Technical Paper 3

Noise and Vibration

North West Rail Link

Noise and Vibration Technical Paper for Operations and Additional Construction Works

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Contents

Glossary

Item	Description / Definition
AAAC	Association of Australian Acoustic Consultants
AADT	Annual Average Daily Traffic (AADT) is the total yearly traffic volume in both directions divided by the number of days in the year
CNVIS	Construction Noise and Vibration Impact Statement
CNVS	Construction Noise and Vibration Strategy
CORTN	Calculation of Road Traffic Noise
DEC	Department of Environment and Conservation (now OEH / EPA)
DECC	Department of Environment and Climate Change (now OEH / EPA)
DECCW	Department of Environment, Climate Change and Water (now OEH / EPA)
DoP	NSW Department of Planning – now DP&I
DP&I	Department of Planning and Infrastructure
ECRL	Epping to Chatswood Rail Line
EIS	Environmental Impact Statement
EPA	Environment Protection Authority
FEL	Front End Loader
ICNG	Interim Construction Noise Guideline
IGANRIP	Interim Guideline for Assessment of Noise from Rail Infrastructure Projects
INP	Industrial Noise Policy
NML	Noise Management Level
NSW	New South Wales
NWGC	North West Growth Centre
NWRL	North West Rail Link
OEH	Office of Environment and Heritage
PA	Public Address System
PERL	Parramatta to Epping Rail Line
Q1, Q2, Q3, Q4	Quarter 1 to 4 of a year
RMS	Root Mean Square

Item	Description / Definition
RNP	Road Noise Policy
SLR Consulting	SLR Consulting Australia Pty Ltd
SWL	Sound Power Level
TBM	Tunnel Boring Machine
TCA	Transport Construction Authority (now TfNSW Transport Projects Division)
TfNSW	Transport for NSW
T-Way	Transitway

Executive Summary

The proposed North West Rail Link (NWRL) comprises the provision of a new railway from Epping to beyond Rouse Hill in north west Sydney, linking directly into the existing Epping to Chatswood Rail Line (ECRL). It will provide eight new stations and services over 23 kilometres. Approximately 15.5 km of the new railway is underground from Epping to Bella Vista with the remainder of the route being above ground. Train stabling and maintenance facilities will be provided at Tallawong at the north western end of the route.

The objective of this study is to evaluate and assess the potential noise and vibration impacts associated with the operation of the NWRL, and with the construction of operational rail infrastructure and stations. The impacts of the major civil construction works (including the excavated tunnels, viaduct and stabling facility earthworks) have been assessed separately. This report identifies appropriate noise and vibration design objectives and management levels based on local and international guidelines. Where noise and vibration levels are predicted to exceed the identified objectives, options and recommendations for mitigating or managing the potential impacts are presented.

Identification of Sensitive Receivers

The sensitivity of building occupants to noise and vibration varies according to the nature of the occupancy and activities within the affected premises. Site inspections were undertaken within a corridor extending approximately 100 m either side of the proposed alignment and typically 200 m from the construction sites to identify the sensitivity of each nearby receiver (building occupancy). Receivers beyond 200 m are unlikely to receive any appreciable impacts. Receivers were classified as commercial, educational, industrial, residential, worship or other sensitivity to assist in determining appropriate noise and vibration goals and management levels.

Ambient Noise Monitoring

In order to characterise the existing ambient noise environment across the project area, environmental noise monitoring was performed at ten representative locations during October and November 2011. This information has been supplemented with ambient noise data collated during the previous NWRL proposal and other recent projects, resulting in an ambient noise database for a total of 25 representative locations across the project area.

The purpose of the noise monitoring was to quantify the existing noise environment and to determine the existing L_{Aeq}, L_{A90} and other relevant statistical noise levels during the daytime, evening and night-time periods. The results are used to assist in determining noise criteria for the operation of fixed facilities such as the stations, substations, tunnel ventilation systems and the train stabling facility, and also to determine the noise management levels (NMLs) for airborne construction noise.

Airborne Operational Noise

For airborne noise created by train operations on surface track (from the tunnel portal at Bella Vista to the entrance of the Tallawong Stabling Facility), noise trigger levels are applicable. If these are exceeded, consideration of noise mitigation for existing and planned sensitive receivers, both at opening and at an indicative time in the future (taken to be ten years after opening), is required. For this assessment, proposed future residential areas include the Area 20 precinct, the Rouse Hill Town Centre, 301 Samantha Riley Drive and future development areas around the proposed NWRL stations.

Without any noise mitigation measures, the noise modelling indicates the potential for widespread exceedances of the noise trigger levels (design objectives). To mitigate noise impacts, it is recommended for the current NWRL Concept Design that noise barriers of height 1 m above rail level be included at all above-ground locations (except where the tracks are located in cuttings). It is noted that alternative mitigation options to the 1 m noise barriers are available for consideration during detailed design.

Rail dampers are also recommended in all areas of surface track between Kellyville Station and Cudgegong Road Station, except in the vicinity of the stations where lower speeds result in compliance with the noise trigger levels. Rail dampers are not proposed initially between Bella Vista Station and Kellyville Station, as the surface track design with 1 m high noise barriers results in compliance with the airborne noise trigger levels for all existing sensitive receivers and the predicted levels comply with the airborne noise trigger levels.

Adjacent to the OK Caravan Park in Rouse Hill, the track emerges from a cutting and proceeds onto an embankment. At this location a noise barrier of height 2 m above rail level on the Up side is likely to be required to meet the noise trigger levels. A 2 m high noise barrier along the embankment on the Down side near the OK Caravan Park is also recommended to mitigate noise impacts on future developments in the Area 20 precinct.

It is anticipated that the noise trigger levels (design objectives) can be met at the majority of existing receivers with the proposed noise mitigation measures. Residual exceedances remain at a number of existing properties. In all cases these residual exceedances are marginal (less than 2 dB in the future scenario ten years after project opening). The noise levels at the affected properties include a structure-radiated contribution that is predicted to be greater than or similar to the direct noise from the tracks. It is noted that the noise predictions are sensitive to the detailed design of the viaduct structure and it may be possible to reduce the noise radiated from the structure to below the levels assumed in this assessment.

A number of options remain to further reduce noise impacts on existing receivers, for consideration during the detailed design stage:

- Managing train speeds between Kellyville and Rouse Hill (subject to operational consequences)
- Design viaduct structure (shape, materials and track design) to minimise structure-radiated noise
- Application of additional absorptive material, for example to the viaduct deck (only effective in conjunction with reduced structure-radiated noise levels)
- Property noise impact mitigation treatments.

Acceptance of higher noise levels is also an option, recognising that the exceedances of the non-mandatory noise trigger levels are only small and that in many cases, the existing noise levels at the nearest residences are controlled by road traffic noise, at levels above those predicted to result from the proposed NWRL operations.

The final form of the proposed mitigation measures will be determined during detailed design.

Ground-borne Operational Vibration

The potential impacts of ground-borne vibration in buildings fall into three main categories: human comfort (disturbance); impacts on building contents; and structural damage. A fourth effect is ground-borne noise generated within buildings as a result of the vibration.

For this project, no potential ground-borne vibration impacts would occur to receivers located beyond an approximate 50 m wide corridor above the centreline of the proposed tunnels (dependent upon the local depth of the tunnel). Ground-borne vibration impacts at sensitive receivers adjacent to the surface sections have not been considered, because the offset distance from the tracks to the receivers is generally sufficient to ensure that any associated ground-borne vibration impacts are negligible.

People can perceive floor vibration at levels well below those likely to cause damage to building contents or affect the operation of typical equipment. The controlling vibration design objectives during operations are therefore the human comfort goals. Ground-borne noise goals tend to result in still more stringent vibration requirements than the human comfort goals, so vibration mitigation measures are determined by the ground-borne noise assessment.

Compliance with the ground-borne vibration objectives is predicted for all residential receivers and the majority of other sensitive receiver locations above or near to the proposed NWRL alignment. Three premises which may contain highly vibration sensitive equipment (such as lithography or optical/electronic inspection equipment with high resolution) have been identified with potential exceedances of the vibration design objective:

- Medical Centre/Dental Clinic, 74 Rawson Street, Epping
- West Pennant Hills Veterinary Hospital, 138 Castle Hill Road, West Pennant Hills
- Sydney Animal Hospital, 3 Celebration Drive, Bella Vista.

Ground-borne Operational Noise

Train noise in buildings adjacent to rail tunnels is predominantly caused by the transmission of ground-borne vibration rather than the direct transmission of noise through the air. After entering a building, this vibration may cause the walls and floors to vibrate faintly and hence to radiate noise, which is commonly termed ground-borne or regenerated noise.

Ground-borne noise levels are relevant only where they are higher than the airborne noise from railways, such as when the railway is underground. The NWRL will be underground between Epping and Bella Vista. Some especially sensitive spaces and activities, such as theatres, cinemas, studios and sleeping areas are more prone to disturbance from ground-borne noise than others.

Predictions of ground-borne noise levels for buildings located above or close to the proposed rail alignments have been made. These predictions consider a range of resilient rail fasteners that can be incorporated in the track design to reduce ground-borne vibration and noise, providing different levels of attenuation. Specific locations are identified where High or Very High Attenuation track instead of Standard Attenuation track may be required to achieve compliance with the ground-borne noise design objectives.

With the proposed track forms, ground-borne noise levels are predicted to comply with the design objectives at all residential and other sensitive receiver locations.

Train Stabling Facility Operational Noise

The Tallawong Stabling Facility is considered to be a fixed facility and is assessed in accordance with the NSW *Industrial Noise Policy* (INP). At opening, the facility would have capacity to stable and maintain 20 trains. The capacity of the facility would increase in future in line with increases in operational services. The noise impacts have been assessed both at project opening and for an indicative future capacity.

Since the proposed facility will accommodate modern single deck trains, the noise impacts of train arrivals at the facility will be minimal. Trains will be stabled powered off without auxiliary equipment operating. The worst-case noise impacts of the facility will be concentrated in the night-time and early morning period (before 7:00 am) when trains are arriving or preparing to depart the facility and noise criteria are more stringent than during the daytime and evening.

The noise impact assessment indicates that train auxiliary systems have the potential to result in exceedances of the INP intrusiveness noise goals at the nearest existing residential receivers in a worst-case scenario before 7:00 am.

The overall predicted L_{Aeq} noise levels under adverse meteorological conditions at the nearest receivers are up to 47 dBA in the night-time and early morning period (before 7:00 am). The maximum predicted exceedance of the relevant criteria is 5 dB in the future night-time scenario. Under neutral weather conditions, the predicted noise impacts are 4 dB lower.

While these noise levels exceed the intrusiveness criteria and may be noticeable above the background noise in the night-time and early morning, they are around 10 dB below the measured existing L_{Aeq} noise levels. The predicted levels are not considered to have adverse impacts on acoustic amenity and no specific mitigation is proposed beyond limiting the maximum auxiliary source noise levels in the specifications for the new single deck trains.

The modelling indicates that noise from inside the maintenance building can be contained through appropriate design of the building, under the assumption that train access doors to the maintenance facility will be closed (except when a train movement is required) during the night-time and early morning period.

Unmitigated noise from compressed air release from brakes has the potential to exceed the sleep disturbance screening criterion; however the predicted noise levels and the existing noise environment indicate that air release noise from brakes is unlikely to cause awakening reactions at the most exposed existing receivers.

Operational Noise from Stations, Ancillary Facilities, Public Roads and Car Parks

The potential operational noise impacts from stations, Public Address (PA) systems, station car parks, and ancillary equipment such as substations and ventilation systems have been assessed. The detailed design of these facilities and details of equipment to be used are not available at this stage, and the locations of shafts and service buildings may change during the detailed design stage. The approach to the assessment was therefore to determine allowable noise emissions from stations and ancillary equipment, to inform the detailed design of the project and to provide an early indication on whether the noise criteria are able to be achieved by reasonable and feasible means.

Mitigation measures are likely to be required for some station and tunnel ventilation equipment / locations in order to comply with the project noise design criteria. Mitigation measures that may need to be considered at some locations include appropriate “quiet” equipment selection, in-duct attenuators, noise barriers, acoustic enclosures and the strategic positioning of critical plant away from sensitive receivers.

Train noise break-out through the draught relief shafts from trains operating within the tunnel is not expected to exceed the applicable noise design criteria. To achieve this outcome, all tunnel exhaust shafts and draught relief shafts near sensitive receivers will require mitigation measures (typically in-duct noise attenuation).

Operational noise from proposed car parks has been assessed and in most cases is predicted to comply with the project noise criteria at all sensitive receivers. Noise levels exceeding the noise criteria have been predicted at Cherrybrook Station and Showground Station. It is recommended that a noise barrier be installed along the north-east boundary of the east car park at Cherrybrook Station and openings in the Showground Station parking building may need to be minimised around the south-east corner. The details of the noise mitigation measures would be further developed during the detailed design stage of the project when car park design details are being finalised.

Noise from PA systems will be required to achieve the INP criteria. It is anticipated that these criteria can be achieved with appropriate acoustic design measures such as loudspeaker selection and placement, and installation of ambient noise sensing microphones to control loudspeaker volume levels.

Traffic noise increases from existing roads due to traffic generated by the NWRL stations have been calculated and it was found that exceedances (up to 10 dB) of the Road Noise Policy criteria for traffic generating developments may be exceeded during the daytime peak periods on Robert Road and Franklin Road near Cherrybrook Station.

Exceedances up to 5 dB of the RNP criteria for new local roads at Cherrybrook Station and Kellyville Station are predicted during the morning peak period. It is recommended that noise mitigation measures be considered for the proposed new roads in these station precincts.

Operational Noise from ECRL

As part of the NWRL proposal, rapid transit trains would operate on the ECRL. In relation to potential noise and vibration impacts, these operations are likely to include additional train movements (compared with the existing CityRail timetable). Train operations may also occur at higher speeds (up to 100 km/h where possible), compared with the current maximum speed of 80 km/h for ECRL.

The assessment considered the noise and vibration approval conditions for the ECRL project and how noise and vibration levels are anticipated to change. The review identified two areas where the introduction of rapid transit trains may generate higher airborne noise levels or higher ground-borne noise and vibration levels.

For the section of surface track between Chatswood Station and the ECRL tunnel portals, night-time noise levels are anticipated to remain relatively unchanged. During the daytime period noise levels are predicted to increase by up to 2 dB between Year 2017 and Year 2031. This increase is a result of natural growth and revised signalling systems to facilitate more frequent train operations.

If maximum train speeds in the existing ECRL surface track section between Chatswood and the tunnel portals are increased from 80 km/h to 90 km/h, the change in maximum noise levels (L_{Amax}) associated with individual passbys is not likely to be noticeable (ie less than 2 dB) at the nearest residences.

Whilst the number of daytime train movements on the North Shore Line and ECRL tracks could increase from approximately 30 trains per hour in Year 2017 to 40 trains per hour in Year 2031, this increase is likely to occur gradually over a long time period in response to timetable changes.

For the section of tunnel track between Epping and Chatswood, there would be a more frequent train service, with NWRL trains potentially travelling at higher speeds (up to 100 km/h where possible).

For single deck rapid transit trains, the key factors with potential to change the ground-borne noise and vibration levels are the unsprung mass and axle load of the proposed trains, and the train speed. These factors would likely result in marginally lower source vibration levels for single deck rapid transit trains. Other factors including the wheel and rail condition, track fasteners, rail type and tunnel design are the same or not likely to change.

The corresponding increase in ground-borne noise and vibration levels is estimated to be approximately 2 dB at locations where the maximum train speed increases from 80 km/h to 100 km/h. A change of 1 dB or 2 dB in maximum (L_{Amax}) noise level is difficult for most people to detect and is unlikely to be noticeable.

In relation to the ground-borne noise and vibration criteria which formed part of the ECRL approval, the assessment noted that compliance with the ground-borne noise and vibration criteria was achieved at all locations. Furthermore, apart from one complaint received in Year 2009 (shortly after project opening – which was investigated and cleared by RailCorp), no other complaints have been received by RailCorp in relation to ground-borne noise and vibration from train operations in the ECRL tunnels.

The assessment concluded that it is unlikely that higher speed single deck train operations within the ECRL tunnels would result in a noticeable increase in ground-borne noise and vibration levels within sensitive occupancies above the tunnel alignment.

Construction Noise and Vibration

Depending on the particular site, the ‘handover’ from the major civil construction works will occur from Q4 2015, with the sites being progressively handed over to the construction contractor(s) undertaking the works described in this report. The total period of the construction works described in this report is expected to be approximately four years. Above-ground construction works would primarily be undertaken during daytime periods (7 am to 6 pm Monday to Friday and 8 am to 1 pm on Saturdays). Construction noise and vibration levels during these stages would be similar to those occurring at many other building sites across the Sydney metropolitan area.

At this early stage in the planning process of the NWRL, detailed information about the proposed construction works, equipment selections and site layouts is not available. The construction noise and vibration assessments have therefore been based on preliminary information and previous project experience, and will be reviewed in more detail as the project progresses and the future land-uses in the vicinity of the proposed construction sites are either established and/or become better understood.

At all the sites, the land-use in the immediate surrounding area is mostly commercial or residential, with schools, childcare centres, places of worship and performance venues located near some station sites.

Consistent with the requirements of the *Interim Construction Noise Guideline*, the construction noise impacts are based on a realistic worst-case assessment. For most activities, it is expected that the construction noise levels will be lower than have been (conservatively) predicted in this report.

At the majority of the station sites the predicted construction noise levels for station construction and fit out works indicate compliance with the daytime NMLs for most receivers, with some moderate exceedances. The predicted impacts assume that noise mitigation measures proposed for the major civil works will remain in place throughout the construction period.

At Cherrybrook and Cudgegong Road Stations, the predicted noise levels indicate moderate to high exceedances of the NMLs at some receivers during construction of the car parks. The works at the Tallawong stabling and maintenance facility are predicted to comply with the daytime NMLs. The noise from track construction activities above ground and on the viaduct will also result in moderate to high exceedances of the NMLs at some receivers; however these noise impacts will only occur for a relatively short time at any one location.

Construction activities would also be required in the tunnels between Epping and Bella Vista including the construction of the tunnel floor concrete slab, installation of the permanent rail tracks, installation of the overhead wiring system and other associated mechanical and electrical systems.

It is assumed that the successful contractor would first construct the tunnel floor concrete slab and then install the permanent rail tracks. This would then be used to transport construction equipment and workers through the tunnels using hi-rail vehicles or work trains.

As the design of the permanent rail tracks includes operational ground-borne noise and vibration mitigation (ie higher attenuation track form in areas where the alignment is shallower), the potential impacts from the use of construction work vehicles, which would be travelling at considerably slower speeds than the passenger trains, are likely to be minimal.

After construction of the track form, the contractor will then fit out all of the remaining tunnel systems. This will likely require the use of handheld equipment such as drills, grinders, saws, etc for the majority of the required activities. When considering the type of equipment necessary for these works and given that the works will likely only be in a certain location for a short duration, the potential impacts are likely to be minimal for the majority of the alignment. Notwithstanding, the successful contractor would need to review their proposed construction methodologies and consider all feasible and reasonable mitigation measures at locations where a risk that adverse ground-borne noise and /or vibration impacts may occur.

A *Construction Noise and Vibration Strategy* (CNVS) has been developed by the NWRL project team and will be adopted by all contractors to manage construction noise and vibration emissions across the various construction sites. In preparing this strategy, consideration has been given to several guideline documents including the DECCWs *Interim Construction Noise Guideline*, TCA's *Construction Noise Strategy,* Australian Standard AS 2436-2010 *Guide to noise and vibration control on construction, demolition and maintenance sites* and the *Road Noise Policy*.

1 Introduction

In conjunction with Transport for NSW (TfNSW), a team of specialist consultants has prepared two Environmental Impact Statements (EIS) for the construction and operation of the proposed North West Rail Link (NWRL).

The NWRL comprises the provision of a new electrified passenger railway between Epping and Tallawong Road Rouse Hill, extending the rail network to north west Sydney. It would be a two-track rail corridor 23 km in length, providing eight new stations between Epping to beyond Rouse Hill, and linking directly into the existing Epping to Chatswood Rail Line (ECRL). Approximately 15.5 km of the new railway is underground in deep excavated tunnels from Epping to Bella Vista with the remainder of the route being above ground. Train stabling and maintenance facilities will be provided in the area near Tallawong Road.

Major civil construction works are expected to commence in Year 2014. Construction of the project, including commissioning, is expected to take approximately six years.

The objective of this study (to support EIS2) is to evaluate and assess the potential noise and vibration impacts associated with the operation of the rail line. The impacts of the major civil construction works (including the excavated tunnels, viaduct and stabling facility) have been assessed separately in EIS1[1]. This current study also considers noise and vibration impacts of construction activities not forming part of the major civil construction works, including the operational rail infrastructure and station construction. It identifies relevant noise and vibration objectives, criteria and management levels based on local and international guidelines. Where noise and vibration levels are predicted to exceed the identified design objectives, criteria or management levels, this report presents options and recommendations for mitigating and/or managing the potential impacts.

1.1 Report Overview

This report provides an assessment of the potential operational noise and vibration impacts of the NWRL, including ground-borne noise and vibration where trains will operate in tunnels, airborne noise for the above ground sections, and operational noise from the train stabling and maintenance facility, stations, substations, and ventilation systems (refer Section 2.3 for a detailed description of the proposed works). It also assesses the potential noise and vibration impacts associated with construction activities not covered in the major civil works (EIS1), including the construction of operational rail infrastructure, station construction and fit-outs.

Chapter 2 provides an overview of the project, a detailed description of the proposed route and the operational and construction activities assessed in this report. Acoustic terminology important to understanding the technical noise and vibration aspects relating to this technical paper is defined.

Chapter 3 provides a summary of the environmental assessment requirements for noise and vibration and where these are assessed within the report.

Chapter 4 provides a description of the existing noise environment within the project area and presents the results of the ambient noise studies. The results of the ambient noise studies are used to assist in determining noise criteria for the operation of fixed facilities such as the stations, substations,

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[1] Report NWRL-10046-R-NO-00005-v2.0-Major Civil NV - *North West Rail Link - Noise and Vibration Technical Paper for Major Civil Construction Works* dated March 2012

tunnel ventilation systems and the train stabling and maintenance facility, and also to determine the noise management levels (NMLs) for the airborne construction noise assessment.

Chapter 5 describes the process for predicting and assessing airborne operational noise impacts associated with train passbys. Noise levels are identified that trigger the need to consider noise mitigation for the affected sensitive receivers adjacent to the surface track section. Feasible and reasonable mitigation options are identified along with residual noise impacts.

Chapter 6 assesses the operational ground-borne vibration impacts associated with train passbys, including a description of the relevant trigger levels, the prediction process and options for vibration mitigation.

Chapter 7 considers the operational ground-borne noise (or regenerated noise) in buildings above the tunnels as a result of train passbys, following from the ground-borne vibration predictions in Chapter 6.

Chapter 8 provides a summary of the noise design objectives applicable to the Tallawong Road stabling and maintenance facility, and assesses the potential noise impacts arising from operation of the facility.

Chapter 9 considers the operational noise impacts from stations, public roads with additional project-related traffic, station car parks and ancillary facilities such as substations and ventilation systems.

Chapter 10 considers the operational noise and vibration impacts associated with single deck train operations on the existing ECRL tracks between Epping and Chatswood.

Chapter 11 provides a summary of the noise and vibration guidelines applicable to the construction works. These are based on guidelines administered by the NSW Environment Protection Authority (EPA), and also on Australian and International Standards.

Chapter 12 provides an overview of the construction noise and vibration prediction process and the assessment of noise and vibration impacts at sensitive receivers adjacent to each construction site. The assessment of construction site noise and vibration is undertaken from east to west (Epping to beyond Rouse Hill).

Chapter 13 provides an overall summary and conclusions for the noise and vibration assessment.

The assessment embodied within this report is based upon the current NWRL alignment and preliminary information relating to the likely construction methods and operations. This represents one example of how the project could be constructed, operated and maintained. More detail on the planned work methods, location of plant and equipment and scheduling is normally available during the post-approval stage, and it will be necessary to undertake further detailed analysis of the potential noise and vibration impacts and mitigation measures at this time.

Should circumstances arise that result in minor changes to the NWRL design or proposed operations, the noise and vibration impacts as a result of the project would not be expected to be greater than those described and assessed within this report. It is noted that the project noise and vibration design objectives are unlikely to change throughout the project, and that the successful tenderers would be required to comply with the recommended performance criteria described in this report.

2 Project Description

2.1 Overview of North West Rail Link

In June 2012 TfNSW announced a new rail plan for Sydney, *Sydney's Rail Future*[2].

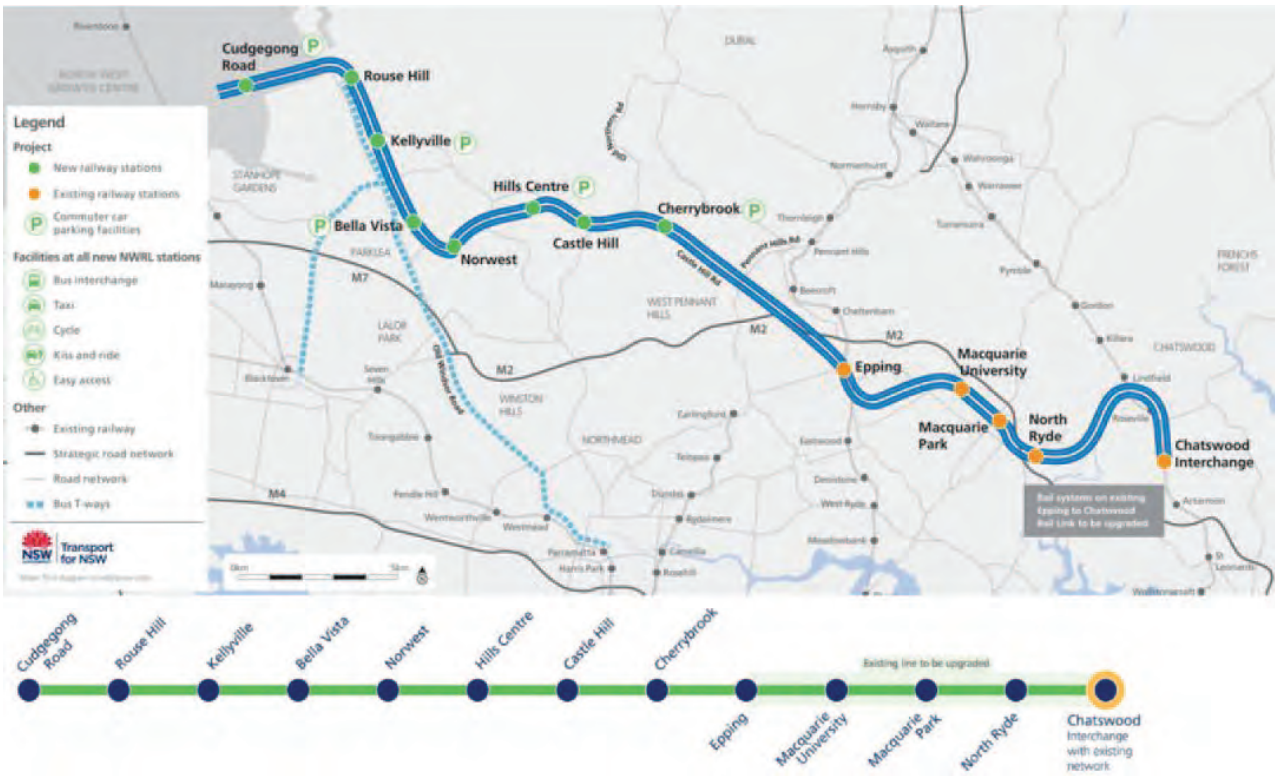
Sydney's Rail Future is a long term plan to increase the capacity of Sydney's rail network through investment in new services and upgrading of existing infrastructure. It is a plan to improve the customer's experience. A central aim of the plan is to transform and modernise Sydney's rail network so that it can grow with the population and meet the needs of customers now and into the future.

Sydney's Rail Future is an integral part of the *NSW Long Term Transport Master Plan* currently being developed by the NSW Government.

The NWRL forms part of Sydney's Rail Future, a customer focused public transport plan to modernise Sydney's rail network and trains.

The NWRL project is shown in Figure 2.1.

Figure 2.1 NWRL Route Overview



2 http://haveyoursay.nsw.gov.au/article/sydneys-rail-future

NWRL comprises the provision of a new electrified passenger railway between Epping and Tallawong Road Rouse Hill, extending the rail network to north west Sydney. It would be a two track rail corridor 23 km in length, comprising the following main components:

- A direct underground connection into the existing Epping to Chatswood Rail Line (ECRL) at Epping, with single deck rapid transit trains operating between the north west and Chatswood
- A service facility at Epping
- An intermediate service facility between Epping and Cherrybrook
- Safeguarding of two stub tunnels for the future Parramatta to Epping Rail Link.
- Eight new stations located at Cherrybrook, Castle Hill, Showground, Norwest, Bella Vista, Kellyville, Rouse Hill and Cudgegong Road
- An underground section of route comprised of 15.5 km of twin tunnels with cross passages at regular intervals between Epping and Bella Vista
- A 7.5 km above ground section of route from Bella Vista to the Tallawong Road Stabling Facility, which would be a combination of viaduct, embankment, at grade and cutting
- Initial stabling and maintenance activities at Tallawong Road.

2.2 Route Description by Section

2.2.1 Chatswood Station to Epping Station

NWRL trains would operate between Chatswood and Epping using the existing ECRL.

The NWRL would continue from the existing underground tunnel stubs located immediately north of the underground ECRL Epping Station platform. The rail line between Epping and Chatswood would be retrofitted to accommodate modern single deck trains before the NWRL project opens to customers. An assessment of the potential noise and vibration impacts associated with single deck train operations on the existing ECRL is provided in Chapter 10.

2.2.2 Epping Station to Bella Vista Station

The first 15.5 km of the rail line between Epping and Bella Vista is proposed to be in twin underground rail tunnels. This underground tunnel section of the project would include stations at Cherrybrook, Castle Hill, Showground and Norwest.

From the Epping connection the twin tunnels would turn north west onto a long straight section and descend to pass beneath Devlins Creek and the M2 Motorway before rising on a long and comparatively steep grade beneath Pennant Hills Road and towards Cherrybrook Station.

This section of the route would also include:

- The site of the Epping Services Facility at Beecroft Road, approximately 350 m from the ECRL connection
- An alignment that would allow for any future Parramatta to Epping Rail Link to join the tunnels approximately 800 m north of Epping
- The site of the Cheltenham Services Facility near Cheltenham Oval, approximately 1.8 km from the ECRL connection

- Provision for a cross over cavern in the vicinity of the Epping Services Facility.

Continuing under Pennant Hills Road, the alignment would rise towards Cherrybrook Station. Beyond Cherrybrook the alignment would run to the west beneath Castle Hill Road descending on a long moderate grade before turning south west at the location of Castle Hill Station beneath Arthur Whitling Park. A crossover cavern would be provided on the city side of Castle Hill Station.

West of Castle Hill Station the alignment would descend and curve north westerly onto a straight section of route located below Showground Road before turning due west on the approaches to Showground Station which would be located south of the showground and adjacent to Carrington Road.

Leaving the station and moving west, the alignment would pass below Cattai Creek before traversing to the south and falling gradually as it passes under the Castle Hill trading estate precinct on a long straight section in a south westerly direction. Just beyond Windsor Road the alignment would curve to bring the corridor directly below the southern edge of Norwest Boulevard. Norwest Station would be located here between Strangers Creek and Brookhollow Avenue immediately to the south east of Norwest Boulevard.

Leaving Norwest Station the alignment would continue to follow Norwest Boulevard in a south westerly direction up to the intersection with Solent Circuit. Past this point of the alignment it would begin to diverge from Norwest Boulevard taking a more westerly route on a long curved section which would eventually turn the alignment around to the north west and parallel to Old Windsor Road. The alignment would continue in tunnel to a portal located immediately north of Celebration Drive and beyond this Bella Vista Station would be located a little further to the north.

2.2.3 Bella Vista Station to Rouse Hill Station

From Bella Vista Station, the alignment would continue to follow a route located roughly parallel to the eastern side of Old Windsor Road and would begin to climb to become elevated north of Balmoral Road. This elevated section of alignment (the Skytrain) would at first be located on an earthwork embankment but this would soon become an elevated rail viaduct as the route passes over an area of local floodplain in the vicinity of Samantha Riley Drive with Kellyville Station located immediately to the south of this road. A crossover would be provided for between Bella Vista and Kellyville Stations.

The Skytrain would continue to the north west, crossing and then following the eastern side of Windsor Road with Rouse Hill Station located on a straight section of elevated track between Rouse Hill Town Centre and Windsor Road, above the existing North West T-Way interchange.

2.2.4 Rouse Hill Station to Tallawong Road

From Rouse Hill Station the alignment would then curve westwards to pass over Windsor Road to run towards the south west, parallel and to the north of Schofields Road. The alignment would cross Second Ponds Creek and pass beneath Cudgegong Road which would be located on a new bridge. The terminus station, Cudgegong Road, would be sited just beyond in a shallow cutting. On the far side of the platforms, beyond a new bridge carrying Tallawong Road, the alignment would broaden into the stabling and maintenance facility at Tallawong Road. Provision would be made for a possible future extension of the line further to the west.

2.3 Overview of Environmental Impact Assessment

This Environmental Impact Statement (EIS2) covers operational noise and vibration impacts. It also covers construction activities associated with the NWRL but not assessed in EIS1 (the major civil works EIS). An overview of the activities included in this EIS is as follows:

- Airborne noise from trains operating on the NWRL
- Ground-borne noise and vibration from trains operating on the NWRL
- Ground-borne noise and vibration from modified train operations on the ECRL
- Operational noise from stations
- Operational noise from tunnel ventilation systems
- Noise from the operation of the Tallawong stabling and maintenance facility
- Operational noise from traction substations and other ancillary facilities
- Station fit out works, including construction of station buildings
- Track construction, including overhead wiring construction
- Construction of roads over the NWRL rail corridor (except those which were included in the major civil works EIS)
- Construction of the Tallawong Road stabling and maintenance facility, with the exception of earthworks (which were included in the major civil works EIS).

2.4 Terminology

2.4.1 Noise and Vibration Terminology

Detailed descriptions of the acoustic terminology used within this report are presented within Appendix A. A Glossary of terms is also provided.

2.4.2 Track Chainage and Directions

Consistent with normal rail terminology, track chainages for the main alignment are referenced to 0 km at Central Station. Down and Up directions refer to trains travelling away from and towards Central Station, respectively. The Down and Up sides of the corridor are the left-hand and right-hand sides, respectively, when facing away from Central Station towards north west Sydney.

2.4.3 Types of Noise and Vibration

The most common form of noise experienced by people is termed ‘airborne noise’, indicating that it propagates between the source and receiver primarily through the air. This is the primary form of noise that occurs adjacent to surface railway tracks, roads and construction sites.

Airborne noise does not propagate through the ground. For below ground construction activities and for trains operating in tunnels, ground-borne noise may be heard by building occupants. Energy propagates as vibration through the ground and is ‘re-radiated’ by the building floor and walls as ground-borne noise.

In some cases, ground-borne vibration can be felt by building occupants. Without appropriate controls, vibration may also induce secondary effects such as the rattling of crockery and other loose fittings and furnishings, but is rarely of sufficient magnitude to cause direct damage to buildings. For trains operating in tunnels, compliance with operational ground-borne noise objectives effectively always precludes perceptible vibration impacts and damage to buildings.

3 Environmental Impact Assessment Requirements

This report provides an assessment of the potential noise and vibration impacts associated with the construction and operation of the NWRL proposal. It has been prepared in accordance with the requirements in the current noise and vibration guidelines administered by the NSW EPA[3].

This report has also been prepared to address specific noise and vibration assessment requirements and commitments in the following documents:

- Director General Requirements for State Significant Infrastructure application
- Staged Infrastructure Approval
- Statement of Commitments
- ECRL Conditions of Approval (refer Chapter 10).

3.1 Director General Requirements for State Significant Infrastructure Application

Project Applications for the staged NWRL proposal were lodged with the Department of Planning and Infrastructure (DP&I). Following receipt of the Project Applications, Director General's Requirements (DGR's) were issued for the Environmental Impact Statement (EIS) in February 2012 (for Stage 1) and in August 2012 (for Stage 2). These DGR's are supplementary requirements, to be read in conjunction with the existing environmental assessment requirements of the Staged Infrastructure Approval and associated statement of commitments (described in the following Sections 3.2 and 3.3).

In the February 2012 DGR's, the specific modification requirements that relate to NWRL noise and vibration are that the assessment shall consider '*the Area 20 Precinct proposed land uses, infrastructure and strategies, taking into account Development in Special Area – Cudgegong Station Area (Precinct 6 – Area 20 Precinct Plan)*' and that '*the assessment of construction noise shall have consideration of the Interim Construction Noise Guideline (DECC, 2009)*' (ICNG).

In the August 2012 DGR's, the specific supplementary requirements relating to noise are that *'The assessment of construction and operational noise and vibration shall have consideration of the relevant components of Assessing Vibration: a technical guideline (DECCW,2006), Interim Construction Noise Guideline (DECC, 2009), NSW Industrial Noise Policy (EPA, 2000), Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects (DECC, 2007), and the NSW Road Noise Policy (DECCW, 2011).'*

Within this report, the requirement to consider future land uses in the Area 20 Precinct is met by considering operational noise impacts of the NWRL on the Area 20 Precinct proposed land uses.

All other supplementary requirements are met by adopting the relevant guidelines for the assessment procedure.

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[3] http://www.environment.nsw.gov.au/noise/

3.2 Staged Infrastructure Approval

A Staged Infrastructure Approval (previously Concept Plan Approval) for the western portion of the previous North West Metro proposal (i.e. from Epping to Rouse Hill) was provided by the Department of Planning in 2008. The Staged Infrastructure Approval included the following conditions relating to noise and vibration:

> *"**Performance Standards***
>
> *2.6 In relation to operational noise and vibration, the Proponent shall ensure that:*
>
> *a) the project rail corridor is designed consistent with the Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects (DECC, 2007);*
>
> *b) the project stabling facilities are designed consistent with the Industrial Noise Policy (EPA, 2000); and*
>
> *c) the project is designed consistent with Assessing Vibration: A Technical Guideline (DECC, 2006)."*

> *"**Noise and Vibration***
>
> *3.6 The Proponent shall review the noise and vibration impacts of the project during construction (including construction traffic) and operation, considering all reasonable and feasible mitigation options at existing and planned future receivers."*

This report describes the noise and vibration impacts of construction and operation of the NWRL and details reasonable and feasible mitigation options at existing and future receivers. The noise and vibration assessments have been undertaken in accordance with the abovementioned performance standards.

For construction activities, a Construction Noise and Vibration Strategy (CNVS) has been developed for the NWRL project (refer Appendix J) which addresses the above conditions. The CNVS includes requirements for the construction contractor(s) to prepare Construction Noise and Vibration Impact Statements (CNVIS) for each worksite and major construction phase, identifying reasonable and feasible mitigation measures at sensitive receivers.

3.3 Statement of Commitments

As part of the Staged Infrastructure Approval, commitments were made in relation to construction and operational noise and vibration. Table 3.1 shows each commitment and describes the section of this report where each commitment has been addressed.

Table 3.1 Noise and Vibration Commitments

Reference	Commitment	Addressed
Desired Outcome	Design development and assessment adopts best practice measures to minimise construction and operational noise and vibration impacts.	This report
Action 20	A detailed noise and vibration assessment of the proposed construction activities, including blasting if required, would be undertaken as part of design development and would include the investigation of the potential need for reasonable and feasible mitigation in accordance with relevant policies and guidelines.	Section 12

Reference	Commitment	Addressed
Action 21	Consult with local Councils, Growth Centres Commission and RailCorp in relation to land use planning and development controls to minimise the need for physical noise mitigation.	Section 5.8
Action 22	In regard to operational noise, the *Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects* (Department of Planning, 2007) would be used to implement the following activities: – Modelling of operational noise impacts (including ground borne noise) in more detail as part of the design development; – Identification of acoustic mitigation measures to meet, where reasonable and feasible, the design goals; and – Select representative locations for the project at which it is appropriate to later assess compliance.	Section 5 and Section 7
Action 23	In regard to train stabling operational noise, the following would be undertaken: – Determine the extent of any physical noise mitigation measures in consultation with Department of Environment and Climate Change, RailCorp and Growth Centres Commission; and – Review the results of RailCorp's investigations into addressing horn noise and consider the feasibility in consultation with RailCorp of implementing a low volume horn test. This is no longer required as horn noise testing is not proposed for NWRL operations.	Section 8
Action 24	Investigate feasible and reasonable mitigation measures to manage operational vibration in consultation with Councils, the Department of Environment and Climate Change and RailCorp.	Section 6

4 Description of the Existing Environment

The existing noise environment varies along the length of the proposed alignment, as would be expected from the wide range of commercial, urban, residential and industrial land uses within the study area.

4.1 Sensitive Receivers

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

The sensitivity may also depend on the existing noise and vibration environment. For example, the *'Industrial Noise Policy'* (EPA 2000) and Australian / New Zealand Standard AS/NZS 2107:2000 *'Recommended Design Sound Levels and Reverberation Times for Building Interiors'* recommend higher acceptable noise levels in noisier urban areas compared with quieter suburban areas. Guidelines produced by the American Public Transit Association (APTA) also nominate higher ground-borne noise goals for buildings with multiple residences than for single residences.

4.2 Sensitive Receiver Categories

Following receipt of the horizontal alignment for the NWRL, SLR Consulting staff reviewed the existing and proposed land use within a corridor extending approximately 100 m either side of the proposed rail alignment and typically 200 m from the construction sites. This information was collated from a combination of site inspections, street-level imagery and review of aerial photography. Each building was classified into one of the following receiver categories:

1. Commercial
2. Educational
3. Industrial
4. Mixed commercial/residential
5. Residential
6. Place of Worship
7. Special Sensitive (e.g. hospital, precision laboratories, recording studios).

The noise and vibration assessment presented in this report considers all residential receivers to be of a sensitive nature. Commercial receivers are generally considered to be less sensitive to noise and vibration compared to residential receivers.

4.3 Ambient Noise Surveys and Monitoring Locations

In order to characterise the existing ambient noise environment across the project area and to establish ambient noise levels upon which to base the construction noise management levels, environmental noise monitoring was performed at ten representative locations during October and November 2011. This information has been supplemented with ambient noise data collated during the previous NWRL proposal and other recent projects, resulting in a database for a total of 25 representative locations across the project area.

Noise monitoring locations were selected based on a detailed inspection of all the potentially affected areas and considering the following:

- Other noise sources which may influence the recordings
- Security issues for the noise monitoring devices
- Gaining permission for access to the location from the resident or landowner.

The "potentially most affected" receiver locations near each construction site have been chosen in accordance with the guidelines in Section 3.1.2 of the *'Industrial Noise Policy'* (INP), which is reproduced in part below:

> *"**NSW Industrial Noise Policy 3.1.2***
>
> ***Most affected location(s)** – locations that are most affected (or that will be most affected) by noise from the source under consideration as per Note 2 in Section 2.2.1. In determining these locations, the following need to be considered: existing background levels, noise source location/s, distance from source/s (or proposed source/s) to receiver, and any shielding (for example, building, barrier) between source and receiver. Often several locations will be affected by noise from the development. In these cases, locations that can be considered representative of the various affected areas should be monitored."*

Table 4.1 lists the various monitoring locations, whilst Appendix B illustrates the locations graphically on a site plan.

Table 4.1 Ambient Noise Monitoring Locations

Location	Address	Project Area	Year Collated
BG01	12/10 Edensor Street, Epping	Epping Services Facility and Decline site	2011
BG02	32A Castle Howard Road, Cheltenham	Cheltenham Services Facility	2011
BG03	2 Ferndale Road, Beecroft	Cheltenham Services Facility	2010
BG04	130 Franklin Road, Cherrybrook	Cherrybrook Station	2008
BG05	11 Kayla Way, Cherrybrook	Cherrybrook Station	2011
BG06	329 Old Northern Road, Castle Hill	Castle Hill Station	2011
BG07	142 Showground Road, Castle Hill	Showground Station	2011
BG08	3 Carrington Road, Castle Hill	Showground Station	2008
BG09	33 Jacqui Circuit, Baulkham Hills	Norwest Station	2011

Location	Address	Project Area	Year Collated
BG10	8 Maley Grove, Glenwood	Bella Vista Station	2005
BG11	12 Craigend Place, Bella Vista	Bella Vista Station	2011
BG12	24 Emmanuel Terrace, Glenwood	Bella Vista Worksite	2005
BG13	36 Rothwell Circuit, Glenwood	Surface Track	2005
BG14	15 Kentwell Street, Stanhope Gardens	Surface Track	2005
BG15	16 Wenden Avenue, Kellyville	Kellyville Station	2011
BG16	9 Clovelly Circuit, Kellyville	Surface Track	2005
BG17	45 Lycett Avenue, Kellyville	Surface Track	2005
BG18	1 Beck Place, Kellyville	Surface Track	2005
BG19	9-19 Kilbenny Street, Kellyville	Surface Track	2005
BG20	19 Bellcast Road, Rouse Hill	Surface Track	2011
BG21	107 Schofields Road, Rouse Hill	Surface Track	2009
BG22	830 Windsor Rd, Rouse Hill	Surface Track	2009
BG23	88 Rouse Road, Rouse Hill	Surface Track	2009
BG24	75 Schofields Road, Rouse Hill	Cudgegong Road Station	2009
BG25	43 Schofields Road, Rouse Hill	Tallawong Stabling Facility	2011

4.4 Methodology for Unattended Noise Monitoring

The purpose of the unattended noise monitoring is to determine the existing L_{Aeq}, L_{A90} and other relevant statistical noise levels during the daytime, evening and night-time periods. These were used to assist in determining the appropriate noise management levels for the proposed construction works and for determining acceptable noise levels adjacent to fixed facilities such as stations and the train stabling facility.

Unattended noise loggers were deployed adjacent to sensitive receivers over a minimum period of one week in order to measure the prevailing levels of ambient noise. The measurements were generally conducted at a height of 1.5 m above the local ground level.

All noise measurement instrumentation used in the surveys was designed to comply with the requirements of Australian Standard AS 1259.2-1990 *'Acoustics - Sound Level Meters. Part 2: Integrating – Averaging'* and carried appropriate and current NATA calibration certificates.

The equipment utilised for the continuous unattended noise surveys comprised Australian Research Laboratories Type 316 and Type 215 environmental noise loggers, together with Svantek Type 957 noise loggers. All noise loggers were fitted with microphone wind shields.

The calibration of the loggers was checked before and after each measurement survey, and the variation in calibration at all locations was found to be within acceptable limits at all times.

All noise loggers were set to record statistical noise descriptors in continuous 15 minute sampling periods for the duration of their deployment.

The results of the noise monitoring have been processed in accordance with the procedures contained in the INP so as to establish representative sensitive receiver background noise levels.

Weather data recorded during the noise monitoring survey periods by the Sydney Bureau of Meteorology (at Horsley Park) was used to assist in identifying potentially adverse weather conditions, such as excessively windy or rainy periods, so that weather affected data could be discarded. Based on the meteorological results, rain and wind affected results have been excluded from the summary results.

4.5 Unattended Noise Monitoring Results

The results of the unattended ambient noise surveys are presented in Table 4.2, with the 24 hour average noise level plots for each monitoring location being shown graphically in Appendix C.

Representative Rating Background Levels (RBL's) and L_{Aeq} (energy averaged) noise levels during the standard daytime, evening and night-time hours, are shown in Table 4.2.

Table 4.2 Summary of Unattended Noise Logging - Construction Noise Parameters

Location	Noise Level (dBA)[1]						
	Daytime 7.00 am to 6.00 pm		Evening 6.00 pm to 10.00 pm		Night-time 10.00 pm to 7.00 am		
	RBL	L_{Aeq}	RBL	L_{Aeq}	RBL	L_{Aeq}	L_{Amax}[4]
BG01	45	56	41	54	32	51	61-70
BG02	49	55	41	52	31	48	53-62
BG03	55	61	52	60	35	55	63-69
BG04	45	53	41	51	34	49	47-65
BG05	37	50	38	48	30 [2]	45	53-63
BG06	50	61	47	59	31	54	66-73
BG07	54	70	48	67	30	65	75-83
BG08	54	64	45	59	34	54	65-71
BG09	47	53	45	52	38	47	53-68
BG10	46	53	45	52	36	50	59-63
BG11	36	52	35	46	31	43	47-58
BG12	51	61	48	60	33	57	69-75
BG13	51	60	50	58	34	54	63-69
BG14	47	62	48	61	38	58	69-73
BG15 [3]	39	49	41	48	39	48	53-62

Location	Noise Level (dBA)[1]						
	Daytime 7.00 am to 6.00 pm		Evening 6.00 pm to 10.00 pm		Night-time 10.00 pm to 7.00 am		
	RBL	L_{Aeq}	RBL	L_{Aeq}	RBL	L_{Aeq}	L_{Amax} [4]
BG16 [3]	45	55	46	53	37	51	57-62
BG17	48	62	44	59	32	56	68-75
BG18	54	63	52	60	47	58	70-74
BG19	52	64	49	62	32	59	70-74
BG20	41	52	41	50	33	48	55-62
BG21	51	60	51	58	39	55	63-67
BG22	52	68	51	66	39	63	78-83
BG23	44	57	43	51	34	48	49-72
BG24 [3]	45	59	49	59	38	55	66-71
BG25 [3]	43	53	44	54	30 [2]	58	61-86

Note 1: The RBL and L_{Aeq} noise levels have been obtained using the calculation procedures documented in the INP

Note 2: In accordance with the INP, where the RBL is found to be less than 30 dBA, then it is set to 30 dBA

Note 3: Where the daytime RBL is lower than the evening RBL, then the daytime RBL has been used to determine conservatively lower construction NMLs

Note 4: Maximum noise levels during the night-time period have been determined from the daily noise logging plots where the lower noise level is based on the 25th percentile of the 15-minute L_{Amax} noise levels and the upper range is based on the 75th percentile of the 15-minute L_{Amax} noise levels

4.6 Attended Airborne Noise Measurements

Attended noise measurements were undertaken at the majority of locations listed in Table 4.1 (and illustrated on the site plan in Appendix B) in order to quantify the relative contributions from the various noise sources in the vicinity of the unattended noise monitoring locations. These attended noise measurements were undertaken at the same locations where the unattended noise monitoring was performed.

At each location, measurements were performed using a Brüel & Kjær Type 2260 sound level meter for a minimum period of 30 minutes. Wind Speeds were measured to be below 5 m/s at all times, and all measurements were performed at a height of 1.5 m above ground level.

Calibration of the sound level meter was checked before and after each measurement and the variation in calibration at all locations was found to be within acceptable limits at all times. A summary of the measured noise levels and observations is provided in Appendix D. During each of the attended noise measurements the observer noted the various noise sources and levels influencing the ambient noise environment.

5 Airborne Operational Noise

5.1 Assessment Process

Guidance in relation to the operational assessment process for the project is provided in the *Interim Guideline for Assessment of Noise from Rail Infrastructure Projects* (IGANRIP). The main purpose of the guideline is to assist the ongoing expansion of rail transport by ensuring that potential noise impacts associated with rail developments are assessed in a consistent and transparent manner. The guidelines are not mandatory and are intended to encourage the best outcomes for the community as a whole, given the application of feasible and reasonable means to control noise and vibration generated by rail traffic.

The assessment process is illustrated in Figure 5.1 (based on Figure 2 in IGANRIP).

Figure 5.1 Assessment Process

Planning Focus Stage (Completed)

Consult with the community and relevant agencies to determine the environmental noise and vibration values to be protected.

Environmental Assessment (This Report)

1. Determine the noise and vibration trigger levels
2. Undertake a noise and vibration assessment to determine locations where the noise and vibration trigger levels are likely to be exceeded as a result of the project.
3. At locations exceeding the noise and vibration trigger levels, undertake a cost-benefit analysis of feasible and reasonable mitigation measures and prioritise these to maximise the protection of the environment. This includes noise, vibration, community views and aesthetic impacts.
4. Incorporate the proposed mitigation measures and identify the noise and vibration levels achievable for the project.

Public Exhibition and Submissions Report Stage

1. Consult with the affected community to review the noise and vibration levels achievable for the project (exhibition stage of the Environmental Assessment).
2. Review the proposed mitigation measures following community consultation and produce a report (e.g. submissions report) documenting the proposed mitigation measures and achievable noise and vibration levels for the project.

Planning Approval Stage

Achievable noise and vibration levels and/or mitigation measures for the project are included in the approval conditions.

5.2 Operational Noise Metrics

The primary noise metrics used to describe airborne railway noise emissions in the modelling and assessments are:

- $L_{Amax,95\%}$ — The *"typical maximum noise level"* for a train passby event. In IGANRIP, L_{Amax} refers to the maximum noise level not exceeded for 95% of rail passby events and is measured using the 'fast' response setting on a sound level meter.
- $L_{Aeq(24hour)}$ — The *"energy average noise level"* evaluated over a 24 hour period. The $L_{Aeq(24hour)}$ represents the cumulative effects of all the train noise events occurring in one day.
- $L_{Aeq(15hour)}$ — The $L_{Aeq(15hour)}$ represents the cumulative effects of all the train noise events occurring in the daytime period from 7.00 am to 10.00 pm.
- $L_{Aeq(9hour)}$ — The $L_{Aeq(9hour)}$ represents the cumulative effects of all the train noise events occurring in the night-time period from 10.00 pm to 7.00 am.
- $L_{Aeq(1hour)}$ — The busiest 1-hour "*energy average noise level*" The $L_{Aeq(1hour)}$ represents the typical L_{Aeq} noise level from all the train noise events during the busiest 1-hour of the assessment period.
- L_{AE} — The "*Sound Exposure Level*", which is used to indicate the total acoustic energy of an individual noise event. This parameter is used in the calculation of L_{Aeq} values from individual noise events.

The subscript "A" indicates that the noise levels are filtered to match normal human hearing characteristics (i.e. A-weighted).

5.3 Operational Noise Trigger Levels

IGANRIP provides "noise trigger" levels that flag the need for an assessment of the potential noise and vibration impacts from a project. IGANRIP also suggests measures that may be feasible and reasonable to apply to reduce a project's impacts.

For airborne noise created by the operation of surface track, trigger levels are provided for rail infrastructure projects including a "new railway line" or "redevelopment on an existing railway line". The NWRL corridor project falls into the former category from the tunnel portal at Bella Vista to the entrance of the Tallawong Stabling and Maintenance Facility.

The noise trigger levels for residential and other sensitive receiver locations are provided in Table 5.1 and Table 5.2.

In assessing noise levels emitted by the project at residential receiver locations, the outdoor noise level to be addressed is that prevailing at a location 1 m in front of the most affected building facade. Any "internal noise level" refers to the noise level at the centre of the habitable room that is most exposed to the noise source and applies with windows open sufficiently to provide adequate ventilation.

Table 5.1 Airborne Noise Trigger Levels for Surface Track - Residential

Type of Development	Residential Noise Trigger Levels (dBA)		
	Daytime 7.00 am to 6.00 pm	**Night-time 10.00 pm to 7.00 am**	**Comment**
New Rail Line	Development increases existing rail noise levels AND Resulting rail noise levels exceed:		These numbers represent external levels of noise that trigger the need for a rail infrastructure project to conduct an assessment of its potential noise impacts. An increase in existing rail noise levels is taken to be an increase of 2.0 dB or more in L_{Aeq} in any hour or an increase of 3.0 dB or more in $L_{Amax,95\%}$.[1]
	60 $L_{Aeq(15hour)}$ 80 $L_{Amax,95\%}$	55 $L_{Aeq(9hour)}$ 80 $L_{Amax,95\%}$	

Note 1: As the NWRL is a new rail line where sensitive receivers are not exposed to existing rail noise, the noise increase component of the trigger levels are not applicable.

Table 5.2 Airborne Noise Trigger Levels for Surface Track – Other Sensitive Land Uses

Sensitive Land Use	Noise Trigger Levels (dBA)
	New Rail Line Development
	Development increases existing rail noise levels by 2.0 dB or more in L_{Aeq} in any hour [1] AND Resulting rail noise levels exceed:
Schools, educational institutions – internal	40 $L_{Aeq(1hour)}$
Places of worship – internal	40 $L_{Aeq(1hour)}$
Hospitals – internal	35 $L_{Aeq(1hour)}$
Hospitals – external	60 $L_{Aeq(1hour)}$
Passive recreation	L_{Aeq} as per residential noise level values in Table 5.1 (does not include maximum noise level component)
Active recreation (eg golf course)	65 $L_{Aeq(24hour)}$

Note 1: As the NWRL is a new rail line where sensitive receivers are not exposed to existing rail noise, the noise increase component of the trigger levels are not applicable.

For new rail projects, the noise trigger levels apply both immediately after operations commence and for projected traffic volumes at an indicative period (ten years or similar) into the future to represent the expected future level of rail traffic usage. For this assessment, the future scenario represents rail operations approximately 10 years after project opening.

5.4 Operational Noise Modelling

5.4.1 Introduction to Noise Modelling

SoundPLAN Version 7.1 has been used to calculate railway noise emission levels for this project. Of the train noise prediction models available within SoundPLAN, the Nordic Rail Traffic Noise Prediction Method (Kilde 1984) has been used.

Noise emissions from suburban electric passenger trains on surface track are predominantly caused by the rolling contact of steel wheels on steel rails. Even under ideal conditions with “smooth” rail and wheels, noise would occur as a result of the elastic deformation at the rolling contact point and due to the finite residual roughness of typical wheel and rail running surfaces. Other noise sources on electric passenger trains (such as air-conditioning plant and air compressors) are generally insignificant in noise level when compared with the wheel rail interaction, unless the train is travelling at very low speed or is stationary. Where track is located on bridges or viaducts, vibration is transmitted to the structure resulting in structure-radiated noise in addition to the direct rolling noise from the track and wheels of the trains.

Noise modelling, using SoundPLAN, has been used by SLR Consulting on many projects. Predicted noise levels in previous rail modelling projects have shown good correlation with the values measured at the completion of the projects, once operations began.

5.4.2 Source Noise Levels

The SoundPLAN input data used in the modelling for this project has been chosen so that the calculated noise levels reflect the likely future NWRL fleet of new single-deck trains operating on slab track. The reference noise levels used for the noise modelling are shown in Table 5.3.

The *Handbook of Railway Vehicle Dynamics*[4] states that slab tracks *“are generally found to be noisier than conventional ballasted track, typically by 3 to 5 dB. This can be attributed to two features of such tracks. Firstly, they tend to be fitted with softer rail fasteners in order to introduce the resilience normally given by the ballast. Second, they have a hard sound-reflecting surface, whereas ballast has an absorptive effect. The latter affects the overall noise by 1 to 2 dB.”*

The increase in noise emissions resulting from softer rail fasteners can be controlled by the addition of tuned absorbers (rail dampers). The noise reduction that can be achieved by rail dampers in any situation will depend on the starting noise level. Measurements on the ECRL (on similar track to that proposed for the NWRL) found a benefit of 4 dB from the installation of rail dampers[5].

The reference noise levels shown in Table 5.3 are consistent with the standard source noise levels applied for modern passenger trains by SLR Consulting on other projects, with the following adjustments to account for the higher noise emissions from track on slab rather than ballasted track.

- While noise emissions from the rail will be approximately 4 dB higher with slab track as the result of softer rail fasteners, this increase in noise will be controlled where required by application of source mitigation in the form of rail dampers, giving a net change of zero in both L_{AE} and L_{Amax}.
- An increase of 2 dB in L_{AE} and L_{Amax} is included, to account for increased reflection (reduced absorption) from slab track (without ballast).

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[4] S. Iwnicki (Editor) *Handbook of Railway Vehicle Dynamics*, Taylor and Francis 2006

[5] C.M. Weber and D. Sburlati, *Source Noise Control to Mitigate Airborne Noise at High Rise Developments – Epping to Chatswood Rail Link*. Proceedings of 20th International Congress on Acoustics 2010.

The passby noise levels used in the noise modelling assume slab track in good condition and that the running surface of the rail head is free of visible defects. Wheel tread condition is also assumed to be in good to fair condition.

Table 5.3 Reference Noise Levels for NWRL Rolling Stock on Slab Track (8-car trains)

Train Types	Source Mitigation	Reference Conditions	$L_{Amax, 95\%}$	L_{AE}
Single-deck	With Rail Dampers	15 m, 80 km/h	87 dBA	90 dBA
Single-deck	Without Rail Dampers	15 m, 80 km/h	91 dBA	94 dBA

Over the past few decades, the majority of railway lines in the Sydney metropolitan area have been upgraded from jointed track to continuously welded rail. With jointed track, sections of track are bolted together at regular intervals with typically a small gap between each section. This results in the familiar “clickety-clack” noise when each bogie (axle pair) runs over the gap in the rail running surface. The overall noise levels for jointed track are approximately 10 dB higher than continuously welded rail.

