CHATSWOOD TO SYDENHAM

# ENVIRONMENTAL IMPACT STATEMENT

MAY 2016

## TECHNICAL PAPER 2: NOISE AND VIBRATION

global environmental solutions

# Sydney Metro Chatswood to Sydenham

# Technical Paper 2: Noise and Vibration

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# Executive Summary

Sydney Metro is a new standalone rail network identified in Sydney's Rail Future. The Sydney Metro network consists of Sydney Metro City & Southwest and Sydney Metro Northwest.

The proposed Sydney Metro City & Southwest comprises two core components:

- The Chatswood to Sydenham project (the project), the subject of this technical paper, would involve construction and operation of an underground rail line between Chatswood and Sydenham
- The Sydenham to Bankstown upgrade would involve the conversion of the 13.5 kilometre Bankstown line to metro standards and upgrade of existing stations between Sydenham and Bankstown.

The Sydenham to Bankstown upgrade will be subject to a separate environmental impact assessment.

Investigations have started on the possible extension of Sydney Metro from Bankstown to Liverpool. The potential extension would support growth in Sydney's south west by connecting communities, businesses, jobs and services as well as improving access between the south west and Sydney's CBD. It would also reduce growth pressure on road infrastructure and the rail network, including the potential to relieve crowding on the T1 Western Line, T2 South Line and T2 Airport Line.

The Sydney Metro Chatswood to Sydenham project (the project) involves the construction and operation of a metro rail line. The project would be mainly located underground in twin tunnels extending from Chatswood on Sydney's north shore, crossing under Sydney Harbour, and continue to Sydenham.

The key components of the project would include:

- About 15.5 kilometres of twin rail tunnels (that is, two tunnels located side-by-side) between Mowbray Road, Chatswood and north of Sydenham Station (near Bedwin Road, Marrickville).
- Realignment of the existing T1 North Shore Line surface track within the existing rail corridor between Chatswood Station and in the vicinity of Brand Street, Artarmon, including a new bridge for a section of the 'down' (northbound) track to pass over the proposed northern dive structure.
- About 250 metres of aboveground metro tracks between Chatswood Station and the Chatswood dive structure.
- A dive structure (about 400 metres long) and tunnel portal south of Chatswood Station and north of Mowbray Road, Chatswood (the Chatswood dive structure).
- A substation (for traction power supply) at Artarmon.
- Metro stations at Crows Nest, Victoria Cross, Barangaroo, Martin Place, Pitt Street and Waterloo; and new underground platforms at Central Station.
- A dive structure (about 400 metres long) and tunnel portal between Sydenham Station and Bedwin Road, Marrickville (the Marrickville dive structure).
- A services facility (for traction power supply and an operational water treatment plant) adjacent to the Marrickville dive structure.

The project would also include a number of ancillary components, including new overhead wiring and alterations to existing overhead wiring, signalling, access tracks / paths, rail corridor fencing, noise walls, fresh air ventilation equipment, temporary and permanent alterations to the road network, facilities for pedestrians, and other construction related works.

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### 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 management levels.

### Ambient Noise Monitoring

In order to characterise the existing ambient noise environment across the project area, environmental noise monitoring was performed at 25 representative locations during June 2015 and September 2015. This information has been supplemented with ambient noise data collated for other recent projects, resulting in an ambient noise database for a total of 29 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. These results were used to assist in determining the appropriate noise management levels (NMLs) as a basis for assessing the potential noise impacts during construction.

### Construction Noise Guidelines

The Interim Construction Noise Guideline (ICNG) was adopted to determine the NMLs for residential receivers as follows:

- Daytime (7:00 am to 6:00 pm) Rating Background Level +10 dB
- Evening (6:00 pm to 10:00 pm) Rating Background Level + 5 dB
- Night-time (10:00 pm to 7:00 am) Rating Background Level + 5 dB

At commercial receivers, the recommended NML is 70 dBA (external). Construction NMLs have also been established for other sensitive receivers such as schools, childcare centres and places of worship, and are discussed in the relevant sections of the report.

The ICNG provides residential NMLs for ground-borne noise, which are applicable when ground-borne noise levels are higher than the corresponding airborne noise levels. NMLs of 40 dBA and 35 dBA are applicable for the evening and night-time periods respectively. Additionally for project environmental impact assessment purposes two interim daytime NMLs have been adopted, a residential NML of 45 dBA, and commercial receiver NML of 50 dBA.

### Construction Noise and Vibration Strategy

A Sydney Metro City & Southwest Construction Noise and Vibration Strategy (Sydney Metro CNVS – refer to Appendix E of the Environmental Impact Statement) has been developed by the project design 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 (EPA 2011).

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**Daytime Construction Works**

At all sites, following site establishment and earthworks, construction activities are likely to occur over a period of several years. The potential noise and vibration impacts would be highest during any demolition works (if required), earthworks and during excavation works. These works would primarily be undertaken during daytime periods (7:00 am to 6:00 pm Monday to Friday and 8:00 am to 1:00 pm on Saturdays) using conventional methods. Construction noise and vibration levels during these stages would be similar to those occurring at many other building sites across the Sydney metropolitan area.

**Out of Hours Works**

Several of the sites support the operation of tunnel boring machines (TBMs) and roadheaders, which operate underground on a 24 hour per day basis and up to 7 days per week. Furthermore at most of the station sites it is required to excavate the shafts on a 24 hour per day basis and up to 7 days per week as this work is required to be completed prior to the TBM arrival. At these construction sites, mitigation measures are likely to involve the construction of acoustic enclosures and/or noise barriers to contain noise emissions. Prior to undertaking significant “out of hours” works, noise mitigation and management measures would be implemented (where required) to minimise the potential noise and vibration impacts at nearby sensitive receivers.

**Construction Sites**

At this early stage in the planning process of the project, detailed information in relation to the proposed construction works, equipment and site layouts is not available. The construction noise and vibration assessments have therefore been based on preliminary information and previous project experience, and would 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 construction activities, it is expected that the construction noise levels will be lower than predicted in this report.

At the TBM support and underground station sites, predictions indicate that there would be exceedances of more than 20 dB of the NMLs at the nearest surrounding receivers during site establishment and excavation, occurring during the daytime construction period. These are a direct result of the relative close proximity of receivers to the construction activities and the absence of any appreciable shielding between sites and receivers. Where spoil handling and station box/shaft excavation is required during the night-time, an acoustic shed has been included to reduce exceedances of the NMLs. Three metre perimeter hoarding has been included in the modelling to reduce impacts.

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Careful management of the noise and vibration impacts will be required at all construction sites. To mitigate impacts, feasible mitigation measures are likely to include the use of 3 m to 6 m high perimeter noise walls or full enclosures of the noise-producing areas of the worksites (for night-time activities), noting that noise walls are effective for receivers at or near ground level (e.g. outdoor recreation areas and single story dwellings) and not so effective for higher receivers overlooking the sites. The indicative enclosure construction would consist of metal cladding with internal insulation faced with perforated steel sheet or aluminium foil on the walls and roof. Where increased noise insulation is required for the acoustic enclosures, this can be achieved by upgrading the enclosure elements by using, for example, double metal-skin-cladding or masonry construction. The reasonableness of the identified feasible mitigation measures would be assessed during the construction planning and site establishment phases of the project. This assessment will include aspects such as the cost of mitigation, the noise benefit received, the number of receivers protected, the time of day and the duration of the noise emissions.

Having considered all feasible and reasonable noise mitigation as part of the design, the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement) would be implemented to manage the potential noise impacts.

A summary of the recommended site specific noise and vibration mitigation measures to reduce the potential impacts at sensitive receivers is provided in **Table 106**.

### Construction Ground-borne Noise

Potential ground-borne noise impacts are likely to be highest at sensitive receiver locations close to the underground stations and the main tunnel alignments. At the station construction sites, shaft and station excavation by rockbreaker, and cavern excavation by roadheaders, are anticipated to operate during the daytime and night-time periods.

Ground-borne noise levels from rockbreakers would exceed the NML by up to and more than 30 dB at the nearest commercial and residential receivers for many of the stations sites where shaft excavations occur. The duration of the excavation of each shaft varies; however, these impacts can be expected for up to six to twelve months at the worst affected properties. These exceedances at night-time would trigger alternative accommodation in accordance with the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement). Where these exceedances are predicted at residential and commercial receivers during the daytime for prolonged durations it has been recommended that alternative accommodation be considered as a mitigation option. A potential alternative to continuous rock breaking for the station shaft excavations is through the use of controlled blasting. When blasting is feasible (at a safe depth) the effective duration of rock breakers required for the station shaft excavations would be significantly reduced.

Roadheaders, which are used to excavate the station caverns, create far less ground borne noise and are unlikely to exceed the NMLs even when the roadheader is located close to sensitive receivers.

The rail tunnels are proposed to be excavated using TBMs. Tunnelling activities are anticipated to occur on 24 hour per day basis, up to 7 days per week. At any particular receiver, the potential ground-borne noise impact from tunnelling is anticipated to occur only for short periods of time when each TBM passes by. Given the progression rate of the TBM (around 20 m per day), it is anticipated that the worst-case ground-borne noise impacts along the majority of the alignment would only be apparent for a relatively short period of time (ie up to approximately four days for each TBM) whilst the tunnelling works are directly beneath a particular receiver. For roadheaders, the rate of progress would be less than for the tunnel boring machines (around 4 m per day), but the overall ground-borne noise levels would be lower.

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Where exceedances of the NMLs are predicted, these would need to be managed or mitigated in accordance with the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement).

## 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 inconvenienced or possibly disturbed (human perception or human comfort vibration).
- Those where the building contents may be affected.
- Those in which the integrity of building elements or the structure itself may be prejudiced.

A conservative vibration damage screening (trigger) level of 25 mm/s for reinforced or framed structures (industrial and heavy commercial buildings) and 7.5 mm/s for unreinforced or light framed structures (residential or light commercial type buildings) has been adopted for the project and has been established with reference to the minor cosmetic damage criteria in British Standard BS 7385 Part 2-1993. The vibration levels specified in this standard are designed to minimise the risk of threshold or cosmetic surface cracks, and are set well below the levels that have potential to cause damage to the main structure. The recommended unreinforced structure screening level of 7.5 mm/s is also applicable to heritage structures.

Buildings that are potentially at risk of threshold or cosmetic damage would be identified by the contractor prior to the commencement of construction works. At these locations, impacts will be managed in accordance with the procedures outlined in the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement), which may require building condition surveys to be conducted before the commencement of construction activities and after construction is completed.

Where buildings are located close to vibration generating activities, attended vibration measurements would be undertaken under carefully controlled equipment testing regimes at the commencement of the works to establish environmentally safe operating distances. At some sites, long-term monitoring systems may be required to ensure that vibration levels remain within the established limits.

Buildings are generally far more resistance to vibration than is commonly realised. Humans are far more sensitive to vibration than is commonly realised and can perceive vibration at very low levels and would generally be very uncomfortable at vibration levels well below those that present any risk of structural damage. Human comfort vibration management levels have been established on the basis of the Assessing Vibration - a technical guideline (DEC 2006). During construction, the potential impact of vibration on building occupants will be managed in accordance with the procedures outlined in the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement), which may involve the observance of respite periods, alternative construction methods or attended monitoring.

Blasting is assessed as an option for the excavation works, as noise and vibration impacts are significantly shorter in duration than conventional excavation techniques. Guidance in relation to acceptable overpressure and vibration from blasting is based on recent NSW infrastructure project approvals resulting in a vibration limit of 25 mm/s and overpressure limit of 125 dBL for the project.

A more detailed assessment of the realistic worst-case noise and vibration levels from blasting would need to be undertaken and compared with noise and vibration criteria. Alternative construction methods such as penetrating cone fracture would need to be considered if the predicted noise and vibration levels from blasting exceed the criteria.

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## Construction Traffic

The proposed traffic access routes to construction sites is via arterial, sub-arterial or local roads which all have significant daytime flows. The additional daytime construction traffic is not predicted to result in a noticeable change in traffic noise levels on these access routes.

Night-time spoil removal may be required at some sites, however as access is generally via arterial and sub-arterial roads with moderate night-time flows, the additional heavy vehicles movements result in a minor increase in traffic noise levels on the public road network. Whilst the maximum noise levels associated with truck movements exceed the background + 15 dB sleep disturbance screening criterion at most locations, the maximum noise levels will be similar to other heavy vehicles using the public road network. At Chatswood, Crows Nest, and Victoria Cross, site access is via a local road with low night-time flows and a resultant sleep disturbance risk. Unless compliance with the road traffic noise criteria can be achieved, night-time heavy vehicles movements on local roads at these sites would be restricted.

The maximum noise levels associated with on site truck movements can potentially cause awakening reactions (or sleep disturbance) at nearby residences. At each of the TBM and underground station sites, it is anticipated that truck movements would be required during night-time periods. At these sites, with the exception of those in the CBD, maximum noise levels from on site truck movements are predicted to exceed the background + 15 dB sleep disturbance screening criterion at the nearest residences.

## Operational Airborne Noise - Surface Tracks

Airborne noise created by train operations on surface track requires the assessment of noise impacts against the noise trigger levels defined in the NSW EPA Rail Infrastructure Noise Guideline (2013). If these trigger levels are exceeded, consideration of noise mitigation for existing sensitive receivers, both at opening and at an indicative time in the future (taken to be 10 years after opening), is required.

The introduction of the new rail lines associated with the project would result in rail tracks being closer to the adjacent receivers than the existing case in some areas. Furthermore, the project would also result in a considerable increase in the total number of trains operating within the rail corridor. In the opening 2024 timeframe the project would more than double the number of trains operating, whilst in the future 2034 timeframe the project would result in an increase of over 108%.

The project proposes to include several noise abatement elements in the base case design. The base case noise mitigation options include rail dampers and deck absorption on slab track in the region of the Chatswood Dive, and increasing the height of existing noise barriers on the up and down sides of the rail corridor at several locations between Nelson Street, Chatswood and Albert Avenue, Chatswood

With the inclusion of the base case mitigation options, noise modelling indicates the potential for exceedances of the noise trigger levels at one sensitive receiver building adjacent the proposed surface track at Chatswood. No exceedances of noise trigger levels are predicted for sensitive receivers surrounding the Marrickville dive structure.

Residual impacts at the multistorey residential apartment building at Chatswood may require consideration of property treatments if detailed design studies determine alternative controls are not feasible and reasonable.

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## Operational Ground-borne 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 track sections associated with the project would typically be limited to less than 10 to 15 m from the surface track, depending on speed.

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 vibration comfort goals, so vibration mitigation measures are normally determined by the ground-borne noise assessment.

Compliance with the ground-borne vibration objectives is predicted for all residential receivers and other sensitive receiver locations above or near to the proposed project alignment.

## Operational Ground-borne 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. Therefore, the surface track sections at Chatswood and Marrickville are not prone to ground-borne noise impacts. 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 have been made for all buildings located above or close to the proposed rail alignments. 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 the Standard Attenuation track may be required to achieve compliance with the ground-borne noise design objectives.

With the proposed track forms as outlined in **Table 84** ground-borne noise levels are predicted to comply with the design objectives at all residential and other sensitive receiver locations.

## Operational Airborne Noise from Stations and Ancillary Facilities

The potential operational noise impacts from stations 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.

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Mitigation measures are likely to be required for some station and tunnel ventilation equipment 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, acoustic enclosures and the strategic positioning and direction of ventilation discharges away from sensitive receivers.

