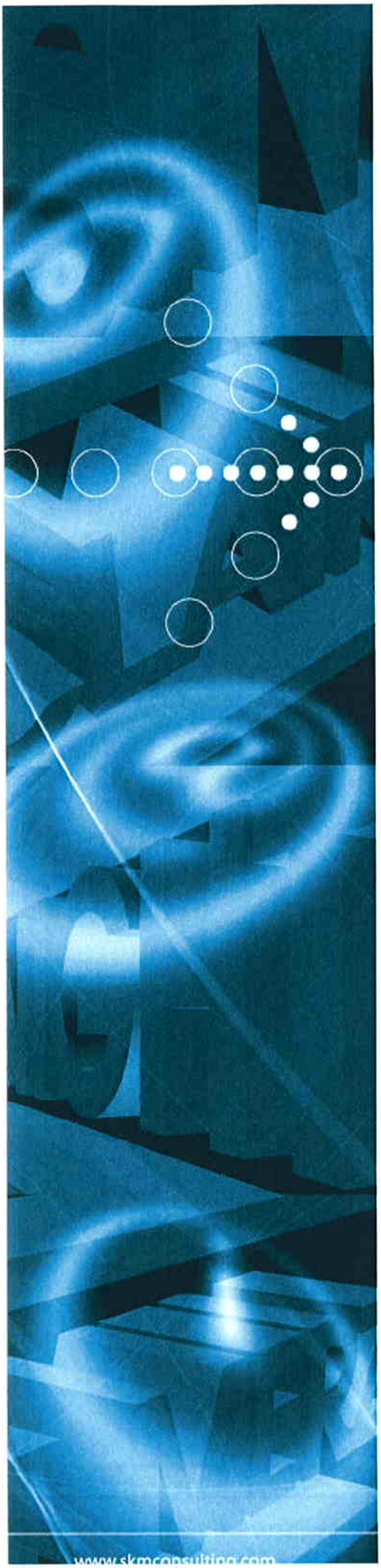


North West Rail Link

Working Paper No. 6

Noise and Vibration Assessment

Final

April 2003

SINCLAIR KNIGHT MERZ

North West Rail Link

Working Paper No. 6

Noise and Vibration Assessment

Final

April 2003

SINCLAIR KNIGHT MERZ

Sinclair Knight Merz Pty Limited
ACN 001 024 095
ABN 37 001 024 095
100 Christie Street
PO Box 164
St Leonards NSW
Australia 1590
Telephone: +61 2 9928 2100
Facsimile: +61 2 9928 2500

Contents

1. Introduction

1.1 Background

Sinclair Knight Merz Pty Ltd has prepared this Technical Paper. Its aim is to report on the extent of noise and vibration impacts associated with the proposed North West Rail Link project and to present relevant mitigation measures for consideration and/or adoption during the construction and operation of the proposal.

The requirements for preparing this report are primarily based on the Environment Protection Authority (EPA) standard requirements regarding the assessment of construction and operational noise. The most likely requirements that would be issued by the Director-General of PlanningNSW (based on previous rail-based projects) have also been considered during the preparation of this report.

1.2 The proposal

The North-West is a major growth area of Sydney. In the next 20 years, 12% of Sydney's anticipated residential growth is expected to occur in Sydney's North-West. It has been predicted that over 140,000 new residents would live in the area by 2026.

The transport challenge facing Sydney's North-West is how to accommodate a fast growing population in an area currently with little public transport choice. As stated in *Action for Transport 2010* (Department of Transport, 1998), North-West Sydney's residential and employment growth is already moving beyond the current transport network. The roads in the region have experienced significant growth in traffic over the last 10 years and the existing Richmond and Main North rail lines cannot readily cope with increasing pressure. Many people are therefore finding it difficult to get to or from work and services without a car. The North-West is now the area of Sydney most heavily dependent on cars for transport. In the Baulkham Hills area some 85% of people currently travel to work by car.

There is a clear imperative to improve the transport network, especially in North-West Sydney, not only to serve existing needs but also to provide for future growth.

As indicated in *Action for Air* (Environment Protection Authority, 1998), a number of initiatives are needed to reduce the growth of vehicle kilometres travelled (VKT) by private motor vehicles to minimise vehicle emissions and progress towards improving Sydney's air quality. There is also a need to provide opportunities to redress the imbalance of public transport provision in North-West Sydney compared to other areas of Sydney.

At present, the public transport system in the Sydney Region is predominantly in the form of a radial network that traditionally focused on servicing central Sydney as the city's population spread outwards. But employment is no longer concentrated in the CBD and, because of this, Sydney needs improved transport options between other centres.

The region that would be served by the proposed North West Rail Link (NWRL) is a large area of North-West Sydney. The proposed NWRL would be the principal trunk public transport line linking the residents of North-West Sydney with the employment, health, education and recreation destinations between Epping, Chatswood, North Sydney and the Sydney CBD. It would also greatly improve access to Castle Hill, Norwest Business Park and Rouse Hill Town Centre.

1.2.1 Objectives of the Project

The key NSW Government strategic objectives that can be achieved by the delivery of the proposed North West Rail Link include:

- Improving access to employment opportunities, education and health services;
- Connecting Sydney's North West to the metropolitan rail network;
- Reducing car dependency;
- Improving air quality;
- Improving local environments; and
- Improving travel times for all journeys.

1.2.2 Project Description

As shown in **Figure 1-1**, the existing preferred alignment for the rail line is 19 kilometres in length and would commence on the Main North Rail Line between Beecroft and Cheltenham and terminate at Rouse Hill Town Centre. The eastern section (11.6 kilometres) would be in tunnel between the existing Main North Rail Line and Norwest Business Park. The western section would be on surface from Norwest Business Park to Rouse Hill Town Centre.

The NWRL would be a dual-track heavy rail system that encompasses six stations:

- Franklin Road Station;
- Castle Hill Station;
- Hills Centre Station;
- Norwest Business Park Station;
- Burns Road Station;
- Rouse Hill Town Centre Station.

The first three stations are proposed to be located along the eastern tunnel section and would be underground. The remaining three stations would be along the western above ground section of the proposal. Car parking facilities are proposed at all but the Castle Hill Station.

The rail line could be developed as a single stage project or in two stages. If the project is developed in stages, the first stage would be from the Main North Line in the east to Norwest Business Part station. Stage two would be from Norwest Business Park to Mungerie Park in the west.

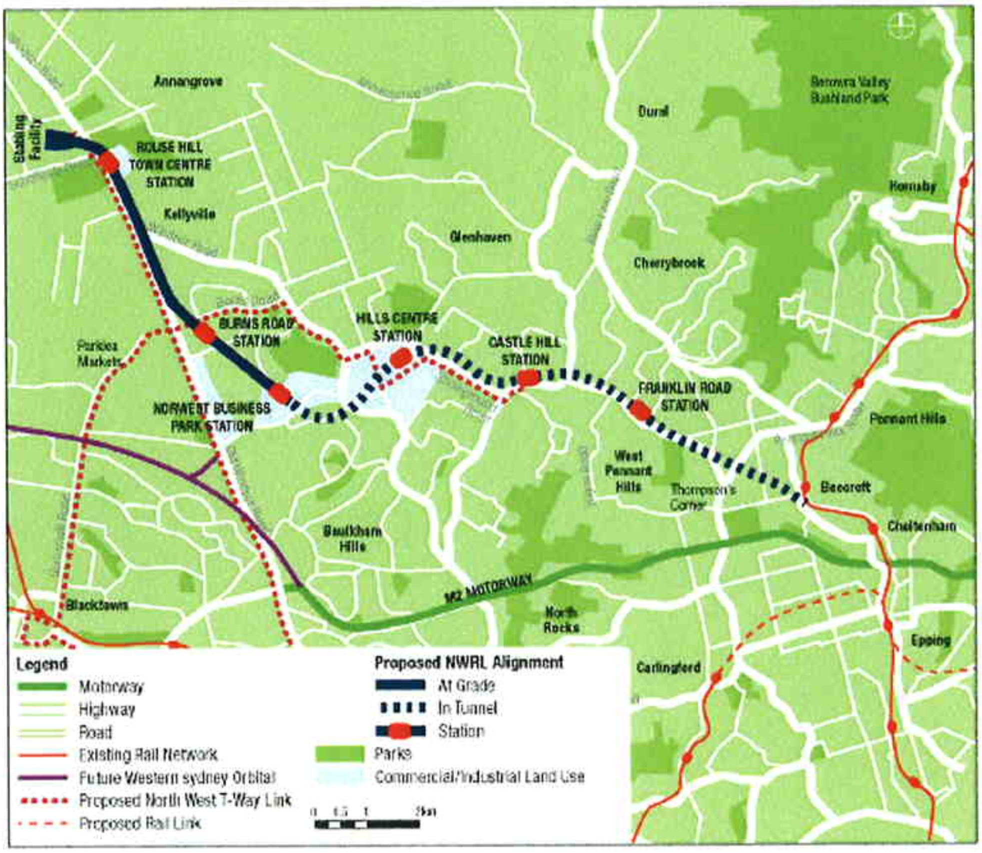


Figure 1-1 Preferred Alignment for the Proposed North West Rail Link

2. Project Overview

2.1 Acoustically sensitive structures

As well as the residential dwellings above the tunnel section of the route, there are a number of particularly noise or vibration sensitive buildings along the proposed route. The two most critical are:

- Hillsong Church, and its new convention centre; and
- Hills Centre.

In addition there have been a number of buildings and structures identified in the *Indigenous & Non-Indigenous Heritage Assessment* due to their cultural value (refer Working Paper 5). Buildings or other structures within 50 m of the proposed tunnel alignment were identified due to their heritage value and are reproduced in **Table 2-1** below. There is frequently a community reservation that due to their age, such buildings are more susceptible to vibration impacts. This report presents a qualified overview of the vibration impacts, given that no dilapidation surveys of the structures were undertaken.

Table 2-1 Identified Heritage Structures (Non-Indigenous)

Item No	Address	Item	Heritage Listing	Location from tunnel alignment	
				Alignment under	Within 50m
1	1 Murray Farm Rd, Beecroft	House	LEP		✓
8	115 Beecroft Rd, Beecroft	Carmel	LEP		✓
15	100 Beecroft Rd, Beecroft	Vintage Cellars	LEP		✓
21	90-96 Beecroft Rd, Beecroft	Beecroft P. School	LEP	✓	
23	11 Beecroft Road, Beecroft	Beecroft Community Centre	LEP	✓	
24	97 Sutherland Rd, Beecroft	Beecroft Station	LEP	✓	
25	86 Copeland Rd, Beecroft	House	LEP	✓	
26	84 Copeland Rd, Beecroft	Waveney	LEP		
27	127 Copeland Rd, Beecroft	House	LEP	✓	
29	74 Beecroft Rd, Beecroft	House	LEP		✓
31	72 Beecroft Rd, Beecroft	House	LEP	✓	
32	30 Hannah, Beecroft	House	LEP	✓	
34	62 Beecroft Rd, Beecroft	St Johns Church	LEP	✓	
40	38 Hannah, Beecroft	House	LEP		✓
43	29B Albert, Beecroft	House	LEP	✓	
45	540 Pennant Hills Rd, WPH	Blue Gum	LEP		✓
46	5 Fairburn Ave, WPH	House	LEP	✓	✓
48	150 Castle Hill Rd, Castle Hill	House	LEP		
49	160-168 Castle Hill Rd, Castle Hill	Inala, Tangaraols	LEP	✓	
50	284 Castle Hill Rd, Castle Hill	Mowli Village Group	LEP	✓	

Item No	Address	Item	Heritage Listing	Location from tunnel alignment	
				Alignment under	Within 50m
52	67 Castle Hill Rd, WPH	House	LEP	✓	
54	113 Castle Hill Rd, WPH	Glenhope	LEP		✓
55	266 Old Northern Rd, Castle Hill	Dunrath	LEP	✓	
56	151 Castle Hill Rd, WPH	Pine Ridge	LEP	✓	
57	153 Castle Hill Rd, WPH	Gate and gatepost	LEP		✓
58	157 Castle Hill Rd, Castle Hill	Fairholme	LEP	✓	
60	14 Garthowen Crescent, Castle Hill	Garthowen (Graigowan)	LEP		✓
64	266 Old Northern Road, Castle Hill	Castle Hill Public School	AHC	✓	
65	264 Old Northern Rd, Castle Hill	Police Station	LEP	✓	
66	30 Showground Rd, Castle Hill	House	LEP	✓	
67	74 Showground Rd, Castle Hill	Dogwoods	LEP	✓	
68	107 Showground Rd, Castle Hill	House	LEP		✓
69	128 Showground Rd, Castle Hill	House	LEP		✓
70	Cnr Barina Downs Rd and Mackillop Dr, Baulkham Hills	St Josephs Novitiate (Bellevue)	LEP	✓	

LEP – Local Environmental Plan
AHC – Australian Heritage Council

2.2 Timetabling

The operational information on which this assessment is based assumed the rail fleet mix along the new dedicated corridor indicated in **Table 2-2**.

Table 2-2 Train Timetabling [i]

Train Type	Peak hour movements	Off peak hour movements	Total daily movements
Tangara	16	49	65
Standard Double Decker	24	73	97
Freight, Intercity EMU[ii], Diesel (passenger or freight) Diesel Electric Locomotive, Electric Locomotives, Wagons	Nil	Nil	Nil

The detailed train timetabling has not yet been considered, other than identifying that 25% of the train movements occur in the morning and afternoon two-hour peak period.

Given the long distances between stations, and the wide curves inherent in the design, train speeds of up to 120 km/h may be expected. Speeds along the tracks are based on details in the *Rail Infrastructure Study* (Arup, 2001)[iii].

Tangara type trains in the suburban network are assembled as either a four car configuration, or two sets coupled together as an eight car train. Similarly, Double Decker type trains can comprise four, six or eight car sets, depending upon passenger demand. The acoustical implications of the differing configuration train lengths is limited to changes in the energy averaged L_{AE}, and L_{Aeq} indices, the $L_{A,Max}$ would not be expected to change. For one train event, the differing length may result in as much as a 3 dB(A) change, however it is likely that only 10% of the train fleet may have four carriages. The overall difference in the daily $L_{Aeq(24hour)}$ index would be a very marginal 0.2dB(A), well within the prediction error. For the purpose of this assessment therefore, all trains are considered to have eight carriages.

2.3 Tunnel geometry

The tunnel is planned as two parallel tunnels, with each tunnel having a diameter of 7 m, and the tunnels located 21 m apart (centre to centre). A typical tunnel section is presented in **Figure 2-1**.

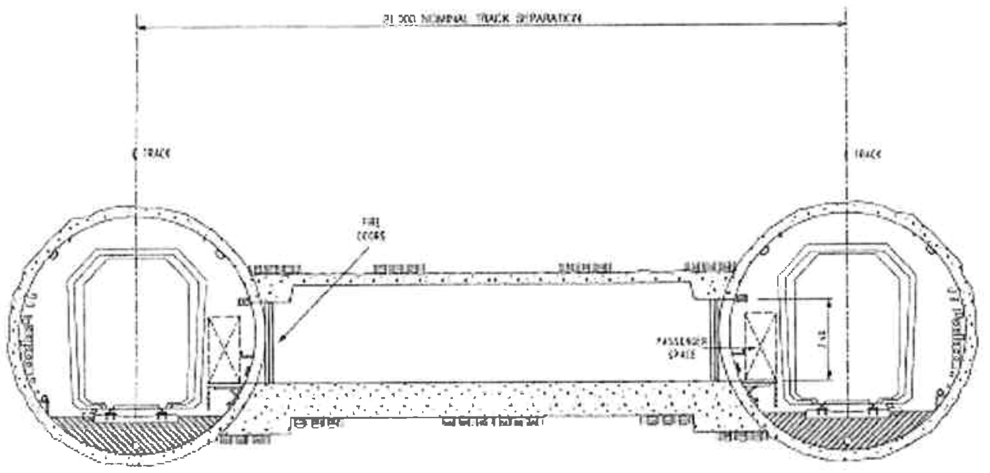


Figure 2-1 Typical Tunnel Section

It is proposed that ballasted track would be adopted as the preferred treatment both the tunnel section and for all surface tracks. This is consistent with the Main North Line and would provide compatibility for maintenance operations.

Wheel squeal is a frequent source of tonal noise frequently associated with complaints from residents in the immediate area. Consideration in the design of the track geometry has effectively eliminated this as a source of complaint from this project as the tighter track curves are typically around 800 m.

It is possible that at some time in the future, sections of the line could be used for Light Rail Transport (LRT) as well as suburban rail vehicles (as proposed). It would be expected that LRT would result in lower impacts than would heavy rail, with the main design considerations relating to the introduction of any new crossovers and introduction of access any gaps through acoustic barriers or moundings. Notwithstanding these design considerations, the overall acoustical implications are considered minor with feasible mitigation measures likely to resolve any issues, should this option ever eventuate.

2.4 Train Stabling

The first phase of the NWRL project would be the construction of the tunnelled section from the Main Northern Railway Line to the north of Norwest Business Park, with the second phase extending the line to west of Windsor Road at Rouse Hill Town Centre. In order to provide functionality, one temporary and one permanent stabling area would be required.

During the first phase of the works, the temporary stabling yard would be to the north of Norwest Business Park Station, which would be decommissioned with the successful operation of the permanent stabling west of Windsor Road at Rouse Hill Town Centre.

Both the temporary and the permanent stabling yards would likely be constructed on substantial areas of fill. Conventional earth moving plant such as trucks, dozers, scrapers and compacters would be used during construction works.

North of Solent Circuit the railway would be on fill for a 600 metre length then enters a cutting at Ch 38.800 km. The section of track between Ch 38.700 km and Ch 38.900 km would be graded at 0% (for the temporary stabling) to accommodate the temporary train stabling if the NWRL were to be constructed in two stages. The temporary stabling facility would not be designed to carry out major train cleaning or servicing.