Most modern railways including passenger lines in Sydney and the proposed NWRL are constructed with continuously welded rail. For this type of track, the rail sections are welded together to form a continuous and smooth running surface. Assuming that there are no rail defects or other rail discontinuities, “clickety-clack” noise should not occur on track with continuously welded rail.

Impact noise from rail discontinuities such as turnouts, crossovers, expansion joints or rail defects increase the level of wheel-rail noise as each wheel of the train passes over the discontinuity. In the surface track section, crossovers are proposed to be located at the following locations:

- North of Bella Vista Station (trailing and facing, between chainage 41.075 km and 41.328 km)
- East of Cudgegong Road Station (trailing and facing, between chainage 45.830 km and 46.109 km)
- Near Tallawong Road (scissor crossovers between chainage 47.176 km and 47.251 km).

In areas where there are tight radius curves, flanging noise or curve squeal may also increase the levels of noise emission. There are some sections of surface track between Rouse Hill Station and Cudgegong Road Station with tight curves. The first is where the alignment crosses Windsor Road, with a radius of 400 m. There is also an S-shaped curve centred on chainage 46.350 km, to the east of Cudgegong Road Station, with radii of around 500 m.

The modelling includes the following allowances for localised increases in noise emission:

- Turnouts, an adjustment of +6 dB over 10 m track distance
- A facade reflection of 2.5 dB for receivers located adjacent to buildings
- Curves greater than 300 m radius and less than 500 m radius, an adjustment of +3 dB.

Structure-radiated noise from some types of rail bridges (especially open-transom steel bridges) may also increase overall levels of noise emission. The form of the NWRL viaduct is currently proposed to comprise concrete box girder sections with concrete spans, which are inherently quieter than steel or composite constructions. Even so, at locations close to and below the viaduct, where the line of sight to the rails is blocked, the structural component of noise will dominate.

The proposed track design for the surface section (including the viaduct) is proposed to be concrete slab track (direct-fix track). The noise emissions from the viaduct structure have been estimated as shown in Table 5.4. In practice, the structure-radiated noise levels will depend strongly on the detailed design of the viaduct cross-section and the proposed track fastening system. The levels in Table 5.4

are considered to be realistic for environmental impact assessment purposes, and will be reviewed during the detailed design of the viaduct.

Table 5.4 Estimated Noise from Concrete Viaduct Structure

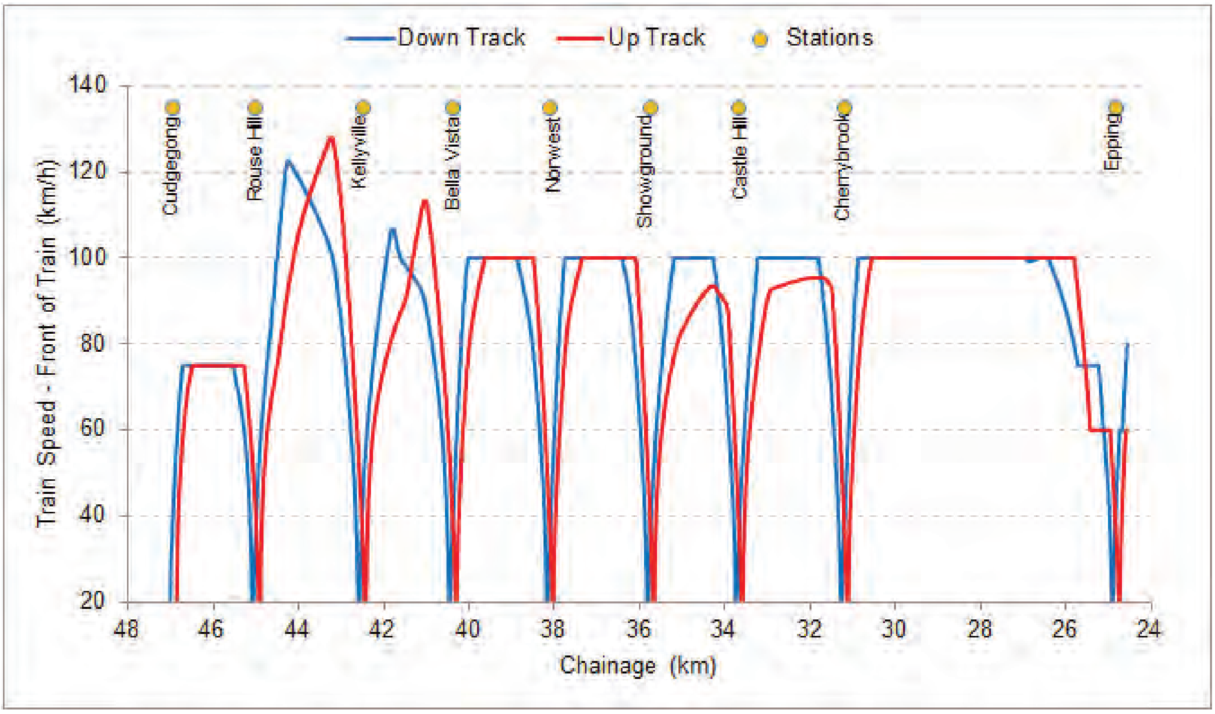
Viaduct Track Type	Reference Conditions	$L_{Amax, 95\%}$ [1]	L_{AE} [2]
Direct-fix fasteners with dynamic stiffness 20 kN/mm	15 m, 80 km/h	75 dBA	82 dBA

Note 1: $L_{Amax,95\%}$ estimated from studies of the Hong Kong Westrail, see Crockett and Pyke (2000)[6] and Cooper and Harrison (2002)[7]

Note 2: L_{AE} estimate assumes L_{Aeq} levels equal to L_{Amax} for the duration of the train passby (8-car train)

The noise model uses the noise values listed in Table 5.3 and Table 5.4 above as a reference and calculates noise levels at varying train speeds. The speed profile for noise and vibration assessment purposes through the new track sections is shown in Figure 5.2. The maximum train speeds are up to 100 km/h within the tunnel section and up to 130 km/h on the surface track section.

Figure 5.2 NWRL Speed Profile for Noise and Vibration Assessment



5.4.3 Track Alignment and Ground Terrain

The track alignments for the proposed NWRL were provided by the project team in the form of 3 dimensional track strings in AutoCAD format.

The ground terrain was based on a survey of the project area, modified to incorporate the NWRL, including cuttings or embankments where necessary.

[6] A.R. Crockett and J.R. Pyke, Journal of Sound and Vibration 231 (2000) pp 883–897.

[7] J. H. Cooper and M. F. Harrison, Proceedings of the ICE – Transport 153 (2002) pp 87–95.

5.4.4 Viaduct Design

The viaduct will result in the tracks being elevated relative to the majority of existing receivers. In this situation, existing receivers will receive some shielding of direct noise from tracks by the viaduct structure, even in the absence of noise barriers. The amount of shielding depends on the width of the viaduct structure and the height of nearby buildings in relation to the viaduct deck.

The final design of the viaduct is not available at this stage as it will form part of the successful tenderers' detailed designs. A number of conceptual alternatives are under development. These preliminary designs indicate that the deck will be approximately 11 m to 12 m wide; and that the top of rail is approximately 250 mm above the viaduct edge level. The design of the viaduct will facilitate the construction of noise barriers to mitigate potential exceedances of the noise trigger levels at existing and proposed sensitive receivers. The positioning of the noise barriers on the viaduct is taken to be 3.35 m from the track centreline for the purpose of this assessment, but there are a number of alternative noise mitigation options available for consideration in the detailed design stage.

The current proposal is for all surface track to be constructed using a direct-fix track form (concrete slab track). Concrete slab track typically requires softer rail supports than ballasted track. As a consequence, the track decay rate is lower and more noise is radiated by the rails, although this could be controlled through the use of rail dampers. In addition, directly fixing the track to a concrete slab results in more noise radiated from the viaduct structure than is the case with (for example) either ballasted track or floating slab track.

The noise predictions (both direct rolling noise and noise from the structure) are sensitive to the detailed design of the viaduct structure. Several design options are feasible to reduce the potential noise impacts if required.

5.4.5 Rail Traffic Data

The IGANRIP specifies that the noise trigger levels apply both immediately after operations commence and for projected traffic volumes at an indicative period into the future to represent the expected typical maximum level of train usage. In order to support the noise modelling predictions, estimated train numbers for the after opening and 10-years after opening operating scenarios have been provided.

The rail traffic estimates used in the modelling scenarios are summarised in Table 5.5. The train numbers in Table 5.5 are indicative only, based on the estimated passenger demand, minimum service levels and the upper design limit of the NWRL of 20 trains per hour in future peak times.

Table 5.5 Rail Traffic Scenarios for Noise Assessment Purposes

Scenario	Trains per Weekday Period				
	Day 7.00 am to 10.00 pm		Night 10.00 pm to 7.00 am		Total 24 hour
	Up	Down	Up	Down	
Opening	122	124	29	27	302
Future Scenario	172	182	39	29	422

5.4.6 Noise Modelling Outputs

The operational noise modelling predicts facade noise levels at each floor for each existing receiver building. The most exposed floor is commonly the upper storey, for buildings with two or more levels, as lower floors receive more shielding from the viaduct structure or intervening terrain. Where exceedances of the noise trigger levels are identified for an individual receiver at any floor level, the predicted noise levels are described in this report.

Noise contour plots are calculated for the future scenario at second floor level, at a height of 4.5 m above the local ground level, over a grid spaced at 10 m intervals (see Appendix E). The second floor noise levels are representative of the most exposed floor level for the majority of existing receivers. Noise levels for single-storey buildings will typically be lower than shown in the noise contour plots. Noise levels at the upper floors of buildings with three or more storeys may be higher than shown in the noise contour plots.

5.4.7 Noise Trigger Levels and Assessment Parameters

In terms of the $L_{Amax,95\%}$ assessment parameter, the noise emission trigger levels at residential receiver locations are the same during the daytime and night-time periods. This is on the basis that the maximum train speeds are the same during the daytime and night-time periods. The $L_{Aeq(9hour)}$ noise trigger levels during the night-time period are 5 dB lower (ie more stringent) than the daytime period.

The $L_{Aeq(period)}$ noise parameter is based on the number of trains during the relevant daytime or night-time period, and the L_{AE} noise level associated with a single representative passby.

For other receivers with noise trigger levels defined on the basis of the $L_{Aeq(1hour)}$ assessment parameter, the maximum number of trains per hour is 20 each way in the future scenario.

5.5 Approach to Noise Mitigation

As described in the IGANRIP, assessment of reasonable and feasible mitigation options is warranted at sensitive receiver locations where the noise trigger levels are exceeded. Although the IGANRIP only requires consideration of existing receivers (and approved developments), the assessment undertaken for the NWRL project also considers proposed future residential areas as identified in Council land use plans and master planning documentation. Areas where future residential developments are known to be proposed include 301 Samantha Riley Drive, the Area 20 Precinct, and the Rouse Hill Town Centre. Future potential development areas around and between the proposed stations are also discussed.

The first step is to develop an understanding of the key noise issues to establish the baseline mitigation requirements. The project area is then modelled in detail to determine the residual noise impacts and the need for additional noise mitigation. The approach taken to determine locations where noise mitigation measures should be considered for existing receivers and for future developments can be summarised as follows:

- Noise mitigation requirements and options investigation
  - Predict the operational noise impacts on representative receivers adjacent to the viaduct, for the future scenario, without noise mitigation
  - Develop an understanding of the key noise issues and mitigation requirements
  - Develop the baseline noise mitigation strategy
- Detailed noise modelling for existing receivers
  - Predict the baseline operational noise at existing receivers for the at-opening and future scenarios

  - Identify locations where IGANRIP trigger levels are exceeded for existing receivers
  - Consider additional reasonable and feasible noise mitigation options for these locations
  - Determine whether mitigation will result in reducing noise levels to the design objectives, potential residual noise impacts and any further mitigation that may be required
- Consideration of impacts on future developments
  - Consider future development by predicting noise impacts, assuming potential high-rise residential development adjacent to and overlooking the railway
  - Examine noise mitigation options for the known proposed future development locations.

5.6 Noise Mitigation Requirements and Options Investigation

In order to establish the likely requirements for noise mitigation, particularly adjacent to the proposed viaduct, preliminary investigations of the noise impacts on indicative “representative” receivers has been undertaken.

The purpose of these investigations is to develop an understanding of the balance between direct noise and structure-radiated noise, for an indicative scenario with the viaduct deck 10 m above flat terrain and a train speed of 100 km/h, with representative buildings located at 50 m to 100 m from the viaduct, and the future train numbers. A series of mitigation scenarios for direct noise are considered, beginning with no specific noise mitigation, then examining source noise control (in the form of rail dampers) and path noise control (in the form of absorptive noise barriers).

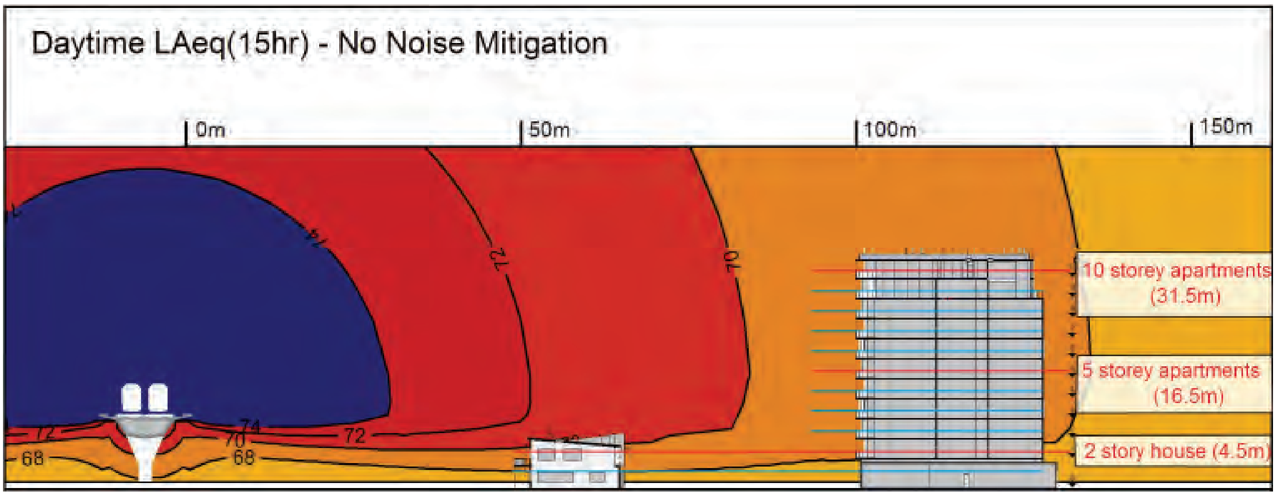
In the following sections, daytime $L_{Aeq(15hour)}$ noise levels are discussed. The future scenario daytime $L_{Aeq(15hhour)}$ noise levels will be 5 dB higher than future night-time $L_{Aeq(9hour)}$ noise levels. Any exceedances of the daytime trigger levels will be matched during the night-time. L_{Amax} noise trigger level exceedances are found to be less than the L_{Aeq} exceedances and hence the investigation of mitigation is based on the L_{Aeq} noise levels.

5.6.1 Indicative Impacts without Noise Mitigation

Figure 5.3 shows that where one or two-storey houses are located close to the proposed viaduct structure, they would receive shielding of direct noise from the tracks even without noise barriers on the edge of the viaduct structure. Taller buildings would receive shielding only at their lower levels, with upper levels being exposed to more direct noise.

Without mitigation measures, the $L_{Aeq(15hour)}$ noise trigger level of 60 dBA would be exceeded at representative two-storey receivers at distances of 150 m or even more from the viaduct. Recognising that in some areas speeds will be higher and existing receivers are located closer to the proposed viaduct, it is clear from Figure 5.3 that noise mitigation will be required.

Figure 5.3 Indicative Impacts without Mitigation



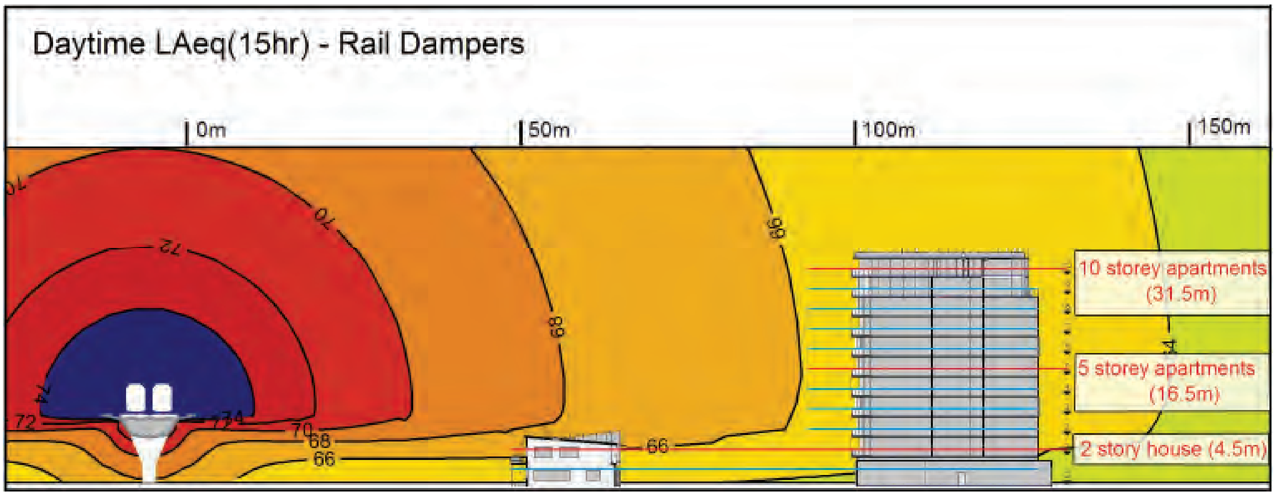
Note: Sound pressure levels include 2.5 dB facade reflection. The daytime L_{Aeq} noise trigger level is 60 dBA.

5.6.2 Indicative Impacts with Source Noise Control

Figure 5.4 shows that the application of source noise control in the form of rail dampers would reduce direct noise impacts. Structure-radiated noise would be unchanged.

With rail dampers only, the $L_{Aeq(15hour)}$ noise trigger level of 60 dBA would still be exceeded at representative two-storey receivers at distances of 150 m or even more from the viaduct.

Figure 5.4 Indicative Impacts with Source Noise Control



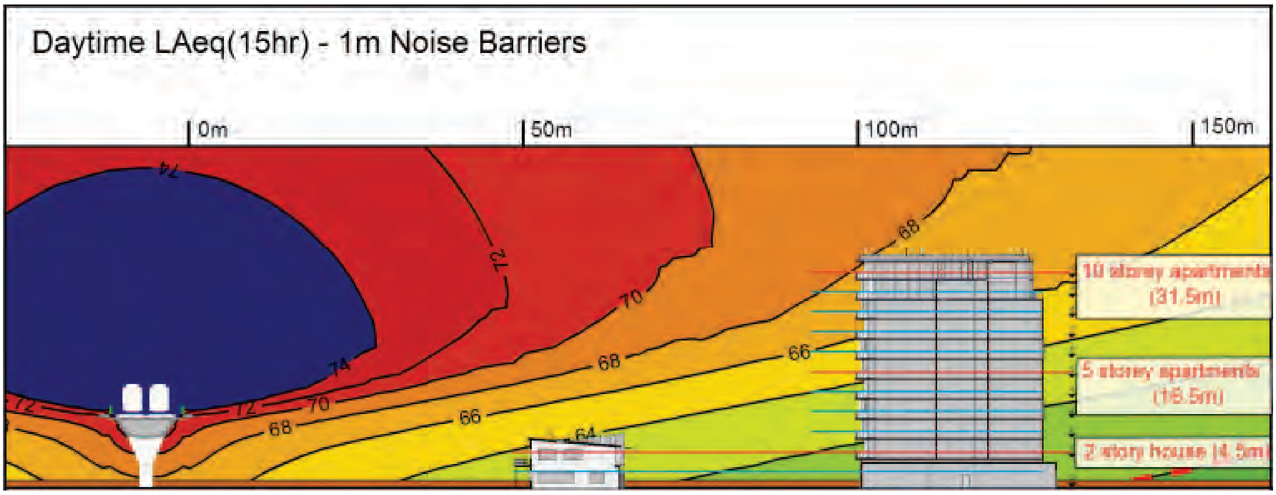
Note: Sound pressure levels include 2.5 dB facade reflection. The daytime L_{Aeq} noise trigger level is 60 dBA.

5.6.3 Indicative Impacts with Noise Barriers

The addition of noise barriers to the viaduct edge (without rail dampers) would also reduce direct noise impacts. A similar or greater benefit could be achieved by designing the viaduct to include an edge, raised section or walkway above the rail height (the benefit would be expected to increase for a barrier closer to the noise source).

Figure 5.5 shows the effect on radiated noise of the introduction of noise barriers 1 m high (above top of rail) placed at the edge of the viaduct. Structure-radiated noise would remain unchanged. In comparison with Figure 5.4, Figure 5.5 shows greater benefits from the 1 m barriers than the rail dampers for receivers below viaduct deck level (the majority of existing receivers). Receivers above viaduct deck level would benefit more from rail dampers than from 1 m barriers.

Figure 5.5 Indicative Impacts with 1 m Noise Barriers at Edge of Viaduct

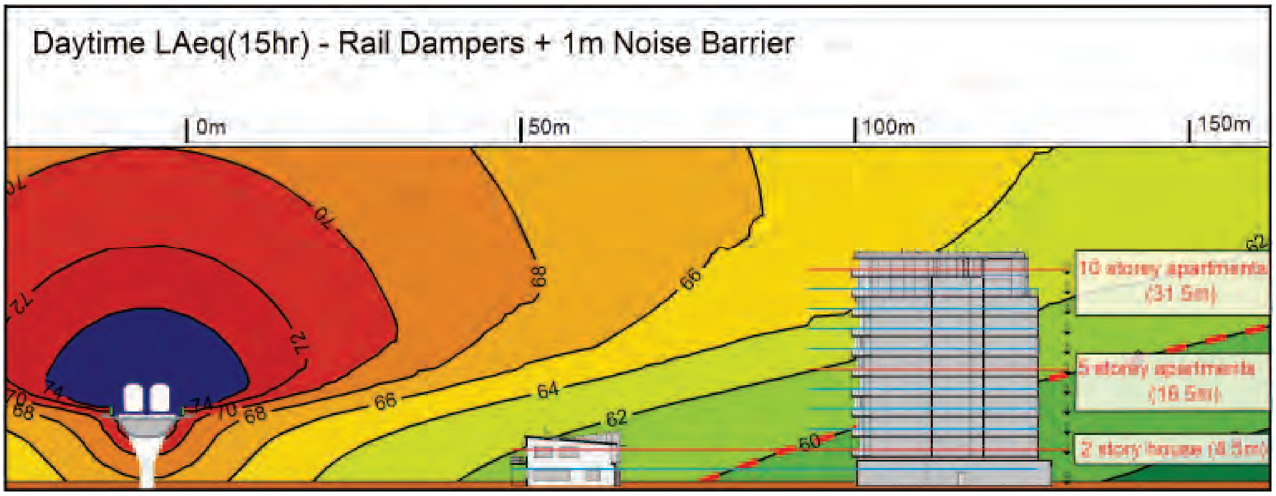


Note: Sound pressure levels include 2.5 dB facade reflection. The daytime L_{Aeq} noise trigger level is 60 dBA.

5.6.4 Indicative Impacts with Both Source Noise Control and Noise Barriers

The combination of source noise control (rail dampers) and 1 m high noise barriers placed at the edge of the viaduct is shown in Figure 5.6. This indicates that with these mitigation measures in place, the direct rail noise impacts on one or two storey buildings have been significantly reduced compared with the unmitigated case shown in Figure 5.3. In this situation, structure-radiated noise will dominate at lower levels. Compliance with the daytime $L_{Aeq(15hour)}$ noise trigger level of 60 dBA is indicated for two storey receivers at around 100 m from the railway, for the indicative scenario with the viaduct deck 10 m above flat terrain and a train speed of 100 km/h.

Figure 5.6 Indicative Impacts with Source Control and 1 m Noise Barriers at Edge of Viaduct



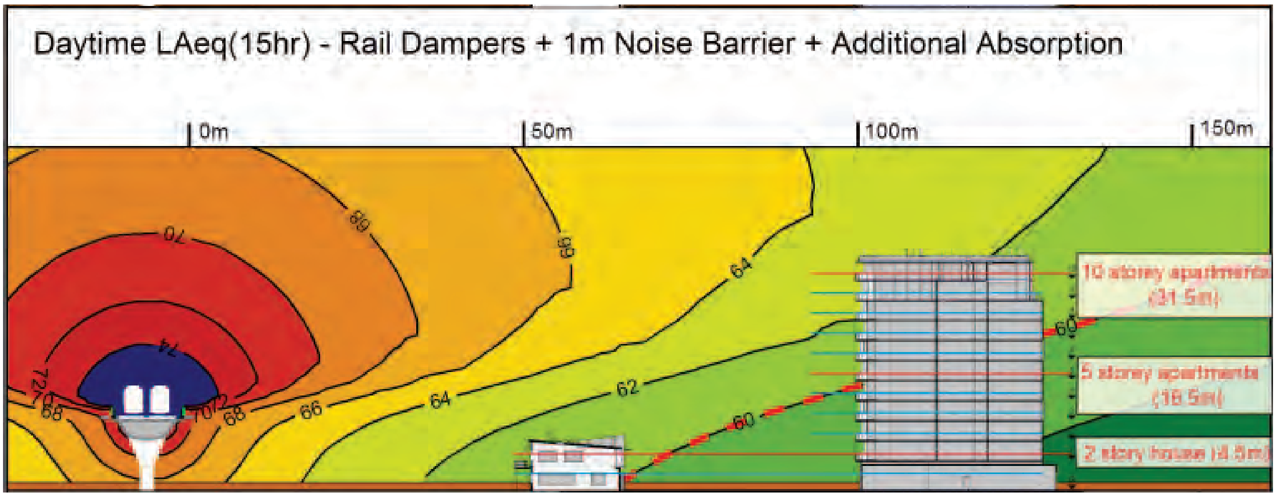
Note: Sound pressure levels include 2.5 dB facade reflection. The dashed red line shows the daytime L_{Aeq} noise trigger level 60 dBA.

5.6.5 Indicative Impacts – Additional Direct Noise Mitigation

Figure 5.7 and Figure 5.8 show the effect of applying additional direct noise mitigation measures in the form of additional deck absorption and a central noise barrier (between tracks). In this situation, structure-radiated noise dominates at lower levels and further reductions in airborne noise do not translate to a noticeable difference in the overall noise levels on receiver levels below the viaduct deck level. Without a reduction in the structure-radiated noise, additional mitigation measures would not be effective for the majority of existing residential receivers. The additional mitigation measures have the potential to be of benefit to future multi-storey developments.

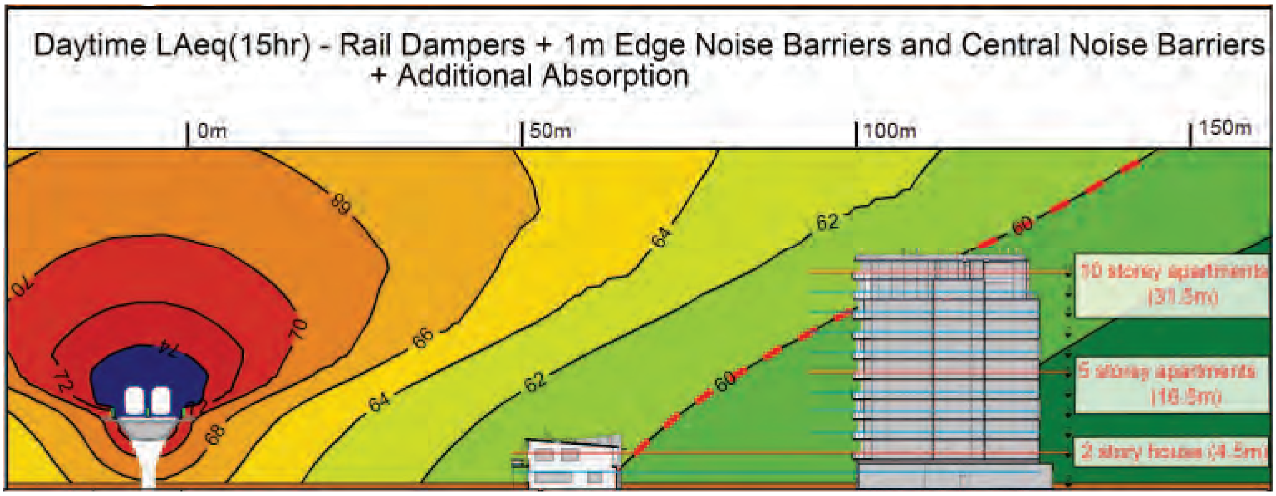
In the case of central noise barriers, these would provide around a 2 dB benefit at the tenth floor of a block set back 100 m from the railway, but the benefit would be reduced in closer proximity to the rail line.

Figure 5.7 Indicative Impacts with Source Control, Noise Barriers and Additional Absorption



Note: Sound pressure levels include 2.5 dB facade reflection. The dashed red line shows the daytime L_{Aeq} noise trigger level 60 dBA.

Figure 5.8 Indicative Impacts - Source Control, Edge and Central Barrier and Absorption



Note: Sound pressure levels include 2.5 dB facade reflection. The dashed red line shows the daytime L_{Aeq} noise trigger level 60 dBA.

5.6.6 Baseline Noise Mitigation Requirements

On the basis of the above investigation, it is clear that mitigation of direct noise will be required in areas of the track adjacent to the viaduct structure.

Source noise control in the form of rail dampers would be expected to provide around a 4 dB reduction in direct noise. The full benefit of rail dampers would be apparent at receivers where direct airborne noise is dominant, particularly for receivers that are elevated relative to the tracks. At locations where structure-radiated noise dominates the net benefit would be reduced, to around 2 dB to 3 dB.

1 m high noise barriers above the top of rail height, located on the viaduct edge have been found to give typically a 6 dB reduction in net noise to existing one or two-storey detached houses around 50 m to 100 m from the proposed viaduct. As with rail dampers, the benefit of noise barriers is reduced at locations where structure-radiated noise dominates.

The reductions in direct airborne noise expected from source control and noise barriers are cumulative in areas where the track is at grade, in cutting or on embankment. However in the viaduct sections, the net noise benefit for typical existing one or two-storey detached houses is limited by the noise contribution from the viaduct structure. Once the direct airborne noise level is reduced to below the structure-radiated noise, further reductions in airborne noise will not significantly reduce the overall noise levels. To be effective, noise mitigation efforts must concentrate on the dominant noise source.

On the basis of the preliminary investigations, the baseline noise mitigation measures in Table 5.6 have been adopted for the more detailed assessment.

Table 5.6 Summary of Baseline Noise Mitigation Requirements

Noise Mitigation Measure[1]	Location	Comments
1 m high noise barriers	Bella Vista Station to Cudgegong Road Station	Noise barriers with absorptive facing are assumed in the noise modelling, 1 m high above rail level. For viaduct section, barriers are located on the outer edge of both sides of the viaduct. For other surface track locations at-grade or on embankment, the noise barriers should be positioned as close as possible to the train (subject to track access and safety requirements).
2 m high noise barriers	Up side adjacent to OK Caravan Park	A 2 m high noise barrier with absorptive facing is assumed in the noise modelling at this area based on the close proximity of adjacent receivers. The noise barrier should be positioned as close as possible to the train (subject to track access and safety requirements).
Rail Dampers	Kellyville Station to Cudgegong Road Station (except near stations)	Rail dampers are not required for existing sensitive receivers between Bella Vista Station and Kellyville Station, or in the immediate vicinity of stations where train speeds are lower and noise levels comply with the trigger levels.
Resilient Rail Fasteners	Viaduct Track and Bridges	Direct-fix fasteners with dynamic stiffness 20 kN/mm are assumed in the noise modelling to minimise structure-radiated noise from the viaduct and bridges.

Note 1: There are several options which may be implemented for the detailed design of the surface track sections, based on the detailed design of the track form and elevated structures. The proposed baseline measures are based on the NWRL Concept Design.

5.7 Noise Impacts and Mitigation for Existing Receivers

5.7.1 Baseline Operational Noise Impacts on Existing Receivers

After the opening of the NWRL, noise levels with the baseline mitigation measures in Table 5.6 are predicted to be below the IGANRIP noise trigger levels at the majority of existing receivers with the exception of one residence on Terry Road (between Rouse Hill Station and Cudgegong Road Station) west of the OK Caravan Park, and a number of residential properties between Kellyville Station and Rouse Hill Station.

The predicted exceedances at opening are marginal, typically within 1 dB of the L_{Aeq} trigger levels. No exceedances of the $L_{Amax,95\%}$ trigger level are predicted.

For the future operating scenario, there is not expected to be an increase in the $L_{Amax,95\%}$ noise levels over the levels at opening, but the daytime $L_{Aeq(15hour)}$ and night-time $L_{Aeq(9hour)}$ noise levels are predicted to increase, by 1.6 dB and 0.8 dB respectively (as a result of additional trains).

In this future operating scenario, the number of L_{Aeq} noise trigger level exceedances increases. Exceedances of the residential noise trigger levels for the future operating scenario (approximately 10 years after opening) are shown in Table 5.7 and are also illustrated on the noise contour plots in Appendix E.

No exceedances of the noise trigger levels have been identified for non-residential receivers.

Table 5.7 Noise Trigger Level Exceedances for Existing Receivers (Future Scenario Approximately 10 years After Opening)

Location	Description	Maximum Predicted Noise Levels		
		$L_{Amax,95\%}$ (dBA)	$L_{Aeq(15hour)}$ (dBA)	$L_{Aeq(9hour)}$ (dBA)
Terry Road, Rouse Hill	1 detached house	80	**61**	**56**
Fitzroy Place to Lycett Avenue, Kellyville	5 detached houses	78	**62**	**57**
Bentwood Terrace, Stanhope Gardens	5 detached houses	77	**61**	**56**
Miller/Farrier Way, Kellyville Ridge	19 detached houses	77	**62**	**57**
Kilbenny Street, Kellyville Ridge	5 apartment buildings (upper levels)	77	**62**	**57**

Note: The noise trigger levels are L_{Amax} 80 dBA, $L_{Aeq(15hour)}$ 60 dBA and $L_{Aeq(9hour)}$ 55 dBA. Exceedances of the relevant noise trigger levels are shown in bold text.

5.7.2 Discussion of Additional Feasible and Reasonable Mitigation Measures

The noise modelling results presented in Table 5.7 and illustrated in Appendix E (for the future scenario) includes the baseline mitigation measures presented in Table 5.6. With these measures, several locations have been identified where the IGANRIP trigger levels are exceeded at existing residences. Further assessment of feasible and reasonable noise mitigation measures therefore needs to be undertaken for the surface section of the NWRL corridor.

Section 3.1 of IGANRIP provides the following guidance in relation to determining feasible and reasonable mitigation measures:

Feasibility relates to engineering considerations and what can practically be built or modified, given the opportunities and constraints of a particular site.

Reasonableness relates to a judgement which takes into account the following factors:

- Noise-mitigation benefits - noise reduction provided, number of people protected
- Cost of mitigation - total cost and cost variation with level of benefit provided
- Community opinion
- Aesthetic impacts
- Track maintenance and access requirements
- Noise levels for affected land uses - existing and future levels, expected changes in noise levels
- Benefits arising from the development or its modification.

A summary of airborne operational noise mitigation options considered for existing receivers along the NWRL corridor is provided in Table 5.8, along with comments on their feasibility and reasonableness. Source control measures are typically more cost effective to implement in terms of the resulting noise benefit compared with path and receiver controls respectively. On this basis, the hierarchy of noise control is to give preference to source control measures, then to path control measures and finally receiver controls.

Table 5.8 Summary of Additional Operational Noise Mitigation Options

Description	Estimated Noise Reduction	Comments on Feasibility and Reasonableness
Source Control Measures		
Rail dampers	4 dB reduction in L_{Amax} and L_{Aeq} at locations where low stiffness rail pads are required to minimise structure-radiated noise	Rail dampers are included in the baseline noise mitigation assumptions where they provide a benefit to existing receivers and known future developments.
Reduce train speeds	A 20% reduction in maximum train speed would reduce L_{Amax} noise levels by 2.5 dB and L_{Aeq} noise levels by 1.5 dB	Potentially feasible to limit the maximum speeds to (for example) 100 km/h. This would eliminate the predicted exceedances between Kellyville Station and Rouse Hill Station.
Reduce overall number of train passbys	No change in L_{Amax} 1 dB reduction in L_{Aeq} for 20% change 2 dB reduction in L_{Aeq} for 35% change	Not feasible as train numbers are required to meet service frequency demands.
Reduce train lengths	Negligible change in L_{Amax} 1.3 dB reduction in L_{Aeq} for 6-car trains in lieu of 8-car trains 3 dB reduction in L_{Aeq} for 4-car trains in lieu of 8-car trains	Not feasible as train lengths are required to meet capacity demand.
Exclude “noisy” individual trains from NWRL	Negligible	The base case operation of the NWRL proposes to use the quietest available train types, and will include a maintenance strategy to identify and repair noisy trains.

Description	Estimated Noise Reduction	Comments on Feasibility and Reasonableness
Optimise track design (rail pad stiffness, rail fastening system etc)	Varies	The noise impacts in the above ground sections are a combination of direct airborne noise and structure-radiated noise from the viaduct. Increasing the rail support stiffness would reduce the direct noise but result in an increase in structure-radiated noise. The design will need to balance these two sources.
Optimise viaduct structure design	Up to 5 dB reduction in L_{Aeq} and L_{Amax}	Up to 5 dB at locations where structure-radiated noise dominates, otherwise less. With the proposed 1 m high noise barriers incorporated in the viaduct, the structure-radiated noise contributes to the overall noise level at many existing receivers.
Minimise wheel and rail roughness	Limited by whether rail roughness or wheel roughness dominates the combined system	The specifications for NWRL operations include requirements for maintaining the rail surface (via rail grinding) and train wheel condition (via wheel lathe) in accordance with defined acceptance standards.
Path Control Measures		
Design of viaduct structure to incorporate shielding	Similar benefit to the proposed 1 m noise barriers.	It may be more cost-effective to include shielding as part of the viaduct structure than to design a separate component. There would be minimal maintenance required. May impact viaduct aesthetics.
Addition of absorptive material	Up to 2 dB in L_{Aeq} and $L_{Amax.}$	Additional absorptive material could reduce reflected noise from the deck or barriers. This would be of most benefit to elevated receivers where direct noise dominates.
Higher noise barriers	Potential noise reduction of up to 2 dB in L_{Amax} and L_{Aeq} for a barrier 1.5 m above rail height (over the base 1 m barrier case).	Increasing the barrier height affects the aesthetics of the viaduct. For existing 1-2 storey receivers close to the viaduct, structure-radiated noise is a significant component of the overall noise level, meaning higher barriers would not give a noticeable additional benefit.
Noise barriers between tracks	Potential noise reduction at some levels of elevated receivers of up to 2 dB in L_{Amax} and L_{Aeq} for a barrier 1 m above rail height.	Would only be effective in the event of future high-rise developments at distances of about 100 m from the rail line.
Low level absorptive noise barriers in conjunction with rolling stock side-skirts (in place of edge noise barriers)	Up to 8 dB reduction in L_{Aeq} and L_{Amax} over unmitigated case. Benefit depends on the gap remaining between the low barrier and the vehicle side-skirt, and the balance between direct and structure-radiated noise.	Could remove the need for noise barriers on the edge of the viaduct. Requires careful integration of rolling stock and track parameters, and may restrict choice of rolling stock. Also subject to safety standards and maintenance access requirements. Would benefit both existing receivers and future high-rise developments.

Description	Estimated Noise Reduction	Comments on Feasibility and Reasonableness
Earth mounds (in non-viaduct track sections)	Smaller noise reduction than noise barriers of similar height, performance is compromised by the need to be located further from the near track compared with a noise barrier.	Can be cost effective if sufficient spoil and space are available. Not feasible on embankments due to extra footprint required for embankment. Less visual impact than sheer barrier wall. None of the NWRL areas with predicted trigger level exceedances are suitable for earth mounds.
Receiver Control Options		
Property boundary fence	Up to 5 dB at ground floor for 1.8 m high solid fence.	Noise benefit is reduced or eliminated for track on embankment or viaduct.
Ventilation in accordance with Building Code requirements to allow windows to be closed (if desired)	10 dB to 15 dB reduction in internal noise levels compared with windows open for standard glazing. Higher noise reductions possible for laminated and double glazing with acoustic seals. No benefit for outdoor areas or if windows are opened.	This option could be applicable as a final measure for existing residences or for upper levels of future developments overlooking the rail corridor. It is often required for new developments affected by rail noise to meet the internal noise criteria.
Acceptance of higher rail noise levels	No rail noise reduction	A reasonable option in locations where existing noise levels from other sources (for example road traffic noise) are higher than the predicted rail noise impacts, and are accepted as being unlikely to decrease in future. In this situation, the provision of rail noise mitigation is unlikely to provide an appreciable benefit. This is also a reasonable option in locations where future land use is proposed to change significantly in the period soon after project opening. For example, property treatments for existing single receivers would not be reasonable in the Area 20 Precinct where development will lead to land use changes and higher density zonings.

Of the additional noise mitigation options listed in Table 5.8, those which may be feasible and reasonable for reducing the impact of operational noise at existing receivers are summarised below:

- Managing train speeds between Kellyville and Rouse Hill
- Design viaduct structure (shape, materials and track design) to minimise structure-radiated noise (in the detailed design stage)
- Application of additional absorptive material, for example to the viaduct deck (only effective in conjunction with reduced structure-radiated noise levels)
- Acceptance of minor exceedances of the noise trigger levels at locations where road traffic noise dominates
- Property treatments.

5.7.3 Discussion of Location-Specific Noise Mitigation Options for Existing Receivers

The following discussion provided a summary of the noise mitigation options for the five receiver areas identified in Table 5.7 with minor exceedances of the noise trigger levels.

With the exception of the Terry Road receiver, all of the sensitive receiver locations with minor exceedances of the noise trigger levels are adjacent to the NWRL track section (between Kellyville Station and Rouse Hill Station) where the proposed train speed is greater than 100 km/h. In these areas, limiting the train speeds to a maximum of 100 km/h is predicted to reduce the direct and structure-radiated noise levels to below the noise trigger levels. During the detailed design stage, this option would be considered as a potential noise mitigation measure, taking into account other factors such as the change in journey time, the existing noise exposure from road traffic and other factors.

Terry Road, Rouse Hill

This residence is situated approximately 13 m from the Up track, adjacent to a section of viaduct. For the future scenario, a marginal 1 dB exceedance of the L_{Aeq} noise trigger levels is predicted for the daytime and night-time periods with compliance predicted for the L_{Amax} noise trigger level. Noise levels at this location would be predominantly influenced by structure-radiated noise.

The affected property is located within the Area 20 Precinct and the plan for the area shows land marked for medium density development at some point in the future.

The noise mitigation options at this locality are limited to designing the viaduct structure (as part of the detailed design) to minimise the structure-radiated noise. Additional airborne noise mitigation in the form of a higher noise barrier or additional sound absorption would be of no benefit to this receiver. Building treatments would not normally be considered in locations such as this where there are minor exceedances of the noise trigger levels.

Kilbenny Street, Kellyville Ridge

Kilbenny Street has approximately 100 apartments spread over five blocks. Minor exceedances of the L_{Aeq} noise trigger levels are predicted for upper level apartments facing Windsor Road and the rail corridor, with increasing direct rail noise impacts at higher levels of the buildings.

Noise mitigation options include optimisation of the detailed design of the viaduct (shape, materials and track design) and/or the addition of absorptive materials on the viaduct deck.

Acceptance of the marginal 2 dB exceedances of the L_{Aeq} noise trigger levels is recognised as an option for this location, in view of the fact that the affected apartments are likely to have been planned and designed to minimise road traffic noise intrusion from Windsor Road. Noise logging conducted on this site in 2005 as part of the North-West T-Way Project (BG19, see Section 4) indicates that the existing noise levels are dominated by road traffic noise, with L_{Aeq} levels above those associated with the proposed NWRL operations.

Farrier Way and Miller Way, Kellyville Ridge

19 houses have been identified in this area with marginal exceedances of the L_{Aeq} noise trigger levels for the future scenario. The 19 houses are between Farrier Way and Miller Way, and Windsor Road (some of the street addresses are Beck Place, Loft Place and Stave Place).

With the proposed noise barriers and rail dampers, the direct contribution and the structural contribution to overall noise are comparable at this location. Noise mitigation options include optimisation of the detailed design of the viaduct (shape, materials and track design) and/or the addition of absorptive materials on the viaduct deck.

The acceptance of marginal 2 dB exceedances of the L_{Aeq} noise trigger levels is also an option, recognising that existing noise levels are dominated by road traffic noise, at L_{Aeq} levels above those associated with the proposed NWRL operations.

Fitzroy Place to Lycett Avenue

Five houses have been identified with exceedances of the L_{Aeq} noise trigger levels for the future scenario; spread along the ends of the streets between Fitzroy Place and Lycett Avenue on the Up side. The predicted exceedances are a marginal 1 dB to 2 dB in L_{Aeq}, with compliance predicted for the L_{Amax} noise parameter.

With the proposed noise barriers and rail dampers, the structural contribution to overall noise is predicted to be several dB above the direct contribution. Noise mitigation options include optimisation of the detailed design of the viaduct (shape, materials and track design) to reduce structure-radiated noise or acceptance of the marginal 1 dB to 2 dB exceedances of the L_{Aeq} noise trigger levels.

Bentwood Terrace, Stanhope Gardens

Five houses have been identified on Bentwood Terrace with marginal exceedances of the L_{Aeq} noise trigger levels in the future scenario. The exceedance is predicted to be up to 1 dB for the daytime and night-time L_{Aeq}, with compliance predicted for L_{Amax} noise parameter.

With the proposed noise barriers and rail dampers, the direct noise and the structural noise contributions to overall levels are comparable at this location. Noise mitigation options include optimisation of the detailed design of the viaduct (shape, materials and track design) and/or the addition of absorptive materials on the viaduct deck.

It is also recognised that acceptance of the marginal 1 dB exceedances of the L_{Aeq} noise trigger levels is an option, recognising that the existing noise levels are dominated by road traffic noise, at L_{Aeq} levels above those predicted to result from the proposed NWRL operations.

5.8 Noise Impacts and Mitigation for Future Developments

For future developments the IGANRIP notes that the control of noise and vibration issues resulting from rail traffic should be the joint responsibility of the rail operator and of surrounding land users. Future land use planning measures must take into account the rail link and include relevant mitigation measures in design / planning requirements.

In this report, potential future developments are taken to be as described in Chapter 14 of *Environmental Impact Statement - Stage 2 (Stations, Rail Infrastructure and Systems)*. The key areas (in the above ground section of the alignment) are around Bella Vista Station, around Kellyville Station, around Rouse Hill Station, the Area 20 Precinct, and around Cudgegong Road Station. Most of these future developments have been defined in only a general sense, although some specific developments are in the Concept Planning stage.

For new developments, increased separation distance from the rail corridor can be used as a noise mitigation measure. Acoustic setbacks and buffer zones can be employed, with roadways or open recreation areas providing the buffer zone. Where a buffer zone is insufficient or impractical for controlling noise, it may be necessary to control the layout and construction of buildings, with sensitive areas of occupancy in a building being oriented away from the noise source. Part 87 of the Infrastructure SEPP requires sensitive non-rail developments to achieve internal $L_{Aeq(9hour)}$ noise levels of 35 dBA during the night-time period within bedrooms, and 40 dBA in other habitable areas at any time of the day. Advice to developers on how to achieve these levels is given in the NSW Department of Plannings *Development Near Rail Corridors and Busy Roads - Interim Guideline.*

Notwithstanding the options for mitigation available to the developer, the mitigation options described in Table 5.8 for existing receivers can also benefit future developments. Of the noise mitigation options in Table 5.8, those considered to be feasible and reasonable for reducing the impact of operational noise from the NWRL on future receivers are:

- Design viaduct structure (shape, materials and track design) to minimise structure-radiated noise in the detailed design stage

- Application of rail dampers (in locations where these are not already proposed)
- Application of additional absorptive material, for example to the viaduct deck
- Provision of low-height barriers close to the track in conjunction with vehicle side skirts, in place of the proposed 1 m barriers on the viaduct edge
- Facade and glazing design to achieve the internal noise criteria for new developments.

Standard window glazing of a building will typically attenuate external noise levels by 20 dB to 25 dB with windows closed. Even with windows open, the indoor noise level is approximately 10 dB lower than the external noise level. Where attenuation of more than 20 dB is required, then upgraded glazing could be considered (eg, double glazing or laminated glazing with acoustic seals), along with provision of mechanical ventilation to meet the requirements of the Building Code of Australia.

5.8.1 Discussion of Noise Mitigation Options for Future Developments

The following discussion of noise mitigation options for any future medium to high-density development areas is representative of worst-case noise impacts on a multi-storey building overlooking the rail line, even where the tracks are constructed on elevated viaducts. Refer also to Section 5.6 for indicative impacts on multi-storey developments at different set-back distances from the viaduct.

Consistent with development that occurs around existing railway lines, future development would be subject to standard noise mitigation measures which are well understood and applied in the development industry.

Bella Vista Station to Kellyville Station
Future planning indicates that mixed use development may occur in the immediate vicinity of Bella Vista Station from the time of opening, and extend north over time. In this section the rail tracks are proposed to be located in a cutting after emerging from the tunnels at Bella Vista Station.

Train speeds will be lower when departing from the station and the cutting will provide shielding to future developments immediately north of Bella Vista Station. Consequently the noise impacts on developments close to the station are expected to be low.

Midway between Bella Vista Station and Kellyville Station, trains are expected to reach a speed of approximately 100 km/h. Assuming a multistorey building set back 40 m from the nearest track at the location with the highest speeds gives worst-case facade noise levels at future capacity as shown in Table 5.9.

Table 5.9 Noise at Future Developments Between Bella Vista Station and Kellyville Station

Location	Building Level	$L_{Amax,95\%}$ (dBA)	$L_{Aeq(15hour)}$ (dBA)	$L_{Aeq(9hour)}$ (dBA)	Required Facade Attenuation (dB)
Mid-way between Bella Vista Station and Kellyville Station, set back 40 m from the near track	1	76	59	54	19
	2	77	60	55	20
	3	78	61	56	**21**
	4	80	63	58	**23**
	5	83	65	60	**25**
	6	87	68	63	**28**
	7	90	71	66	**31**
	8	92	72	67	**32**

Note: Required facade attenuation with windows closed, assuming provision of mechanical ventilation to meet the requirements of the Building Code of Australia. Indicative areas requiring upgraded glazing to achieve the indoor $L_{Aeq(9hour)}$ 35 dBA Infrastructure SEPP noise limit are shown in bold text. Standard window glazing will typically attenuate 20 dB.

Kellyville Station to Rouse Hill Station

Future planning indicates that commercial and retail development may occur in the immediate vicinity of Kellyville Station from the time of opening, with mixed use development on the Up side of the railway over time.

Through this section the rail tracks are on viaduct. Train speeds and hence noise impacts will be highest midway between the two stations, with the highest speeds of the NWRL occurring in this section. The resulting noise levels for multi-storey developments set back 40 m from the nearest track are shown in Table 5.10.

Planning is underway to rezone 301 Samantha Riley Drive for a high density mixed use development. Noise impacts on this development have been predicted and are also shown in Table 5.10.

Planning is also underway for further development to the north of the existing Rouse Hill Town Centre area. Current plans indicate that while this development will include residential areas, these will be set back from the rail corridor behind commercial buildings. At this stage, it is considered that rail noise impacts on residential receivers in this development will be low.

The proposed mitigation between Kellyville Station and Rouse Hill Station includes rail dampers in addition to the 1 m noise barriers. Future developments in close proximity to the rail line will need to consider rail noise impacts in their design, including upgraded glazing with acoustic seals and the provision of mechanical ventilation to enable residents to keep windows closed (if desired) to meet the internal noise criteria.

Table 5.10 Noise Levels at Future Multistorey Residence Between Kellyville and Rouse Hill.

Location	Building Level	$L_{Amax,95\%}$ (dBA)	$L_{Aeq(15hour)}$ (dBA)	$L_{Aeq(9hour)}$ (dBA)	Required Facade Attenuation (dB)
301 Samantha Riley Drive	1	75	58	53	18
	2	75	58	53	18
	3	76	59	54	19
	4	76	59	54	19
	5	78	60	55	20
	6	80	62	57	**22**
	7	82	64	59	**24**
	8	84	65	60	**25**
	9+	85	65	60	**25**
Mid-way between Kellyville Station and Rouse Hill Station, set back 40 m from the near track	1	75	58	53	18
	2	76	60	55	20
	3	78	62	57	**22**
	4	80	64	59	**24**
	5	82	65	60	**25**
	6	85	67	62	**27**
	7	88	69	64	**29**
	8	88	70	65	**30**

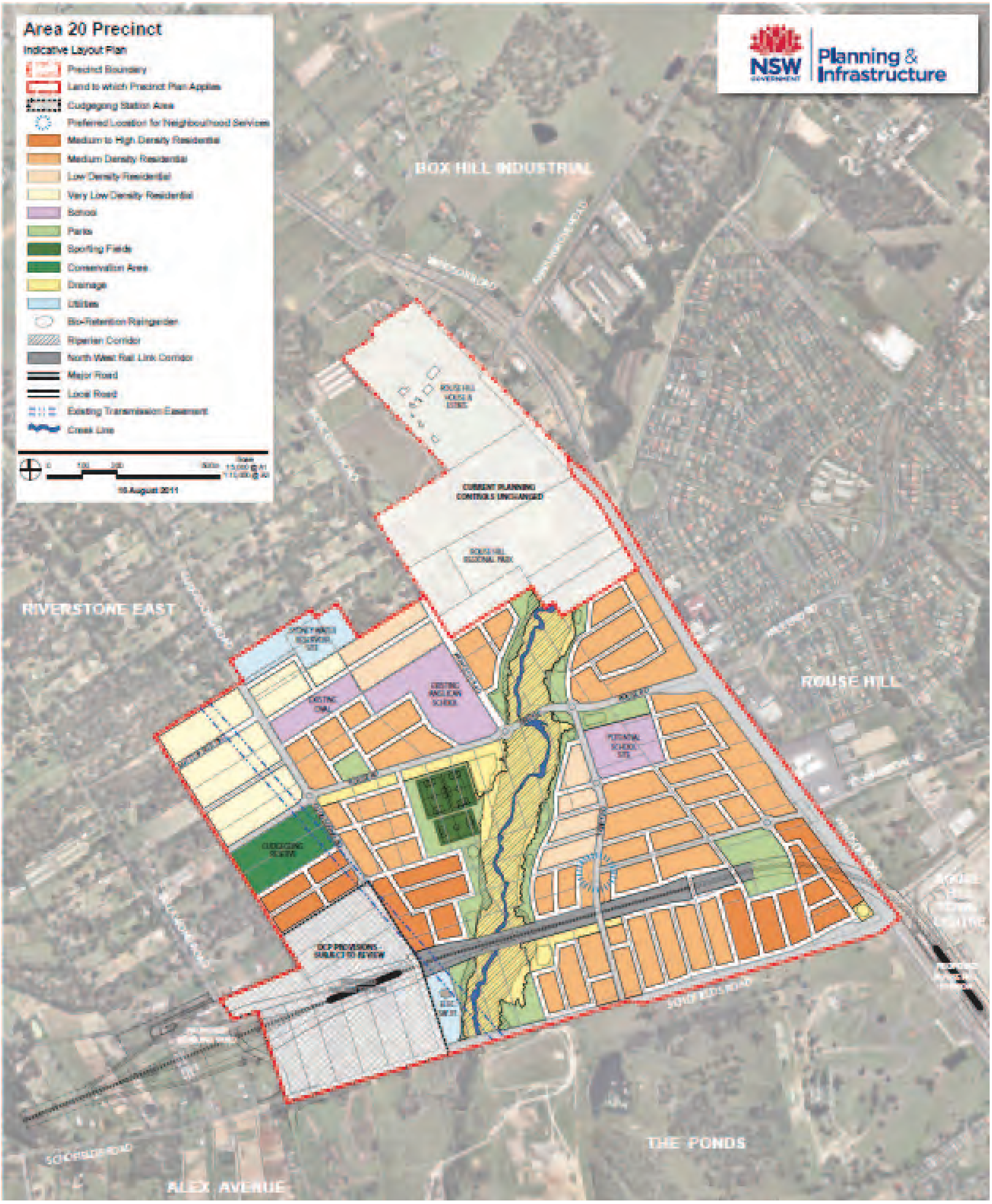
Note: Required facade attenuation with windows closed, assuming provision of mechanical ventilation to meet the requirements of the Building Code of Australia. Indicative areas requiring upgraded glazing to achieve the indoor $L_{Aeq(9hour)}$ 35 dBA Infrastructure SEPP noise limit are shown in bold text. Standard window glazing will typically attenuate 20 dB.

Area 20 Precinct

The Area 20 Precinct Indicative Layout Plan is reproduced in Figure 5.9.

Figure 5.9 shows an area of high density future development immediately west of Windsor Road and north of Schofields Road (on both sides of the viaduct track section), some open space and then medium density development west of the end of the main viaduct, where the track goes into cutting then moves onto embankment (near the existing caravan park) then an additional viaduct section.

Figure 5.9 Area 20 Precinct Indicative Layout Plan



Train speeds through this section are generally lower than in the rest of the above ground section. For this reason, noise impacts are generally lower than between (for example) Kellyville Station and Rouse Hill Station. However, near curves and adjacent to crossovers, increased noise levels may occur.

Resulting maximum noise levels for multi-storey developments in the Area 20 Precinct near Windsor Road are predicted to be up to 86 dBA L_{Amax}, 69 dBA $L_{Aeq(15hour)}$ and 64 dBA $L_{Aeq(9hour)}$ at a setback distance of 40 m from the railway line. High density developments adjacent to the curving viaduct over Windsor Road would benefit from the proposed noise barriers and rail dampers. Further from Windsor Road, noise levels are generally lower, except in the vicinity of the crossovers which result in localised higher noise levels. Noise from these crossovers could potentially be mitigated by increasing the height of the noise barrier on the Down side, to approximately 2 m above top of rail height, where the track is on embankment adjacent to the Cudgegong crossovers.

Cudgegong Road Station Area

Cudgegong Road Station is proposed to be located in a cutting and the area around the station will in future be developed to form a town centre. Due to the low train speeds in this area and the location of the station in a cutting, no consideration of specific noise mitigation to protect future development opportunities is necessary around Cudgegong Road Station.

5.9 Summary of Noise Mitigation Recommendations

To mitigate noise impacts at existing residential receivers, it is recommended that the NWRL design incorporates noise barriers of height 1 m above top of rail at all above-ground locations (except where track is in cutting). On the Up side adjacent to the OK Caravan Park, the height of the barrier should increase to 2 m above top of rail. A 2 m high noise barrier along the embankment on the Down side opposite the caravan park is also recommended to mitigate noise impacts on future Area 20 Precinct developments in the vicinity of the crossovers.

Rail dampers are recommended in all areas of surface track between Kellyville Station and Cudgegong Road Station, except in the immediate vicinity of the stations where lower speeds mean there would be no benefit. Rail dampers are not proposed between Bella Vista Station and Kellyville Station, as the 1 m high noise barriers in this area are expected to reduce the direct noise levels to below the structure-radiated levels and noise trigger levels for all existing sensitive receivers.

The resulting noise modelling results at all existing receivers adjacent to viaduct sections are predicted to include a structure-radiated noise contribution. It may be possible to reduce the noise radiated from the structure to below the levels assumed in this assessment. This would be investigated in the detailed design phase.

It would be possible to reduce noise impacts by up to 2 dB between Kellyville Station and Rouse Hill Station by limiting the maximum train speeds to 100 km/h. The benefits of this option should be considered against the operational consequences.

5.10 Residual Noise Impacts at Existing Receivers

It is anticipated that the noise trigger levels (design objectives) can be met at the majority of existing receivers with the proposed baseline noise mitigation measures described in Table 5.6. Residual exceedances remain at a number of existing properties. In all cases these residual exceedances are marginal (less than 2 dB in the future scenario). A number of options remain to further reduce noise impacts at these receivers:

- Reduce train speeds to a maximum of 100 km/h between Kellyville and Rouse Hill (subject to operational consequences)
- Design viaduct structure (shape, materials and track design) to minimise structure-radiated noise (requires assessment in the detailed design stage)
- Application of additional absorptive material, for example to the viaduct deck (only effective in conjunction with reduced structure-radiated noise levels)

- Acceptance of minor exceedances of the noise trigger levels at locations where road traffic noise dominates
- Property treatments.

With the exception of restricting operational speeds, the preferred means of minimising noise emissions is to design the viaduct structure (shape, materials and track design) to minimise the structure-radiated noise to levels below those assumed in this assessment.