Train noise break-out through the draught relief shafts from trains operating within the tunnels is not expected to exceed the 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).

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**APPENDICES**

# GLOSSARY

| Item | Description / Definition |
|---|---|
| AADT | Annual Average Daily Traffic (AADT) is the total yearly traffic volume in both directions divided by the number of days in the year |
| CNS | Construction Noise 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) |
| 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 |
| INP | Industrial Noise Policy |
| Lidar | Light Detection and Ranging |
| NML | Noise Management Level |
| NSW | New South Wales |
| RBL | Rating Background Level |
| RING | Rail Infrastructure Noise Guideline |
| RMS | Root Mean Square |
| RNP | Road Noise Policy |
| SEAR | Secretary’s Environmental Assessment Requirement |
| SLR | SLR Consulting Australia Pty Ltd |
| Sydney Metro CNVS | *Sydney Metro City & Southwest Construction Noise and Vibration Strategy (draft)* |
| SWL | Sound Power Level |
| TBM | Tunnel Boring Machine |
| TfNSW | Transport for NSW |

# 1 INTRODUCTION

## 1.1 Project Background

Sydney Metro is a new standalone rail network identified in Sydney's Rail Future. The Sydney Metro network consists of Sydney Metro City & Southwest and Sydney Metro Northwest.

The proposed Sydney Metro City & Southwest comprises two core components:

- The Chatswood to Sydenham project (the project), the subject of this technical paper, would involve construction and operation of an underground rail line between Chatswood and Sydenham.
- The Sydenham to Bankstown upgrade would involve the conversion of the 13.5 kilometre Bankstown line to metro standards and upgrade of existing stations between Sydenham and Bankstown.

Both components are subject to assessment by the Department of Planning and Environment and approval by the Minister for Planning under Part 5.1 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). The Sydenham to Bankstown upgrade will be subject to a separate environmental impact assessment.

Sydney Metro Northwest (formerly the North West Rail Link) is currently under construction, services will start in the first half of 2019. This includes a new metro rail line between Rouse Hill and Epping and conversion of the existing rail line between Epping and Chatswood to metro standards.

Investigations have started on the possible extension of Sydney Metro from Bankstown to Liverpool. The potential extension would support growth in Sydney's south west by connecting communities, businesses, jobs and services as well as improving access between the south west and Sydney's CBD. It would also reduce growth pressure on road infrastructure and the rail network, including the potential to relieve crowding on the T1 Western Line, T2 South Line and T2 Airport Line.

The Sydney Metro Delivery Office has been established as part of Transport for NSW to manage the planning, procurement and delivery of the Sydney Metro network.

The Sydney Metro rail network is shown in **Figure 1**.

## 1.2 The Sydney Metro network

The customer experience underpins how Sydney Metro is being planned and designed. The customer experience incorporates all aspects of travel associated with the transport network, service and project including:

- The decision on how to travel.
- The travel information available.
- The speed and comfort of the journey.
- The range and quantity of services available at stations, interchanges and within station precincts.

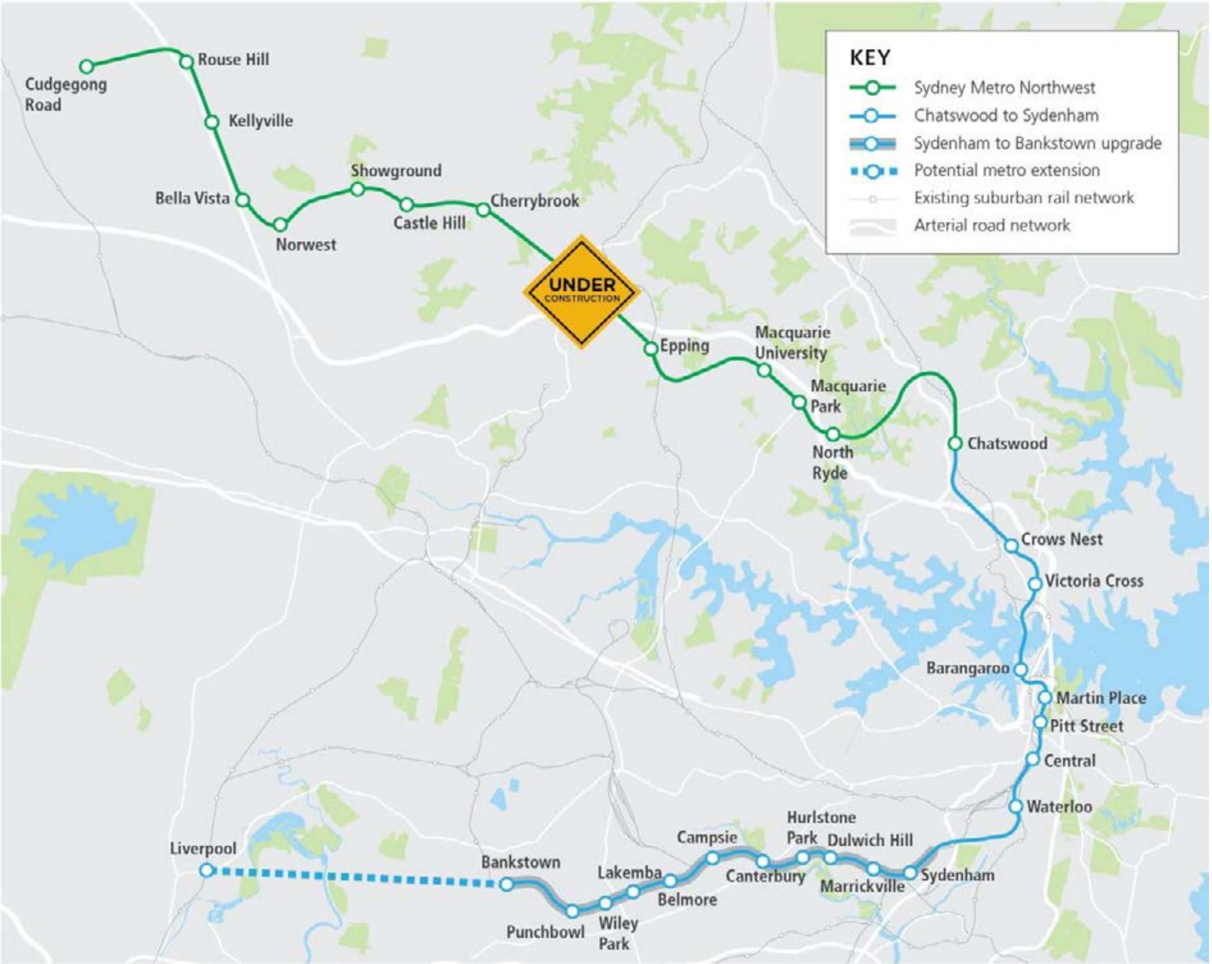
A high quality 'door to door' transport product is critical to attract and retain customers and also to meet broader transport and land use objectives. This includes providing a system that is inherently safe for customers on trains, at stations and at the interface with the public domain; providing direct, comfortable, legible and safe routes for customers between transport modes; and provide a clean, pleasant and comfortable environment for customers at stations and on trains.

Key features of the metro product include:

- Comfortable carriages with space for customers to sit or stand.
- A 'turn-up-and-go' service, with high frequency trains Reduced journey times with faster trains, and new underground routes through the Sydney CBD.
- Increased capacity to safely and reliably carry more customers per hour due to the increased frequency of trains.
- Reduced dwell times at stations as each carriage would be single-deck with three doors, allowing customers to board and alight more quickly than they can with double-deck carriages.

The Chatswood to Sydenham project would have the capacity to run up to 30 trains per hour through the Sydney CBD in each direction, which would provide the foundation for delivering a 60 per cent increase in the number of trains operating in peak periods, and cater for an extra 100,000 customers per hour.

**Figure 1 The Sydney Metro network**



## 1.3 Overview of the Project

### 1.3.1 Location

The Sydney Metro Chatswood to Sydenham project (the project) involves the construction and operation of a metro rail line. The project would be mainly located underground in twin tunnels extending from Chatswood on Sydney's north shore, crossing under Sydney Harbour, and continue to Sydenham.

### 1.3.2 Key Features

The proposed alignment and key operational features of the project are shown **Figure 2** and would include:

- Realignment of T1 North Shore Line surface track within the existing rail corridor between Chatswood Station and Brand Street, Artarmon, including a new bridge for a section of the 'down' (northbound) track to pass over the proposed northern dive structure.
- About 250 metres of aboveground metro tracks between Chatswood Station and the Chatswood dive structure.
- A dive structure (about 400 metres long) and tunnel portal south of Chatswood Station and north of Mowbray Road, Chatswood (the Chatswood dive structure).
- About 15.5 kilometres of twin rail tunnels (that is, two tunnels located side-by-side) between Mowbray Road, Chatswood and Bedwin Road, Marrickville. The tunnel corridor would extend about 30 metres either side of each tunnel centre line and around all stations.
- A substation (for traction power supply) in Artarmon, next to the Gore Hill Freeway, between the proposed Crows Nest Station and the Chatswood tunnel portal.
- Metro stations at Crows Nest, Victoria Cross, Barangaroo, Martin Place, Pitt Street and Waterloo; and new underground platforms at Central Station.
- A dive structure (about 400 metres long) and tunnel portal between Sydenham Station and Bedwin Road, Marrickville (the Marrickville dive structure).
- A services facility beside the Marrickville dive structure and tunnel portal, including a tunnel water treatment plant and a substation (for traction power supply).

The project would also include:

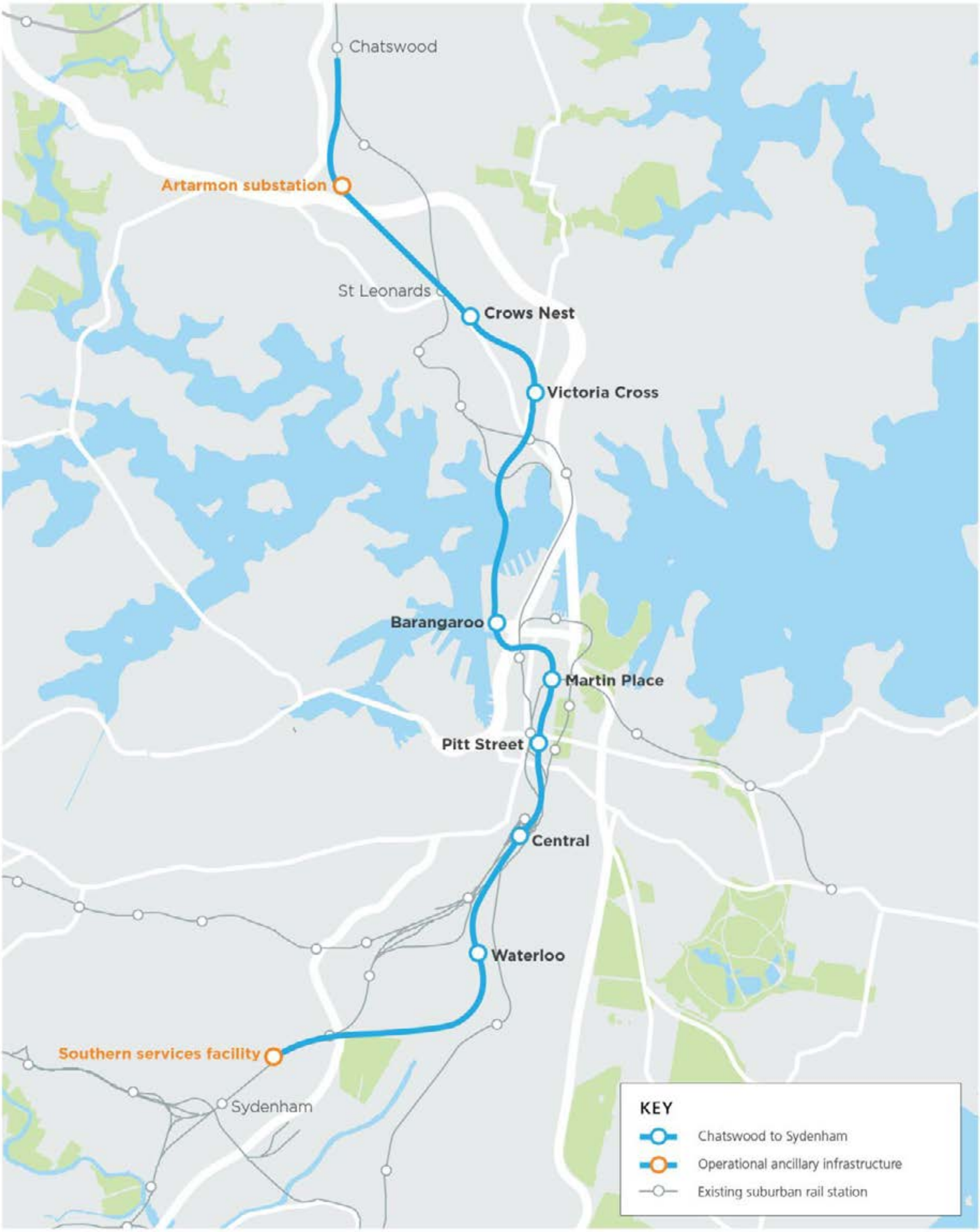
- Permanent closure of the road bridge at Nelson Street, Chatswood, and provision of an all vehicle right-turn movement from the Pacific Highway (southbound) into Mowbray Road (westbound).
- Changes to arrangements for maintenance access from Hopetoun Avenue and Albert Avenue, Chatswood as well as a new access point from Brand Street, Artarmon.
- Underground pedestrian links at some stations and connections to other modes of transport (such as the existing suburban rail network) and surrounding land uses.
- Alterations to pedestrian and traffic arrangements and public transport infrastructure (where required) around the new stations and surrounding Central Station.
- Installation and modification of existing Sydney Trains rail systems including overhead wiring, signalling, rail corridor fencing and noise walls, within surface sections at the northern end of the project.
- Noise barriers (where required) and other environmental protection measures.

The proposed construction activities for the project broadly include:

- Demolishing buildings and structures at the station sites and other construction sites.
- Constructing tunnels, dive structures and tunnel portals.
- Excavating, constructing and fitting out metro stations
- Fitting out tunnel rail systems and testing and commissioning of stations, tunnels, ancillary infrastructure, rail systems and trains.
- Excavating shafts, carrying out structural work and fitting out ancillary infrastructure at Artarmon
- Carrying out structural work and fitting out ancillary infrastructure at Marrickville.

A number of construction sites would be required to construct the project. These include locations for tunnel equipment and tunnel boring machine support at Chatswood, Barangaroo and Marrickville as well as at station sites; a casting yard and segment storage facility at Marrickville and a temporary tunnel boring machine retrieval site at Blues Point.

**Figure 2 Project Overview**



## 1.4 Purpose and Scope of this Report

The project has been declared State significant infrastructure and critical State significant infrastructure and therefore is subject to assessment by the Department of Planning and Environment and approval by the Minister for Planning under Part 5.1 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act).

This technical paper, *Technical Paper 2: Noise and Vibration* is one of a number of technical documents that forms part of the Environmental Impact Statement. The purpose of this technical paper is to identify and assess the noise and vibration impacts of the project during both construction and operation. In doing so it responds directly to the Secretary's environmental assessment requirements outlined in **Section 1.4.1**.

This technical paper considers the construction and operational noise and vibration impacts on the surrounding noise and vibration sensitive receives.