The permanent stabling facility would be designed to accommodate twelve eight-carriage trains. Also, the site would include a train washing and light maintenance facility.

2.5 Bridge Structures

There would be a total of ten bridge structures between the Norwest portal and the Rouse Hill stabling yard. These would be situated at the following locations:

❑ Overbridge at Solent Circuit	Chainage: 38.100 km
❑ Overbridge at Balmoral Road	Chainage: 39.710 km
❑ Overbridge at Burns Road	Chainage: 40.410 km
❑ Burns Road Station	Chainage: 40.500 km
❑ Overbridges at Windsor Road/Old Windsor Road Interchange	Chainage: 42.350 km
❑ Overbridge at Mungerie Park Avenue Extension	Chainage: 43.480 km
❑ Rouse Hill Town Centre Station Box	Chainage: 43.750 km
❑ Overbridge at Schofields Road Extension	Chainage: 44.080 km
❑ Overbridge at Windsor Road	Chainage: 44.300 km

In all cases above the configuration is such that the road would pass over the rail line due to the rail being in cut, or where the rail is at natural surface, the road would be raised at the abutment to an overpass.

The bridge structure type is presented in **Appendix B**.

In addition to the above, bridge structures would be required to support the rail tracks at the following locations:

❑ Strangers Creek: It is assumed that the approaches across the existing gully would be backfilled, excepting for the gully crossing;	Chainage 38500
❑ A viaduct structure to minimise impacts on the flood plain flows	Chainage: 41.350 km to 43.200 km
❑ Caddies Creek Viaduct	Chainage: 43.642 km to 43.650 km

2.6 Acoustical terms

A number of acoustical terms are used within this report. **Appendix A** presents a complete glossary of terms. The more common terms used include:

- **$L_{Aeq(24hour)}$** - a 24 hour weighted averaged index. As the index is a reflection of the acoustical energy, increases arises either due to long-term exposure to relatively low noise or several short term exposure to higher noise events;
- **$L_{A,Max}$** - the maximum noise associated with a noise event. A more thorough discussion on what constitutes a reproducible maximum passby noise event is further discussed in *Section 4.1.1*;
- ***rating Background Level (RBL)*** - the single-figure background level used in the EPA's *Industrial Noise Policy*. The RBL is the median of the daily 10^{th} percentile level of the background noise levels for each day, evening and nighttime period. That is, three assessment background levels are determined for each 24-h period. The procedure is defined in Appendix B of the EPA's *Industrial Noise Policy*;
- ***background noise*** - the underlying level of noise present in the ambient noise, excluding the noise source under investigation, when extraneous noise is removed. This is described using the L_{A90} descriptor;
- **ppv** - is an acronym for the peak particle velocity of a vibration signal. It represents the highest of the three individual directional components (ie vertical, longitudinal and horizontal) of a signal;
- **rms** - is an acronym for the root-mean-square level of a vibration signal. Mathematically it is the square-root of the square of the three individual directional components;
- **pvs** - is an acronym for the peak vector sum of a vibration signal. It represents the highest value of the vector summation of all three directional components of a signal.

3. Ambient Noise Surveys

3.1 Baseline Noise Monitoring

To obtain information on the existing levels of environmental noise with in the community along the proposed surface corridor and in the general vicinity of the stations, a series of baseline noise surveys were conducted. The surveys were conducted between July and October 2002 and supplemented by noise surveys extracted from *Technical Paper No. 26 – Noise and Vibration Impact Assessment* (2002), prepared by Sinclair Knight Merz, as part of the North-West T-way Network Environmental Impact Statement (EIS). The duration of the surveys at each site was nominally 7 days, but at some locations bnger monitoring was conducted due to the possibility of adverse meteorological conditions, the potential of undue influence from local activity or logistical reasons.

Periods of adverse meteorological conditions were excluded from the analysis, as were periods where it was clear that the noise environment was influenced by events other than road traffic.

The noise monitoring locations were based on a review of residential properties along the surface route of the proposed alignment, railway stations along the surface route and the tunnel section. Details of the monitoring locations are detailed below:

Noise Monitoring Location	Nearest Project Activity
Location 1: 2 Sutherland Road, Cheltenham	Beecroft Dive Structure
Location 2: 52 The Crescent, Cheltenham	Beecroft Dive Structure
Location 3: 30 Sutherland Road, Beecroft	Beecroft Dive Structure
Location 4: 2A The Crescent, Beecroft	Near Tunnel Portal
Location 5: 10 Fleur Close, West Pennant Hills	Near Ventilation Shaft
Location 6:113 Castle Hill Road, Cherrybrook	Franklin Road Station
Location 7: 128 Franklin Road, Cherrybrook	Franklin Road Station
Location 8: 18 Old Castle Hill Road, Cherrybrook	Castle Hill Station
Location 9: 2 Brisbane Road, Castle Hill	Castle Hill Station
Location 10: 49 Showground Road, Castle Hill	Above tunnel
Location 11: 112 Showground Road, Castle Hill	Above tunnel
Location 12: 20 Carrington Road, Castle Hill.	Above tunnel
Location 13: 31 Fairway Drive, Castle Hill	Temporary Stabling Yards, Norwest Portal
Location 14: 10 Emmanuel Tce, Glenwood -facing Old Windsor Rd	Along Route
Location 15: 21 Balmoral Road Kellyville	Along Route
Location 16: 27 Burns Road, Kellyville	Along Route
Location 16b: 15 Burns Road, Kellyville	Along Route
Location 17: Lot 26, Old Windsor Rd, Kellyville	Along Route
Location 18: 11 Weynden Avenue, Kellyville	Near viaduct
Location 19: 7 Austin Place, Kellyville	Near viaduct
Location 20: 9 Terry Road, Rouse Hill	Permanent Stabling Yards
Location 21: 109 Rouse Road, Rouse Hill.	Permanent Stabling Yards

Noise monitoring was not undertaken in the immediate vicinity of the Hillsong Church due to works associated with the construction of the new convention centre. Additional noise monitoring should be undertaken near this site, prior to or during the EIS phase of the works.

3.2 Monitoring procedures

The unattended noise monitoring was undertaken using a range of Acoustic Research Laboratories type EL 015 and EL 215 noise monitors. These monitors were set to store a range of statistical descriptors in consecutive 15 minute intervals throughout the daytime and night-time for a minimum period of seven days. Where it is obvious that the monitoring location was influenced by adverse weather, additional monitoring was conducted. The noise loggers used are designed to comply with the requirements of AS 1259.2-1990, *Acoustics – Sound Level Meters*, and all monitors have current NATA certification.

The calibration level of the noise loggers was checked prior to, and at the completion of each survey. The variation in calibration was minor, well within the guidelines detailed in the relevant Australian Standards.

3.3 Results of noise surveys

The noise surveys were analysed to obtain the key noise indices used in the determination of the construction noise indices, as listed in **Table 3-1**. Due to the bulk of the graphs, these have not been included in this report.

Table 3-1 Summary of Key Noise Indices

Location / Address	Rating Background Level (RBL)			Typical L_{A10} levels	$L_{Aeq(24hour)}$	$L_{Aeq(15hour)}$	$L_{Aeq(9hour)}$
	7:00am to 6:00pm	6:00pm to 10:00pm	10:00pm to 7:00am	7:00am to 6:00pm			
Location 1: 2 Sutherland Road, Cheltenham	39	38	34	58	59	59	59
Location 2: 52 The Crescent, Cheltenham	39	37	31	55	58	58	57
Location 3: 30 Sutherland Road, Beecroft	43	41	36	63	60	60	59
Location 4: 2A The Crescent, Beecroft	44	44	34	59	62	61	62
Location 5: 10 Fleur Close, West Pennant Hills	41	36	30	56	51	53	45
Location 6:113 Castle Hill Road, Cherrybrook	43	42	30	52	49	50	45
Location 7: 128 Franklin Road, Cherrybrook	49	47	35	64	59	60	56
Location 8: 18 Old Castle Hill Road, Cherrybrook	54	49	38	63	59	60	55
Location 9: 2 Brisbane Road, Castle Hill	51	46	37	62	58	59	55
Location 10: 49 Showground Road, Castle Hill	57	51	39	68	64	65	60
Location 11: 112 Showground Road, Castle Hill	58	52	33	71	66	67	62
Location 12: 20 Carrington Road, Castle Hill.	48	43	35	65	60	62	53
Location 13: 31 Fairway Drive, Castle Hill	41	39	36	52	50	52	46
Location 14: 10 Emmanuel Tce, Glenwood -facing Old Windsor Rd	48	44	34	65	61	62	58
Location 15: 21 Balmoral Road Kellyville	38	40	35	58	54	55	52
Location 16: 27 Burns Road, Kellyville	55	51	38	65	60	61	57
Location 16b: 15 Burns Road, Kellyville	47	44	32	64	61	60	55
Location 17: Lot 26, Old Windsor Rd, Kellyville	46	46	35	60	57	57	56
Location 18: 11 Weynden Avenue, Kellyville	38	41	36	48	49	50	48
Location 19: 7 Austin Place, Kellyville	41	41	34	51	49	49	47
Location 20: 9 Terry Road, Rouse Hill	41	41	37	53	49	49	46
Location 21: 109 Rouse Road, Rouse Hill.	37	36	32	53	49	50	47

4. Criteria

4.1 Operational Emissions

4.1.1 Airborne Rail Emissions (operational phase)

The NSW Environment Protection Authority (EPA) specifies emission limits that apply to noise from rolling stock within a rail corridor. Chapter 171 of the *Environmental Noise Control Manual* (EPA 1994) provides guidance for planning and maximum acceptable noise levels. Planning levels are to be used for all new rail corridors, whereas the higher maximum levels are sometimes used for existing rail corridors or the upper limit for new corridors when the planning levels cannot be met. It is appropriate that the lower planning levels be used as the basis for assessment and for the determination of noise control measures, given that the introduction of rail noise into the area would be a new noise source. Two noise criteria apply. One is a daily (weighted) averaged level which increases as the number and/or the level of rail movements increases, whilst the other criteria is a maximum bypass level.

A summary of the EPA's criteria is presented in **Table 4-1**.

Table 4-1 Summary of EPA Rail Noise Criteria

	Planning Level	Maximum Level
Daily averaged index: $L_{Aeq(24hour)}$	55 dB(A)	60 dB(A)
Maximum By-pass Level: L_{AMax}	80 dB(A)	85 dB(A)

There has been extensive discussion as to how the $L_{A,Max}$ level is defined, given the variability between trains and the differences in track conditions along a network. The index needs to reflect the louder rail emissions and yet be reproducible on a daily basis. Whilst there is no clear policy decision made on this, there is general agreement within the EPA and RIC to define the $L_{A,Max}$ in terms of the 5% exceedance level, or the loudest 1 in 20 train movements (based on sufficient samples to be statistically valid).

This definition of the $L_{A,Max}$ index is considered a reasonable balance between the intent of the EPA's criteria to protect the acoustical amenity of residents, whilst ensuring that the criteria is 'workable' and monitoring results are consistent and reproducible.

The EPA has commenced a process of reviewing the rail noise criteria, though at this point the review process is in its early stages of the development. Should these revised criteria be released prior to any project approvals being issued, it is appropriate that the noise and vibration impacts be re-evaluated.

The EPA's criteria requires that the rail noise emission levels apply 1 m from the facade of the nearest residential building [iv]. This requirement is interpreted as requiring a 2.5 dB(A) facade correction to be applied to all calculated noise levels.

4.1.2 Groundborne noise (operational phase)

Groundborne noise results from vibration in the building structure or radiated through the building elements (walls, floors and ceiling) as noise. In other literature groundborne noise can be referred to as structure-borne or regenerated noise (due to its source and nature). The noise has a characteristic low-frequency rumbling.

The EPA does not have a policy for the acceptable levels of groundborne noise from transport infrastructure, such as railways, nor are there any guidelines provided in any Australian Standard.

Based on the approval conditions for the Parramatta Rail Link, the EPA and Planning NSW have set the following conditions to apply in any habitable room of any residential building:

- For 50% of the train by-passes in the excavated tunnel area the regenerated noise shall not exceed an $L_{A,\ Max}$ level of 30 dB(A)[v] (fast meter response); and
- For at least 95% of the train by-passes in the excavated tunnel area, the regenerated noise shall not exceed an $L_{A,\ Max}$ level of 35 dB(A) within the sleeping area of any residence (fast meter response).

At the upper limit of this approval condition, the noise would be audible, due to its character, but considered a level that should not result in the loss of acoustical amenity to residential occupants.

Groundborne noise criterion should also apply for spaces other than residential dwellings. **Table 4-2** presents a more complete list of recommended criteria, based on consideration of a wide range of factors but mainly AS 2107 with consideration of other relevant international standards and guidelines.

It should be noted that these levels only apply when the space is normally occupied. If for example a building such as a Church were used only specific times, then the criterion would apply only at those times.

Table 4-2 Groundborne Noise Criteria (operational phase)

Building Use	Recommended Maximum Ambient Noise Level – dB(A) (reference AS 2107)	Proposed Groundborne Train Noise Design Goal [v] dB(A)
Studio Buildings		
Sound stages, music recording studios	25	25
Television, film or drama studios	30	30
Cinemas	35	35
Places of Worship		
With speech amplification system	40	40
Residential Buildings (including hotels/Motels) – near minor roads Note 1		
Sleeping areas	35	35
Other habitable spaces	40	45
Industrial Buildings		
Packaging areas	60	70
Light machinery	70	75
Lunchrooms	55	60
Laboratory test/precision assembly areas	50	55
Foremen's office	50	55
Education Buildings		
Teaching spaces (primary & secondary)	45	50
Large lecture theatres Note 2	45	50
Administrative offices and drama studios	40	45
Conference rooms, music studios and small lecture theatres Note 3	35	40
Office Buildings		
Board and conference rooms	40	45
Cafeterias, public spaces, corridors and lobbies	50	55
Private offices	40	45
Open plan office spaces	45	50
Shop Buildings		
Department stores (main floor), Showrooms, small retail stores	50	55
Supermarkets, shopping malls	55	60
Car parks (enclosed)	65	70

Note 1: Buildings on major roadways may have levels 5 dB (A) higher than that specified
Note 2: greater than 250 seats
Note 3: less than or equal to 250 Seats

4.1.3 Vibration Assessment (operational phase)

The assessment of vibration should be considered in terms of its influence on occupants (ie. human comfort), and the effects on the structure of the building. It is not always possible to operate major infrastructure projects in very close proximity to residential dwellings and comply with the human comfort criterion without some form of vibration isolation in the design of the system. However this should always be used as the target objective, and be the basis of assessment.

4.1.4 Vibration - Human Comfort (operational phase)

Vibration from the movement of vehicles is best assessed in terms of aiming to comply with the more stringent human comfort criteria.

Chapter 174 of the *Environmental Noise Control Manual* (EPA, 1994) provides vibration limits which were based on the Australian Standard AS 2670.2-1990, *Evaluation of Human Exposure to Whole Body Vibration – Continuous and Shock Induced Vibration in Buildings.* This standard was itself based on an early draft of the British Standard BS 6472: - 1992 *Evaluation of Human Exposure to Vibration in Buildings*, and has itself been revised.

The revised BS 6472 assesses the impact from continuous vibration in terms of a "Low probability of adverse comment" and provides a daytime and night-time relationship between vibration dose and various levels of public comment expected in residential buildings for continuous or impulsive vibration sources. The three levels of public comment are:

- low probability of adverse comment (being the more stringent);
- adverse comment possible; and
- adverse comment probable (being the least stringent).

Assuming the vibration occurs sufficiently frequently to be classified as "continuous", the following vibration levels for residential areas should not be exceeded so as to remain within "the low probability of adverse comment":

- 0.2 mm/s to 0.35 mm/s during the day[vi]; and
- 0.15 mm/s at night [vi].

4.1.5 Vibration - Criteria for Building Structures (operational phase)

There are a number of Standards designed for the assessment of damage to building structures. DIN 4150 (is often used however a more recent standard for assessing building damage is BS 7385: Part 2 – 1993 *Evaluation and Measurement of Vibration in Buildings Part 2.* This standard was developed following a full review of available data, including national (UK) and international standards, publications, and a review of UK blast data. The standard provides guidance for threshold vibration values corresponding to the minimum risk of cosmetic damage from vibration. The standard is widely accepted for use by the NSW EPA.

The minimum risk threshold vibration values are summarised in **Table 4-3**.

Table 4-3 BS 7385: Transient Vibration Levels for Cosmetic Damage

Line	Type of Building	Peak Particle Velocity	
		4 Hz to 15 Hz	Greater than 15 Hz
1	Reinforced or framed structures. Industrial or heavy commercial buildings	50 mm/s	50 mm/s
2	Non-reinforced or light framed commercial type buildings (most residential dwellings fall into this category)	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

The standard specifically notes:

- historic buildings should not be assumed to be more sensitive to vibration (unless structurally unsound); and
- structures below ground are known to sustain higher levels of vibration and are very resistant to damage, unless in poor condition.

4.1.6 Vibration – Electronic Equipment (operational phase)

Unrelated to the vibrations caused by the proposed rail system during operations and construction, vibrations are generated by every-day activities such as the closing of doors, foot-falls, the re-arrangement of furniture, and the "collapsing" of a person onto a chair. The vibrations generated by such activities can vary dramatically but would be expected to exceed 1 mm/s within typical building structures. These events are correctly perceived as not resulting in any problems for normal domestic and office equipment, whilst the introduction of a new vibration source (even of equal magnitude) can result in some anxiety, particularly towards concerns of interference or damage to electronic equipment.

Normal desktop and even large computer facilities are relatively tolerant to vibration. In general, vibration levels of between 1 mm/s to 5 mm/s are considered acceptable. There were no commercial/industrial operations along the tunnel section that were identified as being highly sensitive to vibration. On that basis, the lower range of the generalised criterion discussed above is considered appropriate for adoption, at this stage of the project. These levels maybe subject to some refinement during the course of the project, should the occurrence of relevant operations be identified.