5.11 Compliance Monitoring

The IGANRIP guideline recommends the selection of representative noise monitoring locations in order to assess compliance with the design objectives (noise levels achievable for the project) at a later date. The design objectives for the NWRL are equal to the IGANRIP trigger levels. If compliance monitoring indicates that these levels are not achieved, additional mitigation measures may be applied.

For the NWRL surface track section it is recommended that approximately five noise monitoring locations be selected for future compliance monitoring. The representative receiver locations should be reasonably distributed along the alignment and represent a mix of the existing and proposed receivers. It is noted that measurements at receivers adjacent to Windsor Road would likely be dominated by road traffic noise and would therefore be of limited use for compliance purposes.

Suggested compliance measurement locations are:

- The OK Caravan Park
- Adjacent to the tight curve north-west of Rouse Hill
- Bellcast Road, Rouse Hill (to assess structure-radiated noise)
- At the southern end of Swann Place or Fitzroy Place, Kellyville
- On the Up side, between Memorial Avenue and Balmoral Road.

It is anticipated that compliance monitoring at the selected locations would need to be based on operator-attended measurements for a minimum of 20 train passbys at each monitoring location. These measurements should be undertaken at the commencement of train operations. When assessing compliance, it should be recognised that noise emissions from electric passenger trains are variable and that it is usual practice to base assessments of noise emissions on the 95th percentile of trains, consistent with the $L_{Amax,95\%}$ noise assessment parameter.

6 Ground-borne Vibration – Train Operations

6.1 Introduction

Railway vibration is generated by dynamic forces at the interface of the rail head and train wheels, and can be transmitted into adjacent buildings via the tunnel structure and intervening ground. If the levels of vibration are sufficiently high (ie in buildings very close to rail tracks), then this vibration can be felt as tactile vibration by the occupants of nearby buildings. In extreme conditions (and in the absence of mitigation measures), rattling or visible movement of loose objects (crockery, plants, etc) may also sometimes occur.

The effects of vibration in buildings can be divided into three main categories:

- Those in which the occupants or users of the building are inconvenienced or disturbed – termed human perception or human comfort vibration
- Those where the building contents may be affected
- Those in which the integrity of the building or the structure itself may be prejudiced.

A fourth effect is audible 'rumbling' noise generated within buildings as a result of the vibration. This is termed ground-borne or regenerated noise and is discussed further in Section 7.

The assessment of the potential operational noise and vibration impacts for the NWRL project has been undertaken for the underground tunnel sections of the alignment from Epping to the portals near Bella Vista.

Ground-borne noise and vibration impacts at sensitive receivers adjacent to the surface sections have not been considered, primarily because the offset distance from the tracks to the receivers is sufficient to ensure that any associated ground-borne impacts are negligible and the fact that airborne noise levels are expected to be higher than the ground-borne noise levels.

For this project, the potential ground-borne vibration impacts would be limited to receivers located within an approximate 50 m wide corridor above the centreline of the proposed tunnels (dependent upon the local depth of the tunnel).

6.1.1 General

Humans are far more sensitive to vibration than is commonly realised. They can detect vibration levels well below those required to cause any risk of damage to a building or its contents.

The actual perception of motion or vibration may not in itself be disturbing or annoying. An individual's response to that perception and whether the vibration is 'normal' or 'abnormal' depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as normal in a car, bus or train is considerably higher than what is perceived as normal in a shop, office or dwelling. The vibration caused in a home by a child running across a timber floor may be acceptable to most people, but similar vibration caused by nearby road construction may be considered unacceptable.

Human tactile perception of random motion, as distinct from human comfort considerations, was investigated by Diekmann and subsequently updated in German Standard DIN 4150 Part 2-1975. On this basis, the resulting degrees of perception for humans are suggested by the vibration level categories given in Table 6.1.

Table 6.1 Peak Vibration Levels and Human Perception of Motion

Approximate Vibration Level		Degree of Perception
Peak Vibration Level	**RMS Vibration Level**	
0.10 mm/s	0.07 mm/s	Not felt
0.15 mm/s	0.1 mm/s	Threshold of perception
0.35 mm/s	0.25 mm/s	Barely noticeable
1 mm/s	0.7 mm/s	Noticeable
2 mm/s	1.4 mm/s	Easily noticeable
6 mm/s	4.2 mm/s	Strongly noticeable
14 mm/s	10 mm/s	Very strongly noticeable

Note: These approximate vibration levels (in floors of building) are for vibration having a frequency content in the range of 8 Hz to 80 Hz. The RMS vibration levels assume a crest factor of 1.4 for sinusoidal vibration.

Table 6.1 suggests that people will just be able to feel floor vibration at levels of about 0.1 mm/s (RMS) and that the motion becomes "noticeable" at a level of approximately 0.7 mm/s.

The *Assessing Vibration: a technical guideline* (DEC 2006) notes that *"vibration in buildings can be caused by many different external sources, including industrial, construction and transportation activities. The vibration may be continuous (with magnitudes varying or remaining constant with time), impulsive (such as in shocks) or intermittent (with the magnitude of each event being either constant or varying with time)."*

Examples of intermittent vibration events include vibration generated by vibratory rollers, drilling and materials handling. Examples of impulsive vibration events include the vibration the dropping of heavy equipment. The vibration generated by train passbys is classified as intermittent.

Where vibration is intermittent or impulsive in character, the DEC vibration guideline (and other similar guidelines) recognises that higher vibration levels are tolerable to building occupants than for continuous vibration. As such, higher vibration goals are usually applicable for short term, intermittent and impulsive vibration activities than for continuous sources.

6.1.2 Human Perception of Vibration

Although people are able to perceive relatively low vibration levels, it is not appropriate to set vibration emission limits requiring 'no vibration' since there will always be some measurable vibration in any environment. Realistic design objectives should therefore be set to minimise disturbance and adverse impacts on occupants' amenity. The recommended approach is discussed in Section 6.2.

6.1.3 Effects on Building Contents

People can perceive floor vibration at levels well below those likely to cause damage to building contents or affect the operation of typical equipment. As such, the controlling vibration design objectives during operations will be the human comfort goals. It is therefore not necessary to set separate design objectives for this EIS in relation to the effect of railway vibration on common building contents.

Some scientific equipment (eg electron microscopes and microelectronics manufacturing equipment) can however require more stringent design goals than those applicable to human comfort. In such cases, vibration design objectives should be obtained from the specific equipment manufacturers or if unavailable, from commonly referenced sources in the literature [8].

6.1.4 Effects of Vibration on Structures

The levels of vibration required to cause damage to buildings tend to be at least an order of magnitude (10 times) higher than those at which people may consider the vibration to be intrusive or disturbing. It is therefore also not necessary to set separate design objectives for this project in relation to building damage from railway vibration, as compliance with the human comfort design objectives will always ensure compliance with any criteria related to potential structural damage.

6.2 Ground-borne Vibration Design Objectives

On the basis of the above discussion, the vibration design objectives adopted for this project are based on human comfort considerations, rather than the less stringent building damage risk criteria or potential effects on building contents. There are several sources from which vibration design objectives may be drawn, including:

- Australian Standard AS 2670.2 1990 – *Evaluation of Human Exposure to Whole Body Vibration - Part 2: Continuous and Shock Induced Vibration in Buildings (1 Hz to 80 Hz)*
- The United States Federal Transit Administration (FTA) guideline *Transit Noise and Vibration Impact Assessment*
- British Standard BS 6472-1992 – *Evaluation of Human Exposure Vibration in Buildings (1 Hz to 80 Hz)*
- The NSW DEC document *Assessing Vibration: A Technical Guideline*.

The following discussion expresses vibration velocity levels in terms of decibels (dB_V re 10^{-9} m/s). A level of 100 dB corresponds to 0.1 mm/s (RMS) and a level of 120 dB corresponds to 1 mm/s (RMS).

AS 2670.2 provides recommended vibration levels corresponding to 106 dB_V (0.2 mm/s) to 112 dB_V (0.4 mm/s) for residential buildings during the daytime, reducing to 103 dB_V (0.14 mm/s) during the night-time. These levels apply to both continuous and intermittent vibration. For office and industrial buildings, the recommended vibration levels are 112 dB_V (0.4 mm/s) and 118 dB_V (0.8 mm/s) respectively, when in use, independent of the time of day. Much higher vibration levels are permitted for transient events with only a few occurrences per day.

For residential buildings, the US FTA guideline recommends a vibration level of 100 dB_V (0.1 mm/s) for frequent events (ie more than 70 per day), 103 dB_V (0.14 mm/s) for occasional events (ie between 30 and 70 per day) and 108 dB_V (0.25 mm/s) for infrequent events (ie less than 30 per day). For schools, churches, quiet offices, etc, the recommended vibration levels are 3 dB higher than residential receivers.

BS 6472 has similar vibration level objectives for continuous vibration, but also includes a vibration dose relationship for intermittent events such as trains, which for a “low probability of adverse comment” would permit vibration levels of up to approximately 110 dB_V (0.32 mm/s) on the basis of the frequent nature of the proposed NWRL operations.

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[8] *ANC Guidelines - Measurement and Assessment of Ground-borne Noise & Vibration,* Association of Noise Consultants (2001) and *Vibration Control Design of High Technology Facilities*, Journal of S & V, Ungar, Sturtz & Amick (1990).

The DEC's *Assessing Vibration: A Technical Guideline* is based on the guidelines contained in BS 6472. For vibration associated with train passbys, the guideline indicates that vibration levels should be assessed on the basis of the vibration dose value. This would correspond to a maximum level of approximately 110 dB_V for each train passby as discussed above for BS 6472.

6.2.1 Proposed Vibration Design Objectives

The proposed NWRL vibration design objectives for residential receivers are based on the continuous vibration levels in AS 2670 and *Assessing Vibration: A Technical Guideline*, namely 106 dB_V (0.2 mm/s) for the daytime period (7.00 am - 10.00 pm) and 103 dB_V (0.14 mm/s) for the night-time period (10.00 pm - 7.00 am).

For other sensitive receiver categories, the proposed design objectives are listed in Table 6.2. For design purposes, these objectives may be regarded as applicable to the maximum 1 second RMS vibration level not to be exceeded for 95% of rail passby events.

Table 6.2 Human Comfort Vibration Design Objectives

Receiver Type	Period	Vibration Design Objective[1]
Residential	Day	106 dB_V (0.2 mm/s)
	Night	103 dB_V (0.14 mm/s)
Commercial (including offices, schools and places of worship)	When in use	112 dB_V (0.4 mm/s)
Industrial	When in use	118 dB_V (0.8 mm/s)
Theatres	When in use	106 dB_V (0.2 mm/s)
Critical working areas[2]	Any time	100 dB_V (0.1 mm/s)

Note 1: The vibration design objectives are based on the maximum 1 second rms vibration level not exceeded for 95% of train passbys

Note 2: Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring

In the case of railway tunnels, the ground-borne noise trigger levels presented in Section 7 almost always dictate lower vibration levels than the vibration objectives indicated in Table 6.2. Hence other than at specific specialist facilities with particularly high sensitivity to vibration, compliance with the ground-borne noise trigger levels should ensure that the vibration design objectives will also be achieved.

The BBN criterion curve C[9] is used as a trigger level for further investigation for identified receivers likely to have highly vibration sensitive equipment. The BBN-C curve (also referred to as the VC-C curve in other literature) specifies a design objective of 82 dB_V per 1/3 octave band for frequencies between 8 Hz and 80 Hz and is appropriate for most lithography and inspection equipment down to 1 micron detail size.

[9] *ANC Guidelines - Measurement and Assessment of Ground-borne Noise & Vibration,* Association of Noise Consultants (2001).

6.3 Ground-borne Noise and Vibration Modelling Methodology

International Standard ISO 14837-1 2005 *Mechanical vibration - Ground-borne noise and vibration arising from rail systems - Part 1: General Guidance* provides useful information in relation to the extent of assessment that is normally required for new rail systems. A brief description of the modelling options from this document is provided below.

> *"A single model may be used for all stages with appropriate selection of input parameters (e.g. worst case for scoping assessment). Otherwise, three types of ground-borne vibration and/or ground-borne noise prediction model should be considered, as follows.*
>
> *a) **Scoping model**: to be used at the very earliest stages of development of a rail system to identify whether ground-borne vibration and/or ground-borne noise is an issue and, if so, where the "hot spots" along the length of the system's alignment are located. This type of model should be used to generate input to either environmental comparative frameworks (as part of the selection of a mode of transport) or the scoping stage of an environmental assessment.*
>
> *b) **Environmental assessment model**: to be used to quantify more accurately the location and severity of ground-borne vibration and/or ground-borne noise effects for a rail system and the generic form and extent of mitigation required to reduce or to remove the effects. This type of model should form part of the planning process for a scheme, developing the environmental statement where required and supporting preliminary design.*
>
> *c) **Detailed design model**: to be used to support the detailed design and specification of the generic mitigation identified as being required by the environmental assessment model. This type of model should form part of the design and construction stages of a scheme, with particular focus on the rolling stock and permanenT-Way design."*

At this stage of the NWRL project, a combined environmental assessment/detailed design model has been adopted to assess the potential impacts from ground-borne noise and vibration levels and identify the extent of the likely in-principle mitigation measures.

In accordance with the ISO standard, the model considers all of the parameters that are critical in determining the absolute levels of ground-borne noise and vibration, and the benefits (or otherwise) of different design and mitigation options.

The key parameters of the NWRL modelling algorithms are described in the following section under the headings:

- **Source** – route alignment, rolling stock design, rail type, track form design, tunnel design, turnouts, construction tolerances, operations and maintenance
- **Propagation Path** – ground type and vibration propagation wave types
- **Receivers** – building construction.

6.3.1 Modelling Approach

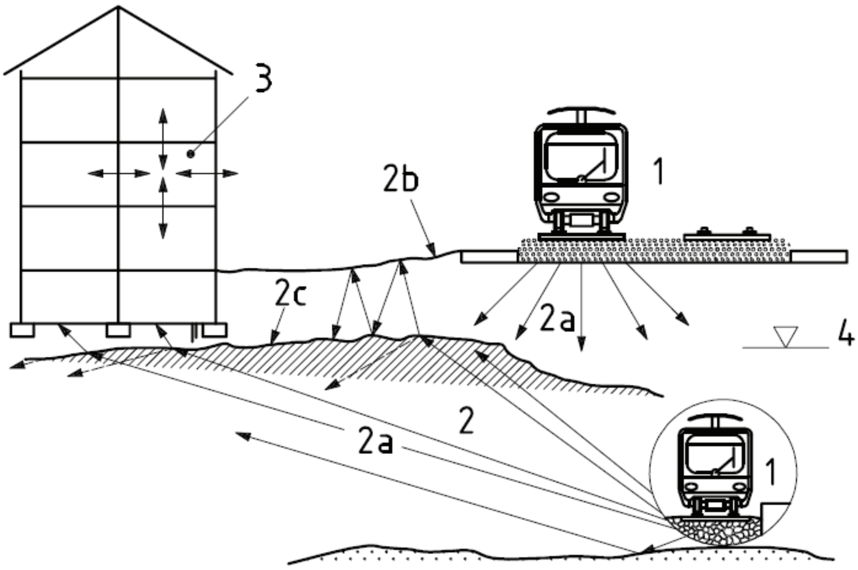
The prediction of ground-borne noise and vibration from rail systems is a complex and developing technical field. Whilst much research has been undertaken into various aspects associated with ground-borne impacts from rail systems, there are currently no commercially available modelling software packages.

The modelling for the NWRL was therefore carried out using a modelling process for the core calculations developed by SLR Consulting. The algorithms incorporated into the SLR model are well documented in authoritative references and are widely used within the acoustical consulting profession, both in Australia and internationally.

Furthermore, as part of the Epping to Chatswood Railway Line (ECRL) project, ground-borne noise and vibration measurements were undertaken by SLR Consulting whilst a test train was operating in the tunnel under controlled conditions. As part of this testing, SLR Consulting undertook ground-borne noise and vibration measurements on the surface and within the tunnel at a number of locations. The results from this testing have been used to validate and refine the ground-borne noise and vibration modelling algorithms for the NWRL assessment.

An overview of the ground-borne noise and vibration modelling approach is illustrated in Figure 6.1. The figure shows that the model takes into account the source vibration levels (1), the vibration propagation between the tunnel and nearby building foundations (2 and 4), and the propagation of vibration within the building elements (3).

Figure 6.1 Example of Source, Propagation and Receiver System (ISO 14837)



Key

1 source

2 propagation:
  2 a body waves (compression, shear)
  2 b surface waves (e.g. Rayleigh, Love)
  2 c interface waves (e.g. Stoneley)

3 receiver (vibration, re-radiated noise)

4 water table

NOTE The components of the system comprising source, propagation and receiver are interdependent.

6.3.2 Source Vibration Levels

Source vibration levels within tunnels are dependent on a number of factors including the track design, train type, train speed, wheel condition, ground conditions and tunnel design.

Given the assumed similarities of the NWRL to the ECRL (in terms of tunnel diameter, concrete lining, slab track design, etc), the source vibration levels for the new fleet of single deck, rapid transit trains for use in the ground-borne noise and vibration modelling have been determined from historical measurements of the ECRL conducted by SLR Consulting between 2009 and 2011.

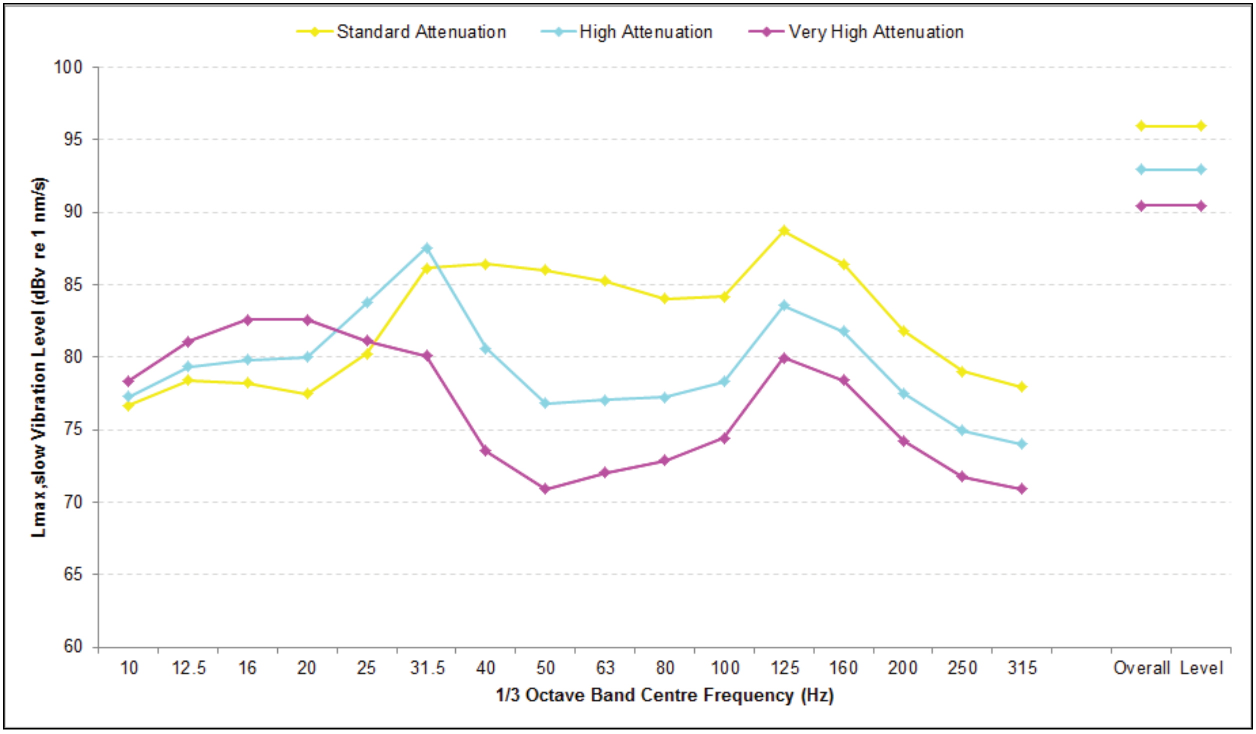
In the absence specific data relating to the proposed single-deck trains, source vibration levels have been assumed to be equivalent to A-Set (Waratah) trains, which are the most modern trains currently operating on the Sydney rail network. This assumption is considered to be slightly conservative on the basis that the proposed single-deck passenger trains are likely to have reduced axle loads and unsprung mass compared with A-Set trains, resulting in marginally lower source vibration levels.

A summary of the reference vibration levels for three forms of slab track are provided in Table 6.3 and Figure 6.2. These track forms are NWRL-specific, taking into account the relevant design factors described below under the Track Form Design heading.

Table 6.3 Reference Source Vibration Levels (Tunnel Wall at 80 km/h Reference Speed)

Track Type	Vibration Levels (dB_V re 1 nm/s) in 1/3 Octave Bands (Hz) – $L_{max,slow,95\%}$																Overall Level
	10	12.5	16	20	25	31.5	40	50	63	80	100	125	160	200	250	315	
Standard Attenuation	77	78	78	77	80	86	86	86	85	84	84	89	86	82	79	78	96
High Attenuation	77	79	80	80	84	88	81	77	77	77	78	84	82	78	75	74	93
Very High Attenuation	78	81	83	83	81	80	74	71	72	73	74	80	78	74	72	71	90

Figure 6.2 Reference Source Vibration Levels (Tunnel Wall at 80 km/h) – $L_{max,slow,95\%}$



Route Alignment

In order to reduce proximity to sensitive receivers, the NWRL alignment has, where practicable, been located below or near to major roads including the M2 Motorway, Castle Hill Road, Old Northern Road, Showground Road and Norwest Boulevard. From a ground-borne noise and vibration perspective this is advantageous because the nearest sensitive receivers have existing noise exposure from road traffic (which often masks the effects of ground-borne noise) or are commercial or industrial nature and therefore less susceptible to ground-borne noise and vibration emissions. In other sections, the proposed alignment runs beneath suburban residential areas away from major roads where the ambient noise level environment is typically quieter - the potential sensitivity to train passbys is increased at these locations.

On curved track, wear patterns and vehicle steering characteristics can affect the source vibration emissions at the wheel rail interface. The risk of poor rail condition (such as corrugation) is also greater on curves than on straight track, as is the risk of other effects such as heavy flanging.

For the tunnel section of the alignment, the design of the NWRL has a minimum curve radius of approximately 600 m, meaning that the effects of flanging noise and wheel squeal that would occur on tighter curves are likely to be minimal.

Long sections of the alignment which illustrate the depth of the tunnels in relation to the existing ground surface above are provided in Appendix F.

Rolling Stock Design

The proposed rolling stock to be utilised on the NWRL would comprise a new fleet of modern, single-deck, rapid transit trains. These trains are approximately 160 m to 170 m long in an 8-car configuration. These proposed trains are likely to incorporate dynamic brakes, friction disc brakes (at low speeds) and anti-skid systems to ensure that the wheel running profile remains smooth.

Rail Type

The proposed rail type for the NWRL project is 60 kg/m rail.

Track Form Design

The track form design (and its interaction with the operational rolling stock) is one of the primary ways in which ground-borne noise and vibration can be minimised on new underground railway lines.

The broad principles of vibration isolation for railways consist of a reduction in the dynamic stiffness of the track support and the introduction or increase in the mass of elements above the resilient track support. In general, the lower the natural frequency of the track support system, the better the vibration isolation. Low natural frequency is achieved by increased mass above the resilient support layer and reduced dynamic stiffness of the resilient support.[10]

Mitigation of ground-borne noise and vibration levels in buildings near railway lines is usually achieved through the insertion of a resilient layer between the rail and tunnel floor, either in the form of a resilient rail fastener, booted sleeper, floating track slab or a combination of approaches. The resilience is usually in the form of elastic/resilient pads or mats (or moulded rubber elements in the resilient baseplates/fasteners).

Figure 6.3 presents the principal features of generic designs for slab tracks and the location of the resilient components in each case, whilst examples of moderately resilient and highly resilient baseplates from two manufacturers (Delkor and Pandrol) are provided in Figure 6.4.

Resilient baseplates are available from a range of suppliers including ATP, CDM, Delkor, Getzner, Hilti, Lord, Pandrol, Schwihag and Vossloh. The dynamic stiffness of resilient baseplates varies significantly, ranging from around 5 kN/mm to 40 kN/mm.

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[10] *ANC Guidelines - Measurement and Assessment of Ground-borne Noise & Vibration,* Association of Noise Consultants (2001), Page132.

The final track form design and associated mitigation measures will be addressed in the detailed design to be undertaken by the successful contractor. The track form design assessed as part of this EIS forms part of the Concept Design and identifies one option on how the ground-borne noise and vibration objectives can be achieved.

Figure 6.3 Generic Track Forms to Mitigate Ground-borne Noise and Vibration on Slab Track

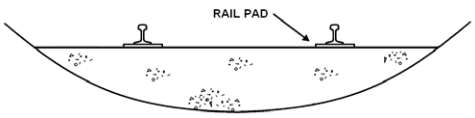
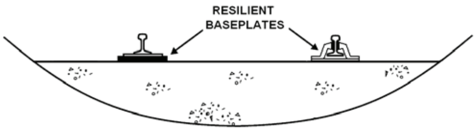
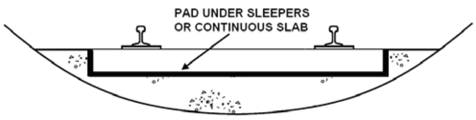
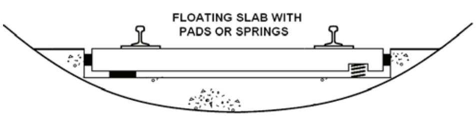
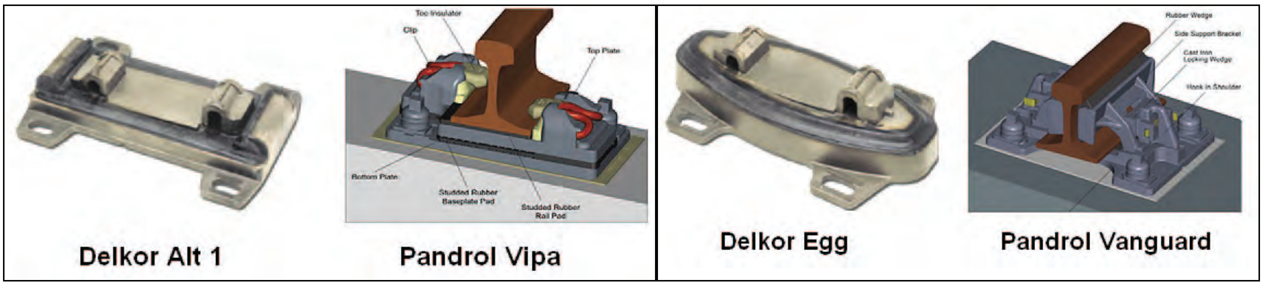
Generic Track Form Layouts	***Acoustic Performance***	***Description***
		*Direct fixation with standard rail foot pads (eg HDPE)*
	*Increasing Ground-borne Noise and Vibration Reduction*	*'Hard' resilient baseplates (eg, Delkor Alt 1, Pandrol Vipa, Pandrol Double Fastclip)*
		'Soft' resilient baseplates (eg, Delkor Egg or Pandrol Vanguard)
		*Resiliently supported sleepers/blocks or continuously supported slabs (eg slab on ballast mat)*
		*Floating Slab Track (FST) systems using short, long or continuous slabs with rubber or spring elements*

Figure 6.4 Hard Resilient Baseplates (left) and Soft Resilient Baseplates (right)



For the purpose of this assessment, generic performance data have been obtained for the Delkor fasteners (used on the ECRL) and the Pandrol fasteners (used on the Perth Metro). The source vibration levels for a number of different track forms are provided in Table 6.4.

Table 6.4 Properties of Delkor and Pandrol Rail Fasteners

Fastener Type	Static Stiffness[1,2]	Dynamic Stiffness[1,2]	Dyn/Stat Ratio	Comments
Standard Rail Fasteners				
ECRL Delkor Alt 1	20 kN/mm	28 kN/mm	1.4	As installed on ECRL
Delkor Alt 1	12 - 30 kN/mm	17 - 42 kN/mm	1.4	Stiffness options can be varied to suit
Pandrol Vipa	17 - 20 kN/mm	17 - 21 kN/mm	1.05	-
High Attenuation Rail Fasteners				
ECRL Delkor Egg	10 kN/mm	12 kN/mm	1.2	As installed on ECRL
Delkor Egg	6 - 15 kN/mm	8 - 20 kN/mm	1.3	Stiffness options can be varied to suit
Very High Attenuation Rail Fasteners				
Pandrol Vanguard	3 - 5 kN/mm	5 - 7.5 kN/mm	1.5	Assume dynamic stiffness of 6 kN/mm
Low Profile Delkor Egg	6 kN/mm	7.2 kN/mm	1.2	Stiffness options can be varied to suit

Note 1: The Static and Dynamic stiffness values have been obtained from product brochures (for Delkor and Pandrol products) and from the ECRL 100% Design Report (for the ECRL Alt 1 and Egg products).

Note 2: Various testing methods are employed in order to calculate the static and dynamic stiffness values of different systems. This makes a direct like for like comparison of the different systems difficult.

For the current assessment, the vibration performance of the ECRL Delkor Egg has been used as a starting point (based on tunnel wall measurement data within ECRL), with adjustments to the source levels being made for Delkor Alt 1 and Pandrol Vanguard fasteners based on the typical Dynamic Stiffness values. In practice, the vibration attenuation performance will also be affected by other parameters including the loss factor (damping), mass and dynamic interaction with the tunnel and rolling stock. Furthermore, various testing methods are employed in order to calculate the static and dynamic stiffness values of different systems which make a direct like-for-like comparison difficult. These other factors will be required to be investigated as part of the detailed design stage of the project.

Other important factors related to the use of softer baseplates which should be noted for consideration during detailed design are listed below:

- Care needs to be exercised to ensure that a low stiffness track design does not give rise to excessive passenger discomfort vibration levels or unacceptable reliability, availability, maintainability and safety (RAMS) implications.
- Careful attention is needed to ensure that the loaded natural frequency of the resilient rail fastener does not coincide with other frequencies associated with the fastener spacing, wheel diameter, bogie passing frequency, etc. If this occurs, the performance of the system will be impaired.
- An increase in the fastener spacing and decrease in the static stiffness of the resilient rail fasteners will increase the maximum rail deflection (and rail stress).

NWRL Track Forms

For the ground-borne vibration modelling undertaken for the NWRL project, the source vibration levels with ECRL Delkor Egg fasteners have been adopted as a reference, on the basis of attended measurements undertaken by SLR Consulting on the ECRL.

For the Delkor Alt 1 and Pandrol Vanguard fastening system, the relative performance (compared with the ECRL Delkor Egg) has been evaluated using a Single Degree of Freedom (SDoF) analysis including the unsprung axle mass of the rolling stock and rail pad stiffness per track metre. The NWRL design assumes a rail fastener spacing of 700 mm for all track form options.

In the NWRL ground-borne noise and vibration assessment, the following three track form options have been evaluated:

- **Standard Attenuation Track** – ground-borne noise performance of Delkor Alt 1, or equivalent from other suppliers/systems. Assumed dynamic stiffness of 28 kN/mm.
- **High Attenuation Track** – ground-borne noise performance of ECRL Delkor Egg or equivalent from other suppliers/systems. Assumed dynamic stiffness of 12 kN/mm.
- **Very High Attenuation Track** – ground-borne noise performance of Pandrol Vanguard Direct Fix Track System or equivalent from other suppliers/systems. Assumed dynamic stiffness of 6 kN/mm.

Standard attenuation track is proposed as standard in the design process with higher attenuation or very high attenuation track being required in more sensitive areas where the standard attenuation design is not sufficient to achieve the ground-borne noise and vibration design objectives. The source vibration levels for the above three track forms are provided in Table 6.3 and Figure 6.2.

Turnouts

The NWRL alignment has turnouts at a number of locations. As there is a discontinuity in the rail running surface at these locations, vibration levels will be higher than on smooth continuous track. Turnout locations for the project are provided in Table 6.5.

Table 6.5 Turnout Locations

Track Feature Requiring Turnout	Turnout Chainage (km)	
	Down Track	Up Track
Castle Hill Crossover Cavern	33.396	33.417
	33.549	33.570

References such as the US FTA *Transit Noise and Vibration Impact Assessment* indicate that vibration levels are typically 10 dB higher adjacent to conventional turnouts, which is in accordance with SLR Consulting's experience on previous projects. This adjustment has been incorporated into the model for a 10 m track increment at each turnout. Increases in overall vibration levels at individual receiver locations are however less than 10 dB, as the 10 m track increment represents only a portion of the total train passby vibration emission.

Where exceedances of the design objectives are predicted adjacent to conventional turnout locations, ground-borne noise and vibration impacts can be further mitigated through the specification of alternative turnouts (such as swing noise).

Tunnel Design

The design properties of the tunnel including the diameter, wall thickness and material properties influence the vibration energy transmitted into the surrounding ground. An internal tunnel diameter of 6.1 m has been evaluated for the NWRL design.

Construction Tolerances

Construction tolerances refer to factors such as the variation in stiffness values between rail fasteners, the quality of the track construction and any change in stiffness values with time.

The potential effect of construction tolerances has not been evaluated as part of the NWRL assessment and will be required to be addressed in detailed design. These effects are however not anticipated to be significant.

Operations

The main factors associated with operational patterns are the train speeds and timetabling. The speed profiles for both the down and up track used for the modelling are provided in Figure 5.2. For the purpose of the ground-borne noise and vibration modelling, a minimum speed of 50 km/h has been assumed at the stations.

For train operations in tunnels, the vibration levels typically increase by 6 dB for each doubling of train speed. This relationship has been observed by SLR Consulting on other projects (including ECRL) and has therefore been adopted for the NWRL modelling.

The reference vibration levels adopted in the modelling process are for a train speed of 80 km/h (refer to Table 6.3). The maximum train speeds proposed for the NWRL are 130 km/h for the open track section and 100 km/h for the tunnel track section. Figure 5.2 shows the trains speeds which have been adopted for the noise and vibration modelling. Speed adjustment of the 80 km/h reference vibration level has therefore been made using the following formula on a 1/3 octave frequency basis:

$$V(speed\_adjusted) = V(reference) + 20\log_{10}\left(\frac{speed}{80}\right)$$

As per the above, the maximum increase in ground-borne noise and vibration levels would be approximately 2 dB in the worst-case situation for the tunnel section.

The potential impact of passing trains at particular receiver locations on a regular basis has not been evaluated in detail as part of the NWRL assessment. The maximum increase in vibration levels in the event of two trains passing at the same time is 3 dB. In practice, this situation would occur infrequently and since ground-borne noise and vibration levels from trains are variable, any increase in noise levels would likely be limited to 1 dB or 2 dB and is not likely to be noticeable.

Maintenance

The maintenance of the track and rolling stock can have a significant influence on the ground-borne noise and vibration levels. The source vibration levels which form the starting point of the modelling assume that the track is maintained in a reasonable condition consistent with what has been observed and measured on ECRL. In the case of poor track condition, it is assumed that rail grinding would be undertaken if the surface roughness values of the track are outside the permitted tolerances. Furthermore, it is also assumed that the condition of the track would be monitored on a regular basis using on-car or hand-held monitoring equipment.

The source vibration levels are also based on the 95th percentile (highest 5%) of train vibration levels observed, as required by IGANRIP. The NWRL project will include wheel condition monitoring systems and a wheel lathe at the proposed maintenance facility. On this basis, it is reasonable to assume that the condition of the wheels would remain steady over time.

In the case of poor wheel condition, it is assumed that the potential for wheel flats would be minimised through design of anti-skid braking systems. If wheel flats or other wheel defects do occur however, it is assumed that these would be identified by a permanent monitoring station and rectified using the wheel lathe or other measures to return the wheel condition to an acceptable degree of smoothness.

Safety Factor

The modelling process incorporates a +5 dB safety factor to the predictions of ground-borne noise and vibration to accommodate for site specific factors such as atypical ground conditions and/or abnormal building construction methods which could lead to higher than anticipated levels.

6.3.3 Propagation Path

The propagation of vibration through the ground is a complex phenomenon. Even for a simple source, the received vibration at any point includes the combined effects of several different wave types, plus reflections and other effects caused by changes in ground conditions along the propagation path.

Attenuation with distance occurs due to the geometric spreading of the wave front and due to other losses within the ground material known as ‘damping’. The attenuation due to geometric spreading occurs equally for all frequencies, whereas the damping component is frequency dependent, with greater loss per metre occurring at high frequencies than at low frequencies.

Vibration Attenuation due to Geometric Spreading

For geometric spreading, a 160 m long train was modelled as a cylindrical line source based on the tunnel wall vibration levels at a distance of 2 m from the track centreline. For this project, the trains were represented by point sources spaced at 5 m intervals, with the distance attenuation from each point calculated according to the following formula:

$$V(spreading) = 10\log_{10}\left(\frac{2}{\text{Distance}}\right)$$

where: *V(spreading)* is the change in vibration level (in dB), Distance is the slant distance between the point source and the receiver location.

Vibration Attenuation due to Material Damping

Initial geological surveys indicate that the ground geology along the proposed alignment is predominantly Hawkesbury sandstone and Ashfield shale.

The excess attenuation due to material damping for the NWRL project was based on bore hole vibration testing undertaken by SLR Consulting as part of the NWRL project and former West Metro proposal. The measurement results are consistent with the force transmissibility measurements undertaken by Wilkinson Murray Pty Ltd as part of the ECRL project.

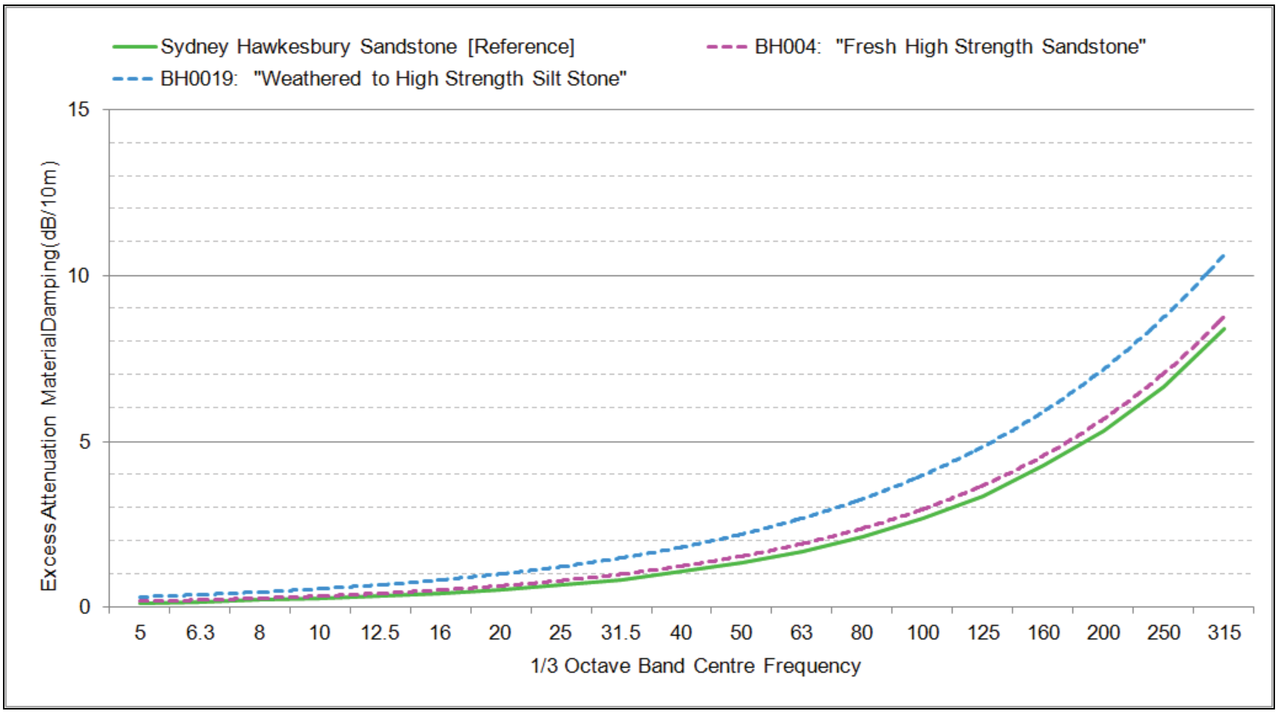
These excess attenuation levels (shown by the green line in Figure 6.5) were adopted on the basis that they provided a good conservative estimate of the measured damping properties for Hawkesbury sandstone and Ashfield shale, which are the predominant ground types through which the NWRL alignment passes.

The measured excess attenuation due to material damping for Hawkesbury sandstone (pink dashed line in Figure 6.5) was found to be consistent with previous measurement data for this ground type. The measurements for Ashfield shale (blue dashed line in Figure 6.5) found slightly higher excess attenuation values compared to Hawkesbury sandstone.

A conservative estimate of the excess attenuation according to values presented in Figure 6.5 has therefore been implemented for the length of the underground sections of the NWRL alignment.

This conservative estimate for the excess attenuation due to material damping may result in a slight over-prediction of the ground-borne noise and vibration levels at some locations. Since it is not possible to know exactly what ground conditions exist at all locations, a conservative approach is required at this stage in the assessment process to provide confidence that the design objectives are achievable along the NWRL alignment.

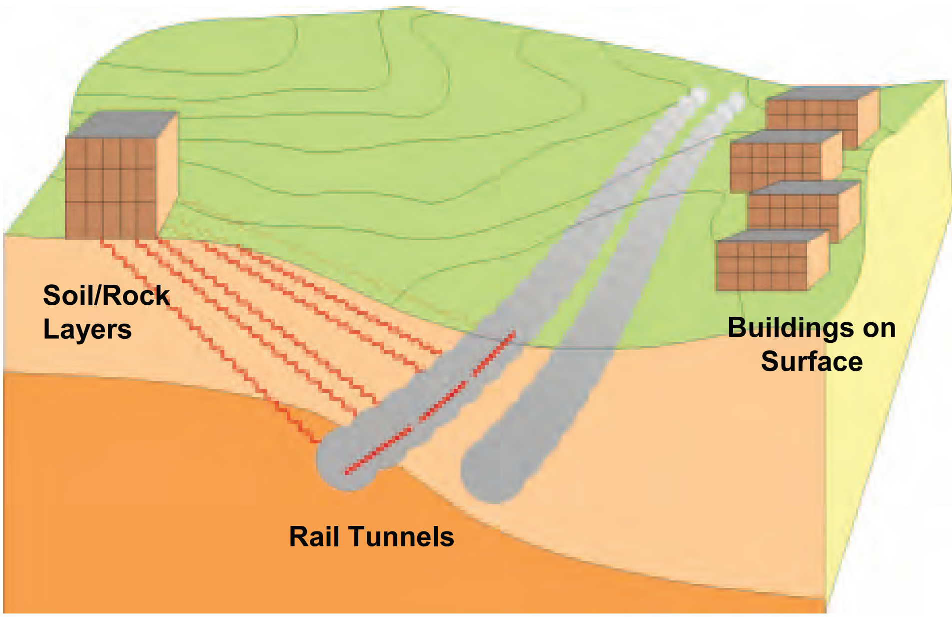
Figure 6.5 Excess Attenuation Due to Material Damping



Three-Dimensional Modelling

The importance of undertaking three-dimensional modelling is illustrated in Figure 6.6. For a 160 m long train vibration source, changes in track form or train speed, crossovers, curves and other local characteristics can result in variations in vibration emissions within the zone of influence of a given building. Hence, it is desirable for modelling to represent the train over its full length. Therefore it is necessary to model the tunnel in three dimensions, rather than as a simple cross section.

Figure 6.6 Possible Propagation Paths from Train in Tunnel to Surface Buildings



6.3.4 Receivers

Propagation of Vibration into Buildings

With many types of building, a coupling loss occurs at the ground/footing interface, resulting in lower levels of vibration in the building's footings than in the surrounding ground. The ground-borne vibration and noise model permits assessment with a variety of coupling loss categories, representative of several different building construction methods.

For many buildings situated near to the NWRL, it is likely that the building footings will be founded on the underlying sandstone. On this basis, a conservative coupling loss midway between zero and that for a single level building has been assumed in the model for all buildings. This is detailed in Table 6.6 together with typical coupling loss data for common building structures.

Table 6.6 Coupling Loss Values (dB)

Type	Coupling Loss (dB) in 1/3 Octave Bands (Hz)																		
	5	6.3	8	10	12	16	20	25	31.5	40	50	63	80	100	125	160	200	250	315
Values adopted for NWRL	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2
Large Masonry on Piles	6	6	6	6	7	7	7	8	9	10	11	12	13	13	14	14	15	15	15
Large Masonry on Spread Footings	11	11	11	11	12	13	14	14	15	15	15	15	14	14	14	14	13	12	11
2-4 Storey Masonry on Spread Footings	5	6	6	7	9	11	11	12	13	13	13	13	13	12	12	11	10	9	8
1-2 Storey Commercial	4	5	5	6	7	8	8	9	9	9	9	9	9	8	8	8	7	6	5
Single Residential	3	3	4	4	5	5	6	6	6	6	6	6	6	5	5	5	4	4	4

Note: Coupling loss values have been obtained from Nelson[11] and have been extrapolated to include frequency bands below 16 Hz.

Propagation of Vibration within Buildings

Losses also occur with the transfer of vibration from floor-to-floor within buildings. The model incorporates the losses listed in Table 6.7, which are also based on data presented by Nelson, extrapolated to include frequency bands below 16 Hz. The ground-borne noise and vibration levels attenuate by approximately 2 dB per floor for the first four floors and by approximately 1 dB per floor thereafter.

[11] *Transportation Noise Reference Book*, Nelson, J (1987).

Table 6.7 Floor-to-Floor Loss Values

Floor Level Above Grade	Floor-to-Floor Loss (dB) in 1/3 Octave Bands																		
	5	6.3	8	10	12	16	20	25	31.5	40	50	63	80	100	125	160	200	250	315
1	1	1	1	1	1.5	1.5	1.5	2	2	2	3	3	3	2	2	2	3	3	3
2	1	1	1	1	1.5	1.5	1.5	2	2	2	2	2	2	3	3	3	3	3	3

Note: The floor to floor losses in this table are additive (ie for assessment on the second level above ground, the loss at 50 Hz would be 5 dB).

Low frequency vibration can be amplified within buildings by resonances in floors and walls. On the basis of data presented by Nelson, the amplification spectrum presented in Table 6.8 has been adopted. Nelson indicates that amplification values found in practice are typically within ±3 dB of these values. Slightly lower values are assumed for the ground-borne noise calculations as the use of the full floor amplification values can result in over-estimation of the resultant noise[12]. The values below have been adopted in the NWRL model for all receivers.

Table 6.8 Amplification within Buildings Values

Floor Level Above Grade	Floor-to-Floor Loss (dB) in 1/3 Octave Bands																		
	5	6.3	8	10	12	16	20	25	31.5	40	50	63	80	100	125	160	200	250	315
Floor Vibration	10	10	10	10	10	10	10	11	11	11	10	9	9	-	-	-	-	-	-
Ground-borne Noise	-	-	-	-	-	-	6	7	7	7	6	6	5	5	4	3	2	1	1

Note: Note that the frequency range used for vibration assessment is 5 Hz to 80 Hz and the frequency range for ground-borne noise assessment is 20 Hz to 315 Hz.

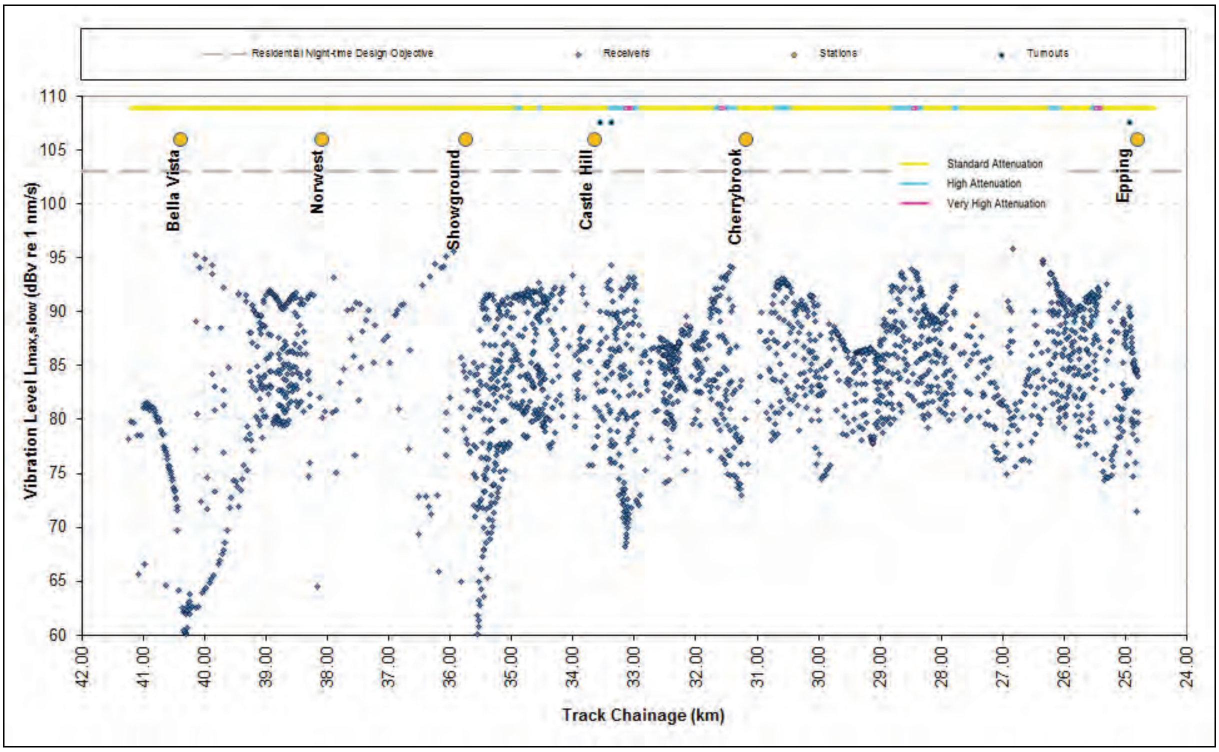
6.4 Ground-borne Vibration Predictions

On the basis of the ground-borne vibration modelling assumptions discussed above, Figure 6.7 presents a summary of the predicted ground-borne vibration levels for buildings located above or near the proposed rail alignment.

The predicted ground-borne vibration levels are for the proposed track design to meet the ground-borne noise levels (refer Figure 7.2) and represent the maximum mid-floor vibration levels within multi-storey buildings. For a building with a slab on ground construction, the highest vibration levels would be expected to occur on Level 2, due the amplification resulting from the suspended slab.

[12] *ANC Guidelines - Measurement and Assessment of Ground-borne Noise & Vibration,* Association of Noise Consultants (2001).

Figure 6.7 Predicted Ground-borne Vibration Levels (Proposed Track Form)



6.4.2 Special Receivers Which May Contain Highly Vibration Sensitive Equipment

At this stage, it is not known whether any commercial facilities contain highly sensitive measurement or fabrication equipment. For preliminary assessment purposes, it is assumed that all nearby medical facilities may contain highly sensitive equipment such as lithography or optical/electronic inspection equipment with high resolution (down to 1 micron). Table 6.9 presents predicted ground-borne vibration levels for facilities that are located in proximity of the proposed alignment.

Table 6.9 Special Receivers which may contain Highly Vibration Sensitive Equipment

Receiver	Chainage (km)	Maximum 1/3 Octave Band Vibration Level (dB ref 1 nm/s)[1]	
		Design Objective	**Predicted**
Medical Centre and Dental Clinic – 74 Rawson Street, Epping.	25.120	82	**85**
Veterinary Hospital – 138 Castle Hill Road, West Pennant Hills.	30.575		**89**
Bella Vista Medical Centre, 10 Century Circuit, Baulkham Hills.	37.925		74
Norwest Medical Imaging, 6 Meridian Place, Bella Vista.	39.965		67
Sydney Animal Hospital, 3 Celebration Drive, Bella Vista.	40.130		**83**

Three exceedances of the design objective for receivers which may contain highly vibration sensitive equipment have been predicted in the above assessment at Medical Centre/Dental Clinic, 74 Rawson Street, Epping; West Pennant Hills Veterinary Hospital, 138 Castle Hill Road, West Pennant Hills; and the Sydney Animal Hospital, 3 Celebration Drive, Bella Vista.

6.4.3 Summary of Ground-borne Vibration Assessment

As discussed in Section 6.2, the human comfort (perception) objectives for ground-borne vibration are more stringent than other possible design limits relating to building damage risk or the potential effects on building contents.

On the basis of the input data and modelling assumptions described in the previous sections, compliance with the ground-borne vibration objectives (the human comfort vibration criteria from *Assessing Vibration: A Technical Guideline*) is predicted for all residential receivers and the majority of other sensitive receiver locations above or near to the proposed NWRL alignment.

For receivers which may contain highly vibration sensitive equipment, three minor exceedances of the design objective have been predicted. These establishments would already be subject to relatively high levels of ambient vibration due their location adjacent to major roads.

7 Ground-borne Noise – Train Operations

7.1 Introduction

Train noise in buildings adjacent to rail tunnels is predominantly caused by the transmission of ground-borne vibration rather than the direct transmission of noise through the air. After entering a building, this vibration may cause the walls and floors to vibrate faintly and hence to radiate audible noise, which is commonly termed ground-borne or regenerated noise.

If it is of sufficient magnitude to be audible, this noise has a low frequency rumbling character, which increases and decreases in level as a train approaches and then departs the site. This type of noise can be experienced in buildings adjacent to many urban underground rail systems, including several buildings close to the existing CityRail tunnels in the Sydney CBD.

In some CBD buildings where no precautions have been taken in the tunnel or building design to limit ground-borne noise and vibration effects, the rumbling noise can sometimes be heard several storeys above ground level. The depth of the railway tunnels at many locations within the CBD is also less than 5 m compared with a typical depth of 20 m to 70 m for NWRL.

For most new railway lines, the track design usually incorporates resilient rail fasteners to reduce the transmission of dynamic forces that occur at the wheel-rail interface. This resilience also serves to provide some isolation of ground-borne vibration, which in turn reduces the ground-borne noise levels in buildings near the railway tunnel.

Some especially sensitive spaces and activities, such as theatres, cinemas, studios and sleeping areas are more prone to disturbance from ground-borne noise than others, such as shopping areas, office spaces or industrial premises.

Ground-borne noise levels are relevant only where they are higher than the airborne noise, such as when the railway is underground. The NWRL will be underground between Epping and Bella Vista.

7.1.1 Ground-borne Noise Metrics

The primary noise metric used to describe railway ground-borne noise emissions in the modelling and assessments is:

- $L_{Amax(slow),95\%}$ — The *"typical maximum noise level"* for a train passby event. For operational rail noise, $L_{Amax(slow)}$ refers to the maximum noise level not exceeded for 95% of rail passby events measured using the 'slow' response setting on a sound level meter.

The subscript 'A' indicates that the noise levels are filtered to match normal human hearing characteristics (i.e. A-weighted). On the basis of guidance in International Standard ISO 14837-1 2005 *Mechanical vibration - Ground-borne noise and vibration arising from rail systems - Part 1: General Guidance*, ground-borne noise levels are evaluated over the 20 Hz to 315 Hz frequency range.

7.1.2 Assessment Process

The assessment of ground-borne operational noise impacts is described in the *Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects* (IGANRIP) and follows the process shown in Figure 5.1.

7.2 Operational Ground-borne Noise Objectives

The ground-borne noise and vibration assessment is required to be undertaken in accordance with the requirements of the IGANRIP noise guideline. The noise design objectives contained within this guideline are expressed as non-mandatory “trigger levels” which, if exceeded, require the need to consider feasible and reasonable mitigation measures.

The ground-borne noise trigger levels for residential and other sensitive receiver locations are provided in Table 7.1.

Table 7.1 Ground-borne Noise Trigger Levels (Internal)

Receiver	Time of Day	Noise Trigger Levels (dBA)
		Development increases existing rail noise levels by 3.0 dB or more AND resulting rail noise levels exceed:
Residential	Day (7:00 am to 10:00 pm)	40 $L_{Amax(slow)}$
	Night (10:00 pm to 7:00 am)	35 $L_{Amax(slow)}$
Schools, educational institutions, places of worship	When in use	40-45 $L_{Amax(slow)}$

The ground-borne noise levels in Table 7.1 refer to noise caused by the proposed rail operations only and do not include ambient noise from other sources such as major roads and industry. The train noise levels are evaluated inside buildings at the centre of the most affected habitable room (ie kitchens, bathrooms, laundries and the like are not considered “habitable”).

“Residential” typically means any residential premises located in a zone as defined in a planning instrument that permits new residential land use as a primary use. The $L_{Amax,95\%}$ noise level refers to the noise levels not to be exceeded by 95% of train passby events (ie 5% of train passbys are permitted to exceed the trigger levels). The absolute maximum event is not used for design, as it cannot be precisely defined and would be a highly infrequent event. The ground-borne noise level of the “average” or median train event would typically be approximately 5 dB lower than the 95th percentile event.

For new rail projects, the noise trigger levels apply immediately after operations commence and for projected traffic volumes over an indicative period into the future that represents the expected typical level of rail traffic usage (eg 10 years or a similar period into the future).

For schools, educational institutions and places of worship, the lower value of the range is most applicable where low internal ambient noise levels are expected, such as in areas assigned to studying, listening and praying.

The guideline also states:

> *“It appears reasonable to conclude that ground-borne noise at or below 30 dB L_{Amax} will not result in adverse reactions, even where the source of noise is new and occurs in areas with low ambient noise levels. Levels of 35–40 L_{Amax} are more typically applied and likely to be sufficient for most urban residential situations, even where there are large numbers of noisy events.*
>
> *The noise trigger levels … are aimed at providing a reasonable basis for triggering the assessment of impacts from ground-borne noise. They are necessarily set to the lower end of the range of possible trigger values so that potential impacts on quieter suburban locations are addressed. In practice, higher levels of ground-borne noise than the trigger level for assessing impacts may be suitable for urban areas where background noise levels are relatively high.”*

As the NWRL project represents a new rail infrastructure project, the noise trigger levels have been adopted as design objectives which are to be achieved at all locations, where feasible and reasonable.

For residential receivers, this results in a ground-borne noise design objective of 40 dBA $L_{Amax,slow, 95\%}$ during the daytime and 35 dBA $L_{Amax,slow, 95\%}$ during the night-time. For schools, educational institutions and places of worship, this results in a noise design objective of 40 dBA to 45 dBA $L_{Amax,slow, 95\%}$.

For commercial receivers, shopping centres and industrial buildings, IGANRIP does not provide guidance on acceptable levels. On other projects, SLR Consulting has applied ground-borne noise objective of 45 dBA for general office areas and 50 dBA to 55 dBA for retail areas depending on the particular sensitivity of the receiver. A ground-borne noise design objective of 40 dBA is desirable for commercial receivers with private offices or conference rooms.

Provided in Table 7.2 is a summary of the proposed ground-borne noise design objectives for the NWRL project incorporating these receiver types.

Table 7.2 NWRL Ground-borne Noise Design Objectives for Sensitive Receivers

Receiver	Time of Day	Noise Trigger Level (dBA)[1]
Residential	Day (7.00 am to 10.00 pm)	40 dBA
	Night (10.00 pm to 7.00 am)	35 dBA
Schools, educational institutions, places of worship	When in use	40 dBA to 45 dBA[2]
Retail Areas	When in use	50 dBA
General Office Areas	When in use	45 dBA
Private Offices and Conference Rooms	When in use	40 dBA
Cinemas, Public Halls and Lecture Theatres	When in use	35 dBA
Drama Theatres	When in use	NR 25[3]
Film/Television Studios and Sound Recording Studios	When in use	NR 15[3]
Workshops / Industrial Buildings	-	N/A

Note 1: The ground-borne noise design objectives are based on the maximum $L_{Amax(slow)}$ noise level, not to be exceeded for 95% of train passbys over any 24 hour period.

Note 2: The lower value of the range is most applicable where low internal noise levels are expected, such as in areas assigned to studying, listening and praying.

Note 3: NR curves are used for rating noise levels and are a set of octave band curves which provide limiting sound pressure level values. NR 15 is equivalent to approximately 20 dBA and NR 25 is approximately 30 dBA.