The assessment of noise and vibration has included:

- Ambient noise and vibration surveys to determine the existing noise and vibration environment within the surrounding environment of the proposal.
- Identification of receivers along the alignment and major construction sites potentially sensitive to noise and vibration.
- Prediction of noise and vibration from the construction and operation of the metro service, including stations and ancillary facilities.
- Assessment of potential noise and vibration impacts in accordance with relevant legislation and guidelines.
- Identification of potential improvement to existing noise environments as a result of the proposal.
- Identification of management and mitigation measures to reduce and control potential impacts where noise and vibration levels are predicted to be above the relevant assessment criteria.

### 1.4.1 Secretary's Environmental Assessment Requirements

The Secretary's environmental assessment requirements relating to noise and vibration, and where these requirements are addressed in this technical paper, are outlined in **Table 1**.

**Table 1 Secretary's Environmental Assessment Requirements - *Noise and Vibration***

| Secretary's environmental assessment requirements | Where addressed |
|---|---|
| **8. Noise and Vibration - Amenity**<br>Construction noise and vibration (including airborne noise, ground-borne noise and blasting) are effectively managed to minimise adverse impacts on acoustic amenity.<br>Increases in noise emissions and vibration affecting nearby properties and other sensitive receivers during operation of the project are effectively managed to protect the amenity and well-being of the community.<br>1. The Proponent must assess construction and operational noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must include consideration of impacts to sensitive receivers including commercial premises, and include consideration of sleep disturbance and, as relevant, the characteristics of noise and vibration (for example, low frequency noise).<br>2. If blasting is required, the relevant requirements of the Technical basis for guidelines to minimise annoyance due to blasting overpressure and ground vibration (ANZEC 1990) are to be assessed. | Applicable guidelines outlined in **Sections 3.1, 4.2.3, 4.3.3,** and **4.4.2**.<br>Assessment throughout **Sections 3** and **4**.<br>Blasting guideline values are outlined in **Section 3.1.12,** and a consideration and assessment of blasting at each relevant construction site is provided in **Section 3**. |
| **9. Noise and Vibration - Structural**<br>Construction noise and vibration (including airborne noise, ground-borne noise and blasting) are effectively managed to minimise adverse impacts on the structural integrity of buildings and items including Aboriginal places and environmental heritage.<br>Increases in noise emissions and vibration affecting environmental heritage as defined in the *Heritage Act 1977* during operation of the project are effectively managed.<br>1. The Proponent must assess construction and operation noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must include consideration of impacts to the structural integrity and heritage significance of items (including Aboriginal places and items of environmental heritage).<br>2. The Proponent must demonstrate that blast impacts are capable of complying with the current guidelines, if blasting is required. | Applicable guidelines outlined in **Sections 3.1** and **4.1.2**.<br>Assessment throughout **Sections 3** and **4**.<br>Blasting guideline values are outlined in **Section 3.1.12,** and a consideration and assessment of blasting at each relevant construction site is provided in **Section 3**. |

## 1.5 Relevant Guidelines

Noise from the operation of the rail line has been assessed in accordance with guidance provided by the NSW Environment Protection Authority (EPA) in the *Rail Infrastructure Noise Guideline* (RING), NSW EPA, 2013[i].

Noise from mechanical plant at stations and ancillary facilities has been assessed in accordance with the NSW *Industrial Noise Policy* (INP), NSW EPA, 2000[ii], with guidance on sleep disturbance criteria taken from the online Application Notes to the INP.

Construction noise has been assessed in accordance with the *Interim Construction Noise Guideline* (ICNG), DECC, 2009[iii]. Construction road traffic noise has been assessed in accordance with the NSW *Road Noise Policy* (RNP), NSW EPA, 2011[iv].

Vibration from operation and construction has been assessed in accordance with *Assessing Vibration: A technical guideline*, DEC, 2006[v].

## 1.6 Terminology

The assessment has used specific acoustic terminology; an explanation of common terms is included as **Appendix A**.

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 consistent with standard transport terminology.

# 2 DESCRIPTION OF EXISTING ACOUSTIC 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 project area (within approximately 100 m on either side of the alignment and within 200 m of the proposed construction sites).

## 2.1 Sensitive Receivers

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

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

## 2.2 Sensitive Receiver Categories

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 was reviewed. 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. Child care
8. Special Sensitive (eg hospital, precision laboratories, recording studios)

The noise and vibration assessment presented in this report considers all residential receivers, educational receivers, places of worship, theatres, etc to be of a sensitive nature. Commercial receivers are generally considered to be less sensitive to noise and vibration compared to residential and similar sensitive receivers.

The project area has been divided into multiple Noise Catchment Areas (NCAs). These NCAs reflect the changing land uses and ambient noise environments adjacent to the project. The NCAs and sensitive receivers are illustrated in Appendix C Project Site Plan.

A more detailed description of the nearest sensitive receivers to each major works site is provided in **Section 3.1.2** of this report.

## 2.3 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 on which to base the construction noise management levels, environmental noise monitoring was performed at 25 representative locations during June to July and August to September 2015. This information has been supplemented with ambient noise data collated during the now abandoned CBD Metro project and other recent projects, resulting in a database for a total of 29 representative locations across the project area. The previous ambient noise surveys were conducted in 2009, 2013 and 2014, and whilst the 2009 survey is dated a review of the data and comparison to other Sydney CBD results have indicated valid results.

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 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 2** lists the various monitoring locations, whilst **Appendix B** illustrates the locations graphically as well as the noise monitoring results.

**Table 2 Ambient Noise Monitoring Locations**

| Location | Address | Project Area | Monitoring Period | Year Collated |
|---|---|---|---|---|
| B.01 | 104 Unwins Bridge Road, St Peters | Marrickville dive site | 19 June 2015 to 2 July 2015 | 2015 |
| B.02 | 322 Edgeware Road, Newtown | Marrickville dive site | 31 August 2015 to 3 September 2015 | 2015 |
| B.03 | 1B Leicester Street, Marrickville | Marrickville dive site | 19 June 2015 to 2 July 2015 | 2015 |
| B.04 | 46 Dickson Street, Newtown | Above alignment just north of Marrickville tunnel portal | 19 June 2015 to 2 July 2015 | 2015 |
| B.06 | 122 Wellington Street, Waterloo | Waterloo Station | 31 August 2015 to 13 September 2015 | 2015 |
| B.09 | 101 Chalmers Street, Chippendale (Railway Institute) | Central Station | 4 September 2015 to 17 September 2015 | 2015 |
| B.10 | 8/10 Lee Street, Sydney (YHA Railway Square) | Central Station | 19 June 2015 to 2 July 2015 | 2015 |
| B.11 | 1 Hoskings Place, Sydney | Martin Place Station | 19 June 2015 to 2 July 2015 | 2015 |

| Location | Address | Project Area | Monitoring Period | Year Collated |
|---|---|---|---|---|
| B.12 | 26A High Street, Millers Point (Barangaroo) | Barangaroo Station | 1 September 2015 to 13 September 2015 | 2015 |
| B.13 | 2-60 Cumberland Street, The Rocks | Sydney Harbour ground improvement works | 19 June 2015 to 2 July 2015 | 2015 |
| B.14 | 20/30 Blues Point Road, McMahons Point | Blues Point temporary site | 31 August 2015 to 15 September 2015 | 2015 |
| B.15 | 23 Queens Avenue, McMahons Point | Above alignment south of Victoria Cross Station | 19 June 2015 to 1 July 2015 | 2015 |
| B.16 | Unit 3004 / 77-81 Berry Street, North Sydney | Victoria Cross Station | 1 September 2015 to 14 September 2015 | 2015 |
| B.17 | 12-16 Berry Street, North Sydney | Victoria Cross Station | 22 June 2015 to 1 July 2015 | 2015 |
| B.18 | 237 Miller Street, North Sydney | Victoria Cross Station | 1 September 2015 to 12 September 2015 | 2015 |
| B.19 | 420 Pacific Highway, Crows Nest | Crows Nest Station | 19 June 2015 to 2 July 2015 | 2015 |
| B.20 | 7 Francis Street, Naremburn | Artarmon substation | 19 June 2015 to 2 July 2015 | 2015 |
| B.21 | 6 Milner Road, Artarmon | Artarmon Substation | 1 September 2015 to 12 September 2015 | 2015 |
| B.22 | 14 Raleigh Street, Artarmon | Chatswood dive site | 31 August 2015 to 13 September 2015 | 2015 |
| B.23 | 518 Pacific Highway, Lane Cove North (Chatswood South Uniting Church) | Chatswood dive site | 1 September 2015 to 12 September 2015 | 2015 |
| B.24 | 14 Nelson Street, Chatswood (Ausgrid) | Chatswood dive site | 3 September 2015 to 12 September 2015 | 2015 |
| B.25 | 13 Hopetoun Avenue, Chatswood | Surface track south of Chatswood Station | 27 August 2015 to 6 September 2015 | 2015 |
| B.26[1] | 812 George Street, Sydney (Christ Church St Laurence) | Central Station | 16 April 2009 to 28 April 2009 | 2009 |
| B.27[1] | 260 Pitt Street (Criterion Hotel) | Pitt Street Station | 15 April 2009 to 29 April 2009 | 2009 |
| B.28[1] | 56A Pirrama Road, Pyrmont (Wharf 8) | Barangaroo Station | 26 August 2014 to 9 September 2014 | 2014 |
| B.29[1] | Goat Island | Barangaroo Station | 18 January 2013 to 4 February 2013 | 2013 |

Note 1: Noise monitoring data were taken from SLR's database.

### 2.3.1 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.

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*[vii] (AS1259.2) and carried appropriate and current NATA calibration certificates. All noise loggers were fitted with microphone wind shields.

The equipment utilised for the continuous unattended noise surveys are outlined in **Table 3** below.

**Table 3 Noise Survey Instrumentation**

| Location | Equipment | Serial Number |
|---|---|---|
| *Unattended Noise Monitoring Instrumentation* | | |
| B.01 | ARL Type 316 environmental noise loggers | 16-207-046 |
| B.02 | SVANTEK Type 957 noise logger | 23816 |
| B.03 | SVANTEK Type 957 noise logger | 27580 |
| B.04 | ARL Type 316 environmental noise loggers | 16-306-047 |
| B.06 | SVANTEK Type 957 noise logger | 23245 |
| B.09 | SVANTEK Type 957 noise logger | 23244 |
| B.10 | SVANTEK Type 957 noise logger | 20667 |
| B.11 | SVANTEK Type 957 noise logger | 23245 |
| B.12 | SVANTEK Type 957 noise logger | 27578 |
| B.13 | SVANTEK Type 957 noise logger | 23243 |
| B.14 | SVANTEK Type 957 noise logger | 20670 |
| B.15 | SVANTEK Type 957 noise logger | 23816 |
| B.16 | SVANTEK Type 957 noise logger | 20667 |
| B.17 | SVANTEK Type 957 noise logger | 23241 |
| B.18 | ARL Type 316 environmental noise loggers | 16-306-047 |
| B.19 | SVANTEK Type 957 noise logger | 23241 |
| B.20 | SVANTEK Type 957 noise logger | 23241 |
| B.21 | ARL Type 316 environmental noise loggers | 16-306-039 |
| B.22 | SVANTEK Type 957 noise logger | 20674 |
| B.23 | ARL Type 316 environmental noise loggers | 16-306-041 |
| B.24 | SVANTEK Type 957 noise logger | 21884 |
| B.25 | SVANTEK Type 957 noise logger | 23815 |
| B.26 (2009) | ARL Type 215 environmental noise loggers | 193410 |
| B.27 (2009) | ARL Type 316 environmental noise loggers | 16-207-048 |
| B.28 (2014) | SVANTEK Type 957 noise logger | 23243 |
| B.29 (2013) | SVANTEK Type 957 noise logger | 23815 |
| *Operator Attended Noise Monitoring Instrumentation* | | |
| Various | Brüel & Kjær Type 2270L Sound Level Meter | 3004635 |
| Various | Brüel & Kjær Type 2260 Sound Level Meter | 2414604 |
| Various | Brüel & Kjær Type 2260 Sound Level Meter | 3004636 |
| Various | SVANTEK Type 957 Sound Level Meter | 21884 |
| Various | Brüel & Kjær Type 2260 Sound Level Meter | 3003632 |

| Location | Equipment | Serial Number |
|---|---|---|
| Various | Brüel & Kjær Type 4231 Acoustic Calibrator | 2218228 |
| Various | Brüel & Kjær Type 4231 Acoustic Calibrator | 2482669 |
| Various | SVANTEK SV30A Acoustic Calibrator | 24614 |

Note: ARL - Australian Research Laboratories.

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 Observatory Hill Weather Station for city centre and north of the harbour, and Sydney Airport Weather Station for locations beyond Central station to the south) 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 results.

### 2.3.2 Unattended Noise Monitoring Results

The results of the unattended ambient noise surveys are presented in **Table 4**, with the 24 hour average noise level plots for each monitoring location being shown graphically in **Appendix B**.

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**.

**Table 4 Summary of Unattended Noise Monitoring Results**

| Location | Noise Level (dBA)[1, 2] | | | | | |
|---|---|---|---|---|---|---|
| | 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 | $L_{Aeq}$ |
| B.01 | 59 | 71 | 53 | 69 | 41 | 65 |
| B.02 | 58 | 69 | 52 | 66 | 38 | 62 |
| B.03 | 52 | 66 | 43 | 64 | 38 | 58 |
| B.04 | 47 | 61 | 47 | 59 | 47 | 53 |
| B.06 | 54 | 65 | 47 | 62 | 39 | 58 |
| B.09 | 56 | 68 | 53 | 66 | 45 | 64 |
| B.10 | 51 | 65 | 50 | 64 | 49 | 62 |
| B.11 | 61 | 66 | 56 | 62 | 52 | 63 |
| B.12 | 50 | 61 | 45 | 64 | 40 | 51 |
| B.13 | 62 | 66 | 62 | 65 | 52 | 63 |
| B.14 | 51 | 62 | 49 | 61 | 40 | 54 |
| B.15 | 38 | 51 | 38 | 47 | 36 | 45 |
| B.16 | 65 | 68 | 63 | 65 | 52 | 62 |
| B.17 | 55 | 61 | 50 | 55 | 44 | 51 |

| Location | Noise Level (dBA)[1, 2] | | | | | |
|---|---|---|---|---|---|---|
| | Daytime<br>7:00 am to 6:00 pm | | Evening<br>6:00 pm to 10:00 pm | | Night-time<br>10:00 pm to 7:00 am | |
| | RBL | LAeq | RBL | LAeq | RBL | LAeq |
| B.18 | 65 | 74 | 57 | 71 | 51 | 66 |
| B.19 | 59 | 68 | 55 | 67 | 50 | 62 |
| B.20 | 45 | 56 | 45 (46)[3] | 54 | 38 | 50 |
| B.21 | 49 | 55 | 46 | 50 | 41 | 48 |
| B.22 | 42 | 55 | 41 | 50 | 34 | 48 |
| B.23 | 63 | 71 | 60 | 70 | 45 | 67 |
| B.24 | 50 | 59 | 47 | 58 | 39 | 55 |
| B.25 | 41 | 54 | 40 | 53 | 35 | 49 |
| B.26 (2009) | 58 | 70 | 56 | 69 | 52 | 66 |
| B.27 (2009) | 66 | 71 | 64 | 70 | 61 | 68 |
| B.28 (2014) | 51 | 56 | 46 | 52 | 41 | 47 |
| B.29 (2013) | 49 | 55 | 49 | 55 | 41 | 49 |

Note 1: The RBL and LAeq 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: Evening RBL reduced to equal daytime RBL in accordance with INP application notes.