It is recognised that these levels would be clearly perceivable to occupants of the building. Further the groundborne noise resulting from the vibration may exceed the appropriate criterion and consequently require that lower vibration levels apply.

4.1.7 Industrial Noise Sources – Airborne Noise (operational phase)

Noises associated with the project that arises from sources (other than from rolling stock) are assessed using the criteria detailed in the NSW Governments *Industrial Noise Policy* (INP), though they are not strictly from an "industrial" source. Such sources of noise may include fans from ventilation stacks, mechanical services from platforms, PA systems etc.

The INP requires that the noise from a source be assessed against the more stringent of:

- The intrusive criteria – A noise source will be deemed to be non-intrusive if the $L_{Aeq,\,15\,minute}$ level does not exceed the RBL[vii] by more than 5 dB(A) for each of the day evening and night-time periods, and does not contain tonal, impulsive, or other modifying factors as detailed in Chapter 4 of the INP; and
- The amenity criteria – which is a predefined and recommended upper level of industrial noise within an area, given the land-use and zoning of the surrounding area. There are recommended intrusiveness criteria for the daytime evening and night-time period.

Table 4-4 presents a summary of the noise criteria for which any sources of noise (other than rail noise) should comply.

Table 4-4 Summary of Industrial Noise Criteria

Location	Time period	RBL	Intrusiveness Criteria	Base Amenity Criterion	Modified Amenity Criterion	Governing Criterion
Location 1: 2 Sutherland Road, Cheltenham	Day	39	44	55	55	44
	Evening	38	43	45	45	43
	Night-time	34	39	40	40	39
Location 2: 52 The Crescent, Cheltenham	Day	39	44	55	55	44
	Evening	37	42	45	45	42
	Night-time	31	36	40	40	36
Location 3: 30 Sutherland Road, Beecroft	Day	43	48	55	55	48
	Evening	41	46	45	45	45
	Night-time	36	41	40	40	40
Location 4: 2A The Crescent, Beecroft.	Day	44	49	55	55	49
	Evening	44	49	45	45	45
	Night-time	34	39	40	40	39
Location 5: 10 Fleur Close, West Pennant Hills	Day	41	46	55	55	46
	Evening	36	41	45	45	41
	Night-time	30	35	40	40	35
Location 6:113 Castle Hill Road, Cherrybrook	Day	43	48	55	55	48
	Evening	42	47	45	45	45
	Night-time	29	34	40	40	34
Location 7: 128 Franklin Road, Cherrybrook	Day	49	54	55	55	54
	Evening	47	52	45	45	45
	Night-time	35	40	40	40	40
Location 8: 18 Old Castle Hill Road, Cherrybrook	Day	54	59	55	55	55
	Evening	49	54	45	45	45
	Night-time	38	43	40	40	40
Location 9: 2 Brisbane Road, Castle Hill	Day	51	56	55	55	55
	Evening	46	51	45	45	45
	Night-time	37	42	40	40	40
Location 10: 49 Showground Road, Castle Hill	Day	57	62	55	55	55
	Evening	51	56	45	45	45
	Night-time	39	44	40	40	40
Location 11: 112 Showground Road, Castle Hill	Day	58	63	55	55	55
	Evening	52	57	45	45	45
	Night-time	33	38	40	40	38
Location 12: 20 Carrington Road, Castle Hill	Day	48	53	55	55	53
	Evening	43	48	45	45	45
	Night-time	35	40	40	40	40

Location	Time period	RBL	Intrusiveness Criteria	Base Amenity Criterion	Modified Amenity Criterion	Governing Criterion
Location 13: 31 Fairway Drive, Castle Hill	Day	41	46	55	55	46
	Evening	39	44	45	45	44
	Night-time	36	41	40	40	40
Location 14: 10 Emmanuel Tce, Glenwood – facing Old Windsor Rd	Day	48	53	55	55	53
	Evening	44	49	45	45	45
	Night-time	34	39	40	40	39
Location 15: 21 Balmoral Road Kellyville	Day	38	43	55	55	43
	Evening	40	45	45	45	45
	Night-time	35	40	40	40	40
Location 16: 27 Burns Road, Kellyville	Day	55	60	55	55	55
	Evening	51	56	45	45	45
	Night-time	38	43	40	40	40
Location 16b: 15 Burns Road, Kellyville	Day	47	52	55	55	55
	Evening	44	49	45	45	45
	Night-time	32	37	40	40	40
Location 17: Lot 26, Old Windsor Rd, Kellyville	Day	46	51	55	55	51
	Evening	46	51	45	45	45
	Night-time	35	40	40	40	40
Location 18: 11 Weynden Avenue, Kellyville	Day	38	43	55	55	43
	Evening	41	46	45	45	45
	Night-time	36	41	40	40	40
Location 19: 7 Austin Place, Kellyville	Day	41	46	55	55	46
	Evening	41	46	45	45	45
	Night-time	34	39	40	40	39
Location 20: 9 Terry Road, Rouse Hill	Day	41	46	55	55	46
	Evening	41	46	45	45	45
	Night-time	37	42	40	40	40
Location 21: 109 Rouse Road, Rouse Hill	Day	37	42	55	55	42
	Evening	36	41	45	45	41
	Night-time	32	37	40	40	37

A potential source of industrial noise would be around the stabling yards, proposed for Rouse Hill, west of Windsor Road. This area is currently a rural/residential area, with residences on large blocks of land. As the Rouse Hill Town Centre develops, it would be expected that the general noise environment would also increase, in line with the increasing urbanisation of the area. With increasing ambient noise in an area, the controlling criterion usually becomes the amenity criteria, which for a suburban area at night is 40 dB(A). Allowing some contribution from distant industrial sources (unrelated to the project) it would seem reasonable that the design be 38 dB(A). By comparison with the criterion based on the current noise environment, the proposed criterion of 38 dB(A) is consistent with the criterion determined for Location 20 and Location 21.

4.1.8 Station Acoustics (operational phase)

Rail noise is very difficult to control on the platforms of stations. Criteria exists for the mechanical services associated with specific areas as detailed below:

- ticketing areas 45 dB(A) to 50 dB(A); and
- general waiting areas (excluding station platforms) of 45 dB(A) to 55 dB(A).

In addition, it is essential that design of the PA system and the acoustical characteristics of the platform area be designed to maximise speech intelligibility, and commuter comfort. As a general rule, the reverberation times (RT) in an enclosed station should be minimised (as far as practical) so as to minimise the build-up of train noise in the platform area.

4.2 Construction Emissions

4.2.1 Airborne Noise Assessment (construction phase)

Noise from construction works is usually assessed under the guidelines detailed in Chapter 171 of the EPA's *1994 -Environmental Noise Control Manual.*

The acceptability of construction noise within a community is likely to depend upon the potential for its interfering with activities, the duration of the event, and the extent of its emergence above the background noise. Therefore the design objectives would be expected to vary along the route, and with differing levels during the day, evening and night-time periods.

Noise from the construction activity is of limited duration, therefore the community would tend to tolerate higher noise levels than would be acceptable for a permanent noise source, so long as any particular piece of equipment is not obviously producing an excessive amount of noise. Short-term, medium and long-term noise objectives reflect this acceptance.

The EPA recommends that the free-field $L_{A10\,(15\,minute)}$ noise levels arising from a construction site (or works) and measured in the general vicinity of any noise sensitive premises should not exceed:

- background plus 20 dB(A) for a cumulative period of noise exposure not exceeding four weeks;
- background plus 10 dB(A) for a cumulative period of noise exposure between four weeks and 26 weeks; and
- background plus 5 dB(A) for a cumulative period of exposure greater than 26 weeks.

The EPA recognises that it is not always possible to achieve the construction noise objectives at all residents and normally advocates that noise control measures must be both "reasonable and feasible".

The *Rail Infrastructure Study* (Arup, 2001) indicates that the *overall* duration of the construction works along the above ground section of the NWRL alignment would be greater than 26 weeks. The EPA's general approach is that the criterion should be based on the "background +5 dB(A)", even though for some residents, their exposure to the construction works would be less than 26weeks. In adopting this criterion, it is understood that it is likely to be very conservative for many residents away from the tunnel portals. During the next phase of the works when the construction methodology is still further refined, negotiations with the EPA regarding variations to the 'background + 5 dB(A)" rule for specific areas along the route should be undertaken.

On this basis, the external construction noise guidelines are detailed in **Table 4-5**.

For residential dwellings there is an assumed noise reduction across the building facade and the residential criteria takes that into account. For the Hillsong Church Buildings and The Hills Centre however, the building envelope provides significant attenuation and it is more appropriate that an internal criteria apply for these spaces, given that is where the impacts are likely to occur. With reference to the recommended internal noise levels presented in AS 2107, (part reproduced in **Table 4-2**) and considering the transient form of the construction activities, the target construction noise should be set at 30dbA. Such levels would apply when facade doors are normally closed and cooperative efforts are made to assist in minimising noise transfer. It should be noted that further monitoring is required, and should it prove that ambient levels exceed this proposed criterion, then the construction noise target may be revised.

- **Table 4-5 Daytime Construction Noise Criteria**

Location	RBL	Construction Noise Criteria – Daytime only
Location 1: 2 Sutherland Road, Cheltenham	39	44
Location 2: 52 The Crescent, Cheltenham	39	44
Location 3: 30 Sutherland Road, Beecroft	43	48
Location 4: 2A The Crescent, Beecroft	44	49
Location 5: 10 Fleur Close, West Pennant Hills	41	46
Location 6:113 Castle Hill Road, Cherrybrook	43	48
Location 7: 128 Franklin Road, Cherrybrook	49	54
Location 8: 18 Old Castle Hill Road, Cherrybrook	54	59
Location 9: 2 Brisbane Road, Castle Hill	51	56
Location 10: 49 Showground Road, Castle Hill	57	62
Location 11: 112 Showground Road, Castle Hill	58	63
Location 12: 20 Carrington Road, Castle Hill.	48	53
Location 13: 31 Fairway Drive, Castle Hill	41	46
Location 14: 10 Emmanuel Tce, Glenwood –facing Old Windsor Rd	48	53
Location 15: 21 Balmoral Road Kellyville	38	43
Location 16: 27 Burns Road, Kellyville	55	60
Location 17: Lot 26, Old Windsor Rd, Kellyville	46	51
Location 18: 11 Weynden Avenue, Kellyville	38	43
Location 19: 7 Austin Place, Kellyville	41	46
Location 20: 9 Terry Road, Rouse Hill	41	46
Location 21: 109 Rouse Road, Rouse Hill.	37	42

Hours of Construction

The EPA guidelines recommend confining the permissible noisy work times to:

- 7.00 am to 6.00 pm, Monday to Friday;
- 7.00 am to 1.00 pm on Saturdays if inaudible at residences otherwise (8.00 am to 1.00 pm); and
- no construction is permitted on Sundays or Public Holidays.

The EPA must be advised of out of hour's work. Works may be conducted outside these hours, if it can be demonstrated that the construction activities have negligible impacts on nearby residential dwellings. Works outside of hours may also be conducted with consideration of issues of safety or when construction work would result in major traffic disturbances.

4.2.2 Vibration (construction phase)

The assessment of vibration should be considered in terms of its influence on occupants (ie human comfort), and the effects on the structure of the building. It is not always possible for construction works of major infrastructure projects that are in very close proximity to residential dwellings to comply with the human comfort criterion, however this should always be used as the target objective, and be the basis of assessment.

The Hillsong Church and Hills Centre are two buildings where the vibration from construction works has the potential to disrupt the intended use of the space(s), when they are in use.

It is recommended that the vibration levels during construction aim for compliance with 1 mm/s at these sensitive spaces as discussed in *Section 4.1.6*, although intermittent higher levels events are unlikely to result in any significant impacts, particularly if they occur when the building is otherwise not being used.

4.2.3 Groundborne Noise from Tunnelling works (construction phase)

Levels of vibration can be transmitted into the ground by some construction operations, such as tunnel boring machines, rockhammering, or road-headers. These vibration levels can cause a low-frequency rumbling sound to be generated within rooms of a building, particularly those rooms below ground level.

Although the EPA does not have any policy for groundborne noise from construction works, based on the approval conditions of other major infrastructure projects, a target objective of 35 dB(A) would most likely be applied to residential receivers in the vicinity of the works.

Experience shows that this level is not always achievable, however "best practice" methods of excavation should be adopted to approach this value as closely as possible and to minimise any exceedances. Based on what is considered practically achievable, a level of groundborne noise of 40 dB(A) is considered more appropriate for residential dwellings, subject to the noise not containing impulsive characteristics (such as that resulting from rock-hammering). This higher level reflects the more transient nature of the noise source.

Construction emissions at the Hills Centre and the Hillsong Church buildings, should aim for compliance with the operational criteria **Table 4-2**.

5. Predicted Levels and Assessment – Construction Works

5.1 Driven Tunnels

The 11.6 km of twin tunnels would be constructed using Tunnel Boring Machines where the excavation rates would vary between 150 m to 200 m per week in Hawkesbury Sandstone and 80 m to 100 m per week through Ashfield Shale [viii], [ix].

Tunnelling would commence at the Norwest Portal and advance eastwards. All spoil from the excavation of the tunnel would be removed by truck from the Norwest Portal.

An overview of the excavation procedures is presented in **Figure 5-1**.

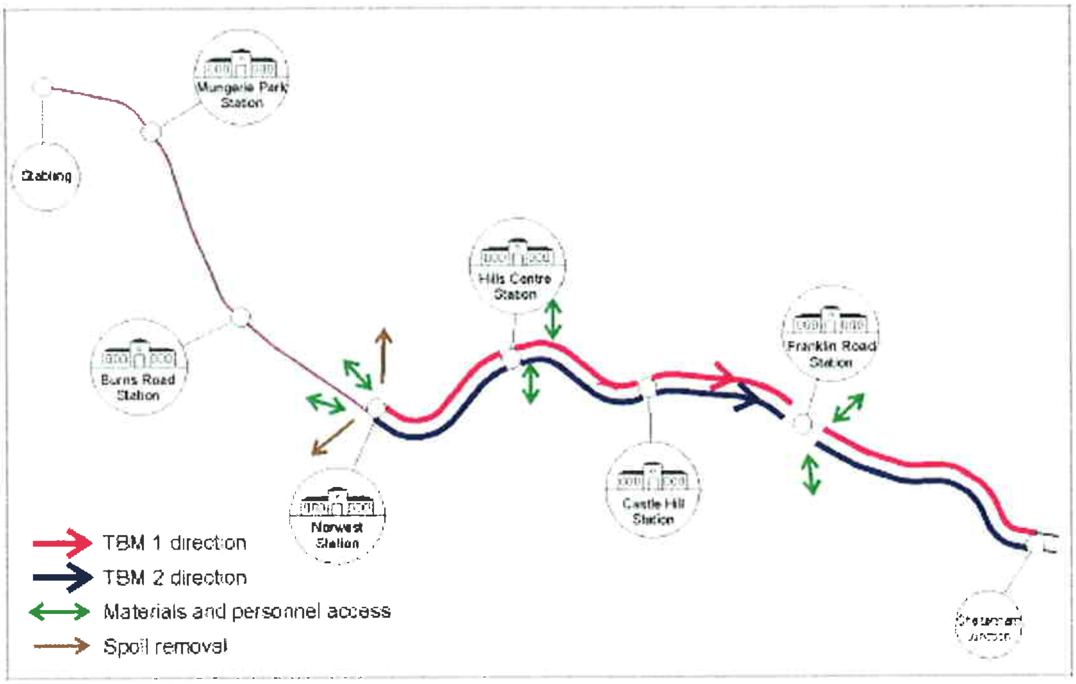


Figure 5-1 Excavation of Driven Tunnels[x]

The depth of the tunnel varies along the length but is around 30 m (or shallower) for half its length and is considered to be relatively shallow. **Figure 5-2** presents a distribution of the tunnel depth. The tunnel is at is shallowest at chainage 35340, just west of the Hills Centre Station, where it is only around 5 m (to the centre of the tunnel), though at this location there are no buildings immediately above. At chainage 30460, (near the western end of Franklin Road Station) the distance to the centre of the tunnel is only 11 m deep, though there are no residents immediately above the tunnel.

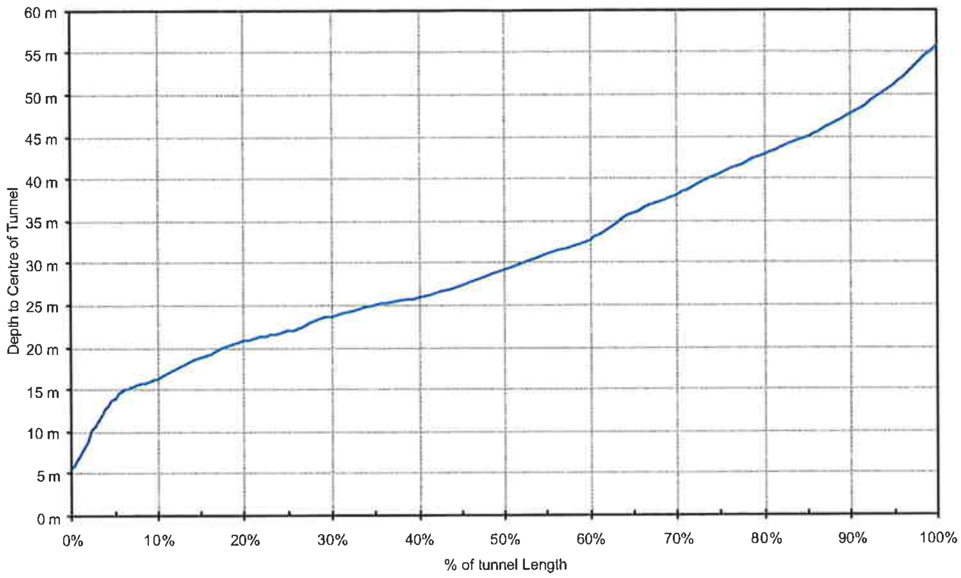


Figure 5-2 Cumulative Distribution of Tunnel Depth (to centre of tunnel)

5.2 Beecroft Dive Structure

As part of the wider project, the dive structure would be designed as an integral part of the Quadruplication of the tracks between Beecroft and Epping. The final design of these works is in the preliminary phase, and is not assessed as part of this study. The assessment procedure is therefore considered preliminary.

