9. Noise and Vibration

Northern Link

Phase 2 – Detailed Feasibility Study

CHAPTER 9

NOISE AND VIBRATION

- September 2008

Contents

9. Noise and Vibration

TThis chapter addresses Part B, Section 5.4 of the Terms of Reference (ToR). Technical studies upon which this chapter is based are reported in Technical Report No. 9A - Construction Noise and Vibration and in Technical Report No. 9B - Operational Noise and Vibration in Volume 3 of the EIS. Baseline monitoring at selected sites within the study corridor and in its vicinity provides the background noise environment upon which the Project may be modelled.

Noise and vibration impacts from tunnelling, road works, worksite operations and spoil haulage routes are identified and assessed against relevant criteria. Where assessment or modelling suggests that threshold standards may be exceeded, management measures have been developed to minimise or eliminate these effects including details of any screening, lining, enclosing or bunding of facilities or timing schedules for construction. A noise monitoring program for the construction phase of the project is outlined and appropriate monitoring locations are identified. Anticipated vibration levels in the Toowong cemetery are assessed as to whether or not they would impact on graves.

Planning levels stated in relevant Australian Standards, the Environmental Protection (Noise) Policy 1997 and Department of Main Roads 'Road Traffic Noise Management: Code of Practice 2000' are used to assess identified operational noise and vibration impacts. A 3D noise contour model is used to model air-borne noise transmission, including existing and predicted traffic noise, around critical portal areas which include potential ventilation outlet site, new surface roadways and sensitive receivers. Where predicted noise and vibration levels are found to exceed criteria or guidelines, appropriate mitigation measures are suggested to manage these impacts. Measures to manage potential impacts of vibration on health care facilities and other sensitive receivers are developed including reference to EPA's guideline 'Noise and Vibration from blasting'.

9.1 Description of Existing Environment

The record of the existing noise and vibration environment of the Northern Link study corridor provides a baseline for assessment of potential noise emissions associated with the construction and operational phases of the Project. Criteria are developed for the assessment of noise and vibration impacts associated with the project and the design of appropriate noise control measures.

Aspects of the Project that are of particular interest in respect to the noise environment are:

- construction sites;
- ventilation outlets operations; and
- operation of tunnel portals and entry/exit ramps.

Information about the existing noise environment has been obtained from:

- site inspections during peak traffic periods, the evening period and during quiet late night periods, incorporating short-term operator attended noise and vibration measurements; and
- unattended continuous measurement of sound pressure levels at selected locations over periods of at least seven days.

9.1.1 Noise Monitoring

The details of the selected noise monitoring sites, and their relevance to potential tunnel noise issues is summarised in **Table 9-1**.

Table 9-1 Noise Monitoring Locations

Site	Monitoring Location	Relevance to Tunnel Noise Issues
1	22 Crag Road, Taringa	Operational (surface traffic)
2	115 Elizabeth Street, Toowong	Construction and operational (surface traffic and/or ventilation station) impacts associated with western portal
3	6 Wool Street, Toowong	Operational (ventilation station) impacts associated with western portal
4	128 Sylvan Road, Toowong	Operational impacts associated with Frederick Street portal
5	29 Valentine Street, Toowong	Construction and operational (surface traffic) impacts associated with Frederick Street portal
6	69 Frederick Street, Toowong	Construction and operational (road traffic) impacts associated with Frederick Street portal
7	9 Victoria Crescent, Toowong	Construction and operational (road traffic) impacts associated with Frederick Street portal
8	5 Clyde Street, Brisbane City	Operational impacts associated with the eastern portals
9	26 Lower Clifton Terrace, Red Hill	Construction and operational (road traffic and ventilation station) impacts associated with the eastern portals
10	7 Westbury Street, Red Hill	Construction and operational (surface traffic) impacts associated with the Kelvin Grove portal
11	Inner Northern Busway (INB), Normanby Station	Construction and operational (surface traffic) impacts associated with the Inner City Bypass (ICB) portal
12	43 Normanby Terrace, Kelvin Grove	Construction and operational (surface traffic) impacts associated with the ICB portal
13	9 Horrocks Street, Toowong	Construction and operational (surface traffic) impacts associated with the Western Freeway portal
14	QUT, Kelvin Grove Campus	Operational (ventilation station) impacts associated with the ICB portal

The noise environment in the study corridor is typical of many inner urban areas, in that it is largely determined by road traffic noise. However, at some locations rail noise and/or mechanical plant noise are other significant sources.

Monitoring sites were inspected during morning or afternoon peak traffic times, the evening period and also during the late night/early morning period when background noise is typically quietest. The dominant audible sounds at each location are summarised in **Table 9-2**. As can be seen in **Table 9-2,** traffic noise from nearby major roadways was a dominant source of noise at all times of the day.

Table 9-2 Description of Existing Noise Sources

Site	Monitoring Location	Dominant Daytime and Evening Noise Sources	Dominant Noise Sources Late at Night
1	22 Crag Road, Taringa	Western Freeway traffic	Western Freeway traffic
2	115 Elizabeth Street, Toowong	Western Freeway traffic	Western Freeway traffic
3	6 Wool Street, Toowong	Western Freeway road traffic and mechanical plant and equipment noise from bus depot	Western Freeway and occasional Miskin Street traffic
4	128 Sylvan Road, Toowong	Milton Road and Sylvan Road traffic	Milton Road and Sylvan Road traffic
5	29 Valentine Street, Toowong	Milton Road and Frederick Street traffic	Milton Road and Frederick Street traffic
6	69 Frederick Street, Toowong	Frederick Street traffic and transformer noise	Frederick Street traffic and transformer noise
7	9 Victoria Crescent, Toowong	Frederick Street traffic	Frederick Street traffic and transformer noise
8	5 Clyde Street, Brisbane City	Musgrave Road and Hale Street traffic	Musgrave Road and Hale Street traffic
9	26 Lower Clifton Terrace, Red Hill	Kelvin Grove Road and ICB traffic	Kelvin Grove Road and ICB traffic
10	7 Westbury Street, Red Hill	Kelvin Grove Road traffic	Kelvin Grove Road traffic
11	Inner Northern Busway (INB), Normanby Station	Ithaca Street, ICB, INB road traffic and rail traffic (including freight)	Ithaca Street and ICB road traffic and rail traffic (incl. freight)
12	43 Normanby Terrace, Kelvin Grove	ICB road traffic and rail traffic (including freight)	ICB road traffic and rail traffic (including freight)
13	9 Horrocks Street, Toowong	Mt Coot-tha Road and Western Freeway traffic	Western Freeway traffic
14	QUT, Kelvin Grove Campus	Victoria Park Road and ICB traffic	ICB traffic

Continuous noise logger measurements at each site were made for at least 10 days between Wednesday 7 November and Tuesday 27 November 2007 when weather conditions were typically fine and mild to warm with some brief periods of rainfall and with winds generally light to moderate with typically calm conditions, or light winds, at night.

The noise logger measurements, in the form of a rating background level (as described above), are summarised in **Table 9-3.** Details, including the prevailing weather conditions, are provided in Appendix B of *Technical Report No. 6 – Flood Potential in Volume 3* of the EIS. Monitoring results obtained during high winds (greater than 5m/s) are not included as recommended in AS 1055.1, nor are those from rain periods greater than 0.5mm per 15 minute interval. Operator-attended noise measurements are summarised in **Table 9-4.**

Table 9-3 Summary of (Unattended) Noise Logging Results

Site	Monitoring Location	Description	Rating Background Levels, $minL_{A90}$ (dBA)		
			Day 7am - 6pm	Evening 6 - 10pm	Night 10pm - 7am
1	22 Crag Road, Taringa	Front yard of detached single storey dwelling, facing Western Freeway	48	46	39

Site	Monitoring Location	Description	Rating Background Levels, minL_{A90} (dBA)		
			Day 7am - 6pm	Evening 6 - 10pm	Night 10pm - 7am
2	115 Elizabeth Street, Toowong	High side of front yard of detached highset	46	41	34
3	6 Wool Street, Toowong	Front yard of single-storey detached dwelling	47	41	37
4	128 Sylvan Road, Toowong	Front yard of block of units	49	44	35
5	29 Valentine Street, Toowong	Front yard (facing Milton Road) of detached highset	53	50	43
6	69 Frederick Street, Toowong	Front verandah of highset detached dwelling	61	48	35
7	9 Victoria Crescent, Toowong	Front yard of detached double-storey dwelling	48	43	35
8	5 Clyde Street, Brisbane City	Front patio of detached single-storey dwelling	54	51	43
9	26 Low Clifton Terrace, Red Hill	Front yard of detached double-storey dwelling	58	56	45
10	7 Westbury Street, Red Hill	Front yard of detached single-storey dwelling	49	44	34
11	INB, Normanby Station	Located on parcel of Translink land between Ithaca Street and INB east of Normanby Busway Station	56	51	40
12	43 Normanby Terrace, Kelvin Grove	Rear yard (overlooking ICB) of detached highset dwelling	53	52	39
13	9 Horrocks Street, Toowong	Low side yard of highest dwelling	51	48	37
14	QUT, Kelvin Grove Campus	Adjacent to south end of block Y1	47	45	43

- **Table 9-4 Summary of Operator-Attended (Short-term) Noise Measurements**

Site	Measurement Location	Time of day	Date and Time	L_{A10} (dBA)	L_{Aeq} (dBA)	L_{A90} (dBA)	Discernible Sources
1	22 Crag Road	Day	14/11/07 8:42	65	61	50	Traffic on Western Freeway and Crag Road
		Evening	14/11/07 20:15	55	55	49	Traffic on Western Freeway and Crag Road
		Night	15/11/07 1:00	50	49	39	Traffic on Western Freeway and Crag Road
2	115 Elizabeth Street	Day	14/11/07 9:04	49	51	43	Traffic on Western Freeway
		Evening	14/11/07 20:42	45	43	40	Traffic on Western Freeway
		Night	15/11/07 1:23	44	41	34	Traffic on Western Freeway
3	6 Wool Street	Day	14/11/07 9:27	57	56	46	Western Freeway road traffic and mechanical plant and equipment noise from bus depot

Site	Measurement Location	Time of day	Date and Time	L_{A10} (dBA)	L_{Aeq} (dBA)	L_{A90} (dBA)	Discernible Sources
		Evening	14/11/07 21:04	54	52	49	Western Freeway and Miskin Street traffic (higher background noise than during the daytime)
		Night	15/11/07 1:43	47	45	41	Western Freeway and Miskin Street road traffic
4	128 Sylvan Road	Day	14/11/07 9:48	67	64	51	Milton Road and Sylvan Road traffic
		Evening	14/11/07 19:53	66	61	48	Milton Road and Sylvan Road traffic
		Night	15/11/07 00:38	56	54	39	Milton Road and Sylvan Road traffic
5	29 Valentine Street	Day	14/11/07 8:12	59	57	54	Milton Road and Frederick Street traffic
		Evening	14/11/07 19:33	57	55	50	Milton Road and Frederick Street traffic
		Night	15/11/07 00:17	56	52	44	Milton Road and Frederick Street traffic
6	69 Frederick Street	Day	22/11/07 10:11	70	67	59	Frederick Street traffic and transformer noise
		Evening	26/11/07 20:54	64	59	42	Frederick Street traffic and transformer noise
		Night	27/11/07 00:31	60	57	39	Frederick Street traffic and transformer noise
7	9 Victoria Crescent	Day	22/11/07 9:53	58	55	48	Frederick Street traffic
		Evening	26/11/07 20:34	54	51	42	Frederick Street traffic and transformer noise
		Night	27/11/07 00:47	40	41	33	Frederick Street traffic and transformer noise
8	5 Clyde Street	Day	14/11/07 11:17	64	61	56	Musgrave Road and Hale Street traffic
		Evening	14/11/07 19:00	64	62	59	Traffic on Musgrave Road and Hale Street
		Night	15/11/07 2:09	56	53	41	Musgrave Road and Hale Street traffic
9	26 Lower Clifton Terrace	Day	14/11/07 10:32	63	60	54	Kelvin Grove Road and ICB road traffic
		Evening	14/11/07 18:14	64	57	62	High traffic volumes on Kelvin Grove Road (predominantly northbound) and ICB
		Night	15/11/07 2:28	54	51	40	Kelvin Grove Road and ICB road traffic
10	7 Westbury Street	Day	14/11/07 10:51	66	63	52	Kelvin Grove Road traffic
		Evening	14/11/07 18:34	61	58	50	Kelvin Grove Road traffic and residents
		Night	15/11/07 2:45	53	50	40	Kelvin Grove Road traffic

Site	Measurement Location	Time of day	Date and Time	L_{A10} (dBA)	L_{Aeq} (dBA)	L_{A90} (dBA)	Discernible Sources
11	Normanby Station (INB)	Day	22/11/07 9:10	67	69	62	Ithaca Street, ICB and INB road traffic and rail traffic (including freight)
		Evening	26/11/07 19:56	67	65	62	Ithaca Street, ICB and INB road traffic and rail traffic (including freight)
		Night	27/11/07 1:28	61	59	37	ICB and Ithaca Street traffic
12	43 Normanby Terrace	Day	22/11/07 8:45	65	63	60	ICB road traffic and rail traffic (including freight)
		Evening	26/11/07 19:33	60	58	53	ICB road traffic and rail traffic (incl. freight)
		Night	27/11/07 1:11	56	52	38	ICB road traffic
13	9 Horrocks Street, Toowong	Day	7/05/08 8:58	59	56	51	Mt Coot-tha Road and Western Freeway traffic
		Evening	6/05/08 19:52	59	56	51	Mt Coot-tha Road and Western Freeway traffic
		Night	7/05/08 1:43	49	45	34	Western Freeway traffic
14	QUT, Kelvin Grove Campus	Day	7/05/08 8:13	57	55	51	Victoria Park Road and ICB traffic
		Evening	6/05/08 19:21	52	50	47	Victoria Park Road and ICB traffic

Vibration

In any premises, day-to-day activities (eg: footfalls, closing of doors, etc) would cause levels of vibration in floors and walls that exceed 1mm/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.

Vibration measurements were carried out at various locations to determine existing vibration levels prior to the start of construction using an Instantel Minimate Vibration Logger (Minimate S/N BE12563, geophone S/N BQ7806). All measurements were taken directly on the ground in the vicinity of the chosen receiver locations. The summarised results of the vibration measurements are documented in **Table 9-5**. In urban areas, ambient vibration levels are generally below or near the minimum threshold of measurement instruments.

Table 9-5 Summarised Vibration Measurements

Site	Monitoring Location	Date - Time	Peak Component Particle Velocity (mm/s)	Dominant Frequency (Hz)
1	Normanby Terrace (behind #43 near cycle path)	29/11/07 – 8:36	0.03	<1.0
2	Normanby Terrace (adjacent to #9)	29/11/07 – 9:07	0.04	<1.0
3	Normanby Busway Station	29/11/07 – 9:31	0.09	1.2
4	Kelvin Grove Road side of 25 Musgrave Road	29/11/07 – 9:58	0.26	20
5	Adjacent to 25 Upper Clifton Terrace	29/11/07 – 10:31	0.09	<1.0
6	Westbury Street Kelvin Grove Road intersection	29/11/07 – 10:56	0.11	N/A
7	Toowong Cemetery (south-west corner)	29/11/07 – 11:48	0.05	<1.0
8	Thorpe Street Frederick Street intersection	29/11/07 – 12:31	0.07	N/A
9	In front of 5 Thorpe Street	29/11/07 – 12:53	0.02	<1.0

These vibration levels are below the threshold level of human perception (~ 0.15mm/s) except at Site 4 where heavy vehicles travelling northbound along Kelvin Grove Road (down the hill from Musgrave Road) were generating vibration levels in excess of 0.2mm/s (peak 0.26mm/s) due to deformities in the pavement surface.

Existing vibration levels at the nearest corner of the Toowong Cemetery to the Western Freeway tunnel portal were at or below 0.05mm/s.

9.2 Assessment Criteria

Noise Terminology

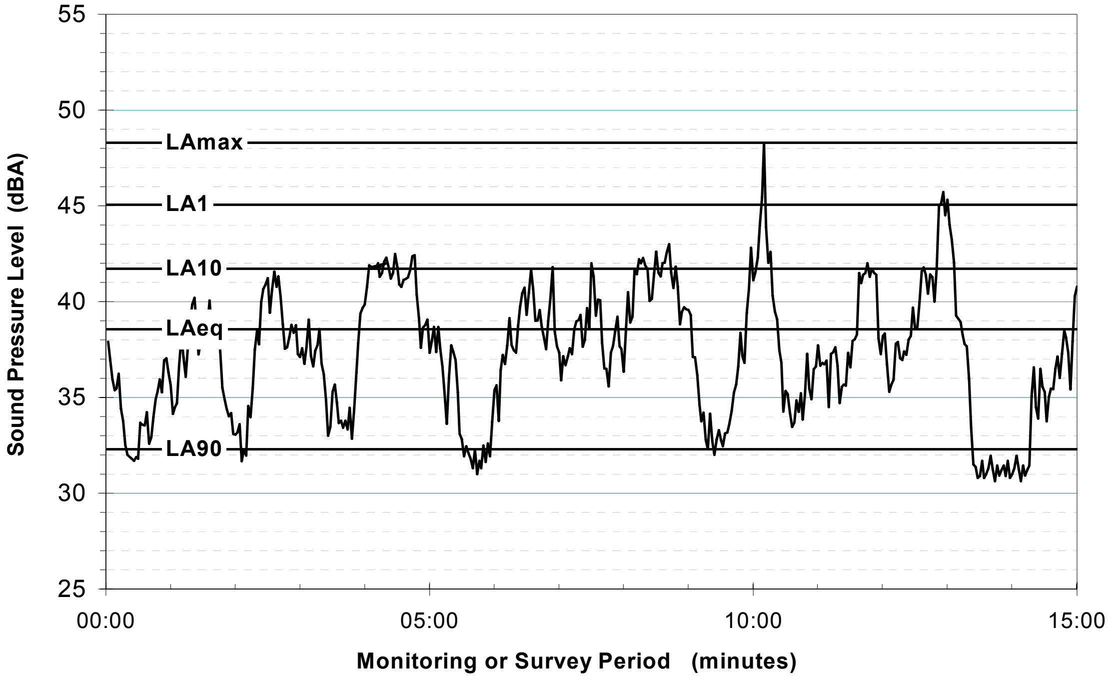
The terms 'sound' and 'noise' are almost interchangeable, except that in common usage 'noise' is often used to refer to unwanted sound. Sound consists of minute fluctuations in atmospheric pressure capable of evoking the sense of hearing. The human ear responds to changes in sound pressure over a very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

LA represents A-weighted Sound Pressure Level. Noise descriptors utilised herein (**Figure 9-1)** are:

- LA_{max} - the maximum A-weighted noise level associated with a noise sampling period;
- LA_1 - the 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;
- LA_{10} - the A-weighted sound pressure level exceeded 10% of a given measurement period and is utilised normally to characterise average maximum noise levels;
- LA_{eq} - the average sound level. It is defined as the steady sound level that contains the same amount of acoustical energy as a given time-varying sound over the same measurement period; and

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

- **Figure 9-1 Graphical Display of Typical Noise Indices**



9.2.1 Community Values Relating to Noise and Vibration

The Queensland Environmental Protection (Noise) Policy 1997 defines the values to be protected as the qualities of the acoustic environment that are conducive to:

d. The wellbeing of the community or a part of the community, including its social and economic amenity; or

e. The wellbeing of an individual, including the individual's opportunity to have sleep, relaxation and conversation without unreasonable interference from intrusive noise.

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.

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.

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.

Evaluating Impacts

The impact of a project on community values relating to noise and vibration and 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.

9.2.2 Noise Impact Assessment Goals

Standard Statutory Construction Noise Regulations

The Environmental Protection Amendment (No 2) Regulation 1999 (EPAR) requires that a builder or building contractor not to carry out building work on a building site in a way that makes or causes audible noise to be made from the building work:

> *f. On a Sunday or public holiday, at any time; or*
>
> *g. On a Saturday or business day, before 6.30 am or after 6.30 pm.*

When the activity is an Environmentally Relevant Activity (ERA) or has had an EIS prepared, the penalties as defined in the Regulation, including the time restrictions above, do not automatically apply. Environmental safeguards for such activities are determined on a project specific basis and are detailed in the project's Approval Conditions.

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, providing the machinery being used is in good working condition. On Sunday, Public Holidays and all other times construction must be inaudible at noise sensitive locations

This Project would involve some instances where construction activity would be required to be undertaken on a 24 hour basis and that would likely be audible outside of the regulated construction hours. Accordingly, the Project would require approval to operate outside of the regulated hours[1].