## 2.4 Operator Attended Train Passby Measurements

The train passby noise measurements were carried out on 27 October 2014, and on 24 November 2015 at two representative locations in the project area.

The train passby vibration measurements were carried out on 16 October 2014, 27 October 2014 and on 24 November 2015 at three representative locations in the project area.

The operator attended measurements were undertaken at each location for up to four hours. All train passby events during the attended measurements were passenger trains.

The instrumentation used for the attended passby measurements comprised of calibrated Brüel & Kjær Type 2260 and 2250L Sound Level Meters and one Brüel & Kjær Type 4231 Acoustic Calibrator. Calibration of the sound level meters was carried out before, during and after the measurements at each location and no significant calibration drift was noted.

### 2.4.1 Attended Passby Noise Measurements

The noise measurements captured A-weighted, fast response $L_{Amax}$ and $L_{AE}$ (sound exposure level). One third octave $L_{max}$ measurements were also obtained for each train passby event. The $L_{max}$ values are the maximum levels occurring in each 1/3 octave band during the train passby, and are therefore not necessarily time coincident.

The $L_{AE}$ measurements were commenced as the train noise rose significantly above the background level and were terminated as the train noise approached the background level. In the event that noise from other sources significantly affected the measurement results, the measurement was discarded.

### 2.4.2 Train Passby Noise Measurement Locations

The attended passby measurements (free-field) were conducted at the locations described in **Table 5**.

**Table 5 Train Passby Measurements - Noise Locations**

| Reference | Line | Chainage (km) | Measurement Dates | Distance to Near Track (m) | Description |
|---|---|---|---|---|---|
| N1 | T1 North Shore Line | 10.740 | 27/10/2014 | 7.5 | Adjacent to the end of Hawkins Street, Artarmon. Up side of corridor. |
| N2 | T4 Illawarra Line | 4.460 | 24/11/2015 | 15 | Corridor access gate at the end of Murray Street, Marrickville. Up side of corridor. |

### 2.4.3 Attended Passby Noise Levels

**Table 6** presents a summary of the measured noise levels at each location. For each track, the average noise levels ($L_{AE}$ and $L_{Amax}$) have been determined, along with the 95$^{th}$ percentile $L_{Amax}$ levels recorded during the attended measurements. Results for individual train types are not shown in **Table 6**, it is noted that the majority of trains were newer generation trainsets (T, M or A sets), with very few older S, K or C sets.

The passenger train speeds observed during the attended measurements at each location for each track are included in **Table 6**. These speeds were estimated by measuring the passby time with a stopwatch, and observing the number of carriages and the typical carriage lengths. At both locations, typical passenger train speeds are between 55 km/h and 67 km/h.

**Table 6 Summary of Attended Measured Noise Levels and Average Train Speeds**

| Location | Track | Distance from track centre (m) | Number of Trains | Average Speed (km/h) | Average $L_{AE}$ (dBA)[1] | Average $L_{Amax}$ (dBA) | 95$^{th}$ Percentile $L_{Amax}$ (dBA) |
|---|---|---|---|---|---|---|---|
| N1 | T1 Main Up | 7.5 | 10 | 55 | 88 | 81 | 85 |
| | T1 Main Down | 11.5 | 8 | 58 | 88 | 83 | 84 |
| N2 | Local Up | 15 | 9 | 63 | 82 | 76 | 77 |
| | Local Down | 19 | 6 | 63 | 78 | 70 | 71 |
| | Main Up | 23 | 21 | 67 | 76 | 69 | 73 |
| | Main Down | 27 | 21 | 66 | 75 | 66 | 71 |

Note 1: Logarithmic average.

The NSW Rail Noise Database Stage III Measurements and Analysis - January 2015 (SLR Consulting Report 610.14035-R1) provides a summary of measured noise levels for rolling stock operating in the Sydney network under standard reference conditions. The noise levels shown in **Table 6** have been adjusted to match the reference conditions of 80 km/h speed and 15 m distance, following the guidance provided in the Rail Noise Database. The resulting measured levels are compared with the Rail Noise Database levels in **Table 7**.

**Table 7 Comparison of Measured Levels with Rail Noise Database Reference Levels[1]**

| Location | Track | Measured $L_{AE}$ (dBA)[1] | Measured 95th Percentile $L_{Amax}$ (dBA) | Reference $L_{AE}$ (dBA) | Reference 95th Percentile $L_{Amax}$ (dBA) |
|---|---|---|---|---|---|
| N1 | T1 Main Up | 88 | 82 | S, K, C Sets: 88<br>T, G Sets: 85<br>M Sets: 86<br>A Sets: 84 | S, K, C Sets: 85<br>T, G Sets: 83<br>M Sets: 86<br>A Sets: 80 |
| | T1 Main Down | 90 | 84 | | |
| N2 | Local Up | 84 | 80 | | |
| | Local Down | 81 | 77 | | |
| | Main Up | 79 | 80 | | |
| | Main Down | 79 | 80 | | |

Note 1: All levels have been adjusted to the reference conditions of 80 km/h train speed and 15 m measurement distance.

It can be seen from **Table 7** that the measured $L_{AE}$ noise levels at Location N1 are 2 to 6 dB above the Rail Noise Database levels for newer generation train sets. Measured $L_{Amax}$ noise levels at this location were broadly consistent with the Rail Noise Database.

At location N2, both $L_{AE}$ and $L_{Amax}$ noise levels from trains on the two Local tracks were equal to or less than the reference levels for A set trains, which are the quietest rolling stock type on the network. On the Main tracks at this location the measured $L_{Amax}$ noise levels were also consistent with the reference levels for A Set trains, and the measured $L_{AE}$ noise levels were 5 dB less than the quietest reference levels.

#### 2.4.3.1 Attended Passby Location N1

Measurement Location N1 was 7.5 m from the near (Up) track at approximate chainage 10.740 km. The track in the area was observed to be in good condition (free from audible defects or rail joints).

The rail tracks are located at the top of a ballast mound which is approximately 0.8 m higher than the average cess elevation. The track in this location had an approximate radius of curvature of 1255 m.

Varying levels of flanging was observed on passenger trains travelling in the Down direction with flanging contributing to $L_{Amax}$ levels of up to 84 dBA. Minor wheel flats were observed on some of the trains but were typically not considered to significantly increase the overall passby noise levels.

The duration and level of the flanging events also influenced the $L_{AE}$ noise levels particularly from the Down track. Overall, similar noise levels were observed from trains on both tracks, even though the Down track was further away from the measurement position.

The contribution of flanging noise alone is not thought to be the sole reason for the elevated measured $L_{AE}$ noise levels relative to the rail noise database reference at this location. Rail roughness above the reference levels may also be a contributing factor.

#### 2.4.3.2 Attended Passby Location N2

Measurement Location N2 was 15 m from the near (Up Local) track at approximate chainage 9.710 km. The track condition in the area was observed to be acceptable for acoustic measurements, free from audible defects or rail joints.

Noise levels from passenger train passbys on the Local tracks were observed to be at the lower end of typical levels around the greater Sydney heavy rail network. Noise levels from passenger train movements on the Main tracks were observed to be less than typically observed elsewhere. This indicates that the track condition (rail roughness) for the Up and Down main track in this region is likely to be very good acoustically, compared with typical Sydney passenger heavy rail track.

The observed rail speeds were typically lower than the 80 km/h line speed on all tracks.

The bulk of the rail services were observed to utilise the Main tracks which carried approximately 74% of all train movements. Because the majority of services use the slightly quieter mainline, the $L_{Aeq}$ wayside noise levels in this area are potentially lower than might be expected from the Rail Noise Database reference levels.

$L_{Amax}$ noise levels were generated by wheel flats and occasional flanging. These $L_{Amax}$ events are more typical of operations on the broader network.

### 2.4.4 Attended Surface Track Passby Vibration Measurements

Attended passby vibration measurements were conducted at two locations adjacent the existing T1 North Shore Line and T4 Illawarra Line.

Measurements undertaken at measurement location V1 were within the T1 North Shore Line rail corridor at the end of Hawkins Street, Artarmon. The track at this location was ballast track with 60 kg/m rail on concrete sleepers.

Measurements undertaken at measurement location V2 were on the boundary of the T4 Illawarra Line rail corridor at the end of Murray Street, Marrickville. The track at this location was ballast track with 60 kg/m rail on concrete sleepers.

The attended passby vibration measurements locations are described in **Table 8**.

Measurements were undertaken at two distances from the track at location V1 (9.7 m and 12.7 m from the near track) and at one location at measurement location V2 (15 m from the near track). Vibration transducers were fixed to hardwood stakes by use of magnetic bases. The stakes were driven into the raw earth to a minimum depth of 200 mm. The measurements were conducted with a Brüel & Kjær Type 2260 vibration level meter and a B&K Type 4370 accelerometers. Calibration of the measurement system was checked before and after each set of measurements and no significant measurement drift was observed.

**Table 8 Train Passby Measurements - Vibration Locations**

| Reference | Chainage (km) | Measurement Date | Distance to Near Track (m) |
|---|---|---|---|
| V1 | 10.740 | 27/10/2014 | 9.7 and 12.7 |
| V2 | 9.710 | 24/11/2015 | 15 |

### 2.4.5 Attended Surface Track Passby Vibration Levels

**Table 9** presents a summary of the measured vibration levels at each location. For each train type, the average vibration levels ($L_{eq}$ and $L_{max}$) have been determined. The maximum $L_{max}$ levels recorded during the attended measurements are also shown. Maximum results presented in **Table 9** are unweighted slow-response maximum vibration levels.

**Table 9 Summary of Measured Vibration Levels**

| Location | Distance to track | | Train Type | Number of Trains | | Average Leq (dB)[1] | | Average Lmax (dB) | | Maximum Lmax (dB) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Up | Down | | Up | Down | Up | Down | Up | Down | Up | Down |
| V1 | 9.7 | 13.5 | A-Set | 7 | 8 | 93 | 90 | 102 | 98 | 105 | 101 |
| | | | T-Set | 2 | 1 | 89 | 89 | 98 | 96 | 98 | 96 |
| | 12.7 | 16.5 | A-Set | 7 | 8 | 91 | 88 | 99 | 96 | 102 | 101 |
| | | | T-Set | 2 | 1 | 88 | 87 | 95 | 93 | 96 | 93 |
| V2 | 15 | 18.7 | A-Set | 3 | 4 | 100 | 95 | 102 | 101 | 109 | 104 |
| | | | M-Set | 2 | 2 | 98 | 96 | 108 | 103 | 110 | 106 |
| | | | D-Set | 4 | - | 95 | - | 101 | - | 102 | - |
| | 22.8 | 26.4 | H-Set | 4 | 4 | 87 | 88 | 94 | 94 | 100 | 94 |
| | | | M-Set | 3 | 3 | 88 | 84 | 93 | 91 | 96 | 92 |
| | | | T-Set | 14 | 14 | 95 | 93 | 101 | 97 | 104 | 104 |

Note 1: Logarithmic average.

# 3 CONSTRUCTION NOISE AND VIBRATION ASSESSMENT

## 3.1 Construction Noise and Vibration Goals

The ICNG and the TfNSW *Sydney Metro City & Southwest Construction Noise and Vibration Strategy (draft)* (Sydney Metro CNVS), TfNSW, 2015[viii], contain goals for construction noise that are applicable for this proposal.

The following sections outline the noise and vibration goals applicable to the construction of the project.

### 3.1.1 Construction Noise Metrics

The three primary noise metrics used to describe construction noise emissions in the modelling and assessments are:

$L_{A1(1minute)}$ The typical 'maximum noise level for an event', used in the assessment of potential sleep disturbance during night-time periods. Alternatively, an assessment may be conducted using the $L_{Amax}$ or maximum noise level

$L_{Aeq(15minute)}$ The 'energy average noise level' evaluated over a 15-minute period. This parameter is used to assess potential construction noise impacts.

$L_{A90}$ 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. The $L_{Aeq(15minute)}$ construction noise management levels are based on the $L_{A90}$ background noise levels.

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

### 3.1.2 Noise Management Levels for Surface Construction Activities

The ICNG contains a quantitative assessment method which is applicable to new infrastructure projects. Guidance levels are given for airborne noise at residential receivers and other sensitive land uses, including commercial and industrial premises. For residential receivers, 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. The ICNG sets out a quantitative assessment method involving predicting noise levels at sensitive receivers and comparing them with the proposal specific Noise Management Levels (NMLs) to be established for noise affected receivers. In the event construction noise levels are predicted to be above the NMLs, all feasible and reasonable mitigation and work practices are investigated to minimise noise emissions.

#### 3.1.2.1 Residential Receivers

The ICNG provides an approach for determining $L_{Aeq(15minute)}$ NMLs at residential receivers along the alignment applying the measured $L_{A90(15minute)}$ background noise levels, as described in **Table 10**.

**Table 10 Determination of NMLs for Residential Receivers**

| Time of Day | NML $L_{Aeq(15minute)}$ | How to Apply |
|---|---|---|
| Standard hours<br>Monday to Friday<br>7:00 am to 6:00 pm<br>Saturday<br>8:00 am to 1:00 pm<br>No work on Sundays or public holidays | RBL + 10 dBA | The noise affected level represents the point above which there may be some community reaction to noise.<br>• 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.<br>• 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<br>75 dBA | The highly noise affected level represents the point above which there may be strong community reaction to noise.<br>Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restructuring the hours that the very noisy activities can occur, taking into account:<br>• 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).<br>• If the community is prepared to accept a longer period of construction in exchange for restrictions on construction times. |
| Outside recommended standard hours | RBL + 5 dBA | • A strong justification would typically be required for works outside the recommended standard hours.<br>• The proponent should apply all feasible and reasonable work practices to meet the noise affected level.<br>• Where all feasible and reasonable practice 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.