The Beecroft tunnel would not be used to remove spoil from the Tunnel, as excavation would generally advance from the Norwest Portal. Works would however be required for the dive structure, track laying, overhead cabling, some track rearrangement etc.

Although the residential areas are located adjacent to the existing rail network between Beecroft and Cheltenham, the noise environment does not result in a relatively high background noise. Baseline measurements indicate that daytime construction objectives of between 44 dB(A) to 49 dB(A) would apply to residents along the corridor near the proposed dive structure, assuming the construction works extend more than six months.

As part of the dive structure and trackwork, it would be expected that retaining walls would be piled (bored), with the material excavated using a rock-breaker or similar process, and the spoil ultimately removed from the site by truck. The rail tracks would be laid using a track laying machine and finished using a ballast tapping machine.

The activities are predicted to result in a range of L_{A10} noise levels of between 61 dB(A) to 74 dB(A), depending upon the activity and depth of works and the final construction site layout. Such emissions are significantly above the noise objectives, and it would be expected that some impacts would result.

In order to mitigate the extent of impacts, the following measures should be considered:

- Use of portable barriers should be considered, though this may prove feasible;
- The establishment of a pro-active community consultation program;
- Monitoring of the emission levels during construction.

5.3 Tunnelling Impacts on Residential Dwellings

The groundborne noise experienced at residential dwellings resulting from tunnelling works would increase at the TBM approaches, then progressively decrease as the machine continues to advance. Depending upon the rock and rate of progression the higher noise levels would be expected to last only several days, though the works may be audible at much lower levels for between one to two weeks.

The predicted upper limits of groundborne noise from the TBM are expected to comply with the 35 dB(A) criterion beyond a nominal 50 m offset distance, as shown in **Figure 5-3**.

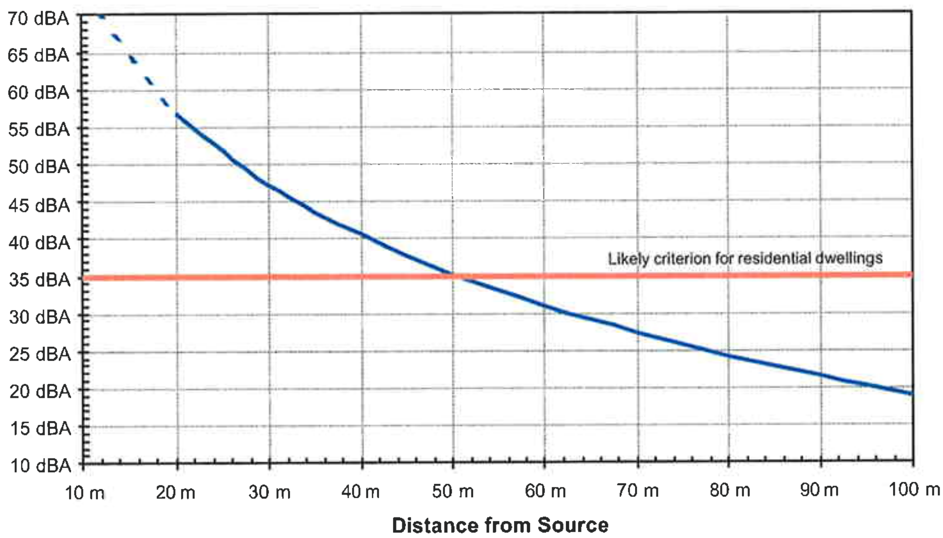
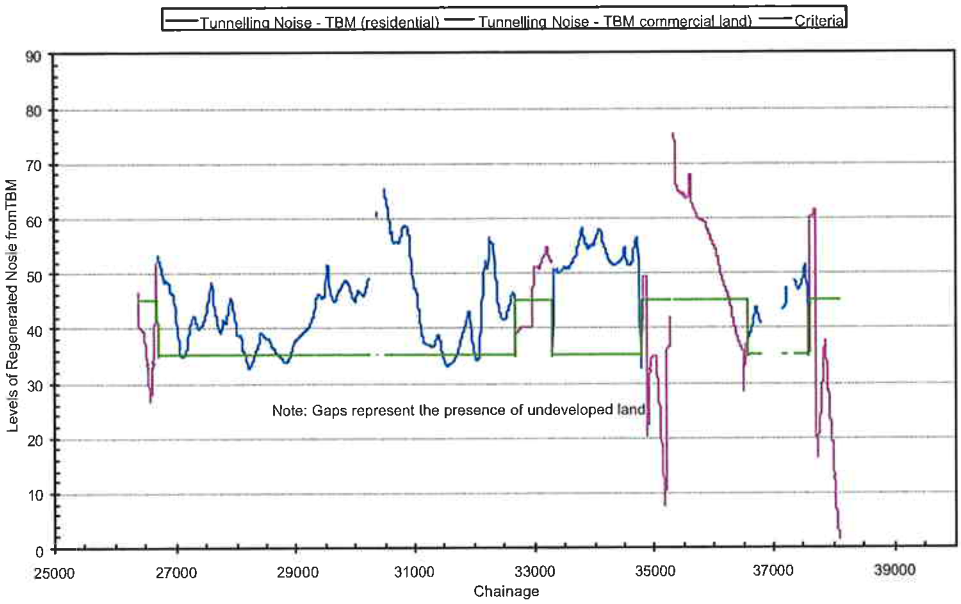


Figure 5-3 Predicted Groundborne Noise from TBM [xi]

Predictions of the level of groundborne noise from the tunnelling works are based on generalised formula based on empirical data and are considered representative. Predictions of the levels of groundborne noise presented in other EIS's (eg. Parramatta to Chatswood Rail Link) show general agreement with the levels presented in **Figure 5-3** for offset distances of 20 m to 40 m. The predicted levels of groundborne noise at 10 m offset distances are slightly higher than other published data, but care must be taken as they are more prone to higher levels of uncertainties in measurement distances; and other local effects, such as strata differences; structural response of the dwelling; wall constructions etc.

Figure 5-4 presents the potential upper levels of groundborne noise for any buildings, currently or potentially located immediately above the proposed tunnels.

It is clearly apparent that residents immediately above the tunnel(s) would be expected to experience short-term levels of construction noise well in excess of the EPA's criteria, and some acoustic impacts would be expected. In order to assist in mitigating the impacts, progressive monitoring would need to be undertaken, and a pro-active community consultation program developed, with the most affected residents invited to focus group meetings.



■ **Figure 5-4 Expected Levels of Groundborne Noise Levels from the TBM, in Buildings Immediately above the Tunnel**

It is emphasised that the levels predicted in **Figure 5-4** apply for the closest resident to the progressive tunnel workings. The groundborne noise is predicted to generally be up to the mid fifty range (as measured on the dB(A) scale), however there is a small region (around Ch 30510) where the levels may be a further 10 dB(A) higher. At these higher impact areas, where the tunnel is quite shallow, the further measures will need to be developed, as the project becomes more refined. Such measures may include:

- studying the effects of the lowering rate of progression of the TBM (at key areas only) on the levels of regenerated noise;
- use of substitute means of excavation in key areas only;
- lowering of the depth of the tunnel; or
- short-term relocation of the residents.

Given the area of affectation presented in **Figure 5-4**, compliance with the EPA's 35 dB(A) objective can only be considered an ideal objective. Even the more realistic 40 dB(A) criterion would be exceeded for short periods for the houses directly above the TBM.

A roadheader would also be used at some locations along the route, the operation of a relatively large roadheader results in groundborne noise levels approximately 5dB(A) lower than that of a TBM, thus the impacts from the somewhat isolated use of the roadheader are expected to be noticeably lower.

The vibration resulting from the use of the roadheader is predicted to be less than 0.2 mm/s at any location and therefore not likely to result in any significant impacts.

In addition to the use of the TBM, is also possible that rockbreakers may be used at discrete locations to break up localised areas of very hard rock. The use of rockbreakers result in much higher levels of groundborne noise and vibration, and may be the source of complaint (mainly from the noise, rather than the vibration) from residents 50 m or more from the works area. Consequently, consistent with other recent tunnelling projects, it is recommended that rockbreaking (or the use of other impulsive machines) be restricted to daytime hours only.

The Building Damage Criterion for vibration, as discussed in *Section 4.1.5*, is not expected to be exceeded, though it is important that changes are not made to the vertical alignment such that the tunnel becomes shallower around Chainage 35360, where the tunnel is quite close to the surface.

5.4 Impacts on Council Chambers and Hills Centre

The Hills Centre is located adjacent to the Baulkham Hills Council Chambers on Carrington Road. At the closest point, the nearside tunnel is located approximately 50 m away, the far-side tunnel is approximately 70 m away from the Hills Centre.

The use of the facility is such that a construction noise objective of 30dB(A) should apply inside the centre, when the facility is being used. When not in use, higher noise levels can apply. Given the offset distances, it is predicted that the Hills Centre would only experience levels of up to 33 dB(A), which represents a marginal exceedance and would not result in any significant acoustical impacts. Based on the expected rate of progression of the TBM, such impacts would be for duration of up to two weeks.

With reference to **Table 4-2**, the more sensitive spaces of the Council Chambers building can be viewed in a similar manner to a "board or conference rooms" in an office building, and construction noise objective of 45 dB(A) would normally apply. Predictions indicate that as a portion of the Council Chambers is located directly above one of the tunnels, there will be up to a 4dB(A) exceedance of the design criteria when works are directly below. Given the higher noise levels are generally limited to the daytime and would only occur for a few days, the overall extent of impacts would be considered relatively small, but more importantly manageable. Given this, it is recommended that a works timetable or schedule be developed with the Council that allow for the acceptable integration and cohabitation of both activities.

5.5 Construction Impacts on Hillsong Church

The Norwest portal, proposed to be located adjacent to the Hillsong Church, would be used as a major construction area for the removal of spoil from the tunnelling works.

The area would need to be initially excavated to a depth of between 13 m to 17 m below existing natural ground. The geology of the area is the subject of further investigation, but it is understood **Table 5-1** is a fair representation.

Table 5-1 Geology of the Norwest Station and Rail Area

Local Geology	Methods of excavation
One to five meters of colluvium and or residual soil	Conventional earthmoving equipment (excavator or bulldozer)
Nine to 12 m of Ashfield Shale	- If weathered: excavator or bulldozer; or - If fresh (ie not weathered): heavy ripping equipment (D9 or larger)
Up to 10 m of the Mittagong Formation	
Hawkesbury Sandstone	

A detailed construction program has yet to be developed, but it assumed that a "ripper" mounted on the rear of a bulldozer would be used to excavate the site between Solent Circuit to the portal at Chainage 37770. At the closest point from the edge of the cutting, it is 50 m to the facade of the existing Church building and 25 m from the new Convention Centre.

At the portal, it would be expected that a roadheader(s) would be used to excavate the first 200 m (nom) of the tunnel, prior to the assembly and subsequent use of the TBM.

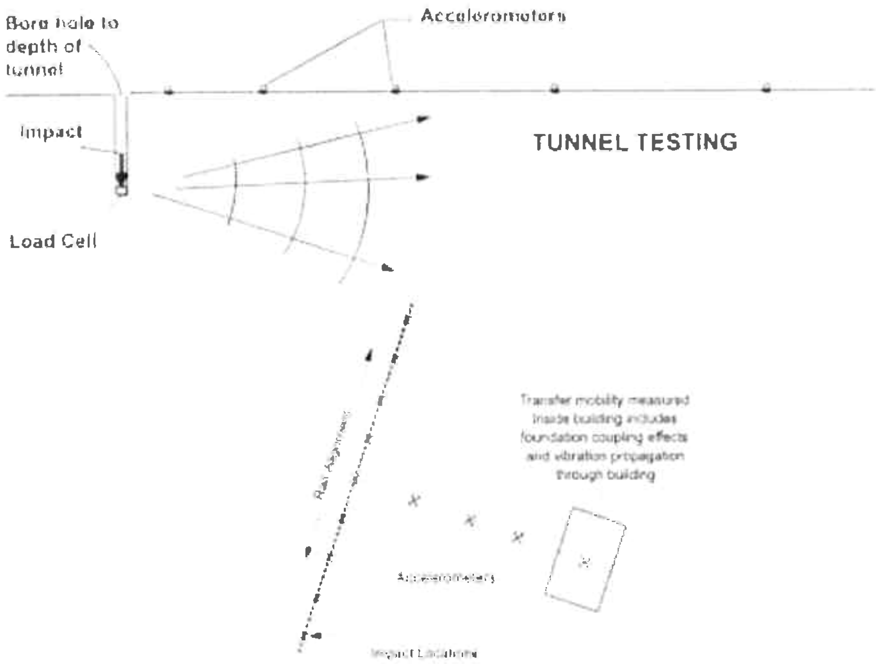
Noise from the surface works would be expected to vary as detailed below:

Construction Works	Typical external construction design objective	Predicted L_{A10} Levels to the new Convention Centre Building	Predicted L_{A10} Levels to the existing Hillsong Church Building
Earthworks	To be confirmed, typically 50 dB(A)	69 – 80 dB(A)	62 –71 dB(A)
Roadheader	To be confirmed, typically 50 dB(A)	72 dB(A) near the surface reducing to 61 dB(A) at depth	80 dB(A) near the surface reducing to 68 dB(A) at depth

During the initial phase of the works, some significant exceedances of the EPA's general guidelines would be expected. A site inspection undertaken showed that the main entrance doors for the new centre overlook the carpark wich will lead to the Norwest Boulevard end of the station, however the design of the facility was such that there would be a considerable transmission loss[xii] through the building structure between the internal performance area and the external environment. No measurements of the transmission loss of the building have been undertaken. There are two sets of doors between the carpark area and the internal spaces, with the doors strategically offset from one another. With all relevant doors closed, it would be anticipated that an STC [xiii](or R_w) would be in the order of 50 to 55 (and possibly much higher). This would imply that the impacts inside the facility might not be as significant as the external noise levels would initially suggest. Acoustic testing of Transmission Loss of the facade should be undertaken to fully determine the extent of impacts, to allow for strategy plan to be developed which allows the successful cohabitation of the church activities and the construction works.

Notwithstanding, it would be recommended that temporary barriers be installed along the eastern edge of the construction works to assist with minimising the acoustical impacts. The height of the walls would be fully documented as the construction program for the site is progressively developed, but preliminary calculations would indicate that a 2 m to 4 m wall may be required.

The level of groundborne noise from the use of the roadheader into the new convention centre is estimated to vary between less than 25 dB(A) when working at the extremities of the local site area to 44 dB(A) when at the closest point. Groundborne noise of 25 dB(A) would result in almost no acoustic impacts, whilst levels around 44 dB(A) would likely give rise to acoustical impacts, with restricted use of the space likely at during this period. Given that groundborne noise is propagated as vibration, the use of barriers does nothing to reduce these levels. The calculations assume a somewhat homogenous rock stratum between the roadheader and Convention Centre, the presence of small faults, fissures, or other inconsistencies would act to lower the levels of vibration, and hence groundborne noise. In order to quantify this, it is recommended that the transfer mobility be measured between the proposed rail corridor and the Convention Centre, to allow for the more accurate determination of impacts at this site, as schematically detailed in **Figure 5-5**.



■ **Figure 5-5 Schematic of Mobility Testing**

This procedure is quite well documented and is the procedure recommended in the *Transport Noise and Vibration Impact Assessment,* Harris Miller Miller and Hansen for the US Department of Transportation.

Vibration from the construction works is not expected to result in any significant acoustical impacts to the existing buildings. At the closest point, the operation of the roadheader would be expected to result in a rms[xiv] vibration level in the order of

0.03 mm/s, which would subjectively be described as being below the threshold of human perception.

The Norwest portal would also be the main route by which spoil is removed from the tunnel.

During excavation of the tunnel, the maximum stock pile size has been estimated to be 100 x 40 x 3 metres high. The type of truck used for material transfer out of the tunnel is yet to be determined however, an estimate of the maximum number of trucks required to clear this stockpile is 202 trucks per 24 hour period (404 truck movements). Such a stockpile represents 36 hours of production. The trucks exit the portal at grade and would travel at the RL of the tracks, nominally 15 m below natural ground. During excavation at the stations, the volume of spoil would be expected to be around 3,500 tonnes per week (based on a ten hour working day, five day week). Therefore the average number of trucks using a station site on a per day basis could be as high as 28 trucks (56 movements).

Impacts on local activities would be fully determined once transport routes have been determined. It is expected that the impacts are likely to be clearly audible outside the Convention Centre, but not inside. Vibration from the movements of trucks can be effectively managed through the maintenance of a pot-hole free road surface, from the portal to around Solent Circuit. Impacts on the surrounding road networks would be detailed once the options for the truck route have been refined.

During construction, it is also likely that a ventilation fan and a dust collection system would be required at the Norwest portal. The degree of treatments would need to be reviewed during the detailed design, and would need to be designed so as not to exceed the proposed 30 dB(A) internal design objective. The achievement of these noise objectives would require extensive noise control treatments to be considered in the design from the onset including:

- the need for inlet and discharge silencers on the fans;
- the fans be totally encased with an independently but demountable framed structure faced with several layers of plasterboard or Compressed Fibrous Cement (CFC) sheeting with the fans being located well into the tunnel, or if this is not practical they should be enclosed in an enclosure or fan room; and
- dust collection systems may require housing in a purpose enclosure, designed with access to the dust-bags, with the discharge going through a low pressure plenum or similar noise control system.