Assessment Philosophy for Extended Construction Works

It is anticipated that the project would involve the operation of certain noise sources on worksites (eg temporary ventilation and spoil extraction to surface from tunnelling) on a 24 hour per day basis. These construction noise sources would begin to resemble a permanent rather than temporary feature of the noise environment at neighbouring noise sensitive locations. 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 goals criteria in Queensland for the assessment of impacts associated with longterm construction noise sources, especially at night. It is suggested that assessment goals for long-term construction noise sources should reflect the noise environment that is considered acceptable for normal functioning of adjoining developments (eg residential, healthcare and educational uses).

[1] A function of this report is to define the possible impacts associated with operation outside regulated hours to support the application for this permission.

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

4. Sleep disturbance goals contained in statutory guidelines and policies.

5. 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.

6. Comparison with the existing noise environment.

These goals are generally similar to those expressed in the Brisbane City Council's *Noise Impact Assessment Planning Scheme Policy (NIAPSP),* except that the above goals do not make any reference to 'background noise creep'. Background noise creep requires consideration where a locality is subject to various (continuous) noise sources from on-going development. However in this instance, as the proposed construction works are not permanent, it would be unreasonable to apply a 'background creep' goals to this project.

It must be emphasised that the purpose of these goals is to enable an assessment of impacts to be made. This is distinctly different from the function of criteria in the normal application of NIAPSP, which is for setting design limits.

Sleep Preservation

Both the Brisbane City Council's *Noise Impact Assessment Planning Scheme Policy* (NIAPSP) and the Queensland Environmental Protection Agency's Ecoaccess Guideline *Planning for Noise Control* recommend maximum internal noise levels in sleeping areas to avoid sleep disturbance. The recommended maximum levels from these two policies are summarised in **Table 9-6**.

- **Table 9-6 Regulatory Guidelines for Avoidance of Noise-induced Sleep Disturbance**

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

Table Note 1: Contained in the NIAPSP Draft Guideline 2001.

The "R-category" descriptions in AS1055.1 are somewhat subjective. R3 is described as "Areas with medium density transportation or some commerce or industry" and is tabulated with an average night-time (10.00pm to 7.00am) background noise level of 40 dBA (LA90). R4 is described as "Areas with dense transportation or with some commerce or industry" with an average night-time (10.00pm to 7.00am) background noise level of 45 dBA (LA90).

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

Acceptable levels of steady or near-steady ("quasi-steady") noise for sleeping environments are recommended in Australian Standard AS2107 *Acoustics – Recommended Noise Levels and Reverberation Times for Building Interiors.* These are detailed below:

Functional Noise Levels for Various Building Uses

The maximum recommended internal noise levels specified in AS/NZS 2107: 2000 *Acoustics –Recommended design sound levels and reverberation times for building interiors* are shown in **Table 9-7** for a selection of building uses that may be relevant to building uses near construction sites.

Table 9-7 Selection of Design Noise Levels from AS/NZS 2107:2000

Type of Building Occupancy	Maximum Design Level LAeq(60sec) (dBA)	Maximum Design Level LA10 (15min) (dBA)
Residential buildings (living areas)	45 (near major roads) 40 (near minor roads)	55 (near major roads) 50 (near minor roads)
Place of Worship	40 (with speech amplification)	50 (with speech amplification)
School music rooms	45	55
School teaching area	45	55
School library	50	60
School Gymnasium	55	65
Commercial buildings – offices	45	55
Commercial Buildings – retail	50	60

The stated scope of AS/NZS 2107 applies to noise that is steady or quasi-steady in nature. In practice the design levels from AS/NZS 2107 are widely used by Councils (eg Brisbane City Council NIAPSP) and the Department of Main Roads10[2] 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/NZS 2107 for the assessment of mechanical plant noise intrusion into new residential developments. A measurement period of between 15 minutes and 1 hour is normally used to evaluate the LAeqdBA parameter. Thus the proposed use of AS/NZS 2107 levels for the assessment of relatively steady plant noise emanating from construction sites has some similarities to the utilisation of AS/NZS 2107 in contemporary assessments of traffic noise and of mechanical plant noise intrusion into dwellings.

Because the AS/NZS 2107 design levels are expressed in terms of the LAeqdBA parameter, some variability in a noise source is implicitly included when the average level meets the design level. For residential receptors, the implicit variability permitted by the LAeqdBA parameter can be problematic at night. For this reason, night-time noise sources need to be assessed against sleep disturbance goal for the LAmax parameter in addition to the AS/NZS 2107 LAeqdBA levels.

Comparison with Existing Noise Levels

The use of existing noise levels for the assessment of noise impacts is a common impact assessment practice. The Brisbane City Council NIAPSP refers to this type of assessment as “Comparison of like parameters or descriptors”. Adjustments are normally made to the source levels as per AS1055.1-1997 in order to account for the increased subjective loudness associated with noises that are particularly tonal or impulsive.

Regenerated Noise

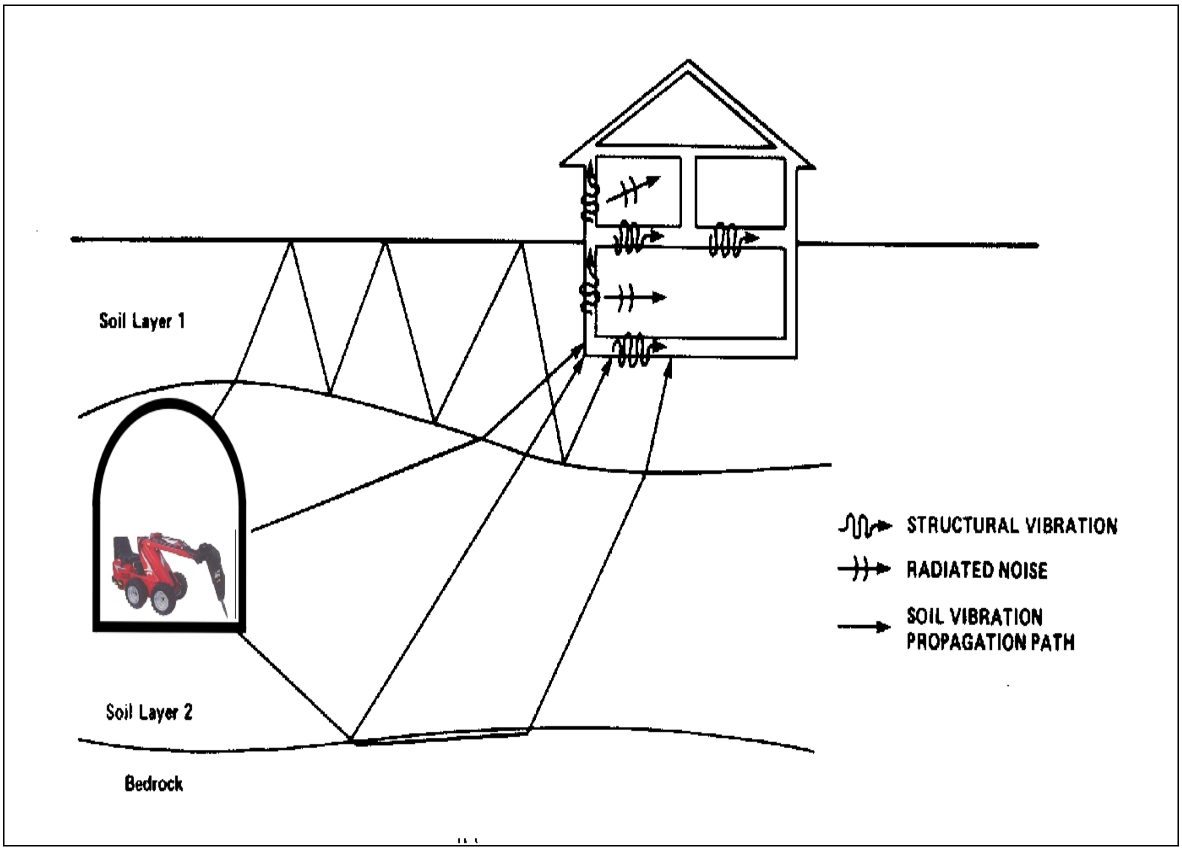
Noise that propagates through a structure as vibration and is radiated by vibrating wall and floor surfaces is termed ‘regenerated noise’, ‘structure-borne noise’, or sometimes ‘ground-borne noise’. Regenerated noise originates as vibration and propagates between the source and receiver through the ground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

[2] Queensland Department of Main Roads “Road Traffic Noise Management – Code of Practice”.

Typical sources of regenerated noise include tunnelling works, underground railways, excavation plant (eg: rockbreakers), and building services plant (eg: fans, compressors and generators).

Figure 9-2 indicates the various paths by which vibration and regenerated noise may be transmitted from construction activities within a tunnel to a receiver on the surface.

Figure 9-2 Vibration and Regenerated Noise Transmission Paths



9.2.3 Vibration Impact Assessment Goals

Concepts and measures

Vibration may be defined as cyclic or transient motion and measured in terms of its displacement, velocity or acceleration. Human response to vibration or the risk of damage to buildings is measured in terms of 'peak' or 'rms' velocity. The former is the maximum instantaneous velocity, without any averaging 'peak particle velocity' (PPV) whereas the latter incorporates 'root mean squared' averaging over a defined time period.

People may 'feel' vibration but not be disturbed by the vibration at levels lower than those required to cause superficial damage to the most susceptible building. An individual's response to vibration depends very strongly on previous experience and expectations, and on 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 that perceived as 'normal' in a shop, office or dwelling.

Human tactile perception of random motion, as distinct from human comfort considerations, (from German Standard DIN 4150 Part 2-1975) are categorised in **Table 9-8**.

Table 9-8 Vibration Levels and Human Perception of Motion

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

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

Vibration criteria vary primarily according to whether the sources are continuous or intermittent and whether they occur during the day or night. The effects of vibration in buildings can be divided into three main categories:

- those in which the occupants or users of the building are inconvenienced or possibly disturbed;
- those where the building contents may be affected; and
- those in which the integrity of the building structure may be prejudiced.

Vibration criteria which are relevant to the disturbance of building contents are more stringent than criteria relating to cosmetic building damage. However, vibration criteria relating to human comfort are the most stringent. This is because people are able to 'feel' vibration at levels lower than those required to cause even superficial damage to the most susceptible classes of building.

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 potential for human discomfort is generally lower for short-duration vibrations. The potential for cosmetic building damage is also lower for short duration vibrations compared to continuous vibrations of the same magnitude. Short duration vibrations will be less likely to fully 'excite' resonant vibration responses in a building structure.

Vibration criteria during construction

The environmental management objectives for construction activities for Northern Link are:

- to maintain a reasonable acoustic environment for living, in particular for sleeping, and use of properties along the corridor of construction influence during construction works;
- to protect significant heritage buildings and other structures from the effects of vibration from tunnelling activities; and
- to consult effectively with concerned property owners and occupants in the corridor of the construction influence.

Australian Standard AS 2670.2-1990 provides 'human comfort' vibration velocity levels as shown in **Table 9-9**. These levels, below which the probability of reaction (commonly referred to as 'adverse comment') are low, are based on worldwide experience.

Table 9-9 Typical Vibration Levels for Human Comfort – 8Hz-80Hz – AS2670.2

Type of Space Occupancy	Time of Day	Vibration Velocities (mm/s) corresponding to a 'Low Probability of Adverse Comment'			
		Continuous Vibration (16h Day, 8h Night)		Transient Vibration Excitation with several Occurrences per Day	
		Vertical	Horizontal	Vertical	Horizontal
Critical working areas (eg: hospital operating theatres, some precision laboratories, etc)	Day Night	0.1 0.1	0.3 0.3	0.1 0.1	0.3 0.3
Residential	Day Night	0.2 to 0.4 0.14	0.6 to 1.1 0.40	3 to 9 0.14 to 2.0	9 to 26 0.4 to 6.0
Offices	Day Night	0.4 0.4	1.2 1.2	6 to 13 6 to 13	17 to 37 17 to 37
Workshops	Day Night	1.2 1.2	3.2 3.2	9 to 13 9 to 13	26 to 37 26 to 37

To determine recommended peak vibration velocities that can be readily monitored during various construction activities, the vibration velocities presented in **Table 9-9** need to be multiplied by an appropriate 'crest' factor to obtain a 'peak' vibration velocity. Crest factors would vary from 1.4 for construction activities such as continuous vibratory rolling and rotating plant, and up to 4 or more for intermittent activities such as rock-breaking and ripping.

Table 9-10 presents the expected 'peak' vibration velocity levels to achieve 'low probability of adverse comment' for continuous and transient vibration sources based on human comfort considerations.

Table 9-10 Expected 'Peak' Vibration Velocity Levels for Human Comfort

Type of Space Occupancy	Time of Day	Peak Vibration Levels (in mm/s corresponding to a Low Probability of Reaction)			
		Continuous Vibration (16h Day, 8h Night)		Transient Vibration Excitation with several Occurrences per day	
		Vertical	Horizontal	Vertical	Horizontal
Critical working areas	Day or 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 or Night	0.6	1.7	8 to 18	24 to 52

Table Note: *Sinusoidal limits should apply to vibratory rollers and vibratory piling. Rock-hammers, tunnel boring, ripping and general vehicle movements generate non-sinusoidal vibration.

As can be seen from **Table 9-9**, situations can exist where vibration magnitudes above those generally corresponding to the low probability of adverse comment level can be tolerated, particularly for temporary disturbances and infrequent and intermittent events, such as those associated with construction projects.

Sleep preservation

In relation to human perception, it is the duration and time of day when the vibration occurs that is important in the consideration of potential impacts. Human comfort vibration guidelines are expressed in terms of time of day and duration, rather than frequency.

For people, vibration in buildings that is 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.

For this purpose, a vibration guide level of 0.5mm/s (peak) has been adopted. This level 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 AS 2670-1990, and the qualitative perception scale for continuous vibration outlined in German Standard DIN 4150 Part 2-1975.

Vibration values to protect building contents

The threshold for visible movement of susceptible building contents (eg: plants, hanging pictures, blinds, etc.) is approximately 0.5mm/s over the frequency range typical of vibration in buildings from excavation and construction equipment (approximately 8Hz to possibly 100Hz),. Audible rattling of loose objects (eg: crockery) generally does not occur until levels of about 0.9mm/s are reached. Typical maximum floor vibration levels (along vertical and horizontal axes) for satisfactory operation of sensitive items are presented in **Table 9-11**.

- **Table 9-11 Typical Maximum Vibration Levels for Sensitive Building Contents**

Equipment Type	Maximum Vibration Levels
Precision balances	0.5mm/s to 2mm/s
Some optical microscopes	0.5mm/s
Large computer disk drives Sensitive electronic instrumentation	1mm/s to 5mm/s

Short duration vibration events such as rock-breaking may be permitted to somewhat higher levels, depending on vibration frequency content and on the specific susceptibility of particular objects and their location.

The Queensland Environmental Protection (Noise) Policy 1997, (EPP (Noise)) defines acceptable vibration limits for blasting with 80% compliance in stating that:

"The noise from blasting is reasonable if, measured outside the most exposed part of an affected noise sensitive place:

h. the air-blast overpressure is not more than 115 dB(Lin Peak) for 4 out of any 5 consecutive blasts; and

i. the ground vibration is

a. for vibrations of more than 35 Hz - not more than 25 mm/s ground vibration, peak particle velocity;

b. for vibrations of not more than 35 Hz - not more than 10 mm/s ground vibration, peak particle velocity."

Part 6 of the Brisbane City Council Local Law 5 - *Permits and Licences* specifies vibration limits for blasting. The key environmental management requirements of this are:

- Provision of formal notification of intention to blast 24 hours in advance.
- Performance of 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.
- Compliance with the ground vibration limits shown in **Table 9-12.**

Table 9-12 Council Ground Vibration Limits for Blasting – Part 6 of Local Law 5

Type of Building or Structure	Ground Vibration Limit (peak particle velocity)
Historical buildings, monuments or ruin	2 mm/s
Visibly damaged or cracked buildings or structures	10 mm/s
Structurally sound buildings or structures	20 mm/s
Reinforced concrete or steel buildings or structures	50 mm/s

The Council vibration limits are not related to the frequency of the ground vibrations. The simplification in the expression of the Council limits results in increased conservatism at high frequencies, but greater leniency at low frequencies where the potential for resonance-related building damage may be greater.

Vibration design goals to protect building structures

In the absence of an Australian Standard, BS 7385: Part 2 - 1993 and DIN 4150 - Part 3: 1999 are internationally recognised as providing vibration velocity guideline (peak) levels for use in evaluating the effects of vibration on structures.

British Standard 7385:Part 2-1993 *Evaluation and Measurement for Vibration in Buildings* is a definitive standard against which the likelihood of cosmetic building damage from ground vibration can be assessed. Sources of vibration which are considered in the standard include demolition, blasting (carried out during mineral extraction or construction excavation), piling, ground treatments (eg compaction), construction equipment, tunnelling, road and rail traffic and industrial machinery.

BS 7385 sets guide values for building vibration based on the lowest vibration levels above which cosmetic damage has been credibly demonstrated. These levels are judged to give a minimal risk of vibration-induced cosmetic damage, where 'minimal risk' for a named effect is usually taken as a 95% probability of no effect. Where the dynamic loading of a building caused by continuous vibration of foundations is such as to give rise to dynamic magnification of vibration between the foundations and other parts of the building due to resonance, especially at the lower frequencies where lower guide values apply, BS 7385 advises that guide values may need to be reduced by up to 50%.

For impact assessment purposes, the EPP (Noise) limits for blasting (transient vibration) have been utilised for residential and other sensitive buildings. A 50% reduction of the guide values has been utilised to assess continuous vibration in line with the recommendation of BS 7385. The Council limit of 2 mm/s has been utilised for evaluating vibration levels at historical buildings. Guide values specific to reinforced structures have not been specifically referenced in this assessment of vibration as specific construction details of buildings are not known for all buildings along the corridor.

The assessment guide values for transient and continuous vibration in order to ensure a minimal risk of cosmetic damage to residential and other sensitive buildings are presented numerically in **Table 9-13**. These guide values are conservative, because the actual degree of tolerance of any building depends in a complex way on both the structural characteristics of the building and the frequency spectrum of the exciting vibration. At this stage of assessment, neither of these items of information are known in detail. However, such information will likely act to increase the values in **Table 9-13**.

Table 9-13 Guide Values for Vibration Assessment – Minimal Risk of Cosmetic Damage

Vibration Type	Peak Particle Velocity (mm/s)		
	Heritage Listed	Residential	Sensitive Commercial
Transient Vibration (eg blasting)	2	10	10
Continuous Vibration (eg TBM, roadheading, rockhammering)	2	5	5

9.3 Construction Impacts and Mitigation Measures

9.3.1 Reference Noise and Vibration Data

Machinery

Although specific size and type of machinery are not yet known, typical items of plant have been nominated based on similar tunnelling activities at existing worksites in the Brisbane region[3] and on indicative sizing of materials handling equipment required to transport the spoil at the anticipated rates of tunnel excavation. Indicative source sound power levels have been obtained from AS 2436-1981[4].

A summary of these plant items, their function, likely location of use on the project and indicative sound power level are summarised in Table 19 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS.

Sound power refers to rate of sound generation which is independent of distance from the plant item and allows direct comparison of different plant items. From this data, the sound pressure level (or noise level) at any distance from the plant can be calculated.

The proposed enclosure of night-time noise sources is more effective at containing high-pitched noises (eg: hisses, scrapes, whines) than low-pitched noises (eg: thuds, deep exhaust notes). Therefore, to understand effectiveness of an enclosure would require estimates of the frequency spectrum (or pitch) and the frequency-dependent (or pitch-dependent) sound transmission characteristics. Typical spectral shape data for representative types of noise sources that may be used within worksite enclosures are summarised in Table 20 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS.

Ventilation plant would be an item of plant operating at all worksites on a 24 hour basis. Sound power levels have not been listed for this plant because the acoustic specification for this plant would be determined by site-specific acoustic constraints in accordance with the standard EPA licensing requirements for fixed stationary noise sources.

Acoustic Properties of Enclosure Materials

Reduction of acoustic energy as it passes through a material is 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 9-14**.

3 The Clem Jones Tunnel (CLEM7) worksites (formerly known as the North-South Bypass Tunnel).
4 Australian Standard 2436-1981 – Guide to Noise Control on Construction, Maintenance and Demolition Sites.

Table 9-14 Indicative Transmission Loss Spectra for Representative Enclosure Constructions

Option	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 0.62mm metal decking	3	8	14	20	23	26	27	35
2	Medium Performance Option 0.62mm metal decking lined with 50mm fibreglass[5]	5 (est)	10	15	22	32	37	43	43
3	High performance Option 0.62mm metal decking, 110mm airspace, 50mm fibreglass blanket in airspace, internal lining of 18 kg/m^2 porous-faced fibre-board[6]	15 (est)	20	29	43	46	57	63	63

The effectiveness of the possible enclosure materials listed in **Table 9-14** in reducing internal noise sources has been calculated and are shown in **Table 9-15**.