Adopting the measured background noise levels in **Table 4**, the NMLs derived for the project are detailed in **Table 11.**

**Table 11 Residential Receiver NMLs for Construction**

| Precinct | NCA | Monitoring Location | $L_{Aeq(15minute)}$ Construction NMLs (dBA) | | | |
|---|---|---|---|---|---|---|
| | | | Daytime[1] | Daytime OOH[2] | Evening[3] | Night[3] |
| Chatswood dive site | NCA01 | B.25 | 51 | 46 | 45 | 40 |
| | NCA02 | B.25 | 51 | 46 | 45 | 40 |
| | NCA03 | B.24 | 60 | 55 | 52 | 44 |
| | NCA05 | B.23 | 73 | 68 | 65 | 50 |
| | NCA04 | B.22 | 52 | 47 | 46 | 39 |
| Artarmon substation | NCA06 | B.21 | 59 | 54 | 51 | 46 |
| | NCA07 | B.20 | 55 | 50 | 50 | 43 |
| | NCA08 | B.20 | 55 | 50 | 50 | 43 |
| | NCA09 | B.20 | 55 | 50 | 50 | 43 |
| Crows Nest Station | NCA10 | B.19 | 69 | 64 | 60 | 55 |
| | NCA11 | B.19 | 69 | 64 | 60 | 55 |
| | NCA12 | B.19 | 69 | 64 | 60 | 55 |
| Victoria Cross Station | NCA13 | B.18 | 75 | 70 | 62 | 56 |
| | NCA14 | B.17 | 65 | 60 | 55 | 49 |
| | NCA15 | B.16 | 75 | 70 | 68 | 57 |
| | NCA16 | B.17 | 65 | 60 | 55 | 49 |
| Blues Point temporary site | NCA17 | B.15 | 48 | 43 | 43 | 41 |
| | NCA18 | B.14 | 61 | 56 | 54 | 45 |
| Sydney Harbour ground improvement work | NCA18 | B.14 | 61 | 56 | 54 | 45 |
| | NCA19 | B.29 | 59 | 54 | 54 | 46 |
| | NCA20 | B.12 | 60 | 55 | 50 | 45 |
| Barangaroo Station | NCA19 | B.29 | 59 | 54 | 54 | 46 |
| | NCA20 | B.12 | 60 | 55 | 50 | 45 |
| | NCA21 | B.13 | 72 | 67 | 67 | 57 |
| | NCA22 | B 28 | 61 | 56 | 51 | 46 |
| Martin Place Station | NCA23 | B.11 | 71 | 66 | 61 | 57 |
| Pitt Street Station | NCA24 | B.27 | 76 | 71 | 69 | 66 |
| Central Station | NCA25 | B.26 | 68 | 63 | 61 | 57 |
| | NCA26 | B.09 | 66 | 61 | 58 | 50 |
| Waterloo Station | NCA29 | B.06 | 64 | 59 | 52 | 44 |
| | NCA31 | B.06 | 64 | 59 | 52 | 44 |
| Marrickville dive site | NCA32 | B.02 | 68 | 63 | 57 | 43 |
| | NCA33 | B.03 | 62 | 57 | 48 | 43 |
| | NCA34 | B.01 | 69 | 64 | 58 | 46 |

Note 1: Standard construction Daytime is Monday to Friday between 7:00 am and 6:00 pm, Saturday between 8:00 am to 1:00 pm.

Note 2: Out of hours Daytime (DOOH) is Saturday between 1pm and 6pm, and Sunday 8:00 am to 6:00 pm.

Note 3: Evening is between 6:00 pm and 10:00 pm and night-time is between 10:00 pm and 7:00 am.

Where construction would be undertaken during the night-time period the potential for sleep disturbance should be assessed. Sleep disturbance noise goals are discussed in **Section 3.1.5**.

At construction sites where spoil removal and or excavation anticipated to be undertaken during night-time periods, tunnel ventilation fans and other fixed plant are likely to be required to support the TBM or roadheader operations. Diesel generators may also be used to support roadheader operations. At these sites, noise mitigation treatments for the ventilation equipment and other fixed plant such as diesel generators and water treatment plant would be designed to meet the RBLs at the nearest residences.

#### 3.1.2.2 Other sensitive Land Uses

The proposal specific $L_{Aeq(15minute)}$ NMLs for other non-residential noise sensitive receivers from the ICNG are provided in **Table 12**.

**Table 12 Noise Management Levels for Other Sensitive Receivers**

| Land Use | NML $L_{Aeq(15minute)}$ (Applied when the property is in use) |
|---|---|
| Classrooms at schools and other education 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, e.g. 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 AS 2107 for specific uses. |

For sensitive receivers such as schools, hospitals and places of worship, the NMLs presented in **Table 12** are based on internal noise levels. For the purpose of this assessment, it is conservatively assumed that all schools, hospitals 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.

Other noise-sensitive businesses require separate proposal specific noise goals and it is suggested in the ICNG that the internal construction noise levels at these premises are to be referenced to the 'maximum' internal levels presented in AS 2107. Recommended 'maximum' internal noise levels from AS 2107 are reproduced in **Table 13** for other sensitive receiver types identified within the proposal area.

The ICNG and AS 2107 do not provide specific guideline noise levels for childcare centres. Childcare centres generally have internal play areas and sleep areas. The Association of Australian Acoustical Consultants *Technical Guideline Child Care Centre Noise Assessment* provides criteria for road, rail traffic and industry. The guideline recommends a $L_{Aeq\ (1hour)}$ of 55 dBA for external play areas and $L_{Aeq\ (1hour)}$ of 40 dBA for indoor play areas and sleeping areas. For internal play areas an internal 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 at the facade and would also be applicable to external play areas. For sleeping areas on the assumption that windows are open, the external NML is $L_{Aeq(15minute)}$ 50 dBA.

**Table 13 AS 2107 Recommended Maximum Internal Noise Levels**

| Description | Time Period | AS 2107 Classification | Recommended "Maximum" Internal $L_{Aeq}$ (dBA)[1] |
|---|---|---|---|
| Hotel | Daytime & Evening | *Bars and Lounges* | 50[2,3] |
| | Night-time | *Sleeping Areas*:<br>- Hotels near major roads | 40[4] |
| Café | When in use | *Coffee bar* | 50[2,3] |
| Bar/Restaurant | When in use | *Bars and Lounges / Restaurant* | 50[2,3] |
| Library | When in use | *Reading Areas* | 45[5] |
| Recording Studio | When in use | *Music Recording Studios* | 25[6] |
| Theatre / Auditorium | When in use | *Drama Theatres* | 30[6] |

Note 1: Design noise levels specified in AS 2107 internal noise levels

Note 2: Where no external seating has been identified, fixed window glazing and air conditioning is assumed to mitigate high existing ambient noise levels (refer to **Section 1**) and/or control internal noise break-out. A minimum outside-to-inside attenuation of 20 dB is assumed. The internal ICNG noise goal then corresponds to a facade level of 70 dBA.

Note 3: Where an open frontage or outdoor seating area has been identified, the external noise goal is taken as 60 dBA.

Note 4: Hotels (sleeping areas during the night-time) are assumed to have fixed window glazing and air conditioning in order to mitigate high existing ambient noise levels (refer to **Section 1**). In this case, a minimum (conservative) outside-to-inside attenuation of 20 dB can be assumed, meaning that the internal ICNG noise goal criterion would correspond to an external noise level at the building facade of 70 dBA. Hotels outside the City Centre Precinct are conservatively assumed to have open windows with an ICNG noise goal criterion corresponding to an external noise level at the building facade of 60 dBA.

Note 5: Receiver conservatively assumed to have open windows with an ICNG noise goal criterion corresponding to an external noise level at the building facade of 55 dBA.

Note 6: These receivers are typically well insulated from external noise break-in. For the purpose of this assessment, a minimum (conservative) outside-to-inside attenuation of 20 dB can be assumed, meaning that the internal ICNG noise goal criterion would correspond to an external noise level at the building facade of (internal +20) dBA

#### 3.1.2.3 Commercial and Industrial Premises

For commercial premises, including offices, retail outlets and small commercial premises an external NML of $L_{Aeq(15minute)}$ 70 dBA has been adopted. An external NML of $L_{Aeq(15minute)}$ 75 dBA has been adopted for industrial premises. In both land uses, the external noise levels should be assessed at the most affected occupied point on the premises.

### 3.1.3 Construction Traffic Noise

When trucks and other vehicles are operating within the boundaries of the various construction sites, 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*[ix] (RNP), DECCW, 2011.

One of the objectives of the RNP is to protect sensitive residential receivers against excessive decreases in amenity as the result of a project by first comparing traffic noise levels with the development, 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.

Where traffic noise levels from the existing traffic plus the additional traffic generated by the development exceeds the above criteria, any increase in the total traffic noise level should be limited to 2 dB above that of the corresponding 'no build option'.

In considering feasible and reasonable mitigation measures where the relevant noise increase is greater than 2 dB, consideration would also be given to the actual noise levels associated with construction traffic.

Construction traffic noise impacts on public roads are assessed in **Section 3.4** to **Section 3.15**.

### 3.1.4 Ground-borne Noise Management Levels

The ICNG provides residential NMLs for ground-borne noise, which are applicable when ground-borne noise levels are higher than the corresponding airborne noise levels. The ICNG provides ground-borne noise levels at residential receivers for evening and night-time periods only, as the objectives are to protect the amenity and sleep of people when they are at home. The following ground-borne noise levels are applicable for residential receivers:

- Daytime $L_{Aeq(15minute)}$ 45 dBA
- Evening $L_{Aeq(15minute)}$ 40 dBA
- Night-time $L_{Aeq(15minute)}$ 35 dBA.

For other sensitive receivers such as education institutions, hospital wards and operating theatres and place of worship the internal the ICNG does not provide guidance in relation to acceptable ground-borne noise levels. However, the internal NML's provided in the ICNG for these receivers have been adopted in order to assist in identifying potential impacts.

For commercial receivers such as offices and retail areas, the ICNG does not provide guidance in relation to acceptable ground-borne noise levels. An internal NML of $L_{Aeq(15minute)}$ 50 dBA has been adopted in order to assist in identifying potential impacts. The NML has been based on the ICNG external NML of 70 dBA, and that commercial premises have windows closed and would provide typically 20 dB of noise reduction from outside to inside. The internal ground-borne NML of $L_{Aeq(15minute)}$ 50 dBA thus equals the expected internal noise level resulting from the external airborne NML of $L_{Aeq(15minute)}$ 70 dBA.

These NMLs are applicable to residential receivers, other sensitive receivers and commercial receivers located above TBM and roadheader works, and also apply to other construction activities such as rock breaking where ground-borne noise levels are higher than airborne noise levels. This situation may occur at construction sites where airborne noise levels are shielded by noise barriers or other structures, or sensitive areas within residential or commercial buildings which are removed from the airborne noise source.

### 3.1.5 Sleep Disturbance and Maximum Noise Level Events

The EPA's most recent policy considers sleep disturbance as the emergence of the maximum level ($L_{A1(1minute)}$ or $L_{Amax}$) above the $L_{A90(15minute)}$ background level at the time. The appropriate screening criterion for sleep disturbance is determined to be a maximum level 15 dB above the RBL, normally during the night-time period (10:00 pm to 7:00 am).

The EPA reviewed research on sleep disturbance in the *NSW Environmental Criteria for Road Traffic Noise*[x] (ECRTN), EPA, 1999, and in the RNP. EPA's most recent publication, the RNP notes "*despite intensive research, the triggers for and effects of sleep disturbance have not yet been conclusively determined*".

The EPA notes in its Application Notes of the INP that the current sleep disturbance screening criterion is not ideal. Nevertheless, as there is insufficient evidence to determine what should replace it, EPA continues to use it as a guide to identify the likelihood of sleep disturbance. This means that where the criterion is met, sleep disturbance is not likely, but where it is not met, a more detailed analysis is required.

Some guidance on possible impacts is contained in the RNP which contains a section on sleep disturbance that includes a summary of current literature. This indicates that the main noise characteristics that influence sleep disturbance are the number of noisy events heard distinctly above the background level, the emergence of these events above the background level and the highest (maximum) noise level event.

Notwithstanding, the RNP concludes from the research to date 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, an external sleep disturbance screening criterion of RBL + 15 dB and sleep disturbance NML of $L_{Amax}$ 55 dBA (internal) have been adopted – the latter equates to an external NML of 65 dBA (assuming open windows).

### 3.1.6 Categories of 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 inconvenienced 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 compromised.

### 3.1.7 Human Comfort Vibration

The EPAs *"Assessing Vibration: a technical guideline"* (DEC, 2006) recommends the use of BS 6472-1992 for the purpose of assessing vibration in relation to human comfort.

British Standard BS 6472-1992 *Guide to evaluation of human exposure to vibration in building*[xi] (BS6472-1992) nominates guideline values for various categories of disturbance, the most stringent of which are the levels of building vibration associated with a "low probability of adverse comment" from occupants.

BS 6472-1992 provides guideline values for continuous, transient and intermittent events that are based on a Vibration Dose Value (VDV), rather than a continuous vibration level. The vibration dose value is dependent on the level and duration of the short-term vibration event, as well as the number of events occurring during the daytime or night-time period.

The vibration dose values recommended in BS 6472-1992 for which various levels of adverse comment from occupants may be expected are presented in **Table 14**.

**Table 14 Vibration Dose Value Ranges which Might Result in Various Probabilities of Adverse Comment Within Residential Buildings**

| Place and Time | Low Probability of Adverse Comment ($m/s^{1.75}$) | Adverse Comment Possible ($m/s^{1.75}$) | Adverse Comment Probable ($m/s^{1.75}$) |
|---|---|---|---|
| Residential buildings 16 hr day | 0.2 to 0.4 | 0.4 to 0.8 | 0.8 to 1.6 |
| Residential buildings 8 hr night | 0.1 to 0.2 | 0.2 to 0.4 | 0.4 to 0.8 |

Note: For offices and workshops, multiplying factors of 2 and 4 respectively should be applied to the above vibration dose value ranges for a 16 hr day.

### 3.1.8 Structural Damage Vibration

Most commonly specified 'safe' structural vibration limits are designed to minimise the risk of cosmetic damage such as surface cracks, and are set well below the levels that have potential to cause structural damage. Cosmetic damage is very minor in nature, is readily repairable and does not affect the structural integrity of the building.

In terms of the most recent relevant vibration damage goals, AS 2187: Part 2-2006 *'Explosives - Storage and Use - Part 2: Use of Explosives'* [xii] recommends the frequency dependent guideline values and assessment methods given in British Standard BS 7385 Part 2-1993 *'Evaluation and measurement for vibration in buildings Part 2'* [xiii] as they "are applicable to Australian conditions".

The Standard sets guide values for building vibration based on the lowest vibration levels above which damage has been credibly demonstrated. These levels are judged to give a minimum risk of vibration-induced damage, where minimal risk for a named effect is usually taken as a 95% probability of no effect.

Sources of vibration that are considered in the standard include demolition, blasting (carried out during mineral extraction or construction excavation), piling, ground treatments (eg compaction), construction equipment, tunnelling, road and rail traffic and industrial machinery.

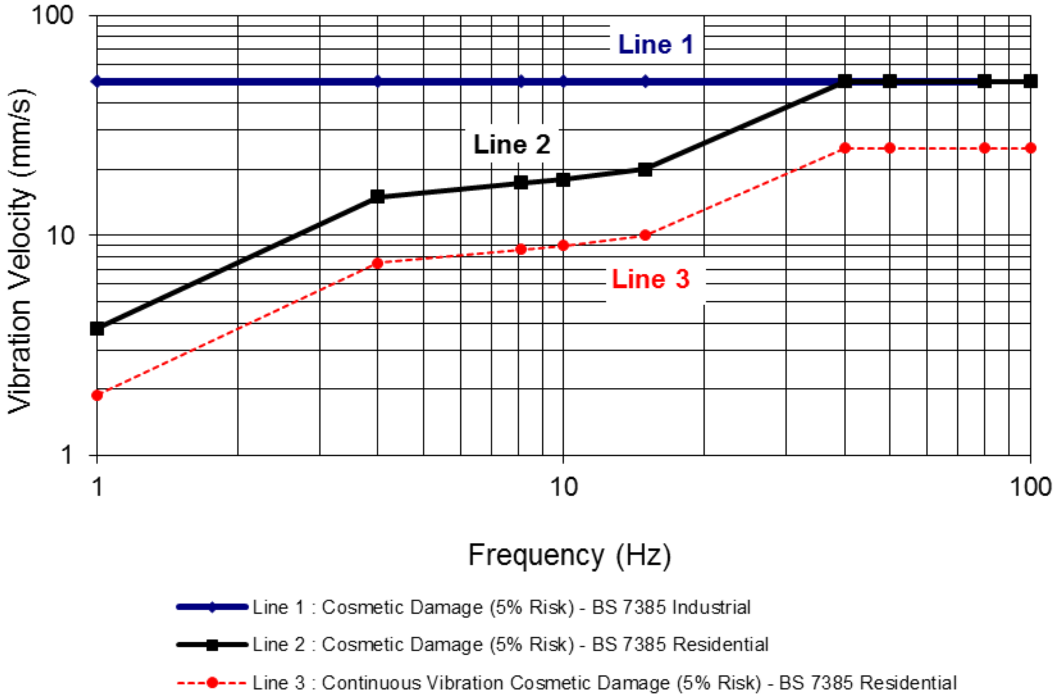
### 3.1.9 Cosmetic Damage Vibration

The recommended limits (guide values) for transient vibration to ensure minimal risk of cosmetic damage to residential and industrial buildings are presented numerically in **Table 15** and graphically in **Figure 3**.