7.3 Ground-borne Noise Modelling Methodology

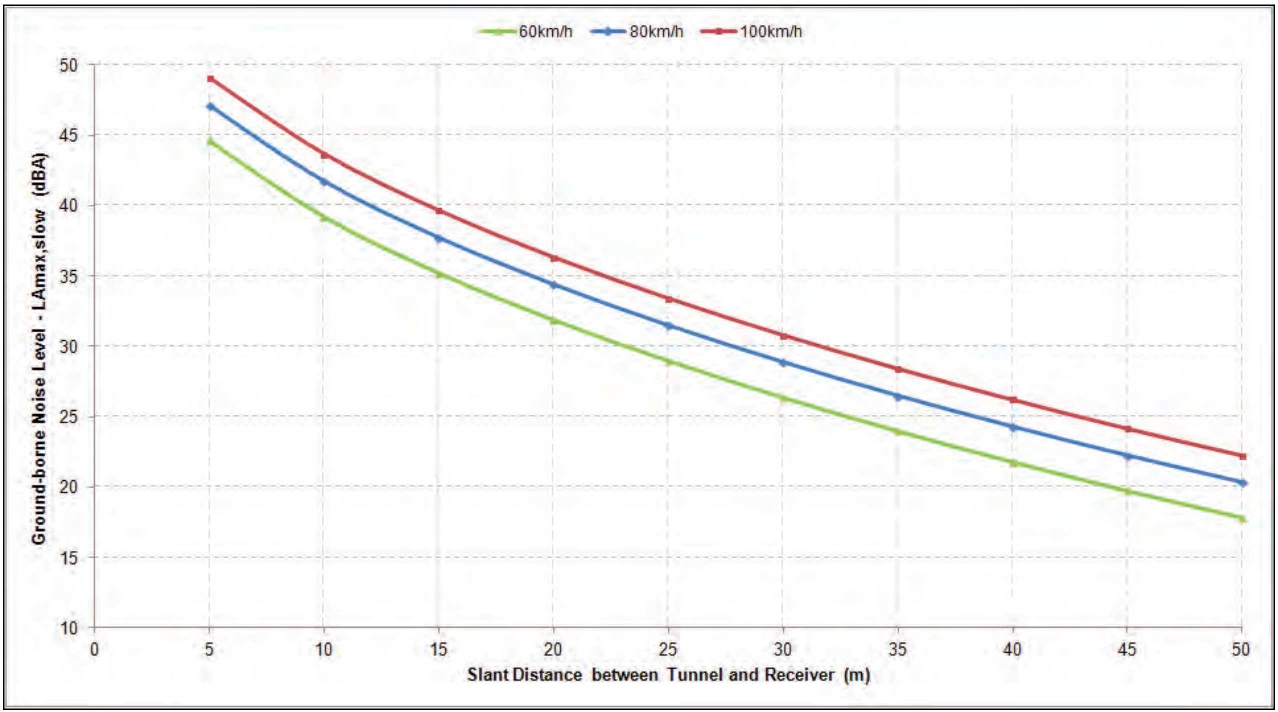
The ground-borne noise and vibration modelling methodology is discussed in Section 6.3, with the addition of two final steps to account for the conversion of surface vibration into noise.

In accordance with Nelson (1987) and the ANC Guidelines (2001), an adjustment of -27 dB was used in the model to convert each 1/3 octave band vibration level (dB_V re 1 nm/s) to a sound pressure level (dB re 20 μPa). The 1/3 octave band sound pressure levels were then A-weighted and logarithmically summed to provide the overall $L_{Amax(slow)}$ noise level predictions.

7.3.1 Ground-borne Noise Prediction Curve

On the basis of the ground-borne noise and vibration modelling assumptions discussed in Sections 6.3 and 7.3, Figure 7.1 presents a summary of the indicative ground-borne noise levels at various distances from the proposed railway tunnels for train speeds of 60 km/h, 80 km/h and 100 km/h, assuming a Standard Attenuation track form design.

Figure 7.1 Ground-borne Noise Level vs. Slant Distance (Illustrative Only)



Note: The distance refers to the slant distance between the receiver location (on the surface) and the track (within the tunnel). For example, if the track is located 30 m below ground and the receiver is located 40 m to the side of the tunnel, the receiver would be located at a slant distance of 50 m from the track.

7.4 Ground-borne Noise Mitigation Options

The potential ground-borne noise mitigation options for a new railway line include the following:

- Operational measures such as reduced train speeds or allowing system access only to trains with wheels in 'good' condition (or modern trains)
- Avoiding tight curves (less than approximately 600 m radius) and optimising the vertical alignment (maximising tunnel depth) where possible
- Track design measures including the provision of resilient rail fasteners, booted sleepers or floating slab track to reduce the vibration energy transferred to the tunnel footing, foundation, surrounding ground and nearby buildings (refer to Section 6.3.2 for more detail on track from mitigation options)
- Track maintenance / rolling stock measures such as maintenance to ensure rail and wheel roughness is kept within required tolerances, maintaining existing rolling stock to ensure "good" wheel condition and / or implementing long-term measures to improve wheel condition over time

- Receiver controls at existing or proposed developments such as full or partial vibration isolation of the building using springs or rubber bearings
- Planning measures such as locating sensitive developments at an acceptable distance from the tunnel alignment

The alignment has been designed to avoid major buildings insofar as possible by running the route in-line with existing roads. This approach also minimises the extent to which the rail alignment is below residential areas where background noise levels from road traffic are inherently lower.

Further approaches to mitigation therefore focus on operational measures, track design, maintenance regimes and source control measures. These options are likely to be more cost effective than receiver controls such as full or partial vibration isolation of buildings above the railway tunnel (which are also usually impracticable for most existing buildings).

Operational measures such as improved wheel and rail condition would provide ground-borne noise and vibration benefits across the whole project area, whilst track design measures and a reduction in train speeds could provide benefits in specific areas. New single-deck trains are proposed to operate on the NWRL with modern braking systems to minimise the risk of wheel defects forming. The source vibration levels are conservatively assumed to be equivalent to A-set (Waratah) trains.

As previously discussed, for the NWRL ground-borne noise and vibration modelling, it has been assumed that the condition of the wheels and rails would be maintained within specified limits and that a monitoring program would be implemented by the operators to identify and repair track and wheels in poor condition.

In order to reduce the potential for ground-borne noise impacts at sensitive receivers without impacting operations via speed reductions, mitigation measures would need to focus on improving the vibration isolation characteristics of the track.

7.5 Ground-borne Noise Predictions

On the basis of the speed profile for the NWRL (shown in Figure 5.2), the proposed vertical alignment (shown in Appendix F) and the modelling assumptions described in the previous sections, predictions of ground-borne noise levels for buildings located above or close to the proposed rail alignments have been undertaken. These calculations have been made for the standard, high and very high attenuation track forms, as outlined in Section 6.3.2.

On the basis of the predicted ground-borne noise levels for the different track forms, Table 7.3 provides a summary of the likely extent of the various track forms that are required to achieve compliance with the ground-borne noise design objectives at all sensitive receiver locations. For this assessment, it is assumed that the extent of the proposed track forms will be identical for each tunnel. The extents of the proposed track forms are illustrated in Figure 7.2.

As discussed in Section 6.3.2, the final track form design and associated mitigation measures will form part of the detailed design to be undertaken by the successful contractor. The track form design assessed as part of this EIS forms part of the Concept Design and identifies one option on how the ground-borne noise and vibration objectives can be achieved.

The current assessment identifies that a very high attenuation track form would be required to achieve the ground-borne noise design objectives at four locations. The assessment currently assumes that the ground-borne noise objectives at these locations can be achieved with a slab track design incorporating Pandrol Vanguard baseplates. It is noted that other systems could also be adopted by the successful contractor to achieve the same outcomes with baseplate designs from other suppliers or via various floating slab track (FST) designs.

Table 7.3 Proposed[1] Track Forms per Tunnel (5 m track increments referenced from Down Track)

Down Track Chainage (km)	Extent of Proposed Track Forms (m)		
	Standard Attenuation	High Attenuation	Very High Attenuation
24.930 – 25.420	490	-	-
25.420 – 25.505	-	-	85
25.505 – 25.555	-	50	-
25.555 – 26.100	545	-	-
26.100 – 26.255	-	155	-
26.255 – 27.760	1,505	-	-
27.760 – 27.825	-	65	-
27.825 – 28.340	515	-	-
28.340 – 28.430	-	90	-
28.430 – 28.470	-	-	40
28.470 – 28.805	-	335	-
28.805 – 30.500	1,695	-	-
30.500 – 30.705	-	205	-
30.705 – 31.380	675	-	-
31.380 – 31.565	-	185	-
31.565 – 31.605	-	-	40
31.605 – 31.685	-	80	-
31.685 – 32.970	1,285	-	-
32.970 – 33.060	-	90	-
33.060 – 33.155	-	-	95
33.155 – 33.430	-	275	-
33.430 – 34.555	1,125	-	-
34.555 – 34.585	-	30	-
34.585 – 34.885	300	-	-
34.885 – 34.920	-	35	-
34.920 – 41.200	6,280	-	-
TOTAL	**14,415**	**1,595**	**260**
Track Form Percentage	**89%**	**10%**	**2%**

Note 1: Concept design proposed track form, subject to detailed design investigations. The standard, high and very high attenuation track forms are specified in Section 6.3.2.

Figure 7.2 Extent of Proposed[1] Track Forms

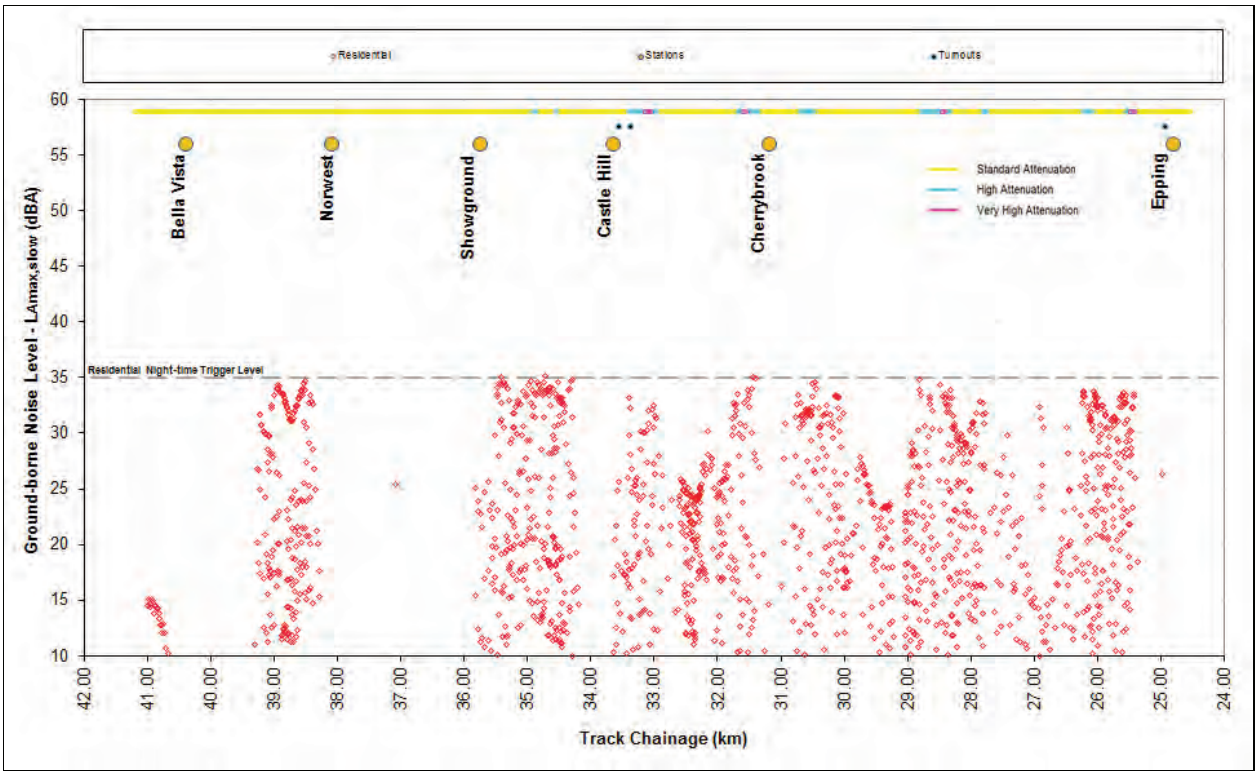
Note 1: Concept design proposed track form, subject to detailed design investigations.

Note 2: High attenuation baseplates are not suitable for use at turnout locations.

The ground-borne noise predictions for the residential receivers along the alignment (with the above proposed track form) are provided in Figure 7.3. This graph is also provided in Appendix G in a larger format. The proposed track form is illustrated on the graph by the yellow, turquoise and magenta bars at the top.

The track is designed to meet the noise objectives at the nearest receivers to the alignment. The predictions are based on a 'best estimate' plus a 5 dB safety factor. On average, the predicted ground-borne noise levels (for the highest 1 in 20 trains) at the nearest locations would be 30 dBA. At most locations the noise levels will be much lower.

Figure 7.3 Predicted Ground-borne Noise Levels – Residential Receivers



7.5.2 Other Sensitive Receivers

The assessment of ground-borne noise for other sensitive receivers near to the NWRL alignment is presented in Table 7.4. The predictions for commercial and other sensitive receivers are provided in Figure 7.4. This graph is also provided in Appendix G in a larger format. The proposed track form is illustrated on the graph by the yellow, turquoise and magenta bars at the top.

Figure 7.4 Predicted Ground-borne Noise Levels – Commercial and Other Sensitive Receivers

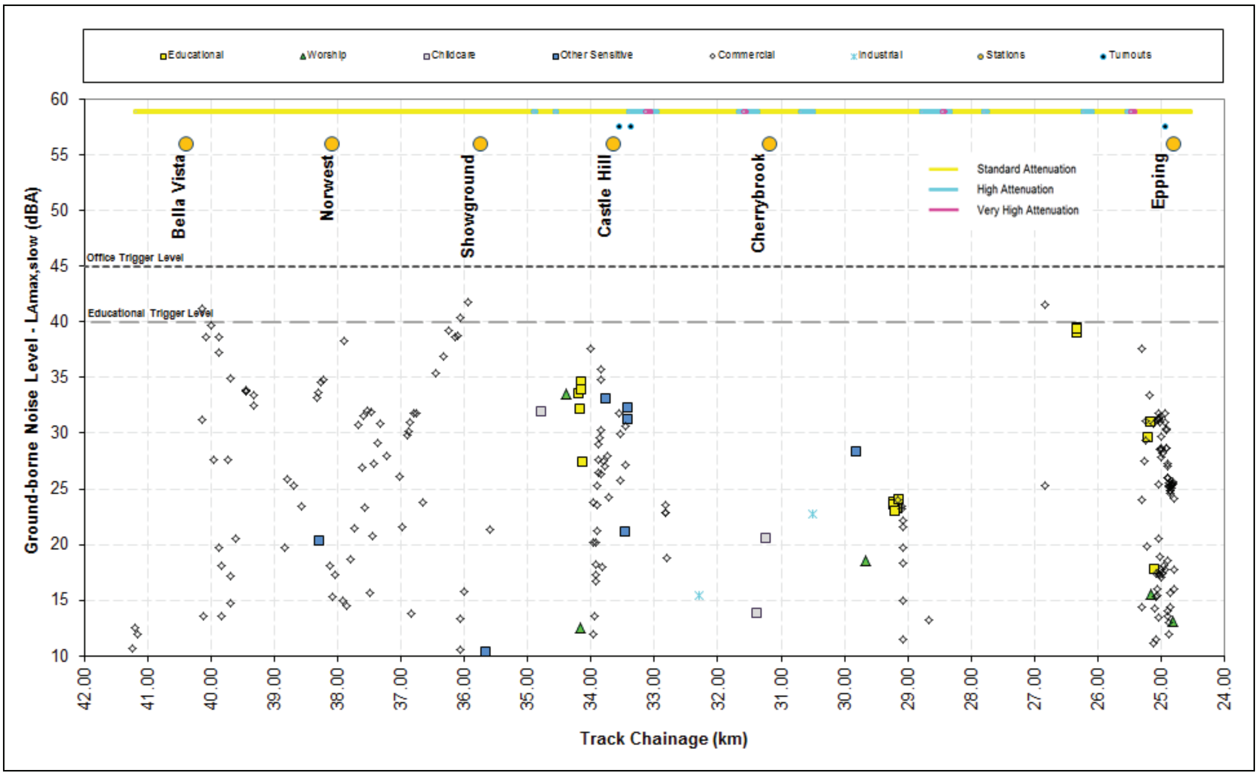


Table 7.4 Predicted Ground-borne Noise Levels – Other Sensitive Receivers

Receiver	Chainage (km)	Ground-borne Noise Level – $L_{Amax,slow,95\%}$ (dBA)	
		Design Objective	**Predicted**
Educational			
Our Lady Help of Christians, 8 Cambridge Street, Epping.	25.185	40 to 45	31
Epping Heights Public School	26.345		40
West Pennant Hills Public School	29.235		24
2 Pennant Street, Castle Hill	34.175		35
Worship			
Our Lady Help of Christians Parish Church, 29 Oxford Street, Epping.	25.130	40 to 45	Less than 20
St Matthew's Anglican Church, New Line Road & Castle Hill Road, West Pennant Hills	29.670		Less than 20
Wesley Uniting Church, 32 Showground Road, Castle Hill	34.385		33
Hillsong Chapel	38.165		Less than 20

Receiver	Chainage (km)	Ground-borne Noise Level – $L_{Amax,slow,95\%}$ (dBA)	
		Design Objective	Predicted
Other Sensitive			
Koala Park, Castle Hill Road, West Pennant Hills	29.820	50	28
Castle Hill Senior Citizens Centre, 2 McMullen Avenue, Castle Hill	33.430	50	32
Event Cinema, Castle Hill Shopping Centre	33.785	35	33
Hillsong Main Auditorium, Dance Studio and Tutorial Rooms	38.280	35	Less than 20
Hillsong HUB Auditorium and Demo Studio	38.310	NR 15	NR 13
Hillsong – Proposed New Recording Studio	38.165	NR 15	NR 8

7.5.3 Summary of Ground-borne Noise Assessment

On the basis of the proposed vertical alignment, the modelling assumptions described in the previous sections and the proposed track form in Table 7.3, ground-borne noise levels are predicted to comply with the ground-borne noise design objectives at all residential and other sensitive receiver locations.

7.6 Compliance Monitoring

The IGANRIP guideline recommends the selection of representative noise monitoring locations in order to assess compliance with the design objectives at a later date. For the NWRL it is recommended that ten ground-borne noise and vibration monitoring locations be selected. The representative receiver locations should be reasonably distributed along the tunnel alignment and include a mix of the existing occupancy types (ie residential, commercial, educational, place of worship, heritage and medical). The receiver locations should be selected in consultation with the communities and property occupiers.

It is anticipated that compliance monitoring at the selected locations would need to be based on operator-attended measurements for a minimum of 20 train passbys at each monitoring location. Measurements should be undertaken for a sub-set of locations during the project commissioning stage and at all locations within three months after the commencement of train operations.

8 Stabling Facility Noise

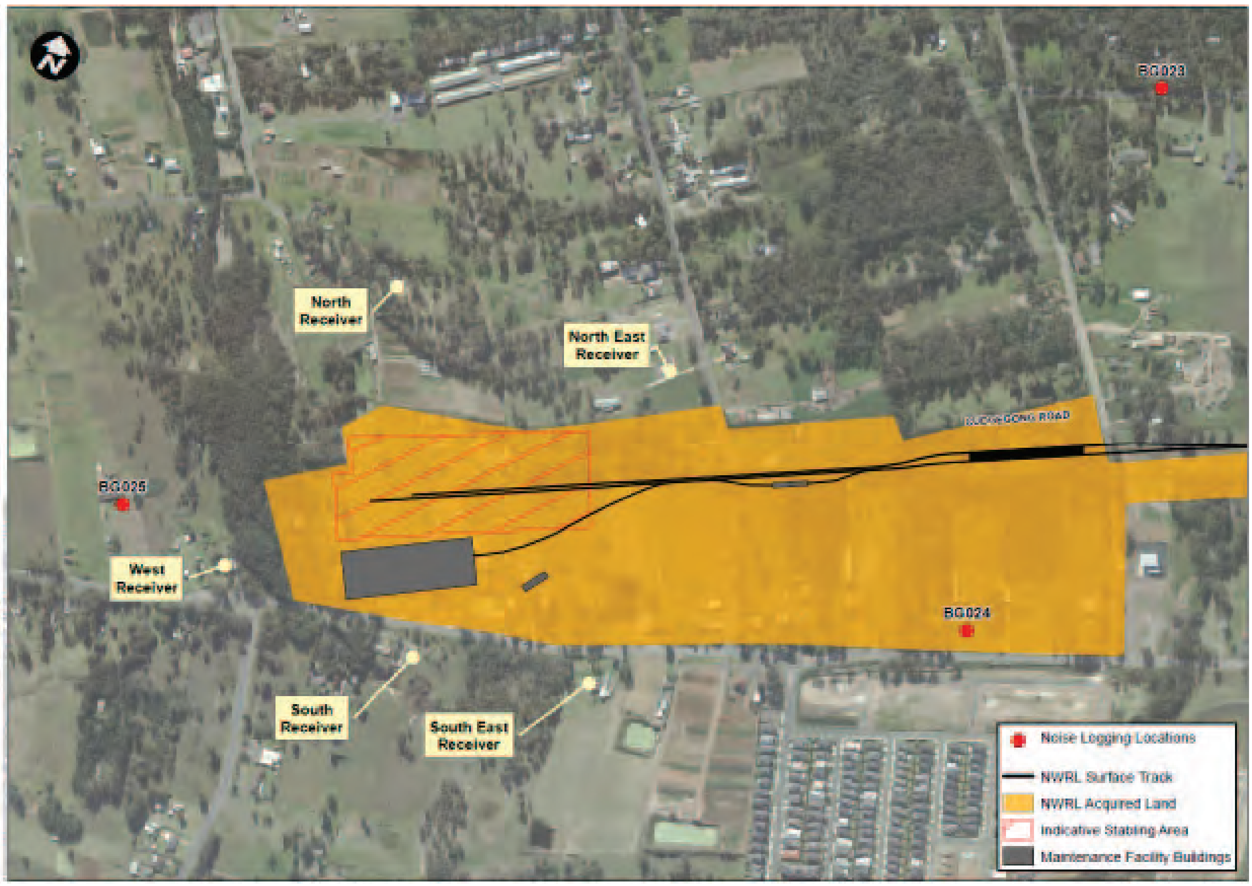
8.1 Assessment Process

The Tallawong stabling facility is considered to be a fixed facility and as such, noise levels are required to be assessed in accordance with the NSW *Industrial Noise Policy* (INP). All noise emissions emanating from within the facility, including train movements and maintenance, need to be assessed in accordance with the INP. Modelling has been carried out using the CONCAWE noise prediction algorithm in SoundPLAN V7.1.

At opening, the Tallawong stabling facility would have capacity for 20 trains. In the future, the capacity of the facility may increase in line with the expected increase in train services. For this assessment, the noise impacts of the facility after opening and for a future scenario are assessed against criteria based on the anticipated noise environment.

The nearest existing sensitive receivers to the proposed stabling and maintenance facility are residential. This assessment therefore considers only impacts on residential receivers as these give the controlling criteria. Figure 8.1 shows the general location of the stabling facility, the locations of ambient noise monitoring, and the nearest existing residential receivers around the facility. Noise levels are predicted at these representative locations in the following sections.

Figure 8.1 Acquired Land, Monitoring Locations and Nearest Sensitive Receivers



8.2 Operational Noise Metrics

The primary noise metrics used to describe noise emissions from fixed facilities in the modelling and assessments are:

- L_{Amax} — The *"typical maximum noise level"* measured using the 'fast' response setting on a sound level meter. In the INP assessment of sleep disturbance, L_{Amax} is used interchangeably with $L_{A1(1minute)}$.
- $L_{A1(1minute)}$ — The noise level which is exceeded for 1% of the sample period, used interchangeably with the L_{Amax} noise level in the assessment of potential sleep disturbance during night-time periods.
- $L_{Aeq(15minute)}$ — The *"energy average noise level"* evaluated over a 15 minute period, used in the assessment of the intrusiveness of noise sources.
- $L_{Aeq(period)}$ — The $L_{Aeq(period)}$ is the *"energy average noise level"* evaluated over the relevant time period, either day (11 hours) evening (4 hours) or night (9 hours). It is used in the assessment of amenity.

8.3 Stabling Facility Noise Criteria

The INP sets two separate noise criteria to meet environmental noise objectives: one to account for intrusive noise and the other to protect the amenity of particular land uses. These criteria are to be met at the most-affected boundary of the receiver property. When determining project specific noise criteria, both the amenity and intrusive criteria are considered. The more stringent of these two criteria usually defines the project specific noise levels. For both amenity and intrusiveness, night-time criteria are more stringent than daytime or evening criteria. As the train stabling facility will operate 24 hours a day, the night-time period is likely to be the controlling time period.

In addition to intrusiveness and amenity, the risk of sleep disturbance must be assessed. Sleep disturbance is assessed in accordance with the screening criterion described in the online Application Notes to the INP and the more detailed review of sleep disturbance contained in the *Road Noise Policy* (RNP).

The INP notes that land uses can change as a result of urban-type residential developments in a village or rural area with few residences, or the encroachment of industrial developments near residential areas and vice versa. As developments introduce increased activities, they also increase environmental noise levels. Therefore, previously low ambient noise levels will not be maintained, and assessments of noise sources for control purposes should be made against the acceptable noise level relevant to the modified land use.

8.3.1 Assessing Intrusiveness

To provide for protection against intrusive noise, the INP states that the L_{Aeq} noise level of the source, measured over a period of 15 minutes, should not be more than 5 dB above the ambient (background) L_{A90} noise level (or RBL), during the daytime, evening and night-time periods at the nearest sensitive receivers. In this case, the RBLs listed in Table 8.1 describe the current noise environment as measured at locations BG24 and BG25 near the proposed facility (see also Section 4 and Figure 8.1). These locations are approximately 1.2 km apart but exhibit markedly different existing background noise levels, especially during the night-time period.

The variation in RBL between these locations (particularly at night) is indicative of the extent of existing development in the area and proximity to Windsor Road and Schofields Road. BG24 with the higher RBLs is located closer to Windsor Road, Schofields Road and the Ponds residential development than BG25, which is currently more rural in character.

Table 8.1 Summary of Unattended Noise Logging Near Tallawong Stabling Facility

Location	Noise Level (dBA)[1]						
	Daytime 7.00 am to 6.00 pm		Evening 6.00 pm to 10.00 pm		Night-time 10.00 pm to 7.00 am		
	RBL	L_{Aeq}	RBL	L_{Aeq}	RBL	L_{Aeq}	L_{Amax}[4]
BG24 [3]	45	59	49	59	38	55	66-71
BG25 [3]	43	53	44	54	30 [2]	58	61-86

Note 1: The RBL and L_{Aeq} noise levels have been obtained using the calculation procedures documented in the INP

Note 2: In accordance with the INP, where the RBL is found to be less than 30 dBA, then it is set to 30 dBA

Note 3: Where the daytime RBL is lower than the evening RBL, then the daytime RBL has been used to determine the relevant evening noise criteria

Note 4: Maximum noise levels during the night-time period have been determined from the daily noise logging plots where the lower noise level is based on the 25th percentile of the 15-minute L_{Amax} noise levels and the upper range is based on the 75th percentile of the 15-minute L_{Amax} noise levels

The area is currently undergoing considerable development, including an upgrade of Schofields Road to link Windsor Road to Richmond Road. When the stabling facility opens, it is reasonable to expect background noise levels to the west of the facility will have increased. A night-time background noise level of 35 dBA would correspond to the estimated noise level in Australian Standard AS 1055.2:2007 *Acoustics-Description and measurement of environmental noise Part 2: Application to specific situations*, for areas with low density transportation (Noise Area Category R2, see Table 8.2). It is noted that the RBLs at location BG25 during the daytime and evening periods (43 dBA and 44 dBA respectively) are already close to or greater than the Noise Area Category R2 noise levels of 45 dBA and 40 dBA. The existing RBLs at location BG24 are already equal to or above the Noise Area Category R2 noise levels during all time periods.

Table 8.2 Estimated Background A-Weighted Sound Pressure Levels (AS 1055.2:2007)

Area	Description	RBL Noise Level (dBA)		
		Daytime	Evening	Night-time
R1	Areas with negligible transportation	40	35	30
R2	Areas with low density transportation	45	40	35
R3	Areas with medium density transportation or some commerce or industry	50	45	40
R4	Areas with dense transportation or some commerce or industry	55	50	45
R5	Areas with very dense transportation or in commercial districts or bordering industrial districts	60	55	50
R6	Areas with extremely dense transportation or within predominantly industrial districts	65	60	55

8.3.2 Assessing Amenity

To protect against impacts on amenity, the INP identifies recommended acceptable and maximum $L_{Aeq(period)}$ noise levels for particular land uses and activities during the daytime, evening and night-time periods. The residences in the vicinity of the proposed stabling facility are considered to be 'Suburban' at the time of the project opening. According to the INP, a 'Suburban' area would be characterised by local traffic with intermittent traffic flows, decreasing noise levels in the evening period; and/or evening ambient noise levels defined by the natural environment and infrequent human activity. The amenity criteria for suburban residential receivers are shown in Table 8.3.

Table 8.3 INP Amenity Noise Levels for Suburban Residential Receivers

Type of Receiver	Land Use	Time of Day	Existing L_{Aeq} Noise Level[1] (dBA) BG24/BG25	Recommended L_{Aeq} Noise Level (dBA)	
				Acceptable	Recommended Maximum
Residential	Suburban	Day	59/53	55	60
		Evening	59/54	45	50
		Night	55/58	40	45

Note 1: It is likely that the measured L_{Aeq} noise levels during the evening and night-time include insect noise or noise from other natural sources.

At both logging locations, the existing evening and night-time L_{Aeq} noise levels are higher than the recommended maximum noise levels. The attended measurements at these locations describe a noise environment dominated by traffic on Schofields Road and natural sources (eg birds, insects). In the absence of other noise sources, it is likely that the high evening and night-time L_{Aeq} noise levels at these locations are controlled by insect noise or other natural noise sources.

8.3.3 Modifying Factor Adjustments

Where a noise source contains certain characteristics, such as tonality, impulsiveness, intermittency, irregularity or dominant low-frequency content, there is evidence to suggest that it can cause greater annoyance than other less-obtrusive noise sources at the same level. To account for this additional annoyance, the INP describes modifying factors to be applied when assessing amenity and intrusiveness. According to the definitions in the INP, the noise sources at the stabling and maintenance facility are not likely to require the addition of modifying factors.

8.3.4 Shoulder Periods

The early morning period (prior to 7:00 am) is defined as part of the standard 10.00 pm to 7.00 am night-time period by the INP. In some circumstances however, where early morning operations are proposed, the INP allows for the relevant period of time to be assessed as a 'shoulder period'. This is because it may be unduly stringent to assess early morning noise emissions against the overall night-time background noise levels, when at the time of operation background noise levels are rising steadily. The INP states that:

> *"As a rule of thumb it may be appropriate to assign a shoulder period rating background level as the mid-point value between the rating background levels of the two assessment periods that are either side of the shoulder period."*

The noise logging at both BG24 (Figure 8.2) and BG25 (Figure 8.3) indicates that existing background noise levels are lowest before 4:00 am. At BG24 the background noise increases steadily from around 37 dBA at 4:00 am up to around 45 dBA at around 7:00 am. At BG25 the increase in background noise is sharper, rising from below 30 dBA at 4:00 am up to 45 dBA by 6:00 am.

Considering the time of year of the monitoring and the noise environment observed during the attended noise measurements, it is likely that the early morning increase in noise levels at BG25 is due to natural sources (eg birdsong around sunrise), and that this increase may not be consistent throughout the year (ie, it may occur later during winter). The more gradual increase in background noise levels seen at BG24 is considered to be more representative of a noise environment affected by road traffic noise, where background levels increase steadily up to a peak corresponding with the morning traffic peak.

In this case, the first train will begin preparations to enter service at around 4:00 am on weekdays, before the first scheduled departure. On the basis of the measured background noise at BG24, it is considered that the operation of the facility from before 5:00 am should be assessed against the standard night-time criteria. It is appropriate to assess the operation of the stabling facility between 5:00 am and 7:00 am against shoulder period noise criteria, taken to be midway between the daytime and night-time noise criteria, ie 5 dB higher than in the night-time period.

Figure 8.2 Ambient and Background Noise at BG24

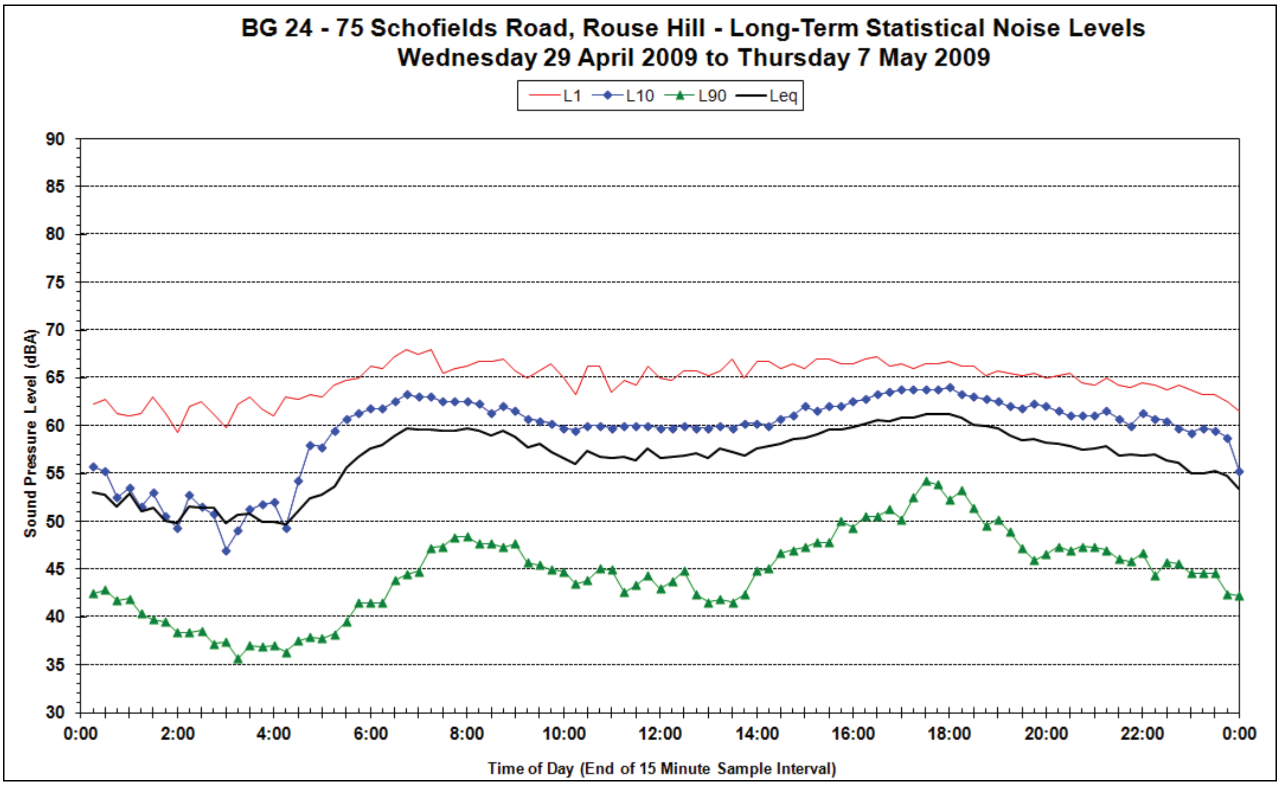
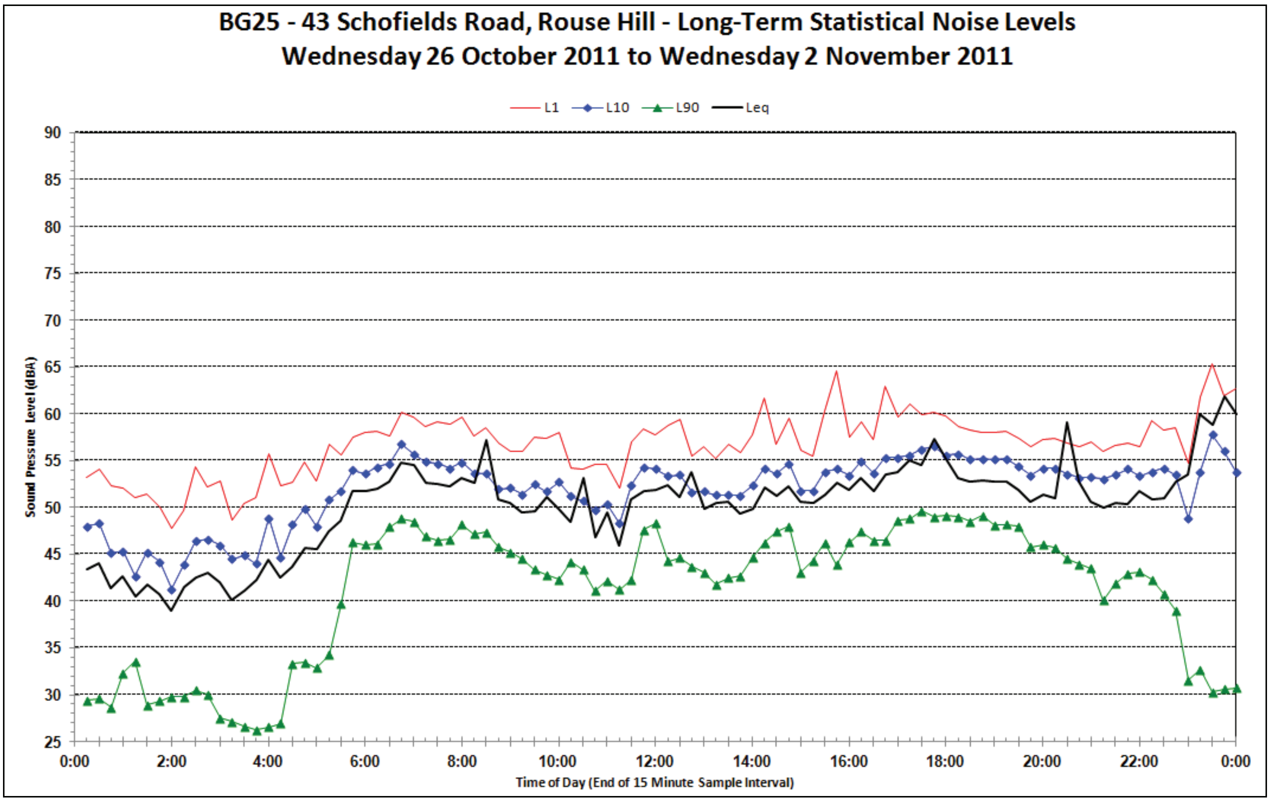


Figure 8.3 Ambient and Background Noise at BG25



8.3.5 Assessing Sleep Disturbance

The current approach to assessing potential sleep disturbance is to apply an initial screening criterion of background plus 15 dB (as described in the Application Notes to the INP), and to undertake further analysis if the screening criterion cannot be achieved. The sleep disturbance screening criterion applies outside bedroom windows during the night-time period. Where the screening criterion cannot be met, the additional analysis should consider the level of exceedance as well as factors such as:

- How often high noise events will occur
- The time of day (normally between 10 pm and 7 am)
- Whether there are times of day when there is a clear change in the noise environment (such as during early morning shoulder periods).

Other guidelines that contain advice relating to potential sleep disturbance impacts should also be considered, including the *Road Noise Policy* (RNP). The RNP provides a review of research into sleep disturbance. From the research to date, the RNP concludes that:

- Maximum internal noise levels below 50 dBA to 55 dBA are unlikely to awaken people from sleep
- One or two events per night, with maximum internal noise levels of 65 dBA to 70 dBA, are not likely to affect health and wellbeing significantly.

It is generally accepted that internal noise levels in a dwelling, with the windows open are 10 dB lower than external noise levels. Based on a worst case minimum attenuation, with windows open, of 10 dB, the first conclusion above suggests that short term external noises of 60 dBA to 65 dBA are unlikely to cause awakening reactions. The second conclusion suggests that one or two noise events per night with maximum external noise levels of 75 dBA to 80 dBA are not likely to affect health and wellbeing significantly.

8.4 Summary of Stabling Facility Noise Criteria

For the proposed stabling and maintenance operations, the intrusive, amenity and sleep disturbance noise goals will apply. A summary of the operational noise criteria for the facility is provided in Table 8.4.

Table 8.4 Summary of Stabling Facility Noise Criteria

Scenario	Period	Estimated RBL[1] (dBA)	Operational Noise Criteria (dBA)		
			$L_{Aeq(15minute)}$ Intrusive	$L_{Aeq(Period)}$ Amenity	$L_{A1(1minute)}$ Sleep Disturbance Screening Level
At Opening and for Future Scenario	Early Morning (5am to 7am)[2]	40	45	45	50[3]
	Day (7am to 6pm)	45	50	55	-
	Evening (6pm to 10pm)	45	50	45	-
	Night (10pm to 5am)	35	40	40	50

Note1: Daytime and night-time background noise levels are estimated from AS1055.2 noise area category R2. Evening levels are taken to be the same as daytime noise levels as no decrease in the evening period was recorded at either measurement location.

Note 2: The early morning shoulder period applies from 5:00 am to 7:00 am (the period when existing background noise levels are observed to be rising steadily). Noise criteria in this period are taken to be midway between the daytime and night-time criteria.

Note 3: The sleep disturbance screening level is taken to be the same throughout the night-time and early morning shoulder period.

8.5 Stabling and Maintenance Activities

There are several types of single deck trains which could be utilised for the NWRL. As part of the operational requirements, detailed specifications relating to the source noise level requirements will be provided to minimise environmental noise impacts. These specifications will be developed consistent with international best practice.

The following description of stabling activities is based on the typical requirements for modern trains and would be reviewed in more detail during the detailed design stage.

When trains are returning to the train stabling facility, some trains will enter the proposed train wash facility. This facility is similar to a car wash facility, except on a larger scale. The train wash facility is fully enclosed (except at the two ends). The train passes through the train wash at walking pace over a period of a few minutes. The design of the shed and washing equipment will include noise mitigation measures (as required) to comply with the noise criteria at the nearest noise sensitive receivers.

When a train enters a stabling facility, a number of activities occur. Once the train comes to a standstill, the brakes are applied by exhausting the brake pipe and the parking brake is engaged. Exhausting the brake pipe releases compressed air to atmosphere, causing peak noise levels of short duration. The air typically exhausts from underneath the train at the two end carriages.

After the parking brake is applied, the trains will be stabled with all auxiliary equipment shut down, as is typical with modern rapid-transit trains. These trains can be shut down in a few minutes. While stabled, train interiors are cleaned.

Safety checks are undertaken prior to the train entering service the following morning. Prior to the train departing, all auxiliary equipment is assumed to operate for up to fifteen minutes. This equipment includes air-conditioning, air compressors and static inverters.

Train horn testing will not be required within the stabling facility. If required, an alternative warning system will be employed to alert staff of impending vehicle movements in areas of the stabling and maintenance facility. Such systems may be required inside the maintenance building.

Train movements within the facility will occur at low speeds and therefore $L_{Aeq(15minute)}$ noise emissions would be controlled by on-board equipment (such as air compressors and air-conditioners) rather than wheel-rail noise, including at crossovers and turnouts.

8.6 Noise Modelling Assumptions

8.6.1 Meteorological Conditions

The INP requires adverse meteorological conditions to be considered in some situations, where temperature inversions or prevailing winds may increase noise levels by focusing sound wave propagation paths at a single point. Temperature inversions are a meteorological effect that may occur in some areas, generally during the night-time and early morning periods in winter.

The INP describes a staged approach to the assessment of meteorological conditions, designed to require a detailed assessment only where initial screening tests show that effects on noise are potentially significant.

As an initial screening stage, Appendix D of the INP gives estimates of the increase in noise levels due to temperature inversions with distance. The proposed stabling facility location is a non-arid area with rainfall greater than 500 mm per year. The facility is proposed to be elevated relative to receivers to the west. In these conditions, the estimated increase in noise levels due to meteorological effects is 3 dB for the nearest receivers at distances up to 300 m from the development. As described in the INP, additional noise impacts due to temperature inversions of 3 dB or more are considered to be significant. Therefore in this case the analysis is required to include meteorological effects.

Regional wind effects due to synoptic factors are independent of drainage flow wind and may occur in any direction. Wind effects need to be assessed where wind is a feature of the area, as determined by the frequency of occurrence of wind and wind speed. The Bureau of Meteorology annual wind rose for the Rouse Hill area indicates that in all directions there is a less than 30% occurrence of wind up to 3 m/s, therefore only drainage flow wind effects have been included.

At this stage a detailed analysis of seasonal weather data (wind and atmospheric stability) has not been undertaken. Instead default inversion parameters for a non-arid area are assumed during the night-time and early morning periods:

- Temperature inversion strength 3°C / 100 m
- Source to receiver drainage flow wind speed of 2 m/s.

The online Application Notes to the INP state that in all cases, the noise impacts should be predicted (or measured) under neutral (calm) conditions as well as any significant weather conditions. *“It is particularly useful to provide predicted noise impacts for calm weather conditions where predicted noise impacts under adverse weather conditions exceed the project-specific noise levels. This allows for a better understanding of potential noise impacts from the development.”*

The approach to this assessment has been to assess the impacts for all night-time and early morning scenarios with the adverse meteorological conditions described above. One scenario has then been calculated under neutral conditions for comparative discussion purposes.

8.6.2 Timing of Train Arrivals, Preparation and Departure

SLR Consulting has been provided with indicative details of timings of train arrivals and departures for both the at-opening case and for a future scenario when the capacity of the facility may be increased. Table 8.5 shows the arrivals and departures in each time period.

For the purposes of noise assessment, the maximum number of trains in preparation is based on the assumption that auxiliary equipment would operate for 15 minutes before a train departs from the facility. The assessment also assumes preparation of the first train would begin at around 4:00 am.

Table 8.5 Train Arrivals, Preparation and Departures for the Purpose of Noise Assessment

Scenario	At Opening				Future Scenario			
	Early Morning	Day	Evening	Night	Early Morning	Day	Evening	Night
Train arrivals	9	90	34	18	11	130	52	18
Train departures	14	94	28	15	24	134	38	15
Maximum trains in preparation for departure	2	3	2	2	4	5	3	2

Note: Early morning is from 5:00 am to 7:00 am, day 7:00 am to 6:00 pm, evening 6:00 pm to 10:00 pm, night 10:00 pm to 5:00 am

8.6.3 Stabling and Maintenance Facility Layout

An indicative layout for the proposed stabling and maintenance facility is shown in Figure 8.1. The most significant noise sources associated with the proposed facility include those associated with the train stabling area, maintenance shed and train wash plant.

8.7 Stabling and Maintenance Modelled Noise Sources

Table 8.6 shows sound power levels[13] used to model the various stabling and maintenance noise sources. Table 8.7 shows the source directivities. The source levels and directivities have been derived from attended noise measurements taken by SLR Consulting and other consultants on similar projects.

[13] Refer Appendix A for Sound Power Level definition

Table 8.6 Assumed Sound Power Levels and Durations for Train Stabling and Maintenance

Noise Source	Sound Power Level	Location of Noise Source
Brake Air Release Noise	105 dBA – L_{Amax}	Under floor, two units per four cars, located at the ends of each four car set
Air Compressor, including brake air release noise	87 dBA – $L_{Aeq(15minute)}$	Under floor, two units per four cars, located at the ends of each four car set
Static Inverter	83 dBA – $L_{Aeq(15minute)}$	Top of train[1], two units per four cars, located at the ends of each four car set
Air-Conditioner	82 dBA – $L_{Aeq(15minute)}$	Top of train, one unit per car, located at the centre of each car
General Workshop Noise	105 dBA – $L_{Aeq(15minute)}$	Inside maintenance building
Train Wash Facility	84 (75)[2] dBA – $L_{Aeq(15minute)}$	Train wash facility facades

Note 1: May be located in the vehicle underframe rather than at the top of the train. Modelled location is assumed worst-case.

Note 2: Sound Power Level in brackets represents the noise emissions through the walls due to the noise sources inside the building. Sound Power Level of 84 dBA represents the noise emission through the end openings of the building.

Table 8.7 Source Directivity for Train Stabling and Maintenance Sources

Noise Source	Directivity Adjustment by Angle (dBA)				
	0 degrees	45 degrees	90 degrees	135 degrees	180 degrees
Air Compressor and Brake Air Release[1]	-12	-5	0	-5	-12
Static Inverter and Air-Conditioner[2]	0	0	0	-9	-15
Train Wash Facility End Openings[3]	+4	+4	-5	-10	-10

Note 1: For sources below and to the side of the train directivity is horizontal. The zero degrees position is directly in front of the train.

Note 2: For sources on top of the train, the directivity is in the vertical direction and zero degrees is taken to point directly upwards.

Note 3: For facade sources, the zero degrees position is perpendicular to the centre of the facade, pointing out from the building.

8.7.2 Other Noise Sources

The majority of train maintenance activities would be undertaken within the proposed maintenance facility building. Other noise sources with potential impacts around the stabling and maintenance facility include:

Infrastructure Maintenance

Rail grinding and major track maintenance of the NWRL would occur during night-time shutdown periods and would give rise to additional noise sources at the stabling and maintenance facility. These activities (with the exception of routine inspections) are likely to be performed on an infrequent basis. The potential noise impacts associated with infrastructure maintenance will be managed as part of the proposed Operational Noise and Vibration Management Plan (ONVMP) to be prepared prior to commencement of operations.

Wheel Lathe

A separate wheel lathe facility forms part of the proposal which is utilised to remove wheel defects and restore wheels to the correct profile. The wheel lathe facility is fully enclosed (except at the two ends). The train passes through the facility and stops at the required location during the wheel lathe operations. The design of the shed and mechanical equipment will include noise mitigation measures (as required) to comply with the noise criteria at the nearest noise sensitive receivers.

Given that the correcting of train wheels would be performed on an infrequent basis and that the proposed underfloor wheel lathe is likely to be built in an acoustic enclosure, the noise contribution from this facility is regarded as being minimal.

Alarm Systems for Infrastructure Maintenance Rail Vehicles

It is anticipated that some form of visible and audible warning system will be used in and around the maintenance building for the purpose of alerting staff of train movements. It is recommended that all audible alarm systems should be non-tonal and that the maintenance hard stand areas and turning spaces should be designed such that vehicles do not need to reverse unnecessarily. Considering that the facility is located some distance away from the nearest residences, the noise impacts due to alarm systems is expected to be minimal.

Train Cleaning

Internal train cleaning does not involve external noise sources and will therefore not contribute significantly to noise impacts on the surrounding community.

Stabling Facility Staff Car Park and Vehicle Movements

Noise levels from staff arrivals and departures from the facility have not been assessed at this stage. Considering the proximity of Schofields Road to the facility it is anticipated that road traffic noise would be likely to mask the noise emissions from the staff car park and vehicle movements within the facility.

PA System

A Public Address (PA) system is likely to be used at the maintenance facility. PA systems can typically be designed to minimise noise impact using measures such as speaker selection and placement. Installation of ambient noise sensing microphones allows speaker gain to be set automatically relative to the existing ambient noise at particular zones of the facility. This is typically set at 10 dB to 15 dB above the ambient noise level which in most cases would minimise noise impacts on the nearest noise sensitive receivers.

It is expected that with appropriate design measures in place, the contribution of the PA system to the overall ambient L_{Aeq} noise level at the nearest receivers would be minimal.

8.8 Noise Modelling Scenarios

The approach to stabling facility noise modelling is first to assess the noise impacts with no specific noise mitigation apart from shielding provided by the proposed site buildings, natural terrain and site earthworks (the stabling facility is partially located in a cutting). This base case is assessed for both the at opening and future capacity scenarios. Where exceedances of the noise criteria are identified, reasonable and feasible noise mitigation measures are considered.

Brake air release noise is modelled as individual discrete noise events for assessment against the sleep disturbance screening criterion (due to its short duration and higher maximum noise levels). For this noise source, the predicted L_{Amax} noise levels represent the typical maximum levels that are likely to occur. Noise from auxiliary equipment, brake air release, train washing and maintenance operations is modelled to determine the worst-case $L_{Aeq(15minute)}$ noise levels during each assessment period. The noise sources are based on the train numbers shown in Table 8.5.

For the $L_{Aeq(15minute)}$ scenarios, it is assumed that the trains undergoing preparation and departing from the facility have been stabled on outside roads, near to the affected receivers. This represents a worst case operating scenario and allows full operational flexibility of the facility. In the event that the first trains to depart in the early morning are those stabled on the inside roads, reduced noise impacts would be expected due to shielding of some noise sources by the trains stabled on the adjacent roads. The predicted L_{Amax} noise impacts represent a worst case at each affected receiver. This has been achieved by modelling the relevant noise source at a number of possible locations, and taking the maximum predicted noise level for each receiver from the various possible source locations.

8.8.1 Modelling Scenarios

The scenarios that have been modelled in the base case are summarised in Table 8.8. The following assumptions have been made about the maintenance building train access doors:

- During the night-time and early morning period, all maintenance building train access doors would be closed
- During the evening period, half of the maintenance building train access doors would be closed
- During the daytime period, all maintenance building train access doors would be open.

Table 8.8 Modelling Scenarios

Scenario	Parameter	Noise Sources	Time Period
1	L_{Amax}	Brake Air Release	All Periods, but potential impacts most significant during night-time period
2	$L_{Aeq(15minute)}$	- Three trains undergoing preparation with air compressors, air-conditioners, brake air release and static inverters operating - Train wash facility - Maintenance facility with 4 doors open and 1 train inside with all auxiliary equipment operating	Daytime, at opening
3	$L_{Aeq(15minute)}$	- Two trains undergoing preparation with air compressors, air-conditioners, brake air release and static inverters operating - Train wash facility - Maintenance facility with 4 doors closed and 1 train inside with all auxiliary equipment operating	Early Morning, at opening
4	$L_{Aeq(15minute)}$	- Two trains undergoing preparation with air compressors, air-conditioners, brake air release and static inverters operating - Train wash facility - Maintenance facility with 2 doors open, 2 doors closed and 1 train inside with all auxiliary equipment operating	Evening, at opening
5	$L_{Aeq(15minute)}$	- Two trains undergoing preparation with air compressors, air-conditioners, brake air release and static inverters operating - Train wash facility - Maintenance facility with 4 doors closed and 1 train inside with all auxiliary equipment operating	Night-time, at opening

Scenario	Parameter	Noise Sources	Time Period
6	$L_{Aeq(15minute)}$	- Five trains undergoing preparation with air compressors, air-conditioners, brake air release and static inverters operating - Train wash facility - Maintenance facility with 8 doors open and 2 trains inside with all auxiliary equipment operating	Daytime, future capacity
7	$L_{Aeq(15minute)}$	- Four trains undergoing preparation with air compressors, air-conditioners, brake air release and static inverters operating - Train wash facility - Maintenance facility with 8 doors closed and 2 trains inside with all auxiliary equipment operating	Early Morning, future capacity
8	$L_{Aeq(15minute)}$	- Three trains undergoing preparation with air compressors, air-conditioners, brake air release and static inverters operating - Train wash facility - Maintenance facility with 4 doors open, 4 doors closed and 2 trains inside with all auxiliary equipment operating	Evening, future capacity
9	$L_{Aeq(15minute)}$	- Two trains undergoing preparation with air compressors, air-conditioners, brake air release and static inverters operating - Train wash facility - Maintenance facility with 8 doors closed and 2 trains inside with all auxiliary equipment operating	Night-time, future capacity

With reference to Table 8.5, the predictions of noise impacts will be the same for Scenarios 3 and 5 as the numbers of trains in preparation and the source locations in the worst-case 15 minute period is the same. Therefore, these scenarios have been combined for modelling purposes.

8.9 Predicted Noise Levels

Plots of the predicted worst case $L_{Aeq(15minute)}$ and L_{Amax} noise contours around the stabling facility for each scenario under adverse meteorological conditions are included in Appendix H. Table 8.9 lists the predicted noise level at the nearest existing residential receivers (shown in Figure 8.1), for each scenario.

With the exception of the evening time period, the amenity noise criteria levels are equal to or greater than the intrusiveness noise criteria. The controlling noise criterion for both the at-opening and future scenarios is the night-time intrusiveness criterion.

Table 8.9 Predicted Noise Levels at Representative Receivers

Scenario and Description		Noise Criterion (dBA)	North East Receiver	North Receiver	West Receiver	South Receiver	South East Receiver
1	Night-time L_{Amax} – Brake Air Release[1]	50	**54**	**53**	**53**	**56**	**52**
2	Daytime $L_{Aeq(15minute)}$ Opening	50	41	41	38	38	41
3	Early Morning (5am to 7am) $L_{Aeq(15minute)}$ Opening[1]	45	44	43	39	40	44
4	Evening $L_{Aeq(15minute)}$ Opening	45	40	38	34	38	41
5	Night-time $L_{Aeq(15minute)}$ Opening[1]	40	**44**	**43**	39	40	**44**
6	Daytime $L_{Aeq(15minute)}$ Future	50	42	44	41	40	43
7	Early Morning (5am to 7am) $L_{Aeq(15minute)}$ Future[1]	45	45	**47**	44	43	45
8	Evening $L_{Aeq(15minute)}$ Future	45	41	41	38	40	42
9	Night-time $L_{Aeq(15minute)}$ Future[1]	40	**44**	**43**	39	**41**	**45**

Note 1: Noise levels for these scenarios have been calculated under adverse meteorological conditions.
Note 2: Exceedances of the noise criteria are shown in **bold** text.

The noise levels shown for night-time and early morning scenarios in Table 8.9 have been calculated under the adverse meteorological conditions described in Section 8.6.1. Under neutral weather conditions, the predicted noise levels are typically 4 dB lower at the nearest representative receivers.

8.9.2 Discussion of Predicted $L_{Aeq(15minute)}$ Noise Levels

At the nearest sensitive receivers, the most significant contributors to the L_{Aeq} noise levels are those associated with the train stabling operations, namely the static inverters, air-conditioning, brake air release and air compressors.

Early morning period (5.00 am to 7.00 am) – Scenarios 3 and 7
No noise criterion exceedances are predicted during the early morning period for the at-opening scenario.

For the future scenario, an exceedance of the noise criterion of up to 2 dB is predicted at the nearest sensitive receiver to the north under adverse weather conditions. Compliance is predicted under neutral weather conditions.

Daytime period (7.00 am to 6.00 pm) – Scenarios 2 and 6
No noise criterion exceedances are predicted during the daytime period for either the at-opening or future scenarios.

Evening period (6.00 pm to 10.00 pm) – Scenarios 4 and 8
No noise criterion exceedances are predicted during the evening period for either the at-opening or future scenarios.

Night-time period (10.00 pm to 5.00 am) – Scenarios 5 and 9
For the at-opening scenario with adverse weather conditions, exceedances of the noise criterion of up to 4 dB are predicted at the nearest sensitive receivers to the south east and north east, and an exceedance of up to 3 dB is predicted at the nearest receiver to the north. Compliance is predicted under neutral weather conditions.

For the future scenario with adverse weather conditions, exceedances of the noise criterion of up to 5 dB are predicted at the nearest sensitive receiver to the south east. Exceedances ranging from 1 dB to 4 dB are predicted for the nearest receivers to the north east, north and south. Under neutral weather conditions the exceedance is predicted to reduce to a marginal 1 dB at the south-east receiver.

8.9.3 Discussion of Predicted Maximum Noise Levels – Scenario 1

The source noise levels assumed for brake air release are based on noise measurements results obtained for modern RailCorp trains. It is understood that for the proposed NWRL trains, it may be possible to incorporate silencers in the compressed air lines to reduce the noise levels associated with brake air release. This option will be investigated during the detailed design stage.

With the assumed unmitigated source levels, and under adverse meteorological conditions, brake air release noise is predicted to exceed the sleep disturbance screening criterion by up to 6 dB at the nearest sensitive receivers adjacent to the proposed stabling and maintenance facility. In accordance with the Application Notes to the INP, this indicates the potential for sleep disturbance and requires further analysis, considering the levels of exceedance, how often the high noise events will occur, and whether the times of occurrence are during a period when there is a clear change in the noise environment.

For the ‘at opening’ scenario, around 20 trains are likely to arrive at or prepare to depart from the facility during each night-time period. The number of night-time events would increase in the future scenario in line with the expected increase in services. It is estimated that several brake air releases would be required for each train during the night-time, divided between the train arrival at the facility and departure the next day.

There will be some variation in noise level from each of these events since brake air release is a variable source. Noise impacts would be significantly lower in the event that the train is shielded by other trains stabled on adjacent roads, and under neutral weather conditions.

From Figure 8.2 it can be seen that the existing noise environment in the early morning near the most exposed receiver includes L_{A1} noise levels around 60 dBA to 65 dBA. Table 8.1 shows existing night-time L_{Amax} noise levels at Location BG24 ranging from 66 dBA to 71 dBA. The predicted maximum noise levels (even without specific attenuation) associated with brake air releases will therefore be lower than the existing L_{Amax} noise levels in this area. Short term external noise levels of this magnitude are also described as being “unlikely to cause awakening reactions” according to guidance provided in the RNP.

It is concluded that while noise associated with brake air releases may be noticeable at the nearest existing receivers, the likelihood of potential sleep disturbance is considered to be low.

8.10 Train Stabling Facility Noise Mitigation Considerations

The investigation of noise mitigation begins with consideration of options to reduce the dominant contributors to L_{Aeq} noise levels. Examination of the noise modelling results indicates that the dominant noise sources are associated with the train stabling operations, namely the train auxiliary systems: static inverters, air-conditioning, and air compressors (including brake air releases).