Effectiveness of an enclosure is maximised by minimisation of holes, isolation of machinery from interior of walls and inclusion of sound absorption on interior wall surfaces of the enclosure.

'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 9-14** 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 9-15**.

Table 9-15 Effective Noise Reductions Achieved by Enclosure

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

Substantial improvement can be achieved by effectively creating a double layer construction for walls and ceiling elements (Option 3). Effective noise reduction can vary as much as 10dBA depending on the frequency content of the plant item. Plant emissions that are dominated by high frequency noises, such as rockbreaking, would benefit most from an acoustic enclosure.

5 Report No. 3668/159/4517B-5-83 in accordance with AS1276-1979 – Louis A. Challis and Associates Pty Ltd

6 Report No. 3798-1-82 – Louis A. Challis and Associates Pty Ltd

Indicative Effectiveness of Noise Barriers

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

Attenuation would depend on frequency spectrum of the noise and length of the diffracted noise path compared with the direct noise path. For a noise spectrum dominated by sound in the range 300-500 Hz, the relationship between the barrier attenuation and geometrical parameters is illustrated on Figure 7 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS.

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

The effective height of noise sources would 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 3-4m. For a front-end loader or excavator, the effective source height may be in the range 2-3m.

Therefore, for many construction noise sources typical barriers 2.4-3.0m high would not obscure line-of-sight and would not produce significant attenuation. The height of temporary barriers may need to be 5-6m high in many instances to provide optimal noise reductions.

Indicative Effectiveness of Upgrading Building Facades

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

This type of improvement would require the following 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.

Ceiling fans and/or air-conditioning 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.

Exact prediction of possible gains in inside/outside noise level differences requires specific knowledge of construction for each dwelling. This could be achieved in a detailed noise management plan.

Vibration

Vibration levels generated at the ground surface during excavation is a function of many variables, including excavation method, advance rate, depth below surface, ground (rock) hardness and 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 vibration levels experienced may be lower than predicted levels.

Reference Vibration Levels

Drill and Blast

Vibration levels from blasting do not represent a constant vibration source. Design of a blast can be controlled to ensure that vibration levels remain within specified bounds. Indicative blast vibration levels associated with tunnelling have been sourced from measurements carried out during the trial blasting for Brisbane Rail Tunnel Duplication[7]. These trials were conducted at the Creek Street tunnel portals that were excavated in hard rock. Vibration transducers were located on the foundations of nearby buildings, including the Incholm Building on Wickham Terrace and All-Saints Anglican Church on Anne Street. Further detail of the assessment of blast vibration levels is provided in *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS

Tunnel Boring Machines (TBMs)

The proposed TBMs are approximately 12m in diameter. TBMs of this diameter have been employed in Brisbane (in hard rock) for the Clem Jones Tunnel (CLEM7)[8]. The hardest rock expected for Northern Link is Bunya Phyllite, with uniaxial compressive strength (UCS) values ranging up of 70 MPa.

Likely ground vibration levels for the Northern Link TBMs are shown in **Table 9-16.**

Roadheaders and Rockbreaking

The typical maximum levels of ground vibration from heavy roadheading and rockbreaking operations are also listed in **Table 9-16.** The frequency of the ground vibration associated with roadheaders and rockbreaking is normally in the range 10-50 Hz. Vibration levels associated with road headers are very low in comparison to other excavation methods.

- **Table 9-16 Indicative Maximum Ground Vibration Levels for Mechanical Tunnel Excavation Methods**

	Peak Vibration Levels (mm/s) Versus Distance					
12m hard rock TBM	35	10	3	1.5	0.8	0.5
Heavy Rockbreaking	4.5	1.3	0.4	0.2	0.14	0.1
Heavy Roadheading	0.5	0.13	0.04	0.02	0.01	0.01
Blasting - ICI tunnelling formula						
5 kg Maximum Instantaneous Charge	168	55	18	10	6	4
1 kg Maximum Instantaneous Charge	46	15	5	2.6	1.7	1.2
0.2 kg Maximum Instantaneous Charge	13	4.2	1.4	0.7	0.5	0.3

Regenerated Noise

Regenerated noise, first transmitted to the ground by machinery as vibration, travels to a sensitive location (such as a house) through the ground and foundations, from where the walls, floor and ceiling radiate the vibration as audible noise.

7 Heggies Pty Ltd Report Q02-R1, 1 June 1990 'Trail Blast Monitoring and Site Law Development – Duplication of Brisbane Inner City Rail Tunnels' Prepared for Connell Wagner (Qld) Pty Ltd

8 Formerly known as the North-South Bypass Tunnel (NSBT).

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

An indicative summary of vibration levels anticipated from mechanical tunnel excavation methods is presented in **Table 9-17** based on a -30 x $\log_{10}$(distance) relationship[9] between distance and regenerated noise level.

- **Table 9-17 Indicative Regenerated Noise Levels for Mechanical Tunnel Excavation Methods**

Operation	Regenerated Noise Levels (dBA) Vs Distance					
	5m	10m	20m	30m	40m	50m
12m hard rock TBM (based on Dublin Port Tunnel estimate of 55dBA at 23m, and Wilkinson Murray data for 7.2m TBM in sandstone, factored up for size, assuming vibration velocity is proportional to TBM face area)	69-75	60-66	51-57	45-51	42-48	39-45
Roadheading (Wilkinson Murray 38dBA @ 20m)	56-62	47-53	38-44	32-38	29-35	26-32
Rockbreaking (RHA 60dBA @ 10m)	69-75	60-66	51-57	47-53	42-48	39-45
Rockdrilling (RHA 38dBA @ 23m)	58-64	49-54	40-46	36-42	31-37	29-35

The lower bounds of these regenerated noise levels shown for rock drilling and roadheading are based on field measurements for sandstone rock conditions in the Sydney area. Based on a comparison of regenerated noise levels from TBMs in hard and sandstone rock conditions, it is estimated that these regenerated noise levels may increase by up to 6dBA for hard rock conditions.

9.3.2 Work Sites

The modelling methodology used to assess potential noise impacts from the worksites is outlined in *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS.

Western Freeway Worksite (WS1)

The primary noise-generating activities anticipated during the preparation and operation of WS1 are summarised in **Table 9-18**.

- **Table 9-18 Western Freeway Worksite Surface Works Noise Sources**

Construction Phase and Approx. Duration	Enclosed/Underground Day and Night-time Noise Sources	Additional Daytime Noise Sources
Site Establishment (2 weeks)	Nil	Delivery trucks, excavators, hydraulic rockbreakers, bulldozers, dump trucks, manual trades, compressors, generators
Enclosures Construction (8 weeks)	Nil	Mobile cranes, concrete trucks, concrete pump, delivery trucks, manual trades, excavator, structural steelwork
Works in Encl-osure (14 months)	Spoil removal, supply of concrete lining, support material, ventilation plant,	Removal of spoil and delivery of materials

[9] Sound pressure is related to vibration velocity as 20 x log10(V), in the ground, vibration velocity varies with distance-1.5 as an approximation across a range of rock conditions. (The exponent can typically vary from -0.5 to -2.5) depending on the particular rock conditions.) Combining these, the sound pressure is related to distance as -30 x log10 (distance).

Site Preparation

Site preparation would involve installation of safety barriers, site clearance, delivery of worksite infrastructure and enclosure construction. Noise intensive activities for these works would be during the daytime only. The most noticeable source of noise during site preparation would be earthmoving and rockbreaking. Noise levels that could be received at surrounding buildings during site preparation earthworks are compared with functional internal noise goals for surrounding building uses in Table 30 in *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS.

At the closest residences on the southern side of Wool Street, highest noise levels would be due to the rockbreaker and dozer. Based on 'typical' emissions, a marginal 3dBA above the external noise goal is predicted whilst the rockbreaker is in use. Given the limited duration of this particular component of the work it is not likely to result in a significant impact.

Daytime Tunnelling

Indicative LAeq dBA noise levels that could be received at representative surrounding buildings are compared with noise goals in Table 31 in *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS. Noise levels are not expected to exceed goals at residences south of Wool Street or north of Mt Coot-tha Road.

Night-time Tunnelling

During night-time tunnelling, most surface noise sources would be confined within either an enclosure extending over the eastbound tunnel portal and cut and cover sections or entirely within the completed cut and cover structure including closed portal door. Both options would likely achieve a similar acoustic benefit.

Spoil removal would be via conveyor directly to Mt Coot-tha quarry. Construction noise sources would include intermittent dump-truck noise and continuous noise from the temporary tunnel ventilation system.

Indicative LAeq dBA noise levels that could be received at night during the tunnelling phase are compared with noise goals in **Table 9-19.**

- **Table 9-19 Noise Assessment – Western Connection Worksite (WS1) - Night-time Tunnelling**

		Representative Receptors			
		Residences south Wool Street		Residences north of Mt Coot-tha Road	
Minimum Separation from Works (indicative only)		200 m		325 m	
AS/NZS 2107 Maximum Internal Noise Goal (LAeq - dBA)		40 (sleeping area, near major roads)		40 (sleeping area, near major roads)	
Internal Sleep Disturbance Noise Goal (LAmax - dBA)		50		50	
Nominal Facade Reduction (dBA)		10		10	
External Noise Goal (LAeq dBA)		**50**		**50**	
External Noise Goal (LAmax dBA)		**60**		**60**	
Monitoring Sites (external)		2		13	
Existing night time average LA90, 15minute - dBA		39		43	
Existing night time average LAeq,15minute - dBA		48		52	
Existing night time average LAmax,15minute - dBA		60		64	
Typical Plant Items	**Effective Sound Power Level (LAmax dBA)**	**Indicative External Plant Noise Level at Receptor - (dBA)**			
		LAeq	**LAmax**	**LAeq**	**LAmax**
25 t Articulated off-road Dump Truck	114-4=110[1]	48	56	44	52
25 t, 200 kW Front-end Loader	116-4=112[1]	50	58	46	54
Spoil Conveyor[2]	83 per metre	52	55	50	53
Ventilation	Design to meet Background LA90+3 dB at residences	42		46	
External Noise Goal (LAeq dBA)		**50**		**50**	
External Noise Goal (LAmax dBA)			**60**		**60**

At nearest residences on Wool Street and north of Mt Coot-tha Road noise from plant items during the night-time is not expected to exceed the LAeq dBA or LAmax design goal with the exception of the spoil conveyor which is predicted to marginally exceed the LAeq dBA noise goal by up to 2dBA. This assessment has not included topographical considerations which would be expected to have ameliorating effect where ground slope or vegetation removes line of sight to noise source. As a result, no significant acoustical impacts would be expected.

Apart from the detailed design of the enclosure (dedicated structure or enclosed cut and cover), the provision of additional noise mitigation is not expected to be necessary.

Noise control measures recommended for noise mitigation at the Western Freeway worksite (WS1) are:

- provide advance notification of time, type and duration of earthworks involved in site preparation;
- minimise the use of particularly noisy activities such as rockbreaking;
- ensure the construction of a ‘low’ performance (see Table 9-15) acoustic enclosure over the portal and stockpile or acoustic door entry to completed cut and cover structure is optimised, to ensure there are no ‘leakage paths’ to degrade the attenuation performance of the enclosure;

- design of continuously operating ventilation plant and any other plant that operates at night to meet 'reasonable' night-time noise objectives as defined in Section 2.2 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS;
- truck movement within the worksite should 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;
- noise monitoring at the commencement of and periodically during noise intensive activities.

Vibration Impacts

The nearest vibration sensitive location to the western connection worksite (WS1) is the Toowong Cemetery. Likely sources of vibration associated with the construction and operation of the worksite would be rockbreakers and dozers. Due to separation distances between the majority of the earthworks on the worksite and the cemetery, significant vibration impacts are not anticipated from site preparation or surface activities.

Toowong Connection Worksite (WS2)

Proposed Activities

The Toowong worksite (WS2) is within the parcel of land between Valentine Street, Frederick Street and Milton Road and is illustrated in Figure 9 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS.Noise-generating activities anticipated during the preparation and operation of the Toowong connection worksite is summarised in **Table 9-20**.

- **Table 9-20 Toowong Connection Worksite Noise Sources**

Construction Phase and Approx. Duration	Enclosed/Underground Day and Night-time Noise Sources	Additional Daytime Noise Sources
Removal of Buildings (2 weeks)	Nil	Excavators, bulldozers, dump trucks, manual trades
Site prep., Enclosure Construction (8 weeks)	Nil	Mobile cranes, trucks, concrete pumps, manual trades, excavator, steelwork
Roadheader Tunnelling (25 months)	Spoil removal, ventilation, supply of support materials and concrete	Removal of spoil and delivery of materials to inside enclosure

Site Preparation

Site preparation would involve removal of existing buildings, site hoarding and safety barrier installation, delivery of worksite infrastructure and enclosure construction. The noise intensive activities associated with these works would be carried out during the daytime only. It is anticipated that the most noticeable source of noise during site preparation would be heavy earthmoving machinery during demolition and material excavation.

Indicative LAeq dBA noise levels that could be received at representative surrounding buildings during site preparation at the Toowong connection worksite (WS2) are compared with noise goals in **Table 9-21**.

Table 9-21 Noise Impacts – Toowong Connection Worksite (WS2) - Site Preparation

		Representative Receptors	
		Residences north of Valentine Street	Residences South of Milton Road
Minimum Separation from Works (indicative only)		10m	20m
AS/NZS 2107 Maximum Internal Noise Goal (LAeq - dBA)		45 (living area, near major roads)	45 (living area, near major roads)
Nominal Facade Reduction (dBA)		10	10
External Noise Goal (LAeq dBA)		**55**	**55**
Monitoring site (external)		5	4
Existing average LAeq,15minute dBA		58	68
Existing average LAmax,15minute dBA		73	79
Typical Plant Items	**Plant Sound Power Levels (LAmax dBA)**	**Indicative External Plant Noise Level at Receptor (LAeq dBA)**	
Bobcat	112	76	70
Dozer	118	82	76
Hydraulic Rockbreaker	120	84	78
35 t, 200 kW Excavator	114	78	72
Roller	104	68	62
Compressor 285 L/s	100	69	63
Water Truck	105	69	63
25 t, 200 kW Front-end Loader	116	80	74
On-road Truck and Dog	103	67	61
20 t Mobile Crane	105	69	63
Semi Trailer	114	78	72
Concrete Truck	112	76	70
Concrete Pump	107	71	65
External Noise Goal (LAeq dBA)		**55**	**55**

Exceedances of noise goals of this nature are common when construction works occur in such close proximity (minimum of 10m) to receivers. Mitigation of noise levels from several plant items anticipated to be used would be essential for residents of Valentine Street. It is important that the use of significant noise generating plant be minimised insofar as possible and that nearby residents are notified of the works in advance. In this position it may be necessary to erect permanent or temporary noise barriers between the worksite and the residences before site preparation begins.

For the majority of the short duration construction works required for site preparation, construction noise levels at Milton Road residences would likely be similar in the level or below existing road traffic noise levels from Milton Road despite predicted exceedances of up to 23dBA of the daytime noise goals.

Daytime Tunnelling

During daytime tunnelling works, the dominant noise sources would be associated with spoil removal from the roadheaders and material deliveries to site. Indicative LAeq dBA noise levels that could be received at surrounding buildings are compared with noise goals in **Table 9-22**.

Table 9-22 Noise Impacts – Toowong Connection Worksite (WS2) - Daytime Tunnelling

		Representative Receptors	
		Residences north of Valentine Street	Residences South of Milton Road
Minimum Separation from Works (indicative only)		10m	40m
AS/NZS 2107 Maximum Internal Noise Goal (LAeq -dBA)		45 (living area, near major roads)	45 (living area, near major roads)
Nominal Facade Reduction (dBA)		10	10
External Noise Goal (LAeq dBA)		**55**	**55**
Monitoring site (external)		5	4
Existing average LAeq,15minute dBA		58	68
Existing average LAmax,15minute dBA		73	79
Typical Plant Items	**Effective Sound Power Level (LAmax dBA)**	**Indicative External Plant Noise Level at Receptor (LAeq dBA)**	
24 t Concrete Truck	112	76	64
Semi Trailer	114	78	66
On-road Truck and Dog	103	67	55
25 t, 200 kW Front-end Loader	116-19=97*	61	55
25 t Articulated off-road Dump Truck	114-19=95*	59	53
External Noise Goal (LAeq dBA)		**55**	**55**

Table Note: *Indicates that the effective sound power level has been adjusted for a high performance acoustic enclosure as per corrections in **Table 9-15** with a reduction in performance of 5dBA associated with open doors.

Installation of a temporary noise barrier along the eastern side of the tunnel off ramp adjacent to the Valentine Street cul de sac Due would be a necessary mitigation measure due to the close proximity (10m minimum) to the tunnel portal and worksite. The temporary barrier would need to be a minimum of 5m high as the adjacent buildings are double storeys. As an alternative, consideration could be given to upgrading the façade windows, and provision of air-conditioning to the affected residents, where it proves cost effective and acceptable to the community.

Predicted noise levels from spoil removal and concrete deliveries are likely to be below existing road traffic noise levels at residences along Milton Road although in excess of the daytime noise design goal. Therefore they are unlikely to result in a significant impact.

Night-time Tunnelling

During night-time tunnelling, all surface noise sources would be confined within the tunnel portal enclosure. Spoil haul-out and stockpiling would be achieved by loaders and trucks within the enclosure. Indicative LAeq dBA noise levels that could be received during night-time tunnelling are compared with noise goals in **Table 9-23**.

- **Table 9-23 Noise Impacts – Toowong Connection Worksite (WS2) - Night-time Tunnelling**

		Representative Receptors			
		Residences north of Valentine Street		Residences South of Milton Road	
Minimum Separation from Works (indicative only)		10m		150m	
AS/NZS 2107 Maximum Internal Noise Goal (LAeq - dBA)		40 (sleeping areas, near major roads)		40 (sleeping areas, near major roads)	
Internal Sleep Disturbance Noise Goal (LAmax - dBA)		50		50	
Nominal Facade Reduction (dBA)		10		10	
External Noise Goal (LAeq dBA)		**50**		**50**	
External Noise Goal (LAmax dBA)		**60**		**60**	
Monitoring sites (external)		5		4	
Existing night-time average LA90, 15minute dBA		48		41	
Existing night-time average LAeq,15minute dBA		55		58	
Existing night-time average LAmax,15minute dBA		68		74	
Typical Plant Items	**Effective Plant Sound Power Levels (LAmax dBA)**	**Indicative External Plant Noise Level at Receptor - (dBA)**			
		LAeq	**LAmax**	**LAeq**	**LAmax**
25 t Articulated off-road Dump Truck	114-24=90*	54	62	30	38
25 t, 200 kW Front-end Loader	116-24=92*	56	64	32	40
Ventilation	Design to meet Background LA90+3 dB at residences	51		44	
External Noise Goal (LAeq dBA)		**50**		**50**	
External Noise Goal (LAmax dBA)			**60**		**60**

Table Note: * Indicates that the effective sound power level has been adjusted for a high performance acoustic enclosure as per corrections in **Table 9-15**.

A high performance enclosure would be required at this location to reduce the extent of the likely impact. As shown in **Table 9-23**, night-time noise levels are still predicted to be up to 6dBA above the recommended goals with a high performance enclosure. This would generally be described as a 'noticeable' exceedance. However, when machinery is located further within the tunnel, noise levels would decrease. The temporary noise wall advocated for the worksite boundary between the workshed and Valentine Street cul-de-sac would also diminish the impact through the night.

As night-time construction would occur within the acoustic enclosure at the Toowong worksite, received noise levels from spoil stockpiling works would be below the LAmax and LAeq dBA noise goal.

The following noise control measures may be suitable for noise mitigation at the Toowong connection worksite (WS2):

- advance notification of the time, type and duration of demolition and initial earthworks;
- where feasible install noise barriers that may be:
  - operational requirements to be permanent structures
  - temporary structures for the period of construction in that area, or
  - where noise is modelled to be above goals for a shorter period or in a specific site temporary structures as appropriate to reduce construction noise during 'Site Preparation' and on-site vehicle movements at

adjacent property boundaries on Valentine Street. A noise barrier would need to be a minimum of 5m in height as the adjacent buildings are all double storeys or Queenslanders. As an alternative, consideration could be given to upgrading the façade windows, and provision of air-conditioning to the affected residents, where it proves cost effective and acceptable to the community;

- construction of a high performance acoustic enclosure over the portal and stockpile area with indicative acoustic performance (subject to detailed design);
- further assess and consult with property owners immediately adjoining the site as to the best form of mitigation (eg relocation for period of noisy construction, noise barriers or the provision of architectural treatment (and ventilation) to impacted rooms facing the worksite) to address noise during site preparation and/or rock-drilling at or near the access shaft;
- 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;
- design of continuously operating ventilation plant and any other plant that operates at night to meet 'reasonable' night-time noise objectives; and
- noise monitoring at the commencement of and periodically during noise intensive activities.

