to allow sufficient time to develop an appropriate management strategy.
- Preference is given to drill and blast for the station shaft excavation and subject to the findings of ground-borne noise trials at the site, drilling of blast holes may also need to be restricted during the night-time period.

Drill and Blast

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). Furthermore, the predicted ground-borne noise indicate that drilling of blast holes results in a better environmental outcome compared with rockbreaking the entire station shaft.

Considerable exceedances of the internal noise goals for drilling are still predicted to occur within the commercial and residential levels of the adjacent Mary Street building as well as the adjacent George Street commercial building. Should drill and blast be required for this worksite, the following management measures would be required to deal with these exceedances:

- Restricting drilling to the daytime period until measurement results achieve compliance with the ground-borne noise goals or affected residents have been temporarily relocated.
- Investigate the benefits of cut-off trenches in the rock created by either rock saws or diamond wire (e.g. blind hole cutting) along the boundaries of the shaft shared with adjacent buildings. The cuts would increase the propagation path of the vibration emitted from the drilling (as well as for blasting).
- Use of latest available blasting technology (e.g. 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 (i.e. blast design model) based on measurement data from the site.
- Monitoring of the blast emissions.

12.2.4 Roma Street Station

Air-borne Noise

The highest noise goal exceedance (i.e. of up to 10 dBA), is predicted to occur during the operation of the bored piling rigs adjacent to the Parkland Boulevard receiver building. A similar exceedance of the noise goal is anticipated during the operation of rockbreakers, particularly during the initial stages of the shaft excavation prior to the construction of acoustic enclosure over the shaft.

Given the height of the receiver building and its proximity to the worksite, increasing the 3 m high acoustic barrier around the site would have a negligible effect on construction noise emission levels at the Parkland Boulevard receiver building. The airborne noise assessment has therefore identified the requirement of a high performance acoustic shed over the Roma Street Station worksite.

Ground-borne Noise & Vibration from Mechanical Excavation

The ground-borne noise levels for rockbreaking during excavation of the Roma Street Station shaft is predicted to significantly exceed the daytime noise goals for both the commercial and residential receivers inside the adjacent Parkland Boulevard receiver building. The night-time noise goal for the residential receivers in this building is also predicted to be significantly exceeded as a result of ground-borne noise from rockbreaking.

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 all levels of the apartment building would be impacted during the night-time period.

A marginal 1 dBA exceedance of the night-time noise goal is predicted inside the Parkland Boulevard apartment building during roadheading of the station cavern.

The close proximity of the Parkland Boulevard receiver building to the rockbreaking required for the BaT project is the reason for the predicted exceedance of the vibration criteria for the night-time period. Notwithstanding this, it is noteworthy that the predicted construction vibration levels at the Parkland Boulevard apartment building is well below the guide values, judged to result in a minimal risk of cosmetic damage, as provided in BS 7385 for heavy reinforced buildings such as the Parkland Boulevard building.

Given the predicted regenerated noise and vibration exceedances for the Parkland Boulevard apartment building adjacent the site, it is strongly recommended that:

- Rockbreaking be restricted to the day-time period only until measurement results achieve compliance with the ground-borne noise goals or affected residents have been temporarily relocated.
- Ground-borne noise and vibration measurement trials are carried out for rockbreaking during the detailed design stage of the BaT project to accurately determine the extent of the impact and to allow sufficient time to develop an appropriate management strategy.
- Preference is given to drill and blast for the station shaft excavation and subject to the findings of ground-borne noise trials at the site, drilling of blast holes may also need to be restricted to the day-time period only unless temporary relocation of residents can be negotiated.

Drill and Blast

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 from rockbreaking have been identified) provided appropriate building damage limits are achieved.

Although to a lesser extent of impact compared with rockbreaking, ground-borne noise from blast hole drilling is also predicted to exceed the daytime noise goals for both the commercial and residential receivers inside the adjacent Parkland Boulevard receiver building. The night-time noise goal for the residential receivers in this building is also predicted to be significantly exceeded as a result of ground-borne noise from drilling.

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

- Restricting drilling to the daytime period until measurement results achieve compliance with the ground-borne noise goals or affected residents have been temporarily relocated.
- Investigate the benefits of cut-off trenches in the rock created by either rock saws or diamond wire (e.g. blind hole cutting) along the boundaries of the shaft shared with adjacent buildings. The cuts would increase the propagation path of the vibration emitted from the drilling (as well as for blasting).
- Use of latest available blasting technology (e.g. 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 (i.e. blast design model) based on measurement data from the site.
- Monitoring of the blast emissions.

12.2.5 Northern Connection

Air-borne Noise

Careful planning of the construction footprint for the Northern Connection worksite has ensured a significant buffer between the worksite and sensitive receivers. This buffer together with a recommended 3 m high acoustic hoarding has resulted in the prediction of relatively minor exceedances of the daytime noise goals. Predicted Northern Connection construction noise levels indicate that increasing the proposed 3 m acoustic hoarding along the eastern boundary to up to 6 m should achieve compliance with the noise goals at all sensitive receivers during the noisiest stages of the construction.