5.6 NW of the Norwest Portal

Beyond the Norwest Business Park the tracks are generally in cut, excepting for two bridge structures.

Construction works would be undertaken using conventional earth moving techniques, with the spoil removed from the site by truck.

The land in this section of the project is undergoing extensive redevelopment. This assessment is based on those dwelling locations that are currently identifiable, though it is acknowledged the population density will increase along the length of the line.

Between the Norwest Business Park Portal and just north of Burns Road, the rail corridor passes through a number of "isolated" dwellings, which are typically 50 m to 100 m from the railway tracks. Given the nature of the construction works it is estimated that construction noise levels would vary according to:

Construction Works	Typical Construction Design Objective	Predicted L_{A10} Levels
Earthworks, including laying of tracks	41	48 – 63

These calculations do not include the noise emissions from the use of a rockhammer, should it be required. Given the reasonably isolated nature of the works, some exceedances of the design objectives are expected when works are being undertaken immediately adjacent to the property.

In order to mitigate these impacts, it is expected that temporary barriers be considered where feasible and reasonable, and time restrictions be imposed on the use of rockbreakers, such that they be limited to Monday to Friday, and then one-hour shorter (morning and night) than the EPA standard construction hours.

To the south of the Old Windsor Road / Windsor Road intersection, the rail is constructed on a viaduct and travels parallel to Old Windsor Road. On the western side of Old Windsor Road, new residential subdivisions and land shortly to be developed exists. The suburb of Kellyville lies to the east of the corridor.

Given the nature of the construction works it is estimated that construction noise levels would vary according to:

Construction Works	Predicted L_{A10} Levels		Typical Construction Design Objective
	Earthworks	Construction of Viaduct	
Residences to the east of Old Windsor Road (south Kellyville)	30 to 36	30 to 36	43
Residences to the east of Old Windsor Road (north Kellyville)	30 to 36	30 to 36	46
Residences to the West of Windsor Road	47-51	47-51	51-53

For this section of the rail line, the construction noise emissions are likely to comply with the design objectives, and therefore not result in any significant impacts.

The construction of the permanent stabling yards has not been fully defined. The location of baseline noise surveys were therefore selected so that they would be broadly representative of ambient noise in the wider area. It is proposed to be constructed on up to 8 m of fill. This would be undertaken using conventional earth moving equipment, trucks, dozers, graders, compacters etc.

Given the typical construction objectives of 42 dB(A) to 46 dB(A) and the operations, there would need to be a buffer of around 150 m to 200 m so as to achieve the design objectives. It is noted that there is a school located on the corner of Worcester Road and Rouse Road. Should the yard be sited such that the noise objectives were to be achieved at this location, then no impacts at the school would be expected.

Levels of vibration and groundborne noise are predicted to be below the criterion along the entire surface section of the route.

5.7 Vibration Impacts on Heritage Buildings

Section 2.1 presents a list of the heritage structures identified above the tunnel section of the project. No structural inspection of these buildings has been undertaken. Anecdotal comments indicate that the structure is understood to be of a sound condition, but it is understood that some of the buildings have reported to contain "weak mortar" (personal communication, Robynne Mills).

As discussed, British Standard BS 7385 has been adopted as the basis for vibration assessment, due to its general acceptance by approval authorities, and it representing the most recent major review of the international vibration standards.

The standard suggests that *the probability of damage tends towards zero at 12.5 mm/s peak component particle velocity*[xv]. Also, it suggests that the values recommended should be reduced by 50% as a safety measure to eliminate the possible effects of dynamic magnification due to resonance in the structure. Thus for the assessment of impacts on damage to heritage buildings, a limit of 6 mm/s should apply. BS 7385 also states that *a building of historic value should not (unless it is structurally unsound) be assumed to be more sensitive [to vibration].* Thus there is an implication that the criteria applies to buildings that are in "normal" condition.

The other standard commonly used for vibration assessment is the German Standard DIN 4150*: Structural vibrations in Buildings: Effects on Structures*. This standard presents maximum vibration criteria for *buildings that are under a preservation order*, which varies between 3 m/s and 10 m/s depending upon the frequency content.

The operation of the TBM would not result in any exceedances of either criterion, however it is possible that the use of a rock-breaker may approach or exceed the limits in some circumstances. It is therefore recommended that rockbreaking within 50 m of a heritage structure should result in a consultation and monitoring program.

5.8 Construction of the Railway Stations

The stations fall into three basis types:

- Underground Stations: Franklin Road, Castle Hill, and the Hills Centre Station are constructed within bored/mined caverns or in cuttings and then filled over;
- Stations in Cuttings: Norwest Business Park and Rouse Hill Town Centre Stations are relatively close to the surface and are designed to maximise light and ventilation; and
- Above ground Stations: Burns Road would be built above the ground with the concourse level acting as pedestrian bridges to link the communities either side of the at grade railway line.

Franklin Road Station

The station and a commuter carpark would be built in a cutting, which will be then covered over. The station level would be suspended from the roof above, thus eliminating the need for column structures on the platform. The exposed cuttings would be stabilised with a form of piled wall and lined with precast concrete panels. Bridge and stair construction is steel framed concrete decking.[xvi] The station would be constructed prior to the tunnelling works.

The general area around the station is largely undeveloped with residential to the north and south.

During period construction works, the following construction emissions could be expected:

Construction Works	Typical Construction Design Objective	Predicted L_{A10} Levels
General earthworks	54	60-68
Piling	54	Up to 76 (depending on method and location)

Predicted noise levels during construction would exceed typical construction design objectives. Therefore, during the detailed design phase, all feasible noise mitigation measures should be examined, including barriers and time restrictions (for at least certain operations), including a review of all options to minimise piling noise, particularly the use of bored piles.

Castle Hill Station

Castle Hill Station is located within a commercial area, but close to some residents on Old Northern Road and the surrounding local roads.

This station would be a cavern construction, with the excavated walls rockbolted and shotcreated for stability. The visible walls would be lined with precast concrete panels. The construction space around the station box would be very restricted due to the town centre location[xvi]. The TBMs would pass through the Castle Hill Station site after the station main box and cavern has been fully excavated.

Noise from the operations is likely to be in the range:

Construction Works	Typical Daytime Construction Design Objective	Predicted L_{A10} Levels
Cavern construction	55	59-66
Rockbolting and shotcreteing	55	57-62

Some minor impacts may be expected whilst works are being undertaken. A review of the construction noise emissions should be undertaken once a detailed construction plan has been prepared.

Hills Centre Station

The station is located within a commercial area, with residents located approximately 200 m to the south.

The station would be a cut and cover construction. The excavated walls and are rockbolted and shotcreated as required. The visible walls are to be lined with concrete panels. The concourse would be suspended from the roof. [xvi]

The noise from the operations is likely to be in the range:

Construction Works	Typical Daytime Construction Design Objective	Predicted L_{A10} Levels
Cavern construction	53	50- 56
Rockbolting and shotcreteing	53	52-58

Impacts are expected to be relatively minor, although some exceedances of the criteria are predicted at residents having line-of-sight to the works.

Norwest Business Park Station

Construction impacts associated with the excavation of the station are discussed in *Section 6.4*. Without the barriers previously recommended, works associated with the station fitout are expected to be slightly less that for construction works, and the expected levels of impacts within the Convention Centre are expected to be minimal, though. This would need to be further explored after transmission loss testing of the facility is undertaken.

Burns Road Station

Burns Road Station is an at grade station incorporating steel framed concrete floor type bridges and stair structures

The existing residences are likely to be at least 150 m from the station, and the noise from the construction is likely to be in the range:

Construction Works	Typical Daytime Construction Design Objective	Predicted L_{A10} Levels
Earthworks	52	55
Trackwork	52	55

Although exceedances of the design objectives are predicted, the magnitude of the exceedance is considered low, and suitable measures should be able to be considered during the detailed design phase.

Rouse Hill Town Centre Station

Rouse Hill Station will be constructed in an open cut for the full length of the platforms. The cutting will be stabilised with rock bolts and shotcrete.

The future residences are likely to be nominally 250 m from the station, and the noise from the construction is likely to be in the range:

Construction Works	Typical Daytime Construction Design Objective	Predicted L_{A10} Levels
Earthworks	52	48
Trackwork	52	50

No exceedances of the design objectives are predicted for local residents.

6. Predicted Operational Noise and Assessment – Surface Tracks

6.1 Prediction Methodology

Predictions of the noise emissions from the movement of trains along the surface section of the rail corridor west of the Norwest Business Park was undertaken using the *Nordic Prediction Method for Train Noise* (1996) procedure as implemented within the SoundPLAN (Version 5.6) suite of noise prediction programs.

The input spectra (these values should be documented in the report) was based on measurements taken by Sinclair Knight Merz and other sources[xvii,xviii] and is considered representative of the emissions from the suburban rail network.

The $L_{A,Max}$ level is based on the 5% exceedance level (loudest 1 in 20 trains, averaged across the fleet), whilst the $L_{Aeq(24hour)}$ index is based on the weighted average noise level from a wide number of measurements.

The three-dimensional topography of the surrounding region was sourced from Ausimage, and was based on ortho-rectified aerial imagery, flown in March 2002.

The input sound power data used in the modelling was all pre-calculated and entered into the model at the appropriate points along the proposed route. Changes in the sound power levels were based on:

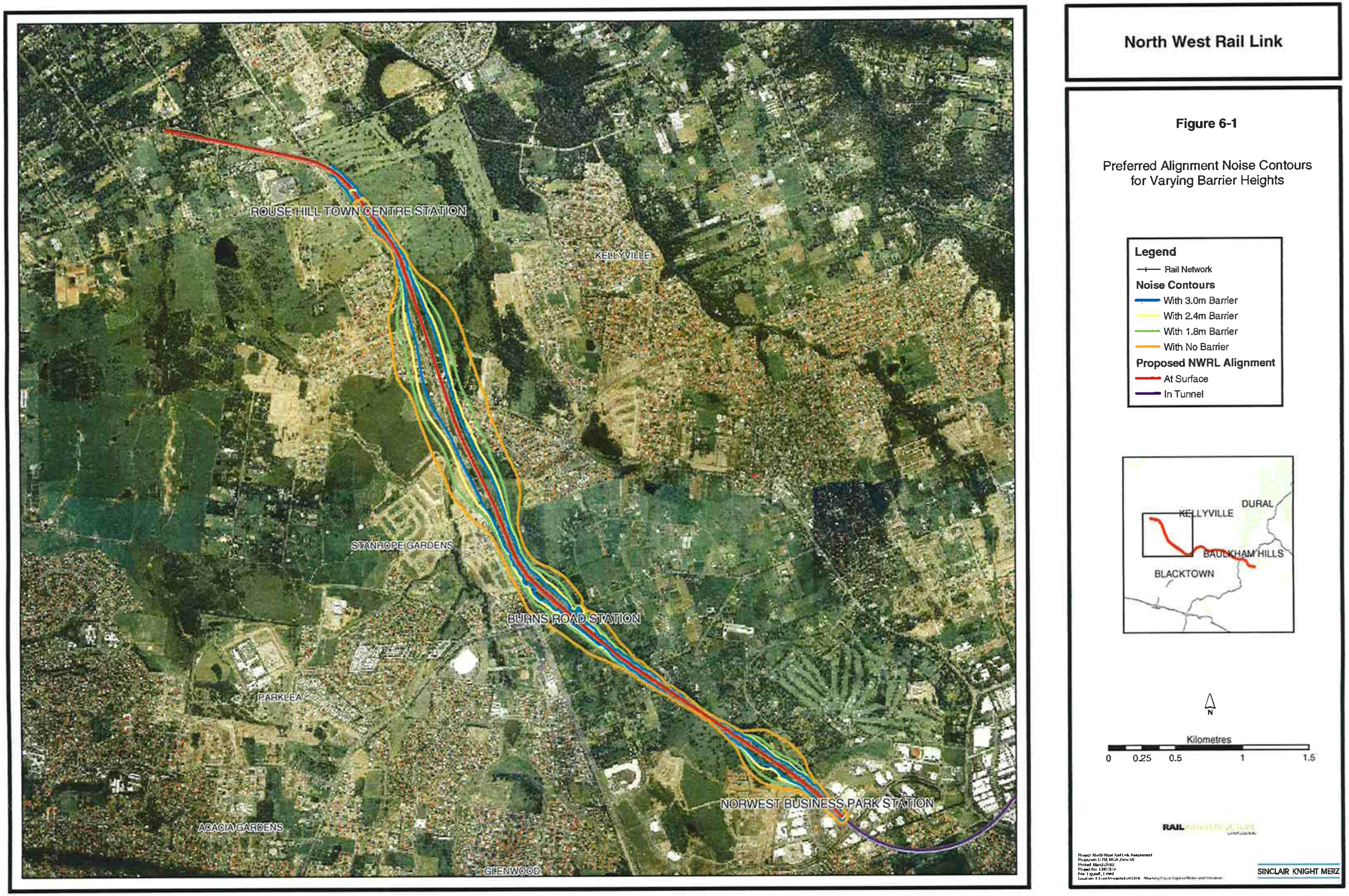
- Correction for L_{Aeq} index: 20*log(speed/80);
- Correction for $L_{A,Max}$ index: 30*log(speed/80);
- Eight car carriages; and
- Corrections for track type.

In order to ensure the validity of the model, the noise emissions predicted were compared against documented emission levels as sourced from the RIC Noise Database, with close correlation at various distances. The emissions agreed well with measurements undertaken by Sinclair Knight Merz on this and other commissions.

6.2 Prediction Output – Preferred Alignment

The output from the SoundPLAN run files is presented in **Figure 6-1** for the exposed section of track between the Norwest Business Park and Rouse Hill Town Centre Station. The image shows the $L_{A,Max}$, (as this is the dominant criterion) both with and without treatment. The following sections provide an explanation of the treatments adopted for each section. They vary between a number of scenarios:

- No noise controls;
- Erection of a 1.8 m barrier;
- Erection of 2.4m barrier;
- Erection of a 3 m barrier;



North West Rail Link

Figure 6-1

Preferred Alignment Noise Contours for Varying Barrier Heights

RAIL INFRASTRUCTURE CORPORATION

SINCLAIR KNIGHT MERZ

- Erection of a 3 m barrier together with speed restriction on the viaduct.

It can be seen that for the sections of the corridor where the track is in cutting, the width of the contours is relatively thin, that is the edge of the cutting provides an effective form of acoustic shielding. However, the following areas are observed to have local increases in the width of the contours:

- Bridge across Strangers Creek;
- The area around, and south of Burns Road Station, where the tracks are near grade;
- The area north of Burns Road and south of Old Windsor Road , where the rail is on a viaduct;
- Around the permanent railway stabling yards west of Old Windsor Road.

The land south of Burns Road will undergo extensive redevelopment. Currently there are isolated residents, most of which fall outside the area of affectation. When detailing the requirements for mitigation measures, the use of barriers is usually considered more cost-effective when treating groups of three of more dwellings. Isolated dwellings can be more effectively treated by the incorporation of architectural treatment, such as the upgrading of windows, doors and the provision of airconditioning. As new developments are released, it is the responsible of the developer to achieve acceptable noise emissions, in line with Councils criteria.

There are a number of factors that influence the location of the final contours, these include:

- **The structure of bridges**. Consideration should be given to the use of ballasted concrete bridges rather than the use of steel bridges. The use of common steel bridges with no additional measures can result in an in an increase in the $L_{Aeq(24hour)}$ index of between 4dB (A) to 9dB (A)[xix]. The noise emissions from the use of ballasted concrete bridges are generally comparable to that emitted from track at grade. With careful design, it is possible to design steel bridges so as to achieve close to no increase in noise, relative to at-grade track emissions. It is assumed that "low-noise" bridge design applies in all cases.
- **Speed of the rail vehicle**. The speed of the rail vehicle has a direct impact on both the $L_{Aeq(24hour)}$ and $L_{A,Max}$ indices, with the greater influence being on the $L_{A,Max}$ index. The use of speed restrictions in all but critical areas is inconsistent with the design of an effective mass public transport system. In this regard, the report examines the need for speed restrictions along the viaduct be limited to 110 km/h;
- **Welded track joints**. The adoption of welded track joints eliminates a characteristic source of impact noise common with older tracks. A continuously welded rail would be a recommended track configuration. Tracks that are not welded may typically increase the $L_{Aeq(24hour)}$ index by around 3dB(A), but the degree at any one site may be considerably higher;
- **Crossovers**: Similar to track joints, crossovers are a common source of impact noise and would expected to be a common source of complaint if located within close proximity to residential properties. The need to install a "low-noise" cross over system, such as a spring noise or swing noise crossing would need to be considered in the detailed design phase of the works, when the placement is more precisely known;

- **Rail Irregularities**: Irregularities in the state of the surface of the track (corrugations, surface deformations etc) can lead to increases in noise of up to 10 dB(A). It is recommended that rail grinding be undertaken when the tracks are first laid to eliminate manufacturing defects, slight track misalignments in contiguous tracks, etc. Follow up grinding may be required on a periodic basis, dependent on the properties and qualities of the track;
- **Barriers** : Noise barriers can be located at either 4.5 m or 6.5 m[xx] (dependent on the need for vehicle access) from the centre-line of the outer tracks. Barriers can be effective means of reducing airborne noise emissions to a group of residential dwellings. Depending on the available land, earth mounding can also be used, although low slope (1 in 3) usually preferred by Landscape Architects means the base can be substantial land area. For a 3 m high barrier, a minimum 18 m base would be required.

  For a barrier to be as effective as mounding, it is usual that the mounding may need to be a little higher than a barrier. As a "rule of thumb", mounding may need to be typically 0.5 m higher, assuming a barrier height of 3 m.