Vibration Impacts

The anticipated sources of vibration during the site preparation works at WS2 are rockbreaking during demolition works to break up existing slabs and footings and vibratory rolling during earthworks. The bulk of the vibration intensive works would take place beyond 20m from sensitive receivers and is therefore unlikely to exceed the vibration criteria set out in **Table 9-9**. However it is normal environmental monitoring practice to monitor vibration on structures from vibratory rolling that occurs within a nominal distance of 25m. This may be relevant for Valentine Street buildings.

Kelvin Grove Connection Worksites (WS3)

The Kelvin Grove connection worksite (WS3) is illustrated in Table 37 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS.

The primary noise-generating activities anticipated during the preparation and operation of the Kelvin Grove worksite (WS3) are the same as for the Toowong Worksite (**Table 9-21**) except that the roadheader tunnelling would take seven months longer at this site.

Site Preparation

Site preparation would involve removal of existing buildings, initial earthworks and enclosure construction. The noise intensive activities associated with these works would be carried out during the daytime only. It is anticipated that the most noticeable source of noise during site preparation would be heavy earthmoving and rockbreaking machinery during the demolition and material excavation stage.

Indicative LAeq dBA noise levels that could be received at representative surrounding buildings during site preparation are compared with noise goals in **Table 9-24**.

Table 9-24 Noise Impacts – Kelvin Grove Connection Worksites (WS3) - Site Preparation

		Representative Receptors	
		Residences West of Lower Clifton Terrace	Residences North of Upper Clifton Terrace
Minimum Separation from Works (indicative only)		20m	10m
AS/NZS 2107 Maximum Internal Noise Goal (LAeq - dBA)		45 (living area, near major roads)	45 (living area, near major roads3)
Nominal Facade Reduction (dBA)		10	10
External Noise Goal (LAeq dBA)		**55**	**55**
Monitoring sites (external)		9	10
Existing daytime average LAeq,15minute dBA		65	62
Existing daytime average LAmax,15minute dBA		80	72
Typical Plant Items	**Plant Sound Power Levels (LAmax dBA)**	**Indicative External Plant Noise Level at Receptor (LAeq dBA)**	
Bobcat	112	70	76
Dozer	118	76	82
Hydraulic Rockbreaker	120	78	84
35 t, 200 kW Excavator	114	72	78
Roller	104	62	68
Compressor 285 L/s	100	63	69
Water Truck	105	63	69
25 t, 200 kW Front-end Loader	116	74	80
On-road Truck and Dog	103	49	55
20 t Mobile Crane	105	63	69
Semi Trailer	114	72	78
Concrete Truck	112	70	76
Concrete Pump	107	65	71
External Noise Goal (LAeq dBA)		**55**	**55**

Although existing ambient noise levels are relatively high in the area west of Lower Clifton Terrace, predicted construction noise levels, would be discernible within dwellings and likely to have acoustic impacts (eg: interference with passive listening, resting, conversation and TV).

The nearest residence is approximately 20m from the worksite and look down onto the site as the ground rises towards Red Hill. In this area the highest noise levels would be expected from the rockbreaker which may exceed noise goals by up to 23dBA. Although site preparation works may take several months, the maximum noise emission would be over only a part of the period.

Noise mitigation strategies at this site should focus on the use of quietest available plant and construction techniques to establish the site and where possible expediting the early works to allow construction of the acoustic enclosure which would remain in place until tunnelling is complete.

Without mitigation measures as outlined below residents of Upper Clifton Terrace and Westbury Street would experience significant noise impacts as indicated by the predicted noise levels in **Table 9-24**. Unmitigated, noise levels of this magnitude would be audible within dwellings and likely to result in acoustic impacts.

Daytime Tunnelling

Tunnelling of the Kelvin Grove on and off ramps from worksite WS3 would be undertaken with multiple roadheaders. Indicative LAeq dBA noise levels that could be received at representative surrounding buildings during the daytime tunnelling are compared with noise goals in **Table 9-25**. The predictions assume the adoption of a medium performance acoustic enclosure as described in **Table 9-15**.

- **Table 9-25 Noise Impacts – Kelvin Grove Connection Worksites (WS3) - Daytime Tunnelling**

		Representative Receptors	
		Residences West of Lower Clifton Terrace	Residences North of Upper Clifton Terrace
Minimum Separation from Works (indicative only)		20m	10m
AS/NZS 2107 Maximum Internal Noise Goal (LAeq -dBA)		45 (living area, near major roads)	45 (living area, near major roads)
Nominal Facade Reduction (dBA)		10	10
External Noise Goal (LAeq dBA)		**55**	**55**
Monitoring sites (external)		9	10
Existing daytime average $L_{Aeq,15minute}$ dBA		65	62
Existing daytime average $L_{Amax,15minute}$ dBA		80	72
Typical Plant Items	**Effective Sound Power Level (LAmax dBA)**	**Indicative External Plant Noise Level at Receptor (LAeq dBA)**	
24 t Concrete Truck	112	70	76
Semi Trailer	114	72	78
On-road Truck and Dog	103	61	67
25 t, 200 kW Front-end Loader	116-19=97*	55	61
25 t Articulated off-road Dump Truck	114-19=95*	53	59
External Noise Goal (LAeq dBA)		**55**	**55**

Table Note: * Indicates that the effective sound power level has been adjusted for a high performance acoustic enclosure as per corrections in **Table 9-15** with a reduction in performance of 5dBA associated with open doors**.**

Due to the confined nature of worksite WS3, heavy vehicle movements on site would be kept to a minimum. The majority of construction vehicles accessing the site would be for spoil haulage which represent a 6dBA exceedance of the noise goal in the absence of any mitigation measures such as noise walls.

As the tunnelling phase of the project would continue over more than a year, noise mitigation strategies should focus on the use of quietest available plant and construction techniques such as careful design of site access points and vehicle paths to maximise distance to noise sensitive receivers and make use of acoustic enclosures and site buildings to act as screens.

On the basis of existing (Year 2007) vehicle movements along Kelvin Grove Road (27,760 southbound and 22,210 northbound – 18 Hour component of AADT) and the predicted maximum vehicle numbers to site (75 to site per day), it is likely that surrounding receivers would associate Northern Link construction vehicles as part of the normal road network particularly since the worksites are immediately adjacent to Kelvin Grove Road.

Night-time Tunnelling

Indicative LAeq dBA noise levels that could be received at representative residences around the Kelvin Grove worksite (WS3) during night-time tunnelling are compared with noise goals in **Table 9-26**.

- **Table 9-26 Noise Impacts – Kelvin Grove Worksites (WS3) – Night-Time Tunnelling**

		Representative Receptors			
		Residences W of Lower Clifton Tce		Residences N of Upper Clifton Tce	
Minimum Separation from Works (indicative only)		20m		10m	
AS/NZS 2107 Maximum Internal Noise Goal (LAeq -dBA)		40 (sleeping areas, near major roads)		40 (sleeping areas, near major roads)	
Internal Sleep Disturbance Noise Goal (LAmax -dBA)		50		50	
Nominal Facade Reduction (dBA)		10		10	
External Noise Goal (LAeq dBA)		**50**		**50**	
External Noise Goal (LAmax dBA)		**60**		**60**	
Monitoring sites (external)		9		10	
Existing night time average LA90, 15minute dBA		52		41	
Existing night time average LAeq,15minute dBA		60		55	
Existing night time average LAmax,15minute dBA		73		68	
Typical Plant Items	**Effective Plant Sound Power Levels (LAmax dBA)**	**Indicative External Plant Noise Level at Receptor - (dBA)**			
		LAeq	**LAmax**	**LAeq**	**LAmax**
25 t Articulated off-road Dump Truck	114-24=90*	48	56	54	62
25 t, 200 kW Front-end Loader	116-24=92*	50	58	56	64
Ventilation	Design to meet Background LA90+3 dB at residences	55		44	
External Noise Goal (LAeq dBA)		**50**		**50**	
External Noise Goal (LAmax dBA)			**60**		**60**

Table Note: * Indicates that the effective sound power level has been adjusted for a high performance acoustic enclosure as per corrections in **Table 9-15**.

Due to the close proximity of the Lower Clifton Terrace, Upper Clifton Terrace and Westbury Street residences, a high performance enclosure would be required to significantly reduce the noise impact. Erection of noise barriers on the worksite margin may be appropriate to mitigate further expected small exceedances (up to 4dBA) of the night-time noise goal for Upper Clifton Terrace residences.

Noise Mitigation

The following measures are recommended for noise mitigation at the Kelvin Grove worksite (WS3):

- advance notification of the time, type and duration of demolition and initial earthworks;
- where feasible install noise barriers that may be:
  - operational requirements to be permanent structures
  - temporary structures for the period of construction in that area, or
  - where noise is modelled to be above goals for a shorter period or in a specific site temporary structures as appropriate

to reduce construction noise during ‘Site Preparation’ and on-site vehicle movements at adjacent property boundaries. A noise barrier would need to be a minimum of 5m in height due to the rising land. As an alternative, consideration could be given to upgrading the façade windows, and provision of air-conditioning to the affected residents, where it proves cost effective and acceptable to the community;

- minimise the duration of initial noise intensive site works such as rockbreaking;
- use of quietest available plant and construction techniques for works occurring in the open environment;
- construction of a high performance acoustic enclosure over the portal with indicative acoustic performance as shown in **Table 9-14** (subject to detailed design);
- careful design of the site layout to provide shielding for residences from construction noise. The acoustic enclosure and other site buildings may provide some screening if located between residences and construction plant, particularly for spoil vehicles whilst on site;
- as for Toowong and Western Freeway worksites in regard to reversing alarms;
- design of continuously operating ventilation plant and any other plant that operates at night to meet ‘reasonable’ night-time noise objectives; and
- noise monitoring at the commencement of and periodically during noise intensive activities.

Vibration Impacts

Vibration may be expected from rockbreaking during demolition and vibratory rolling during earthworks. The bulk of the vibration intensive works would take place beyond 20m from sensitive receivers and is therefore unlikely to exceed the defined vibration criteria. However, it is general practice to monitor vibration on structures from vibratory rolling that occurs within a nominal distance of 25m. This would likely be applicable for all adjacent residential receivers.

9.3.3 Surface Construction of Roadways

Construction of surface road connections would generally be confined to daytime hours except for special circumstances, which may include work on arterial roads, within rail corridors, and works involving the transport of large pre-fabricated components such as bridge works.

Western Freeway Connection

The primary noise-generating activities anticipated during the construction of the western surface connection roads, interfacing with the Western Freeway, are summarised in **Table 9-27**.

Table 9-27 Western Freeway Surface Road Construction - Noise Sources

Construction Phase (and Approx Duration)	Noise Sources
Earthworks (4 months)	Excavators bulldozers, graders, loaders, bobcats, compaction equipment, dump trucks, water trucks, manual trades
Cut and Cover Construction (9 months)	Bored piling rig, hydraulic rockbreakers, rock ripping, jack hammer, excavators, shotcreting, rock bolting, compressors, cranes, concrete pump
Transition Structure Construction (12 months)	Bored piling rig, hydraulic rockbreakers, rock ripping equipment, jack hammer, excavators, shotcreting, rock bolting, compressors, cranes, concrete pump
Road Construction and Re-surfacing (4 months)	Delivery trucks, paving machine, compaction equipment, line marking

Indicative noise levels that could be received at the nearest residential receivers during the night-time Western Freeway road works are compared with noise goals in **Table 9-28**.

Table 9-28 Noise Impacts - Western Connection Surface Road Construction

		Representative Receptors	
		Residences south of Wool Street	Residences north of Mt Coot-tha Road
Minimum Separation from Works (indicative only)		120m	400m
AS/NZS 2107 Maximum Internal Noise Goal (LAeq - dBA)		45 (living area, near major roads)	45 (living area, near major roads)
Nominal Facade Reduction (dBA)		10	10
External Noise Goal (LAeq dBA)		**55**	**55**
Monitoring sites (external)		2	13
Existing Daytime average LAeq,15minute dBA		52	57
Existing Daytime average LAmax,15minute dBA		67	71
Typical Plant Items	**Effective Sound Power Level (LAmax dBA)**	**Indicative External Plant Noise Level at Receptor (LAeq dBA)**	
Hydraulic Rockbreaker	120	62	52
35 t, 200 kW Excavator	114	56	46
Compressor 285 L/s	100	47	37
Water Truck	105	47	37
100 Tonne Hydraulic Crane	110	52	42
Bored piling rig	118	60	50
Pneumatic Rock Drill	120	62	52
Concrete Pump	107	49	39
24 t Concrete Mixer	112	54	44
External Noise Goal (LAeq dBA)		**55**	**55**

The assessment of impacts on residences in Wool Street is made without incorporating topography, other buildings or thick vegetation obscuring line of sight and these features may have an ameliorating effect up to 5dBA over and above the effect of works in the troughs of the transition and cut and cover structures as noted below.

At the closest residences to the south of Wool Street, the highest noise levels arise due to the operation of the rockbreaker and rock drill. These items of plant are typically used on an intermittent basis and would likely be used below existing ground level (ie: within the cut) therefore creating a barrier effect on noise emissions from the site. This is particularly the case during the latter stages of the cut and cover and transition construction works.

Other plant items such as bored piling rigs and excavators may operate over months and as indicated in **Table 9-28** have the potential to result in an acoustic impact (ie: audible inside dwellings) for residences south of the Western Freeway.

Noise Mitigation

Noise mitigation measures include:

- advance notification of the time, type and duration of noise intensive construction activities, particularly for any special circumstance night-time works;
- selection of quietest available construction plant and techniques to keep noise emissions to a minimum;
- location of plant items to maximise distance to noise sensitive receivers;
- attended noise measurements at the commencement of long-term noise intensive construction works to identify the need for additional noise mitigation measures;
- where feasible, erect temporary acoustic screens to mitigate noise from rockbreaking; and
- noise monitoring at the commencement of and periodically during noise intensive activities.

Vibration Impacts

The anticipated sources of vibration during the construction of the western surface connection roads are vibratory rolling during the existing road (Western Freeway and Mt Coot-tha Road) realignment works and rockbreaking during cut and cover and transition structure construction. The majority of these works would take place far enough away from vibration sensitive receivers to avoid any impact.

Rockbreaking may be required at the TBM launch pits located adjacent to the Toowong Cemetery. If the works are required to take place within 10m of grave sites then vibration monitoring should be carried out to ensure vibration levels do not exceed the 2mm/s criteria listed in Table 5 in *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS.

Toowong Connection

The primary noise-generating activities anticipated during the construction of the Toowong surface connections are summarised in **Table 9-29**.

Table 9-29 Toowong Surface Road Construction - Noise Sources

Construction Phase and Approx. Duration	Noise Sources
Removal of buildings (2 months)	Excavators, hydraulic breakers, bulldozers, dump trucks, manual trades, compressors, generators
Earthworks (8 months)	Excavators, bulldozers, graders, loaders, bobcats, compaction equipment, dump trucks, water trucks, manual trades
Cut and cover Construction (3 months)	Bored piling rig, excavators, rockbreakers, shotcreting, rock bolting, compressors, cranes for precast items, concrete pump, ventilation
Elevated structures (4 and 8 months)	Bored piling rig, excavators, steel fixing, compressors, crane, concrete pump
Road surfacing for traffic diversions (12 months)	Delivery trucks, paving machine, compaction equipment, line marking

Indicative noise levels that could be received at representative surrounding buildings during night-time elevated structure construction are compared with noise goals in **Table 9-30**.

Table 9-30 Noise Impacts – Toowong Surface Construction

		Representative Receptors	
		Residences north of Valentine Street	Residences South of Milton Road
Minimum Separation from Works (indicative only)		10m	10m
AS/NZS 2107 Maximum Internal Noise Goal (LAeq -dBA)		45 (living area, near major roads)	45 (living area, near major roads)
Nominal Facade Reduction (dBA)		10	10
External Noise Goal (LAeq dBA)		**55**	**55**
Monitoring sites (external)		5	4
Existing Daytime average LAeq,15minute dBA		58	68
Existing Daytime average LAmax,15minute dBA		73	79
Typical Plant Items	**Effective Sound Power Level (LAmax dBA)**	**Indicative External Plant Noise Level at Receptor (LAeq dBA)**	
Hydraulic Rockbreaker	120	84	84
35 t, 200 kW Excavator	114	78	78
38 t, 250 kW Dozer	118	82	82
Compressor 285 L/s	100	64	64
Water Truck	105	69	69
100 Tonne Hydraulic Crane	110	74	74
Bored piling rig	118	82	82
Pneumatic Rock Drill	120	84	84
Concrete Pump	107	71	71
24 t Concrete Mixer	112	76	76
200 kW Grader	116	80	80
External Noise Goal (LAeq dBA)		**55**	**55**

All reasonable and feasible noise mitigation, from the list below or others as found appropriate during detailed design, must be examined so as to maintain a reasonable noise environment at these residences during the construction works. The temporary noise barrier on the margin of the Toowong worksite would reduce construction noise levels but further mitigation measures would likely be required from the list below.

Table 9-30 indicates, for example, that without any mitigation, noise levels at the most exposed residences on Valentine Street and south of Milton Road, within 10m of construction, could be up to 29dBA above the external noise goal (55 LAeq dBA) if typical hydraulic rock-breaking plant was being utilised. This would represent the worst case condition and without mitigation would interfere with normal indoor living (eg: interference with passive listening, resting and conversation) and would likely cause sleep disturbance.

Noise Mitigation

The following noise control measures are recommended for the Toowong surface connection works, guided by the 'reasonable' noise objectives for construction noise.

- Construction of temporary noise barriers between the cut and cover work area and Valentine Street residences to reduce construction noise for receivers to the east and north of the site.
- Advance notification of the time, type and duration of noise intensive works, such as bored piling, particularly where required immediately adjacent to residential receivers or at night-time.

- Selection of quietest available construction plant and techniques to keep noise emissions to a minimum.
- Assist owners of properties nearest the construction site to temporarily upgrade the acoustic insulation and ventilation of rooms facing the site.
- Location of plant items to maximise distance to noise sensitive receivers.
- Attended noise measurements at the commencement of and periodically for noise intensive construction works to identify the need for additional noise mitigation measures.
- Early construction of the operational noise barriers north and south of Milton Road to protect residences during the construction period.

Vibration impacts

The anticipated sources of vibration during the construction of the Toowong surface connection roads are vibratory rolling during the road realignment works and rockbreaking during cut and cover and transition structure construction. Some of this work would take place in close proximity (less than 25m) from vibration sensitive receivers presenting potential impacts. Therefore it is important that nearby receivers are notified in advance of the vibration intensive works and that monitoring be carried out at the commencement of the works to confirm the levels are below the nominated criteria.

Kelvin Grove Road Connection

The primary noise-generating activities anticipated during the construction of the Kelvin Grove Road surface connections are the same as for the Toowong Connection without the elevated structures. It is anticipated that the highest noise levels would typically result from the cut and cover construction and road resurfacing of Kelvin Grove Road.

Indicative noise levels that could be received at the most exposed residences during construction of cut and cover areas adjacent to Kelvin Grove Road are compared with noise goals in **Table 9-31.**

▪ **Table 9-31 Noise Impacts – Kelvin Grove Road Construction**

		Representative Receptors	
		Residences West of Lower Clifton Terrace	Residences North of Upper Clifton Terrace
Minimum Separation from Works (indicative only)		60m	25m
AS/NZS 2107 Maximum Internal Noise Goal (LAeq - dBA)		45 (living area, near major roads)	45 (living area, near major roads)
Nominal Facade Reduction (dBA)		10	10
External Noise Goal (LAeq dBA)		**55**	**55**
Monitoring sites (external)		9	10
Existing Daytime average LAeq,15minute dBA		65	62
Existing Daytime average LAmax,15minute dBA		80	72
Typical Plant Items	**Effective Sound Power Level (LAmax dBA)**	**Indicative External Plant Noise Level at Receptor (LAeq dBA)**	
35 t, 200 kW Excavator	114	62	70
Compressor 285 L/s	100	53	61
100 Tonne Hydraulic Crane	110	58	66
Bored piling rig	118	66	74
Pneumatic Rock Drill	120	68	76
Concrete Pump	107	55	63
24 t Concrete Mixer	112	60	68
Asphalt Paver	114	62	70
Semi Trailer	114	62	70
Roller	104	52	60
External Noise Goal (LAeq dBA)		**55**	**55**

If not mitigated the indicative daytime LAeq dBA noise levels from the worst case use of a typical pneumatic rock drill at the most exposed residences north of Upper Clifton Terrace, would be up to 21dBA higher than the noise goals. This would be found to be intrusive. The existing noise environment, with exceedances of 7-10dBA at surrounding sites are probably already intrusive.