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.

Ground-borne Noise & Vibration

As discussed for the airborne noise assessment, the worksite and in particular the location of vibration intensive activities, would occur at significant distances from vibration sensitive receivers. On this basis, prediction of ground-borne vibration and noise is not considered warranted for the Northern Connection.

12.3 Surface Track Worksites

12.3.1 Noise

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 (e.g. 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 BaT project. Significant short duration noise impacts would be expected from the trackwork for receivers at shorter 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 QR's CoP would need to be applied.

12.3.2 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.

12.4 TBM Tunnelling Between Portals

The nearest receivers to the tunnels have been identified and the corresponding ground-borne vibration levels have been predicted. There are no predicted exceedances of the cosmetic damage vibration goal, neither at any of the residential/commercial nor at heritage buildings.

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 exceed the 'strongly noticeable' level (> 2.0 mm/s PPV) only for a few commercial buildings in the CBD. It should be noted that these vibrations will only occur during a relatively short period (less than 1 week for the TBM passby).

Regarding ground-borne noise from the TBM, 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 educational. It should be noted that these exceedances will only occur during a relatively short period (less than 1 week for the TBM passby).

There are several 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 the 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.
- Temporary relocation of residences particularly impacted by ground-borne noise from TBM tunnelling may be required.

12.5 Low Frequency Noise Assessment

Ground-borne noise measurement data for a 12 m diameter TBM used for the CLEM7 project have been used for the low frequency noise assessment. All measurement data have been adjusted to account for the BaT project 15 m diameter TBM in accordance with an assumed 10 x log(Area) relationship (i.e. BaT project TBM would generate 1.9 dBA higher ground-borne noise emission).

The CLEM7 TBM and roadheader measurement results, over slant distances of approximately 45 m and 20 m respectively, indicate that the 55 dBZ level will be exceeded when tunnelling at close distances to receiver buildings that are within approximately 180 m and 40 m from the TBM and roadheader respectively. The low frequency noise assessment also indicated that the difference between the Linear and A-weighted sound pressure level is more than 15 dB indicating the ground-borne noise is of low frequency character.

The spectral data used for the low frequency 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 Project.

The EHP 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 apart from the temporary relocation of affected parties.

12.6 Construction Traffic

Increases in road traffic noise levels of more than 2 dBA have been predicted for Peter Doherty Street and Swanbank Road. The reason for the predicted exceedances is outlined as follows:

- Forecast 2016 traffic volumes on Peter Doherty Street are low (i.e. 24 hour weekday average of 224 vehicles) and therefore the introduction of 57 heavy vehicle movements (i.e. approximately 5 truck passbys per hour) between 6:30 am and 6:30 pm will potentially be noticeable. Accordingly all practicable noise mitigation measures will be required to minimise the predicted impact for the Leukaemia Centre and the proposed multi-storey residential developments adjacent to Peter Doherty Street.
- Forecast 2016 night-time hourly minimum traffic volumes on Swanbank Road are low (i.e. 1 hour night-time minimum of 9 vehicles) and therefore the introduction of (a maximum of) 16 heavy vehicle movements per hour during the night-time period will be potentially noticeable. If Swanbank is selected as a destination for night-time spoil deliveries, then all practicable noise mitigation measures will be required to minimise the predicted impact.

For all other assessed road segments, BaT project construction heavy vehicles are anticipated to result in increases to forecast 2016 road traffic noise levels of 2 dBA or less. 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.

It is noteworthy that absolute maximum noise levels associated with vehicle pass-bys would not be altered by BaT project construction vehicles, however, the frequency of such events would increase.

Recommended construction heavy vehicle noise and vibration 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.
- Restricting spoil trucks movements to and from the Boggo Road site via Joe Baker Street and Boggo Road which, unlike Peter Doherty Street, currently has no adjacent residential receivers. This would avoid exposing Peter Doherty Street to spoil truck noise. Furthermore, due to the height and access arrangements of the proposed residential apartment buildings adjacent to Peter Doherty Street, a temporary road traffic noise barrier along the southern side of Peter Doherty Street is not practicable.
- Where there are a relatively small number of impacted receivers, consideration should be given to providing property treatments to mitigate truck passby noise particularly for the night-time period.
- With regards to noise impacts associated with the processing of spoil at the destination locations, it is anticipated that noise impacts associated with this activity would be managed in accordance with the operating licence conditions or environmental management plan relevant to that site. Notwithstanding this, it is recommended that a detailed assessment of spoil handling and processing noise at the preferred destination site(s) be carried out as part of the detailed design stage of the BaT project.

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

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14 CLOSURE

This report has been prepared by SLR 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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