When designing barrier heights, they apply to a location some distance from the rail tracks. Considering space required for access between the tracks and the property boundary, planning considerations that would dictate that roads should be placed next to boundaries (rather than dwellings), unless otherwise specified, the barrier height was optimised for a distance 30 m from the tracks.

Norwest Business Park Portal to Burns Road

Figure 6-1 shows the expected contours for the section between Norwest Business Park and Burns Road. The rail tracks pass over a short (nom 25 m) length of bridge just to the north of Solent Circuit. At this point the tracks are well above the surrounding topography and result in a small "bulge" in the noise contours. Past this point the tracks go into a cutting (up to 17 m) for 1400 m, after which it continues at grade (around 400 m North of Balmoral Road) until after Burns Road.

Barriers of 3 m on the bridge and associated abutments and for the area just south of Burns Road Station can effectively eliminate the impacts from the rail corridor. For the intervening space, barrier heights would vary between nil and 3 m in a trade-off between barrier height and land acquisition.

Burns Road to Chainage 43200

Figure 6-1 shows the expected contours for the section between Burns Road and Windsor Road. Examining the "no mitigation" contour, it is apparent that the contours extend well into the residential areas of Stanhope Gardens and Kellyville, and that noise mitigation measures would need to be incorporated into the future design of the rail system.

Given the rail tracks are on a viaduct and therefore elevated above the surrounding terrain, the only viable noise control measure is the erection of barriers attached to the side of the viaduct. Along this section of track, it is the $L_{A,Max}$ that is the controlling criterion. Several scenarios were developed to minimise the extent of affectation into the residential areas. The adoption of a 1.8 m barrier resulted in only minor reduction of the contour lines.

In order to achieve the necessary degree of noise reduction, the following measures should be considered in the design:

- the viaduct be a concrete structure or stabilised earth mounding using ballasted continuously welded tracks;
- incorporate a 3 m barrier (relative to the rail height); and
- limit the general speed limit of 110 km/h.

If the above measures were adopted, the impacts on the western side of Old Windsor road would be minimised, such that a 2.5 m barrier would suffice. This would result in compliance for single story dwellings, but not for any upper level. Observations of the existing dwelling in the later subdivision releases along Old Windsor Road would indicate that only a small portion are 2 story. These requirements are typically the same as what would be required by developers in future land release projects along Old Windsor Road to mitigate road traffic noise.

North of Chainage 43200

Between the chainage 43200 and the stabling area, the railway is in cutting, and the contours lie close to the edge of the rail corridor. The noise criterion only applies for residential areas, as there is no requirements to control rail noise within commercial areas. Consequently, as this area is part of the future Rouse Hill Town Centre, there is no requirement for noise barriers to be considered.

6.3 Railway Stabling

The need to construct a rail stabling yard has been identified. If the project is to be split into two phases (as proposed), a temporary stabling yard would be constructed just to the north of the Strangers Creek Bridge. This facility would not contain workshops or wash facilities and would be later moved to land to the west of Windsor Road and north of Schofields Road. Though an exact location is yet to be refined, several options have been assessed.

There are potentially two noise sources, as detailed in **Table 6-1**. The movements and shunting of trains must comply with the general railway criterion, whilst the cleaning, washing facilities and mechanical workshops noise sources is required to comply with the requirements of the *Industrial Noise Policy*.

Table 6-1 Noise sources at Railway Stabling

Activity	Permanent Stabling Facilities	Temporary Stabling Facilities
Movements and shunting of trains	✓	✓
cleaning, washing facilities and (limited) mechanical workshops	✓	-

The noise from the train movements to and from the stabling yards would be very similar for the temporary and permanent railway stabling. Assuming low train speeds from the end of the line to the stabling area (nominally 30 km/h) and continuously welded rail tracks, the facility would require a total width of around 50 m to achieve the rail corridor criterion. It is understood that there would be no significant bridge structure between Rouse Hill Town Centre Station and the stabling facility, consequently no allowances have been incorporated into the analysis.

The extent of maintenance facilities is still to be determined. *Section 5.2.4* of the *Rail Infrastructure Study* (Arups, 2002) report refers to there being *no substantial maintenance facilities*, whilst *Section 6.5.2* in discussing the railway stabling did not mention maintenance works. In assessing the noise that falls under the *Industrial Noise Policy*, the following assumptions were made:

- Washing to be undertaken substantially within a building;
- Cleaning to be undertaken whilst trains are stabled;
- Mechanical workshop activities to be limited and undertaken within a custom designed building; and
- Compressors on trains would not be left on when stabled.

As indicated in **Figure 6-2**, the following locations of the stabling yards were considered:

- Preferred stabling yard location and preferred rail alignment;
- Option 1 stabling yard and Option 1 rail alignment;
- Option 1 stabling yard and Option 1B rail alignment;
- Option 2 stabling yard and Option 2 rail alignment.

For all of the options above the stabling yards were assumed to at a RL of 54.5 m.

In consideration of the noise emissions from the stabling yard, a sound power level of 115 dB(A) was used as the basis of calculation. The source was modelled as an area source commencing at ground levels and extending to 4.8 m high and 3.5 m wide on each end of the workshop/cleaning building.

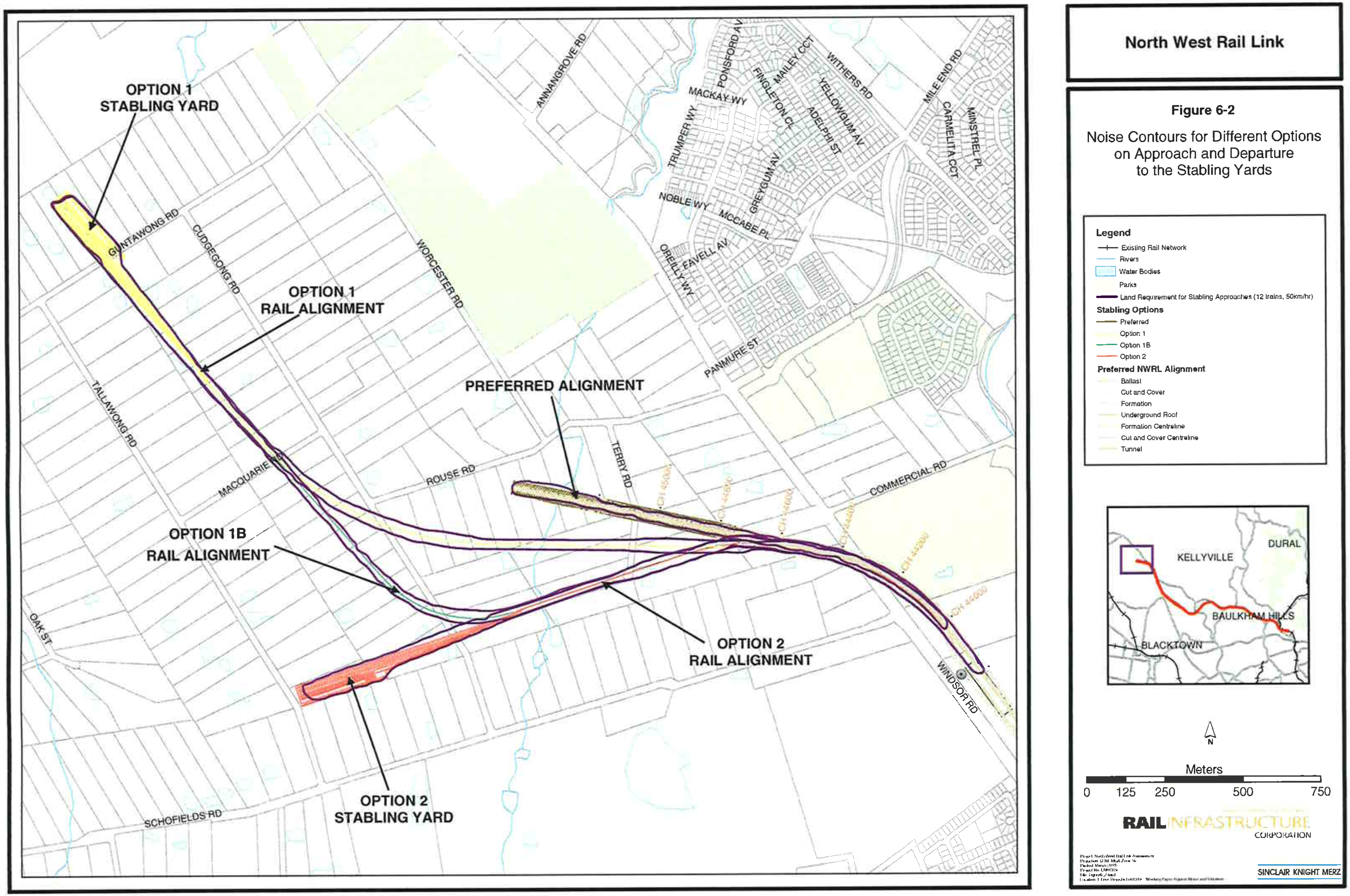
For all options, noise contours were developed for the rail noise on approach to the facility and of the operation of the wash/maintenance facilities assuming no barrier, 1.8 m, 2.4 m and 3.6 m barriers around the perimeter of the stabling yards. These contours are based on the somewhat arbitrary location of the wash/maintenance facility within the facility. **Figure 6-2** and **Figure 6-3** show the contours for the rail noise on approach (and departure) to the yards and the operation of the facility, respectively.

Due to the low speed of the rail vehicles and the continuously welded tracks, the noise contours lie very close to the rail corridor (as shown in **Figure 6-2**).

North West Rail Link

Figure 6-2

Noise Contours for Different Options on Approach and Departure to the Stabling Yards



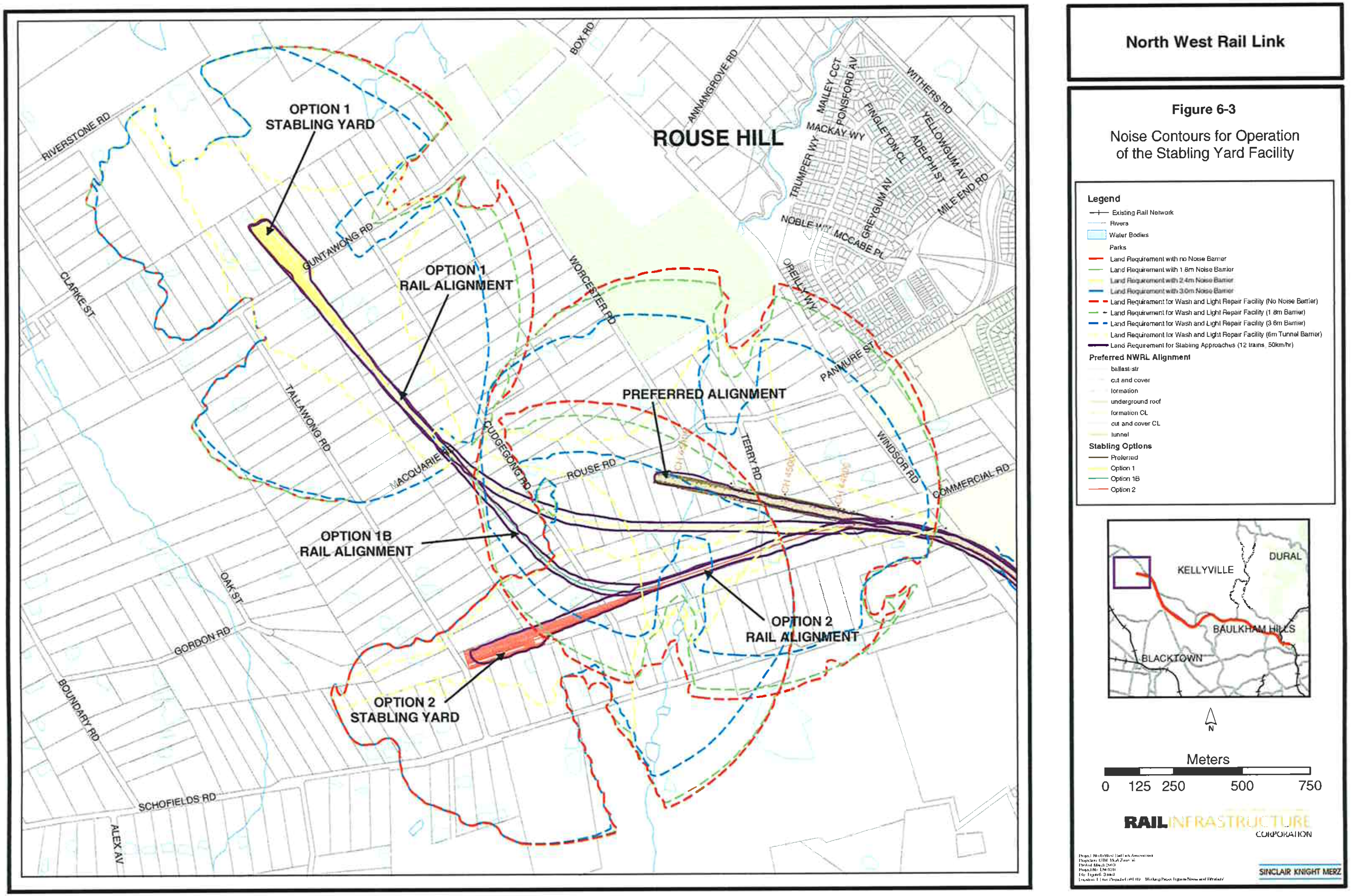
RAIL INFRASTRUCTURE CORPORATION

SINCLAIR KNIGHT MERZ

North West Rail Link

Figure 6-3

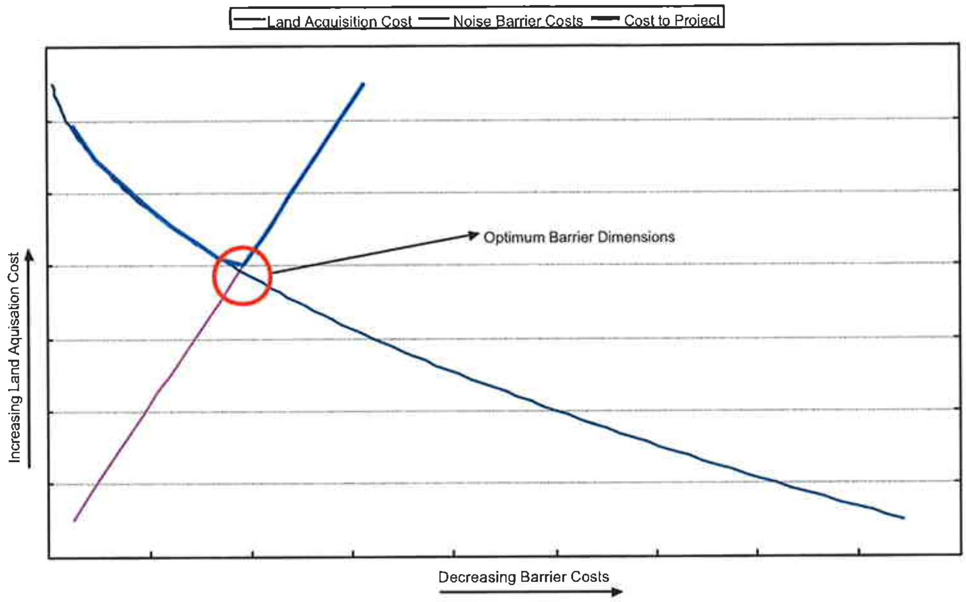
Noise Contours for Operation of the Stabling Yard Facility



RAIL INFRASTRUCTURE CORPORATION

SINCLAIR KNIGHT MERZ

Noise from the operation of the facility however, requires compliance with the 38 dB(A) industrial noise criterion, discussed in *Section 4.1.7,* and results in a wider area of land impacted by the operations. **Figure 6-3** indicates that the acoustic barriers are not very effective in mitigating the noise, due primarily to the exposed sections of the entrance doors which are above the top of the barriers. An additional scenario is also modelled, and referred to as the "tunnel barrier". This was a 6 m high absorptive barrier positioned either side of the track at the entrance and exit of the building. The intent of this exercise was to demonstrate an alternative barrier location, however the dimensions of the barrier have not yet been optimised as part of this commission. Optimisation of the barrier will involve determining its dimensions so as to minimise the corresponding land acquisition costs, schematically shown in **Figure 6-4**. The optimisation process would best be undertaken as soon as a draft layout of the stabling yards is completed.



■ **Figure 6-4 Schematic of Determination of Optimum Barrier Dimensions**

Clearly the industrial noise criterion adversely affects more land compared to the land required for compliance of the noise associated with the movement of trains to and from the stabling facility.

The final siting and eventual layout of the stabling area is dependent upon a variety of environmental, social and visual considerations. Once these considerations have been assessed and a final area designated for its location, the optimisation of the barriers can then be further explored.

In addition, the following should be considered as a way to further minimise the area of impact:

- The contours do not include attenuation from any intervening buildings. It is usual in such circumstances where a development potentially results in exceedances of the design objectives, that multi-level residential or commercial buildings be permitted, subject to appropriate conditions of consent regarding the appropriate internal noise levels. Due to their size and the building density, these buildings provide acoustical shielding to subsequent lands, constricting the 38 dB(A) contour, (being the boundary for the area of impact);
- The land surrounding the rail stabling yard has been assumed to be residential. Should it later be decided that the land surrounding the stabling yards would best being commercial, then a higher noise criteria would apply, resulting in a smaller area of affectation;
- It would likely prove feasible to install rapid-close doors across the two entrances of the wash/maintenance facility to further reducing the area of impact. Alternatively, the "tunnel barrier" option previously described could be fitted with a roof, making an enclosed structure for some of its length.

6.4 Noise Contours – Alignment B Alignment

RIC are investigating several alignment options. Alignment B differs in the horizontal plan compared to the preferred alignment as shown in **Figure 6-5**. Differences in the vertical alignments also occur.