Noise Mitigation

The following noise control measures are recommended for mitigation of construction noise around surface road works for the Kelvin Grove connections, guided by the 'reasonable' noise objectives for construction noise as defined above:

- advance notification of the time, type and duration of works, especially night-time works;
- where possible, select construction processes and plant to minimise construction noise;
- if required, assist owners of properties nearest the construction site to temporarily upgrade the acoustical insulation and ventilation of rooms facing the construction area;
- noise monitoring at the commencement of and periodically during noise intensive activities; and
- early construction of the operational noise barriers west of Kelvin Grove Road to protect residences during the construction period, or erect temporary construction noise barriers in a similar location.

Vibration Impacts

The bulk of the vibration intensive works, anticipated to be excavation of material and compaction for new road construction, at the Kelvin Grove Road connection would take place beyond 20m from sensitive receivers and is therefore unlikely to exceed the nominated vibration criteria.

However it is normal environmental monitoring practice to monitor vibration on structures from vibratory rolling that occurs within a nominal distance of 25m. This would likely be applicable for most adjacent residential receivers in Upper Clifton Terrace and Westbury Street.

Inner City Bypass Connection

Proposed Activities

The primary noise-generating activities anticipated during the construction of the ICB connection are identical with those anticipated at the Western Freeway connection as outlined in **Table 9-27**. It is anticipated that highest noise levels would typically result from cut and cover and transition structure construction south of Normanby Terrace. Indicative noise levels that could be received at the most exposed residences during the daytime construction works at the ICB connection are compared with noise goals in **Table 9-32**.

Table 9-32 Noise Impacts – ICB Connection Construction

		Representative Receptors		
		Normanby Terrace and Victoria Park Road Residences*	Brisbane Grammar School (Indoor Sports Centre)	Brisbane Girls Grammar School (Classrooms)
Minimum Separation from Works (indicative only)		25m	100m	70m
AS/NZS 2107 Maximum Internal Noise Goal (LAeq - dBA)		45 (living areas, near major roads)	45 (school teaching area)	45 (school teaching area)
Nominal Facade Reduction (dBA)		10	10	10
External Noise Goal (LAeq dBA)		**55**	**55**	**55**
Monitoring sites (external)		12	11	12
Existing Daytime average LAeq,15minute dBA		58	63	58
Existing Daytime average LAmax,15minute dBA		68	78	68
Typical Plant Items	**Plant Sound Power Levels (LAmax dBA)**	**Indicative External Plant Noise Level at Receptor (LAeq dBA)**		
35 t, 200 kW Excavator	114	65	58	61
Compressor 285 L/s	100	56	49	52
Water Truck	105	56	49	52
100 Tonne Hydraulic Crane	110	61	54	57
Bored piling rig	118	69	62	65
Pneumatic Rock Drill	120	71	64	67
Concrete Pump	107	58	51	54
24 t Concrete Mixer	112	63	56	59
Asphalt Paver	114	65	58	61
Semi Trailer	114	65	58	61
Roller	104	55	48	51
External Noise Goal (LAeq dBA)		**55**	**55**	**55**

Table Note: *A 5dBA reduction has been assumed for these residences due to the existing ICB noise barrier

If no mitigation measures are emplaced for Normanby Terrace and Victoria Park Road residences, the indicative LAeq dBA noise levels from the use of a bored piling rig would likely be up to 16dBA above the noise goal. It is likely that an exceedance of this magnitude would be intrusive and possibly interfere with indoor amenity. It is likely that for some construction noise sources actual levels would be lower due to a greater barrier effect than the 5dBA (broken line of sight) reduction applied to the results in **Table 9-32**.

The highest Northern Link construction noise levels at Brisbane Grammar School are predicted to result during use of the rock drill and bored piling rig. Other construction noise sources are similar in level to existing ambient noise, primarily from the ICB, for this area.

The highest Northern Link construction noise levels at Brisbane Girls Grammar School are predicted to result during use of the rock drill when an exceedance of 12dBA above the external noise goal is predicted. Levels of this magnitude would be audible within classrooms and may interfere with internal activities. Further investigation of the attenuation through the façade of the school buildings closest to the construction works is recommended to further assess and mitigate noise impacts.

Noise Mitigation

Control measures recommended for mitigation of noise from the ICB connection construction works, guided by the 'reasonable' noise objectives for daytime construction noise include:

- advance notification of the time and duration of works, especially any night works;
- select construction processes and plant to minimise construction noise;
- assist owners of properties nearest the construction site to temporarily upgrade the acoustical insulation and ventilation of rooms facing the construction area;
- a detailed investigation of classroom facades at Brisbane Grammar and Brisbane Girls Grammar Schools to determine actual noise attenuation and therefore assess the need for further mitigation; and
- early construction of the operational noise barriers to protect Normanby Terrace residences during the construction period, or erect temporary construction noise barriers in a similar location.

Vibration Impacts

It is not anticipated that vibration levels associated with vibratory rolling during road surfacing of the Northern Link ICB connection would be significant. However it is normal environmental monitoring practice to monitor vibration on structures during vibratory rolling that occurs within a nominal distance of 25m. This may be relevant for properties in Normanby Terrace and Victoria Park Road that would be nearest to works on the northern side of the ICB.

9.3.4 Ventilation Infrastructure Construction

The western ventilation station and outlet require a ventilation duct approximately 45m^2 in cross sectional area to be constructed below ground level from the air extraction point about 150-200m before the tunnel exit to daylight of the westbound tunnel to the station and on to the outlet as well as a 20m^2 connection to the eastbound tunnel smoke extraction duct.

Construction of the western ventilation station and outlet would be adjacent and similar to the cut and cover construction activities and provided the outlet is located close to the Northern Link mainline tunnel impacts associated with these works would be similar to those identified above for the Western Freeway connection surface road activities. For this reason no further assessment is required.

Eastern Ventilation Station Construction

The eastern outlet point requires a ventilation tunnel approximately 45m^2 in cross section to be constructed from the cut and cover section of the eastbound tunnel to the ventilation station and beyond to the outlet as well as a 20m^2 connection to the westbound tunnel smoke extraction duct.

Construction of the eastern ventilation station and outlet would likely require a combination of driven tunnel (roadheader) near the extraction point and cut and cover close to the outlet point. Daytime construction noise levels have been predicted for the Victoria Park Golf Course ventilation outlet and are presented in **Table 9-33**.

- **Table 9-33 Noise Impacts – Eastern Ventilation Station Construction - Daytime Works**

		Representative Receptors	
		Victoria Park Road Residences	**QUT Kelvin Grove Campus**
Minimum Separation from Works (indicative only)		20m	200m
AS/NZS 2107 Maximum Internal Noise Goal (LAeq -dBA)		45 (living area, near major roads)	45 (university teaching area)
Nominal Facade Reduction (dBA)		10	10
External Noise Goal (LAeq dBA)		**55**	**55**
Monitoring sites (external)		12	14
Existing Daytime average LAeq,15minute dBA		58	54
Existing Daytime average LAmax,15minute dBA		68	68
Typical Plant Items	**Effective Sound Power Level (LAmax dBA)**	**Indicative External Plant Noise Level at Receptor (LAeq dBA)**	
35 t, 200 kW Excavator	114	72	52
Compressor 285 L/s	100	58	38
20 Tonne Mobile Crane	105	63	43
Bored piling rig	118	76	56
Pneumatic Rock Drill	120	78	58
Concrete Pump	107	65	45
24 t Concrete Mixer	112	70	50
Semi Trailer	114	72	52
External Noise Goal (LAeq dBA)		**55**	**55**

Residences in Victoria Park Road would, at times, be as close as 20m to ventilation duct construction. As the works progress towards the outlet point this separation distance would increase to beyond 200m.

Numerous plant items required to carry out the works, would likely exceed the external design goal during normal operation. Exceedances of this nature are common when construction works occur in close proximity to receivers.

It is important that the use of significant noise generating plant be minimised insofar as possible and that nearby residents are notified of the works in advance.

The highest construction noise levels at QUT are predicted to exceed the noise goal by a marginal 3dBA. Levels of this magnitude are unlikely to be audible within classrooms. It was noted during the noise monitoring site visit that the nearest row of buildings to the proposed outlet site were not teaching areas.

Noise Mitigation

The following control measures are recommended for mitigation of potential noise from ventilation station construction works, guided by the ‘reasonable’ noise objectives for daytime construction noise:

- Advance notification of the time, type and duration of works, especially any night works in the case of residential receivers.
- Select construction processes and plant to minimise construction noise.

Vibration Impacts

It is not anticipated that vibration levels associated with the eastern ventilation station construction would result in vibration impacts. However it is normal environmental monitoring practice to monitor vibration on structures during vibratory rolling that occurs within a nominal distance of 25m.

9.3.5 Tunnelling Between Portals

It is proposed that two Tunnel Boring Machines (TBM) would be used to excavate the mainline tunnel between the Western Freeway and ICB. Roadheader and drill-and-blast excavation is likely to be used at the following locations.

- Toowong ramp connections including Frederick Street and Y-Junctions on mainline tunnels.
- Kelvin Grove Road ramp connection tunnels including the Y-Junctions on mainline tunnels.
- Cross passages, low point sumps, substations, etc.

Vibration issues have been considered in relation to residential properties, aged-care facilities, educational facilities, sensitive commercial facilities and known buildings of particular heritage value.

Vibration Impacts

Specific vibration levels have been predicted using the indicative ground vibration levels (based on the measurement results for tunnelling methods in **Table 9-16** and the slant distances to the receivers which are derived as per the method outlined in *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS.

The potential impacts of vibration on buildings and on people have been assessed by comparing the predicted vibration levels using the guide values for minimising the risk of cosmetic (superficial) building damage and/or appropriate statutory requirements and using the guideline values for subjective human disturbance response, respectively.

Summaries of the key parameters describing the impacts on buildings and residents are presented in Tables 55 and 57 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS. Indicative extent of human perception of the tunnelling operations (ie: road header or TBM) and from blast vibration is shown in Table 58 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS. All predictions of vibration levels are below the guide value or statutary limit for cosmetic damage except for short sections of TBM construction at start and finish nearest surface. In these areas a range of mitigation measures area available including modification to the construction methodology during the detailed design phase, slowing the TBM progress to minimise energy output among others.

To address community concerns regarding potential vibration impacts in a pro-active manner, a range of response management measures would be implemented prior to and/or during tunnelling operations. The specific management response measures are dependent on the predicted levels of possible impacts on buildings and their occupants - and are described in **Table 9-34**.

- **Table 9-34 Potential Vibration Impact Response Management Measures**

Predicted Effect of Tunnelling Vibration Emissions	Pre Notification to Building Occupants	Building Condition Survey	Building Sensitivity Study (Refer Note 1)	Vibration Monitoring
Not felt	-	-	-	-
Threshold of perception	-	-	-	
Barely noticeable	✓		✓	
Sleep disturbance Note 2	✓		✓	✓
Noticeable	✓		✓	✓
Easily noticeable	✓	✓	✓	✓
Strongly noticeable	✓	✓	✓	✓
Very strongly noticeable	✓	✓	✓	✓

Table Note:

1 This only applies for specific sensitive buildings identified in *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS of this report.

2 This category is not within **Table 9-8**, and is defined to be 0.5mm/s.

For blasting, the Maximum Instantaneous Charge (MIC) of explosive used in the design of the blast and the distance to a receiver dictate the likely received levels of vibration. Explosive MICs would be selected to ensure that predicted vibration levels do not exceed permissible limits. The representative blast MIC was determined based on previous trial blasts in Brisbane - and is a first approximation.

Wherever blasting is undertaken, building condition surveys, building sensitivity studies and vibration monitoring is recommended.

The threshold vibration levels below which cosmetic building damage from transient vibrations (eg: blasting) do not occur, are comparable to vibration levels readily accepted as being normal by people in buildings during the daytime. Thus, in general terms, the objective of protecting buildings from excessive blast vibrations generally results in vibration levels that people would accept, provided there is an effective community consultation process to ensure that people are well informed of the works and the nature of their vibration emissions.

During the night-time period, it could be expected that blasting would result in significant adverse comment. Blasting would therefore normally be avoided during the night-time period.

Blasting

Depending on the number of blastholes and the millisecond delays used between successive detonations, tunnel face blasting typically results in a series of short vibration 'events' lasting several seconds. Apart from limiting the size of the charge, the normal mitigation method in relation to human comfort impacts is to give clear and concise pre-notification to all persons in the area. People would 'hear' the blast, although vibration (and noise) levels are usually relatively low. It is imperative that the community be properly advised so that ill-informed perceptions do not cause unnecessary concern.

It is often the case with projects where blasting is carried out that a regular schedule is established whereby people come to anticipate blast vibrations at a set time with minimal 'startle effects' or other concerns.

If drill and blast methods are required, the following guidelines would be considered appropriate.

- Appropriate attention to blast design, with a low Maximum Instantaneous Charge.

- Effective pre-warnings and coordination of the timing of the blast activities to minimise impacts on specific healthcare operations via the community consultation team.
- Monitoring of the blast emissions and correlation of the readings with consultation with the staff members.

It is a requirement of Brisbane City Council to conduct pre- and post-blasting Building Condition Surveys where it is considered there may be potential for cosmetic (superficial) building damage.

Tunnel Boring Machine

It is proposed to operate the TBMs on a near continuous basis. If the vibration levels from continuous construction are higher than 0.5mm/s sleep disturbance may result. Vibration is predicted to exceed this guide value for some residences above the mainline tunnels requiring monitoring and mitigation measures to achieve the environmental objective.

The responses of individual people to vibration in their dwellings vary markedly. The 0.5mm/s night-time guideline vibration level for this Project is conservatively low. Some people may be comfortable with higher levels.

The vibration predicted at a small location on the footpath of Mount Coot-tha Road along the southern edge of Toowong cemetery and a small area immediately adjacent in the cemetery would be in the range above 2mm/sec and up to 9.371mm/s. Predicted vibration at these locations would be likely to exceed the guide value (2mm/s) for heritage places if TBM construction was adopted. Vibration levels of 2-5mm/sec are predicted for a small area above the mainline tunnels on both sides of the more southerly drainage line through the cemetery. Effective mitigation, possibly including other methods of construction, would be required to avoid, or minimise the risk of damage to graves and monuments in these small areas of the cemetery. Prior to commencement of construction, the contractor, in the detailed design phase, would need to undertake detailed predictive modelling to estimate likely vibration levels and satisfy the Qld EPA that either:

(a) the predicted vibration levels would be below the guide values and therefore unlikely to present a risk to this part of the cemetery; or

(b) the mitigation measures proposed would be effective in avoiding or limiting damage to graves and monuments to cosmetic levels, and that such damage would be repaired upon completion of tunnel construction in these locations.

Possible mitigation measures would be developed in consultation with staff at the Toowong Cemetery. They would likely include:

- lower energy construction methods;
- stabilisation of susceptible graves and ornaments;
- repair of any damage to graves and monuments; or
- may involve other methods considered effective.

Through the Y-junctions of the mainline tunnels for the Kelvin Grove connection under the Charlotte Street and Hayward Street area, the tunnels are relatively close to the surface (10-13m). The construction methodology through this section of the tunnels would involve roadheader machinery and not TBMs. Vibration levels generated by roadheaders are significantly lower than those from TBMs and the predicted surface vibration levels in this area are well below goals.

At the eastern end of the mainline tunnels, residences in Normanby Terrace are predicted to experience vibration levels less than 5mm for continuous vibration at residential properties. Some higher vibration levels are expected adjacent to the portals in the ICB corridor at the end of the TBM travel. These would not affect any above ground structures and are remote from any sensitive place.

Regenerated Noise Impacts

Possible regenerated noise impacts and mitigation options along the tunnel alignments are summarised in Table 60, Table 61 and Table 62 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS. Details of the method of assessment of impacts are also outlined in *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS. To quantifying the impacts on residents, the following descriptors were used.

- Very Low – <35dBA.
- Low – 35dBA to 40dBA.
- Moderate – 40dBA to 45dBA.
- High – >45dBA (which corresponds to the potential on-set of sleep disturbance in a residential area).

To address community concerns of potential regenerated-noise impacts in a pro-actively, a range of response management measures would be implemented prior to and/or during construction. The specific management response measures are dependent on the predicted levels of impacts on building occupants and are described in **Table 9-35**.

Table 9-35 Potential Regenerated Noise Impact Response Management Measures

Level of Regenerated Noise	Pre Notification	Monitoring
Very Low	-	-
Low	✓	✓ (depending upon community sensitivity)
Moderate	✓	✓
High	✓	✓

Tunnel blasting can generate regenerated noise, although the primary community concern is vibration. Impacts from blasting operations are therefore usually managed by regulating the vibration emission levels.

The potential regenerated noise levels of rock drills have not been specifically calculated at all receptor locations. Regenerated rock drill noise is usually lower than regenerated noise levels from roadheaders.

Roadheading

Predicted worst-case regenerated noise levels from roadheading exceed the AS2107 guide values at many locations. Sleep disturbance impacts are also likely to result from Northern Link on/off ramp tunnelling due to the shallow tunnel depths. All practicable mitigation measures would be required to minimise these impacts.

Tunnel Boring Machine

Tolerances to noise vary markedly. Some people may be comfortable with much higher noise levels at night than the nominated 45dBA sleep disturbance value, depending on many factors, including how the sleeping areas are currently affected by traffic noise. The predicted extent of impacts of TBM regenerated noise and vibration are similar. Worst-case predictions indicate the likelihood that regenerated noise from the TBM would be noticeable in many buildings above the tunnel alignment. All practicable mitigation measures are required to minimise the impact from these works.

Low Frequency Noise Impacts

The methodology and the results of an assessment of potential low frequency noise impacts from construction activities of the project are provided in *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS.

Infrasound and low frequency noise may result from pumps, compressors, diesel engines, aircraft, shipping, combustion, air turbulence, wind and fans. Regenerated or structure borne noise originating as vibration from tunnelling activities (eg: TBMs and roadheaders) may also be a source of low frequency noise.

Guidance on the assessment of low frequency noise impacts can be sought from the (Queensland EPA) Ecoaccess Guideline *Assessment of Low Frequency Noise*. The intent of these criteria is to accurately assess annoyance and discomfort to persons at noise sensitive places.

The results indicate that for a TBM operating at approximately 10m from a receiver building, the Ecoaccess guideline values for infrasound would be exceeded for dwellings. Roadheader tunnelling is expected to marginally exceed the guideline during works approximately 5m from sensitive receiver buildings including dwellings, classrooms and offices. The required minimum operating distances are 30m for a hard rock TBM and 10m for a roadheader to avoid annoyance.

It should be noted that very limited one-third octave spectral data exists for tunnelling operations in local strata and that the above analysis is based on initial results from CLEM7 measurements. Therefore it is recommended that further analysis be undertaken as additional one-third octave spectral data becomes available prior to finalising a mitigation strategy.

The low frequency noise from a TBM at a depth of 10m would be above the audibility threshold for frequency components 20 Hz to 200 Hz with the dominant components at 25 Hz and 31.5 Hz and roadheader at 5m for frequency components 20 Hz to 200 Hz.

At distances of approximately 800m and 300m (for TBM and roadheader, respectively) or greater, compliance with the audibility threshold would likely be achieved, however, in the presence of extraneous noise sources common in most dwellings (eg: traffic noise, domestic noises etc) low frequency noise audibility would almost certainly be lost at much shorter distances.

The recommended limits applicable to non-tonal low frequency noise would be exceeded by Northern Link tunnelling for all receiver types when operating in close proximity.

At distances of approximately 250m and 100m (for TBM and roadheader, respectively) or greater, compliance with the annoyance threshold ($L_{pA,LF}$ 20 dB) would likely be achieved for dwellings during the evening and night-time period.

The Ecoaccess guideline includes a chapter on potential noise reduction measures which focus primarily on design such as incorporating silencers and enclosures near the source of low frequency noise. However, in the case of tunnelling operations, design modifications to the process itself and/or to the receiver environment are not practicable leaving very little options for mitigation. One option for avoiding annoyance from low frequency noise associated with tunnelling is to temporarily provide alternate accommodation (eg: hotel room) for building occupants when the source is operating within a particular distance from the building.

Mitigation of Vibration and Regenerated Noise from Tunnelling

The following impact management and mitigation strategies are recommended to minimise the impacts of tunnelling vibration and regenerated noise.