Noise generated at the top of the train (air-conditioning noise and possibly static inverter noise) is difficult to mitigate via noise barriers. A noise barrier would need to be around 5 m high (above rail height) to provide effective attenuation to the south receivers, and would have high cost and visual impacts. The performance of any noise barriers would also be reduced under adverse weather conditions.

Brake air release and air-compressor noise is generated at the bottom of the train. There is potential for these noise sources to be further reduced if required (eg via the inclusion of silencers in the compressed air lines or by operational measures to maximise the noise barrier effect from adjacent trains). Minimisation of all rolling stock auxiliary noise levels would be investigated during the procurement of rolling stock.

Under adverse meteorological conditions, the highest noise level exceedances are predicted to occur at the nearest sensitive receiver to the south east, with the highest $L_{Aeq(15minute)}$ noise level of 45 dBA occurring during the night-time. Under neutral weather conditions, the predicted noise levels are 4 dB lower. Whilst the predicted noise levels under adverse and neutral weather conditions exceed the intrusiveness criteria, the noise logging results in this area indicate that the existing L_{Aeq} noise levels are around 10 dB higher than the predicted noise levels associated with the train stabling and maintenance facility.

The adverse meteorological conditions assumed in the noise modelling scenarios (temperature inversion and associated drainage flow winds) generally occur only during night-time periods in winter. Furthermore, the noise modelling results are considered to represent the typical worst case scenario with noise sources located in the most exposed locations. On this basis, it is unlikely that noise levels associated with the proposed stabling and maintenance facility would have an appreciable impact on the acoustic amenity at the nearest sensitive receivers.

No specific noise mitigation measures in the form of noise barriers or earth mounding are proposed for the stabling facility. The proposed noise mitigation measures include limiting the source noise levels of the proposed rolling stock (via the procurement process), designing the proposed maintenance buildings to contain noise levels and implementing operational procedures to minimise noise impacts at nearby sensitive receivers.

Further detailed assessment of the potential noise impacts would also be required during the detailed design stage.

8.11 Summary of Tallawong Stabling Facility Noise Impacts

The noise impacts of the proposed Tallawong Stabling and Maintenance facility have been assessed. As the proposed facility will accommodate new single deck electric passenger trains, operating at slow speeds, the noise impact of train arrivals at the facility would be minimal. Trains are proposed to be stabled powered off without auxiliary equipment operating. The worst-case noise impacts of the facility would be concentrated in the night-time and early morning period (between 4:00 am and 7:00 am) when trains are preparing to depart the facility and noise criteria are more stringent than during the daytime and evening.

The noise impact assessment indicates that train auxiliary systems have the potential to result in exceedances of the INP intrusiveness noise goals at existing residential receivers during the night-time and early morning periods. The predicted $L_{Aeq(15minuite)}$ noise levels under adverse meteorological conditions (during night-time periods in winter) at the nearest receivers are up to 45 dBA (5 dB above the intrusive noise criterion). Under neutral weather conditions, the predicted noise impacts are 4 dB lower.

While these noise levels exceed the intrusive noise criterion and may be noticeable above the background noise in the night-time and early morning, they are around 10 dB below the measured existing L_{Aeq} noise levels. It is considered unlikely that noise levels associated with the proposed stabling and maintenance facility would have an appreciable impact on the acoustic amenity at the nearest sensitive receivers.

Noise from compressed air release from brakes has the potential to exceed the sleep disturbance screening criterion; however the predicted noise levels and the existing noise environment indicate that air release noise from brakes is unlikely to cause awakening reactions at the most exposed existing receivers.

No specific noise mitigation measures in the form of noise barriers or earth mounding are proposed for the stabling and maintenance facility. The proposed noise mitigation measures include limiting the source noise levels of the proposed rolling stock (via the procurement process), designing the proposed maintenance buildings to contain noise levels and implementing operational procedures to minimise noise impacts at nearby sensitive receivers.

9 Operational Noise from Stations, Ancillary Facilities, Public Roads and Car Parks

This section provides an assessment of the potential operational noise impacts associated with the NWRL stations, ancillary facilities, public roads and car parks.

9.1 Nearest Receivers and Unattended Noise Monitoring Results

To determine the existing ambient noise climate within the NWRL project area, unattended ambient noise measurements were undertaken (this process is described in detail in Chapter 4, with the monitoring locations being illustrated on the Site Plan in Appendix B). Measurements were performed in the vicinity of all proposed stations of the NWRL project alignment.

9.2 Noise Criteria

At underground sections of track, airborne noise generated by trains is reduced to inaudible levels at above-ground receivers by the intervening rock and soil above the tunnels. The exception to this is at draught relief shafts. At these locations, airborne noise from trains may be potentially audible even though there is little or no visible evidence of rail operations.

In general, these types of noise sources lend themselves readily to mitigation by appropriate equipment selection, design techniques and provision of engineering noise controls such as silencers, acoustic louvers and enclosures.

Public Address (PA) system announcements at stations may potentially impact surrounding noise sensitive receivers. Measures such as automatic volume control (with ambient noise sensing microphones) and optimised loudspeaker selection and placement can be used to control noise to acceptable levels for PA systems.

9.2.1 Criteria for Mechanical and Electrical Services and Stations

The criteria for external noise emissions associated with mechanical and electrical services and stations are taken from the *Industrial Noise Policy* (INP). The assessment methodology embodied within the INP is described in Chapter 8.

Noise emissions from mechanical and electrical services are normally of a continuous nature and do not change unless operational conditions vary. As a result of the general reduction in existing ambient noise levels during the latter periods of the day, the night-time INP intrusive noise criteria are the most stringent for residential receivers and are therefore the controlling design criteria at all residential locations.

“Commercial” and “recreation area” receivers have acceptable amenity noise levels of 65 dBA and 55 dBA L_{Aeq} respectively (when in use). The “active recreation area” criterion has been adopted for external play areas associated with child care centres. This criterion is consistent with noise goals recommended in the Association of Australian Acoustic Consultants (AAAC) *Child Care Centre Noise Guideline*.

The locations of sensitive receivers and their corresponding industrial noise criteria, determined using the procedures defined within the INP, are presented in Table 9.1.

Table 9.1 Noise Criteria for Sensitive Receivers near Stations and Ancillary Facilities

Location	Operational Noise Source	Nearest Receiver Type	Address	Distance to Nearest Boundary or Facade	Reference[2]	External Noise Criteria (dBA)[1]
Epping Services Facility	Ventilation building	Residential	6 Edensor St	25 m	BG01	37
		Commercial	Raine & Horne Strata Sydney, Beecroft Rd	75 m	N/A	65
	Traction substation	Residential	6 Edensor St	25 m	BG01	37
		Commercial	Raine & Horne Strata Sydney, Beecroft Rd	55 m	N/A	65
Intermediate Services Facility (Cheltenham)	N/A – Emergency access only	Residential	56 Castle Howard Rd	60 m	BG02	36
		Active Recreation	Cheltenham Oval	70 m	N/A	55
Cherrybrook Station	W Service building	Residential	125 Castle Hill Rd	30 m	BG04	39
		Childcare Centre	206 Castle Hill Rd	30 m	N/A	55
	E Service building (incl. traction substation)	Residential	117 Castle Hill Rd	65 m	BG04	39
Castle Hill Station	Service building (incl. traction substation)	Commercial	6 Old Castle Hill Rd	40 m	N/A	65
		Residential	327 Old Northern Rd	40 m	BG06	36
Showground Station	W Service building	Residential	34A Ashford Ave	45 m	BG08	39
	E Service building (incl. traction substation)	Residential	2 Middleton Ave	30 m	BG08	39
Norwest Station	W Service building	Commercial	Block A, 34-36 Brookhollow Ave	45 m	N/A	65
		Commercial	30 Brookhollow Ave	45 m	N/A	65
	E Service building	Commercial	19-21 Brookhollow Ave	10 m	N/A	65
	Traction Substation	Commercial	Brookhollow Ave	10 m	N/A	65
Bella Vista Station	N Service building	Residential	21 Sharrock Ave	90 m	BG10	40
	S Service building	Commercial	McDonalds	30 m	N/A	65
Kellyville Station	Service Building	Residential	36 Roxburgh Cres	100 m	BG14	43
		Residential	13 Wended Ave	210 m	BG15	38

Location	Operational Noise Source	Nearest Receiver Type	Address	Distance to Nearest Boundary or Facade	Reference[2]	External Noise Criteria (dBA)[1]
Rouse Hill Station	Service Building	Commercial	Rouse Hill Cinema Complex	70 m	N/A	65
		Residential	35 Waterford St	480 m	BG20	38
Cudgegong Road Station	Service Building	Future Residential	N site boundary	80 m	BG24	43
		Future Commercial	N site boundary	80 m	N/A	65
Tallawong Stabling Yard	Traction Substation	Residential	88 Schofields Rd	200 m	BG24	43
	Bulk Supply Substation	Residential	88 Schofields Rd	150 m	BG24	43

Note 1: As discussed in Section 9.2.1, the night-time intrusive noise criteria are adopted for the design criteria presented in this table. The criteria for commercial and recreational premises are absolute levels and are not relative to existing background noise levels.

Note 2: The reference location refers to the nearest unattended noise logging location in Table 4.2.

9.2.2 Noise Criteria for Draught Relief Shafts

For residential and commercial receivers, train passby noise emitted from draught relief shafts (at underground stations) has been examined against the L_{Amax} (fast) noise criteria in Table 9.2.

Table 9.2 Noise Criteria for Draught Relief Shafts

Usage	Noise Criteria, L_{Amax} (dBA)
Residential	55
Commercial	65

The L_{Amax} noise level refers to the 95th percentile train passby event (ie 95% of train passby events are not permitted to exceed these levels). The absolute maximum event is not used for design, as it cannot be precisely defined and would occur infrequently.

These noise criteria are comparable with the design criteria adopted for the Epping to Chatswood Rail Line (ECRL) and Sydney Airport Rail Line. They are also more stringent than the maximum noise goals applied in the *Interim Guideline for the Assessment of Noise from Infrastructure Projects* (IGANRIP), relating to airborne noise from the operation of trains on surface track (80 dBA).

9.2.3 Noise Criteria for Additional Traffic on Public Roads

New or upgraded public roads are proposed in the vicinity of the station precincts at Cherrybrook, Showground, Bella Vista, Kellyville, and Cudgegong Road to provide access to car parking, bus, taxi, and kiss and ride facilities. The noise impact of the proposed new and upgraded roads has been assessed in accordance with the NSW *Road Noise Policy* (RNP). The station access roads are assumed to be local roads. The applicable noise criteria are shown in Table 9.3. For commercial and industrial premises, the RNP refers to desirable internal noise levels contained in Australian Standard 2107:2000.

Table 9.3 Local Road Noise Criteria

Usage	External Assessment Criteria $L_{Aeq(1hour)}$ (dBA)[1]	
	Day (7 am – 10 pm)	Night (10 pm – 7 am)
Residential	55	50

Note 1: The local road criteria are applicable for: existing residences affected by noise from new local road corridors, existing residences affected by noise from redevelopment of existing local roads, and existing residences affected by additional traffic on existing local roads generated by land use developments.

For land use developments with the potential to generate additional traffic on existing roads, the RNP requires an assessment of the increase in total traffic noise level. Any increase in the total traffic noise as a result of the NWRL project should be limited to 2 dB above that of the corresponding ‘no build option’. The noise level increase criterion of 2 dB is taken to refer to the $L_{Aeq(1hour)}$.

9.2.4 Noise Criteria for Car Parks

New car parks are proposed at five station locations; Cherrybrook, Showground, Bella Vista, Kellyville and Cudgegong Road. The noise criteria for the operational noise emissions from these car parks are derived from the INP.

Intermittent noises, in particular those with short durations, due to activities such as cars starting or car doors closing are not directly addressed by the INP. In order to minimise the risk of sleep disturbance resulting from these sources, the EPA’s *INP Application Notes* recommends that a more detailed analysis be conducted if the $L_{A1(60second)}$ noise level outside a bedroom window is predicted to exceed the prevailing background L_{A90} noise level by more than 15 dB during the 10.00 pm to 7.00 am night-time period.

The detailed analysis should cover the extent to which the maximum noise level exceeds the background level and the number of times this happens during the night-time period. Other factors that may be important include the time of day of the high noise events and whether there is a clear change in the noise environment (such as during early morning shoulder periods).

The NSW *Road Noise Policy* (RNP) contains further guidance on the sleep disturbance as described in Section 8.3.5.

A summary of the project specific noise criteria and sleep disturbance screening criteria for the car parks is presented in Table 9.4.

Table 9.4 Noise Criteria for Car Parks

Station	Ref[1]	Time Period	Existing $L_{Aeq(period)}$ (dBA)	Existing L_{A90} (RBL) (dBA)	Noise Criteria (dBA)		
					Amenity $L_{Aeq(period)}$	Intrusiveness $L_{Aeq(15min)}$	Sleep Disturbance $L_{A1(60sec)}$
Cherrybrook (Residents south of station)	BG04	Day	53	45	55	50	N/A
		Evening	51	41	45	46	N/A
		Night	49	34	40	39	49
Cherrybrook (Residents north of station)	BG05	Day	50	37	55	42	N/A
		Evening	48	38	45	43	N/A
		Night	45	30	40	35	45
Showground	BG08	Day	64	54	60	59	N/A
		Evening	59	45	50	50	N/A
		Night	54	34	45	39	49
Bella Vista	BG10	Day	53	46	55	51	N/A
		Evening	52	45	45	50	N/A
		Night	50	36	40	41	51
Kellyville (Residents west of station)	BG14	Day	62	47	55	52	N/A
		Evening	61	48	45	53	N/A
		Night	58	38	40	43	53
Kellyville (Residents east of station)	BG15	Day	49	39	55	44	N/A
		Evening	48	41	45	46	N/A
		Night	48	39	40	44	54
Kellyville (Residents north of station)	BG16	Day	55	45	55	50	N/A
		Evening	53	46	45	51	N/A
		Night	51	37	40	42	52
Cudgegong Road	BG24	Day	59	45	50	50	N/A
		Evening	59	49	45	54	N/A
		Night	55	38	40	43	53

Note 1: The reference location refers to the nearest unattended noise logging location in Table 4.2

9.3 Predicted Noise Levels - Stations and Ancillary Facilities

9.3.1 Noise Modelling Methodology

The modelling of the mechanical and electrical services airborne noise presented in this assessment is based on the shaft and service building locations forming part of the current NWRL Concept Design, which are potentially subject to change during the detailed design.

The approach to the assessment of noise impacts presented here is to calculate the maximum total allowable emitted sound power level (SWL) at each location, thus specifying the acoustic emission limit for all equipment (combined operation) at each location. Where information is available, the equipment proposed in the Concept Design has been assessed. In some cases, plant and equipment associated with the ECRL project have been considered as representative to provide an early indication of whether the noise criteria are able to be achieved.

The noise sources have been assumed to operate without noticeable tonal, impulsive or intermittent components, unless otherwise stated, and the assessment therefore does not require the application of modifying factors, as defined in the INP.

Noise levels from proposed new and upgraded roads in the station precincts were calculated in accordance with the methodology contained in *Calculation of Road Traffic Noise* (CoRTN) 1988. This calculation method is listed in Appendix B4 of the RNP as having been validated under Australian conditions. The $L_{A10(1hour)}$ is calculated using the peak traffic volumes expected during the daytime and night-time periods. The commonly applied correction for continuous traffic $L_{Aeq} = L_{AF10} - 3$ dB has been used to determine the $L_{Aeq(1hour)}$ noise levels.

Traffic noise levels from the proposed new roads have been calculated in isolation as required for comparison with the RNP assessment criteria. The calculated traffic noise levels assume a dense graded asphalt road surface. No noise barriers or boundary fences have been included in the noise predictions. However, the terrain has been taken into account. Predictions of the daytime $L_{Aeq(1hour)}$ were based on peak traffic numbers from the NWRL EIS2 *Operational Traffic and Transport Technical Paper*. Predictions of the night-time $L_{Aeq(1hour)}$ are based on the available information regarding night-time bus services. Buses are treated as heavy vehicles in the CoRTN noise prediction scheme and this has been validated for Sydney buses travelling at 50 km/h using measurements of Sydney buses undertaken previously by SLR Consulting.

Acoustic modelling of the car park noise emissions has been carried out using the methodology of Bayerisches Landesamt für Umwelt's report *Parking Area Noise*. For each proposed car park the $L_{Aeq(period)}$ and the peak $L_{Aeq(15minute)}$ is predicted at the nearest residence for the daytime and night-time periods. Calculations are based on the location and design of the proposed car parks and estimates of vehicle movements within the car parks during the daytime and night-time periods. Noise levels for the evening period are not covered in the parking area noise prediction methodology and are therefore not provided. It has been assumed that the noise levels during the evening period would cause a lesser impact than those during the night-time period.

With regard to short-term noise events such as door closings, cars accelerating, etc, spread sheet noise calculations have been undertaken predicting the resulting noise levels from such activities at the nearest sensitive receiver. The noise levels from such short-term events are highly variable and a range of noise levels is presented to reflect the typical range. Predicted L_{Amax} levels are based on events occurring at the closest location within the car park to the receiver.

9.3.2 Assessment of Ventilation Systems and Electrical Substations

The maximum allowable sound power levels emitted by industrial-type noise sources have been predicted for each location in order to meet the amenity and intrusive noise criteria at nearby sensitive receivers, where applicable. The predicted maximum allowable levels apply to the combined sound power level of all equipment at a specified location and not to an individual noise source. The results are presented in Table 9.5.

Table 9.5 Maximum Acceptable Noise Emissions from Station Services

Site Location	Ancillary Locations	Maximum Acceptable Sound Power Level (dBA)
Epping Services Facility	Ventilation building	73
	Traction substation	73
Intermediate Services Facility (Cheltenham)	Emergency Access / Egress	80
Cherrybrook Station	W service building	77
	E service building (incl. traction substation)	83
Castle Hill Station	Service building (incl. traction substation)	73
Showground Station	W service building	80
	E service building (incl. traction substation)	77
Norwest Station	W service building	106
	E service building	93
	Traction substation	93
Bella Vista Station	N service building	87
	S service building	99
Kellyville Station	Service building	91
	Traction substation	91
Rouse Hill Station	Service building	100
Cudgegong Road Station	Service building	89
Tallawong Stabling Yard	Traction substation	97
	Bulk supply substation	95

The design of station mechanical and electrical services is yet to be finalised and plant and equipment selection is subject to change. Notwithstanding this, maximum allowable sound power levels (SWLs) provided in Table 9.5 have been compared to plant and equipment selections associated with the ECRL project to determine the feasibility of achieving NWRL project noise criteria.

Electrical Substations

Electrical traction substations are proposed at the stations at Cherrybrook, Castle Hill, Showground, Norwest, and also at the Epping service facility and Tallawong stabling facility. The substations at Cherrybrook, Castle Hill, and Showground are proposed to be incorporated into the city end of the station building. The substations will generally be 36 m long by 13 m wide and will be enclosed on all sides with a removable roof to allow installation, maintenance and repair works when required. The facade of the substations will generally be masonry with acoustic louvres if required for noise reduction purposes.

A bulk supply substation is also proposed at the Tallawong stabling facility.

Acoustically significant plant and equipment associated with ECRL project traction substations include a reactor transformer and traction reactor with a combined SWL of 81 dBA.

It is expected that with appropriate noise attenuation measures in place such as those afforded by the enclosure, installing acoustic louvres, and directing louvres away from nearest receptors, noise from traction substations can be reduced to levels below the maximum levels provided in Table 9.5.

Ventilation Systems

The ventilation systems include the tunnel and track way ventilation systems. Tunnel ventilation systems supply fresh ambient air to the tunnels and include tunnel ventilation fans and draught relief shafts. The track way ventilation system captures heat from the air conditioning exhausts and brakes of trains stopped at stations. Over track way and under track way exhausts are connected via ductwork to the track way exhaust fans. The draught relief shafts also provide a path for make-up air from the track way exhaust system.

A draught relief shaft and two 120 m^3/s tunnel ventilation fans with associated tunnel ventilation shafts are proposed to be located at each station end bounded by a tunnel (Castle Hill, Showground, Norwest, Cherrybrook and city end of Bella Vista). Tunnel ventilation fans are also proposed at the Epping service facility. The tunnel ventilation fans are mainly for congested and emergency operating modes when air flow generated by train movement is insufficient. However, they may operate at part load at strategic stations to maintain temperatures below 40˚C during normal operations in peak summer periods. An impulse fan is also proposed to be mounted in each tunnel at the intermediate services facility at Cheltenham due to the distance between the facility and Cherrybrook Station.

The proposed intermediate service facility at Cheltenham would be utilised for emergency access and egress purposes only. At this stage, it is unlikely that any surface mechanical plant or tunnel ventilation would be required at this site. No noise impacts are therefore predicted during operations at this site.

Three 40 m^3/s track way exhaust fans are proposed to be installed at each end of the underground stations (Castle Hill, Showground and Norwest). However, only two of the three fans are expected to be operating under normal conditions.

Typical tunnel ventilation fan selection for the ECRL project was specified with an SWL of 80 dBA (including 3 m attenuator and 50 % open area). Discussions with the project team confirm that a similar fan and attenuator selection would likely be used for the NWRL project. The tunnel ventilation fans however will have an increased duty and SWL to those used for the ECRL project and an increased allowance for a 5 m attenuator has been made.

For assessment purposes, it has been assumed that a sound power level of 80 dBA could be achieved from a tunnel ventilation fan with a 5 m attenuator on the surface side. The proposed track way exhaust fans have a lower capacity and are expected to have a sound power level approximately 7 dB less than a tunnel ventilation fan. Allowance has been made for 3 m attenuators and the SWL of each track way exhaust fan with a 3 m attenuator installed is likely to be similar to a tunnel ventilation fan with a 5 m attenuator.

Tunnel ventilation fans will typically operate only during times of congestion or in response to emergency events. Congestion in both tunnels between two of the stations is considered to be an unlikely and infrequent event, particularly during the night-time period. For the purpose of this assessment it has been assumed that one tunnel ventilation fan at each end of the station and Epping service facility is operating at any one time. At the underground stations, it has been assumed that two track way exhaust fans are operating at each end of the station.

On this basis, the total SWL from the ventilation buildings is predicted to be in the order of 85 dBA at the underground stations (Castle Hill, Showground and Norwest), and 80 dBA at Bella Vista, Cherrybrook and the Epping service facility.

At the Epping service facility, it is proposed to orient the outlet of the tunnel ventilation fans towards Beecroft Road, away from the residences on Edensor Street, to meet the INP noise criteria at the nearest residences. It is envisaged that with attenuation measures in place such as appropriate attenuator selection, directing ventilation discharges away from the nearest sensitive receivers and acoustically lining plenums and ductwork, that noise emission from fans can be mitigated to comply with the design criteria. Such measures will be developed in the detailed design stage of the project.

9.3.3 Assessment of Train Noise Breakout from Draught Relief Shafts

Although the proposed railway line would operate underground between Epping and Bella Vista, noise generated during train passbys has the potential to escape from the tunnels via the draught relief shafts. The in-tunnel maximum reverberant noise levels used for predictions of the train noise break-out are presented in Table 9.6, based on noise measurements undertaken within the ECRL tunnels for a train speed of 80 km/h.

Table 9.6 In-tunnel Reverberant Noise Levels

Maximum Noise Levels, L_{max} (fast) (dB)										
Octave Band Centre Frequency (Hz)	**31.5**	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**Overall (dBA)**
In-tunnel Noise Levels	89	83	81	88	96	92	87	85	78	102

Note: A 5 dB reduction in noise is included in the above levels from the measured levels at 80 km/h to compensate for the lower speeds near the draught relief shafts.

Discussions with the project team indicate that each station is likely to have one 20 m^2 draught relief shaft opening at each end of the station box. The shafts are proposed to be lined with concrete which is a highly reflective material with practically no absorptive characteristics. As such, reduction losses as noise propagates to the surface through the shafts would be negligible.

It has been assumed that the ventilation system design includes a 3 m long attenuator in each draft relief shaft. The insertion loss provided by these attenuators (assuming 50% open area) will decrease the train noise (L_{Amax}) to approximately 55 dBA at 10 m from the surface discharge of the draught relief shafts.

Noise breakout from ventilation shafts is not expected to exceed the nominated noise criteria (L_{Amax} of 55 dBA for residential receivers) at any receiver surrounding the proposed stations, with appropriate attenuator selection in place.

Although the shaft locations are subject to change during the detailed design, it is anticipated that the noise criteria would still be readily achieved at all sensitive receivers.

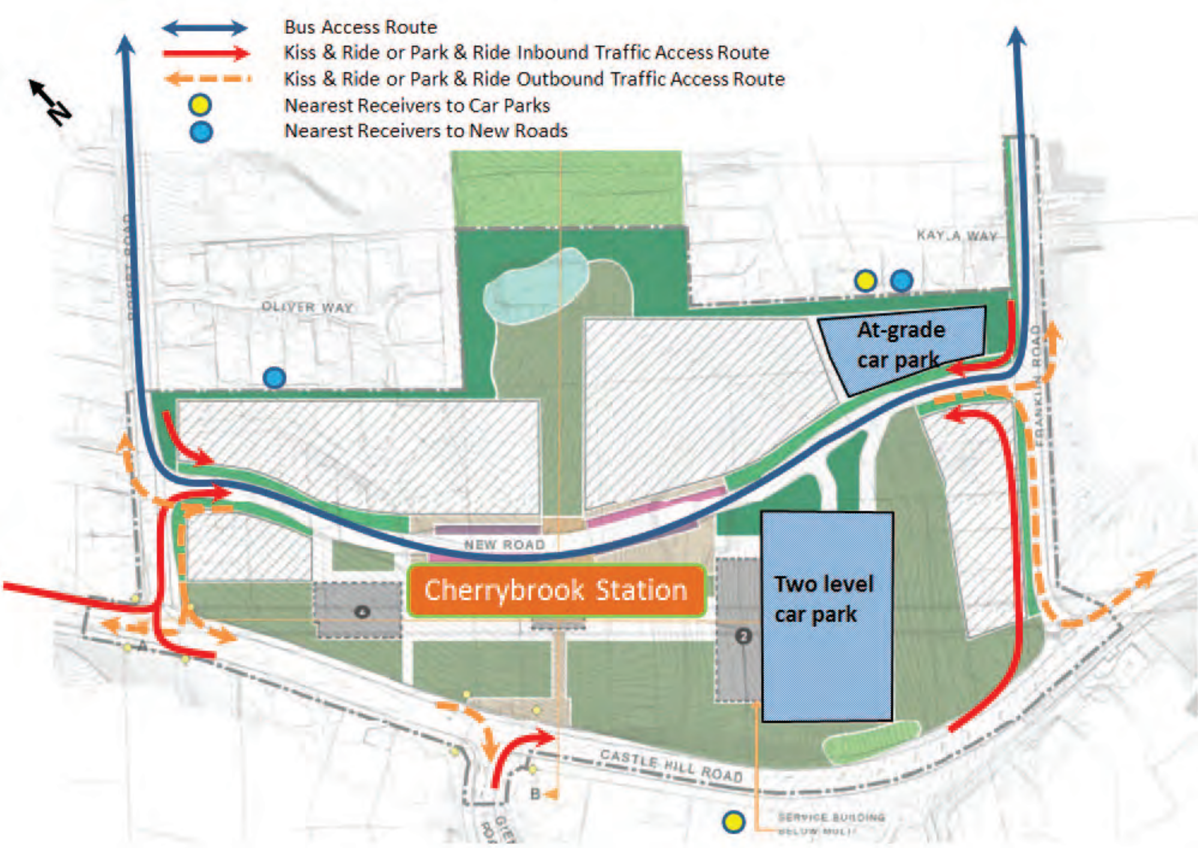
9.3.4 Assessment of Road Traffic Noise

Cherrybrook Station

New Roads

A new access road connecting Robert Road and Franklin Road is proposed at the Cherrybrook Station precinct and will provide access to car parking, bus, taxi, and kiss and ride facilities. The nearest sensitive receivers to the new road are residences to the north on Oliver Way and Kayla Way. The proposed layout of the Cherrybrook Station precinct is shown in Figure 9.1.

Figure 9.1 Layout of Cherrybrook Station Precinct



The closest residences to the new road on Oliver Way and Kayla Way are approximately 40 m away. During the morning peak hour more than 600 vehicle trips to the station are predicted, including 350-450 vehicles parking at the station and 150-200 kiss and ride trips. Kiss and ride vehicles are likely to travel the length of the new access road. Vehicles parking at the station may enter the precinct via Robert Road or Franklin Road and travel to either of the car parks. For assessment purposes, a peak daytime traffic volume of 500 vehicles per hour is predicted on the new access road. 32 bus movements are also expected during the morning and afternoon peak periods. During the night-time, 50 cars per hour and 8 buses per hour are assumed. As a conservative estimate, vehicles are modelled as travelling at 50 km/h along the access road.

The proposed access road is generally elevated in relation to residences to the north. Traffic noise from the station access road at residences on Castle Hill Road would be much lower than the existing noise level from traffic on Castle Hill Road.

Predicted noise levels from traffic on the proposed station access road during the noisiest daytime hour and night-time hour are presented in Table 9.7.

Table 9.7 Traffic Noise from Cherrybrook Station Access Road

Road Description	Time Period	Criteria $L_{Aeq(1hour)}$	Distance to Nearest Residential Facade	Predicted $L_{Aeq(1hour)}$	Exceedance of RNP criteria
Proposed Access Road	Day	55 dBA	40 m	60 dBA	5 dB
	Night	50 dBA		52 dBA	2 dB

The $L_{Aeq(1hour)}$ at the closest residences due to traffic on the proposed station access road is predicted to exceed the RNP daytime criterion of 55 dBA by up to 5 dB during the morning peak period. The night-time $L_{Aeq(1hour)}$ may also be exceeded by up to 2 dB.

The RNP provides guidance on feasible and reasonable noise mitigation measures including road design and traffic management, quieter pavement surfaces, noise barriers/mounds, and at-property treatments. Reducing the posted speed from 50 km/h to 30 km/h is unlikely to achieve more than a 2 dB noise reduction. Where management and design controls are unable to be implemented due to other project constraints, the construction of noise mounds or barriers on the north side of the access road (1 m to 2 m high) are expected to be sufficient to achieve the necessary noise reduction, given that the ground slopes down to the north. However, maximum noise levels from buses (some with high exhausts) may not be reduced by low noise barriers/mounds.

Noise barriers at the boundaries of affected residences may also be considered and would need to be at least 2 m high for single storey dwellings and 4 m high for two storey dwellings to meet the RNP criteria. The installation of alternative means of ventilation to allow windows exposed to the traffic noise to remain closed may also be considered to achieve satisfactory internal noise levels.

A more detailed assessment of the potential road traffic noise impacts and preferred mitigation measures will be undertaken during the detailed design stage.

Additional Traffic on Existing Roads

Vehicles travelling to/from Cherrybrook Station are expected to increase the existing traffic volumes on the roads in the vicinity of the station, particularly near the access points to the station precinct. Cars accessing Cherrybrook Station will approach the station from Castle Hill Road, Franklin Road, or Robert Road. Vehicles approaching from Castle Hill Road will turn onto either Franklin Road or Robert Road before turning onto the station access road. The existing peak hour traffic and the Annual Average Daily Traffic (AADT) on the roads around Cherrybrook Station are given in Table 9.8.

Table 9.8 Existing Traffic Volumes on Roads around Cherrybrook Station

Road	AADT	2011 Peak Hour Volume
Castle Hill Road	43,331	2,164
Franklin Road	400 (approximately)	41
Robert Road	700 (approximately)	74

The NWRL EIS2 *Operational Traffic and Transport Technical Paper* describes the possible bus route options that have been considered to service Cherrybrook Station. Diverting existing bus routes to Cherrybrook Station is preferred to additional bus routes which would largely duplicate existing routes and incur a significant ongoing cost. The potential noise impact is one of many considerations including:

- Safety considerations for pedestrians and road users
- Retainment of bus services to areas served by existing bus routes
- Minimising passenger travel time
- Route efficiency and minimising bus kilometres
- The impact of buses on road congestion
- The impacts of road congestion on the reliability of bus services
- Retention of road side parking spaces.

The proposed bus access arrangement along Franklin Road and Robert Road is preferred for the following reasons:

- It will minimise diversion of existing bus routes and avoid routing buses along Castle Hill Road, which would increase congestion and lengthen journey times for existing bus passengers as well as those accessing Cherrybrook Station
- The proposed bus diversions via Robert and Franklin Roads to the station precinct will increase the catchment area of existing services and enhance accessibility generally
- It will maximise safety and accessibility to and from the station precinct for both pedestrians and vehicles, minimising pedestrian movements across Castle Hill Road and allowing adequate sight distance for vehicles to turn safely into and out of Castle Hill Road
- It will protect traffic flow efficiency along Castle Hill Road whilst equitably balancing traffic change across the local road network.

During the morning peak hour more than 600 vehicle trips to the station are predicted. The majority of vehicles are expected to approach the station from Castle Hill Road. An increase of 500 vehicles per hour on Castle Hill Road during the peak morning period is predicted to increase traffic noise levels by approximately 1 dB. An increase in noise level of 1 dB is typically considered to be a minor increase and is below the RNP increase criterion of 2 dB.

To assess the potential noise impact of increased traffic on Franklin Road and Robert Road, it is estimated that 100 cars per hour and 32 buses per hour will travel along each of these roads during the morning peak period in addition to the existing traffic.

During the morning peak period, $L_{Aeq(1hour)}$ traffic noise levels at building facades 10 m from the edge of either Franklin Road or Robert Road are predicted to be approximately 65 dBA. The contributions of light vehicles and buses to the overall level are 59 dBA and 63 dBA respectively. From traffic noise predictions and noise logger data in the area, existing traffic noise levels are expected to be at least 55 dBA. The predicted worst case noise increase may therefore be up to 10 dB. However, most residences are set back more than 10 m from the road and some residential properties have boundary fences which may provide some noise attenuation.

The RNP provides guidance on reasonable and feasible noise mitigation measures. No road improvements on Franklin Road and Robert Road north of the station are associated with the station development and the potential for noise control is therefore limited. Possible noise control strategies include quieter buses, noise barriers and property treatments. A more detailed assessment of the potential road traffic noise impacts and preferred mitigation measures will be undertaken during the detailed design stage.

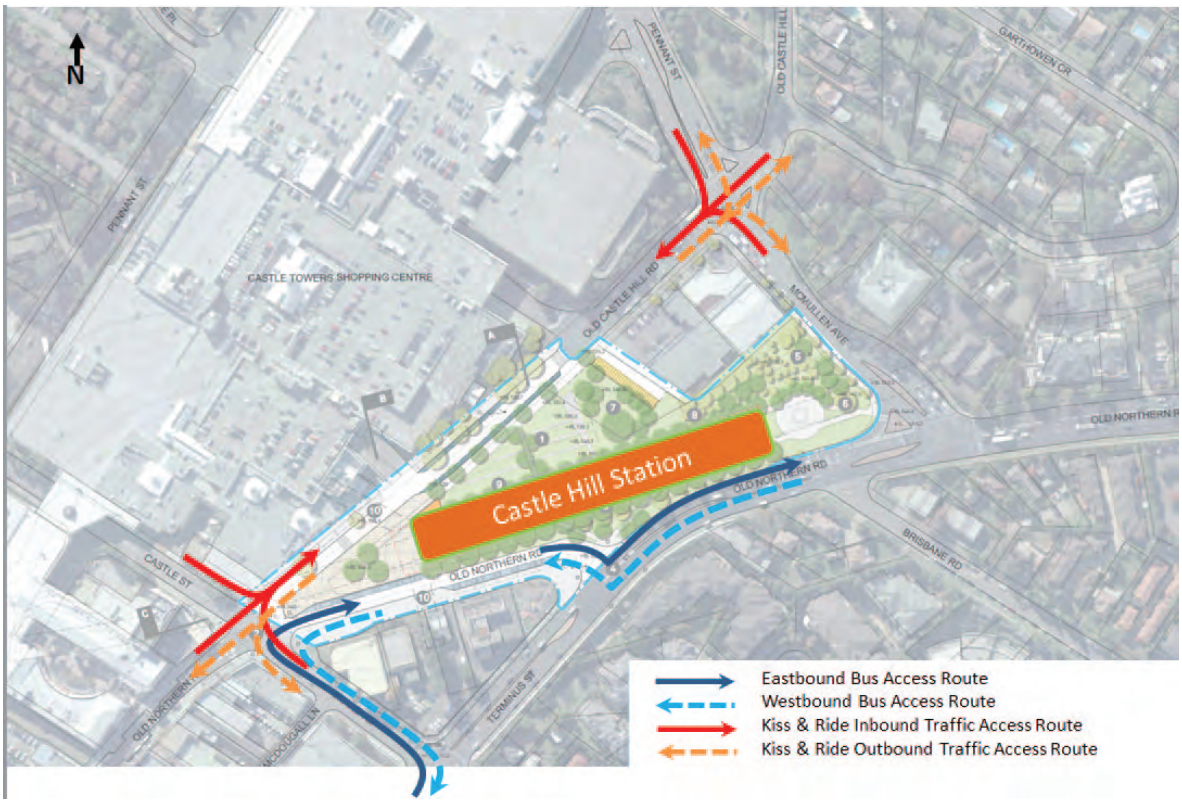
Castle Hill Station

Existing Roads

No internal roads or park and ride spaces are proposed at Castle Hill Station precinct. However, vehicles travelling to/from Castle Hill Station may increase the existing traffic volumes on the roads in the vicinity of the station. The proposed Castle Hill Station is located in a largely commercial and industrial area with some residential usage to the south-west of the proposed station precinct.

It is proposed to locate 17 kiss and ride spaces on Old Castle Hill Road and four bus bays on either side of Old Northern Road. Traffic generation associated with the proposed Castle Hill Station is expected to be more than 400 vehicles per hour during the morning peak period including 250-350 kiss and ride trips. The proposed layout of the Castle Hill Station precinct is shown in Figure 9.2.

Figure 9.2 Layout of Castle Hill Station Precinct



Numerous bus routes currently operate on the roads around the proposed Castle Hill Station. Northbound bus services currently depart from Old Castle Hill Road and southbound services depart from Old Northern Road. It is proposed to relocate all bus services to Old Northern Road as part of the new interchange facility. 101 bus movements per hour are expected to occur during morning and afternoon peak periods. However, this is understood to include numerous existing services and does not reflect traffic generated by Castle Hill Station. Noise impacts from the relocation of bus services at Castle Hill are not considered in this report.

Existing traffic volumes on the roads around Castle Hill Station are given in Table 9.9.

Table 9.9 Existing Traffic Volumes on Roads around Castle Hill Station

Road	AADT	2011 Peak Hour Volume
Old Northern Road	44,947	3,465
Terminus Street	27,694	2,206
Old Castle Hill Road	8,042	751

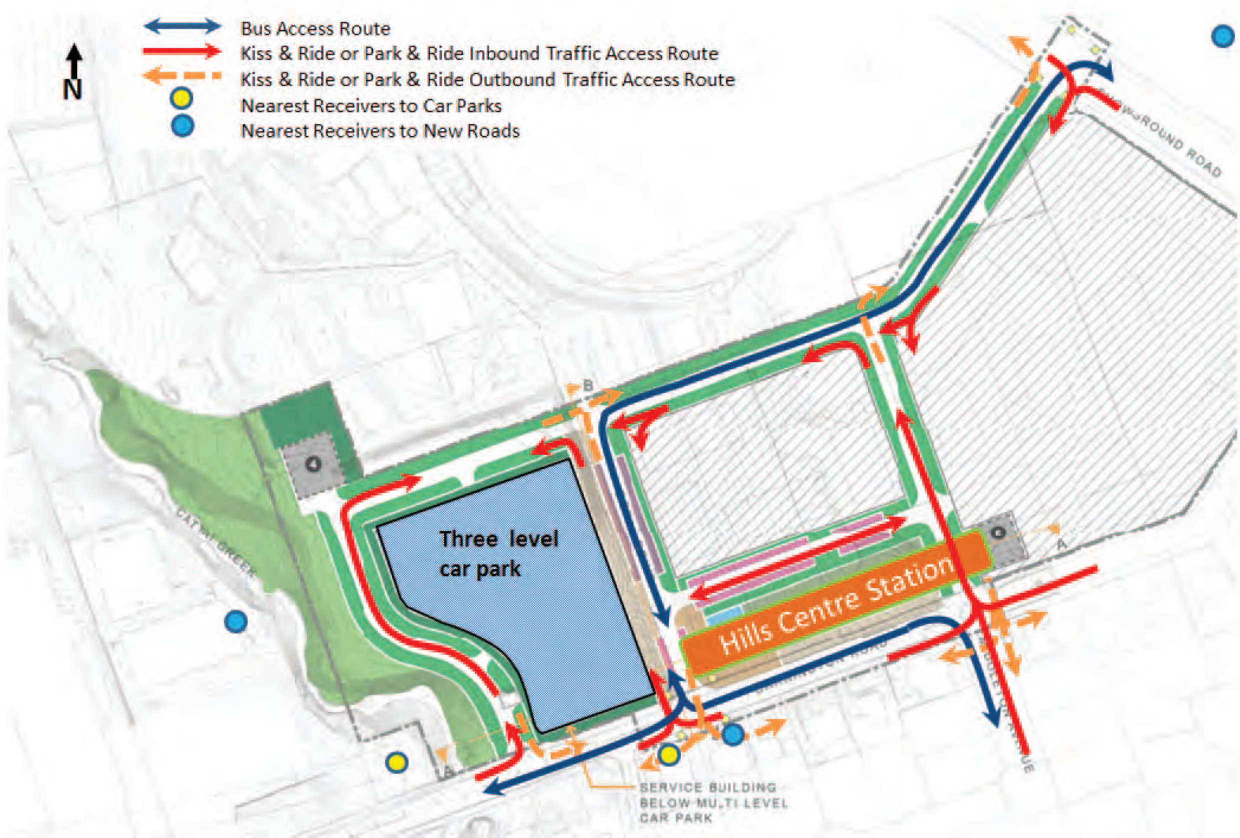
Traffic generated by the Castle Hill Station development is predicted to increase noise levels by less than 2 dB at all receivers. Mitigation of traffic noise is therefore not required.

Showground Station

New Roads

A network of new internal roads is proposed at Showground Station precinct, providing access to the station and the proposed three level car park in the south-west corner of the precinct, and linking Doran Drive to Showground Road. The proposed layout of the precinct is shown in Figure 9.3.

Figure 9.3 Layout of Showground Station Precinct



The nearest sensitive receivers to the new roads are residences on the south side of Carrington Road and on the east side of Showground Road. Commercial/industrial premises are located approximately 60 m to the west of a proposed new road around the multi-level car park. Due to the relatively low traffic expected on the car park access road, traffic noise impacts from the new roads are not expected to be significant at the commercial/industrial receivers.

During the morning peak hour more than 600 vehicle trips to the station are predicted, including 300-400 vehicles parking at the station and 200-300 kiss and ride trips. All residential receivers which may be exposed to traffic noise from vehicles on the proposed internal roads are adjacent to Showground Road or Carrington Road. Noise at these receivers from traffic on the internal roads is not expected to be significant compared to traffic noise from Showground Road or Carrington Road due to the lower traffic volumes and greater distance from road to receiver. Traffic noise impacts at residences on Carrington Road and Showground Road are instead assessed by considering the increase in traffic on these roads.

Existing Roads

Vehicles visiting Showground Station are expected to increase the existing traffic volumes on the roads in the vicinity of the station. Vehicles accessing Showground Station will approach the station from Showground Road or Carrington Road. Existing traffic volumes on the roads around Showground Station are given in Table 9.10.

Table 9.10 Existing Traffic Volumes on Roads around Showground Station

Road	AADT	2011 Peak Hour Volume
Showground Road	44,913	3,456
Carrington Road	15,409	1,543

As a conservative estimate, it is assumed that traffic numbers on both Showground Road and Carrington Road will increase by 500 cars and 27 buses during the peak morning period. Traffic noise levels are predicted to increase by less than 2 dB at all receivers. Mitigation of traffic noise is therefore not required.

Norwest Station

Existing Roads

No internal roads or park and ride spaces are proposed at Norwest Station. Vehicles travelling to/from Norwest Station may increase the existing traffic volumes on the roads in the vicinity of the station. The proposed Norwest Station is located in a commercial/industrial area with the nearest residences located to the south. The proposed station would mainly serve the employees of the Norwest Business Park which is currently being served by a limited bus service. A majority of the employees of the business park commute to work using private vehicles and the existing road network is currently congested during peak periods as a result. The proposed layout of the Norwest Station precinct is shown in Figure 9.4.

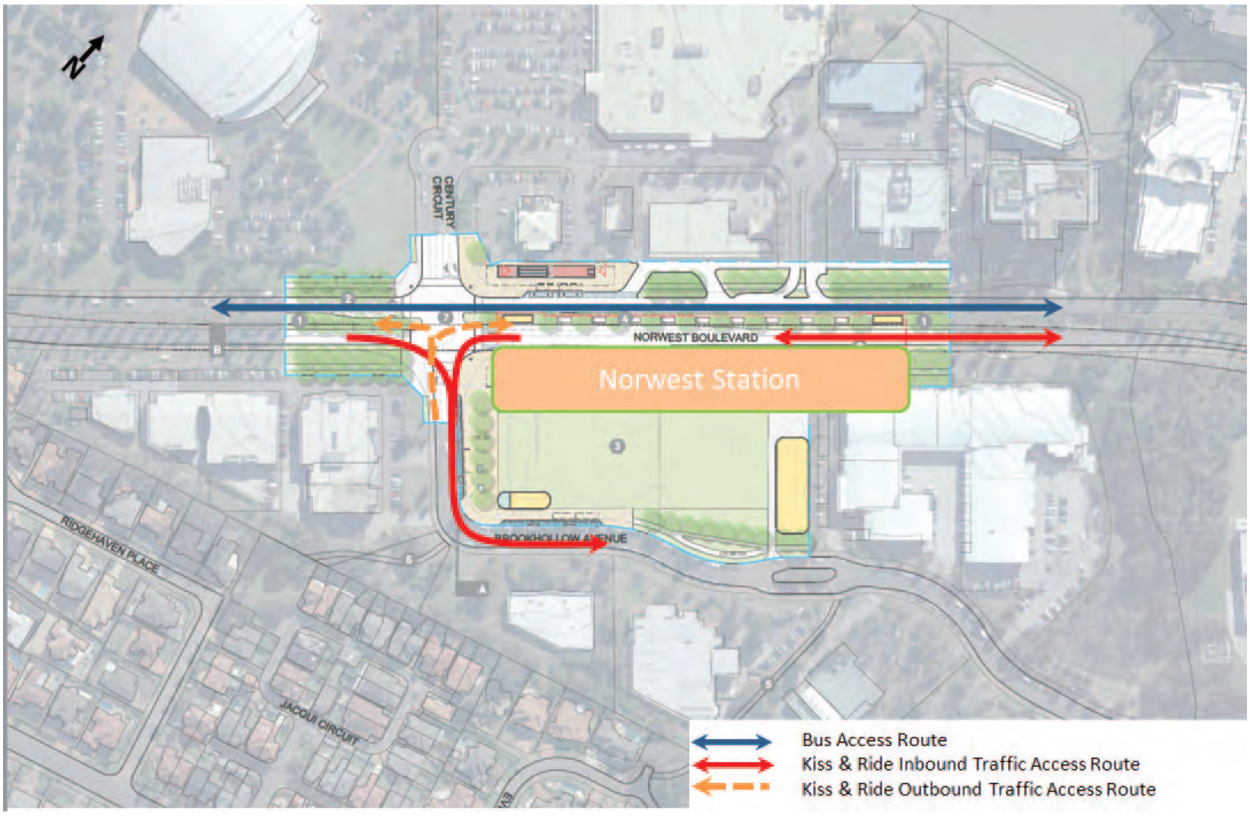
Traffic generation due to Norwest Station is expected to be more than 250 vehicles per hour during the morning peak period including approximately 100 kiss and ride trips and approximately 100 vehicles using on street parking on the surrounding street network. Up to 80 bus movements per hour are expected along Norwest Boulevard during the peak morning period. Kiss and ride spaces are proposed to be located on Brookhollow Avenue. Existing traffic volumes on the roads around Norwest Station are given in Table 9.11.

Table 9.11 Existing Traffic Volumes on Roads around Norwest Station

Road	AADT	2011 Peak Hour Volume
Norwest Boulevard	26,417	2,484
Brookhollow Avenue	2,726	376

Traffic generated by Norwest Station is predicted to increase noise levels by less than 2 dB at all receivers. Mitigation of traffic noise is therefore not required.

Figure 9.4 Layout of Norwest Station Precinct



Bella Vista Station

New Roads

A number of new roads are proposed at the Bella Vista Station precinct to provide access to kiss and ride areas, bus and taxi zones, and the commuter car parks. The proposed roads include extensions of Celebration Drive and Lexington Drive to the north, two link roads running east to west connecting Celebration Drive and Lexington Drive, and an east to west road linking Celebration Drive and Lexington Drive to Old Windsor Road. The proposed layout of the Bella Vista Station precinct is shown in Figure 9.5.

The nearest sensitive receivers to the new roads are residences to the east of Celebration Drive on Waterstone Crescent and Jardine Terrace. Traffic noise from internal roads at Bella Vista Station is not expected to be significant at residences to the west of Old Windsor Road due to the high existing traffic volume on Old Windsor Road. A business park is located to the south of Celebration Drive.

More than 500 vehicles per hour are expected to travel to Bella Vista station during the morning and afternoon peak periods including 300-400 vehicles parking at the station and 200-300 kiss and ride trips. 60 bus movements are expected during the morning and afternoon peak hour.

The majority of traffic travelling to the station is expected to approach from Old Windsor Road and Celebration Drive, or from the north along the Lexington Drive extension. Vehicles accessing the commuter car park are expected to approach from the Lexington Drive extension or from Old Windsor Road. Buses are expected to travel along the Lexington Drive extension. Only a small percentage of vehicles are expected to travel along the Celebration Drive extension.

Future traffic noise levels from Celebration Drive Extension and Lexington Drive Extension have been calculated using the CoRTN prediction method to determine whether noise mitigation is likely to be required. For noise prediction purposes the traffic volumes in Table 9.12 have been assumed.

Figure 9.5 Layout of Bella Vista Station Precinct

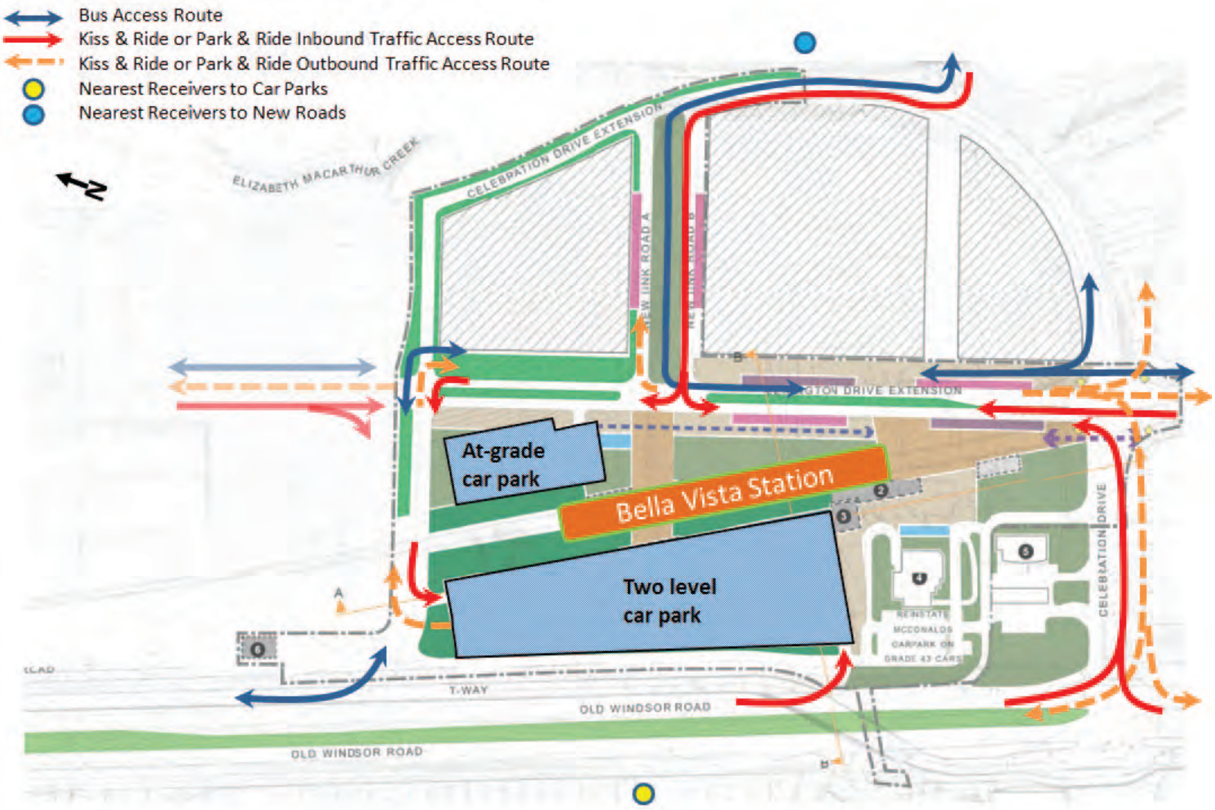


Table 9.12 Assumed Peak Traffic Numbers on Bella Vista Internal Roads

Road Description	Time Period	Peak Hourly Car Volume	Peak Hourly Bus Volume
Celebration Drive Extension	Day	100	0
	Night	20	0
Lexington Drive Extension	Day	600	60
	Night	60	10

As a conservative estimate, vehicles are modelled as travelling at 50 km/h. Predicted noise levels from traffic on the proposed station access roads during the noisiest daytime hour and night-time hour are presented in Table 9.13.

Table 9.13 Traffic Noise from Internal Roads at Bella Vista Station

Road Description	Time Period	Criteria $L_{Aeq(1hour)}$	Distance to Nearest Residential Facade	Predicted $L_{Aeq(1hour)}$	Exceedance of RNP criteria
Celebration Drive Extension	Day	55 dBA	35 m	51 dBA	-
	Night	50 dBA		44 dBA	-
Lexington Drive Extension	Day	55 dBA	185 m	54 dBA	-
	Night	50 dBA		45 dBA	-

Traffic noise levels from proposed new roads at Bella Vista Station are not expected to exceed the $L_{Aeq(1hour)}$ assessment criteria of 55 dBA daytime and 50 dBA night-time and therefore specific noise mitigation measures are not required.

Existing Roads

Vehicles travelling to/from Bella Vista Station are expected to increase the existing traffic volumes on the roads in the vicinity of the station. Cars accessing Bella Vista Station are expected to approach the station from Old Windsor Road and Celebration Drive. Existing traffic volumes on these roads are given in Table 9.14.

Table 9.14 Existing Traffic Volumes on Roads around Bella Vista Station

Road	AADT	2011 Peak Hour Volume
Old Windsor Road	49,004	3,012
Celebration Drive	14,533	1,905

As a conservative estimate, it is assumed that traffic numbers on both Old Windsor Road and Celebration Drive (between Old Windsor Road and Lexington Drive) will increase by 700 cars during the peak morning period. Based on this, traffic noise levels are predicted to increase by less than 2 dB at all receivers. Mitigation of traffic noise from existing roads is therefore not required.

Kellyville Station

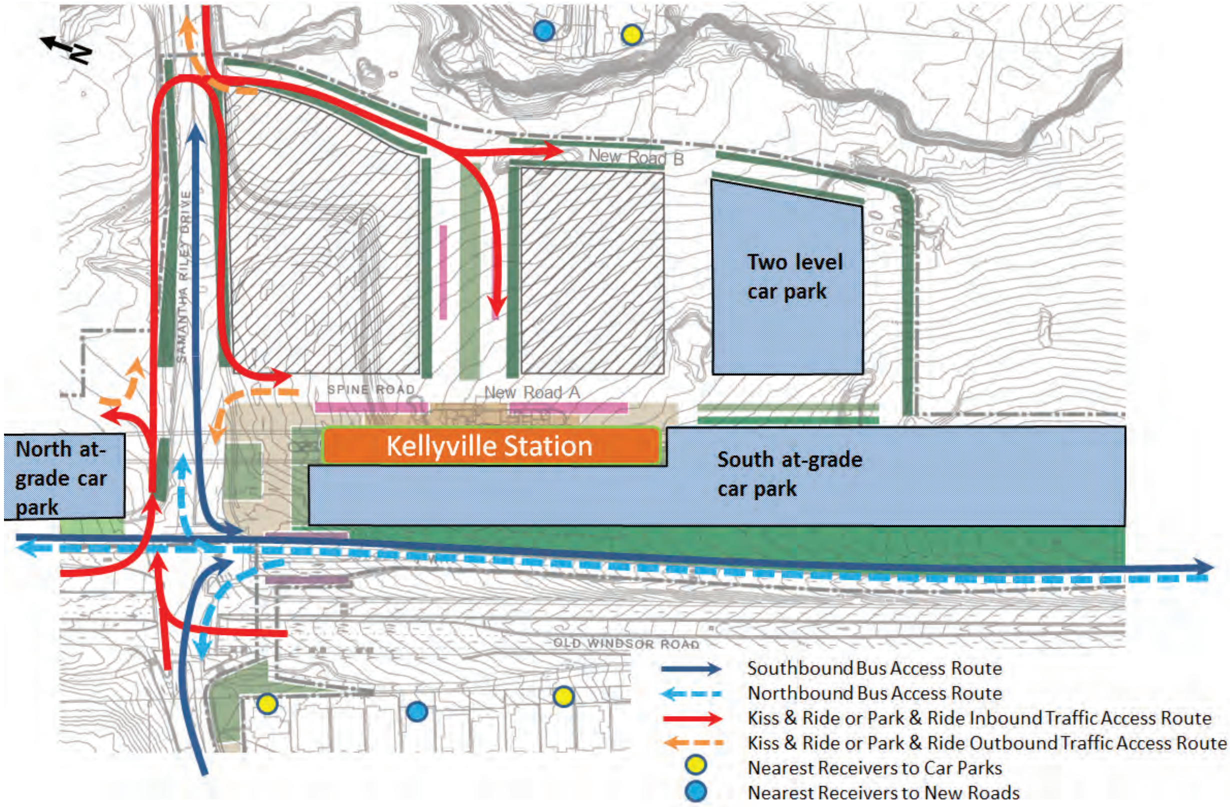
New Roads

A number of new roads are proposed at the Kellyville Station precinct to provide access to kiss and ride areas, bus and taxi zones, and the commuter car parks. The proposed roads include a road running parallel to the NWRL viaduct approximately 25 m to the east designated ‘New Road A’ and a second parallel road designated ‘New Road B’ at the east boundary of the station precinct. Three proposed link roads running east to west connect New Road A and New Road B. The proposed layout of the Kellyville Station precinct is shown in Figure 9.6.

The nearest sensitive receivers to the new roads are residences to the east on Landy Place and Wenden Avenue, approximately 65 m east of New Road B. Traffic noise from internal roads at Kellyville Station is not expected to be significant at residences to the west of Old Windsor Road due to the high existing traffic volume on Old Windsor Road.

More than 900 vehicles per hour are expected to travel to Bella Vista station during the morning and afternoon peak periods including 650-900 vehicles parking at the station and 150-200 kiss and ride trips. 60 bus movements are expected during the morning and afternoon peak hour.

Figure 9.6 Layout of Kellyville Station Precinct



Traffic travelling to the station is expected to approach along Windsor Road, Old Windsor Road, or Newbury Avenue, turning onto Samantha Riley Drive before entering the station precinct by New Road A or New Road B. The intersection of New Road A and Samantha Riley Drive is proposed to be a left in and left out only intersection. Buses are proposed to operate via the T-Way with pick up and set down at the existing T-Way stops to the west of the NWRL viaduct.

Future traffic noise levels at the nearest residences on Landy Place and Wenden Avenue from New Road A and New Road B have been calculated using the CoRTN prediction method to determine whether noise mitigation is likely to be required. For noise prediction purposes, 1,000 vehicles per hour have been assumed on both roads during the morning peak period. During the night-time a maximum of 100 vehicles per hour on each road has been assumed. Buses are expected to operate on the existing T-Way and it is assumed no buses operate on New Road A or New Road B. As a conservative estimate, vehicles are modelled as travelling at 50 km/h. Predicted noise levels from traffic on the proposed station access roads during the noisiest daytime hour and night-time hour are presented in Table 9.15.