Modelling was undertaken of the impacts resulting from the rail corridor, north of the Norwest Business Park extending to just north of the Burns Road Station, for the following scenarios:

- No barrier;
- 1.8 m barrier;
- 2.4 m barrier and
- 3.0 m barrier.

The train speeds used in the modelling were based on those for the Option B alignment. The governing contours are presented in **Figure 6-6**.

North West Rail Link

Figure 6-5

Comparison of Route Alignments (Norwest Business Park to Burns Road Station)

Legend

Preferred Alignment

- Ballast
- Cut and Cover
- Formation
- Underground Roof
- Centreline
- Formation Centreline
- Cut and Cover Centreline
- Tunnel Centreline
- Alignment B

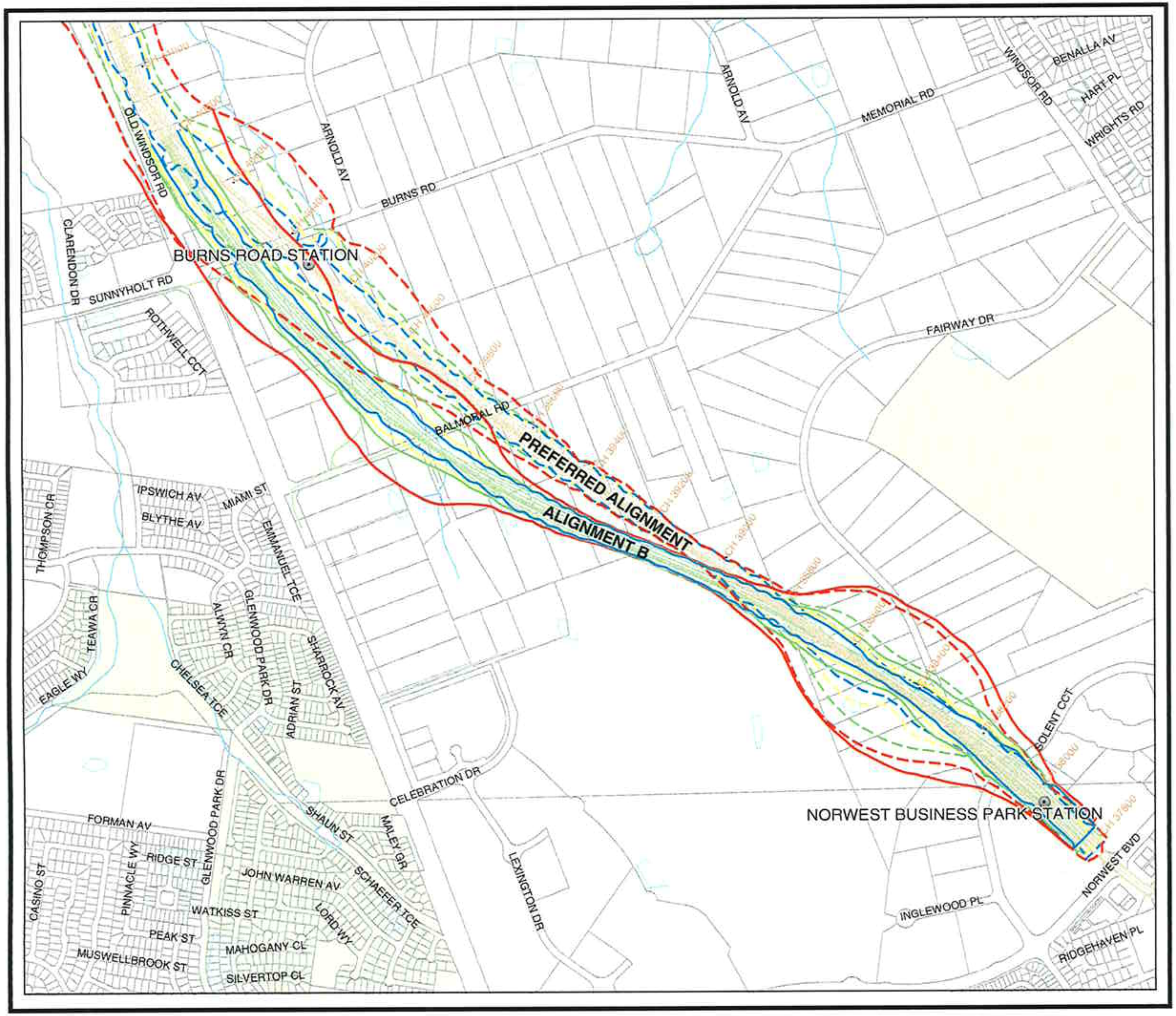
N

Metres

0 100 200 400 600

RAIL

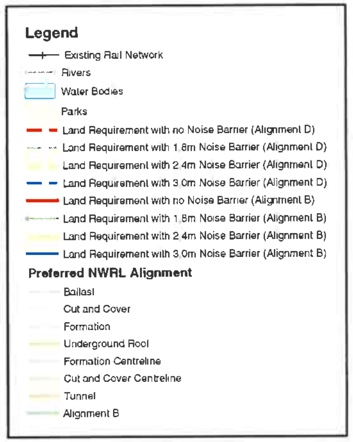
SINCLAIR KNIGHT MERZ



North West Rail Link

Figure 6-6

Noise Contours - Alignment B



N

Metres

0 100 200 400 600

RAIL INFRASTRUCTURE CORPORATION

SINCLAIR KNIGHT MERZ

7. Predicted Operational Noise and Assessment – Tunnel Section

7.1 Prediction Methodology

Predictions to calculate the levels of groundborne noise and vibration from the rail traffic in the tunnel section was determined primarily based on the procedures detailed in *Transportation Noise*[xxi], and a number of other relevant articles.

The horizontal and vertical alignments of the tunnel used in the calculations were provided by RIC at the beginning of this study. The train speed and ground geology was sourced from the *Rail Infrastructure Study* (Arup, 2001).

RIC has indicated that should mitigation measures be required, its preference would be the use of a ballast mat. Where this provides insufficient attenuation, then alternative measures should be considered as necessary.

The locations of existing dwellings (above the tunnel), were scaled from current aerial photographs. There are some areas along the route that are currently undeveloped (for example the area south of Castle Hill Road, east of Old Northern Road), but will most likely be developed by the time construction of the project commences. On that basis, and as a matter of good planning (given that future retrofit measures are extremely costly and generally not as efficient), the length of tunnel between the Beecroft portal and the Castle Hill Station assume residential properties are potentially located above the tunnel.

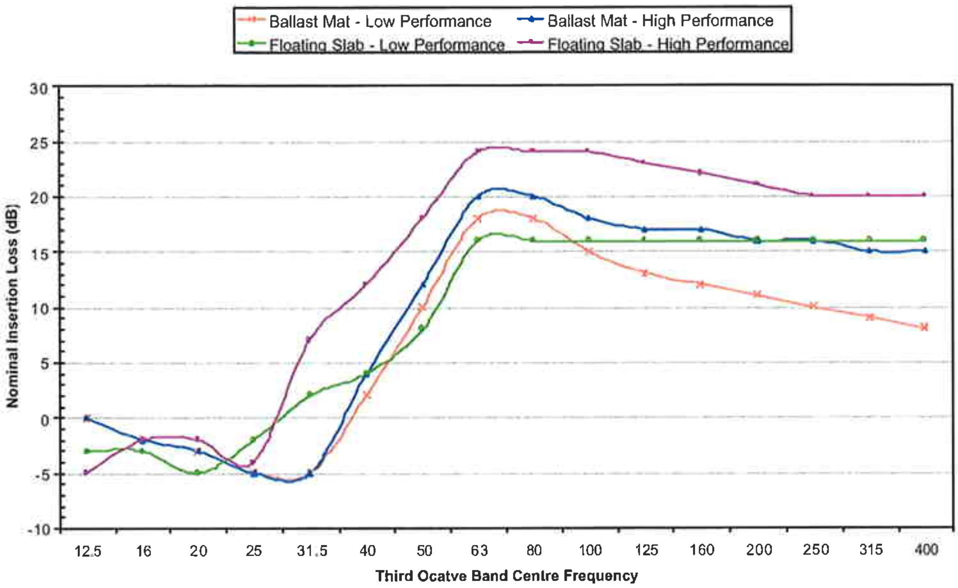
Considering RIC's preference for ballasted trackwork, the treatments identified are categorised according to the following:

- Ballast Mat – High and Low performance
- Floating Slab – High and Low performance

The types of floating track would be refined once the vibration tests recommended at the Hillsong Church have been undertaken. The floating slab would be a concrete slab usually supported on either isolation pads or steel springs. In selecting the isolation system, issues of drainage need to be considered as an integral part of the design, so that the space under the slab does not become water-logger or full of debris (over time), which would result in serious degradation of the vibration isolation system.

Where mitigation measures were identified as being required, the following notional insertion loss figures were used to assess the degree of treatment required. These were sourced from the *Parramatta Rail Link Operational Noise and Vibration Technical Report A6(i)*, Richard Heggie Associates (15 August 2001), and are considered valid for use on this project given the similarities in the bedrock and general conditions where measurements were undertaken.

These insertion loss figures are considered generic, and during the detailed design phase additional survey information collated as part of the studies will need to be considered.



■ **Figure 7-1 Nominal Insertion Loss for Groundborne Noise** [xxii]

7.2 Prediction Output

The calculations for the tunnel section of the project are summarised in **Table 7-2.** This shows the key design parameters, and the recommended treatments.

The procedure has selected the minimum treatments based on progressive amendments to the treatment options so as to meet the criteria. At some locations, the transition exists between a low-grade isolation and a high-grade system, and may identify several "intermediate" options. It is acknowledged that such measures would not be implemented, and the designed would be rationalised.

Table 7-2 Typical Track Treatment

Chainage	Existing RL	Design RL	Depth (centre of tunnel)	Train Speed Km/h	Rock Strata	Treatment required
	Levels apply only at beginning of chaining					
26400 to 30370	124.3	112.9	-7.9	100	Sandstone	Ballast Mat - Low
30370 to 30530	172.0	151.4	-17.1	60	Shale	Ballast Mat - High
30530 to 30560	169.3	151.1	-14.7	80	Shale	Floating Slab - High
30560 to 30600	169.8	150.7	-15.6	80	Shale	Ballast Mat - High
30600 to 30810	171.6	150.0	-18.1	80	Shale	Ballast Mat - Low
30810 to 30940	168.7	146.3	-19.0	100	Shale	Ballast Mat - High
30940 to 32260	169.3	143.9	-21.8	100	Shale	Ballast Mat - Low
32260 to 32340	144.2	120.4	-20.3	100	Shale	Ballast Mat - High
32340 to 33740	144.7	119.0	-22.2	100	Shale	Ballast Mat - Low

Chainage	Existing RL	Design RL	Depth (centre of tunnel)	Train Speed Km/h	Rock Strata	Treatment required
	Levels apply only at beginning of chaining					
33740 to 33910	119.5	94.1	-21.9	100	Sandstone	Ballast Mat - High
33910 to 33920	115.3	89.5	-22.2	100	Sandstone	Ballast Mat - Low
33920 to 34210	114.7	89.3	-21.9	100	Sandstone	Ballast Mat - High
34210 to 34510	108.3	82.3	-22.4	100	Sandstone	Ballast Mat - Low
34510 to 34530	102.2	76.6	-22.1	100	Sandstone	Ballast Mat - High
34530 to 34690	102.0	76.3	-22.2	100	Sandstone	Ballast Mat - Low
34690 to 34750	98.4	73.2	-21.7	100	Sandstone	Ballast Mat - High
34750 to 34900	97.3	72.1	-21.7	100	Sandstone	Ballast Mat - Low
34900 to 35150	100.4	69.2	-27.6	100	Sandstone	Floating Slab - High
35150 to 35160	89.3	67.2	-18.7	100	Sandstone	Floating Slab - Low
35160 to 35170	89.8	67.2	-19.1	100	Sandstone	Ballast Mat - High
35170 to 35210	90.0	67.2	-19.3	100	Sandstone	Ballast Mat - Low
35210 to 35280	90.3	67.2	-19.6	100	Sandstone	No Treatment
35280 to 35320	84.6	67.2	-14.0	100	Sandstone	Ballast Mat - Low
35320 to 35380	80.5	67.1	-9.9	100	Sandstone	Ballast Mat - High
35380 to 35750	81.5	66.9	-11.0	100	Sandstone	Ballast Mat - Low
35750 to 35850	85.9	65.1	-17.4	130	Sandstone	Ballast Mat - High
35850 to 36450	86.0	64.6	-17.9	130	Sandstone	Ballast Mat - Low
36450 to 36510	112.0	61.9	-46.6	120	Sandstone	No Treatment
36510 to 37710	114.0	62.0	-48.5	120	Sandstone	Ballast Mat - Low
37710 to 37730	88.2	68.0	-16.7	100	Shale	Floating Slab - High
37730 to 37760	88.5	68.1	-16.9	80	Shale	Ballast Mat - Low
37760 to 37780	87.5	68.1	-15.9	100	Shale	Floating Slab - Low
37780 to 37970	87.3	68.2	-15.6	100	Shale	Floating Slab - High
37970 to 38000	83.0	68.2	-11.3	100	Shale	Floating Slab - Low
38000 to 38070	81.4	68.2	-9.7	100	Shale	Ballast Mat - Low
38070 to 38100	78.9	68.2	-7.3	100	Shale	No Treatment

The total extent of each treatment type is presented in **Table 7-3**.

Table 7-3 Summary of Treatment Options for Tunnel Section

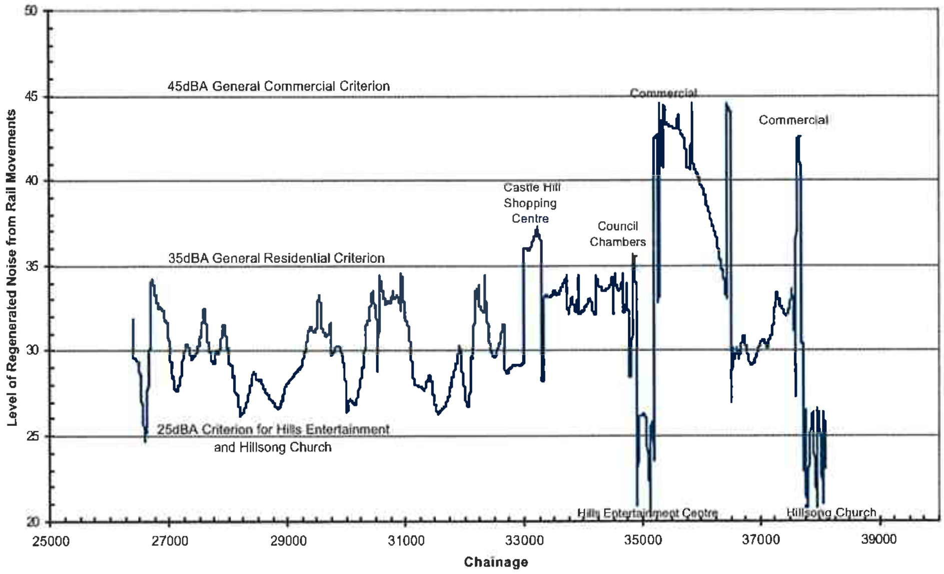
Mat Type A	Mat Type B	Floating Slab A	Floating Slab B
9,870 meters	1,120 meters	60 meters	490 meters

It is immediately apparent that rather than have too many differing types of treatments, the Floating Slab A would be replaced with the higher performance Floating Slab B.

Within the commercial areas it was not feasible to undertake a site by site analysis of the potential impacts. A site inspection was undertaken to look for business known to undertake operations that may be sensitive to noise or vibrations prior to or during the next phase of the project, it is recommended that consultation be undertaken with the business for them to register works they consider may be influenced by the proposal.

This would be followed up by a site inspection with modifications to the recommendations if appropriate.

The resulting levels of groundborne noise predicted using the mitigation measures described above are presented **Figure 7-1**, for buildings close to, or immediately above the rail corridor.



■ **Figure 7-1 Predicted Operational Levels of Groundborne Noise**

It can be seen that levels of 26dB(A) are predicted for the Hills Centre and Hillsong Church Convention Centre. Whilst this is a 1dB(A) exceedance of the criteria, the intent of this 'first run' was to prove the feasibility of the option. The predicted levels only exceed the criteria by a very marginal amount, which would be able to be brought into compliance during detailed design when site specific parameters have been measured.

7.3 Pressure Pulse at Portals

Whenever a train enters or leaves a tunnel portal a pressure wave is generated. The magnitude of this pulse is related to the speed of the train and the cross-sectional ratio of the train to the portal.

Whilst there is no criteria perse, it should be further examined during detailed design, with an aim to minimise this effect. Given the tunnel is a single track configuration, the most practical measures to be considered include:

- access passages between the two tunnels close the portal, to assist in dissipating the pulse;
- a tapering of the tunnels close to the portals; or
- the mounting of slotted panels at the entrance to the tunnel on isolation mounts, to act like a bellow, providing some relief and dissipation of the pressure wave.

7.4 Future expansion of the Hillsong Church

The Hillsong Church have long-term plans and developed sketches showing the preferred location for a new recording studio to be located to the north east of the corridor, adjacent to the existing Ice Skating Rink.

The precise siting of the facility has been outlined, though the detail design is understood not to have commenced. The internal noise criteria for such facility is likely to be 25dB(A), and it would be essential that extensive vibration mitigation measures are incorporated into the design of both the track system, and most likely the proposed building. Such noise control measures, though extensive are considered to be feasible.

At this stage of the design, the isolation of the track and that of the building should ideally be considered together. Preliminary calculations indicate that the system can be adequately designed, to achieve a satisfactory cohabitation of the rail system and studio.

The requirements for the track isolation would be more of a higher performance level if the studio building is to be constructed, maximising the amount of vibration isolated at the source.