- Comprehensive advance notice of intended tunnelling activities in the localities near the tunnel alignment.
- Conduct night-time tunnelling subject to compliance with 'reasonable' night-time vibration and regenerated noise levels.
- 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).
- Conduct pre- and post-blasting Building Condition Surveys in accordance with Brisbane City Council requirements where it is considered there may be potential for cosmetic (superficial) building damage from TBM and drill-and-blast methods.
- The option of temporary relocation of residents.

9.3.6 Construction Traffic

Spoil management proposals and size of the task are detailed in Chapter 4 and also in *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS.

Truck deliveries of materials and machinery would utilise the same site access arrangements as for the spoil removal. These movements would occur during daytime working hours only, except where over-size regulations require transit at other times. Night-time deliveries have not been included as part of this assessment however an activity specific impact assessment should be carried once details are finalised. All employee access to Northern Link worksites is directly from major roads.

Residential Areas along Spoil Routes

Residential areas along spoil routes are summarised in **Table 9-36**.

Table 9-36 Residential Areas along Spoil Routes

Spoil Source	Residential Street Frontages along Route	Destination
Western Freeway (WS1)	Most spoil removed from site via conveyor-some as for Toowong worksite to Swanbank	Mt Coot-tha quarry Swanbank
Toowong (WS2)	Residences south of Western Freeway (eg: Wool Street, Elizabeth Street)	Swanbank
Kelvin Grove (WS3)	Lower Clifton Tce, Normanby Tce and Kingsford Smith Dr	Fisherman Islands
ICB Connection	Normanby Terrace and Kingsford Smith Drive	Fisherman Islands

Noise Impacts

The effect of construction-related heavy vehicle traffic on the noise emission from roadways has been assessed by calculating how the additional truck traffic would alter the L_{A10} (12hour) level of noise emission from roadways using the CoRTN prediction algorithms. This assessment is summarised in Table 71 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS.

The report shows that spoil traffic would not increase average traffic noise levels at any residential sites by more than 0.2dBA. Changes in noise levels of 2dBA or less are considered undetectable to the human ear and therefore negligible. Spoil traffic would not be expected to impact significantly on the noise environment of residential locations.

Mitigation

Recommended mitigation measures include the following.

- 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.

Vibration Impacts

Fully loaded trucks travelling on properly maintained public roadways would not generate significant levels of ground vibration at buildings adjacent to spoil routes.

9.3.7 Construction Noise Monitoring Program

Construction noise and vibration monitoring would assist in planning of excavation and construction works, especially where work activities are less than 100m from residences or other noise sensitive receivers.

Pre-condition surveys would be conducted for buildings and historical sites (eg: Toowong Cemetery) in vibration-sensitive zones. Construction noise and vibration levels would be monitored throughout construction to verify compliance with design goals. Monitoring would be undertaken where predictions indicate exceedance of design noise goals and vibration criteria. Supplementary monitoring may also be conducted to identify issues of concern in response to any complaints.

Weekly inspections would be undertaken throughout construction by Site Environment Officers, Site Supervisor and Project Engineers to ensure that appropriate noise and vibration controls are implemented and are effective. Any issues identified during the weekly inspections would be documented in regular (typically monthly) monitoring reports.

The monitoring program would be refined closer to the commencement of construction as part of the detailed design.

Table 9-37 outlines a construction monitoring program which is recommended as a minimum for Northern Link. The noise monitoring equipment should be calibrated in accordance with the manufacturer's guidelines and meet AS1055 requirements for environmental monitoring.

Table 9-37 Construction Noise Monitoring Recommendations

Monitoring	Schedule	Locations	Procedures and Instrumentation
Operator Attended Noise Monitoring - Worksites and Road Surface Works	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, day and night tunnelling). - Road surfacing	Attended measurements to quantify and qualify construction noise emissions using a calibrated sound level meter capable of measuring LA90, LAeq, LA10 and LA1 statistical noise levels in 15 minute intervals. One 15 minute sample per survey location is generally sufficient. Extraneous noise (eg cars, trains etc) should be excluded from the measurements. Sources contributing to the noise levels are to be noted.
Unattended Noise Monitoring - Worksites	On a continuous basis or as required. Regular (typically weekly or fortnightly) data downloads would be required.	Continuous noise logging at the nearest noise sensitive receiver adjacent to work-sites considering extraneous noise sources such as major roads..	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 plant noise audits would enhance the input data to the predictive modelling. Equipment significantly exceeding plant noise levels used in the predictive modelling should be inspected to identify noise control measures. Where noise control is 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 works and each 12 months.
Regenerated Noise Monitoring	At commencement of driven tunnelling works at each tunnel face.	10 receivers per working face of short-term 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.

9.3.8 Construction Vibration Monitoring Program

Vibration monitoring recommendations for Northern Link are summarised in **Table 9-38**.

Table 9-38 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 Toowong connection tunnels - 2 x Kelvin Grove connection tunnels At the nearest receiver to the cutting face where predictions indicate exceedances. As appropriate to address the particular complaint.	Operator attended measurements using a calibrated instrument capable of measuring peak particle velocity in 3 axes (ie vertical, longitudinal and transverse). The results of the vibration monitoring would enhance the input 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 a heritage listed structure if close to blasting	Measurements using a calibrated instrument capable of measuring peak particle velocity in 3 axes (ie vertical, longitudinal and transverse) and blast overpressure. The results of the blast monitoring would enhance the input data fed into the predictive modelling process.
Buffer Distance Tests for: - Worksite activities - Surface road works	-At the commencement of all vibration intensive activities associated with each worksite and surface road 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.

9.4 Operational Phase Noise Assessment Criteria

9.4.1 Traffic Noise

Traffic noise criteria are contained in Queensland's Environmental Protection (Noise) Policy 1997 [EPP(Noise)] and the Main Roads Road Traffic Noise Management: Code of Practice (January 2000).

Environmental Protection (Noise) Policy 1997

For noise from activities described as 'beneficial assets' (particularly roads, railways and airports), the EPP Noise specifies 'planning levels' which may be used as a guide 'in assessing reasonable noise levels from an activity'.

The planning levels for a public road (measured 1m in front of the most exposed facade of a noise sensitive building) are as follows:

- for a State controlled road - 68dBA L_{A10} (18hour);

- for another public road - 63dBA L_{A10} (18hour);
- the highest 1 hour equivalent continuous A-weighted sound pressure level between 10.00pm and 6.00am - 60dBA LAeq (1hour); and
- a single event maximum sound pressure level - 80dBA LAmax.

Traffic Noise Management: Code of Practice

The Department of Main Roads' *Road Traffic Noise Management: Code of Practice*, provides a number of criteria for assessment of traffic noise.

For *existing residential sites* adjacent to *Upgraded Existing Roads*, the Code of Practice noise objective is 68dBA L_{A10} (18hour) within a 10 year post-construction period.

For *Education and Health Buildings* adjacent to *Upgraded Existing Roads*, the Code of Practice internal noise objective is 55dBA L_{A10} (1hour) within a 10 year post-construction period. The EPP[Noise] does not make any distinction between residences and educational or healthcare facilities - the planning level is 63dBA L_{A10} (18hour). Consistent with the ToR, guidance for the assessment of educational and health care facilities was sought from Main Roads' Code of Practice, where noise mitigation for an 'Upgraded Existing Road' is considered on a case-by-case basis for properties where the L_{A10} (1hour) level is greater than 55dBA (internal) and the increase is 3dBA or more above the pre-construction level.

The 55dBA L_{A10} (1hour) noise level (internal) for the worst hour is essentially equivalent to the 63dBA L_{A10} (18hour) external noise goal nominated in the EPP[Noise] as explained in *Technical Report No. 9B - Operational Noise and Vibration in Volume* 3 of the EIS. Therefore, for simplicity, educational and health care facilities have been assessed against the 63dBA L_{A10} (18hour) external noise goal, as for residences adjacent non-stated controlled roads.

It would be important that during the detailed design phase of this project, specific internal L_{A10} (1hour) (worst hour) noise level predictions be undertaken based on actual building facade noise reductions and internal noise monitoring in the most exposed rooms/spaces used for educational and health care purposes within each facility.

Tunnel Ventilation Plant Noise Criteria

The applicable statutory requirement for noise emissions associated with fixed mechanical plant (such as the tunnel ventilation plant) is the Queensland Environmental Protection (Noise) Policy 1997. The EPP (Noise) nominates qualitative characteristics of the noise environment that are to be protected, but does not specify any numerical limits that are applicable to stationary mechanical plant.

In general continuous noise sources, like ventilation plant noise, 'background creep' would tend to be the controlling issue in the setting of noise goals. Brisbane City Council's Noise Impact Assessment Planning Scheme Policy (NIAPSP) aims to control 'background creep' by recommending that "outside noise levels must not exceed the levels detailed in the table below:"

Noise area category Appendix A AS1055.2[(a)]	Permissable level of exceedance of $L_{A90,T}$ for the appropriate time of day		
	Where there is residential development	Where there is no residential development	Where background levels already exceed stated levels in AS1055.2 (i.e. without the proposed development
R1	by 5dB(A)	N/A	The development's noise contribution must still comply with the stated levels in *AS1055.2*
R2	by 5dB(A)	N/A	
R3	by 0dB(A)	by 10dB(A)	
R4			
R5			
R6			

(a) Refer to Appendix A in AS1055.2 for $L_{A90,T}$ levels for the noise area categories

Source: Brisbane City Council, Noise Impact Assessment Planning Scheme Policy (NIAPSP).

Table Note: Where practicable, measured existing background noise levels are to be used for assessments purposes in place of the stated background noise levels in AS1055.2. The stated levels in AS1055.2 have not been reproduced in this report.

The traditional license conditions used by the EPA throughout Queensland, which are in general less stringent than the NIAPSP criteria, are summarised in **Table 9-39**.

- **Table 9-39 Traditional EPA License Requirements for Stationary Plant**

Time Period	Level at Receptor Location - LAmax,adj,T	
	Residential	Commercial
Day (7am to 6pm) Mon to Sat 8am to 6pm Sun. and Public Hols.	Background + 5dBA	Background + 10dBA
Evening (6am to 10pm)	Background + 5dBA	Background + 10dBA
Night (10pm to 7am/8am)	Background + 3dBA	Background + 8dBA

Noise from large ventilation fans can be tonal. It is common practice in Queensland (as evidenced by the abbreviated adjustment term 'adj' in the above EPA conditions) and throughout Australia to penalise noise emissions containing 'detectable' tonal characteristics (eg: whine, hiss, screech, hum, etc). Adjustments consistent with the corrections for tonality described in Clause 6.6 of AS1055.1 *Acoustics - Description and measurement of environmental noise Part 1: General procedures (1997)* should be applied.

The NIAPSP requirements for the avoidance of 'background creep' are recommended for use on this project on the basis that these limits avoid significant perceptible noise impacts and are consistent with traditional EPA licensing practice. The AS1055 corrections for tonality and impulsiveness would be applied, where necessary.

Regenerated noise

Vibration generated by heavy vehicles on a roadway 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 is situated directly beneath a building. The 'satisfactory' noise levels listed in AS/NZS 2107[10] are recommended as guidance for the purpose of assessing regenerated noise levels within buildings during the operational phase of the project. An extract from AS/NZ 2107, for some common areas is presented in **Table 9-7.**

10 Australian/New Zealand Standard 2107:2000 Acoustics – Recommended design sound levels and reverberation times for building interiors.

9.4.2 Sensitive Community Sites

Apart from residential dwellings in the Northern Link study corridor, 20 noise/vibration sensitive locations in the aged care, child care, place of worship, educational, heritage and commercial categories are considered in assessing potential for impacts arising from airborne or regenerated noise and vibration. Relevant properties have been identified from a variety of sources including the social infrastructure study plans, general project information, site visits and a review of the latest UBD. The list of these properties is provided in *Technical Report No. 9A - Operational Noise and Vibration in Volume 3* of the EIS. Some of these properties are included, even though they are some distance from the actual works. Other places not specifically identified, such as community facilities, would be treated in the same manner as the surrounding residential properties.

9.5 Operational Impacts and Mitigation Measures

Modelling Methodology

The CoRTN (Calculation of Road Traffic Noise) 1988 traffic noise prediction procedure was utilised within the SoundPLAN noise prediction software to calculate the traffic noise emissions. SoundPLAN compiles a 3D ground map containing ground contours, the final 3D road design and building locations, traffic volumes, heavy vehicle composition and speed, road pavement characteristics and noise barriers. CoRTN is a recommended road prediction technique in Main Roads' Code of Practice and has been the primary validated road traffic noise model used in Australia for many years.

Noise Emissions from Portals

Traffic noise from portal openings was modelled as in S. Olafsen's paper '*Noise from Road Tunnel Openings – An Engineering Approach*'. The propagation of the portal noise emissions has been modelled using the Concawe industrial noise model within the SoundPLAN modelling suite. Noise predictions from this model are added logarithmically to the standard CoRTN predictions to give noise levels for the portals + roadways.

Traffic Noise Composition

The model assumes static vehicle fleet noise to 2026. On higher speed roads, where tyre noise is a large component of overall vehicle noise, this may be a reasonable assumption. However on roads with sign-posted speeds of 60km/hr, engine and transmission noise is greater. On these roads, engine and transmission noise would reduce as the fleet modernises. Thus the assumption of static fleet noise emissions is conservative.

Assessment Parameter

The EPP[Noise] Planning Levels are expressed in terms of the L_{A10} (18hour), maximum night-time LAeq (1hour) and the LAmax measurement parameters.

The assessment undertaken in this report is presented in terms of the L_{A10} (18hour) parameter only and the explanation for this choice is provided in *Technical Report No. 9B - Operational Noise and Vibration in Volume 3* of the EIS.

Model Scenarios

The EPP[Noise] identifies Planning Levels for traffic noise emissions from roadways without specifying necessary actions should noise levels from road developments exceed Planning Levels.

Modelling has been undertaken for predicted levels of road traffic noise with and without Northern Link proceeding. The following situations have been modelled in accordance with the ToR:

- do minimum (2014) - includes all future traffic utilising the existing road corridor in the proposed year of opening (ie: 2014), excluding Northern Link, for example, future traffic that would have arisen in the absence of Northern Link. It represents the baseline noise projections for comparison of other scenarios;
- with Northern Link (2014) - Traffic flows including Northern Link in the proposed year of opening (ie: 2014). This scenario represents the change in traffic noise, attributable directly to Northern Link;
- do minimum (2026) - The predictions include all future traffic utilising the existing road corridor in the design year (ie: 2026), excluding Northern Link. This represents future traffic that would have arisen in the absence of transport initiatives, and is the baseline noise projections for comparison of other scenarios; and
- with Northern Link (2026) - Traffic flows including Northern Link in the design year (ie: 2026). This scenario represents the change in traffic noise, attributable directly to Northern Link. Noise barrier design has been undertaken for this scenario.

In addition to the modelling scenarios described above, a model was developed to simulate the existing 2007 traffic flows and existing road network for verification of the noise prediction model.

Model Verification

Table 9-40 compares measured L_{A10} (18hour) noise levels against predicted noise levels from the SoundPLAN model. No road surface correction is applied, as all existing road surfaces are dense graded asphalt.

- **Table 9-40 Comparison of Measured and Predicted Noise Levels in 2007**

Location	Dominant Source of Traffic Noise	L_{A10} (18hour) Noise Level (dBA)		
		Measured	Predicted	Difference
22 Crag Road, Taringa	Western Freeway	59	59	0
115 Elizabeth Street, Toowong	Western Freeway	52	54	+2
6 Wool Street, Toowong	Western Fwy, Miskin Street	54	55	+1
128 Sylvan Road, Toowong	Milton Road and Sylvan Rd	66	67	+1
29 Valentine Street, Toowong	Frederick Street	59	61	+2
69 Frederick Street, Toowong	Frederick Street	73	75	+2
9 Victoria Crescent, Toowong	Frederick Street	55	55	0
5 Clyde Street, Brisbane City	Musgrave Rd and Hale St	61	63	+2
26 Lower Clifton Tce, Red Hill	Kelvin Grove Rd and ICB	67 [1]	69	+2
7 Westbury Street, Red Hill	Kelvin Grove Road	62	61	-1
INB, Normanby Station	ICB and Ithaca Street	66	68	+2
43 Normanby Tce, Kelvin Grove	ICB	59	59	0
9 Horrocks Street, Toowong	Western Fwy, Mt Coot-tha Rd	59	61	+2
QUT, Kelvin Grove Campus	ICB and Victoria Park Rd	55	57	+2

Table Note: Measured value adjusted to compensate for reduced facade effect at time of measurement.

Differences between measured and predicted levels of ± 2dBA are considered readily acceptable for the purpose of model verification. All the predicted L_{A10} (18hour) noise levels for locations directly adjacent existing roads are within 2dBA of the measured results therefore the model is considered to be verified.

Barrier Design

Where required, the heights of roadside barriers have been determined to achieve the appropriate criterion. A cap on the height of any barrier is set to 8m, due to consideration of 'practicality and feasibility' of construction, aesthetics and other urban design issues such as overshadowing.

Two noise barrier designs have been undertaken for Northern Link as optional scenarios.

- The 'status quo' barrier option for the design year (2026) indicates road-side noise barriers, where practical and feasible, to achieve traffic noise levels comparable to the 'Do Minimum' option (ie to maintain noise levels that are predicted to occur if the tunnel is not built but traffic increases as projected).
- The 'planning level' barrier option for the design year (2026) indicates road-side noise barriers, where practical and feasible, to limit traffic noise levels to the 63dBA (non state-controlled roads) or 68dBA (state-controlled roads) L_{A10} (18hour) planning levels wherever possible.

The latter option illustrates the scale of noise controls to achieve the 'planning' noise levels in accordance with the EPP[Noise] and Code of Practice. In many areas this would require noise controls to account for existing exceedances of the planning levels and/or gradual increases in traffic noise over time, neither of which are attributable to the tunnel project itself.

Modelling Output

All the various colour noise contour plots (for all the modelling scenarios outlined above) along with the details of where the monitoring is located and other assumptions of the modelling are presented in *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS.

9.5.1 Results – Western Portal Areas

The planning level for traffic noise in the vicinity of the Western Freeway and along Frederick Street or Mt Coot-tha Road (between the Western Freeway and Frederick Street) is 68dBA L_{A10} (18hour) and for all other residential locations the planning level is 63dBA L_{A10} (18hour). The noise contour plots for this area have been generated 4.5m above ground level, which is generally representative of residences in the area. All the plots are presented in *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS.

2014 'Do Minimum' Results

Appendix H1 of *Technical Report No. 9 - Noise and Vibration in Volume* 3 of this EIS presents the noise contours for 2014, assuming no Northern Link project, (ie: the 'Do Minimum' option).

South of the Western Freeway and west of Miskin Street - All dwellings in the vicinity of the Western Freeway comply with the 68dBA goal. Residences on Miskin Street, facing the bus depot, are predicted to experience noise levels of up to 75dBA which exceeds the 63dBA criterion for local roads.

Residences along Frederick Street are predicted to experience noise levels up to around 76dBA (above 68dBA). Residences located north of Milton Road and away from Frederick Street may experience noise levels up to 75dBA (above 63dBA).

Most dwellings between Miskin Street and Sylvan Road may experience levels up to 68dBA (above 63dBA).

All dwellings along Milton Road (east of Croydon Street) are predicted to exceed the 63dBA criterion, some by up to 18dBA.

Dwellings along Croydon Street are predicted to exceed the 63dBA criterion by up to 13dBA.

2014 'With Northern Link' Results

No Mitigation Measures

Appendix H2 of *Technical Report No. 9 - Operational Noise and Vibration in Volume 3* of this EIS presents the noise contours for 2014, without any mitigation and assuming construction of Northern Link.

South of the Western Freeway and west of Miskin Street - all dwellings in the vicinity of the Western Freeway comply with the 68dBA criterion. Residences along Miskin Street, facing the bus depot, are predicted to experience noise levels of up to 73dBA (63dBA).

East of Frederick Street and north of Milton Road - along Frederick Street noise levels at residences are predicted to be up to 76dBA (68dBA). Residences located north of Milton Road and away from Frederick Street may experience noise levels up to 73dBA (ie above 63dBA).

East of Miskin Street and south of Milton Road – most dwellings in the vicinity of Milton Road and Sylvan Road are predicted to exceed the 63dBA criterion by up to 5dBA.

Along Milton Road and east of Croydon Street – all dwellings along Milton Road (east of Croydon Street) are predicted to exceed the 63dBA criterion by up to 15dBA.

Croydon Street - dwellings on Croydon Street may exceed the 63dBA criterion by up to 14dBA.