Table 9.15 Traffic Noise from Internal Roads at Kellyville Station

Road Description	Time Period	Criteria $L_{Aeq(1hour)}$	Distance to Nearest Residential Facade	Predicted $L_{Aeq(1hour)}$	Exceedance of RNP criteria
New Road A	Day	55 dBA	185 m	52 dBA	-
	Night	50 dBA		42 dBA	-
New Road B	Day	55 dBA	65 m	58 dBA	3 dB
	Night	50 dBA		48 dBA	-

The $L_{Aeq(1hour)}$ due to traffic on the proposed access road along the east boundary of Kellyville Station precinct (New Road B) indicates a potential exceedance of the RNP criteria ($L_{Aeq(1hour)}$ 55 dBA daytime) at the nearest residences by up to 3 dB during the morning peak period. The noise predictions do not take into account possible acoustic shielding between New Road B and the nearest residences and assume that traffic travels the length of New Road B. The terrain is likely to provide some acoustic shielding in places and a significant proportion of traffic is likely to turn onto the link roads.

The measured existing noise level at 16 Wenden Avenue (Location BG15) during the peak morning traffic period is approximately 55 dBA. Traffic noise levels at the residences on Landy Place and at the west end of Wenden Avenue are expected to increase despite additional acoustic shielding of noise from Old Windsor Road that will be provided by the proposed station and car park.

The RNP provides guidance on feasible and reasonable noise mitigation measures including road design and traffic management, quieter pavement surfaces, noise barriers/mounds, and at-property treatments. Decreasing the posted speed from 50 km/h to 30 km/h is expected to achieve a noise reduction of approximately 2 dB. Where management and road design controls are unable to be implemented due to other project constraints, relatively low noise mounds or noise barriers along the east side of a section of New Road B with a height of 1 m to 1.5 m above the road surface are expected to be sufficient to achieve the necessary noise reduction. The requirement for a noise barrier/mound or other mitigation measures would be confirmed during the detailed design stage.

Existing Roads

Vehicles travelling to/from Kellyville Station are expected to increase the existing traffic volumes on the roads in the vicinity of the station. Cars accessing Kellyville Station are expected to approach the station along Windsor Road or Old Windsor Road and travel along Samantha Riley Drive to the access points of the station precinct. Existing traffic volumes on these roads are given in Table 9.16.

Table 9.16 Existing Traffic Volumes on Roads around Bella Vista Station

Road	AADT	2011 Peak Hour Volume
Old Windsor Road	49,004	3,235
Samantha Riley Drive	13,165	1,375
Windsor Road	37,382	1,239

As a conservative estimate, it is assumed that traffic numbers on all roads will increase by 800 cars during the peak morning period. Traffic noise levels are predicted to increase by less than 2 dB at all receivers. Mitigation of traffic noise from existing roads is therefore not required.

Rouse Hill Station

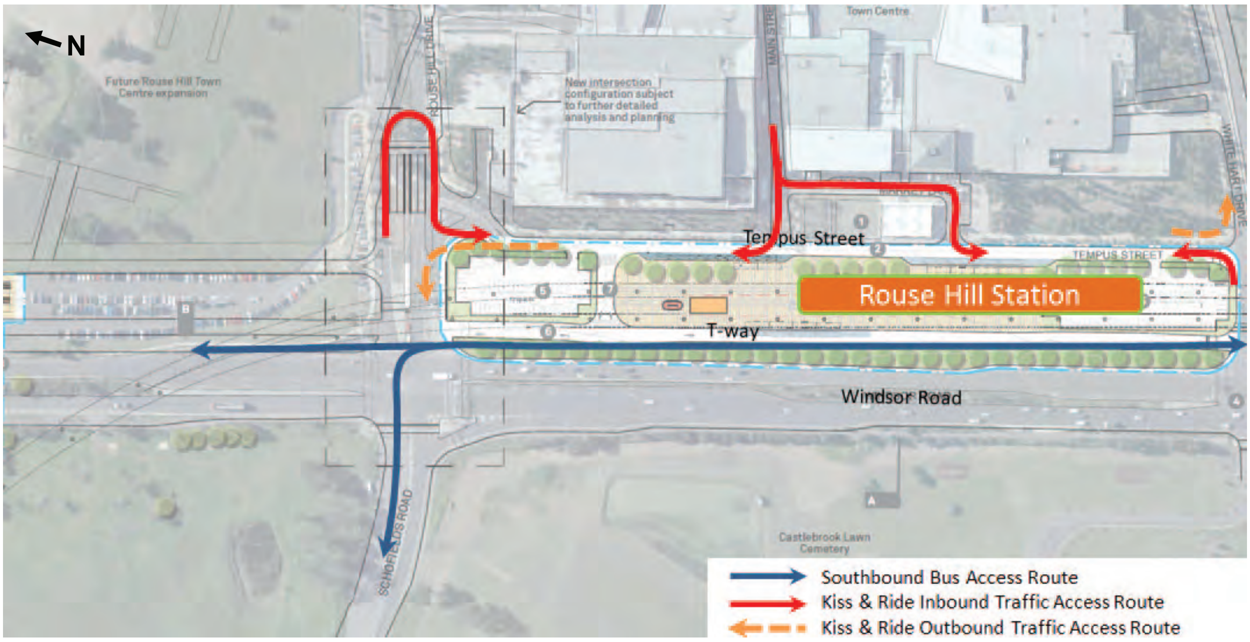
Existing Roads

The proposed Rouse Hill Station is located between the Rouse Hill Shopping Centre and Windsor Road. The proposed layout of the Rouse Hill Station precinct is presented in Figure 9.7.

The proposed location of the station precinct is currently used as a bus interchange. It is proposed to rearrange the T-Way and bus interchange to accommodate Rouse Hill Station. Traffic generation due to Rouse Hill Station is expected to be more than 800 vehicles per hour during the morning peak period including 500-700 kiss and ride trips. Approximately 90 bus movements per hour are expected at the relocated bus interchange.

Due to the existing bus interchange and the close proximity of the proposed Rouse Hill Station to Windsor Road, traffic noise levels are predicted to increase by less than 2 dB at all receivers. Mitigation of traffic noise from existing roads is therefore not required.

Figure 9.7 Layout of Rouse Hill Station Precinct

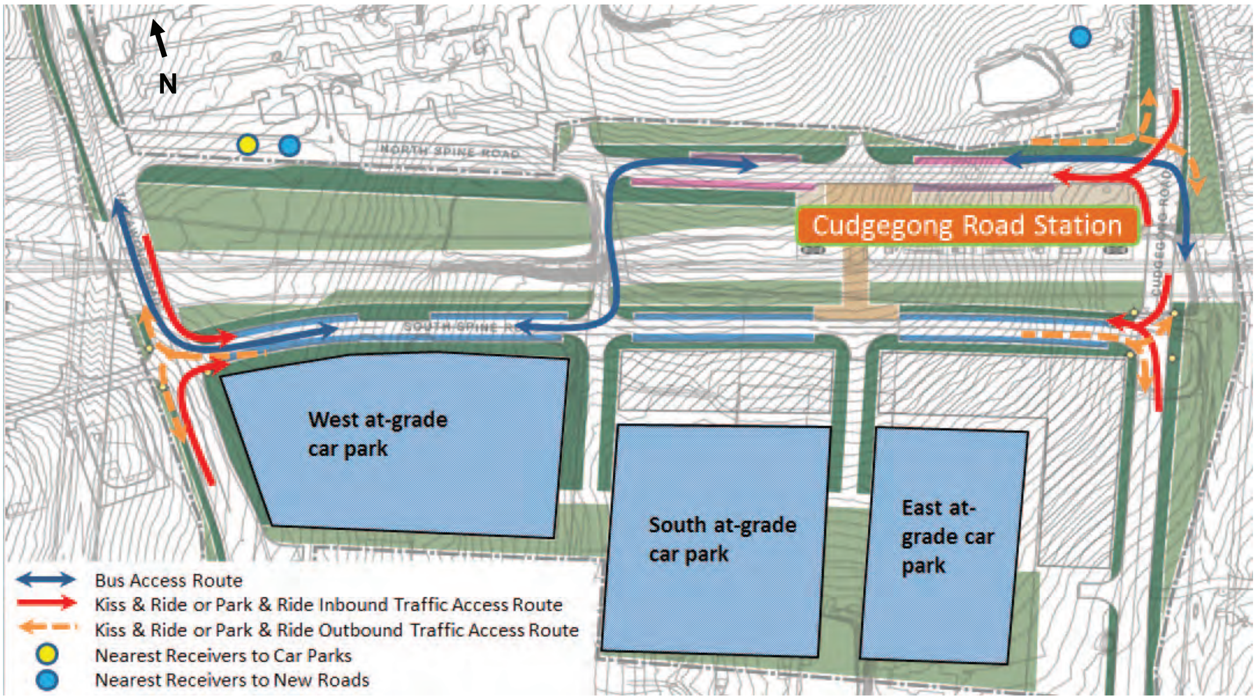


Cudgegong Road Station

New Roads

Access roads are proposed either side of the rail corridor at Cudgegong Road Station. The south access road is proposed to link Cudgegong Road and Tallawong Road and provides access to the on-street and off-street park and ride areas. Kiss and ride spaces and bus zones are proposed to be located on the north access road, accessed from Cudgegong Road. The proposed layout of the Cudgegong Road Station precinct is presented in Figure 9.8.

Figure 9.8 Layout of Cudgegong Station Precinct



The nearest sensitive receivers to the new roads are residences to the north on Cudgegong Road and Tallawong Road. The nearest residence to the north access road is approximately 65 m to the north. The nearest residences to the south access road are approximately 110 m to the north. More than 1,000 vehicles per hour are expected to travel to Cudgegong Road Station during the morning and afternoon peak periods including 700-900 vehicles parking at the station and 250-350 kiss and ride trips. Approximately 24 bus movements are expected during the morning and afternoon peak hour.

The majority of traffic travelling to the station is expected to approach along Schofields Road, turning onto Tallawong Road or Cudgegong Road and entering the precinct on one of the two access roads. Kiss and ride traffic and buses are expected to travel along the north access road whereas park and ride traffic is expected to use the south access road.

Future traffic noise levels at the nearest residences to the north and south access roads have been calculated using the CoRTN prediction method to determine whether noise mitigation is likely to be required. For noise prediction purposes the traffic volumes in Table 9.17 have been assumed.

Table 9.17 Assumed Peak Traffic Numbers on Cudgegong Road Station Internal Roads

Road Description	Time Period	Peak Hourly Car Volume	Peak Hourly Bus Volume
North Access Road	Day	300	24
	Night	60	6
South Access Road	Day	800	0
	Night	80	0

As a conservative estimate, vehicles are modelled as travelling at 50 km/h. Predicted noise levels from traffic on the proposed station access roads during the noisiest daytime hour and night-time hour are presented in Table 9.18.

Table 9.18 Traffic Noise from Internal Roads at Cudgegong Road Station

Road Description	Time Period	Criteria $L_{Aeq(1hour)}$	Distance to Nearest Residential Facade	Predicted $L_{Aeq(1hour)}$	Exceedance of RNP criteria
North Access Road	Day	55 dBA	65 m	54 dBA	-
	Night	50 dBA		48 dBA	-
South Access Road	Day	55 dBA	110 m	54 dBA	-
	Night	50 dBA		44 dBA	-

Traffic noise levels from proposed new roads at Cudgegong Road Station are not expected to exceed the $L_{Aeq(1hour)}$ assessment criteria of 55 dBA daytime and 50 dBA night-time, and specific noise mitigation measures are not likely to be required.

Existing Roads

Vehicles travelling to/from Cudgegong Road Station are expected to increase the existing traffic volumes on the roads in the vicinity of the station. The majority of vehicles are expected to approach the station along Schofields Road, turning onto either Tallawong Road or Cudgegong Road before entering the station precinct. Existing traffic volumes on these roads are given in Table 9.19.

Table 9.19 Existing Traffic Volumes on Roads around Bella Vista Station

Road	AADT	2011 Peak Hour Volume
Schofields Road	11,594	1,094
Cudgegong Road	1,461	205
Tallawong Road	950	107

The areas around the proposed Cudgegong Road Station are part of the North West Growth Centre (NWGC) and traffic on Schofields Road is expected to double between 2011 and 2021, irrespective of the NWRL.

Buses servicing the NWGC will pass by the station on their way to and from Rouse Hill. The expansion of bus services in the area is not directly attributable to Cudgegong Road Station and noise from buses on existing roads has therefore not been assessed.

Most kiss and ride and park and ride vehicles accessing Cudgegong Road Station are only expected to travel along a short length of Cudgegong Road or Tallawong Road between Schofields Road and the access roads (up to 350 m). It is understood that the land adjacent these road sections is proposed to be acquired for the NWRL project. As a conservative estimate, it is assumed that traffic numbers on Schofields Road will increase by 1,000 vehicles per hour during the morning peak period.

The $L_{Aeq(1hour)}$ during the morning peak period is predicted to increase by up to 3 dB at residences on Schofields Road compared with 2011 levels. However, substantial development is expected around Schofields Road and traffic numbers on Schofields Road are expected to double irrespective of the NWRL (ie as a result of natural growth). RMS has plans to upgrade Schofields Road from west of Windsor Road to the intersection with Hambledon Road, with construction works expected to commence toward the end of 2012. Due to the increased density of residential development in the area, traffic speeds may be reduced from the present speed limit of 80 km/h and this may offset the increase in traffic noise.

9.3.5 Assessment of Car Park Operational Noise

Cherrybrook Station

400 park and ride spaces are proposed at Cherrybrook Station. 336 parking spaces are proposed to be located in a two level car park above the south-east end of the station box. A second car park with 64 spaces is proposed at grade in the east corner of the Cherrybrook Station precinct, bordering Franklin Road and the residences on Kayla Way. The proposed layout of the Cherrybrook Station precinct is shown in Figure 9.1.

The design of the two level car park is yet to be finalised. For noise prediction purposes it is assumed the car park is naturally ventilated and therefore not fully enclosed. There is no information available at this stage regarding the design of traffic barriers around the perimeter of each parking level and any potential shielding effect due to traffic barriers has not been taken into account in the following noise predictions.

The closest receivers to the proposed two level car park are residences located on Castle Hill Road and the boundary of the nearest property is approximately 40 m from the edge of the proposed two level car park.

The closest receivers to the proposed at grade car park are the residences located on Kayla Way. The edge of the proposed at grade car park is approximately 10 m from the boundary of the nearest property on Kayla Way.

INP Intrusiveness and Amenity Impacts

Predicted noise levels from the operation of the proposed car parks are presented in Table 9.20.

Table 9.20 Predicted L_{Aeq} Noise Levels at Nearest Sensitive Receivers – Cherrybrook Station

Car park Description	Time Period	Amenity Noise Criteria $L_{Aeq(period)}$ (dBA)	Predicted $L_{Aeq(period)}$ (dBA)	Intrusive Noise Criteria $L_{Aeq(15minute)}$ (dBA)	Predicted $L_{Aeq(15minute)}$ (dBA)
2 level car park (336 spaces)	Day	55	40	50	45
	Night	40	33	39	37
At grade car park (64 spaces)	Day	55	41	42	**46**
	Night	40	34	35	**38**

Note: Values are displayed in **bold** where an exceedance has been predicted.

The predicted operational noise levels at the nearest sensitive receivers from the two level car park comply with the intrusiveness and amenity noise criteria.

For the east at-grade car park, the predicted maximum $L_{Aeq(15minute)}$ levels during the daytime and night-time periods are predicted to exceed the intrusiveness criteria by up to 4 dB. The existing L_{Aeq} noise levels in the area have been measured as typically between 50 dBA and 55 dBA during the morning peak period (6.00 am to 9.00 am) and up to 45 dBA during the night-time. The existing $L_{Aeq(15minute)}$ noise levels are 5 dB to 10 dB higher than the predicted peak levels from the car park. Observations during attended noise surveys note that the existing ambient noise levels are controlled by distant and local traffic noise. The character of noise from the car parks would be similar to that of the existing noise environment. The predicted $L_{Aeq(period)}$ noise levels are at least 5 dB below the amenity criteria.

It is assumed that residential property boundaries are fenced, which is likely to provide an additional 5 dB to 7 dB of noise reduction at the ground floor of the nearby residences. The residences on Kayla Way are typically two-storey and a boundary fence will not provide any significant noise reduction to the upper storey unless the fence breaks the line of sight to the car park.

Sleep Disturbance Assessment

With regard to the potential for sleep disturbance, the predicted $L_{A1(60second)}$ noise levels from events such as cars accelerating, doors closing, etc have been predicted and are presented in Table 9.21.

Table 9.21 Typical Vehicle Noise Events – Cherrybrook Station

Car park Description	Source	Typical $L_{A1(60sec)}$ Sound Power Level	Distance to Nearest Residential Facade	Typical $L_{A1(60sec)}$ Sound Pressure
2 level car park (336 spaces)	Car Moving	83 to 90 dBA	70 m	38 to 45 dBA
	Car Door Closing	88 to 97 dBA		43 to **52** dBA
	Car Starting	91 to 97 dBA		46 to **52** dBA
	Car Accelerating	90 to 98 dBA		45 to **53** dBA
At grade car park (64 spaces)	Car Moving	83 to 90 dBA	15 m	**51** to **58** dBA
	Car Door Closing	88 to 97 dBA		**56** to **65** dBA
	Car Starting	91 to 97 dBA		**59** to **65** dBA
	Car Accelerating	90 to 98 dBA		**58** to **66** dBA

Note: Values are displayed in **bold** where an exceedance has been predicted.

The predicted L_{Amax} noise levels from the two level car park may be up to 4 dB above the sleep disturbance screening criterion of 49 dBA at the nearest residences on Castle Hill Road, but would be much lower than the noise levels from passing traffic. The predicted maximum external noise level of 53 dBA would result in internal L_{Amax} noise levels up to 43 dBA with windows partially open and sleep disturbance is therefore considered unlikely.

The predicted noise levels at the facade of the nearest residents to the proposed east car park are up to 21 dB above the sleep disturbance screening criterion of 45 dBA. This would lead to internal noise levels from car park activity up to 56 dBA with windows open and 46 dBA with windows closed. It should be noted that the predicted internal L_{Amax} noise level of 46 dBA with windows closed applies to the loudest expected noise events at the shortest expected distance of such events from the building façade. Internal L_{Amax} noise levels above 45 dBA are therefore expected to be rare occurrences and sleep disturbance is not considered likely when windows are closed.

Recommendations

The proposed two level car park at the south-east end of the station box is predicted to meet the project noise criteria at the nearby residences on Castle Hill Road without specific noise mitigation measures.

For the proposed at grade car park in the east corner of the station precinct, specific measures may be required to mitigate the possibility of sleep disturbance for occupants of the adjacent residences on Kayla Way and predicted exceedances of the INP intrusiveness criteria up to 4 dB.

A possible mitigation measure includes the construction of a 4 m high noise barrier along the north-east boundary of the east car park, extending at least 5 m either side of the car park. It is anticipated that the design of such a barrier would be confirmed during the detailed design stage of the project when the final car-park designs have been established. Alternatively, closing the east at-grade car park between the hours 10 pm and 7 am may be considered, depending on anticipated traffic movements.

Showground Station

600 park and ride spaces are proposed at Showground Station in a three level parking building in the south-west corner of the station precinct. Access to parking is proposed to be from a new road within the precinct. The proposed layout of the Showground Station precinct is shown in Figure 9.3.

The closest receivers to the car park are residents on Carrington Road and the Carrington Preschool on Carrington Road.

The design of the three level car park is yet to be finalised. For noise prediction purposes it is assumed the car park is naturally ventilated and therefore not fully enclosed. There is no information available at this stage regarding the design of traffic barriers around the perimeter of each parking level and any potential shielding effect due to traffic barriers has not been taken into account in the following noise predictions.

INP Intrusiveness and Amenity Impacts

Predicted noise levels from the operation of the proposed car park are presented in Table 9.22.

Table 9.22 Predicted Noise Levels at Nearest Sensitive Receivers – Showground Station

Car park Description	Time Period	Amenity Noise Criteria $L_{Aeq(period)}$ (dBA)	Predicted $L_{Aeq(period)}$ (dBA)	Intrusive Noise Criteria $L_{Aeq(15minute)}$ (dBA)	Predicted $L_{Aeq(15minute)}$ (dBA)
3 level car park (600 spaces)	Day	60	46	59	51
	Night	45	39	39	**43**

Note: Values are displayed in **bold** where an exceedance has been predicted.

The maximum $L_{Aeq(15minute)}$ noise level during the night-time period is predicted to exceed the night-time intrusiveness criterion by up to 4 dB at the nearest residences on the opposite side of Carrington Road. The night-time criteria do not apply at Carrington Preschool which is understood to operate only during daytime hours. Exceedances of the night-time intrusiveness criteria are limited to the residences at 32 Carrington Road and 34 Carrington Road. The character of noise emissions from the proposed car park will be similar to existing noise from Carrington Road.

Sleep Disturbance Assessment

With regard to the potential for sleep disturbance, the predicted $L_{A1(60second)}$ noise levels from events such as cars accelerating, doors closing, etc have been predicted and are presented in Table 9.23.

Table 9.23 Typical Vehicle Noise Events – Showground Station

Car park Description	Source	Typical $L_{A1(60sec)}$ Sound Power Level	Distance to Nearest Residential Facade	Typical $L_{A1(60sec)}$ Sound Pressure
3 level car park (600 spaces)	Car Moving	83 to 90 dBA	40 m	42 to 49 dBA
	Car Door Closing	88 to 97 dBA		47 to **56** dBA
	Car Starting	91 to 97 dBA		**50** to **56** dBA
	Car Accelerating	90 to 98 dBA		49 to **57** dBA

Note: Values are displayed in **bold** where an exceedance has been predicted.

The predicted maximum noise levels from vehicle related noise events exceed the sleep disturbance screening criterion of 49 dBA by up to 8 dBA at the nearest residences, but would be much lower than the noise levels from passing traffic. The predicted maximum external noise level of 57 dBA is expected to result in internal L_{Amax} noise levels up to 47 dBA with windows partially open.

The predicted maximum external noise level of 57 dBA is based on the loudest expected vehicle related noise event occurring at the closest location in the car park to the residences. Internal maximum noise levels greater than 45 dBA at the nearest residences are therefore expected to be rare occurrences even with windows partially open. Sleep disturbance due to noise events in the car park is therefore considered unlikely.

Recommendations

The predicted maximum $L_{Aeq(15minute)}$ noise level during the night-time period is predicted to exceed the INP intrusiveness criterion by up to 4 dB at two residences on the opposite side of Carrington Road (32 Carrington Road and 34 Carrington Road). Noise mitigation is recommended and options include minimising openings in the car park building at the south-east corner or installing sound absorptive panels on the roof of each car park level near the south end. If ventilation requirements do not allow the construction of a solid wall in the vicinity of the south-east corner, acoustic louvres are likely to provide sufficient noise attenuation for noise emissions to meet INP intrusiveness criterion.

Bella Vista Station

The provision of approximately 940 park and ride spaces is proposed at Bella Vista Station. A two level car park with 800 spaces is proposed along the western boundary of the precinct. A second car park with 140 spaces is proposed at grade adjacent to the northern end of the station. The proposed layout of the Bella Vista precinct is shown in Figure 9.5.

The closest residential receivers to the proposed car parks are on Sharrock Avenue, on the opposite side of Old Windsor Road. The closest residential boundary is approximately 75 m from the proposed 2 level car park and approximately 140 m from the proposed at grade car park.

The design of the two level car park is yet to be finalised. For noise prediction purposes it is assumed the car park is naturally ventilated and therefore not fully enclosed. There is no information available at this stage regarding the design of traffic barriers around the perimeter of each parking level and any potential shielding effect due to traffic barriers has not been taken into account in the following noise predictions.

INP Intrusiveness and Amenity Impacts

Predicted noise levels from the operation of the proposed car parks are presented in Table 9.24.

Table 9.24 Predicted Noise Levels at Nearest Sensitive Receivers – Bella Vista Station

Car park Description	Time Period	Amenity Noise Criteria $L_{Aeq(period)}$ (dBA)	Predicted $L_{Aeq(period)}$ (dBA)	Intrusive Noise Criteria $L_{Aeq(15minute)}$ (dBA)	Predicted $L_{Aeq(15minute)}$ (dBA)
Two level car park (800 spaces)	Day	55	43	51	48
	Night	40	36	41	40
At grade car park (160 spaces)	Day	55	31	51	36
	Night	40	24	41	28

The predicted operational noise levels at sensitive receivers near the Bella Vista station car parks comply with the project noise criteria during all periods.

Sleep Disturbance Assessment

With regard to the potential for sleep disturbance, the predicted $L_{A1(60second)}$ noise levels from events such as cars accelerating, doors closing, etc have been predicted and are presented in Table 9.25.

Table 9.25 Typical Vehicle Noise Events – Bella Vista Station

Car park Description	Source	Typical $L_{A1(60sec)}$ Sound Power Level	Distance to Nearest Residential Facade	Typical $L_{A1(60sec)}$ Sound Pressure
Two level car park (800 spaces)	Car Moving	83 to 90 dBA	75 m	37 to 44 dBA
	Car Door Closing	88 to 97 dBA		42 to 51 dBA
	Car Starting	91 to 97 dBA		45 to 51 dBA
	Car Accelerating	90 to 98 dBA		44 to **52** dBA

Note: Values are displayed in **bold** where an exceedance has been predicted.

The predicted maximum noise levels from the two level car park are up to 1 dB above the screening criterion of 51 dBA at this location. With windows partially open, internal noise levels at the nearest residences due to noise events at the Bella Vista Station car parks are not expected to exceed 45 dBA and sleep disturbance is considered unlikely. Existing maximum noise levels from heavy vehicles on Old Windsor Road are expected to be much louder than noise events from the Bella Vista Station car parks.

Recommendations

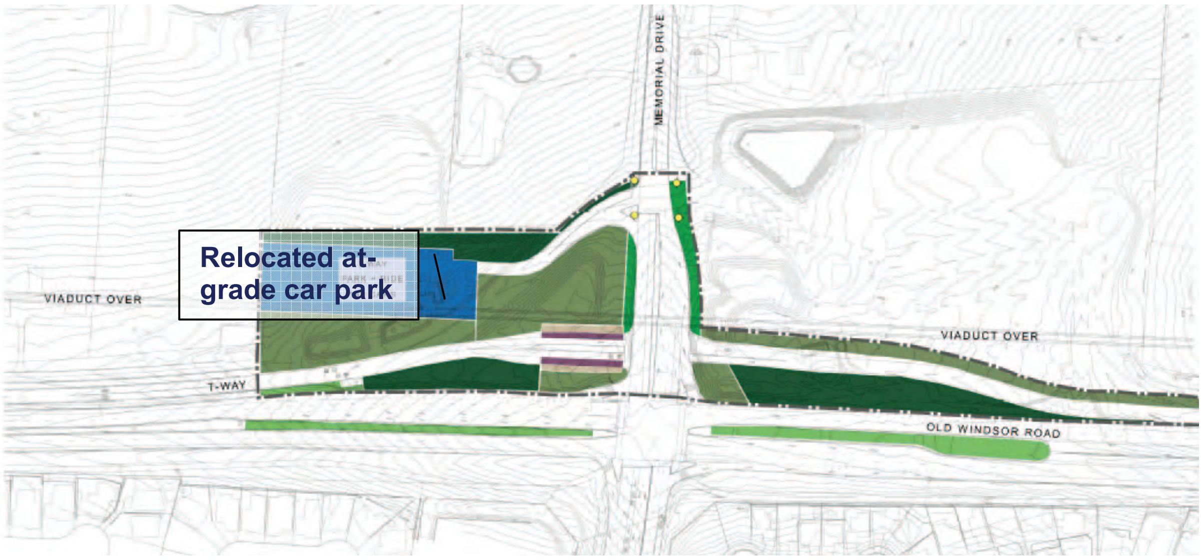
Noise emissions from the Bella Vista Station car parks are predicted to comply with all project noise criteria at the nearest residences and no noise mitigation measures are considered necessary.

Memorial Avenue T-Way Bus Stop

It is proposed to relocate the existing T-Way, T-Way bus stop and commuter car park at Memorial Avenue to accommodate the NWRL rail viaduct. The existing car park south of Memorial Avenue is to be removed and a new car park with 180 park and ride spaces is to be constructed to the north of Memorial Avenue. The proposed arrangement of the T-Way and commuter car park is shown in Figure 9.9.

The nearest residential receivers are to the south-east at a distance of approximately 175 m and to the west on the opposite side of Old Windsor Road at a distance of approximately 120 m. Noise impacts are expected to be similar to the existing car park arrangement. Due to the distance to the nearest sensitive receivers and the proximity to Old Windsor Road, no exceedances of the INP criteria are predicted.

Figure 9.9 Location of Relocated T-Way Commuter Car Park at Memorial Avenue



Kellyville Station

1,415 park and ride spaces are proposed at Kellyville Station. 390 parking spaces are proposed to be located in a two level car park in the south-east corner of the precinct. The other 1,025 spaces are proposed to be located beneath and adjacent to the NWRL viaduct in two at-grade car parks. 620 of these parking spaces are proposed to be located south of Samantha Riley Drive with the remaining 405 spaces north of Samantha Riley Drive. The proposed layout of the Kellyville precinct is shown in Figure 9.6.

The closest receivers to the two level car park are residences to the north-east along Wenden Avenue and recent residential development off Arnold Avenue to the south-east. The closest residential boundary is approximately 90 m from the edge of the two level car park.

The closest receivers to the south-west at-grade car park are residences to the west on Roxburgh Crescent. The closest property boundary is approximately 80 m from the edge of the car park.

The closest receivers to the north at-grade car park are residences on the opposite side of Old Windsor Road, along Newbury Avenue, approximately 95 m from the car park. Noise impacts are also assessed at receivers along Clovelly Circuit approximately 130 m from the car park due to lower background noise levels in this area.

The design of the two level car park is yet to be finalised. For noise prediction purposes it is assumed the car park is naturally ventilated and therefore not fully enclosed. There is no information available at this stage regarding the design of traffic barriers around the perimeter of each parking level and any potential noise shielding effect due to traffic barriers has not been taken into account.

INP Intrusiveness and Amenity Impacts

Predicted noise levels from the operation of the proposed car parks are presented in Table 9.26.

Table 9.26 Predicted Noise Levels at Nearest Sensitive Receivers – Kellyville Station

Car park Description	Time Period	Amenity Noise Criteria $L_{Aeq(period)}$ (dBA)	Predicted $L_{Aeq(period)}$ (dBA)	Intrusive Noise Criteria $L_{Aeq(15minute)}$ (dBA)	Predicted $L_{Aeq(15minute)}$ (dBA)
Two level car park (390 spaces)	Day	55	36	44	41
	Night	40	29	44	33
South at-grade car park (620 spaces)	Day	55	40	52	45
	Night	40	33	43	37
North at-grade car park (405 spaces) At Clovelly Circuit	Day	55	33	50	38
	Night	40	26	42	30
North at-grade car park (405 spaces) At Newbury Avenue	Day	55	35	52	40
	Night	40	28	43	32

The predicted operational noise levels at sensitive receivers near the Kellyville Station car parks comply with the project noise criteria during all periods.

Sleep Disturbance Assessment

With regard to the potential for sleep disturbance, the predicted $L_{A1(60second)}$ noise levels from events such as cars accelerating, doors closing, etc have been predicted and are presented in Table 9.27.

Table 9.27 Typical Vehicle Noise Events – Kellyville Station

Car park Description	Source	Typical $L_{A1(60sec)}$ Sound Power Level	Distance to Nearest Residential Facade	Typical $L_{A1(60sec)}$ Sound Pressure
North Car Park/ South Car Park/ 2 level Car Park	Car Moving	83 to 90 dBA	100 m	35 to 42 dBA
	Car Door Closing	88 to 97 dBA		40 to 49 dBA
	Car Starting	91 to 97 dBA		43 to 49 dBA
	Car Accelerating	90 to 98 dBA		42 to 50 dBA

The predicted maximum noise levels from all car parks are below the minimum sleep disturbance screening criterion of 52 dBA that has been identified in the surrounding areas. The character of noise from the car parks would also be very similar to that from existing surrounding roadways.

Recommendations

Noise emissions from the Kellyville Station car parks are predicted to comply with all project noise criteria at the nearest residences and no noise mitigation measures are considered necessary.

Cudgegong Road Station

Approximately 1,010 park and ride spaces are proposed in three at-grade car parks in the Cudgegong Station precinct. All three car parks are located to the south of Cudgegong Station, between Tallawong Road and Cudgegong Road. The existing area surrounding the proposed station is best described as rural/rural-residential although in future this is likely to become suburban.

Existing properties are located at a distance greater than 120 m in all directions from the proposed car parks. The closest residences are located to the north off Tallawong Road, to the east on Cudgegong Road, and to the south on the opposite side of Schofields Road. The proposed layout of the Cudgegong precinct is presented in Figure 9.8.

INP Intrusiveness and Amenity Impacts

The noise contribution of all three car parks has been calculated at a residence approximately 120 m from the car parks. Predicted noise levels from the operation of the proposed car parks are presented in Table 9.28.

Table 9.28 Predicted Noise Levels at Nearest Sensitive Receivers – Cudgegong Road Station

Car park Description	Time Period	Amenity Noise Criteria $L_{Aeq(period)}$ (dBA)	Predicted $L_{Aeq(period)}$ (dBA)	Intrusive Noise Criteria $L_{Aeq(15minute)}$ (dBA)	Predicted $L_{Aeq(15minute)}$ (dBA)
All Park and Ride Car Parks (1010 spaces)	Day	50 dBA	40 dBA	50 dBA	44 dBA
	Night	40 dBA	32 dBA	43 dBA	36 dBA

The predicted operational noise levels at sensitive receivers near the Cudgegong Station car parks comply with the project noise criteria during all periods.

Sleep Disturbance Assessment

With regard to the potential for sleep disturbance, the predicted $L_{A1(60second)}$ noise levels from events such as cars accelerating, doors closing, etc have been predicted and are presented in Table 9.29.

Table 9.29 Typical Vehicle Noise Events – Cudgegong Road Station

Car park Description	Source	Typical $L_{A1(60sec)}$ Sound Power Level	Distance to Nearest Residential Facade	Typical $L_{A1(60sec)}$ Sound Pressure
West, North and South (Park and Ride)	Car Moving	83 to 90 dBA	120 m	33 to 40 dBA
	Car Door Closing	88 to 97 dBA		38 to 47 dBA
	Car Starting	91 to 97 dBA		41 to 47 dBA
	Car Accelerating	90 to 98 dBA		40 to 48 dBA

The predicted maximum noise levels from all car parks are below the sleep disturbance screening criterion of 53 dBA, and even several coinciding events would not cause the screening criterion to be exceeded. The character of noise from the car parks would also be very similar to that from existing surrounding roadways.

Recommendations

Noise emissions from the Cudgegong Station car parks are predicted to comply with all project noise criteria at the nearest residences and no noise mitigation measures are considered necessary.

9.3.6 Assessment of Public Address Systems

Each station will be fitted with a Public Address (PA) system to allow commuter announcements. Noise emission from PA systems would be required to achieve the INP criteria with relevant adjustments for noise characteristics such as duration and intermittency.

PA systems can typically be designed to minimise noise impact at surrounding noise sensitive receivers using measures such as speaker selection and placement. Installation of ambient noise sensing microphones allows speaker gain to be set automatically relative to the existing ambient noise at particular zones of the station. This is typically set at 10 dB to 15 dB above the ambient noise level which in most cases would minimise noise impacts from the station to surround noise sensitive receivers.

Prediction of noise from station PA systems is not practical at this stage of the project; but should be considered in the detailed design of the stations. It is expected that with appropriate design measures in place, the contribution of these systems to the overall ambient L_{Aeq} noise level would be minimal, but that some care may need to be taken to prevent sleep disturbance impacts. Investigations are being made in relation to whether regular announcements are required at surface and open-cut stations – alternatives include visual displays and on-demand (push-button) audio information stands.

9.4 Summary of Impacts and Mitigation Measures

The maximum allowable mechanical and electrical services sound power levels emitted at each location have for detailed design purposes been calculated and range from 73 dBA to 106 dBA.

Mitigation measures are likely to be required for some station and tunnel ventilation equipment / locations in order to comply with the project noise design criteria. Mitigation measures that may need to be considered at some locations include appropriate equipment selection, in-duct attenuators, noise barriers, acoustic enclosures and the strategic positioning of critical plant away from sensitive receivers.

Train noise break-out through the draught relief shafts from trains operating within the tunnel is not expected to exceed the noise design criteria. All tunnel ventilation and draught relief shafts near sensitive receivers are likely to require mitigation measures (typically in-duct noise attenuation) in order to comply with applicable noise criteria.

Traffic noise increases from existing roads due to traffic generated by the NWRL stations have been calculated. There is the potential for exceedances (up to 10 dB) of the RNP criteria for traffic generating developments during the daytime peak periods on Robert Road and Franklin Road near Cherrybrook Station.

Traffic noise at sensitive receivers from proposed new roads within the station precincts was calculated in accordance with the CoRTN 1988 noise modelling algorithms. Potential exceedances of the RNP criteria for new local roads have been identified during the morning peak period at Cherrybrook Station (5 dB) and at Kellyville Station (3 dB). It is recommended that noise mitigation measures be considered in the detailed design of the proposed new roads at these locations.

Operational noise from proposed car parks has been assessed and in most cases is predicted to comply with the project noise criteria at all sensitive receivers. Noise levels over the noise criteria have been predicted at Cherrybrook Station and Showground Station due to low existing background noise levels and the close proximity of car parks to residential property boundaries. A 4 m high noise barrier may be required along the north-east boundary of the east car park at Cherrybrook Station to minimise potential sleep disturbance. At Showground Station the parking building may need to be enclosed around the south-east corner. The details of the noise mitigation measures should be further developed during the detailed design stage of the project when car parking details have been finalised.

Mitigation of noise from PA systems at surface stations, open cut stations and the stabling facility will be required to achieve INP noise criteria. It is anticipated that these criteria can be achieved with appropriate design such as loudspeaker selection and placement and installation of ambient noise sensing microphones and automatic volume control systems.

10 Operational Noise and Vibration Assessment for ECRL

10.1 Introduction

The Epping to Chatswood Rail Line (ECRL) opened to the public in February 2009 and currently forms part of the CityRail network. Rapid Transit Trains would operate on the NWRL through to Chatswood using the existing ECRL. The potential noise and vibration impacts associated with the change are as follows:

- Train operations within the ECRL tunnels and surface track in Chatswood area would comprise modern single deck trains, rather than the current mix of CityRail trains operating on the line
- The frequency (number) of trains is likely to be higher for the NWRL, compared with the current CityRail timetable
- The train speeds within the tunnel and surface sections may be higher (up to 100 km/h where possible), compared with the current maximum speed of 80 km/h for ECRL.

10.2 ECRL Conditions of Approval

As part of the ECRL (formerly Parramatta Rail Link) approval, a number of Conditions of Approval were issued relating to the operation of the ECRL. The noise and vibration conditions relating to the operational stage of the ECRL are provided in Appendix I.

Table 10.1 provides a brief overview of the noise and vibration conditions and whether there is likely to be any change in noise and vibration levels.

Table 10.1 Summary of ECRL Conditions of Approval relating to Operational Noise and Vibration

Condition No.	Noise and Vibration Aspect	Comments Relating to ECRL as part of NWRL Project
69	Operational Noise and Vibration Management Sub Plan	This condition requires the development of an Operational Noise and Vibration Sub Plan which identifies the relevant noise and vibration criteria for the operational stage of the project, the predicted noise and vibration impacts, monitoring procedures, reporting procedures and response procedures. It is assumed that a similar plan would be required for the NWRL project. This plan would need to include the section of existing track between Epping and Chatswood.

Condition No.	Noise and Vibration Aspect	Comments Relating to ECRL as part of NWRL Project
70	Airborne noise design criteria for surface train operations	This condition specifies the airborne noise design criteria applicable to the ECRL project, namely $L_{Aeq(24hour)}$ 55 dBA and $L_{Amax,95\%}$ 80 dBA. The design of the ECRL was required to meet these levels where feasible and reasonable to do so for the sections of surface track at Epping and Chatswood where physical works were undertaken as part of the project. There are likely to be additional trains, and these trains could potentially travel at higher speeds in the section of track between the Chatswood tunnel portals and Chatswood Station. The potential change in airborne noise levels is discussed in Section 10.3.
71	Airborne noise design criteria for stations, ventilation systems and other fixed facilities	There are unlikely to be any significant changes which would affect noise levels associated with these noise sources.
72	Ground-borne (regenerated) noise design criteria for recording studios	This condition specified the ground-borne noise design criterion ($L_{Amax,95\%}$ 20 dBA) for recording studios (including Global Studios, Film Australia and the Australian Film and Television School). All feasible and reasonable mitigation measures were required to achieve the design criterion. Trains within the tunnel sections may travel at higher speeds. The potential change in ground-borne noise levels is discussed in Section 10.4.
73	Human comfort vibration criteria within buildings above the tunnel alignment	This condition specifies the human comfort vibration guideline applicable to the project, namely the “low probability of adverse comment” criteria in British Standard 6472. Trains within the tunnel sections may travel at higher speeds. The potential change in vibration levels is discussed in Section 10.4.
74	Ground-borne (regenerated) noise design criteria for residences and nursing homes	This condition specified the ground-borne noise design criteria ($L_{Amax,95\%(fast)}$ 35 dBA and $L_{Amax,50\%(fast)}$ 30 dBA) for residences and nursing homes. Trains within the tunnel sections may travel at higher speeds. The potential change in ground-borne noise levels is discussed in Section 10.4.
75	Requirement for specific track forms at several locations within the tunnel	This condition included requirements relating to the specific track forms that were required in the excavated tunnels and confirmed with the Director-General and EPA during the detailed design stage. The track forms within the excavated tunnels are not proposed to be changed.

Condition No.	Noise and Vibration Aspect	Comments Relating to ECRL as part of NWRL Project
76	Ground-borne (regenerated) noise design criteria for recording studios	This condition specified the ground-borne noise design limit ($L_{Amax,95\%}$ 25 dBA) for particularly sensitive receptors such as Global Studios, Australian Film and Television and Radio School, Film Australia and other recording studios). The condition also included procedures which must be followed in the event of complaints relating to impacts on the operation of these businesses. Trains within the tunnel sections may travel at higher speeds. The potential change in ground-borne noise levels is discussed in Section 10.4.
76A	Ground-borne (regenerated) noise design criteria for residences and other noise sensitive premises within Chatswood Transport Interchange	This condition specified the ground-borne noise design criteria ($L_{Amax,95\%(fast)}$ 40 dBA for residences and other noise sensitive premises within Chatswood Transport Interchange. Trains within the tunnel sections may travel at higher speeds. The potential change in ground-borne noise levels is discussed in Section 10.4.
77	High noise train event management strategy	This condition required a technical report to be prepared which identified the potential risk of the ground-borne noise criteria being exceeded by "high noise trains" and a management strategy identifying the timeframes and actions relating such trains or carriages. It is assumed that the operational noise and vibration management plan and maintenance strategy for NWRL will include similar noise and vibration monitoring, reporting and complaints management procedures.
78	Additional ground-borne (regenerated) noise criteria for specific residences	This condition noted that for some residences (with ground-borne noise level predictions greater than 28 dBA in the EIS), the predicted ground-borne noise levels shall not be permitted to exceed the EIS levels by more than 3 dB. Trains within the tunnel sections may travel at higher speeds. The potential change in ground-borne noise levels is discussed in Section 10.4.
79	Complaints management and consideration of additional feasible and reasonable mitigation measures	This condition included a requirement to establish a complaints management procedure as part of the operational noise and vibration management sub plan. If complaints are a result of exceedances to the ground-borne noise criteria, the proponent must consider additional feasible and reasonable mitigation measures. As part of the NWRL project, it is anticipated that a similar condition will form part of the project approval.

Condition No.	Noise and Vibration Aspect	Comments Relating to ECRL as part of NWRL Project
80	Noise and vibration compliance reporting	This condition included requirements for reporting on the operational noise and vibration levels two and seven years after opening (ie 2011 and 2016) and at any other time as required by the Director General. The time period relating to this condition will have expired prior to the proposed NWRL opening.
81	Consideration of additional mitigation measures if exceedances identified in Condition 80	This condition requires the consideration of additional feasible and reasonable mitigation measures if the noise and vibration compliance report referred to in Condition 80 identifies exceedances of the noise and vibration levels in Condition 74 or 76. The time period relating to this condition will have expired prior to the proposed NWRL opening.

Table 10.1 identifies two areas where the proposed NWRL operations on ECRL may generate higher airborne noise levels or higher ground-borne noise and vibration levels. These are discussed in the following sections.

10.3 Potential Increase in Airborne Noise Levels at Chatswood

For the section of surface track between Chatswood Station and the ECRL tunnel portals (near William Street), there would be a more frequent single deck train service, with NWRL trains potentially travelling at higher speeds. These changes have the potential to create additional airborne noise at nearby sensitive receivers.

In this section of railway corridor, there are four tracks. The two inside tracks are associated with the ECRL (and future NWRL trains) and the two outer tracks (closer to the majority of receivers) are associated with train operations on the North Shore Line.

Following the ECRL opening in 2009, a number of complaints were received from members of the public in relation to increased noise emissions and a tonal “roaring” noise from the ECRL line tracks between O’Brien Street and Wilson Street in Chatswood North. Increased noise levels associated with ECRL trains were a result of several factors including increased rail roughness (rail surface condition) condition, reduced sound absorption of the concrete slab track (compared with ballast track) and additional rail-radiated noise (due to low stiffness baseplates on concrete slab track).

A detailed noise measurement campaign and noise mitigation study was undertaken in 2009 to identify additional feasible and reasonable mitigation measures (consistent with the requirements of Condition 70). Several additional mitigation measures were recommended and implemented to minimise airborne noise levels associated with ECRL trains. These included:

- Additional rail grinding to improve the rail surface condition, resulting in less tonal noise and an overall reduction in source noise levels
- Installation of rail dampers between the level crossing (near Wilson Street) and the ECRL tunnel portals, resulting in less tonal noise and an overall reduction in source noise levels

- Installation of acoustic panels between the rails on the ECRL tracks between the level crossing and approximately Ashley Street to reduce reflected noise.

With the above additional measures, the airborne noise levels from North Shore Line trains were reduced by approximately 1 dB at the nearest residences and ECRL trains were reduced by approximately 3 dB to 4 dB at the nearest residences.

The overall noise levels at the nearest residences remained above the Condition 70 noise levels of $L_{Aeq(24hour)}$ 55 dBA and $L_{Amax,95\%}$ 80 dBA, however complied with the IGANRIP redeveloped rail line noise trigger levels of $L_{Aeq(15hour)}$ 65 dBA, $L_{Aeq(9hour)}$ 60 dBA and $L_{Amax,95\%}$ 85 dBA. The noise levels associated with ECRL trains were approximately 1 dB louder than North Shore Line trains, noting that a change of 1 dB or 2 dB in the level of a sound is difficult for most people to detect.

Modelling Assumptions

The noise modelling undertaken for the above assessment was based on a number of assumptions relating to train speeds and the number of trains for a future modelling scenario (Year 2017). These assumptions, together with future traffic data for 2012 and 2031, are provided in Table 10.2.

Table 10.2 Noise Modelling Assumptions for Surface Track at Chatswood

Line	Day/Night	Direction	Existing Train Speeds (km/h)[1]	Trains Per Weekday Period[2]		
				Year 2017	Year 2021	Year 2031
ECRL	Day	Down	80	90	124	182
		Up	80	90	122	172
	Night	Down	80	33	27	29
		Up	80	33	29	39
North Shore Line	Day	Down	80	130	130	130
		Up	60	134	134	134
	Night	Down	80	23	23	23
		Up	60	25	25	25

Note 1: Existing train speeds are as per RailCorp advice in 2009.

Note 2: Projected train numbers for Year 2017 are possible train numbers as per RailCorp advice in 2009. Train numbers for Year 2021 and 2031 are based on the estimated passenger demand and minimum NWRL service levels (refer Table 5.5). For North Shore Line trains, train numbers are assumed to be the same for Year 2017, Year 2021 and Year 2031.

10.3.2 Estimated Noise Level Change due to Single Deck Trains

The source noise levels for single deck rapid transit trains are anticipated to be consistent with modern RailCorp trains including Waratah, Millennium and OSCAR. This is on the basis that the train length and wheel braking systems (which affect wheel condition) are likely to be similar. Whilst other factors including the wheel shape, wheel diameter, unsprung mass and the presence of side skirts can affect the source noise levels, these parameters are currently unknown for the proposed NWRL trains.

10.3.3 Estimated Noise Level Change due to Additional Trains

A change in the number of trains affects the $L_{Aeq(period)}$ noise levels, but has no effect on the L_{Amax} noise level from individual train passbys.

For train operations on the ECRL tracks, the train number information in Table 10.2 indicates that there are likely to be more trains during the daytime period in Year 2021 and Year 2031. These increases are likely to be a result of natural growth and signalling systems which facilitate a more frequent train service. The estimated train numbers during the night-time are reasonably consistent and likely to be controlled by natural growth.

Taking into consideration the overall noise levels from North Shore Line trains and train operations on the existing ECRL tracks, the estimated increase in $L_{Aeq(15hour)}$ daytime noise levels is approximately 0.8 dB between Year 2017 and Year 2021 and a further 1.0 dB between Year 2021 and Year 2031. The overall increase between Year 2017 and Year 2031 is therefore less than 2 dB.

10.3.4 Estimated Noise Level Change due to Higher Train Speeds on ECRL Tracks

For future single deck train operations on the existing ECRL tracks, upgraded signalling systems may facilitate an increase in train speeds. The maximum train speed, however is limited by the presence of crossovers, small curve radii and the proximity of stations. In the area between Chatswood Station and the ECRL tunnel portals, the existing train speed limit is 80 km/h. This may increase to a maximum speed of 100 km/h, however 90 km/h is more likely to be the maximum speed due the small curve radii at the ECRL tunnel portals at the northern end of the surface track section and Chatswood Station at the eastern end of the surface track section.

For a train speed of 90 km/h, the estimated increase in L_{Amax} and L_{Aeq} noise levels are 1.5 dB and 1.0 dB respectively. For a train speed of 100 km/h, the estimated increase in L_{Amax} and L_{Aeq} noise levels are 2.9 dB and 1.5 dB respectively.

10.3.5 Summary

Change in Night-time Noise Levels
For the section of surface track between Chatswood Station and the ECRL tunnel portals, $L_{Aeq(9hour)}$ night-time noise levels are anticipated to remain relatively unchanged. If maximum train speeds are increased from 80 km/h to 90 km/h on the existing ECRL tracks, the change in maximum noise levels (L_{Amax}) associated with individual passbys is not likely to be noticeable (ie less than 2 dB) at the nearest residences.

Change in Daytime Noise Levels
During the daytime period, $L_{Aeq(15hour)}$ noise levels are predicted to increase by approximately 0.8 dB between Year 2017 and Year 2021 and a further 1.0 dB between Year 2021 and Year 2031. This increase is a result of natural growth and signalling systems which facilitate more frequent train operations. If maximum train speeds are increased from 80 km/h to 90 km/h on the existing ECRL tracks, the change in maximum noise levels (L_{Amax}) associated with individual passbys is not likely to be noticeable (ie less than 2 dB) at the nearest residences.

Long-term Increase in Noise Levels between Year 2017 and Year 2031
Whilst the number of daytime train movements on the North Shore Line and ECRL tracks could increase from approximately 30 trains per hour in Year 2017 to 40 trains per hour in Year 2031, this increase is likely to occur gradually over a long time period in response to timetable changes. The maximum noise levels from individual train passbys is not likely to be noticeable if the speed on the ECRL tracks is increased from 80 km/h to 90 km/h.

10.4 Potential Increase in Ground-borne Noise and Vibration Levels in Buildings above ECRL tunnels

For the section of tunnel track between Epping and Chatswood, there would be a more frequent single deck train service, with NWRL trains potentially travelling at higher speeds. These changes have the potential to create additional ground-borne noise and vibration impacts within buildings above the tunnels.

As discussed in Section 6.3, there are a number of factors which can influence ground-borne noise and vibration levels. For the proposed ECRL, the propagation between the train tunnels and sensitive receiver locations will not change, however the source levels may change.

For single deck rapid transit trains, the key factors which are likely to produce a change in the ground-borne noise and vibration levels are the unsprung mass and axle load of the proposed trains and the train speed. Other factors including the wheel and rail condition, track fasteners, rail type and tunnel design are the same or not likely to change.

In relation to the unsprung mass and axle loads, these are likely to be lower for single deck rapid transit trains compared with double deck RailCorp trains. These factors would likely result in marginally lower source vibration levels for single deck rapid transit trains. This factor has not been calculated as the proposed trains for NWRL are currently unknown. The reduction in source vibration levels (also ground-borne noise levels) could be up to 2 dB.

The proposed train speeds in the ECRL tunnels could be up to 100 km/h, compared with the current maximum speed limit of 80 km/h. The corresponding increase in ground-borne noise and vibration levels is estimated be approximately 2 dB at locations where this occurs. A change of 1 dB or 2 dB in maximum (L_{Amax}) noise level is difficult for most people to detect.

In relation to the ground-borne noise and vibration criteria which form part of the ECRL Conditions of Approval (see Table 10.1), it is noted that the ground-borne noise and vibration compliance monitoring required as part of Condition 80 indicated compliance with the criteria at all locations. Furthermore, apart from one complaint received in Year 2009 (shortly after project opening – which was investigated by RailCorp and no alarms raised), no other complaints have been received by RailCorp in relation to ground-borne noise and vibration from train operations in the ECRL tunnels.

On the basis of the above assessment, it is considered unlikely that higher speed single deck train operations within the ECRL tunnels will result in a noticeable increase in ground-borne noise and vibration levels within sensitive occupancies.

11 Construction Noise and Vibration Guidelines

A detailed description of the construction noise and vibration guidelines applicable to the NWRL project is provided in the NWRL *'Construction Noise and Vibration Strategy'* (CNVS – see Appendix J). The following sections provide a brief summary of the noise and vibration guidelines applicable to the proposed construction works.

11.1 Construction Noise Metrics

The three primary noise metrics used to describe construction noise emissions in the modelling and assessments are:

- L_{Amax} (or $L_{A1(1minute)}$) — The *"typical maximum noise level"* for an event, used in the assessment of potential sleep disturbance during night-time periods.
- $L_{Aeq(15minute)}$ — The *"energy average noise level"* evaluated over a 15-minute period.
- L_{A90} — The *"background noise level"* in the absence of construction activities. This parameter represents the average minimum noise level during the daytime, evening and night-time periods respectively and is used to set the $L_{Aeq(15minute)}$ noise management levels for residential receivers.

The subscript "A" indicates that the noise levels are filtered to match normal human hearing characteristics (i.e. A-weighted).

11.2 Noise Management Levels for Surface Construction Activities

The *Interim Construction Noise Guideline* (ICNG) sets out ways to deal with the impacts of construction noise on residences and other sensitive land uses. It does this by presenting assessment approaches that are tailored to the scale of construction projects.

A portion of the main objectives from Section 1.3 of the ICNG which is consistent with the CNVS are presented below:

- Promote a clear understanding of ways to identify and minimise noise from construction works
- Focus on applying all "feasible" and "reasonable" work practices to minimise construction noise impacts
- Encourage construction to be undertaken only during the recommended standard hours unless approval is given for works that cannot be undertaken during these hours
- Streamline the assessment and approval stages and reduce time spent dealing with complaints at the project implementation stage
- Provide flexibility in selecting site-specific feasible and reasonable work practices in order to minimise noise impacts.

The ICNG contains a quantitative assessment method which is applicable to new infrastructure projects. Guidance levels are given for airborne noise at residences and other sensitive land uses, including commercial and industrial premises. For residences, guidance in relation to ground-borne noise and sleep disturbance is also provided.

The quantitative assessment method involves predicting noise levels at sensitive receivers and comparing them with the guidance, or management, levels. In this report, the “management levels” will be referred to as noise management levels (NMLs). They have been reproduced from the guideline and are presented in Table 11.1, Table 11.2 and Table 11.3.

These NMLs apply to all the construction activities and sites associated with the project, including the station sites, the viaduct section and the stabling facility.

Table 11.1 Management Levels for Airborne Construction Noise at Residences

Time of day	Noise Management Level (NML) $L_{Aeq(15minute)}$ [1,2]	How to apply
Recommended standard hours: Monday to Friday 7 am to 6 pm Saturday 8 am to 1 pm No work on Sundays or public holidays	Noise affected RBL + 10 dB	The noise affected level represents the point above which there may be some community reaction to noise. • Where the predicted or measured $L_{Aeq(15minute)}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level. • The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.
	Highly noise affected 75 dBA	The highly noise affected level represents the point above which there may be strong community reaction to noise. • Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account: – 1. Times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences. – 2. If the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.

Time of day	Noise Management Level (NML) $L_{Aeq(15minute)}$ [1,2]	How to apply
Outside recommended standard hours	Noise affected RBL + 5 dB	• A strong justification would typically be required for works outside the recommended standard hours. • The proponent should apply all feasible and reasonable work practices to meet the noise affected level. • Where all feasible and reasonable practices have been applied and noise is more than 5 dB above the noise affected level, the proponent should negotiate with the community.

Note 1 Noise levels apply at the property boundary that is most exposed to construction noise, and at a height of 1.5 m above ground level. If the property boundary is more than 30 m from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30 m of the residence. Noise levels may be higher at upper floors of the noise affected residence.
Note 2 The RBL is the overall single-figure background noise level measured in each relevant assessment period (during or outside the recommended standard hours). The term RBL is described in detail in the NSW Industrial Noise Policy (EPA 2000).

Table 11.2 Management Levels for Airborne Construction Noise at Sensitive Land Uses (other than residences)

Land Use	Noise Management Level (NML), $L_{Aeq(15minute)}$ (applies when properties are being used)
Classrooms at schools and other educational institutions	Internal noise level 45 dBA
Hospital wards and operating theatres	Internal noise level 45 dBA
Places of worship	Internal noise level 45 dBA
Active recreation areas (characterised by sporting activities and activities which generate their own noise or focus for participants, making them less sensitive to external noise intrusion)	External noise level 65 dBA
Passive recreation areas (characterised by contemplative activities that generate little noise and where benefits are compromised by external noise intrusion, for example, reading, meditation)	External noise level 60 dBA
Community centres	Depends on the intended use of the centre. Refer to the recommended “maximum” internal levels in AS2107 for specific uses.

For sensitive receivers such as schools, child care centres and places of worship, the NMLs presented in Table 11.2 are based on internal noise levels. For the purpose of this assessment, it is conservatively assumed that all schools and places of worship have openable windows. On the basis that external noise levels are typically 10 dB higher than internal noise levels when windows are open, an external $L_{Aeq(15minute)}$ NML of 55 dBA has been adopted. Where it is know that sensitive receivers have fixed glazing, a conservative external $L_{Aeq(15minute)}$ NML of 65 dBA has been adopted (on the assumption that a 20 dB reduction from outside to inside is applicable for closed windows).

The ICNG and AS2107 do not provide specific guideline noise levels for childcare centres. Childcare centres generally have internal play areas and sleep areas which are nominally used from 1 pm to 3 pm. For internal play areas a NML of $L_{Aeq(15minute)}$ 55 dBA has been adopted and for sleeping areas, an internal NML of $L_{Aeq(15minute)}$ 40 dBA (when in use) has been adopted.

On the assumption that windows and doors of childcare centres may be opened, an external NML of $L_{Aeq(15minute)}$ 65 dBA for play areas has been applied. This level of $L_{Aeq(15minute)}$ 65 dBA is also applicable to external play areas. For sleeping areas and assuming open windows, the external NML is $L_{Aeq(15minute)}$ 50 dBA.

Table 11.3 Management Levels for Airborne Construction Noise at Commercial and Industrial Premises

Land Use	Management level, $L_{Aeq(15minute)}$ (applies when properties are being used)
Offices, retail outlets	External noise level 70 dBA
Industrial premises	External noise level 75 dBA
Other noise sensitive businesses such as theatres and childcare centres	Assess on a case by case basis. Refer to the recommended “maximum” internal levels in AS 2107 for specific uses.

Tunnel ventilation fans and other fixed plant operating on a 24/7 basis may be required to support daytime operations. At these sites, noise mitigation treatments for the ventilation equipment and other fixed plant such as diesel generators and water treatment plants would be designed to meet the RBLs at the nearest residences.

The noise assessment for the major civil construction works included the associated ground-borne noise impacts from underground works such as tunnel and crossover excavation and construction. Relative to the ground-borne noise impacts of excavation works, the ground-borne noise impacts from the construction activities described in this report are minor and are therefore not considered in this report.

11.3 Construction Traffic Noise

When trucks and other vehicles are operating within the boundaries of the various construction sites, noise levels are assessed as outlined in Section 11.2. That is, road vehicle noise contributions are included in the overall predicted $L_{Aeq(15minute)}$ construction site noise emissions.

When construction related traffic moves onto the public road network a different noise assessment methodology is appropriate, as vehicle movements would be regarded as “additional road traffic” rather than as part of the construction site. The ICNG does not provide specific guidance in relation to acceptable noise levels associated with construction traffic. For assessment purposes, guidance is taken from the '*NSW Road Noise Policy'* (DECCW 2011).

One of the objectives of the *NSW Road Noise Policy* (RNP) is to protect sensitive receivers against excessive decreases in amenity as the result of a project by applying relevant permissible noise increase criteria. In assessing feasible and reasonable mitigation measures, an increase of up to 2 dB represents a minor impact that is considered barely perceptible to the average person.