One option to maximise the path length and hence minimise the vibration between proposed track and the existing Hillsong Church Convention Centre and proposed studios is to substantially lower the level of the rail corridor. It is recognised though, that the type of foundations used for the studio may negate some of the reduction in the vibration. By lowering the level of the rail line, the extent of mitigation measures described above may be reduced. Once schematic design options of the studio has been provided, the range of available options can be further explored.

8. Summary of Results and Recommendations

A summary of the impacts presented in the previous sections and the proposed management and recommendation measures is provided in **Table 8-1**.

- **Table 8-1 Summary of Impacts and Mitigation Measures**

Issue	Main Impact	Extent of impacts	Scope for noise control	Mitigation Measures
Groundborne Noise from Tunnelling works	Annoyance to residents (particularly at night)	As detailed in **Figure 5-4**. Upper limit of predicted levels presented in **Figure 5-3**	Limited	No rockbreaking at night. Pro-active community consultation body. Extensive monitoring program
Groundborne Noise from movement of trains	Annoyance to residents (particularly at night)	Likely acceptable (with control measures)	High	Can be designed out with suitable track isolation. (refer *Section 7.2*)
Vibration from movement of trains	Annoyance to residents (particularly at night)	Likely acceptable (with control measures)	High	Can be designed out with suitable track isolation.(refer *section 7.2*)
Vibration from rockbreaking	Structural damage to Heritage buildings	Within 50 m of tunnel	Moderate to high	Dilapidation survey Consultation program (refer *Section 5.7*)
Vibration to commercial area(s)	Interference to operations during operations or construction	Local to tunnel alignment	Low	To be determined, based on targeted consultation
Construction Noise (NW of Norwest Portal)	General construction emissions	Residents within around 250 m of tracks	Low to moderate	Time restrictions Further time restrictions on rockbreaking (refer *Section 5.6*)
Construction Noise (Beecroft Dive Structure)	General construction emissions	Residents adjacent to existing Main Northern Line corridor	Low to moderate	Use of portable barriers should be considered, though this may not prove feasible; Monitoring of the emission levels during construction.
Impacts on existing Hillsong Church	Disruption to use of facility due to construction impacts	Likely acceptable, further tests required to fully quantify	Moderate	Barriers Extensive controls on ventilation system (refer *Section 5.5*) Establish dialog with facility to ensure a coordinated timetabling of activities
	Disruption to use of facility due to operational impacts	None	High	Can be designed out with suitable track isolation. Further testing recommended.
Impacts on future expansion of the Hillsong Church	Vibration and groundborne noise	Localised	High	Isolation of track and (likely) building.

Issue	Main Impact	Extent of impacts	Scope for noise control	Mitigation Measures
Impacts on Hills Centre	Disruption to use of facility due to construction impacts	Limited to between one to two weeks	Low	Limited. Establish dialog with facility to ensure a coordinated timetabling of activities
	Disruption to use of facility due to operational impacts	None	High	Can be designed out with suitable track isolation
Station Acoustics	Commuter comfort, assistance in PA announcements	Limited to station ares	High	Reduce reverberation times Design levels for mechanical services Refer *Section 4.1.8*
Permanent Stabling Yards	Annoyance to residents (particularly at night)	Impacts expected within 900 m of facility	Moderate	Time controls Mounding/barriers Relocation of facilities to more centralised area
Temporary Stabling Yards	Annoyance to residents (particularly at night)	Impacts expected within 100 m of facility	Low	Mounding/barriers

9. Conclusion

Sinclair Knight Merz has undertaken a noise and vibration survey of the potential impacts associated with the proposed North West Rail Link project.

The tunnel is relatively shallow and during construction the levels of groundborne noise are to be expected to result in some impacts at residential dwellings close proximity to the tunnels, due to the operation of the TBM.

The extent of impacts at the Hillsong Church will require detailed field tests to fully quantify the extent of impacts and allow for the determination of control measures to be properly determined. These tests involve the testing of the transmission loss of the facade of the Convention Centre, and vibration mobility between the proposed rail tracks and the Convention Centre.

As the Hillsong Church is the major construction portal, it is envisaged that significant mitigation measures (particularly for the ventilation system) would be required. Other measures may involve the installation of temporary barriers, and limitations as to when some operations can take place.

All through the construction works, a strong and proactive community consultation program should be developed and implemented. This may include the manning of information booths, holding consultation forums and establishing hot-line numbers etc.

During operation, vibration isolation systems in the tunnel will be required to be incorporated in to the design. For much of the facility, this isolation system may involve the use of ballast mat, but at other areas, higher levels of treatment are required and may involve a floating slab construction. Details of the chainages and lengths of treatments are provided.

In the area north of the Norwest Portal, noise mounding (or barriers) would be required to minimise the area of land sterilised by the rail noise. Practicalities and asthetic considerations would likely limit the height of the barriers to 3 m, with speed restrictions recommended for the viaduct north of Burns Road Station.

Given the opportunity to develop and incorporate noise mitigation options, there appears no impediment to the project proceeding on the grounds of noise or vibration.

10. References

Footnotes

[i]Arup (2001) *North West Rail Link Rail Infrastructure Study*, Section 13.2.1.1;
[ii] EMU – Electric Multiple Unit. A rail term for common or generic suburban electric passenger trains;
[iii] Arup (2001) *North West Rail Link Rail Infrastructure Study*
[iv] Refer paragraph "U1"Page 17, of the Licence;
[v] This is interpreted to mean the maximum level corresponding to the 5% exceedance or the loudest 1 in 20 train movements, across the rail network;
[vi] Vibration criteria rounded to the nearest 0.5mm/s
[vii] RBL: is an acronym for the Rating Background Noise Level. Differing RBL values exist for the day, evening and night-time period. The single-figure represents the background level referred to in the EPA's *Industrial Noise Policy*. The RBL is the median of the 10th percentile level of the individual 15 minute background noise levels for each day, evening and night-time period. The procedure is fully defined in Appendix B of the EPA's *Industrial Noise Policy*;
[viii] Based on 24 hour operation, six days per week;
[ix] Arup (2001) *North West Rail Link Rail Infrastructure Study*, Table 14.1;
[x] Arup (2001) *North West Rail Link Rail Infrastructure Study*, Figure ;
[xi] DM Miller, GI Grabb, *Groundborne vibration caused by mechanised construction works*, TRL Report 429, (2000)
[xii] Transmission Loss is a rating of airborne sound insulation between two spaces. It is usually expressed in terms of octave bands between 63Hz and 8 kHz;
[xiii] R_w or STC is a single number rating of the airborne sound insulation between two spaces. It has a weighting to broadly represent environmental or general construction sources and is derived from the octave band transmission loss;
[xiv] rms is an acronym for the root-mean-squared level of vibration. It is frequently used as an index due to its direct relation to the power content of the vibration;
[xv] BS 7385: Part 2 - 1993, Section 7.4.1
[xvi] Hassell Pty Ltd, *Norwest rail Link, Design for 7 Stations*, (September 2002)
[xvii] Rail Noise Database
[xviii] RHA Line report
xix from a review of the *Calculation of Railway Noise* UK department of Transport (1995), and *Railway Traffic Noise – Nordic Prediction Method* Nordic Council of Ministers (1996)
[xx] Clearance distance required by RAC technical standards;
[xxi] Nelson, *Transportation Noise Reference Handbook* Butterworths
[xxii] *Parramatta Rail Link Operational Noise and Vibration Technical Report A6(i)*, Richard Heggie Associates (15 August 2001);

References

Arup, 2001, *North West Rail Link Rail Infrastructure Study*, Volumes 1 & 2, prepared for Rail Infrastructure Corporation (RIC).

Department of Transport, 1998, *Action for Transport 2010*, NSW Government, Sydney.

Environment Protection Authority, 1998, *Action for Air*, NSW Government, Sydney.

Appendix A Acoustic Terms

Absorption - In acoustics, the energy of the sound waves entering the surface of a material and being dissipated as heat, rather than being bounced off or reflected off the surface. Materials are rated in terms of their ability to absorb sounds;

ADR - Australian Design Rules, ADR-28 details the noise emission limits that apply for new vehicles sold in Australia;

Ambient noise: - The all-encompassing noise associated within a given environment. It is the composite of sounds from many sources, both near and far;

Annoyance - Any sound that is perceived as irritating or a nuisance;

Rating Background Level (RBL): - The single-figure background level used in the EPA's *Industrial Noise Policy*. The RBL is the median of the daily 10^{th} percentile level of the background noise levels for each day, evening and nighttime period. That is, three assessment background levels are determined for each 24-h period. The procedure is defined in Appendix B of the EPA's *Industrial Noise Policy*;

Attenuation - In acoustics, the diluting or holding back of the energy of sound waves as they pass through a material. Materials are rated for their ability to prevent sounds from travelling through them;

A-weighting - An adjustment made to sound level measurement, by means of an electronic filter, to approximate the response of the human ear;

Background noise: - The underlying level of noise present in the ambient noise, excluding the noise source under investigation, when extraneous noise is removed. This is described using the L_{A90} descriptor;

Barrier—noise - Any natural or artificial physical barrier to the propagation of noise (from a transport corridor), but generally referring to acoustically reflective or absorbent fences, walls or mounds (or combinations thereof) constructed beside the corridor;

Buffer - An area of land between a roadway and a noise-sensitive land use, used as open space or for some other noise-tolerant land use;

Compliance: - The process of checking that source noise levels meet with the noise limits in a statutory context;

Construction activities: - Activities that are related to the establishment phase of a development and that will occur on a site for only a limited period of time;

Day: - For road traffic noise, it is the period from 0700 and 2200 (Monday to Sunday), whilst for industrial noise assessment it is the period 0700 to 1800 (Monday to Sunday);

dB: - Abbreviation for decibel—a unit of sound measurement. It is equivalent to 10 times the logarithm (to base 10) of the ratio of a given sound pressure to a reference pressure;

dBA - (A weighted decibel) A single number measurement of the sound pressure based on the decibel but weighted to approximate the response of the human ear with respect to frequencies;

DUAP - Department of Urban Affairs and Planning of NSW;

EPA - Environment Protection Authority of NSW;

Equivalent continuous noise level: - The level of noise equivalent to the energy average of noise levels occurring over a measurement period;

Extraneous noise: - Noise resulting from activities that are not typical of the area. Atypical activities may include construction, and traffic generated during holiday periods or by special events such as concerts or sporting events. Normal daily traffic is not considered to be extraneous.

Feasible and reasonable measures: - Feasibility relates to engineering considerations and what is practical to build; reasonableness relates to the application of judgement in arriving at a decision, taking into account the following factors:

- noise mitigation benefits (amount of noise reduction provided, number of people protected)
- cost of mitigation (cost of mitigation versus benefit provided)
- community views (aesthetic impacts and community wishes)
- noise levels for affected land uses (existing and future levels, and changes in noise levels).

Frequency - Cycles per unit of time. Usually expressed in Hertz (Hz). The frequencies of audible speech lie in the range of 400 to 2000 Hz;

Grade - The line or slope of a road or rail lines, that is, the angle of a road to the horizontal plane, expressed as a percentage;

Greenfield site: - Undeveloped land.. When reference is made to road assessments the site does not have exposure to existing road traffic noise;

Heavy vehicle - A truck, transport or other vehicle with a gross vehicle weight above a specified level (for example: over 8 tonnes);

Hertz (Hz) - One cycle per second;

Immission - Sounds impacting on the human ear;

Impulsive noise: - Noise with a high peak of short duration, or a sequence of such peaks;

Industrial noise sources: Sources that do not generally move from place to place, for example stationary sources. Except where other more specific guidelines apply (for example, construction activities, road or rail traffic, emergency diesel generators etc);

All industrial noise sources that are scheduled under the Protection of the Environment Operations Act 1997 are considered to be industrial sources. In general, these include: individual industrial sources such as:

- heating, ventilating and air conditioning (HVAC) equipment
- rotating machinery
- impacting mechanical sources
- other mechanical equip

Intrusive noise: - Refers to 'industrial' noises that intrudes above the background level by more than 5dB(A)..The intrusiveness criterion is set out in Section 2.1 of the EPA's *Industrial Noise Policy*;

L_{A90} : - The A-weighted sound pressure level that is exceeded for 90 % of the time over which a given sound is measured. This is considered to represent the background noise. During a 15 minute survey, it would represent the quietest 90 seconds;

L_{Aeq} : - The equivalent continuous noise level—the level of noise equivalent to the energy-average of noise levels occurring over a measurement period;

$L_{A,Max}$ - maximum noise level measured at a given location over a specified time interval;

L_{A1} - The sound pressure level that is exceeded for 1% of the time for which the given sound is measured;

L_{A10} - The sound pressure level that is exceeded for 10% of the time for which the given sound is measured. The L 10 level measured over a 1-hour period;

$L_{A10 18 (hour)}$ - The arithmetic average of the L 10(1hr) levels for the 18-hour period between 0600 and 2400 hours on a normal working day. It is a common traffic noise descriptor;

L_{Aeq} - Equivalent sound pressure level—the steady sound level that, over a specified period of time, would produce the same energy equivalence as the fluctuating sound level actually occurring;

$L_{Aeq\,(15hour)}$ - The LAeq noise level for the period 7 am to 10 pm;

$L_{Aeq\,(1hour)}$ - The LAeq noise level for a one-hour period. In the context of The EPA's Road Traffic Noise Policy it represents the highest tenth percentile hourly A-weighted L eq during the period 7 am to 10 pm, or 10 pm to 7 am (whichever is relevant). If this cannot be defined accurately, use the highest A-weighted L eq noise level;

$L_{Aeq\,(9hour)}$ - The LAeq noise level for the period 10 pm to 7 am;

Level - The level of noise, usually expressed in dB(A), as measured by a standard sound level meter with a pressure micro-phone. The sound pressure level in dB(A) gives a close indication of the subjective loudness of the noise;

Median: - The middle value in a number of values sorted in ascending or descending order. Hence, for an odd number of values, the value of the median is simply the middle value. If there is an even number of values the median is the arithmetic average of the two middle values;

Mounding - A type of noise control barrier consisting of an artificial earthen embankment or knoll constructed between a roadway and a noise receptor area;

Noise - Undesired sound. By extension, noise is any unwarranted disturbance within a useful frequency band, such as undesired electric waves in a transmission channel or device;

Noise level goal or noise level objective - A noise level that should be adopted for planning purposes as the highest acceptable noise level for the specific area, land use and time of day;

Reverberation - Persistence of reflected sound in a room after its source has stopped emitting sound;

Reverberation time - Of an enclosure, for a stated frequency or frequency band, time that would be required for the level of time-mean-square sound pressure in the enclosure to decrease by 60 dB, after the source has been stopped. This is approximately equivalent to a decrease of millionth of its original intensity;

RTA - Roads and Traffic Authority of NSW;

Set-back - The distance between the building alignment or face and the corresponding land boundaries of a property, minima for which are controlled through planning regulation;

Signal-to-noise ratio - A measure of the quality of a signal. It is the ration of the strength of a signal to the same measure of the noise;

Sound absorption - Change in sound energy into some other form, usually heat, in passing through a medium or on striking a surface;

Sound Attenuation - The reduction in the intensity or in the sound pressure level of sound which is transmitted from one point to another;

Sound level meter - Device to be used to measure sound pressure level with a standardised frequency weighting and indicated exponential time weighting for measurements of sound level, or without time weighting for measurement of time-average sound pressure level or sound exposure level;

Sound pressure - Root-mean-square instantaneous sound pressure at a point, during a given time interval, where the instantaneous sound pressure is the total instantaneous pressure in that point minus the static pressure;

Sound reduction index R_w - Single-number rating of airborne sound insulation of a partition;

Sound Transmission Class (STC) - A single number rating of a structure's efficiency as a barrier to airborne sound at 16 speech frequencies from 125 to 4000 Hz. (See ASTM procedure E 1414 for rating method.) Rates the ability of a wall or others construction to block sound; STC is a decibel measure of the difference between the sound energy striking the panel or construction on one side and the sound energy transmitted from the other side. This includes sound from all angles of direction, and from low and high sound frequencies;

Appendix B Concept design of bridge structures

Structure	Chainage	Structure Type
Overbridge at Solent Circuit	38.100 km	Free standing bridge structure, Super-T beams, two spans (25 m and 28 m)
Overbridge at Balmoral Road	39.710 km	Free standing bridge structure, Super-T beams, single span (28 m)
Overbridge at Burns Road	40.410 km	Free standing bridge structure, Super-T beams, two spans (2 x 20 m)
Burns Road Station	40.500 km	At-grade construction with precast Concrete U-beam and in situ slab platform, suspended concrete concourse
Caddies Creek Viaduct	41.630 km to 42.290 km	Free standing bridge structure, Super-T beams, twenty-two spans of 30 m - 660 m
Overbridges at Windsor Road/Old Windsor Road Interchange	42.350 km	Three free standing bridge structures above the railway comprising: - 5 lane bridge using Super-T beams, 4 spans (18 m, 25 m, 24 m and 32 m) - 2 lane ramp bridge using Super-T beams, 2 spans (25 m and 36 m) - 2 lane ramp bridge using cast in place concrete box girder, 2 spans (22 m and 34 m)
Overbridge at Mungerie Park Avenue Extension	43.480 km	Free standing bridge structure, Super-T beams, three spans (14 m, 21 m and 16 m)
Rouse Hill Town Centre Station Box	43.750 km	Cut and cover with future development over, constructed in shale, maximum depth 12-15 m below surface level
Overbridge at Schofields Road Extension	44.080 km	Free standing bridge structure, Super-T beams, two spans (25 m and 28 m)
Overbridge at Windsor Road	44.300 km	Two free standing bridge structure, Super-T beams, each single span (45 m)

The above table was extracted from section 12.2 of the Arup (2001) *North West Rail Link Rail Infrastructure Study*,