Based on these findings there is a general reduction in 2014 noise levels with the project by around 2dBA. Logically, as the tunnel removes traffic from the surface roads, dwellings in this area that are away from the immediate portal would be expected to receive a benefit.

With Barriers Designed to Achieve 2026 'Status Quo' Noise Levels in 2026

Appendix H3 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of this EIS presents the noise contours for 2014, with the noise barriers designed to maintain the 'status quo' in the design year (2026).

South of the Western Freeway and west of Miskin Street - all residences south of the Western Freeway and west of Miskin Street are predicted to comply with the 'Status Quo' noise goal.

East of Frederick Street and north of Milton Road - residences along Frederick Street as well as those remote from Frederick Street are predicted to comply with the 'Status Quo' noise goal with the 2026 'Status Quo' noise barriers in place.

South of Milton Road between Miskin and Croydon Streets – all dwellings in this area are predicted to comply with the 'Status Quo' noise goals with the 'Status Quo' noise barriers in place.

Along Milton Road east of Croydon Street – most dwellings in this area are predicted to comply with the 'Status Quo' noise goals. However, one residence on the southern side of Milton Road is predicted to exceed the 'Status Quo' noise goal by 3dBA due to (1) resumptions resulting in increased exposure and (2) traffic lanes moving closer to the property. Noise barriers are not a feasible attenuation treatment for this residence due to property access requirements.

Croydon Street - most dwellings along Croydon Street are predicted to exceed the 'Status Quo' noise goal with the 'Status Quo' noise barriers in place by 2dBA. Two residences on St Osyth Street are predicted to exceed the

'Status Quo' noise goal by up to 2dBA. No additional noise attenuation is achievable from the noise barriers at these locations due to property access requirements.

With Barriers Designed to Achieve 63/68dBA $L_{A10\ (18hour)}$ planning level in 2026

Appendix H4 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of this EIS presents the noise contours for 2014, with the noise barriers designed to maintain the planning noise levels in the design year (2026).

South of the Western Freeway and west of Miskin Street - all dwellings in the vicinity of the Western Freeway comply with the 68dBA criterion. Residences along Miskin Street, facing the bus depot, are predicted to exceed the 63dBA criterion by up to 12dBA. Noise barriers are not a feasible attenuation treatment for these residences due to property access requirements.

East of Frederick Street and north of Milton Road - dwellings along Frederick Street are predicted to exceed the 68dBA criterion by up to 8dBA. Noise barriers are not a feasible attenuation treatment for these residences due to property access requirements. Residences north of Milton Road and away from Frederick Street, are predicted to exceed the 63dBA criterion by up to 7dBA with the 'Planning Level' noise barriers capped at 8m. All residences in this area achieve the 'Status Quo' noise goal with the designed 'Planning Level' noise barriers.

South of Milton Road between Miskin and Croydon Streets – several dwellings in this area are predicted to exceed the 63dBA criterion by up to 4dBA with the 'Planning Level' noise barriers capped at 8m. All residences in this area are able to achieve the 'Status Quo' noise goal with the 'Planning Level' noise barriers.

Along Milton Road, east of Croydon Street – dwellings along Milton Road are predicted to exceed the 63dBA criterion by up to 15dBA. Noise barriers are not a feasible attenuation treatment for these residences due to property access requirements. All but one of these residences achieve the 'Status Quo' noise goal.

Croydon Street - most dwellings along Croydon Street are predicted to exceed the 63dBA criterion by up to 14dBA. Noise barriers are not a feasible attenuation treatment due to property access requirements. All residences are with 2dBA of the 'Status Quo' noise goals with the 'Planning Level' noise barriers in place.

Along Frederick Street where the 68dBA $L_{A10\ (18hour)}$ criterion cannot be achieved, property treatments or other measures would be required in accordance with Main Roads' Code of Practice.

2026 'Do Minimum' Results

Appendix H5 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS presents the noise contours for 2026, assuming no Northern Link, which is referred to as the 'Do Minimum' option.

The 'Do Minimum' for 2026 appears to be generally within 1 to 2dBA of the 2014 'Do Minimum' predictions that are presented in Appendix H1 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS. Given the difference between these two scenarios is the natural increase in traffic over 12 years, unrelated to Northern Link, it would be expected that the two sets of results are very similar.

2026 'With Northern Link' Results

No Mitigation Measures

Appendix H6 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS presents the noise contours for 2026, without any mitigation, assuming Northern Link has been constructed.

Similar to the 'Do Minimum' scenario, the road traffic noise emissions predicted from this scenario are very similar to the results in Appendix H2 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS.

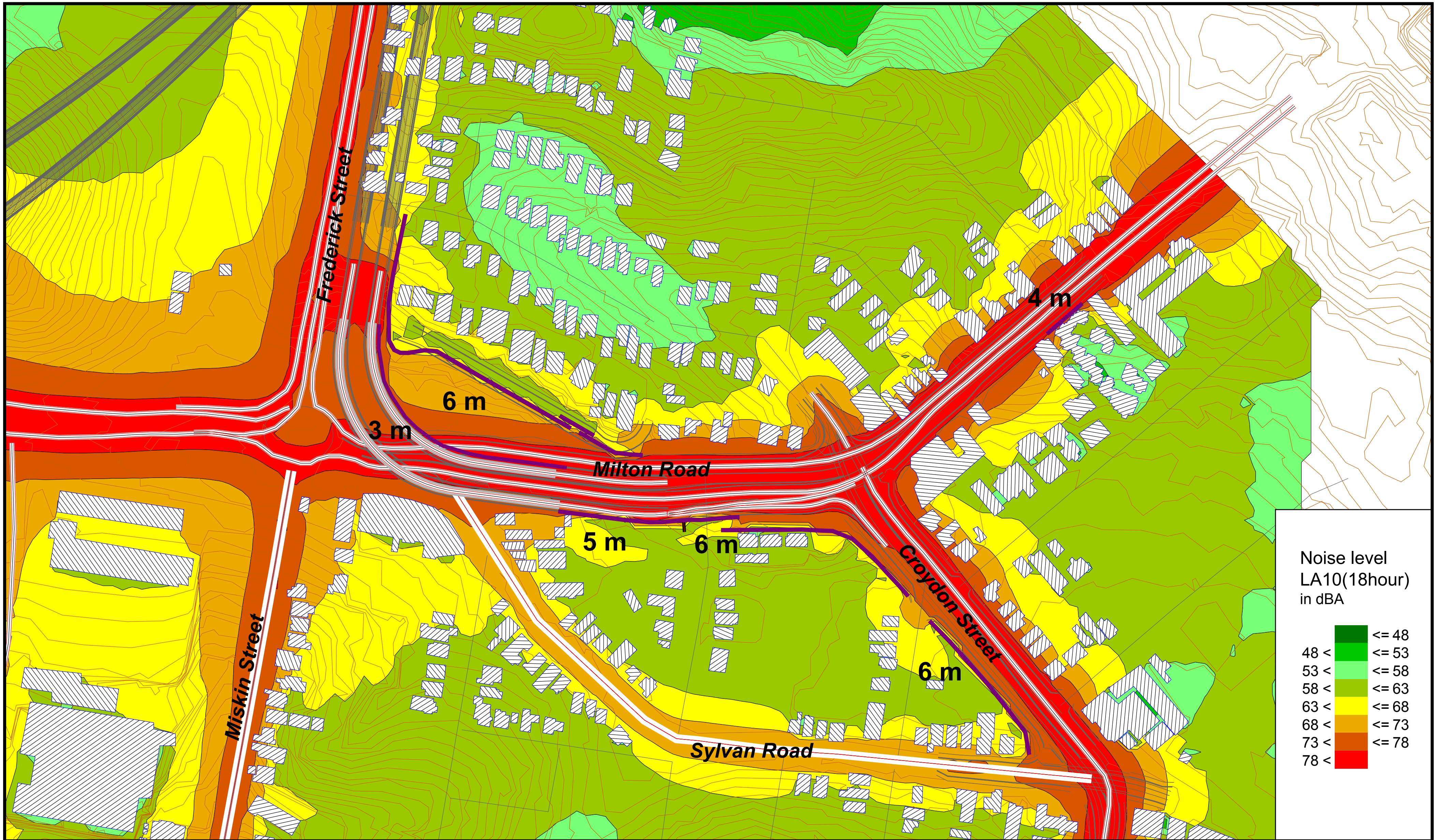
Based on these findings there is a general reduction in 2026 noise levels with the project by around 2dBA. Logically, as the tunnel removes traffic from the surface roads, dwellings in this area that are away from the immediate portal would be expected to receive a benefit from the project.

With Barriers Designed to Maintain 2026 'Status Quo' Noise Levels

The barriers required to maintain the 'status quo' noise levels (ie: to have an acoustic environment, no worse than would occur due to natural network increases) are presented in Appendix H7 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS. The noise barriers necessary to maintain the 'status quo' in the western portals area are shown in **Figure 9-3**.

South of the Western Freeway and west of Miskin Street - all residences in this area are predicted to comply with the 'Status Quo' noise goal.

East of Frederick Street and north of Milton Road – residences along Frederick Street and remote from Frederick Street are predicted to comply with the 'Status Quo' noise goal with the 'Planning Level' noise barriers.



Key
- Road Traffic
- Elevation line
- Building
- Noise Barrier
- Central Reservation

Y2026 "Status Quo Noise Barriers" Toowong Area

Scale 1:4000

0 20 40 80 120 160 m

N

Figure 9-3

Northern Link

SKM Connell Wagner

JOINT VENTURE

East of Miskin Street and south of Milton Road – south of Milton Road, between Miskin Street and Croydon Street, dwellings are predicted to comply with the 'Status Quo' noise goals with the 'Planning Level' noise barriers in place.

Along Milton Road and east of Croydon Street – most dwellings along Milton Road (east of Croydon Street) are predicted to comply with the 'Status Quo' noise goals. However, one residence on the southern side of Milton Road is predicted to exceed the 'Status Quo' noise goal by 3dBA due to increased traffic volumes on Milton Road. Noise barriers are not a feasible attenuation for this residence due to property access requirements.

Croydon Street - most dwellings on Croydon Street are predicted to exceed the 'Status Quo' noise goal with the 'Status Quo' noise barriers by 2dBA. Two residences on St Osyth Street are predicted to exceed the 'Status Quo' noise goal by up to 2dBA. No additional noise attenuation is achievable from the noise barriers at these locations due to property access requirements.

Changes in noise levels of 2dBA or less are generally considered insignificant in acoustic terms. This design incorporates a total of 823 linear meters or 4767m^2 of barrier to maintain the status quo at residential properties.

With Barriers Designed to Achieve 63/68dBA L_{A10} (18hour) Design Objective in 2026

Appendix H8 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS presents the noise contours for 2026 incorporating the noise barriers required to achieve the relevant 63/68dBA L_{A10} (18hour) planning level. The noise barriers to maintain planning levels in the western area are shown in **Figure 9-4**.

South of the Western Freeway and west of Miskin Street - all dwellings in the vicinity of the Western Freeway comply with the 68dBA criterion. Residences along Miskin Street are predicted to exceed the 63dBA criterion by up to 10dBA. Noise barriers are not a feasible attenuation treatment for these residences due to property access requirements.

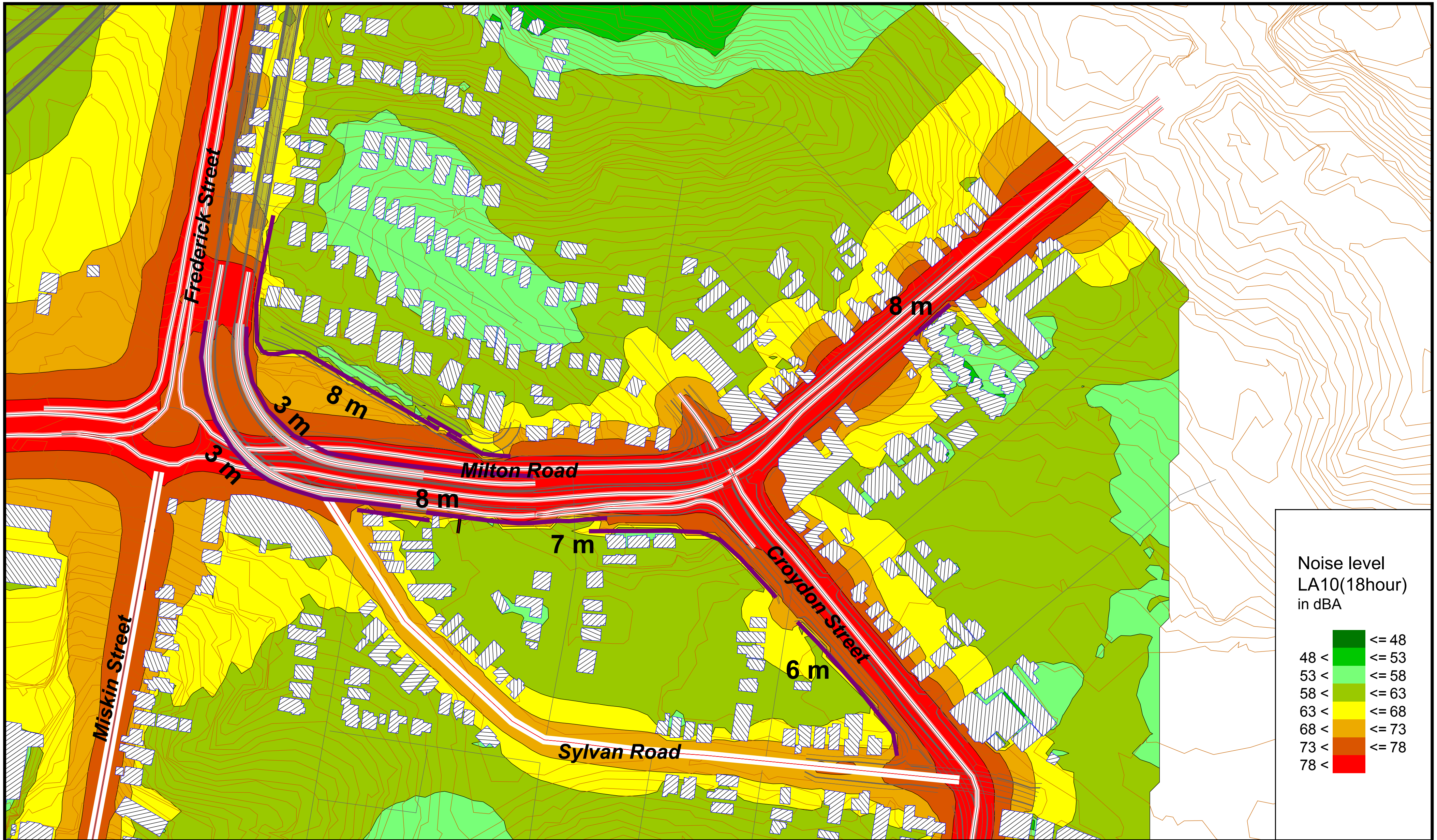
East of Frederick Street and north of Milton Road - dwellings along Frederick Street are predicted to exceed the 68dBA criterion by up to 12dBA. Noise barriers are not a feasible attenuation treatment for these residences due to property access requirements. Residences north of Milton Road and remote from Frederick Street, are predicted to exceed the 63dBA criterion by up to 7dBA with the designed barriers capped at 8m. All residences in this area achieve the 'Status Quo' noise goal with the 'Status Quo' noise barriers in place.

East of Miskin Street and south of Milton Road – several dwellings in this area are predicted to exceed the 63dBA criterion by up to 4dBA with the designed noise barriers capped at 8m, and a 3m (above pavement height) high barrier on the southern side of the north-bound elevated on-ramp. All residences in this area are able to achieve the 'Status Quo' noise goal with the 'Status Quo' noise barriers in place.

Along Milton Road and east of Croydon Street – along Milton Road (east of Croydon Street) residential noise levels could exceed 63dBA criterion by up to 16dBA. Noise barriers are not a feasible attenuation treatment due to access requirements. All but one of these residences is able to achieve the 'Status Quo' noise goal.

Croydon Street - most dwellings on Croydon Street are predicted to exceed 63dBA by up to 14dBA. Noise barriers are not a feasible attenuation treatment for these residences due to property access requirements.

This design incorporates 879m (or 6772m^2) of barrier to achieve the 63dBA design target at most residential properties. Along Frederick Street the 68dBA L_{A10} (18hour) criterion cannot be achieved with noise barriers. Property treatments would be required in accordance with Main Roads' Code of Practice.



Key
- Building
- Road Traffic
- Elevation line
- Noise Barrier
- Central Reservation

Y2026 "Planning Level Noise Barriers" Toowong Area

Scale 1:4000

0 20 40 80 120 160 m

N

Figure 9-4

Northern Link

SKM Connell Wagner JOINT VENTURE

9.5.2 Results - Eastern Portal Areas

The appropriate planning level for traffic noise in vicinity of Kelvin Grove Road and the ICB is 63dBA L_{A10} (18hour) for all residential locations. Noise contours produced for these areas are contained in Appendix I of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS. The noise levels have been generated 4.5m above ground level which height is generally representative of two-storey residences in the area.

2014 'Do Minimum' Results

Appendix I1 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS presents the noise contours for 2014, assuming no Northern Link (ie: the 'Do Minimum' option). Existing noise barriers on the northern side of the ICB are incorporated into the 'Do Minimum' model.

West of Kelvin Grove Road – dwellings south of the portals are predicted to experience noise levels up to 72dBA (planning level = 63dBA) and those north of the portals may experience 76dBA.

In the vicinity of Normanby Terrace, north of the ICB – the dwellings north of the ICB are predicted to experience noise levels up to 70dBA (63dBA goal).

The proposed child care centre on Lot 5 of the Kelvin Grove Urban Village is predicted to experience a noise level of 78dBA, which exceeds the 63dBA goal.

Gregory Terrace – dwellings on the southern side of Gregory Terrace could experience noise levels up to 77dBA (including traffic on Gregory Terrace) and up to 66dBA for ICB traffic only.

Predicted 'Do Minimum' noise levels for Brisbane Grammar School properties along the ICB include:

- the Brisbane Boys' Grammar School Buildings and the Brisbane Girls' Grammar School buildings are predicted to experience noise levels up to 69dBA (planning level of 63dBA L_{A10} (18 hour));
- on the Brisbane Grammar School sports oval south of the rail line, approximately the southern half is below Main Roads' Code of Practice planning level, 63dBA L_{A10} (12 hour), for outside education levels. This is considered acceptable;
- for the Brisbane Grammar School oval north of the ICB (west of the Inner Northern Busway), most of the oval exceeds the planning level with 10-20% of the oval (closest to the tennis courts) under this level. All of the tennis courts are below this planning level and are considered acceptable; and
- the Brisbane Grammar School Indoor Sports Complex could experience up to 75dBA noise levels. This is above the planning level by 12dBA.

2014 'With Northern Link' Results

No Mitigation Measures (2014)

Appendix I2 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS presents the noise contours for 2014, assuming Northern Link has been constructed, with all retained existing noise barriers in place but without any additional mitigation.

Dwellings on the western side of Kelvin Grove Road and south of the tunnel portal area are predicted to experience noise levels up to 72dBA.

Dwellings west of Kelvin Grove Road and north of the tunnel portal area are predicted to experience noise levels up to 77dBA.

Dwellings north of the ICB in the vicinity of Normanby Terrace are predicted to experience noise levels up to 74dBA.

The proposed child care centre on Lot 5 of the Kelvin Grove Urban Village is predicted to experience a noise level of 78dBA.

Dwellings along the southern side of Gregory Terrace are predicted to experience noise levels up to 76dBA for all traffic (including traffic on Gregory Terrace itself) and up to 65dBA for Northern Link and ICB traffic only.

Brisbane Boys' Grammar School and Brisbane Girls' Grammar School buildings are predicted to experience noise levels up to 69 and 71dBA, respectively.

Of the Brisbane Boys' Grammar Oval south of rail line approximately the southern half is below Main Roads' Code of Practice 63dBA L_{A10} (12 hour) planning level for outside education levels

Of the playing fields north of the ICB (west of the Inner Northern Busway), only 10-20% (closest to the tennis courts) are predicted to be below the planning level. All of the tennis courts are below the planning level.

Without mitigation the Brisbane Grammar School Indoor Sports Complex is predicted to experience noise levels of 77dBA.

With Barriers to Maintain 2026 'Status Quo' Noise Levels

Appendix I3 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS presents the noise contours for 2014, with the noise barriers designed to maintain the 'status quo' in the design year, 2026.

All dwellings west of Kelvin Grove Road south of the tunnel portal area are predicted to comply with the 'Status Quo' noise goal.

Most dwellings west of Kelvin Grove Road and north of the tunnel portal area are predicted to comply with the 'Status Quo' goal with the design noise barriers. However, one residence on Dalley Street is predicted to exceed the 'Status Quo' noise goal by 1dBA with the designed barriers. This is considered an insignificant increase in noise level.