**Table 15 Transient Vibration Guide Values - Minimal Risk of Cosmetic Damage**

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

**Figure 3 Graph of Transient Vibration Guide Values for Cosmetic Damage**




The Standard goes on to state that cosmetic damage is possible at vibration magnitudes which are greater than twice those given in **Table 15**, and damage to a building structure may occur at values greater than four times the tabulated values.

Fatigue considerations are also addressed in the Standard and it is concluded that unless calculation indicates that the magnitude and number of load reversals is significant (in respect of the fatigue life of building materials) then the guide values in **Table 15** should not be reduced for fatigue considerations.

In order to assess the likelihood of cosmetic damage due to vibration, AS 2187 specifies that vibration measured should be undertaken at the base of the building and the highest of the orthogonal vibration components (transverse, longitudinal and vertical directions) should be compared with the guidance curves presented in **Figure 3**.

It is noteworthy that extra to the guide values nominated in **Table 15**, the British Standard states that:

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

Also that:

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

#### 3.1.9.1 General Vibration Screening Criterion

The Standard states that the guide values in **Table 15** relate predominantly to transient vibration which does not give rise to resonant responses in structures and low-rise buildings.

Where the dynamic loading caused by continuous vibration may give rise to dynamic magnification due to resonance, especially at the lower frequencies where lower guide values apply, then the guide values in **Table 15** may need to be reduced by up to 50%.

Rockbreaking / hammering and sheet piling activities are considered to have the potential to cause dynamic loading in some structures (eg residences) and it is therefore appropriate to reduce the transient values by 50%.

For construction activities involving intermittent vibration sources such as rockbreakers, piling rigs, vibratory rollers, excavators and the like, the predominant vibration energy occurs at frequencies greater than 4 Hz (and usually in the 10 Hz to 100 Hz range). On this basis, a conservative vibration damage screening level per receiver type is given below:

- Reinforced or framed structures: **25.0 mm/s**
- Unreinforced or light framed structures: **7.5 mm/s**.

At locations where the predicted and/or measured vibration levels are greater than shown above (peak component particle velocity) monitoring should be performed during construction. At these locations a more detailed analysis of the building structure, vibration source, dominant frequencies and dynamic characteristics of the structure would be undertaken to determine the applicable safe vibration level.

#### 3.1.9.2 Heritage

Heritage buildings are to be considered on a case by case bases, as a heritage listed structure may not (unless it is structurally unsound) be assumed to be more sensitive to vibration resulting in application of the 7.5 mm/s screening criterion. Where a historic building is deemed to be sensitive to damage from vibration (following inspection), more conservative superficial cosmetic damage criterion of 2.5 mm/s peak component particle velocity (from DIN 4150) should be considered.

### 3.1.10 Sensitive Scientific and Medical Equipment

Some scientific equipment (eg electron microscopes and microelectronics manufacturing equipment) can require more stringent objectives than those applicable to human comfort.

Where it has been identified that vibration sensitive scientific and/or medical instruments are likely to be in use inside the premises of an identified vibration sensitive receiver, objectives for the satisfactory operation of the instrument should be sourced from manufacturer’s data. Where manufacturer’s data is not available, generic vibration criterion (VC) curves as published by the Society of Photo-Optical Instrumentation Engineers (Colin G. Gordon - 28 September 1999) may be adopted as vibration goals. These generic VC curves are presented below in **Table 16** and **Figure 4**.

**Table 16 Application and Interpretation of the Generic Vibration Criterion (VC) Curves (as shown in Figure 4)**

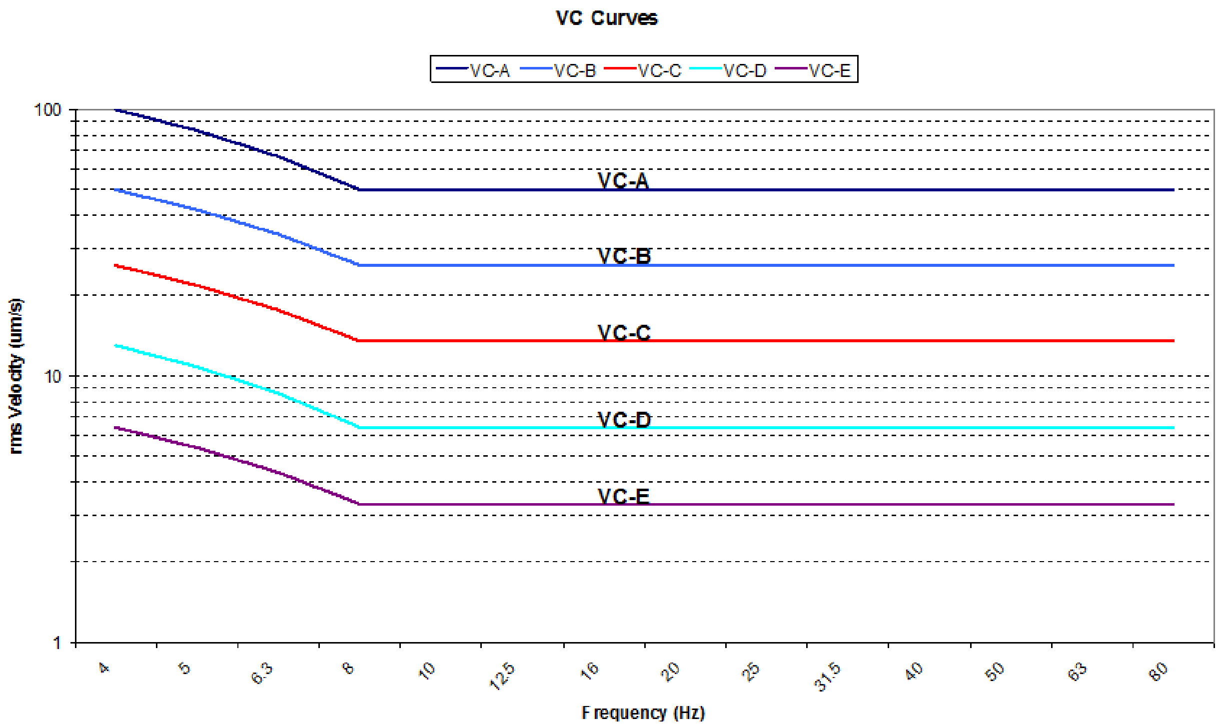
| Criterion Curve | Max Level (µm/sec, rms)[1] | Detail Size (microns)[2] | Description of Use |
|---|---|---|---|
| VC-A | 50 | 8 | Adequate in most instances for optical microscopes to 400X, microbalances, optical balances, proximity and projection aligners, etc. |
| VC-B | 25 | 3 | An appropriate standard for optical microscopes to 1000X, inspection and lithography equipment (including steppers) to 3 micron line widths. |
| VC-C | 12.5 | 1 | A good standard for most lithography and inspection equipment to 1 micron detail size. |
| VC-D | 6 | 0.3 | Suitable in most instances for the most demanding equipment including electron microscopes (TEMs and SEMs) and E-Beam systems, operating to the limits of their capability. |
| VC-E | 3 | 0.1 | A difficult criterion to achieve in most instances. Assumed to be adequate for the most demanding of sensitive systems including long path, laser-based, small target systems and other systems requiring extraordinary dynamic stability. |

Note 1: As measured in one-third octave bands of frequency over the frequency range 8 to 100 Hz.

Note 2: The detail size refers to the line widths for microelectronics fabrication, the particle (cell) size for medical and pharmaceutical research, etc. The values given take into account the observation requirements of many items depend upon the detail size of the process.

Note 3: See Table 46 of Chapter 47 from ASHRAE Sound and Vibration Control Manual for additional equipment items with respect to the VC curves

**Figure 4 Vibration Criterion (VC) Curves**



### 3.1.11 Utilities and Other Vibration Sensitive Structures

Where structures and utilities are encountered which may be considered to be particularly sensitive to vibration, a vibration goal which is more stringent than structural damage goals presented in **Section 3.1.6** may need to be adopted. Examples of such structures and utilities include:

- Tunnels
- Gas pipelines
- Fibre optic cables
- Sydney Water retention basin

Specific vibration goals should be determined on a case-by-case basis by an acoustic consultant. The acoustic consultant would be engaged by the construction contractor and would liaise with the structure or utility's owner in order to determine acceptable vibration levels.

### 3.1.12 Vibration and Overpressure from Blasting

The ICNG recommends that vibration and overpressure from blasting be assessed against the levels presented in the Australian and New Zealand Environment Council's (ANZECC) *Technical Basis for Guidelines to Minimise Annoyance Due to Blasting Overpressure and Ground Vibration*[xiv], ANZECC, 1990. This standard is also referenced in the SEARs as per **Section 1.3.2**.

However, the criteria set by the ANZECC standard are targeted for operations that occur for long periods of time such as those at mining sites. Therefore the ANZECC criteria are targeted to protect human comfort from vibration. As a result the vibration levels are conservative and can introduce unnecessary constraints when applied to construction projects, which typically occur for much shorter time periods.

Recent NSW infrastructure project approvals (eg Northconnex) have recognised the restrictive nature of the ANZECC blasting criteria when applied to construction projects and have therefore allowed the following vibration and overpressure limits:

- Vibration (PPV): **25 mm/s**
- Overpressure: **125 dBL**

These upper limits to vibration and overpressure are intended to target the protection of building structures from cosmetic damage rather than human comfort criteria as construction works are considered short-term. Since these criteria are analogous to the cosmetic damage screening criteria it is appropriate to add an additional criteria which is specific to heritage buildings, which are potentially more sensitive to vibration. A vibration (PPV) of 7.5 mm/s would be used to screen potential vibration impacts at heritage buildings.

#### 3.1.12.1 Times and Frequency of Blasting

The recommended hours for blasting are provided in the ICNG and are as follows:

- Monday to Friday (9:00 am to 5:00 pm)
- Saturday (9:00 am to 1:00 pm)
- No blasting on Sundays or public holidays

As part of the detailed construction planning for blasting, an assessment of the realistic worst-case noise and vibration levels would be undertaken and compared with the above noise and vibration criteria. The hours for blasting would be determined based on reducing impacts to receivers and consideration of what is feasible and reasonable, noting in commercial districts for example blasting outside office hours may be preferred. Should the predicted levels exceed the noise or vibration criteria, alternative construction methods may need to be utilised such as penetrating cone fracture.

Penetrating cone fracture involves the energy efficient breakage of rock using a high-pressure gas pulse. The rock is fractured by the introduction of a gas pulse at the base of a short drill hole (usually less than 1.5 m). This technique has been utilised successfully on a number of construction sites in Sydney, including at the Westfield site in Bondi Junction. Penetrating cone fracture potentially offers the ability to conduct excavation works with a reduced impact on the surrounding area when compared to more conventional techniques such as rock breaking.

## 3.2 Proposed Construction Activities

### 3.2.1 Overview of Potential Noise and Vibration Impacts during Construction

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.

### 3.2.2 Enabling Works

Enabling works are required at construction sites to demolish existing buildings and structures, clear or protect trees, establish a means of heavy vehicle access and provide perimeter site hoarding. In addition, it may be necessary to relocate any above ground and underground services or third party assets. In particular, the provision of high voltage power supplies for the operation of heavy excavation equipment, roadheaders and TBMs is required to be procured early in the project program in readiness for the major tunnel contractor(s).

### 3.2.3 TBM Launch and Support Sites

TBMs are proposed to be launched at the sites near the tunnel portals at Chatswood and Marrickville as well as from the Barangaroo Station construction site. At each of these sites, TBM support activities would be required to provide tunnel ventilation, supply high voltage (HV) power and extract/stockpile spoil to be removed on the surface via road trucks. TBMs would be retrieved at Barangaroo for the Marrickville launch site, Blues Point for the Chatswood launch site and Blues Point for the Barangaroo launch site.

The highest noise and vibration impacts would take place during the site establishment, demolition and excavation stages. The initial site establishment proposed to occur during standard (daytime) construction hours, however once mitigation measures are in place then works would occur up to 24 hours per day and up to 7 days per week.

When excavation works are being undertaken below ground, the potential noise and vibration impacts would be dependent on the distance between the works, the sensitivity of the receiver type (eg residential, commercial, etc), the times and durations when the noise and vibration occurs and the proposed mitigation and management measures.

Once the TBMs are operational, spoil handling and removal activities would occur up to 24 hours per day and up to 7 days per week. The potential noise emissions from such activities are generated by sources including heavy vehicles, spoil conveyors, loading activities, tunnel ventilation fans, dust collectors, and materials and equipment deliveries. Potential noise impacts may therefore occur at the spoil extraction points where sensitive receivers are located nearby.

For the construction activities that are required to be undertaken outside normal daytime periods, careful attention would be required to manage and mitigate the potential noise and vibration impacts. These are documented in later sections of this report.

At the TBM launch sites the following general activities are proposed:

- Establishment of a site compound
- Excavation of the TBM launch area
- Construction of tunnel construction water treatment plant and water tanks
- Supply of electrical power for TBMs
- Tunnel air ventilation supply and extraction plant
- Assembly and launching of TBMs
- Spoil storage and disposal by road
- Tunnel pre-cast segment lining delivery and storage
- Tunnel grout batching plant

### 3.2.4 Stations

The Crows Nest, Victoria Cross, Barangaroo, Martin Place, Pitt Street and Waterloo stations, and the Central Station metro platforms, would be underground. Following site establishment, the demolition of existing structures and excavation and construction works are proposed to occur up to 24 hours per day and up to 7 days per week. The highest noise and vibration impacts are likely to take place during the initial site demolition and surface excavation works.

For the station sites, construction noise and vibration levels would be similar to those experienced next to typical building sites in the Sydney CBD.

As with the TBM launch sites, when excavation works are being undertaken below ground, the potential noise and vibration impacts would be dependent on the distance between the works, the sensitivity of the receiver type (eg residential, commercial, etc), the times and durations when the noise and vibration occurs and the proposed mitigation and management measures.

Nearby receivers may also be affected by materials and equipment deliveries, spoil removal (if required) and general construction of the station entry points.

At the underground stations, the following general activities are proposed:

- Establishment of a site compound
- Demolition of existing structures
- Excavation of the station and vertical transport shafts
- Spoil storage and disposal by road
- Station construction

Excavation of the station and station shafts is a time critical element of the Metro construction project. Excavation of the stations need to be complete to allow free passage of the TBM machines in order to meet the construction programme.

#### 3.2.4.1 Station Shaft Excavation using Rock Breakers

The worst case scenario for noise and vibration associated with the excavation of the station shafts is when large rock breakers are assumed to be the principal construction activity for excavation. It is highly likely that, no matter which construction approach is finally selected, rock breakers will be required, at least in part, for the excavation of these shafts.