On this basis, construction traffic NMLs set at 2 dB above the existing road traffic noise levels during the daytime and night-time periods are considered appropriate to identify the onset of potential noise impacts. Where the road traffic noise levels are predicted to increase by more than 2 dB as a result of construction traffic, consideration will be given to applying feasible and reasonable noise mitigation measures to reduce the potential noise impacts.

In considering feasible and reasonable mitigation measures where the relevant noise increase is greater than 2 dB, consideration will also be given to the actual noise levels associated with construction traffic and whether or not these levels comply with the following road traffic noise criteria in the RNP:

- Existing freeway / arterial / sub-arterial roads $L_{Aeq(15hour)}$ 60 dBA day and $L_{Aeq(9hour)}$ 55 dBA night
- Existing local roads $L_{Aeq(1hour)}$ 55 dBA day and $L_{Aeq(1hour)}$ 50 dBA night.

Sleep Disturbance and Maximum Noise Level Events

The EPA's most recent policy considers sleep disturbance as the emergence of the $L_{A1(1minute)}$ level above the $L_{A90(15minute)}$ level at the time. Appropriate screening criteria for sleep disturbance are determined to be an $L_{A1(1minute)}$ level 15 dB above the RBL for the night-time period (10.00 pm to 7.00 am).

When the criterion is not met, a more detailed analysis may be required which should cover the maximum noise level or $L_{A1(1minute)}$, the extent that the maximum noise level exceeds the background or RBL level and the number of times this occurs during the night-time period.

It is noteworthy that there are no specific criteria for sleep disturbance nominated in the ICNG, the INP, in the INP Application Notes, or in the RNP. Some guidance on possible impacts is contained in the RNP which contains a section on sleep disturbance that includes a summary of current literature. The RNP concludes that:

- Maximum internal noise levels below 50 dBA to 55 dBA are unlikely to cause awakening reactions
- One or two events per night, with maximum internal noise levels of 65 dBA to 70 dBA, are not likely to affect health and wellbeing significantly.

On the basis of the above guidance, ie an external sleep disturbance screening level of RBL + 15 dB, an internal sleep disturbance NML of L_{Amax} 55 dBA has been adopted, which equates to an external noise level of 65 dBA (assuming open windows).

11.4 Construction Vibration

The effects of vibration in buildings can be divided into three main categories; those in which the occupants or users of the building are concerned or possibly disturbed, those where the building contents may be affected and those in which the integrity of the building or the structure itself may be prejudiced.

Construction vibration criteria relating to human comfort and potential structural damage are provided in Appendix A of the CNVS.

In relation to human comfort, the vibration management levels are based on guidance contained in the *'Assessing Vibration – a technical guideline'* (DEC, 2006). Mitigation and management measures including consideration of alternative construction methods, attended monitoring and observance of respite periods are required in situations where vibration levels are predicted to exceed the management levels.

Structural damage vibration limits are based on Australian Standard AS 2187: Part 2-2006 *'Explosives - Storage and Use - Part 2: Use of Explosives'* and British Standard BS 7385 Part 2-1993 *'Evaluation and measurement for vibration in buildings Part 2'*. These standards provide frequency-dependent vibration limits related to cosmetic damage, noting that cosmetic damage is very minor and superficial in nature, is readily repairable and does not affect the structural integrity of the building.

In order to simplify the assessment process and provide a conservative assessment of the potential impacts associated with the proposed construction activities, a conservative vibration damage screening level of 7.5 mm/s has been adopted for the NWRL project. This level of 7.5 mm/s is also applicable to heritage structures, unless it is known that the structure is already structurally unsound – in which case, a lower screening level may be applicable. At this stage in the assessment, no heritage structures have been identified in close proximity to the NWRL alignment and which are known to be structurally unsound.

At locations where the predicted and/or measured vibration levels are greater than 7.5 mm/s, a more detailed analysis of the building structure, vibration source, dominant frequencies and dynamic characteristics of the structure would be required to determine the applicable safe vibration level.

If there is a risk that vibration levels will be greater than 7.5 mm/s and a building or structure may be damaged, building condition surveys will be undertaken prior to and following construction to record any change in building condition as a result of the construction activities.

12 Construction Noise and Vibration Assessment

12.1 Proposed Construction Activities

People are usually more tolerant to noise and vibration during the construction phase of projects than during full operations. This response results from recognition that the construction emissions are of a temporary nature – especially if the most noise-intensive construction impacts occur during the less sensitive daytime period. For these reasons, acceptable noise and vibration levels are normally less stringent during construction than during operations.

Construction often requires the use of heavy machinery which can generate high noise and vibration levels at nearby buildings and receivers. For some equipment, there is limited opportunity to mitigate the noise and vibration levels in a cost-effective manner and hence the potential impacts should be minimised by using feasible and reasonable management techniques.

At any particular location, the potential impacts can vary greatly depending on factors such as the relative proximity of sensitive receivers, the overall duration of the construction works, the intensity of the noise and vibration levels, the time at which the construction works are undertaken and the character of the noise or vibration emissions.

The construction section of this report provides an assessment of the potential noise and vibration impacts associated with those construction activities not assessed in the Environmental Impact Statement for Major Civil Construction Works (EIS 1). These activities include the construction of operational rail infrastructure, tracks and station fit-outs.

The noise assessment EIS 1 included predictions of the likely ground-borne noise and vibration associated with the initial enabling works, construction of the twin tunnels from Epping to Bella Vista, the viaduct concrete support structure from Kellyville Station to Cudgegong Road, and the bulk excavation of the underground and cut and cover stations, surface section and stabling / maintenance area. The potential ground-borne noise and vibration impacts associated with the proposed EIS 2 construction activities would be much lower compared with the EIS 1 activities. For EIS 2, the construction activities likely to generate potential vibration impacts are those associated with ground improvement works using vibratory rollers.

12.1.1 Station Construction

Station construction works include the following:

- Station platform construction and station buildings
- Elevator support structures, lifts and fire stairs
- Completion of concrete support structures (including the ‘cover’ of the underground stations)
- Car park construction
- Construction of roads for the NWRL (except those which were included in EIS 1), including access roads and landscaping works.

12.1.2 Rail Systems

Rail systems construction works includes completion of the rail operational infrastructure following the civil works handover including:

- Tunnel and station ventilation systems
- Tunnel fire and safety systems
- Track formation and track works
- Installation of overhead wire systems and cable support.

12.1.3 Stabling and Maintenance Facility

Stabling facility construction works include:

- Track formation and track works
- Installation of overhead wire systems and cable support
- Construction of the maintenance buildings.

12.1.4 Construction Program

Subject to obtaining the required planning approval, construction of the major civil construction work component of the NWRL is expected to commence in Q2 2013 and be completed at the beginning of Year 2017. Depending on the site, the 'handover' from the major construction works to the station construction and rail infrastructure works will occur progressively from Year 2016. The total period of rail systems and stations construction works assessed in this report is expected to be approximately four years. This indicative program is shown in Table 12.1.

Table 12.1 Indicative Construction Program

Activity	Commence	Complete
Station construction, fit-out and precinct works	Q3 2016	Q4 2018
Epping Services Facility fit-out	Q3 2016	Q3 2017
Cheltenham Services Facility fit-out	Q2 2016	Q3 2017
Trackwork	Q3 2016	Q4 2017
Tunnel systems fit-out	Q4 2016	Q1 2018
Surface and viaduct systems fit-out	Q3 2016	Q4 2017
Testing and commissioning	Q3 2017	Q4 2018
Operational readiness	Q1 2018	Q4 2019
Systems integration	Q4 2018	Q1 2020

12.1.5 Construction Hours

The proposed construction hours for the works are summarised in Table 12.2 and would generally be restricted to the standard daytime construction hours (7.00 am to 6.00 pm Monday to Friday and 8.00 am to 1.00 pm on Saturdays).

Table 12.2 Proposed Construction Hours

Activity	Construction Hours	Comments or Exceptions
Below Ground Construction Activities		
Trackwork, tunnel systems and tunnel rail systems	24 hours per day, seven days per week	Adverse noise impacts of works in tunnels are not anticipated – see Section 12.17. Above ground activities in support of 24 hour below ground works may be undertaken without further approval where these are determined to comply with the relevant NML at the nearest sensitive receiver.
Above Ground Construction Activities		
Construction sites	Standard daytime construction hours, being: - 7am–6pm on weekdays - 8am–1pm on Saturdays - No works on Sundays or Public Holidays	Non-disruptive preparatory work, repairs or maintenance may be carried out on Saturday afternoons or Sundays between 8am and 5pm. Activities requiring the temporary possession of roads may need to be undertaken outside the assumed hours during periods of low traffic to minimise safety impacts and inconvenience to commuters. Activities requiring rail possessions may need to be undertaken outside the standard construction hours up to 24 hours per day, seven days per week.
Construction Traffic	Standard daytime construction hours, being: - 7am–6pm on weekdays - 8am–1pm on Saturdays No works on Sundays or Public Holidays	Restrictions would be in place during peak hours and during special events.

Works which would be undertaken outside of standard construction hours without any further approval include:

- Works which are determined to comply with the relevant Noise Management Level (NML) at the nearest sensitive receiver
- Works required to be undertaken during rail possessions
- The delivery of materials outside of approved hours as required by the Police or other authorities (including Roads and Maritime Services) for safety reasons
- Where it is required to avoid the loss of lives, property and/or to prevent environmental harm in an emergency.

With the exception of emergency, activities would not take place outside standard hours without prior discussion with and/or notification of local residents, businesses and the EPA.

12.2 Construction Noise and Vibration Strategy

A *'Construction Noise and Vibration Strategy'* (CNVS) has been developed by the NWRL project team and will be adopted by all contractors to manage construction noise and vibration across the various construction sites. In preparing this strategy, consideration has been given to several guideline documents including the *'Interim Construction Noise Guideline'* (DECC 1999), Transport Construction Authority's (TCA's) *'Construction Noise Strategy'*, Australian Standard AS 2436-2010 *'Guide to noise and vibration control on construction, demolition and maintenance sites'* and the *'Road Noise Policy'* (DECCW 2011).

The CNVS documents the best-practice techniques specific to the NWRL project for managing construction noise and vibration, and implementing feasible and reasonable mitigation measures.

In addition to the site specific mitigation measures identified in this report, the CNVS includes a standard suite of mitigation measures to be implemented across all NWRL construction sites (such as periodic notification of proposed works, adherence to construction respite periods, use of non-tonal reversing alarms, etc). It also includes additional mitigation and management measures when construction noise is predicted to exceed the NMLs (such as noise monitoring, individual briefings, respite offers and in some instances at night, alternative accommodation). These measures are primarily aimed at pro-active engagement with affected sensitive receivers.

In addition to the mitigation measures described in the CNVS, contractors may introduce further measures or mitigation strategies to reduce noise and vibration impacts at sensitive receivers.

The CNVS is provided in Appendix J.

12.3 Assessment Requirements

Section 7.2.1 of the ICNG provides a summary of the noise and vibration assessment requirements for the pre-approval stage of projects. The guideline notes that the impact assessment can be either quantitative or qualitative, depending on the size, complexity and expected impacts of the proposal. As the NWRL proposal is a major infrastructure project, the noise and vibration assessment in the following sections is based on quantitative modelling.

For large complex proposals (such as NWRL), the guideline notes that the EIS will *"typically involve a conceptual description of feasible and reasonable work practices that can be applied to minimise noise* [and vibration] *impacts. This is made based on preliminary understanding of the expected noise* [and vibration] *impact from proposed construction works and any changes made in response to comments received during public consultation on the proposal."*

The guideline notes that the following issues should be considered in preparing the EIS documentation:

- Description of proposed works, including a discussion of alternate construction methods and justification for selected method. Clear justification of proposed works to be undertaken outside the recommended standard hours must be given.
- Identification of the residences and other sensitive land uses near the works.
- Description of proposed total duration of noise exposure at the identified assessment locations from the proposed works.

- Discussion of expected noise or blasting impacts at the most noise-exposed residences and other sensitive land uses. If a quantitative method is used, the predicted noise levels from the proposed construction works should be presented. A discussion of any community consultation undertaken in assessing the noise impacts should be included.
- Discussion of feasible and reasonable work practices and mitigation measures that will be applied to minimise noise impacts from the works.
- Changes to the proposal in response to submissions and representations received.

At this stage in the assessment, a discussion of the proposed mitigation measures has not been undertaken with specific sensitive receivers near the proposed works. Any changes to the proposed mitigation measures as a result of the community consultation to be undertaken as part of the public exhibition of the EIS will be incorporated into the submissions report.

12.4 Overview of Construction Noise and Vibration Modelling

12.4.1 Airborne Construction Noise Modelling

In order to quantify the likely construction noise emissions, a three-dimensional computer noise model was prepared for each major construction site.

Airborne noise modelling was undertaken using the CONCAWE industrial noise algorithm as implemented in the SoundPLAN Version 7 acoustic modelling software. The model for these sites includes source noise emission levels, ground topography, location of sources and receivers, acoustic shielding provided by intervening ground topography, air absorption, ground effects and the duration of equipment usage within the assessment period. The noise modelling algorithms are consistent with the noise prediction process recommended in Australian Standard AS 2436-2010 *‘Guide to noise and vibration control on construction, demolition and maintenance sites’*.

Ground topography (2 m contour intervals) was provided by the NWRL project team, and construction site layouts were based on the worksite drawings described in the EIS.

L_{Amax} sound power levels for equipment assumed in the modelling are presented in Table 12.3. The sound power levels are maximum noise emission levels of plant that will or may be used on this project in typical operation.

In order to apply the construction NMLs for the project, it is necessary to convert these maximum power levels to equivalent $L_{Aeq(15minute)}$ sound pressure levels.

From numerous field studies on large construction projects, the measured difference values between the L_{Amax} and $L_{Aeq(15minute)}$ noise levels have been found to be up to 10 dB depending on the mixture of the plant, intensity of operation and location of the plant relative to the receiver.

In the present study, where the equipment is generally confined to the station area and the receivers are relatively close, typical adjustments of 2 dB to 5 dB have been conservatively applied during conversion of the L_{Amax} power levels shown in Table 12.3 to $L_{Aeq(15minute)}$ sound pressure levels for comparison with the construction NMLs.

The proposed equipment used at the station sites will be a subset of that presented in Table 12.3, with the station noise models using sound power levels (SWLs) per activity and plant operating loads and cycles, based on the maximum noise levels presented in Table 12.3.

Table 12.3 Summary of Maximum Sound Power Levels used for Demolition, Excavation and Construction Equipment

Plant Item	L_{Amax} Sound Power Level (dBA)	L_{Amax} Sound Pressure Level @ 7 m (dBA)
Dump Truck	108	83
Excavator (approximately 20 tonnes)	105	80
Excavator (approximately 30 tonnes)	110	85
Excavator (approximately 40 tonnes)	115	90
Front End Loader	111	86
Compactor	105	80
Scraper	110	85
Grader	110	85
Water Cart	108	83
Concrete Saw	118	93
Jackhammer	113	88
Mobile Crane	110	85
Generator	104	79
Concrete Pump	109	84
Compressor	105	80
Vibratory Roller	114	89
Hirail Boom Lift	107	76
Water Pump	108	83

Note 1 The sound power levels presented are based on the NWRL *Construction Noise and Vibration Strategy* (CNVS).

Note 2 In accordance with the *Interim Construction Noise Guideline* for activities identified as particularly annoying (such as jack hammering, rock breaking and power saw operation), a 5 dB “penalty” is added to the source sound power level when predicting noise using the quantitative method.

Modelling of Construction Sites

At the underground station sites, activities representative of the typical noise emissions expected to occur during the works are:

- Station construction including platform and support structure concreting and above ground car park construction. Typical equipment includes concrete trucks and vibrators, machinery, cranes and hand tools.
- Station rail systems construction, including track formation, installation of tunnel and station ventilation systems. Typical equipment includes delivery trucks, cranes and hand tools.

At the above ground station sites, activities representative of the typical noise emissions are expected to be similar to those at the underground station sites:

- Station construction including platform and support structure concreting and car park construction. Typical equipment includes concrete trucks and vibrators, cranes and hand tools.
- Station rail systems construction, including track formation, installation of tunnel and station ventilation systems. Typical equipment includes delivery trucks, cranes and hand tools.

At the viaduct section of the rail alignment, activities representative of the typical noise emissions expected to occur during the project are:

- Concrete pouring, installation of stanchions and track construction
- Installation of overhead cabling.

Consistent with the requirements of the ICNG, the construction noise impacts are based on a worst-case assessment. The guideline recommends that the realistic worst-case or conservative noise levels from the source should be predicted for assessment locations representing the most noise-exposed residences or other sensitive land uses. For each construction site, residences and other sensitive receivers have been grouped together into receiver areas or ‘catchments’, which comprise those receivers which will experience a similar level of construction noise. For each receiver area the noise levels are predicted at the most noise-exposed location, which will usually be the closest receiver.

For most construction activities, it is expected that the construction noise levels will frequently be lower than predicted at the most-exposed receiver - as the noise levels presented in this report are based on a realistic worst-case assessment.

Furthermore, other receivers within each receiver area will generally experience lower noise levels compared to the most noise-exposed location. To provide an indication of the likely reduction in construction noise levels, the following can be assumed:

- A doubling of the distance between the source and receiver will provide an approximate 6 dB reduction in noise level. For example the sound pressure levels presented in Table 12.3 will decrease by typically 6 dB as the distance increases to 15 m and by 12 dB as the distance increases to 30 m.
- Buildings and other solid structures located between the construction noise source and sensitive receivers will act as barriers and will typically reduce noise levels by up to 15 dB. For example, in a residential area adjoining a construction site the first row of houses will provide an effective shield to the second and subsequent rows with resulting noise levels up to 10 dB lower than would otherwise be experienced in the absence of the first row.

Noise Mitigation

For the station sites, the major civil works assessment proposed the construction of noise barriers (hoardings) around the perimeters of the construction sites (3 m high). This ‘default’ 3 m site perimeter solid timber fence has been assumed in the calculations.

12.4.2 Construction Traffic Noise Modelling

The calculations of traffic noise on public roads for comparison with the criteria presented in Section 11.3 have been performed using two modelling methods. The models used are Calculation of Road Traffic Noise (CORTN), which has been specifically validated under Australian conditions, and the L_{Aeq} calculation based on the US Environmental Protection Agency - Report 550/9-74-004 (1974). Use of the latter L_{Aeq} calculation recognises that the CORTN algorithms are not valid for low traffic flows. The models predict traffic noise levels at the receiver based on traffic volumes, percentage of heavy vehicles, vehicle speed and distance to the receiver.

12.4.3 Construction Vibration Modelling

During construction, the major potential sources of vibration emission include vibratory rollers and other large construction plant and equipment.

As discussed in Section 11.4, a conservative cosmetic vibration damage screening level of 7.5 mm/s has been adopted for the NWRL project. Table 12.4 provides a summary of the indicative "safe working distances" for the plant items likely to be used for the major civil construction works. The safe working distances are less than those identified in Section 3.3 of the CNVS (refer Appendix J) on the basis of the conservative nature of the 7.5 mm/s screening level.

If there is a risk of the 7.5 mm/s screening level being exceeded, the following control measures will be put in place:

- If there is a risk that a building or structure may be damaged (including minor cosmetic damage), building condition surveys will be undertaken prior to and following construction to record any change in building condition as a result of the construction activities
- The safe working distances for cosmetic damage must be complied with at all times, unless otherwise approved by the relevant authority
- Attended vibration measurements are required at the commencement of vibration generating activities to confirm that vibration levels are within the acceptable range to prevent cosmetic building damage.

For daytime construction activities involving vibration generating equipment such as vibratory rollers, there is potential for human comfort vibration levels to be exceeded within nearby residences. The potential vibration impacts upon building occupants will be assessed on a case-by-case basis in accordance with the guidance in the CNVS during the detailed design and construction stage.

Table 12.4 Safe Working Distances - Cosmetic Damage (based on 7.5 mm/s screening level)

Plant Items	Indicative Safe Working Distance
Vibratory Roller - 10 Tonne	6 m
Vibratory Trench Roller - 3 Tonne	1 m

12.4.4 Construction Site Layouts

In the following report sections, an aerial photograph is provided for each construction site. The aerial photographs have been marked up to identify the construction site boundaries and nearest receivers. For these construction sites and receiver plans, the following colour coding has been adopted:

- Orange — Construction site
- Blue — Residential receivers
- Green — Other sensitive receivers including places of worship, child care centres, performance venues, commercial receivers and the like.

12.5 Epping Services Facility

12.5.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Epping sites and the surrounding receiver areas is provided in Figure 12.1, with the nearest noise sensitive receivers identified in Table 12.5. The Epping services facility is located to the west of Beecroft Road. The Epping services facility site is ultimately proposed to be a tunnel ventilation and emergency access and egress facility.

The proposed construction works would include delivery of material and transportation to the rail tunnels, construction of the services facility building and the installation of rail systems equipment. Access to the site would be via a left-in, left-out arrangement directly from Beecroft Road as well as an access point on Ray Road. At this site the construction works assessed in this report are expected to take place over approximately two years commencing around Q3 2016.

Figure 12.1 Epping Services Facility Site and Receiver Areas

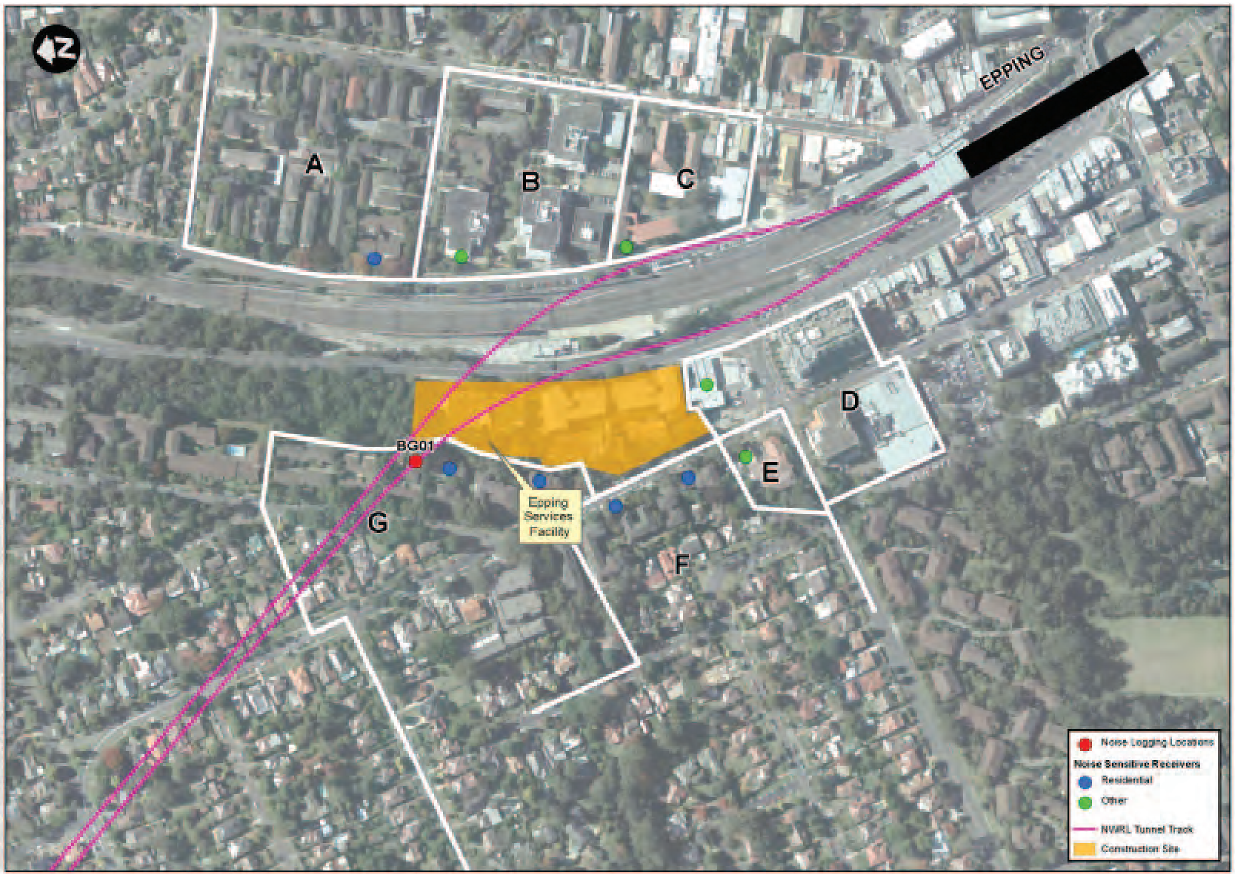


Table 12.5 Nearest Noise Sensitive Receivers – Epping Services Facility

Receiver Area	Location Relative to Works (m)[1]
A – Residences Cambridge Street	110
B – Commercial Cambridge Street	105
C – School	105
D – Commercial adjacent	5
E – Epping Baptist Church	30
F – Residences Ray Road	20
G - Residences Edensor Street/Ray Rd	5

Note 1 The relative distance to works is that from the nearest sensitive receiver to the closest location of construction activity.

12.5.2 Site Specific Construction Noise Management Levels

With reference to the ambient noise survey results summarised in Table 4.2, the site specific construction NMLs are presented in Table 12.6.

Table 12.6 Epping Services Facility Site Construction NMLs

Receiver Area	Receiver Type	Relevant Monitoring Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
			Daytime	Evening	Night-time
A	Residential	BG01	55	46	37
B	Commercial	BG01	70	N/A	N/A
C	Educational (School)	BG01	55	N/A	N/A
D	Commercial	BG01	70	N/A	N/A
E	Church	BG01	65	65	-
F	Residential	BG01	55	46	37
G	Residential	BG01	55	46	37

12.5.3 Noise Assessment at the Nearest Noise Sensitive Receivers

Scenarios were developed for the daytime, evening and night-time periods, to be representative of activities having potentially the greatest noise impact on the surrounding receivers. These scenarios are:

- Delivery of materials
- Services building and supporting structure construction
- Installation of rail systems equipment.

Calculations of the typical $L_{Aeq(15minute)}$ noise levels at the nearest noise sensitive receivers (at ground floor level) are provided in Appendix K and the predicted noise level exceedances are summarised in Table 12.7.

Discussion

The noise levels for each scenario have been considered separately. The findings of the construction noise impact assessment at the Epping Services Facility Site indicate the following:

- The predicted noise levels for delivery of materials indicate compliance with the NMLs at all residential receivers.
- At the nearest commercial receivers, the school and church, compliance with the NMLs is predicted during the delivery of materials.
- The predicted noise levels for the services building and supporting structure construction indicate exceedances of the NMLs for construction of between 10 dB and 20 dB at the nearest receivers in Area G. At all other residential receivers, compliance with the NMLs is predicted.
- During the installation of rail services, there is a predicted exceedance of the NML of up to 10 dB at Area F. At all other residential receivers, compliance with the NMLs is predicted.

- At the nearest commercial receivers, the school and church, compliance with the NMLs is predicted during both services building construction and supporting structure construction, as well as during the installation of rail systems.

Table 12.7 Predicted noise level exceedances at Epping Services Facility

Receiver Area	Noise Modelling Scenario		
	Epping services facility – services facility building construction	Epping services facility – rail systems installation	Epping decline tunnel – delivery of materials
A – Residences Cambridge Street			
B – Commercial Cambridge Street			
C – School			
D – Commercial adjacent			
E – Epping Baptist Church			
F – Residences Ray Road			
G - Residences Edensor Street/Ray Rd			

Legend

Compliance	≤ 10 dB exceedance	10 dB to ≤ 20 dB exceedance	> 20 dB exceedance or $L_{Aeq(15minute)}$ > 75 dBA

Approximate durations: building construction 12 months from Q3 2016, rail systems installation 15 months from Q3 2016 (followed by testing and commissioning), delivery of materials 24 months (throughout).

12.5.4 Vibration Assessment

No vibration impacts are predicted for the Epping services facility site as a result of the construction activities assessed in EIS2.

12.5.5 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access routes to the Epping services facility site. In this instance, the access to the site is via Carlingford and Beecroft Roads which are sub-arterial roads as well as via Ray Road which is a local road. Carlingford Road, Beecroft Road and Ray Road have daytime flows significantly higher than the traffic generated by the site resulting in predicted traffic noise level increases of less than 0.1 dB. The assessment results in compliance with the 2 dB allowance.

12.6 Cheltenham Services Facility

12.6.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Cheltenham services facility and the surrounding receiver areas is provided in Figure 12.2, with the nearest noise sensitive receivers identified Table 12.8. As illustrated in Figure 12.2, the Cheltenham services facility is located to the west of Cheltenham Oval and north of the M2 motorway.

Construction activities will include construction of the services facility building, the installation of rail systems equipment and reinstatement of recreational facilities.

At this site the construction works assessed in this report are expected to take place over approximately two years commencing around Q3 2016.

Light vehicle access is proposed to be directly on and off Castle Howard Road. Two options are currently being investigated for heavy vehicle access, which are:

- Access on and off Kirkham Road. This option would require a new intersection to be developed on Kirkham Road and the establishment of an access road through bushland to the proposed site.
- Access directly on an off the M2 motorway. This option would require the construction of new on and off ramps to the motorway.

It is anticipated an acoustic enclosure will be constructed to house the construction ventilation system as part of the major civil works which would remain while rail systems and infrastructure works continue in the tunnel below.

Table 12.8 Nearest Noise Sensitive Receivers – Cheltenham Services Facility

Receiver Area	Location Relative to Works (m)[1]
A - Residences north east of Castle Howard Road, between Oaklands Road and Murray Road	125
B - Residences north east of Castle Howard Road, between Murray Road and Lyne Road, in addition to the residences on the south west of Castle Howard Road, adjacent to the tennis courts	30
C - Residences south of the M2 Motorway, south and east of vegetated area bordering Kerry Avenue and Merinda Avenue	155
D - Residences south of the M2 Motorway, north and west of the vegetated area bordering Kerry Avenue and Merinda Avenue	110
E - Cheltenham Oval	15

Note 1 The relative distance to works is that from the nearest sensitive receiver to the closest location of construction activity.

Figure 12.2 Cheltenham Services Facility and Receiver Areas

12.6.2 Site Specific Construction Noise Management Levels

With reference to the ambient noise survey results summarised in Table 4.2, the site specific construction NMLs are presented in Table 12.9.

Table 12.9 Cheltenham Services Facility Construction NMLs

Receiver Area	Receiver Type	Relevant Monitoring Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
			Daytime	Evening	Night-time
A	Residential	BG02	59	46	36
B	Residential	BG02	59	46	36
C	Residential	BG03	65	57	40
D	Residential	BG03	65	57	40
E	Active Recreational (Oval)	BG02	65	N/A	N/A

12.6.3 Noise Assessment at the Nearest Noise Sensitive Receivers

Scenarios were developed for the daytime, evening and night-time periods, to be representative of activities having potentially the greatest noise impact on the surrounding receivers. These scenarios are:

- Services building and supporting structure construction
- Installation of rail systems equipment.

The typical $L_{Aeq(15minute)}$ noise levels at the nearest noise sensitive receivers (at ground floor level) are provided in Appendix K and the predicted noise level exceedances are summarised in Table 12.10.

Discussion

The findings of the construction noise impact assessment at Cheltenham Services Facility indicate:

- The predicted noise levels for construction of the services building and supporting structure, and for the installation of rail systems equipment, indicate exceedances of the NMLs of up to 10 dB for these two scenarios at the nearest receivers in Area B. At all other receivers, compliance with the NMLs is predicted.

Table 12.10 Predicted noise level exceedances at Cheltenham services facility

Receiver Area	**Noise Modelling Scenario**	
	Cheltenham – services facility building construction	Cheltenham – rail systems installation
A - Residences north east of Castle Howard Road, between Oaklands Road and Murray Road	Compliance	Compliance
B - Residences north east of Castle Howard Road, between Murray Road and Lyne Road, in addition to the residences on the south west of Castle Howard Road, adjacent to the tennis courts	≤ 10 dB exceedance	≤ 10 dB exceedance
C - Residences south of the M2 Motorway, south and east of vegetated area bordering Kerry Avenue and Merinda Avenue	Compliance	Compliance
D - Residences south of the M2 Motorway, north and west of the vegetated area bordering Kerry Avenue and Merinda Avenue	Compliance	Compliance
E - Cheltenham Oval	Compliance	Compliance

Legend

Compliance	≤ 10 dB exceedance	10 dB to ≤ 20 dB exceedance	> 20 dB exceedance or $L_{Aeq(15minute)}$ > 75 dBA

Approximate durations: building construction 12 months from Q3 2016, rail systems installation 12 months from Q3 2016 (followed by testing and commissioning).

12.6.4 Vibration Assessment

No vibration impacts are predicted for the Cheltenham services facility site as a result of the construction activities assessed in EIS2.

12.6.5 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access routes to the Cheltenham services facility. In this instance, the access to the sites is via either the M2 or Kirkham Roads which are arterial and sub-arterial roads with significant daytime flows. The assessment results in compliance with the 2 dB allowance.

12.7 Cherrybrook Station

12.7.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Cherrybrook Station site and the surrounding receiver areas is provided in Figure 12.3, with the nearest noise sensitive receivers identified in Table 12.11.

Figure 12.3 Cherrybrook Station Construction Site and Receiver Areas

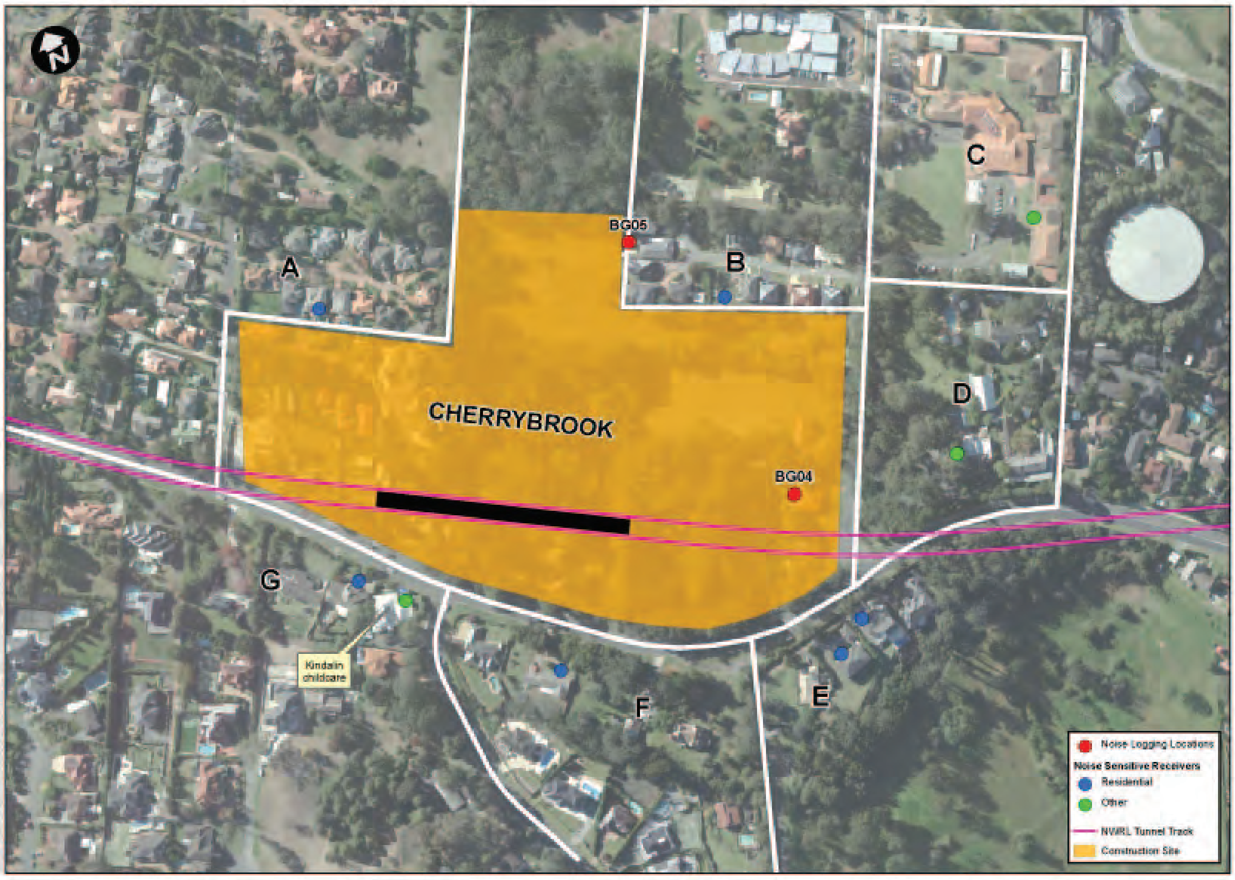


Table 12.11 Nearest Noise Sensitive Receivers – Cherrybrook Station

Receiver Area	Location Relative to Works (m)[1]
A - Residences on Robert Road and Oliver Way to the east and north	7
B - Residences on Kayla Way to the north-east	7
C - Tangara School	130
D - Inala School	80
E - Residences on and south of Castle Hill Road, east of Staley Circuit	35
F - Residences south of Castle Hill Road, between Staley Circuit and Glenhope Road	35
G - Residences south of Castle Hill Road, west of Glenhope Road	30
G – Kindalin Childcare	30

Note 1 The relative distance to works is that from the nearest sensitive receiver to the closest location of construction activity.

Works at the Cherrybrook Station site will include the station platform, support structure and building construction. In addition, there are at ground car parking areas to be constructed north of the station. Rail systems works include installation of track work, overhead wiring and station and tunnel ventilation equipment. At this site the construction works assessed in this report are expected to take place over approximately 21 months commencing around Q3 2016.

12.7.2 Site Specific Construction Noise Management Levels

With reference to the ambient noise survey results summarised in Table 4.2, the site specific construction NMLs are presented in Table 12.12.

Table 12.12 Cherrybrook Station Construction NMLs

Receiver Area	Receiver Type	Relevant Monitoring Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
			Daytime	Evening	Night-time
A	Residential	BG05	47	43	35
B	Residential	BG05	47	43	35
C	Educational (School)	BG05	55	N/A	N/A
D	Educational (School)	BG04	55	N/A	N/A
E	Residential	BG04	55	46	39
F	Residential	BG04	55	46	39
G	Residential	BG04	55	46	39
G	Childcare	BG04	50	N/A	N/A

12.7.3 Noise Assessment at the Nearest Noise Sensitive Receivers

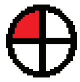
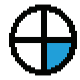
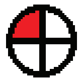
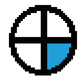
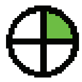
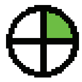
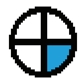
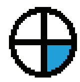
Scenarios were developed to be representative of activities having potentially the greatest noise impact on the surrounding receivers. These scenarios are:

- Station platform supporting structure, station building construction

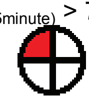
- Car park construction
- Installation of rail systems equipment.

Calculations of the typical $L_{Aeq(15minute)}$ noise levels at the nearest noise sensitive receivers (at ground floor level) are provided in Appendix K and the predicted noise level exceedances are summarised in Table 12.13. The predicted noise levels include the effects of a perimeter noise wall of 3 m as recommended for the major civil works.

Table 12.13 Predicted noise level exceedances at Cherrybrook Station

Receiver Area	**Noise Modelling Scenario**		
	Station platform supporting structure, station building construction	Car park construction	Installation of rail systems equipment.
A - Residences on Robert Road and Oliver Way to the West and North			
B - Residences on Kayla Way to the north-east			
C - Tangara School			
D - Inala School			
E - Residences on and south of Castle Hill Road, east of Staley Circuit			
F - Residences south of Castle Hill Road, between Staley Circuit and Glenhope Road			
G - Residences south of Castle Hill Road, west of Glenhope Road			
G – Kindalin Childcare Centre			

Legend

Compliance	≤ 10 dB exceedance	10 dB to ≤ 20 dB exceedance	> 20 dB exceedance or $L_{Aeq(15minute)}$ > 75 dBA
			

Approximate durations: station structural works 12 months from Q3 2016, car park or precinct works 12 months from Q2 2017, rail systems installation 12 months from Q3 2016 (followed by testing and commissioning).

Discussion

The findings of the construction noise impact assessment at Cherrybrook Station indicate:

- The predicted noise levels for the construction of the car park indicate high exceedances of the NMLs at the residential areas adjacent to the site. The NMLs are exceeded by more than 20 dB at Areas A and B.
- There are minor exceedances during construction of the station platform supporting structure and station building construction at Areas A, B and G, and at the Kindalin childcare centre. Compliance is predicted at the remaining residential areas and the two schools.
- During the installation of rail systems equipment, predicted noise levels indicate minor exceedances of the NMLs during the daytime period at the residential Areas A, B, G and the Kindalin childcare centre. Compliance is predicted at the remaining residential areas, as well as at the two schools.
- Where receivers are "highly noise affected" (i.e. where the predicted noise levels exceed 75 dBA) or the NMLs are exceeded by more than 20 dB, the proponent may need to implement respite periods and liaise with the community as outlined in Table 11.1. The CNVS would be implemented to manage the potential noise impacts. At Cherrybrook this is anticipated to occur during the construction of the car parks north of the station.

12.7.4 Vibration Assessment

During vibratory roller activities at the Cherrybrook Station car park sites, vibration levels may be perceptible at the nearest residential receivers. On the basis that the nearest residential buildings are approximately 15 m from the proposed car park areas, vibration levels are anticipated to be remain well below the safe vibration levels associated with minor cosmetic building damage.

12.7.5 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access routes to the Cherrybrook Station site. In this instance the access to the site is via Castle Hill Road which is a sub-arterial road with significant daytime flows. The assessment results in compliance with the 2 dB allowance.

12.8 Castle Hill Station

12.8.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Castle Hill Station site and the surrounding receiver areas is provided in Figure 12.4, with the nearest noise sensitive receivers identified in Table 12.14.

Works at the Castle Hill Station site will include the station platform, support structure and building construction. In addition there are works associated with the re-instatement of Old Northern Road and bus parking to be constructed south of the station. Rail systems works include installation of track work, overhead wiring and station and tunnel ventilation equipment to the north east of the station.

At this site the construction works assessed in this report are expected to take place over approximately 18 months commencing around Q2 2017.

Figure 12.4 Castle Hill Station Construction Site and Receiver Areas

Table 12.14 Nearest Noise Sensitive Receivers - Castle Hill Station

Receiver Area	Location Relative to Works (m)[1]
A – Commercial NW Castle Hill Shopping Centre	20
B – Commercial adjoining North	2
C – Residences McMullen Avenue North East	30
D – Residences Brisbane Road South East	46
E – Residences Old Northern Road South	35
F - Commercial Old Northern Road South	10

Note 1 The relative distance to works is that from the nearest sensitive receiver to the closest location of construction activity.

12.8.2 Site Specific Construction Noise Management Levels

With reference to the project NMLs and the ambient noise survey results summarised in Table 4.2, the site specific construction NMLs are presented in Table 12.15.

Table 12.15 Castle Hill Station Construction NMLs

Receiver Area	Receiver Type	Relevant Monitoring Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
			Daytime	Evening	Night-time
A	Commercial	BG06	70	N/A	N/A
B	Commercial	BG06	70	N/A	N/A
C	Residential	BG06	60	52	36
D	Residential	BG06	60	52	36
E	Residential	BG06	60	52	36
F	Commercial	BG06	70	N/A	N/A

12.8.3 Noise Assessment at the Nearest Noise Sensitive Receivers

Scenarios were developed for the daytime, evening and night-time periods, representative of activities having potentially the greatest noise impact on the surrounding receivers. These scenarios are:

- Station platform supporting structure and station building construction
- Installation of rail systems equipment.

The typical $L_{Aeq(15minute)}$ noise levels at the nearest noise sensitive receivers (at ground floor level) are provided in Appendix K and the predicted noise level exceedances are summarised in Table 12.16.

Table 12.16 Predicted noise level exceedances at Castle Hill Station

Receiver Area	**Noise Modelling Scenario**	
	Station platform supporting structure, station building construction and roadworks	Installation of rail systems equipment.
A – Commercial NW Castle Hill Shopping Centre	⊕	⊕
B – Commercial adjoining North	⊕	⊕
C – Residences Garthowen Crescent and Old Northern Road North East	⊕	⊕
C – Commercial McMullen Avenue North East	⊕	⊕
D – Residences Brisbane Road South East	⊕	⊕
E – Residences Old Northern Road South	⊕	⊕
F - Commercial Old Northern Road South	⊕	⊕

Legend

Compliance	≤ 10 dB exceedance	10 dB to ≤ 20 dB exceedance	> 20 dB exceedance or $L_{Aeq(15minute)}$ > 75 dBA
⊕	⊕	⊕	⊕

Approximate durations: station structural works 9 months from Q2 2017, rail systems installation 12 months from Q3 2017 (followed by testing and commissioning).

Discussion

The findings of the construction noise impact assessment at Castle Hill Station indicate:

- The predicted noise levels for construction of the station platform supporting structure and station building indicate a minor exceedance of up to 10 dB at commercial Area B. Compliance is predicted at the other commercial receivers and all residential areas.
- During the installation of rail systems equipment compliance is predicted at all residential and commercial receivers.

12.8.4 Vibration Assessment

During vibratory roller activities associated with the reinstatement of bus parking and old northern road at the Castle Hill Station, vibration levels may be perceptible at the nearest commercial receivers. On the basis that the nearest buildings are approximately 10 m from the proposed works, vibration levels are anticipated to remain below the safe levels associated with minor cosmetic building damage.

12.8.5 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access routes to the Castle Hill Station Site. In this instance the access to the site is via Old Northern Road and Terminus Street, which are sub-arterial roads with significant daytime flows. The assessment results in compliance with the 2 dB allowance.

12.9 Showground Station

12.9.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Showground Station site and the surrounding receiver areas is provided in Figure 12.5, with the nearest noise sensitive receivers identified in Table 12.17.

Works at the Showground site will include station platform, support structure and building construction. In addition there is a multilevel car park to be constructed west of the station. Rail systems works include installation of track work, overhead wiring and station and tunnel ventilation equipment.

At this site the construction works assessed in this report are expected to take place over approximately 18 months commencing around Q2 2017.

Figure 12.5 Showground Construction Site and Receiver Areas

Table 12.17 Nearest Noise Sensitive Receivers - Showground

Receiver Area	Location Relative to Works (m)[1]
A – Commercial adjoining South West	35
B – Commercial adjoining North West	140
C – Active Recreation – Castle Hill Showground	5
D – Residences Showground Road North East	40
E – Residences Carrington Road South	30
E – Childcare Carrington Road South	30

Note 1 The relative distance to works is that from the nearest sensitive receiver to the closest location of construction activity.

12.9.2 Site Specific Construction Noise Management Levels

With reference to the project NMLs and the ambient noise survey results summarised in Table 4.2, the site specific construction NMLs are presented in Table 12.18.

Table 12.18 Showground Construction NMLs

Receiver Area	Receiver Type	Relevant Monitoring Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
			Daytime	Evening	Night-time
A	Commercial	BG08	70	N/A	N/A
B	Commercial	BG08	70	N/A	N/A
C	Active Recreation	BG07	65	N/A	N/A
D	Residential	BG07	64	53	35
E	Residential	BG08	64	50	39
E	Childcare	BG08	50	N/A	N/A

12.9.3 Noise Assessment at the Nearest Noise Sensitive Receivers

Scenarios were developed for the daytime, evening and night-time periods, to be representative of activities having potentially the greatest noise impact on the surrounding receivers. These scenarios are:

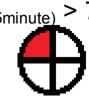
- Station platform supporting structure, station building construction and car park construction
- Installation of rail systems equipment.

The typical $L_{Aeq(15minute)}$ noise levels at the nearest noise sensitive receivers (at ground floor level) are provided in Appendix K and the predicted noise level exceedances are summarised in Table 12.19.

Table 12.19 Predicted noise level exceedances at Showground Station

Receiver Area	Noise Modelling Scenario	
	Station platform supporting structure, station building construction and car park	Installation of rail systems equipment
A – Commercial adjoining SW		
B – Commercial adjoining NW		
C – Active Recreation – Castle Hill Showground		
D – Residences Showground Road North East		
E - Residences Carrington Road South		
E – Childcare Carrington Road South		

Legend

Compliance	≤ 10 dB exceedance	10 dB to ≤ 20 dB exceedance	> 20 dB exceedance or $L_{Aeq(15minute)}$ > 75 dBA
			

Approximate durations: station structural works 9 months from Q2 2017, rail systems installation 12 months from Q3 2017 (followed by testing and commissioning).

Discussion

The findings of the construction noise impact assessment at Showground Station indicate:

- The predicted noise levels for construction of the station platform supporting structure, station building and car park as well as for the installation of rail systems indicate compliance with the NMLs at both the commercial and residential areas adjacent to the site.
- At the childcare centre there is a moderate exceedance of 11 dB during construction of the station platform supporting structure, station building and car park and a minor exceedance of 6 dB during the installation of rail systems.

12.9.4 Vibration Assessment

During vibratory roller activities at the Hill Centre Station access roads, vibration levels may be perceptible at the nearest commercial receivers. On the basis that the nearest buildings are approximately 10 m from the proposed access roads, vibration levels are anticipated to be below the safe vibration levels associated with minor cosmetic building damage.

12.9.5 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access routes to the Showground Station site. In this instance, the access to the site is via Showground Road and Carrington Road, which are sub-arterial roads with significant daytime flows. The assessment results in compliance with the 2 dB allowance.

12.10 Norwest Station

12.10.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Norwest Station site and the surrounding receiver areas is provided in Figure 12.6, with the nearest noise sensitive receivers identified in Table 12.20.

Works at the Norwest Station site will include the station platform, support structure and building construction. Access will be via the services/support access at each end of the station box, with concreting and rail systems activities at these areas. Rail systems works include installation of track work, overhead wiring and station and tunnel ventilation equipment south east of, and at each end of the station.

At this site the construction works assessed in this report are expected to take place over approximately 18 months commencing around Q3 2016.

Figure 12.6 Norwest Construction Site and Receiver Areas

Table 12.20 Nearest Noise Sensitive Receivers - Norwest

Receiver Area	Location Relative to Works (m)[1]
A – Commercial	15
B – Residences	65
C – Hillsong Church site (church)	150
C – Hillsong Church site (recording studio)	150
D – Commercial	15

Note 1 The relative distance to works is that from the nearest sensitive receiver to the closest location of construction activity.

12.10.2 Site Specific Construction Noise Management Levels

With reference to the project NMLs and the ambient noise survey results summarised in Table 4.2, the site specific construction NMLs are presented in Table 12.21.

Table 12.21 Norwest Construction NMLs

Receiver Area	Receiver Type	Relevant Monitoring Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
			Daytime	Evening	Night-time
A	Commercial	BG06	70	N/A	N/A
B	Residential	BG06	57	50	43
C	Other (Church)	BG06	65	65	-
D	Commercial	BG06	70	N/A	N/A

12.10.3 Noise Assessment at the Nearest Noise Sensitive Receivers

Scenarios were developed for the daytime, evening and night-time periods, to be representative of activities having potentially the greatest noise impact on the surrounding receivers. These scenarios are:

- Station building and support structure construction
- Installation of rail systems equipment.

The typical $L_{Aeq(15minute)}$ noise levels at the nearest noise sensitive receivers (at ground floor level) are provided in Appendix K and the predicted noise level exceedances are summarised in Table 12.22.

Discussion

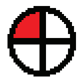
The findings of the construction noise impact assessment at Norwest Station indicate:

- The predicted noise levels for construction of the station building and support structure as well as for the installation of rail systems equipment indicate compliance with the NMLs at the nearest residential and commercial receivers and at the Hillsong church.

Table 12.22 Predicted noise level exceedances at Norwest Station

Receiver Area	Noise Modelling Scenario	
	Station platform supporting structure, station building construction	Installation of rail systems equipment
A – Commercial adjoining south		
B – Residences to the south		
C – Hillsong Church including recording studio		
D – Commercial adjoining north		

Legend

Compliance No exceedance	≤ 10 dB exceedance	10 dB to ≤ 20 dB exceedance	> 20 dB exceedance or LAeq(15minute) > 75 dBA
			

Approximate durations: station structural works 12 months from Q2 2016, rail systems installation 12 months from Q4 2016 (followed by testing and commissioning).

12.10.4 Vibration Assessment

No vibration impacts are predicted for the Norwest Station site as a result of the construction activities assessed in EIS2.

12.10.5 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access routes to the Norwest Station site. In this instance, the access to the site is via Norwest Boulevard and Windsor Road which are sub-arterial roads with significant daytime flows. The assessment results in compliance with the 2 dB allowance.

12.11 Bella Vista Station

12.11.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Bella Vista Station site and the surrounding receiver areas is provided in Figure 12.7. The nearest noise sensitive receivers are identified in Table 12.23. Whilst the site extends to Memorial Avenue to the north west, activities will be at the station.

Works at the Bella Vista station site will include the station platform, support structure and building construction, as well as the station roof structure. Rail systems works include installation of track work, overhead wiring and station and tunnel ventilation equipment. At this site the construction works assessed in this report are expected to take place over approximately 21 months commencing around Q3 2016.

Figure 12.7 Bella Vista Station and Receiver Areas

Table 12.23 Nearest Noise Sensitive Receivers – Bella Vista

Receiver Area	Location Relative to Works (m)[1]
A – Residential adjoining east	570
B – Residential adjoining east	25
C – Residential east of Celebration Drive (Waterstone Crescent and Jardine Terrace)	15
D – Commercial on Old Windsor Road adjacent to the south west	10
E – Residential on Old Windsor Road to the south west	20
F – Other (church) on Old Windsor Road to the south west	30
G - Residential on Old Windsor Road to the west (Sharrock Avenue)	75
H - Residential on Old Windsor Road to the west (Emmanuel Terrace)	175
I - Commercial on Old Windsor Road to the west (Amona Street)	610
J - Residential on Old Windsor Road to the west (Rothwell Circuit)	800

Note 1 The relative distance to works is that from the nearest sensitive receiver to the closest location of construction activity.

12.11.2 Site Specific Construction Noise Management Levels

With reference to the project NMLs and the ambient noise survey results summarised in Table 4.2, the site specific construction NMLs are presented in Table 12.24.

Table 12.24 Bella Vista Station Construction NMLs

Receiver Area	Receiver Type	Relevant Monitoring Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
			Daytime	Evening	Night-time
A	Residential	BG11	46	40	36
B	Residential	BG11	46	40	36
C	Residential	BG11	46	40	36
D	Commercial	BG10	70	N/A	N/A
E	Residential	BG10	56	50	41
F	Other (Church)	BG10	65	65	-
G	Residential	BG12	61	53	38
H	Residential	BG12	61	53	38
I	Commercial	BG12	70	N/A	N/A
J	Residential	BG13	61	55	39

12.11.3 Noise Assessment at the Nearest Noise Sensitive Receivers

Scenarios were developed to be representative of activities having potentially the greatest noise impact on the surrounding receivers. These scenarios are:

- Station platform, supporting structure, station building construction and station roof structure completion
- Installation of rail systems equipment.

Calculations of the typical $L_{Aeq(15minute)}$ noise levels at the nearest noise sensitive receivers (at ground floor level) are provided in Appendix K and the predicted noise level exceedances are summarised in Table 12.25.

Given the large area encompassed by the site, the 3 m perimeter hoarding recommended for the major civil works was assumed to be provided on the north and eastern side of the station at Areas D and C from Old Windsor Road to the end of Celebration Drive, and to the west of the station at Area G from Celebration Drive to Nixon Street.

Table 12.25 Predicted noise level exceedances at Bella Vista Station

Receiver Area	**Noise Modelling Scenario**	
	Station platform supporting structure, station building construction	Installation of rail systems equipment.
A – Residential adjoining east		
B – Residential adjoining east		
C – Residential on Celebration Drive		
D – Commercial on Old Windsor Road adjacent to the south west		
E – Residential on Old Windsor Road to the south west		
F – Other (church) on Old Windsor Road to the south west		
G - Residential on Old Windsor Road to the west (Sharrock Avenue)		
H - Residential on Old Windsor Road to the west (Emmanuel Terrace)		
I - Commercial on Old Windsor Road to the west (Amona Street)		
J - Residential on Old Windsor Road to the west (Rothwell Circuit)		

Legend

Compliance	≤ 10 dB exceedance	10 dB to ≤ 20 dB exceedance	> 20 dB exceedance or $L_{Aeq(15minute)}$ > 75 dBA

Approximate durations: station structural works 9 months from Q2 2016, rail systems installation 12 months from Q3 2016 (followed by testing and commissioning).

Discussion

The findings of the construction noise impact assessment at the Bella Vista site indicate:

- The predicted noise levels for construction of the station platform, supporting structures and station building construction as well as for the installation of rail systems equipment indicate compliance with the NMLs at the nearest residential and commercial receivers.

12.11.4 Vibration Assessment

No vibration impacts are predicted for the Bella Vista Station site as a result of the construction activities assessed in EIS2.

12.11.5 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access routes to the Bella Vista Station site. The access to the site is via Celebration Drive and Windsor Road which local and sub-arterial roads, noting the relevant section of Celebration Drive is north of the Brighton Drive roundabout. The existing flows on Celebration Drive north of Brighton Drive are not available; however they are estimated to be up to only a few vehicles per hour, as only two or three residential properties are accessed. The noise level from daytime movements to the site has been predicted to comply with the local road criterion of 55 dBA to the residences on Celebration Drive.

12.12 Kellyville Station

12.12.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Kellyville Station site and the surrounding receiver areas is provided in Figure 12.8, with the nearest noise sensitive receivers identified in Table 12.26.

Figure 12.8 Kellyville Station Construction Site and Receiver Areas

Table 12.26 Nearest Noise Sensitive Receivers – Kellyville Station

Receiver Area	Location Relative to Works (m)[1]
A – Residences on Bridget Place north	140
B – Residences on Landy Place east	75
C – Residences on Arnold Avenue east	315
D – Residences on Folkstone Terrace west	335
E – Residential on Old Windsor Road to the south west	80

Note 1 The relative distance to works is that from the nearest sensitive receiver to the closest location of construction activity.

The Kellyville Station site currently encompasses a T-Way car park, bus station and open space. The station will be located within the viaduct, with escalators, lifts and fire stairs providing access to the ground level. Works at the Kellyville Station site will include the station platform, escalator, lift, fire stairs and building construction. In addition, there are works associated with the T way cark and new car parks west of the station. Rail systems works include installation of tracks and overhead wiring.

At this site the construction works assessed in this report are expected to take place over approximately 18 months commencing around Q4 2016.

12.12.2 Site Specific Construction Noise Management Levels

With reference to the project NMLs and the ambient noise survey results summarised in Table 4.2, the site specific construction NMLs are presented in Table 12.27.

Table 12.27 Kellyville Station Construction NMLs

Receiver Area	Receiver Type	Relevant Monitoring Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
			Daytime	Evening	Night-time
A	Residential	BG15	49	44	44
B	Residential	BG15	49	44	44
C	Residential	BG15	49	44	44
D	Residential	BG16	55	50	42
E	Residential	BG16	55	50	42

12.12.3 Noise Assessment at the Nearest Noise Sensitive Receivers

Scenarios were developed for the daytime and evening (if required) periods, to be representative of activities having potentially the greatest noise impact on the surrounding receivers. These scenarios are:

- Station platform supporting structure, station building construction, escalator/lift/stair construction and car park construction
- Installation of rail systems equipment.

The typical $L_{Aeq(15minute)}$ noise levels at the nearest noise sensitive receivers (at ground floor level) are provided in Appendix K and the predicted noise level exceedances are summarised in Table 12.28.

Discussion

The findings of the construction noise impact assessment at the Kellyville Station site indicate:

- The predicted noise levels for construction of the station platform supporting structure, station building, escalator/lift/stair and car park indicate a minor exceedance of up to 10 dB at residential Area B. Compliance is predicted at all the other residential receiver areas.
- During the installation of rail systems equipment compliance is predicted at all residential receivers.

Table 12.28 Predicted noise level exceedances at Kellyville Station

Receiver Area	**Noise Modelling Scenario**	
	Station platform supporting structure, station building construction and escalator/lift/stairs	Installation of rail systems equipment
A – Residential on Bridget Pl north		
B – Residential on Landy Pl east		
C – Residential on Arnold Ave east		
D – Residential on Ludlow St west		
E – Residential on Old Windsor Rd west		

Legend

Compliance	≤ 10 dB exceedance	10 dB to ≤ 20 dB exceedance	> 20 dB exceedance or $L_{Aeq(15minute)}$ > 75 dBA

Approximate durations: station structural works 12 months from Q4 2016, rail systems installation 12 months from Q4 2016 (followed by testing and commissioning).

12.12.4 Vibration Assessment

No vibration impacts are predicted for the Kellyville Station site as a result of the construction activities assessed in EIS2.

12.12.5 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access routes to the Kellyville Station site. In this instance the access to the site is via Samantha Riley Drive and Windsor Road which are sub-arterial roads with significant daytime flows. The assessment results in compliance with the 2 dB allowance.