All dwellings north of the ICB in the vicinity of Normanby Terrace and the proposed child care centre are predicted to comply with the 'Status Quo' goal.

All dwellings along the southern side of Gregory Terrace are predicted to comply with the 'Status Quo' goal.

Noise levels at all school properties along the ICB are predicted to comply with 'Status Quo' noise goals.

With Barriers Designed to Achieve 63dBA L_{A10} (18hour) Design Objective in 2026

Appendix I4 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS presents the noise contours for 2014, with the noise barriers designed to maintain the planning noise levels in 2026.

With 8m high noise walls several dwellings west of Kelvin Grove Road and south of the tunnel portal are predicted to experience up to 67dBA (63dBA criterion) which is below the 'Status Quo' noise level.

Most residences west of Kelvin Grove Road and north of the tunnel portal are predicted to comply with the 63dBA criterion with the designed 8m noise barriers. One residence on Kelvin Grove Road and one on Dalley

Street are predicted to exceed the 63dBA criterion by up to 10dBA with the designed barriers. The residence on Kelvin Grove Road does not exceed the 'Status Quo' noise goal.

In the vicinity of Normanby Terrace, north of the ICB several dwellings would experience up to 67dBA with the designed noise barriers which level is below the 'Status Quo' noise level.

The proposed child care centre on Lot 5 of the Kelvin Grove Urban Village is predicted to experience a noise level of 63dBA.

Dwellings along Gregory Terrace are predicted to comply with the 63dBA goal for ICB and Northern Link traffic only but would experience noise levels up to 76dBA for all traffic (ie with Gregory Terrace traffic).

Brisbane Boys' Grammar School buildings are predicted to experience noise levels up to 66dBA with a (capped) 8m high barrier running along the southern edge of the Inner City Bypass.

Brisbane Girls' Grammar School buildings are predicted to comply with the noise goal with an 8m high barrier.

The Brisbane Grammar School sports oval south of the rail line is below the noise goal with an 8m high noise barrier. Of the oval north of the ICB (west of the Inner Northern Busway), most exceeds the 63dBA L_{A10} (12 hour) with 10-20% (closest to the tennis courts) under this level. All of the tennis courts are below this planning level and are considered acceptable.

Noise levels at the Brisbane Grammar School Indoor Sports Complex are predicted to be up to 65dBA.

2026 'Do Minimum' Results

Appendix I5 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS presents the noise contours for 2026, assuming no Northern Link.

The 2026 'Do Minimum' levels are generally within 1-2dBA of the 2014 'Do Minimum' predictions and reflect the natural increase in traffic over 12 years, unrelated to Northern Link.

2026 'With Northern Link' Results

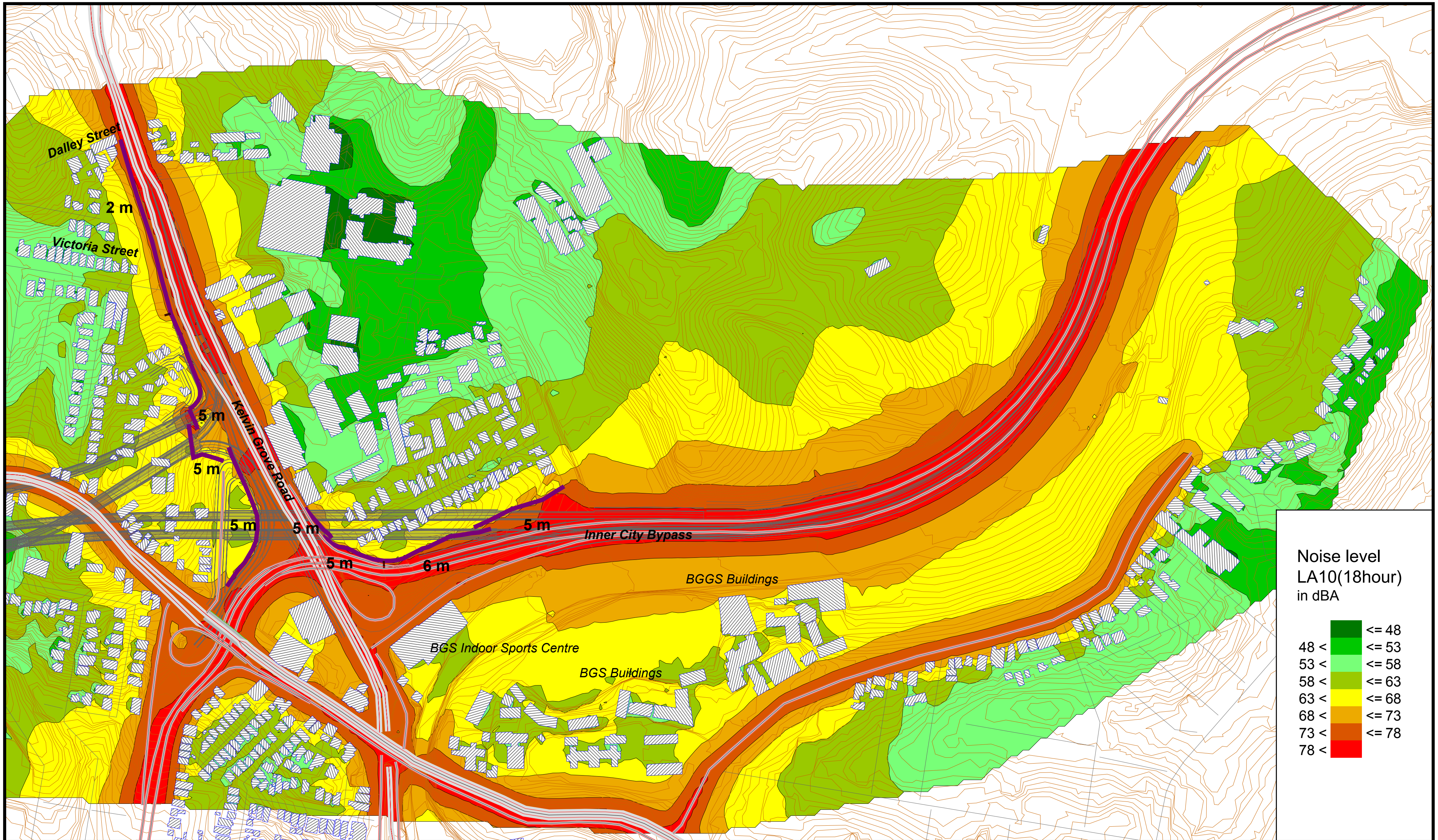
No Mitigation Measures

Comparison of Appendices I2 and I6 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS presenting the noise contours for 2014 and 2026, respectively, assuming Northern Link has been constructed, with all retained existing noise barriers in place but without any additional mitigation are very similar.

With Barriers Designed to Maintain 2026 'Status Quo' Noise Levels

The noise barriers required to maintain the 'status quo' noise levels (ie: to have an acoustic environment, no worse than would have otherwise occurred due to natural network increases) are presented in Appendix I7 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS. The noise barriers necessary to maintain the 'status quo' in the eastern portals area are shown shown in **Figure 9-5**.

All dwellings west of Kelvin Grove Road and south of the tunnel portal are predicted to comply with the 'Status Quo' noise goal with the design noise barriers.



Key
- Building
- Road Traffic
- Elevation line
- Noise Barrier
- Central Reservation

Y2026 "Status Quo Noise Barriers" Kelvin Grove Area

Scale 1:6500

0 30 60 120 180 240 m

N

Figure 9-5

Northern Link

SKM Connell Wagner JOINT VENTURE

Most dwellings west of Kelvin Grove Road and north of the tunnel portal are predicted to comply with the 'Status Quo' noise goal with the design barriers. A Dalley Street residence could exceed the 'Status Quo' noise goal by 1dBA with the designed barriers.

Dwellings in the vicinity of Normanby Terrace, north of the ICB and the proposed child care centre are predicted to comply with the 'Status Quo' noise goals with the designed barriers.

Dwellings along Gregory Terrace are predicted to comply with the 'Status Quo' noise goals without noise barriers.

Noise levels at the Brisbane Boys' Grammar School and Brisbane Girls' Grammar School buildings, on the sports oval south of the rail line, on the playing fields north of the ICB (west of the Inner Northern Busway) and at the Brisbane Grammar School Indoor Sports Complex are predicted to comply with 'Status Quo' noise goals.

This design incorporates 1073m (4762m^2) of barriers to maintain the 'status quo' at residential properties.

With Barriers Designed to Achieve 63dBA L_{A10} (18hour) Design Objective in 2026

Appendix I8 of *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS presents the noise contours for 2026, assuming Northern Link and noise barriers to achieve the 63dBA L_{A10} (18hour) planning level. The noise barriers necessary to maintain the planning levels in the eastern portals area are shown in **Figure 9-6**.

West of Kelvin Grove Road and south of the tunnel portal several dwellings are predicted to exceed the 63dBA criterion by up to 7dBA with 8m noise barriers.

Most residences west of Kelvin Grove Road and north of the tunnel portal most residences are predicted to comply with the 63dBA criterion with the 8m noise barriers. One residence on Kelvin Grove Road and one on Dalley Street are predicted to exceed the 'Status Quo' noise goal by up to 10dBA with the designed barriers. The residence on Kelvin Grove Road is able to achieve the 'Status Quo' noise goal.

In the vicinity of Normanby Terrace, north of the ICB several dwellings are predicted to exceed 63dBA by up to 4dBA with the 8m noise barriers. All of these residences are able to achieve the 'Status Quo' noise goal.

The proposed child care centre on Lot 5 of the Kelvin Grove Urban Village is predicted to experience a noise level of 64dBA, which exceeds the 63dBA goal by a marginal 1dBA.

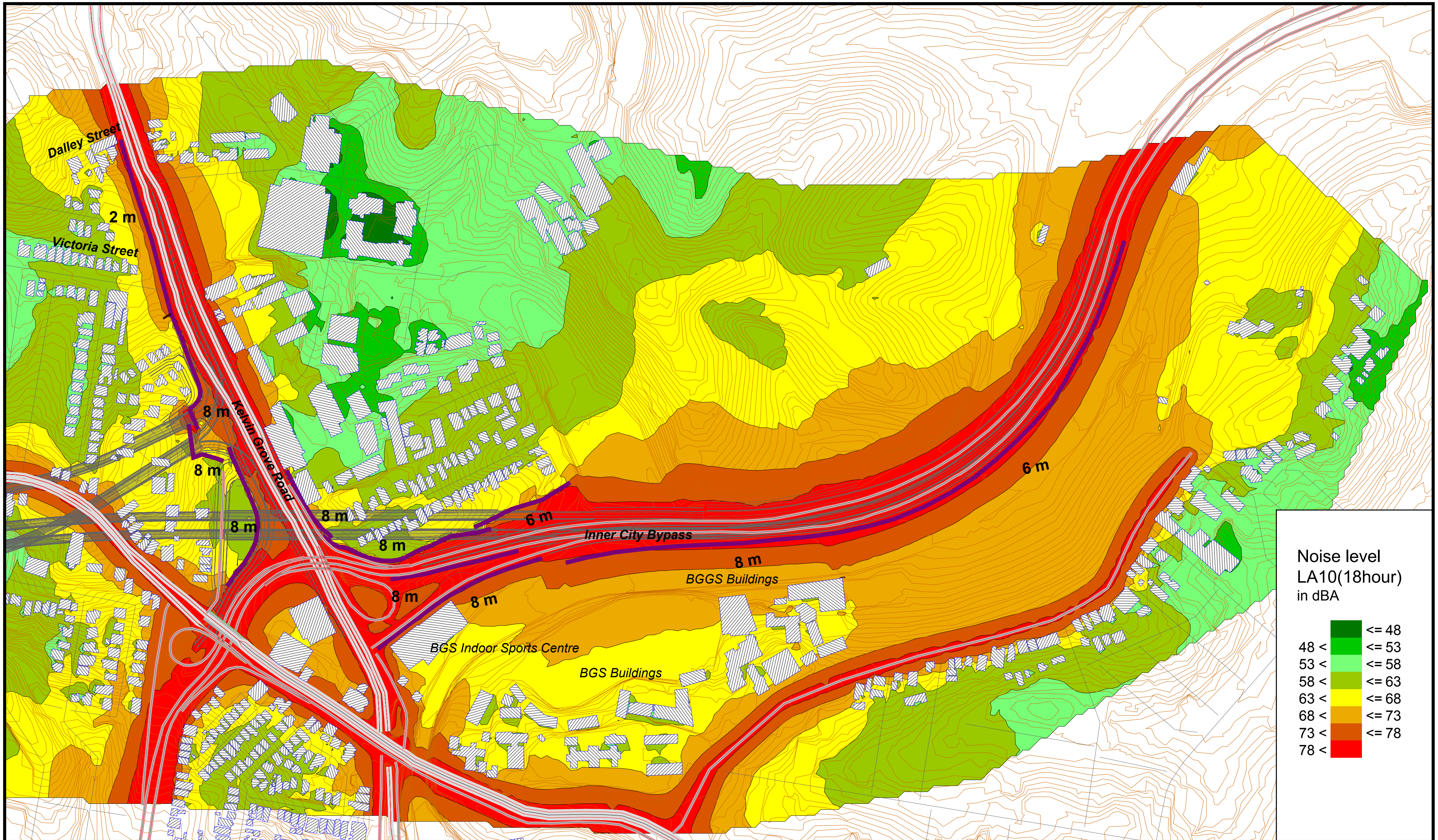
Dwellings along the southern side of Gregory Terrace are predicted to levels up to 61dBA for ICB and Northern Link traffic only but would experience noise levels up to 77dBA for all traffic (including traffic on Gregory Terrace itself). All of these residences are able to achieve the 'Status Quo' noise goal.

Noise levels at the Brisbane Boys' Grammar School Buildings are predicted to be up to 67dBA.

Noise levels at the Brisbane Girls' Grammar School buildings are predicted to experience up to 64dBA.

For the Brisbane Grammar School sports oval south of the rail line, approximately the southern half is below Main Roads' Code of Practice planning level for outside education levels. This is considered acceptable.

For the playing fields north of the ICB (west of the Inner Northern Busway), most of the oval exceeds the planning level with 10-20% of the oval (closest to the tennis courts) below this level. All of the tennis courts are below this planning level. Noise levels at the Brisbane Grammar Indoor Sports Complex are predicted to be up to 66dBA.



Key
- Building
- Road Traffic
- Elevation line
- Noise Barrier
- Central Reservation

Y2026 "Planning Level Noise Barriers" Kelvin Grove Area

Scale 1:6500

0 30 60 120 180 240 m

N

Figure 9-6

Northern Link

SKM Connell Wagner JOINT VENTURE

Should the 2m high noise barrier recommended adjacent to the parkland (north of Victoria Street on the western side of Kelvin Grove Road) be considered unacceptable for urban design or community reasons, predicted noise level increases at homes to the west are all within 2dBA of the 'Do Minimum' predictions. Consequently, if this noise barrier is not installed, noise level increases due to the project would be considered insignificant.

This design incorporates 2434m (17,879m^2) of barrier to achieve the 63/68dBA L_{A10} (18hour) planning level at residential and educational properties.

Recommended Mitigation Measures

State Controlled Roads

The only state controlled road where there are exceedances of the 68dBA L_{A10} (18 hour) planning level for this project is Frederick Street. It is not feasible to build noise barriers to protect these homes due to access requirements. Therefore, in accordance with Main Roads' Code of Practice, property treatments outside the road reserve should be undertaken to achieve an equivalent indoor noise amenity.

Non-State Controlled Roads

For both the Toowong area and the Kelvin Grove area, there are significant numbers of properties that exceed the 'Planning Level' goals with full 8m high barriers. At 8m high, noise barriers would also have significant visual and shading issues. 'Status Quo' noise levels can be achieved at almost every location in both areas with somewhat lower barriers. Where the 'Status Quo' noise level cannot be achieved, predicted increases in noise levels between the 'Do Minimum' and 'With Northern Link' are within 2dBA and are therefore considered insignificant. Therefore, it is recommended that the 'Status Quo' goals be adopted for all non-state controlled roads.

9.5.3 Alternative Mitigation Strategies to Reduce Road Traffic Noise Impacts

During the detailed design phase of the works, consideration should be given to the following options as alternative means of noise control, where noise barriers prove to be unreasonable or feasible:

Road Surface Treatments

The prevailing road surface directly influences noise emissions from the roadway. Open Graded Asphaltic Concrete (OGAC), for example, would result in noise levels that are 3dBA lower than Dense Graded Asphaltic Concrete (DGAC) which is the road surface that has been modelled for all roads in this study. Other similar surfaces include Stone Mastic Asphalt (SMA), where noise reductions of 1-2dBA are reported (compared to DGAC), depending on the stone size.

This option has some limitations in that it is relatively costly to lay, it needs to be periodically replaced due to wear and OGAC cannot be used in tunnels as it is a potential fire hazard. In the case of a petrol or other flammable liquid spill the roadway encourages the absorption of the volatile liquid rather than letting it stay on the surface.

Architectural Acoustic Treatment of Existing Dwellings

For dwellings along state-controlled roads, architectural acoustic treatments are required where the 68dBA L_{A10} (18hour) criterion cannot be reasonably and feasibly achieved.

Along local (non state-controlled) roads, it may be possible to provide upgrading to the facade windows and doors in some circumstances as an alternative to noise barriers.

Depending on the extent of impacts, consideration should be given to the supply of fresh air and/or air-conditioning into habitable rooms (allowing the windows to remain closed for noise control purposes) and to the upgrading of facade windows and doors (subject to qualifications).

Resumptions

In consultation with the property owners, purchase of properties severely impacted by a project could be considered.

Urban Renewal

Councils and other authorities can consider an urban renewal program for areas or buildings that are adversely impacted by road traffic noise, replacing noise sensitive buildings (eg: homes) with non-noise sensitive buildings (eg: commercial).

Vehicular Speed

The overall traffic noise could be reduced by the lowering of the vehicular flow speed. At the higher speeds, noise is emitted from the interaction of the tyres and the roadway, whilst at lower speeds, the noise tends to arise from the engine and exhaust.

Reducing road speed is generally not considered a viable form of noise mitigation due to the relatively small changes involved, and it opposes one of the primary functions of road infrastructure projects which is to decrease travel times between destinations.

Reductions in Vehicle Noise Emissions

Noise emissions for new vehicles are defined within the Australian Design Rule 28/01, within the *Motor Vehicles Standard ACT*. Over time, changes to the standards would result in lower noise levels in the community.

9.5.4 Vibration and Regenerated Noise

On roadways that are well maintained, regenerated noise and vibration from individual vehicle movements is not considered to result in significant acoustical disruption to residents.

Heggies has recently undertaken specific ‘operation road tunnel’ regenerated noise and vibration measurements above two tunnels – the ICB in Brisbane and the M5 East in Sydney. All results and observations showed regenerated noise and vibration levels to be below the threshold of human perception.

As such, there are no tunnel areas beneath sensitive buildings where it is anticipated that vibration or regenerated noise from truck movements on the carriageways would be an issue provided the road surface is well maintained and free of discontinuities.

9.5.5 Traffic Noise on Road Network Remote from the Portal Areas

For the Years 2014 and 2026, the introduction of Northern Link is predicted to result in a small change in the levels of road traffic noise on the wider road network (ie: well removed from the portal areas). Generally noise levels decrease, but at a number of locations the noise levels are predicted to increase.

The expected changes in the traffic noise as a result of the introduction of Northern Link are generally within ± 2dBA. Such changes are considered to be minor and not to be generally noticeable. As such, no noise mitigation is considered necessary.

However, if strict compliance with the 'Status Quo' noise levels is recommended for roads beyond the immediate tunnel infrastructure, the following options could be explored to mitigate increases in traffic noise as attributable to the tunnel.

- Open-graded or stone mastic asphaltic road surfacing.
- Building insulation upgrade programmes.

Road-side barriers are not a feasible option along many roads due to the requirement for property access from the street frontage.

The details of this assessment of noise on the road network remote from the portal areas are provided in *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS.

9.5.6 Ventilation Noise from Ventilation Stations

Preliminary calculations of ventilation outlet noise emissions indicate that it would be feasible for noise emissions to comply with Brisbane City Council's Noise Impact Assessment Planning Scheme Polices and traditional EPA licensing.

Providing that emissions at residential locations are free of distinct tonal characteristics, and do not exceed background noise levels, the normal licensing requirements would allow the ventilation outlets to be developed with negligible noticeable noise impact to residents.

The details of this assessment of noise from the proposed ventilation stations are provided in *Technical Report No. 9 - Noise and Vibration in Volume 3* of the EIS.