The noise and vibration impacts from rock breakers would vary significantly at each receiver depending on the horizontal and vertical offset distances between the rock breaker and the receiver. However, the worst case noise vibration impacts would always occur when the horizontal and vertical offset distances are at their shortest. For any rock breaking activities during construction this report assesses the worst-case offset distances (shortest) between the rock breaker and receivers.

With respect to rock breaking activities where exceedances of the ground-borne NMLs and human comfort vibration criteria are found, it is the duration of those exceedances that need to be considered when determining the appropriate level of noise mitigation for affected receivers, given the time critical nature of this element of the construction.

The depths at which rock breaking activities will be necessary (due to hardness / strength) of rock are given in **Table 17** below.

**Table 17 Approximate Depth of Rock**

| Station Shaft | Approx Depth of Rock (m) |
|---|---|
| Crows Nest | 15 |
| Victoria Cross - North | 0 |
| Victoria Cross - South | 0 |
| Barangaroo | 5 |
| Martin Place - North | 4 |
| Martin Place - South | 0 |
| Pitt Street - North | 5 |
| Pitt Street - South | 5 |
| Waterloo | 9 |

#### 3.2.4.2 Station Shaft Excavation using Blasting

A potential alternative to continuous rock breaking (to reduce ground-borne noise and human comfort vibration exceedances) is to use controlled blasting. However, the blasting criteria (screening for cosmetic damage) as per **Section 3.1.12** means that blasting would only commence at the indicative depths shown in **Table 18** assuming initial charge sizes of 1 MIC (kg) or smaller. As the shafts become deeper (increased offset distances to the receivers) then the charge sizes can be increased while still satisfying the blast criteria.

**Table 18 Approximate Initial Depth of Blasting**

| Station Shaft | Approx Initial Depth of Blasting (m) |
|---|---|
| Crows Nest | 25 |
| Victoria Cross - North | 15 |
| Victoria Cross - South | 15 |
| Barangaroo | 15 |
| Martin Place - North | 4 |
| Martin Place - South | 15 |
| Pitt Street - North | 15 |
| Pitt Street - South | 15 |
| Waterloo | 15 |

In all cases blast charges would be carefully monitored to ensure the vibration and blast over-pressure criteria are always satisfied.

The duration and timing of any ground-borne noise and human comfort vibration impacts would be minimal due to blast events. The durations are virtually instantaneous meaning insignificant disturbance from either noise or vibration. Additionally, the events are only expected to occur, at most, once a day, but more likely 2-3 times a week.

In order to excavate the shafts to a depth suitable for blasting, rock breaking would be required. Therefore, using blasting as a potential alternative to rock breaking would not completely eliminate the need for rock breaking. However, the duration of the impacts due to rock breaking would be reduced.

This report provides the worst-case noise and vibration impacts due to rock breaking and discusses the reduction in duration of these impacts through the use of blasting (from the depths identified in **Table 18**).

#### 3.2.4.3 Station Shaft Excavation using Alternative Methodologies

Traditionally, excavation of the stations would be carried out through the use of excavators and rock hammers. Due to the anticipated magnitude and duration of impacts associated with this excavation method, a number of contemporary alternatives were explored. This includes blasting, track sawing, wire cutting, rock bursting / splitting and penetrative cone fracture; or a combination of methods.

Based on the preliminary construction planning carried out for the project, it is unlikely that track sawing, wire cutting, rock bursting / splitting or penetrative cone fracture would be able to achieve the necessary excavation rates in isolation. However, there is potential they could be used to supplement other excavation methods in order to reduce overall construction noise and vibration impacts.

Blasting is likely to result in an overall improvement in the excavation rate and a reduction in the duration, and associated impacts, of rock hammering. In order to achieve compliance with the relevant criteria for blasting, the use of rock hammers would still be necessary until appropriate offset depths are reached.

Based on the above analysis, the preferred excavation method for the stations is a combination of rock hammers, use of excavators and blasting. Due to the location of the metro platforms at Central Station, there are limited residential and commercial receivers which could be impacted by rock hammering works. Additionally, the site is located within a busy transport interchange and heritage precinct. As a result, the preferred excavation method is the traditional use of rock hammers and excavators for this station site.

### 3.2.5 Concrete Batch Plant and Pre-cast Facility

At the concrete batch plant site the following general activities are proposed:

- Establishment of a site compound
- Construction of batch plant facility
- Operation of batch plant facility

### 3.2.6 Operational Ancillary Facilities

The proposed ancillary facilities are:

- A traction substation at Artarmon, just north of the Gore Hill Freeway.
- A traction substation and water treatment works adjacent to the Marrickville tunnel portal, which would form part of the construction works at that site.

For the Artarmon facility the proposed construction works would include:

- Mobilisation and earthworks
- Vertical shaft excavation using rock breakers
- Concreting
- Traction substation construction

Works at the ancillary facility sites would be conducted during standard working hours, except for those activities required out of hours, such as the delivery of oversize equipment, etc.

### 3.2.7 Tunnels

#### 3.2.7.1 Excavation and Construction

Ground-borne (or regenerated) noise in buildings is caused by the transmission of ground-borne vibration rather than the direct transmission of noise through air. For underground excavation works from activities such as rock breaking, TBM and roadheaders, the soil and rock between the construction activities and sensitive receivers does not permit the transmission of airborne noise. Vibration from these sources can however travel through the ground and into nearby buildings and structures. After entering a building, this vibration can cause the walls and floors to vibrate faintly and hence to radiate noise. For some activities such as rock breaking, ground-borne noise may be heard in buildings located around 50 m to 100 m from the tunnelling works.

Whether or not the ground-borne noise levels are intrusive is dependent on a number of factors including the source vibration levels, distance, ground conditions, time of day, the ambient noise levels, duration of the construction works, and the activities undertaken within the building.

As the tunnelling construction works are proposed to occur on a 24 hour per day basis and up to 7 days per week, the ground-borne noise and vibration levels from tunnelling may exceed the management levels at residential receiver locations during the evening and night-time period when people are resting or sleeping. The vibration caused by underground tunnelling equipment can also impact on sensitive equipment such as electron microscopes and precision balancing equipment.

Depending on the rate of the tunnelling progress, the potential impacts of noise and vibration on sensitive receiver are however likely to prevail for only relatively short periods at most locations.

At this stage, TBMs are proposed to be used for the majority of the proposed twin tunnel alignment, with roadheaders and rock breakers proposed to be at stations, stub tunnels and cross passages.

Spoil from underground tunnelling would be required to be brought to the surface and transported to disposal sites via heavy vehicles.

#### 3.2.7.2 Work Trains

The TBMs require regular and frequent deliveries of material and labour to the workface. This could be achieved through the use of work trains, or with conveyor systems and special purpose rubber tyred vehicles. For the purpose of this assessment, the use of works trains has been assumed as it would result in a worst-case noise and vibration assessment.

Work trains are small, specialised locomotive trains on a temporary narrow gauge rail which is laid in the sections of the tunnel leading up to the workface.

Each work train would be required to transport construction related equipment and items such as:

- Construction personnel in a dedicated car
- Service pipes and other consumables on a flat car
- Precast segmental lining (if required) in specialised segment cars

The work trains would be loaded at the TBM launch and unloaded with specialised lifting equipment once they reach the TBM location.

The operating speed of work trains is likely to be up to 10 km/h. Work trains would be required on a 24 hour per day, up to 7 days per week basis to support the underground tunnelling activities. For a particular location, it is anticipated that there would be a maximum of one work train passing by during the worst-case 15 minute period.

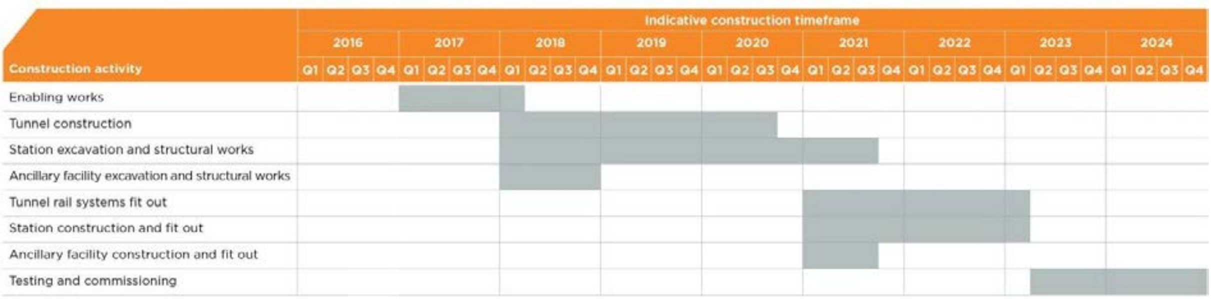
### 3.2.8 Spoil Transport

Spoil transport would be required from the TBM launch and support sites at Marrickville, Chatswood and Barangaroo. In addition, spoil transport would also be required from the station sites and ancillary sites.

### 3.2.9 Indicative Construction Program

Enabling works (preliminary construction activities required to facilitate substantial construction) would likely commence in early 2017, with substantial construction of the project planned to commence in early 2018. The total period for major construction would be about seven years, with the project expected to be opened to the public in late 2024. An indicative construction program is shown in **Figure 5**.

**Figure 5 Indicative Construction Program**



### 3.2.10 Construction Hours

In accordance with the ICNG standard construction hours are 7:00 am - 6:00 pm Monday to Friday, and 8am to 1pm on Saturdays, with no works on Sundays or Public Holidays.

In addition to standard construction hours, the daytime periods from 1:00 pm to 6:00 pm on Saturday, and Sundays 8:00 am to 6:00 pm are referred to as daytime out of hours (DOOH). Evening is 6:00 pm to 10:00 pm and night-time 10:00 pm to 8:00 am. These time periods correlate to the NMLs developed in accordance with the ICNG.

The proposed construction hours are shown in **Table 19**. These hours have been developed based on a balanced consideration of the construction program and minimising noise and traffic related impacts. As the tunnel boring machines operate continuously, the tunnelling works and associated support activities would need to be carried out up to 24 hours per day and seven days per week. The majority of the station fit-out and other aboveground construction activities would be carried out during the ICNG standard construction hours.

**Table 19 Proposed construction hours**

| Activity | Construction hours | Comments or exceptions |
|---|---|---|
| **Aboveground construction activities** | | |
| Demolition works<br>Station and ancillary facility fit-out and construction (surface works) | ICNG standard construction hours | Surface works supporting underground construction activities (eg concrete pumping, truck loading) would be expected to be required 24 hours per day, up to seven days per-week where noise impact management measures have been established.<br>Non-disruptive preparatory work, repairs or maintenance may be carried out on Saturday afternoons between 1:00 pm and 5:00 pm or Sundays between 8:00 am and 5:00 pm.<br>Activities requiring the temporary possession of roads or to accommodate road network requirements may need to be carried out outside the standard daytime construction hours during periods of low demand to minimise safety impacts and inconvenience to commuters.<br>Activities requiring rail possessions may need to be carried out outside the standard construction hours up to 24 hours per day, seven days per week. |
| Construction traffic for material supply to and spoil removal from tunnelling and underground excavation (station and ancillary facility sites) | 24 hours per day, seven days per week | Restrictions would be in place during peak hours and during special events.<br>At locations where night-time sensitive noise receivers are close to construction sites, significant construction vehicle movements are likely to be restricted during evening and night-time periods. |
| **Underground construction activities** | | |
| Tunnelling works | 24 hours per day, seven days per week | Activities that support tunnelling may need to occur 24 hours per day, up to seven days per week.<br>Rock hammering in the tunnel between 10:00 pm and 7:00 am would be precluded except where noise impact management measures have been established.<br>Drill and blast, if required, would be carried out during periods anticipated to have the least impact on receivers. |

| Activity | Construction hours | Comments or exceptions |
|---|---|---|
| Underground excavation at station and ancillary sites | 24 hours per day, seven days per week | May need to occur outside standard daytime construction hours provided appropriate airborne acoustic mitigation is in place.<br>Drill and blast would be carried out during periods anticipated to have the least impact on receivers. |
| Tunnel and station fit-out (underground) | 24 hours per day, seven days per week | Activities that support tunnel and station fit-out may need to occur 24 hours per day, up to seven days per week. |

## 3.3 Overview of Construction Noise and Vibration Modelling

### 3.3.1 Construction Airborne 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'*[xv].

Light Detection and Ranging (Lidar) data was utilised to develop ground topography throughout the project area. Construction site layouts were provided by Transport for NSW.

$L_{Amax}$ sound power levels for equipment assumed in the modelling are presented in **Table 20**. The sound power levels given are maximum noise emission levels of plant that would 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 TBM launch sites or station construction sites and the receivers are relatively close, typical adjustments of 2 dB to 5 dB have been applied during conversion of the $L_{Amax}$ power levels shown in **Table 20** to $L_{Aeq(15minute)}$ sound pressure levels for comparison with the construction NMLs.

The proposed equipment used at the station sites would be a subset of that presented in **Table 20**, 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 20**.

**Table 20 Summary of Maximum Sound Power Levels used for Demolition, Excavation and Construction Equipment**

| Plant Item | LAmax Sound Power Level (dBA) | LAmax Sound Pressure Level @ 7 m (dBA) |
|---|---|---|
| Excavator Hammer | 122 | 97 |
| Dump Truck | 108 | 83 |
| Excavator (approximately 20 tonnes) | 105 | 80 |
| Excavator (approximately 30 tonnes) | 110 | 85 |
| Excavator (approximately 40 tonnes) | 115 | 90 |
| Bulldozer (equivalent to D9) | 120 | 95 |
| 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 |
| Bored Piling Rig | 110 | 85 |
| Concrete Pump | 109 | 84 |
| Compressor | 105 | 80 |
| Vibratory Roller | 114 | 89 |
| Water Pump | 108 | 83 |

Note 1: The sound power levels presented are based on the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement).

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 5dB "penalty" is added to the source sound power level when predicting noise using the quantitative method.

#### 3.3.1.1 Modelling of Construction Sites

At the TBM launch sites a large range of activities is likely to occur over the life of the project. Nevertheless, scenarios representative of activities for significant stages producing the typical noise emissions during the project have been modelled. The equipment modelled in each scenario is a subset of that presented in **Table 20,** and based on the indicative plant and equipment lists provided by Transport for NSW.

At the TBM sites, activities representative of the typical noise emissions expected to occur during the project are:

- Enabling works
  Demolition of existing buildings and structures, vegetation clearing, noise wall construction/relocation, site establishment including buildings, spoil handling facilities.
- Surface track works
  Corridor widening, track slewing lifting and re-alignment, bridge removal.
- Earthworks
  Initial excavation, tunnel dive piling, tunnel dive excavation, tunnel dive lining, laying tunnel dive track, TBM assemble and launch, tunnelling support.
- Acoustic shed construction.

- Tunnelling and excavation with shed.
- Spoil removal by heavy vehicle.
- Fitout and /or reinstatement works.
- Precast factory included as part of the Marrickville dive site.

At the station sites, activities representative of the typical noise emissions expected to occur during the project are:

- Enabling works
  Demolition of existing buildings and structures, vegetation clearing, noise wall construction/relocation, site establishment including buildings, spoil handling facilities.
- Earthworks
  Initial excavation, piling works.
- Acoustic shed construction.
- Excavation of the station shafts using excavators, bulldozers, rock breakers and other construction plant.
- Excavation of the station cavities using roadheaders, bulldozers, rock breakers and other construction plant.
- Spoil removal by heavy vehicle.
- Station construction
  Including concrete trucks, concrete pumps and concrete vibrators.