12.13 Rouse Hill Station

12.13.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Rouse Hill Station site and the surrounding receiver areas is provided in Figure 12.9, with the nearest noise sensitive receivers identified in Table 12.29.

Figure 12.9 Rouse Hill Station Construction Site and Receiver Areas

Table 12.29 Nearest Noise Sensitive Receivers – Rouse Hill Station

Receiver Area	Location Relative to Works (m)[1]
A – Commercial adjacent north east	20
B – Active recreation south east	260
C – Residential south east	370
D – Residential south	240
E – Passive recreation Cemetery south	160
F – Residential north west	380
G – Commercial to the north	300

Note 1 The relative distance to works is that from the nearest sensitive receiver to the closest location of construction activity.

The Rouse Hill Station site currently encompasses a T-Way bus station and car park. The station will be located within the viaduct, with escalators, lifts and fire stairs providing access to the ground level. Works at the station site will include the station platform, escalator, lift, fire stairs and building construction. In addition there are works associated with the reinstatement of the T-Way bus station and car park. Rail systems works include installation of tracks and overhead wiring. At this site the construction works assessed in this report are expected to take place over approximately 18 months commencing around Q4 2016.

Access to the site would be via Windsor Road, with one access point located near White Hart Drive and one near Rouse Hill Drive. An internal access road would be provided between these two points.

12.13.2 Site Specific Construction Noise Management Levels

With reference to the project NMLs and the ambient noise survey results summarised in Table 4.2, the site specific construction NMLs are presented in Table 12.30.

Table 12.30 Rouse Hill Station Construction NMLs

Receiver Area	Receiver Type	Relevant Monitoring Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
			Daytime	Evening	Night-time
A	Commercial	BG21	70	N/A	N/A
B	Active Recreational (tennis & playground)	BG20	65	65	N/A
C	Residential	BG20	51	46	38
D	Residential	BG19	62	54	37
E	Other (passive recreation)	BG19	60	N/A	N/A
F	Residential	BG21	61	56	44
G	Commercial	BG21	70	N/A	N/A

12.13.3 Noise Assessment at the Nearest Noise Sensitive Receivers

Scenarios were developed for the daytime and potentially evening periods, to be representative of activities having potentially the greatest noise impact on the surrounding receivers. These scenarios are:

- Station platform supporting structure, station building construction, escalator/lift/stair construction and car park construction
- Installation of rail systems equipment.

The typical $L_{Aeq(15minute)}$ noise levels at the nearest noise sensitive receivers (at ground floor level) are provided in Appendix K and the predicted noise level exceedances are summarised in Table 12.31.

Discussion

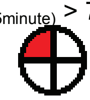
The findings of the construction noise impact assessment at the Rouse Hill Station site indicate:

- The predicted noise levels for construction of the station platform supporting structure, station building, escalator/lift/stair and car park as well as for the installation of rail systems equipment indicate compliance with the NMLs at the nearest residential and commercial receivers.

Table 12.31 Predicted noise level exceedances at Rouse Hill Station

Receiver Area	Noise Modelling Scenario	
	Station platform supporting structure, station building construction and escalator/lift/stairs	Installation of rail systems equipment
A - Commercial adjacent north east		
B - Active recreation south east		
C – Residential south east		
D - Residential south		
E – Passive recreation Cemetery south		
F – Commercial to the north		
G – Commercial to the north		

Legend

Compliance	≤ 10 dB exceedance	10 dB to ≤ 20 dB exceedance	> 20 dB exceedance or $L_{Aeq(15minute)}$ > 75 dBA
			

Approximate durations: station structural works 12 months from Q4 2016, rail systems installation 15 months from Q4 2016 (followed by testing and commissioning).

12.13.4 Vibration Assessment

Vibration impacts are not anticipated to be appreciable at the nearest residential and commercial receivers.

The Reading cinema complex is located approximately 40 m from the proposed construction works at the closest point. The highest ground-borne noise levels are anticipated to be associated with vibratory roller activities. Ground-borne noise levels from the operation of vibratory rolling equipment may be audible within the cinemas and it is recommended measurements be conducted to assist in evaluating and managing impacts in conjunction with the cinemas when the works commence.

12.13.5 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access routes to the Rouse Hill Station site. In this instance, the access to the site is via Windsor Road which is a sub-arterial road with significant existing daytime flows hence project increases result in compliance with the 2 dB allowance.

12.14 Cudgegong Road Station and Train Stabling Facility

12.14.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Cudgegong Road Station site, train stabling facility site and the surrounding receiver areas is provided in Figure 12.10, with the nearest noise sensitive receivers identified in Table 12.32.

The Cudgegong Road Station/train facility site currently encompasses rural land uses. Construction works at the train stabling facility would involve installation of tracks and buildings as well as overhead wiring. Landscaping works would occur at the completion of the train stabling facility.

Works at the Cudgegong Station site will include the station platform, escalator, lifts, fire stairs and building construction. In addition there are works associated with the new car parks to the north and south of the station. Rail systems works include installation of tracks and overhead wiring. At this site the construction works assessed in this report are expected to take place over approximately two years commencing around Q4 2016.

Access to the site would be directly on and off Cudgegong Road, Tallawong Road and Schofields Road. Internal access roads would be established along the entire length of the site adjacent to the alignment.

Figure 12.10 Cudgegong Road Station and Train Stabling Facility Construction Site and Receiver Areas

Table 12.32 Nearest Noise Sensitive Receivers - Cudgegong Road Station and Train Stabling Facility

Receiver Area	Location Relative to Works (m)[1]	
	Train Stabling Facility Works	Cudgegong Road Station
A - Residences north of the site, between Tallawong Road and Cudgegong Road	70	135
B - Residences north of the site, between Cudgegong Road and Terry Road	55	55
C - Residences south of the site, between Cudgegong Road and the west border of Castlebrook Lawn Cemetery and Crematorium	210	210
D - Residences south of Schofields Road, between Cudgegong Road and the west border of 80 Schofields Road	135	250
E - Residences south of Schofields Road and west of the west border of 80 Schofields Road	75	800
F – Residences North of Schofields Road and west of Tallawong Road	140	420

Note 1 The relative distance to works is that from the nearest sensitive receiver to the closest location of construction activity.

12.14.2 Site Specific Construction Noise Management Levels

With reference to the project NMLs and the ambient noise survey results summarised in Table 4.2, the site specific construction NMLs are presented in Table 12.33.

Table 12.33 Cudgegong Road Station and Train Stabling Facility Construction NMLs

Receiver Area	Receiver Type	Relevant Monitoring Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
			Daytime	Evening	Night-time
A	Residential	BG23	54	48	39
B	Residential	BG23	54	48	39
C	Residential	BG24	55	54	43
D	Residential	BG24	55	54	43
E	Residential	BG25	53	49	35
F	Residential	BG25	53	49	35

12.14.3 Noise Assessment at the Nearest Noise Sensitive Receivers

Scenarios were developed to be representative of activities having potentially the greatest noise impact on the surrounding receivers. These scenarios are:

- Installation of tracks and the construction of buildings - train stabling facility
- Rail systems installation – train stabling facility
- Station construction including car parks - Cudgegong Road Station only

- Station rail systems - Cudgegong Road Station only.

The typical $L_{Aeq(15minute)}$ noise levels at the nearest noise sensitive receivers (at ground floor level) are provided in Appendix K and the predicted noise level exceedances are summarised in Table 12.34.

Table 12.34 Predicted noise level exceedances at Cudgegong Road Station and Tallawong Stabling Facility

Receiver Area	**Noise Modelling Scenario**			
	Installation of tracks and the construction of buildings - train stabling facility	Rail systems installation – train stabling facility	Station construction including car parks - Cudgegong Road Station only.	Station rail systems - Cudgegong Road Station only
A - Residences north of the site, between Tallawong Road and Cudgegong Road				
B - Residences north of the site, between Cudgegong Road and Terry Road				
C - Residences south of the site, between Cudgegong Road and the west border of Castlebrook Lawn Cemetery and Crematorium				
D - Residences south of Schofields Road, between Cudgegong Road and the west border of 80 Schofields Road				
E - Residences south of Schofields Road and west of the west border of 80 Schofields Road				
F – Residences North of Schofields Road and west of Tallawong Road				

Legend

Compliance	≤ 10 dB exceedance	10 dB to ≤ 20 dB exceedance	> 20 dB exceedance or $L_{Aeq(15minute)}$ > 75 dBA

Approximate durations: stabling facility installation 18 months from Q3 2016, station structural works 12 months from Q4 2016, rail systems installation 15 months from Q2 2017 (followed by testing and commissioning).

Discussion

The findings of the construction noise impact assessment for construction of the Cudgegong Road Station and train stabling facility indicate:

- During the installation of tracks, the construction of buildings and the rail systems installation works at the train stabling facility, predicted noise levels indicate compliance with the NMLs at all receivers
- During Cudgegong Road station construction and the installation of rail systems, predicted noise levels indicate compliance at all receivers.

12.14.4 Vibration Assessment

During vibratory roller activities at the Cudgegong Road Station car park sites, vibration levels are anticipated to be well below the safe vibration levels associated with minor cosmetic building damage.

12.14.5 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access routes to the Cudgegong Station and Tallawong stabling facility site. In this instance the access to the site is via Schofields Road which is a sub-arterial road with significant daytime flows. The assessment results in compliance with the 2 dB allowance.

12.15 Bella Vista Station to Cudgegong Road Station – Surface Construction Works

The Bella Vista Station to Cudgegong Road Station section of the route is not in tunnel but comprises cuttings, embankments and above ground sections of track. The civil works assessed in this section include concrete pouring, installation of stanchions, rail placement and rail systems installation, noting that the major civil works (including the viaduct construction) have already been completed. These surface construction works are expected to take place over approximately 18 months commencing around Q2 2017, however noise intensive works at any single receiver are expected to occur during a relatively small proportion of this time.

The assessment of this section has been separated into three sub-sections, Bella Vista Station to Kellyville Station, Kellyville Station to Rouse Hill Station and Rouse Hill Station to Cudgegong Road Station. The proposed rail alignment in relation to nearby sensitive receivers is shown in Appendix B.

12.15.1 Proposed Construction Works

Scenarios were developed to be representative of activities having potentially the greatest noise impact on the surrounding receivers. These scenarios are:

- Concrete pouring, installation of stanchions and track construction
- Overhead wiring installation.

12.15.2 Bella Vista Station to Kellyville Station

An aerial photograph of the surface track section between Bella Vista Station and Kellyville Station, and the surrounding receiver areas is provided in Figure 12.11. The nearest noise sensitive receivers to the section of track between Bella Vista Station and Kellyville Station are identified in Table 12.35.

Figure 12.11 Bella Vista Station to Kellyville Station Construction Site and Receiver Areas

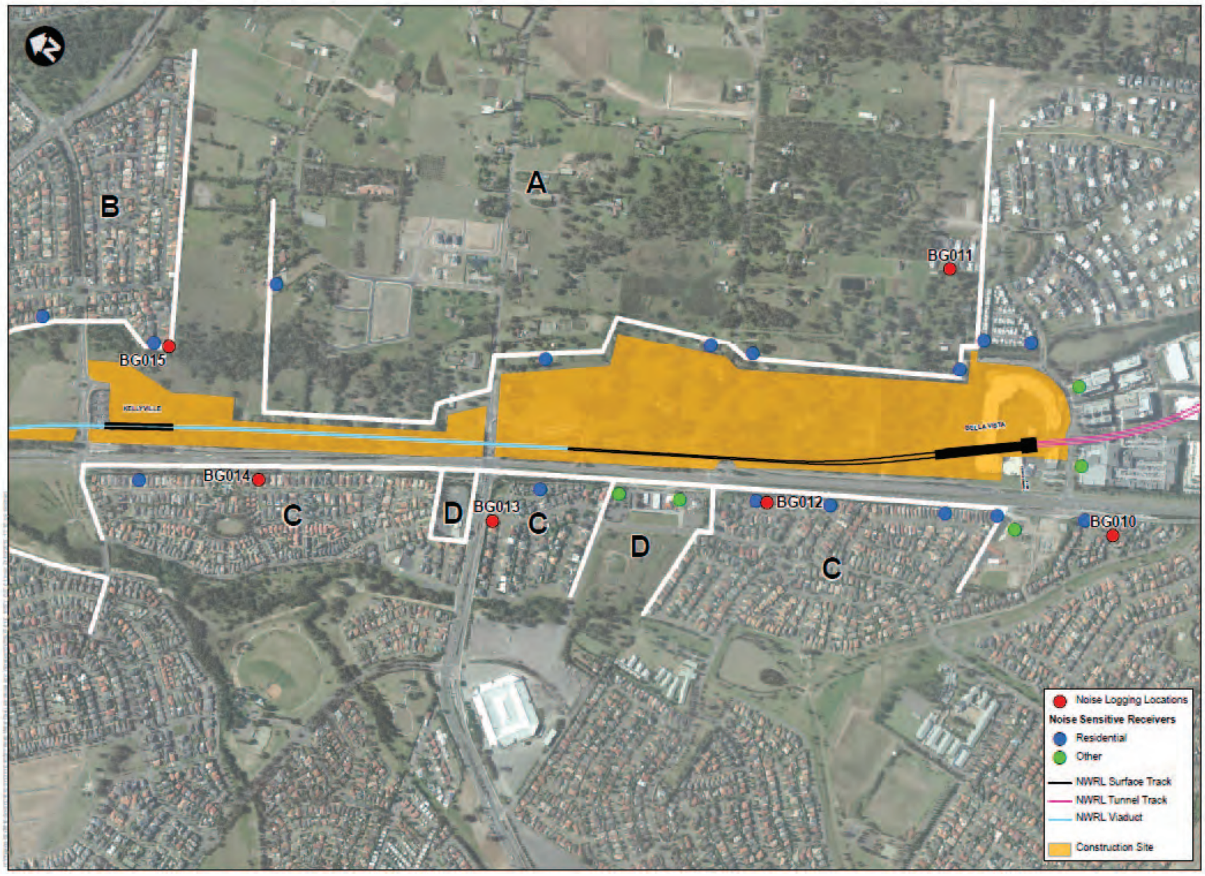


Table 12.35 Nearest Noise Sensitive Receivers – Bella Vista Station to Kellyville Station

Receiver Area	Location Relative to Works (m)
A - Residences east of Old Windsor Road, from the north section of Arnold Avenue to the north border of the Totally Home shopping centre on the corner of Old Windsor Road and Celebration Drive	160
B - Residences east of Old Windsor Road and south of Samantha Riley Drive	205
C - Residences west of Old Windsor Road, between Newbury Avenue and the north border of the Emmanuel Baptist Church	85
D - Commercial sites west of Old Windsor Road, on Sunnyholt Road and on Old Windsor Road	85

Site Specific Construction Noise Management Levels

With reference to the project NMLs and the ambient noise survey results summarised in Table 4.2, the site specific construction NMLs are presented in Table 12.36.

Table 12.36 Bella Vista Station to Kellyville Station Viaduct Construction NMLs

Receiver Area	Receiver Type	Relevant Monitoring Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
			Daytime	Evening	Night-time
A	Residential	BG15	49	46	44
B	Residential	BG15	49	46	44
C	Residential	BG14	57	53	43
D	Commercial	BG13	70	N/A	N/A

Noise Assessment at the Nearest Noise Sensitive Receivers

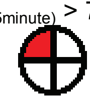
The typical $L_{Aeq(15minute)}$ noise levels at the nearest noise sensitive receivers (at ground floor level) are provided in Appendix K and the predicted noise level exceedances are summarised in Table 12.37.

The predicted noise levels adjacent to the surface track works are representative of the typical worst case levels when construction activities are undertaken adjacent to sensitive receivers. On this basis, any predicted exceedances of the NMLs would only occur for short periods of time at any one location. For many periods during the proposed construction program, the predicted noise levels would be significantly lower than the typical worst case levels.

Table 12.37 Predicted noise level exceedances Bella Vista Station to Kellyville Station

Receiver Area	Noise Modelling Scenario	
	Concrete pouring, installation of stanchions and track construction	Overhead wiring installation
A - Residences east of Old Windsor Road, from the north section of Arnold Avenue to the corner of Old Windsor Road and Celebration Drive		
B - Residences east of Old Windsor Road and south of Samantha Riley Drive		
C - Residences west of Old Windsor Road, between Newbury Avenue and the north border of the Emmanuel Baptist Church		
D - Commercial sites west of Old Windsor Road, on Sunnyholt Road and on Old Windsor Road		

Legend

Compliance	≤ 10 dB exceedance	10 dB to ≤ 20 dB exceedance	> 20 dB exceedance or $L_{Aeq(15minute)}$ > 75 dBA
			

Approximate durations: exceedances of the construction NMLs during track construction and overhead wiring works are expected to be of relatively short duration, of the order of 2 to 4 weeks in total.

Discussion

The findings of the construction noise impact assessment for construction of the viaduct from Bella Vista to Kellyville Station indicate:

- At residences in the Areas A, B and C similar noise levels are predicted, and these noise levels for concrete pouring, installation of stanchions and track construction exceed the NMLs by the minor amounts of 8 dB, 4 dB and 7 dB for the Areas A, B and C respectively. During overhead wiring installation compliance is predicted at all residential areas.
- Residences in Area C are adjacent to Old Windsor Road and existing traffic noise levels are generally similar in level to those predicted for construction activities. No appreciable construction noise impact is therefore predicted in this area.
- At the commercial receivers for Area D compliance is predicted for all scenarios.

12.15.3 Kellyville Station to Rouse Hill Station

The nearest noise sensitive receivers to the section of track between Kellyville Station and Rouse Hill Station are identified in Figure 12.12 and in Table 12.38.

Figure 12.12 Kellyville Station to Rouse Hill Station Construction Site and Receiver Areas

Table 12.38 Nearest Noise Sensitive Receivers – Kellyville Station to Rouse Hill Station

Receiver Area	Location Relative to Works (m)
A - Residences east of Old Windsor Road, between the group of residences north east of the Windsor Road/Old Windsor Road junction and Samantha Riley Drive	30
B - Residences west of Old Windsor Road, between Newbury Avenue and the south border of Castlebrook Lawn Cemetery and Crematorium	80
C – John XXIII Catholic Primary School	185
D - Commercial sites west of Windsor Road, on Windsor Road and on Old Windsor Road	85
E - Castlebrook Lawn Cemetery and Crematorium	280
F – Residences east of Windsor Road, between Bellcast Road and Sanctuary Drive	35
G – Recreation area east of Windsor Road, between White Hart Drive, Sanctuary Drive and Bellcast Road	60
H – Commercial site east of Windsor Road, between Rouse Hill Drive and White Hart Drive	45

Site Specific Construction Noise Management Levels

With reference to the project NMLs and the ambient noise survey results summarised in Table 4.2, the site specific construction NMLs are presented in Table 12.39.

Table 12.39 Kellyville Station to Rouse Hill Station Viaduct Construction NMLs

Receiver Area	Receiver Type	Relevant Monitoring Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
			Daytime	Evening	Night-time
A	Residential	BG16	55	51	42
B	Residential	BG19	62	54	37
C	Educational (School)	BG19	55	N/A	N/A
D	Commercial	BG19	70	N/A	N/A
E	Other (passive recreation)	BG21	60	N/A	N/A
F	Residential	BG20	51	46	38
G	Active Recreational (tennis & playground)	BG20	65	65	N/A
H	Commercial	BG22	70	N/A	N/A

Noise Assessment at the Nearest Noise Sensitive Receivers

The typical $L_{Aeq(15minute)}$ noise levels at the nearest noise sensitive receivers (at ground floor level) are provided in Appendix K and the predicted noise level exceedances are summarised in Table 12.40.

The predicted noise levels adjacent to the surface track works are representative of the typical worst case levels when construction activities are undertaken adjacent to sensitive receivers. On this basis, any predicted exceedances of the NMLs would only occur for short periods of time at any one location.

For many periods during the proposed construction program, the predicted noise levels would be significantly lower than the typical worst case levels.

Table 12.40 Predicted noise level exceedances Kellyville Station to Rouse Hill

Receiver Area	Noise Modelling Scenario	
	Concrete pouring, installation of stanchions and track construction	Overhead wiring installation
A - Residences east of Old Windsor Road, between the group of residences north east of the Windsor Road/Old Windsor Road junction and Samantha Riley Drive	10 dB to ≤ 20 dB exceedance	≤ 10 dB exceedance
B - Residences west of Old Windsor Road, between Newbury Avenue and the south border of Castlebrook Lawn Cemetery and Crematorium	≤ 10 dB exceedance	Compliance
C – John XXIII Catholic Primary School	Compliance	Compliance
D - Commercial sites west of Windsor Road, on Windsor Road and on Old Windsor Road	Compliance	Compliance
E - Castlebrook Lawn Cemetery and Crematorium	Compliance	Compliance
F – Residences east of Windsor Road, between Bellcast Road and Sanctuary Drive	> 20 dB exceedance or $L_{Aeq(15minute)}$ > 75 dBA	10 dB to ≤ 20 dB exceedance
G – Recreation area east of Windsor Road, between White Hart Drive, Sanctuary Drive and Bellcast Road	≤ 10 dB exceedance	Compliance
H – Commercial site east of Windsor Road, between Rouse Hill Drive and White Hart Drive	Compliance	Compliance

Legend

Compliance	≤ 10 dB exceedance	10 dB to ≤ 20 dB exceedance	> 20 dB exceedance or $L_{Aeq(15minute)}$ > 75 dBA

Approximate durations: exceedances of the construction NMLs during track construction and overhead wiring works are expected to be of relatively short duration, of the order of 2 to 4 weeks in total.

Discussion

The findings of the construction noise impact assessment for construction of the viaduct from Kellyville Station to Rouse Hill Station indicate:

- Residential Area A – there are high exceedances of up 17 dB during concrete pouring, installation of stanchions and track construction and up to 10 dB during overhead wiring installation. These exceedances are due to the nearest residences being relatively close to the works.
- Residential Area B – there are minor exceedances of up 2 dB during concrete pouring, installation of stanchions and track construction, and no exceedance during overhead wiring installation. These residences are also predicted to experience construction noise levels that will be similar to

those from existing traffic on Old Windsor Road, hence construction noise will be less noticeable. No appreciable construction noise impact is therefore predicted in this area.

- Educational Area C – there are no exceedances during concrete pouring, installation of stanchions and track construction, and during overhead wiring installation. The school is also predicted to experience construction noise levels that will be similar to those from existing traffic on Old Windsor Road, hence construction noise will be less noticeable. No appreciable construction noise impact is therefore predicted in this area.
- At commercial Area D compliance is predicted, as well as at passive recreation Area E. There is a minor exceedance of 2 dB during concrete pouring, installation of stanchions and track construction, and compliance during overhead wiring installation.
- Residential Area F – there are high exceedances of up to 22 dB during concrete pouring, installation of stanchions and track construction, and up to 14 dB during overhead wiring installation. These exceedances are due to the nearest residences being relatively close to the works.
- At passive recreation Area G there is a minor exceedance of 2 dB during concrete pouring, installation of stanchions and track construction, and compliance during overhead wiring installation.
- At commercial Area H compliance is predicted during concrete pouring, installation of stanchions and track construction, and during overhead wiring installation.
- Where receivers are "highly noise affected" (i.e. where the predicted noise level exceeds 75 dBA) or the NMLs are exceeded by more than 20 dB, the proponent may need to implement respite periods and liaise with the community as outlined in Table 11.1. The CNVS would be implemented to manage the potential noise impacts. For the Kellyville Station to Rouse Hill section this is anticipated to occur during concrete pouring, installation of stanchions and track construction.

12.15.4 Rouse Hill Station to Cudgegong Road Station

The nearest noise sensitive receivers to the section of track between Rouse Hill Station and Cudgegong Road Station are identified in Figure 12.13 and in Table 12.41.

Figure 12.13 Rouse Hill Station to Cudgegong Road Construction Site and Receiver Areas

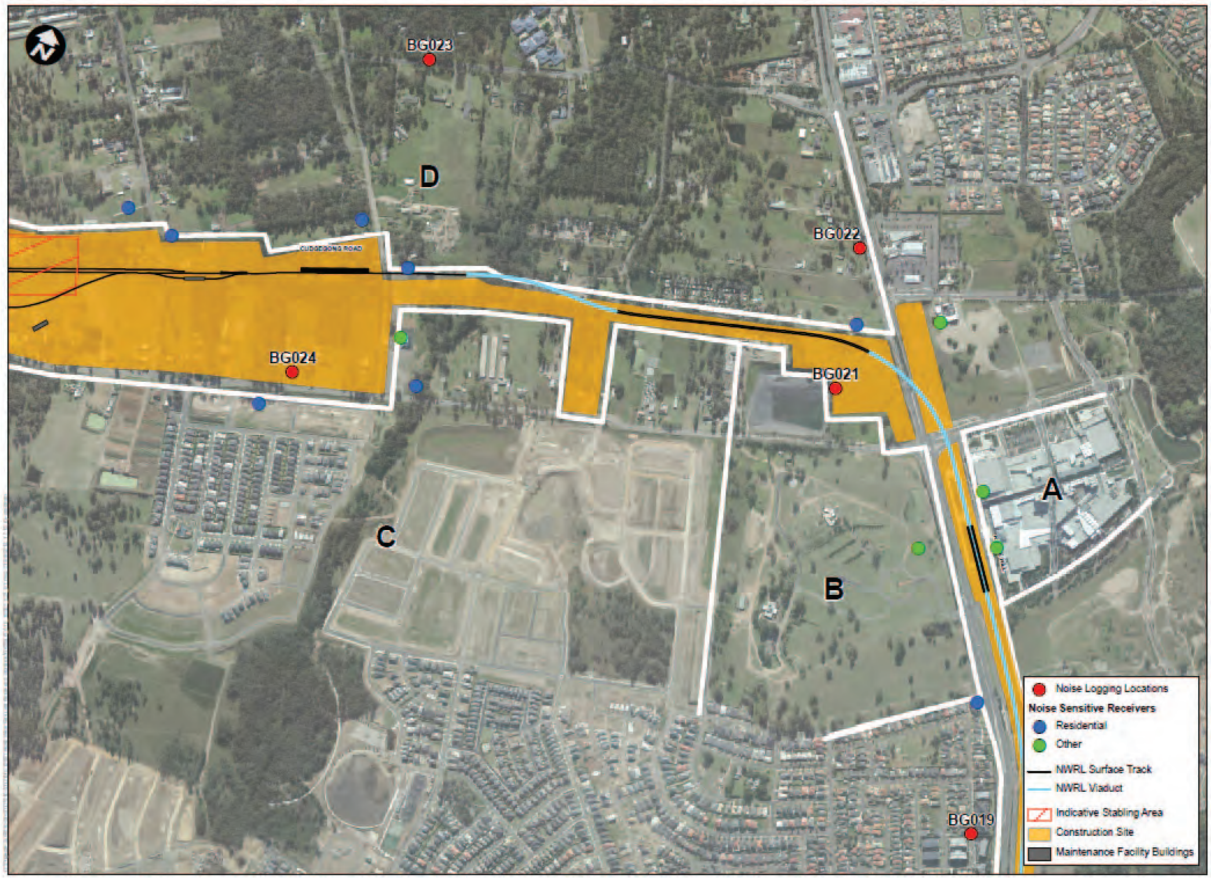


Table 12.41 Nearest Noise Sensitive Receivers – Rouse Hill Station to Cudgegong Road Station

Receiver Area	Location Relative to Works (m)
A - Commercial sites east of Windsor Road, north of White Hart Drive	25
B - Castlebrook Lawn Cemetery and Crematorium	280
C - Residences south of the site and west of Windsor Road	200
D - Residences north of the site and west of Windsor Road	5

Site Specific Construction Noise Management Levels

With reference to the project NMLs and the ambient noise survey results summarised in Table 4.2, the site specific construction NMLs are presented in Table 12.42.

Table 12.42 Rouse Hill Station to Cudgegong Road Station Viaduct Construction NMLs

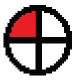
Receiver Area	Receiver Type	Relevant Monitoring Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
			Daytime	Evening	Night-time
A	Commercial	BG22	70	N/A	N/A
B	Other (passive recreation)	BG21	60	N/A	N/A
C	Residential	BG21	61	56	44
D	Residential	BG23	54	48	39

Noise Assessment at the Nearest Noise Sensitive Receivers

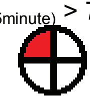
The typical $L_{Aeq(15minute)}$ noise levels at the nearest noise sensitive receivers (at ground floor level) are provided in Appendix K and the predicted noise level exceedances are summarised in Table 12.43.

The predicted noise levels adjacent to the surface track works are representative of the typical worst case levels when construction activities are undertaken adjacent to sensitive receivers. On this basis, any predicted exceedances of the NMLs would only occur for short periods of time at any one location. For many periods during the proposed construction program, the predicted noise levels would be significantly lower than the typical worst case levels.

Table 12.43 Predicted noise level exceedances Rouse Hill Station to Cudgegong Road Station

Receiver Area	Noise Modelling Scenario	
	Concrete pouring, installation of stanchions and track construction	Overhead wiring installation
A - Commercial sites east of Windsor Road, north of White Hart Drive		
B - Castlebrook Lawn Cemetery and Crematorium		
C - Residences south of the site and west of Windsor Road		
D - Residences north of the site and west of Windsor Road		

Legend

Compliance	≤ 10 dB exceedance	10 dB to ≤ 20 dB exceedance	> 20 dB exceedance or $L_{Aeq(15minute)}$ > 75 dBA
			

Approximate durations: exceedances of the construction NMLs during track construction and overhead wiring works are expected to be of relatively short duration, of the order of 2 to 4 weeks in total.

Discussion

The findings of the construction noise impact assessment for construction of the viaduct from Rouse Hill Station to Cudgegong Road Station indicate:

- At commercial Area A, there is a moderate exceedance of 5 dB during concrete pouring, installation of stanchions and track construction, and compliance during overhead wiring installation.
- At passive recreation Area B there are no predicted exceedances.
- At residential Area C there are no predicted exceedances.
- Residential Area D – there are high exceedances of up 36 dB during concrete pouring, installation of stanchions and track construction, and up to 33 dB during overhead wiring installation. These exceedances are due to the nearest residences (including the OK Caravan Park) being relatively close to the works.
- Where receivers are "highly noise affected" (i.e. where the predicted noise level exceeds 75 dBA) or the NMLs are exceeded by more than 20 dB, the proponent may need to implement respite periods and liaise with the community as outlined in Table 11.1. The CNVS would be implemented to manage the potential noise impacts. For the Rouse Hill Station to Cudgegong Road section this is anticipated to occur during concrete pouring, installation of stanchions and track construction, and overhead wiring installation for the residences in Area D (residences north of the site and west of Windsor Road).

12.15.5 Vibration Assessment

No vibration impacts are predicted for the existing buildings and structures adjacent to the proposed rail alignment between Bella Vista Station and Tallawong Road stabling facility.

12.16 Road Bridge Construction Works

The civil works assessed in this section are the construction of the road bridge over the rail corridor at Balmoral Road. The proposed bridges at Tallawong Road and Cudgegong Road were included in the assessment for EIS1.

The Balmoral Road bridge is located approximately 45 m east of Old Windsor Road, within the construction area locating the Precast Facility and Concrete batching plant north of Bella Vista Station.

The nearest residential receivers are located on Emmanuel Terrace to the west and on Balmoral Road to the east, with the works 90 m and 240 m from these receivers respectively. There are also commercial receivers to the west typically 90 from the works.

Site Specific Construction Noise Management Levels
With reference to the project NMLs and the ambient noise survey results summarised in Table 4.2, the site specific construction NMLs are presented in Table 12.44.

Table 12.44 Balmoral Road Bridgeworks Construction NMLs

Receiver Area	Receiver Type	Relevant Monitoring Location	$L_{Aeq(15minute)}$ Construction NMLs (dBA)		
			Daytime	Evening	Night-time
A	Residential west	BG14	57	53	43
B	Residential east	BG15	49	46	44
C	Commercial west	BG14	70	N/A	N/A

Noise Assessment at the Nearest Noise Sensitive Receivers

A scenario corresponding to the nosiest construction phase was modelled. The predicted $L_{Aeq(15minute)}$ noise levels at the nearest noise sensitive receivers (at ground floor level) are provided in are summarised in Table 12.45.

Table 12.45 Balmoral Road Bridgeworks Predicted $L_{Aeq(15minute)}$ Construction Noise Levels

Receiver Area	Receiver Type	$L_{Aeq(15minute)}$ Construction Noise Levels (dBA)
A	Residential west	54
B	Residential east	43
C	Commercial west	54

Discussion

The findings of the construction noise impact assessment for construction of the viaduct from Bella Vista to Kellyville Station indicate:

- At the nearest residences and commercial receivers, compliance with the NMLs is predicted. at all residential areas. No appreciable construction noise impact is therefore predicted for the Balmoral Road Bridge construction works

12.17 Construction Works in Tunnels

EIS1 assessed the potential noise and vibration impacts from the construction of the twin tunnels from Epping to Bella Vista. As part of EIS2, construction activities related to the fit out of the twin tunnels will be required, including construction of the tunnel floor concrete slab, installation of the permanent rail tracks, installation of the overhead wiring system and all other associated mechanical and electrical systems.

It is assumed that construction would commence with the tunnel floor concrete slab and then progress to installation of the permanent rail tracks. This would likely be used to transport construction equipment and workers through the tunnels using hi-rail vehicles or work trains.

As the design of the permanent rail tracks includes operational ground-borne noise and vibration mitigation (ie higher attenuation track form in areas where the alignment is shallower – see Section 6), the potential impacts from the use of construction work vehicles, which would be travelling at considerably slower speeds than the passenger trains, are likely to be minimal.

After construction of the track form all of the remaining tunnel systems would be fitted out. This will likely require the use of handheld equipment such as drills, grinders, saws, etc for the majority of the required activities. When considering the type of equipment necessary for these works and given that the works will likely only be in a certain location for a short duration, the potential impacts are likely to be minimal for the majority of the alignment. Notwithstanding, these works would need to consider all feasible and reasonable mitigation measures at locations where a risk that adverse ground-borne noise and /or vibration impacts may occur.

12.18 Summary of Construction Noise and Vibration Mitigation Measures

Table 12.46 provides a summary of the site specific noise mitigation measures that have been included in the construction noise scenarios (in the case of airborne noise) and the recommended mitigation measures to manage the potential impacts of ground-borne noise and vibration.

Table 12.46 Summary of Site Specific Noise and Vibration Mitigation Measures

Construction Site	Potential Impact	Proposed Mitigation Measure
All Construction Sites	Airborne Noise, Ground-borne Noise and Ground-borne Vibration	Standard noise and vibration mitigation and management measures described in the Construction Noise and Vibration Strategy (refer Appendix J)
Epping services facility	Airborne noise	Construction of noise barriers (hoardings) around perimeter of construction site (3 m high)
Epping decline	Airborne noise	Construction of noise barriers (hoardings) around perimeter of construction site (3 m high)
Cheltenham services facility	Airborne noise	Construction of noise barriers (hoardings) around perimeter of construction site (3 m high)
Cherrybrook	Airborne noise	Construction of noise barriers (hoardings) around perimeter of construction site (6 m high).
Castle Hill	Airborne noise	Construction of noise barriers (hoardings) around perimeter of construction site (3 m high)
	Ground-borne noise	Attended noise measurements in the Gold Class cinema complex during high vibration activities to determine and manage ground-borne noise levels
Showground	Airborne noise	Construction of noise barriers (hoardings) around perimeter of main construction site area (3 m high)
Norwest	Airborne noise	Construction of noise barriers (hoardings) around perimeter of construction site (3 m high)
Bella Vista	Airborne noise	Construction of (3 m high) noise barriers (hoardings) on the north and eastern side of the main construction site at Areas D and C from Old Windsor Road until the end of Celebration Drive, and to the west of the station at Area G from Celebration Drive to Nixon Street.
Rouse Hill	Airborne noise	Construction of noise barriers (hoardings) around perimeter of construction site (3 m high)
	Ground-borne noise	Attended noise measurements in the Reading cinema complex during high vibration activities to determine and manage ground-borne noise levels
Rouse Hill Station to Cudgegong Road Station	Airborne Noise, Ground-borne Noise and Ground-borne Vibration	Standard mitigation measures outlined in the CNVS

Construction Site	Potential Impact	Proposed Mitigation Measure
Cudgegong Road Station and Tallawong stabling facility	Airborne Noise, Ground-borne Noise and Ground-borne Vibration	Standard mitigation measures outlined in the CNVS
24 Hour Ventilation Equipment and other items of plant	Airborne noise	For tunnel ventilation equipment and other items of fixed plant (e.g. pumps, water treatment plant, and diesel generators) that is required to operate on a 24 hour per day basis in support of the completed underground works, mitigation measures may be required. At each site the combined L_{Aeq} noise from the operation of this equipment should not exceed the RBL at the nearest residential receivers. Potential mitigation measures that may be required include ventilation fan enclosures and silencers and additional enclosures and silencers for diesel generating equipment.

13 Summary of Impacts and Mitigation

13.1 Airborne Operational Noise

Airborne noise modelling has been undertaken for the surface track section between Bella Vista Station and Cudgegong Road Station. Without any noise mitigation measures, the noise modelling indicates the potential for widespread exceedances of the noise trigger levels (design objectives).

To mitigate noise impacts, it is recommended for the current NWRL Concept Design that noise barriers of height 1 m above top of rail are included at all above-ground locations (except where the tracks are located in cuttings).

Rail dampers are also recommended in all areas of surface track between Kellyville Station and Cudgegong Road Station, except in the vicinity of the stations where lower speeds result in compliance with the noise trigger levels. Rail dampers are not proposed between Bella Vista Station and Kellyville Station, as the 1 m high noise barriers in this area are expected to reduce the direct noise levels to below the structure radiated levels for all existing sensitive receivers and the predicted levels comply with the airborne noise trigger levels.

Adjacent to the OK Caravan Park in Rouse Hill, the track emerges from a cutting and proceeds onto an embankment. At this location a noise barrier of height 2 m above rail height on the Up side is likely to be required to meet the noise trigger levels. A 2 m high noise barrier along the embankment on the Down side near the OK Caravan Park is also recommended to mitigate noise impacts on future developments in the Area 20 precinct.

It is anticipated that the noise trigger levels (design objectives) can be met at the majority of existing receivers with the proposed noise mitigation measures. Residual exceedances remain at a number of existing properties. In all cases these residual exceedances are marginal (less than 2 dB in the future scenario ten years after project opening). The noise levels at the affected properties include a structure-radiated contribution that is predicted to be greater than or similar to the direct noise from the tracks. It is noted that the noise predictions are sensitive to the detailed design of the viaduct structure and it may be possible to reduce the noise radiated from the structure to below the levels assumed in this assessment.

13.2 Ground-borne Operational Noise and Vibration

In order to mitigate the potential ground-borne noise and vibration impacts, a standard attenuation slab track design incorporating resilient rail fasteners has been adopted. This is a modern track form which includes rail fasteners with rubber elements located between the rail and concrete slab to reduce the vibration energy transmitted into the ground and nearby buildings. At sensitive receiver locations where the standard attenuation track design is not sufficient to achieve the ground-borne noise design objectives, a high attenuation track design with more resilient “Egg-type” rail fasteners is proposed. Very high attenuation rail fasteners or floating slab track can be adopted (if required) at locations where standard attenuation and high attenuation track forms are not sufficient to achieve the ground-borne noise design objectives.

At this stage of the assessment, the modelling results indicate that the ground-borne noise objectives can be achieved with the above-mentioned generic track designs. The final track design will be determined by the successful contractor during the detailed design stage of the project. A performance-based specification will form part of the construction contract, requiring the successful contractor to achieve the ground-borne noise and vibration objectives.

13.3 Train Stabling Facility - Operational Noise

The noise impacts of the proposed Tallawong Stabling Facility have been assessed. Since the stabling facility will house only new rolling stock, the noise impacts of train arrivals at the facility will be minimal. Trains will be stabled powered off without auxiliary equipment operating. The worst-case noise impacts of the facility will be concentrated in the early morning period (before 7:00 am) when trains are preparing to depart the facility and noise criteria are more stringent than during the daytime and evening.

The noise impact assessment indicates that train auxiliary systems have the potential to result in exceedances of the INP intrusiveness noise goals at existing residential receivers in a worst-case scenario before 7:00 am.

The overall predicted L_{Aeq} noise levels under adverse meteorological conditions at the nearest receivers are 47 dBA in the night-time and early morning period (before 7:00 am). Under neutral weather conditions, the predicted noise impacts are 4 dB lower.

While these noise levels exceed the intrusiveness criteria and may be noticeable above the background noise in the night-time and early morning, they are around 10 dB below the measured existing night-time L_{Aeq} noise levels. The predicted levels are not considered to have adverse impacts on acoustic amenity and no specific mitigation is proposed beyond limiting auxiliary source noise levels through specifications during the rolling stock procurement process.

The modelling indicates that noise from inside the maintenance building can be contained through appropriate design of the building, under the assumption that train access doors will be closed (except when a train movement is required) during the night-time and early morning period.

Noise from compressed air release from brakes has the potential to exceed the sleep disturbance screening criterion; however the predicted noise levels and the existing noise environment indicate that air release noise from brakes is unlikely to cause awakening reactions at the most exposed existing receivers.

13.4 Operational Noise from Stations, Ancillary Facilities, Public Roads and Car Parks

The detailed design of these facilities and details of equipment are not available at this stage, and the locations of shafts and service buildings may change. The approach to the assessment was therefore to determine allowable noise emissions from stations and ancillary equipment, to inform the detailed design of the project and to provide an early indication on whether the noise criteria are able to be achieved.

Mitigation measures are likely to be required for some station and tunnel ventilation equipment / locations in order to comply with the project noise criteria. Mitigation measures that may be required at some locations include appropriate equipment selection, in-duct attenuators, noise barriers, acoustic enclosures and the strategic positioning of critical plant away from sensitive receivers.

Train noise break-out through the tunnel ventilation shafts from trains operating within the tunnel is not expected to exceed the noise design criteria. All tunnel exhaust shafts and draught relief shafts near sensitive receivers will require mitigation measures (typically in-duct noise attenuation) in order to comply with the noise criteria.

Operational noise from proposed car parks has been assessed and in most cases is predicted to comply with the project noise criteria at all sensitive receivers. Noise levels exceeding the noise criteria have been predicted at Cherrybrook Station and Showground Station due to low existing background noise levels and the close proximity of the car parks to residential property boundaries. It is recommended that a noise barrier be constructed on the north-east boundary of the Cherrybrook at-grade car park and that openings in the Showground Station parking building be minimised around the south-east corner. The noise barrier and car park design should be further developed during the detailed design stage.

Operational traffic noise from new local roads providing access to the stations has been assessed and exceedances of the NSW Road Noise Policy (RNP) criteria for new local roads has been predicted for the new road at Cherrybrook Station and the new road along the eastern boundary of Kellyville Station precinct. Noise barriers or mounds are recommended. Increases in traffic noise levels from existing roads due to traffic generated by the NWRL stations have also been assessed in accordance with the RNP. The traffic noise increase on Franklin Road and Robert Road near Cherrybrook Station is predicted to exceed RNP criteria for traffic generating developments. The proposed bus routes are a large contributor to the predicted traffic noise levels on Franklin Road and Robert Road.

Noise from PA systems will be required to achieve the *industrial Noise Policy* criteria. It is anticipated that these criteria can be achieved with appropriate design measures such as loudspeaker selection and placement, and installation of ambient noise sensing microphones and automatic volume control systems.

13.5 Operational Noise from ECRL

As part of the NWRL proposal, rapid transit trains would operate on the ECRL. In relation to potential noise and vibration impacts, this is likely to include the following changes:

- Train operations within the ECRL tunnels and surface track in Chatswood area would comprise modern single deck trains, rather than the current mix of CityRail trains operating on the line
- The frequency (number) of trains is likely to be higher for the NWRL, compared with the current CityRail timetable
- The train speeds within the tunnel and surface sections may be higher (up to 100 km/h where possible), compared with the current maximum speed of 80 km/h for ECRL.

The assessment considered the noise and vibration approval conditions for the ECRL project and how noise and vibration levels are anticipated to change. The review identified two areas where higher airborne noise levels or higher ground-borne noise and vibration levels are possible.

For the section of surface track between Chatswood Station and the ECRL tunnel portals, $L_{Aeq(9hour)}$ night-time noise levels are anticipated to remain relatively unchanged. If maximum train speeds are increased from 80 km/h to 90 km/h on the existing ECRL tracks, the change in maximum noise levels (L_{Amax}) associated with individual passbys is not likely to be noticeable (ie less than 2 dB) at the nearest residences.

During the daytime period, $L_{Aeq(15hour)}$ noise levels are predicted to increase by approximately 0.8 dB between Year 2017 and Year 2021 and a further 1.0 dB between Year 2021 and Year 2031. This increase is a result of natural growth and signalling systems which facilitate more frequent train operations. If maximum train speeds are increased from 80 km/h to 90 km/h on the existing ECRL tracks, the change in maximum noise levels (L_{Amax}) associated with individual passbys is not likely to be noticeable (ie less than 2 dB) at the nearest residences.

Whilst the number of daytime train movements on the North Shore Line and ECRL tracks could increase from approximately 30 trains per hour in Year 2017 to 40 trains per hour in Year 2031, this increase is likely to occur gradually over a long time period in response to timetable changes. The maximum noise levels from individual train passbys is not likely to be noticeable if the speed on the ECRL tracks is increased from 80 km/h to 90 km/h.

For the section of tunnel track between Epping and Chatswood, there would be a more frequent single deck train service, with NWRL trains potentially travelling at higher speeds.

For single deck rapid transit trains, the key factors which are likely to produce a change in the ground-borne noise and vibration levels are the unsprung mass and axle load of the proposed trains and the train speed. These factors would likely result in marginally lower source vibration levels for single deck rapid transit trains. Other factors including the wheel and rail condition, track fasteners, rail type and tunnel design are the same or not likely to change.

The proposed train speeds in the ECRL tunnels could be up to 100 km/h, compared with the current maximum speed limit of 80 km/h. The corresponding increase in ground-borne noise and vibration levels is estimated be approximately 2 dB at locations where this occurs. A change of 1 dB or 2 dB in maximum (L_{Amax}) noise level is difficult for most people to detect.

The assessment concluded that it is unlikely that higher speed single deck train operations within the ECRL tunnels would result in a noticeable increase in ground-borne noise and vibration levels within sensitive occupancies above the tunnel alignment.

13.6 Construction Noise and Vibration

At the majority of the station sites, the predicted construction noise levels are anticipated to comply with the daytime NMLs for most receivers, with some moderate exceedances. The predicted impacts assume that noise mitigation measures proposed for the major civil works (assessed separately) will remain in place throughout the construction period. At Cherrybrook Station and Cudgegong Road Station, the predicted noise levels indicate moderate to high exceedances of the NMLs at some receivers during construction of the car park. The works at the Train Stabling Facility are predicted to comply with the daytime NMLs.

The noise from track construction activities above ground and on the viaduct are predicted to result in minor to high exceedances of the NMLs at some nearby receivers; however these noise impacts would only occur for a relatively short time at any one location. Ground-borne noise and vibration associated with track construction and fit out works in the tunnels is not anticipated to be significant within sensitive receivers above the tunnel alignment.

A *Construction Noise and Vibration Strategy* (CNVS) has been developed by the NWRL project team and will be adopted by all contractors to manage construction noise and vibration emissions across the various construction sites. In preparing this strategy, consideration has been given to several guideline documents including the *Interim Construction Noise Guideline*, Transport Construction Authority's *Construction Noise Strategy*, Australian Standard AS 2436-2010 *Guide to noise and vibration control on construction, demolition and maintenance sites* and the *Road Noise Policy*.

Appendix A Acoustic Terminology

1 Sound Level or Noise Level

The terms ‘sound’ and ‘noise’ are almost interchangeable, except that in common usage ‘noise’ is often used to refer to unwanted sound.

Sound (or noise) consists of minute fluctuations in atmospheric pressure capable of evoking the sense of hearing. The human ear responds to changes in sound pressure over a very wide range. The loudest sound pressure to which the human ear responds is ten million times greater than the softest. The decibel (abbreviated as dB) scale reduces this ratio to a more manageable size by the use of logarithms.

The symbols SPL, L or L_P are commonly used to represent Sound Pressure Level. The symbol L_A represents A-weighted Sound Pressure Level. The standard reference unit for Sound Pressure Levels expressed in decibels is 2 x 10^{-5} Pa.

2 ‘A’ Weighted Sound Pressure Level

The overall level of a sound is usually expressed in terms of dBA, which is measured using a sound level meter with an ‘A-weighting’ filter. This is an electronic filter having a frequency response corresponding approximately to that of human hearing.

People’s hearing is most sensitive to sounds at mid frequencies (500 Hz to 4,000 Hz), and less sensitive at lower and higher frequencies. Thus, the level of a sound in dBA is a good measure of the loudness of that sound. Different sources having the same dBA level generally sound about equally loud.

A change of 1 dB or 2 dB in the level of a sound is difficult for most people to detect, whilst a 3 dB to 5 dB change corresponds to a small but noticeable change in loudness. A 10 dB change corresponds to an approximate doubling or halving in loudness. The table below lists examples of typical noise levels

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

Other weightings (e.g. B, C and D) are less commonly used than A-weighting. Sound Levels measured without any weighting are referred to as ‘linear’, and the units are expressed as dB(lin) or dB.

3 Sound Power Level

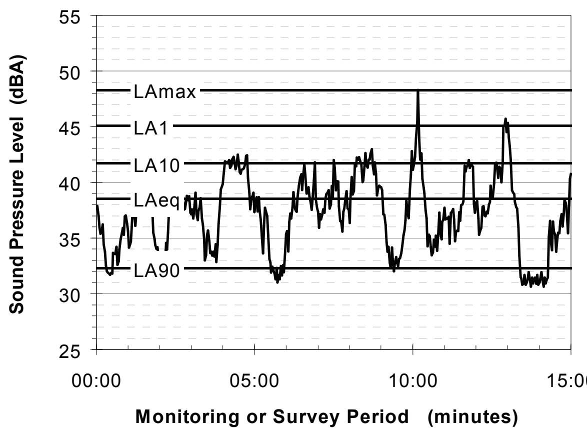
The Sound Power of a source is the rate at which it emits acoustic energy. As with Sound Pressure Levels, Sound Power Levels are expressed in decibel units (dB or dBA), but may be identified by the symbols SWL or L_W, or by the reference unit 10^{-12} W.

The relationship between Sound Power and Sound Pressure may be likened to an electric radiator, which is characterised by a power rating, but has an effect on the surrounding environment that can be measured in terms of a different parameter, temperature.

4 Statistical Noise Levels

Sounds that vary in level over time, such as road traffic noise and most community noise, are commonly described in terms of the statistical exceedance levels L_{AN}, where L_{AN} is the A-weighted sound pressure level exceeded for N% of a given measurement period. For example, the L_{A1} is the noise level exceeded for 1% of the time, L_{A10} the noise exceeded for 10% of the time, and so on.

The following figure presents a hypothetical 15 minute noise survey, illustrating various common statistical indices of interest.



Of particular relevance, are:

L_{Amax} The maximum noise level during the 15 minute interval.

L_{A1} The noise level exceeded for 1% of the 15 minute interval.

L_{A10} The noise level exceed for 10% of the 15 minute interval. This is commonly referred to as the average maximum noise level.

L_{A90} The noise level exceeded for 90% of the sample period. This noise level is described as the average minimum background sound level (in the absence of the source under consideration), or simply the background level.

L_{Aeq} The A-weighted equivalent noise level (basically the average noise level). It is defined as the steady sound level that contains the same amount of acoustical energy as the corresponding time-varying sound.

When dealing with numerous days of statistical noise data, it is sometimes necessary to define the typical noise levels at a given monitoring location for a particular time of day. A standardised method is available for determining these representative levels.

This method produces representative L_{Aeq} and L_{A90} noise levels over the daytime, evening and night-time measurement periods, as required by the EPA. In addition the method produces mean or 'average' levels representative of the other descriptors (L_{Amax}, L_{A10}, etc).

5 Tonality

Tonal noise contains one or more prominent tones (i.e. distinct frequency components), and is normally regarded as more offensive than 'broad band' noise.

6 Impulsiveness

An impulsive noise is characterised by one or more short sharp peaks in the time domain, such as occurs during hammering.

7 Frequency Analysis

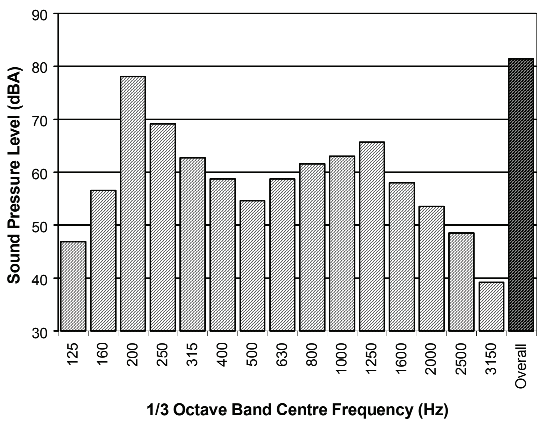
Frequency analysis is the process used to examine the tones (or frequency components) which make up the overall noise or vibration signal. This analysis was traditionally carried out using analogue electronic filters, but is now normally carried out using Fast Fourier Transform (FFT) analysers.

The units for frequency are Hertz (Hz), which represent the number of cycles per second.

Frequency analysis can be in:

- Octave bands (where the centre frequency and width of each band is double the previous band)
- 1/3 octave bands (3 bands in each octave band)
- Narrow band (where the spectrum is divided into 400 or more bands of equal width)

The following figure shows a 1/3 octave band frequency analysis where the noise is dominated by the 200 Hz band. Note that the indicated level of each individual band is less than the overall level, which is the logarithmic sum of the bands.



8 Vibration

Vibration may be defined as cyclic or transient motion. This motion can be measured in terms of its displacement, velocity or acceleration. Most assessments of human response to vibration or the risk of damage to buildings use measurements of vibration velocity. These may be expressed in terms of 'peak' velocity or 'rms' velocity.

The former is the maximum instantaneous velocity, without any averaging, and is sometimes referred to as 'peak particle velocity', or PPV. The latter incorporates 'root mean squared' averaging over some defined time period.

Vibration measurements may be carried out in a single axis or alternatively as triaxial measurements. Where triaxial measurements are used, the axes are commonly designated vertical, longitudinal (aligned toward the source) and transverse.

The common units for velocity are millimetres per second (mm/s). As with noise, decibel units can also be used, in which case the reference level should always be stated. A vibration level V, expressed in mm/s can be converted to decibels by the formula 20 log (V/V_o), where V_o is the reference level (10^{-9} m/s or 1 nm/s). Care is required in this regard, as other reference levels may be used by some organisations.

9 Human Perception of Vibration

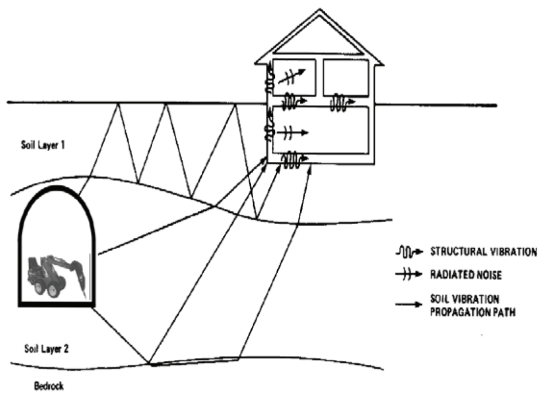
People are able to 'feel' vibration at levels lower than those required to cause even superficial damage to the most susceptible classes of building (even though they may not be disturbed by the motion). An individual's perception of motion or response to vibration depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as 'normal' in a car, bus or train is considerably higher than what is perceived as 'normal' in a shop, office or dwelling.

10 Ground-borne Noise, Structure-radiated Noise and Regenerated Noise

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

Typical sources of ground-borne or structure-radiated noise include tunnelling works, underground railways, excavation plant (e.g. rock breakers), and building services plant (e.g. fans, compressors and generators).

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



The term 'regenerated noise' is also used in other instances where energy is converted to noise away from the primary source. One example would be a fan blowing air through a discharge grill. The fan is the energy source and primary noise source. Additional noise may be created by the aerodynamic effect of the discharge grill in the airstream. This secondary noise is referred to as regenerated noise.

Appendix B Site Plan and Noise Monitoring Locations

Sheet 1

Site plan and noise monitoring locations

LEGEND

- Ventilation
- Noise Logging Locations
- NWRL Tunnel Track
- ECRL
- Construction Site

0 25 50 100 150 200
Metres

NOTES

1. Aerial photography © Transport for NSW

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North West Rail Link
Noise and Vibration

Prepared for:
Transport for NSW

Project No: **610.10597**

Scale	1:5,000 @ A3	Date	16-Oct-2012
Version	05	Approved	John Sleeman

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Sheet 2

Site plan and noise monitoring locations

LEGEND

- Noise Logging Locations
- NWRL Tunnel Track
- Construction Site

0 25 50 100 150 200
Metres

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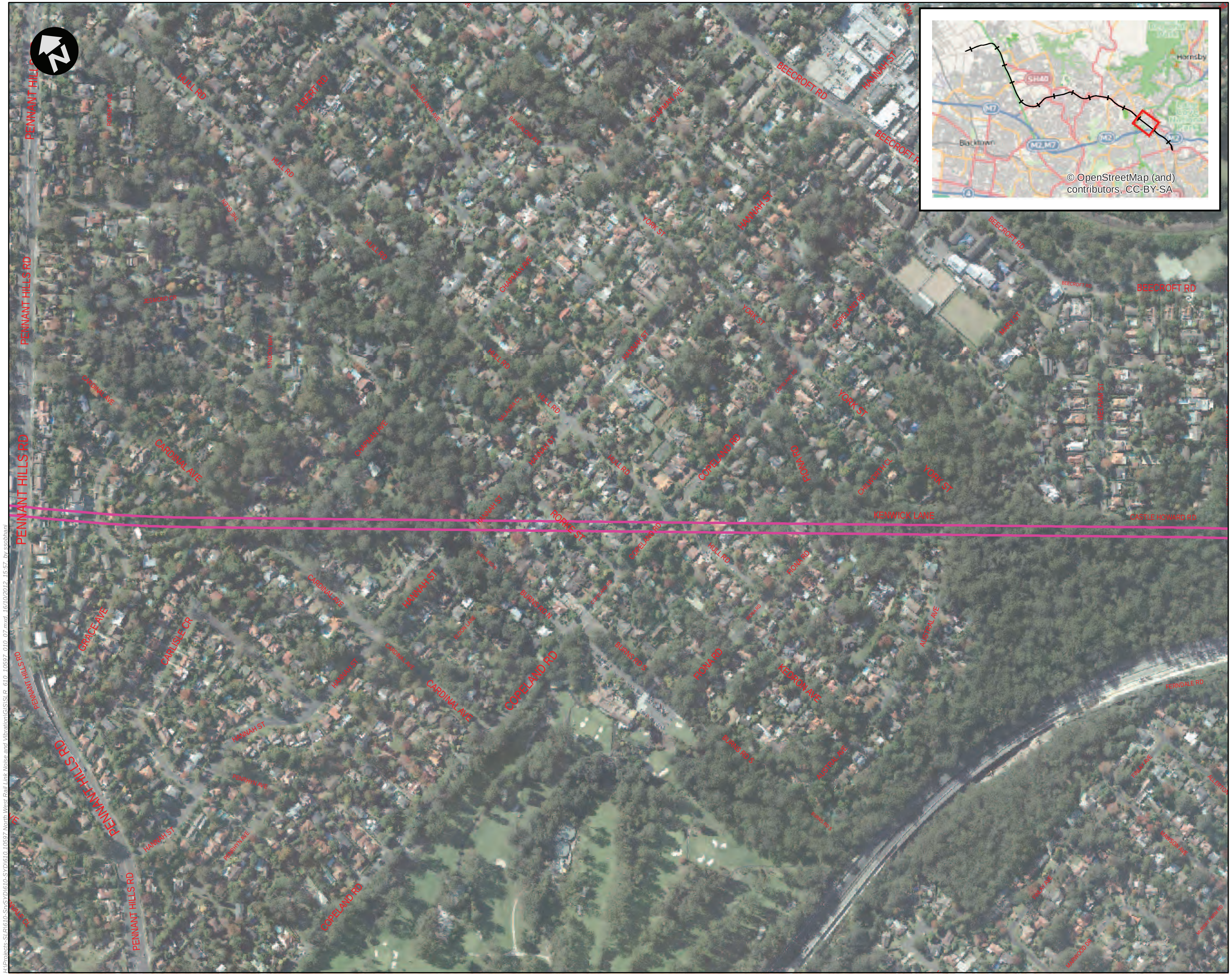
Sheet 3

Site plan and noise monitoring locations



LEGEND

NWRL Tunnel Track

0 25 50 100 150 200
Metres

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Site plan and noise monitoring locations

LEGEND

NWRL Tunnel Track

0 25 50 100 150 200
Metres

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Sheet 5

Site plan and noise monitoring locations

LEGEND

- Noise Logging Locations
- NWRL Tunnel Track
- Construction Site

0 25 50 100 150 200
Metres

NOTES

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