At the ancillary sites, activities representative of the typical noise emissions expected to occur during the project are:

- Enabling works
  Demolition of existing buildings and structures, vegetation clearing, noise wall construction/relocation, site establishment including buildings, spoil handling facilities.
- Earthworks
  Initial excavation, piling works.
- Excavation using excavators, rock breakers and other construction plant.
- Spoil removal by heavy vehicle.
- Building construction, including concrete trucks, concrete pumps and concrete vibrators.

At the Sydney Harbour ground improvement site, activities representative of the typical noise emissions expected to occur during the project are:

- Grout barge.

During most construction activities on the construction sites, for any given receiver the received noise level would depend on the location of the equipment. For example, during site establishment, noise levels would be higher when earthmoving equipment is operating on the nearest part of the site, and lower when the equipment is operating on the far side of the site.

Consistent with the requirements of the ICNG, the construction noise impacts are based on a worst-case assessment corresponding to equipment operating on the nearest part of the site. 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 residential receivers or other sensitive land uses. For each construction site, residential receivers and other sensitive receivers have been grouped together into receiver areas or 'catchments', which comprise those receivers which would experience a similar level of construction noise. For each receiver area the noise levels are predicted at the most noise-exposed location, which would usually be the closest receiver.

For most construction activities, it is expected that the construction noise levels would 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 would generally experience lower noise levels compared with 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 would provide an approximate 6 dB reduction in noise level. For example the sound pressure levels presented in **Table 20** would 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 would act as a barrier and typically reduce the noise level by up to 15 dB. For example in a residential area adjoining a construction site the first row of houses would provide an effective shield to the second and subsequent rows with resulting noise levels up to 10 dB lower than experienced in the first row due to screening effects.

### 3.3.2 Noise Mitigation

#### 3.3.2.1 Barriers

For the TBM and station sites there are negligible existing barriers between the proposed sites and noise sensitive receivers, therefore it is anticipated that the construction of minor to major noise barriers would result in the following reductions in noise levels:

- Minor barrier (hoarding indicative height ~ 3 m) 5 dB to 10 dB reduction
- Moderate barrier (hoarding indicative height ~ 6 m) 10 dB to 15 dB reduction
- Major barrier (enclosure or acoustic shed) 15 dB to 25 dB reduction.

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

The (hoarding) noise barriers are effective for receivers at or near ground level (e.g. single storey dwellings) - they would however not attenuate noise at elevated receivers "overlooking" the construction sites. The use of noise barriers, and in particular site enclosures, is often not feasible prior to completion of the demolition phase of the works.

For all sites operating on a 24 hour per day basis, and/or where residential receivers are close to rockbreaker excavation a 'default' three metre site perimeter solid timber fence has been assumed in the calculations. However, in practice the same noise outcome at the receivers could be achieved through a range of mitigation measures and barrier heights.

#### 3.3.2.2 Acoustic Sheds

Spoil removal would be required during the night at sites supporting TBMs and roadheaders, and acoustic sheds have been assumed. Typically the activities modelled inside the sheds include spoil transport using either a gantry bucket system or conveyor with a front end loader used to organise spoil in the shed. The front end loader would also be used to load trucks via a roller door or similar, which would be kept closed during night-time loading.

For all the station sites (except Central due to the complexity of constructing an effective acoustic shed over the works) acoustic sheds have been assumed as 24/7 station excavation may be required. However, the same noise outcome may be achieved through alternative means, such as acoustic panels over the station excavations. The specific noise mitigation measures would be determined during detailed construction planning taking into account construction program, construction working hours and construction traffic management in accordance with the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement)

The indicative acoustic shed construction would consist of metal cladding with internal insulation faced with perforated steel sheet or aluminium foil on the internal walls and under the roof. Doors that do not compromise performance would be required with no gaps when closed. All ventilation would be required to be designed to maintain the integrity of the shed, which indicatively would require attenuators for supply and return air systems.

Where increased noise insulation is required, this can be achieved by upgrading the enclosure elements by using, for example, a double skin construction with insulation, or masonry construction.

### 3.3.3 Construction Ground-borne Noise and Vibration Modelling

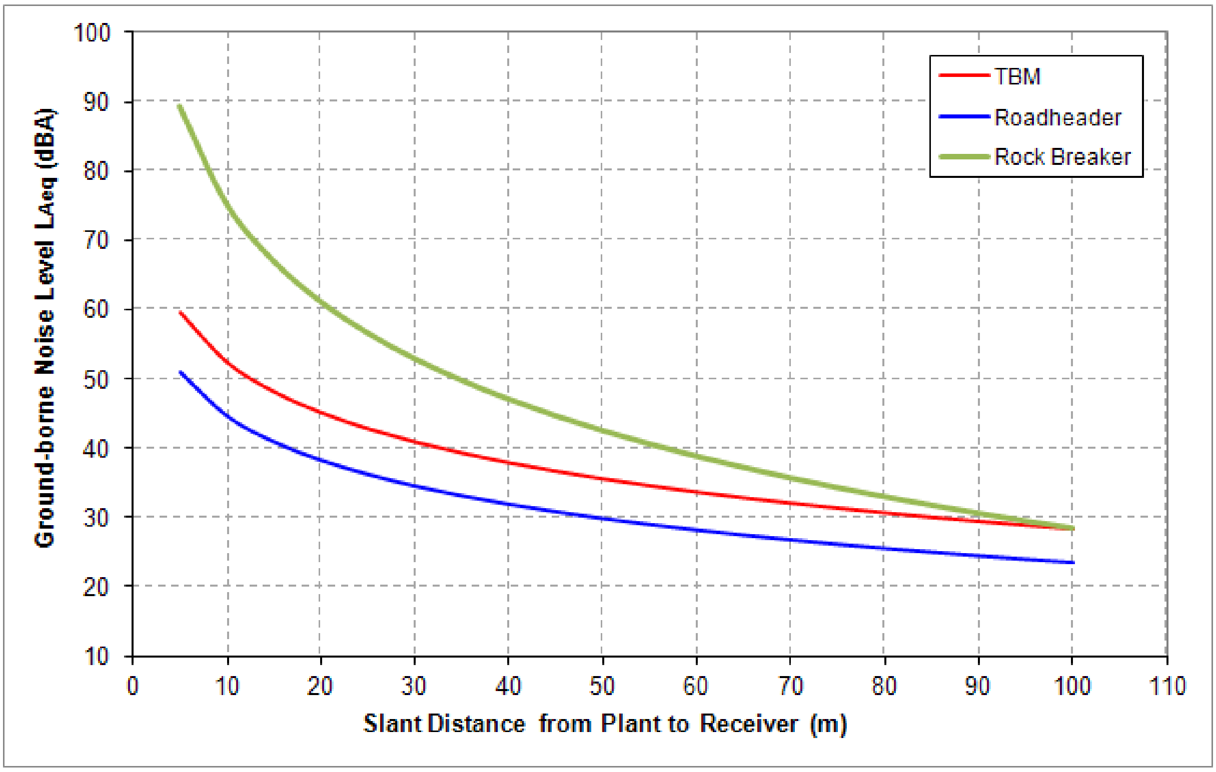
Humans are more sensitive to ground-borne noise than to vibration – in other words humans tend to *hear* vibration before they *feel* vibration. This means that if the ground-borne noise criteria are exceeded then the human comfort criteria for vibration would also be exceeded. This report has taken a conservative approach by assessing ground-borne noise impacts to determine exceedances of the NMLs and therefore any requirements for mitigation.

Ground-borne noise and vibration impacts at the various sensitive receivers near to the proposed tunnelling works and construction sites have been predicted using a three-dimensional model which uses the receiver location and elevation data together with the horizontal and vertical information supplied for the project alignment.

**Figure 6** presents indicative ground-borne noise levels for TBMs, roadheaders and rock breakers as measured on other Sydney tunnelling projects. As the figure demonstrates, ground-borne noise levels reduce as the distance between plant and the receiver increases. SLR database vibration attenuation with distance curves have also been used to calculate ground vibrations due to these sources.

Underground works and station excavations would be typically conducted 24 hours per day; seven days per week, including in-tunnel rail fitout works.

**Figure 6 Indicative Ground-borne Noise Levels from TBMs, Roadheaders and Rock Breakers**




Note 1. The rockbreaker ground-borne noise curve is for a 'heavy' rockbreaker.

Source: TBM and roadheader data is from *Australian Acoustical Society Technical Meeting – Tunnelling Noise and Vibration Management*, Wilkinson Murray, December 2003. Rock breaker data was obtained from SLR Consulting's noise database.

The ground-borne noise and vibration model calculates the three-dimensional slant distance from the works to each sensitive receiver situated above the project alignment. An additional offset distance of 5.8 m from the mean rail height to the tunnel crown has been incorporated into the model for the ground-borne noise calculations for TBMs and roadheaders.

### 3.3.4 Construction Traffic Noise Modelling

The calculation of traffic noise on public roads for comparison with the criteria presented in **Section 3.1.3** has been performed using two modelling methods. The models used are Calculation of Road Traffic Noise (CORTN), which has the advantage of having been specifically validated under Australian conditions, and the $L_{Aeq}$ calculation based on the US Environmental Protection Agency - Report 550/9-74-004 (1974). The $L_{Aeq}$ calculation has also been used as it is recognised 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.

## 3.4 Chatswood Dive Site and Northern Surface works

### 3.4.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Chatswood dive site and the surrounding receiver areas is provided in **Figure 7** with the nearest noise sensitive receivers identified in **Table 21**.

**Figure 7 Chatswood Dive Site and Receiver Areas**


**Table 21 Nearest Noise Sensitive Receivers - Chatswood Dive Site**

| Receiver Area | Location Relative to Works (m)[1] |
|---|---|
| A - Church to the south west on the Pacific Highway | 83 |
| B - Residential receivers to the west on the Pacific Highway | 18 |
| B - Commercial receivers to the west on the Pacific Highway | 20 |
| C –- Residential receivers to the north on Nelson Street | 10 |
| C - Commercial receivers to the north on Nelson Street | 8 |
| C - Active Recreation to the north, west of the railway line | 12 |
| D - Active Recreation to the north, east of the railway line | 34 |
| D - Residential receivers to the east, east of the railway line | 6 |
| E - Residential receivers to the east, east of the railway line | 24 |
| F - Residential receivers to the south on Mowbray Road | 12 |
| F - Commercial receivers to the south on Mowbray Road | 111 |
| F - Industrial receivers to the south on Mowbray Road | 67 |

Note 1: The relative distance to works shown is that from the nearest sensitive receiver to the closest location of construction activity.

### 3.4.2 Site Specific Construction Noise Management Levels

With reference to the ambient noise survey results summarised in **Table 4**, the site specific construction NMLs are presented in **Table 22**.

**Table 22 Chatswood Dive Site Noise Management Levels**

| Receiver Area | Receiver Type | Relevant Monitoring Location | $L_{Aeq(15minute)}$ Construction NMLs (dBA) | | | |
|---|---|---|---|---|---|---|
| | | | Daytime | Daytime OOH | Evening | Night-time |
| A | Church | B.23 | 55 | 55 | n/a | n/a |
| B | Residential | B.23 | 73 | 68 | 65 | 50 |
| B | Commercial | B.23 | 70 | 70 | n/a | n/a |
| C | Residential | B.25 | 51 | 46 | 45 | 40 |
| C | Commercial | B.25 | 70 | 70 | n/a | n/a |
| C | Active Recreation | B.25 | 65 | 65 | n/a | n/a |
| D | Active Recreation | B.25 | 65 | 65 | n/a | n/a |
| D | Residential | B.25 | 51 | 46 | 45 | 40 |
| E | Residential | B.22 | 52 | 47 | 46 | 39 |
| F | Residential | B.23 | 73 | 68 | 65 | 50 |
| F | Commercial | B.23 | 70 | 70 | n/a | n/a |
| F | Industrial | B.23 | 75 | 75 | n/a | n/a |

### 3.4.3 Airborne 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 have been developed to be a subset of those discussed in **Section 3.3.1.1**, and are:

- Enabling works including mobilisation and demolition (12 months)
- Track works (periodic over about four and a half years)
- Earthworks which consist of initial excavation, tunnel dive piling, tunnel dive excavation, tunnel dive lining, laying tunnel dive track (12 months)
- Acoustic shed construction (one month)
- Tunnelling and excavation with shed (18 months)
- Fitout (18 months)

Calculations of the typical $L_{Aeq(15minute)}$ noise level exceedances of the NMLs at the nearest noise sensitive receivers are provided in **Appendix D** and are summarised in **Table 23**. The ‘sleep’ column of the table provides the predicted exceedance of the sleep disturbance screening noise level.

Note that for night-time construction, preliminary modelling indicated that an acoustic shed would be required and was included in the tunnelling and fitout scenarios.

**Table 23 Predicted Noise Level Exceedances at Chatswood Dive Site**

| Receiver Area | Scenario | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Enabling Works | Track Works | Earthworks | Acoustic Shed Construction | Tunnelling with Shed | | | | | Fitout | | | | |
| | Day | Day | Day | DOOH | Day | DOOH | Eve | Night | Sleep | Day | DOOH | Eve | Night | Sleep |
| A – Church to the south west on the Pacific Highway | 2 | 2 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B – Residential receivers to the west on the Pacific Highway | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| B – Commercial receivers to the west on the Pacific Hwy. | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C – Residential receivers to the north on Nelson Street | 3 | 3 | 3 | 1 | 3 | 1 | 1 | 2 | 1 | 0 | 0 | 0 | 1 | 0 |
| C – Commercial receivers to the north on Nelson Street | 3 | 3 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C – Active Recreation to the north, west of the railway line | 3 | 3 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D – Active Recreation to the north, east of the railway line | 1 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D – Residential receivers to the east, east of the railway line | 3 | 3 | 3 | 1 | 3 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 |
| E – Residential receivers to the east, east of the railway line | 3 | 3 | 3 | 1 | 2 | 1 | 1 | 2 | 1 | 0 | 0 | 0 | 1 | 0 |
| F – Residential receivers to the south on Mowbray Road | 3 | 3 | 3 | 1 | 3 | 2 | 2 | 2 | 1 | 0 | 1 | 1 | 1 | 0 |
| F – Commercial receivers to the south on Mowbray Road | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| F – Industrial receivers to the south on Mowbray Road | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Legend**

| Category 0 | Category 1 | Category 2 | Category 3 |
|---|---|---|---|
| NML Compliance | NML exceedance of less than 10 dB | NML exceedance of between 10 dB and 20 dB | NML exceedance of more than 20 dB |

**Discussion**

The preliminary findings of the construction noise impact assessment at Chatswood indicate:

- The predicted noise levels for enabling works indicate high exceedances of more than 20 dB of the NMLs at residential receivers in Area C, D, E and F and at the commercial receivers and active recreation of in Area C. Moderate exceedances of more than 10 dB are predicted for the church in Area A, and at the residential and commercial receivers in Area B. Minor exceedances are predicted at the active recreation Area D. These are a direct result of the relative close proximity of receivers to the construction activities and the absence of any appreciable shielding between sites and receivers.
- During track works predicted noise levels indicate high exceedances of more than 20 dB of the NMLs at residential receivers in Area C, D, E and F and at the commercial receivers and active recreation of Area C. Moderate exceedances of more than 10 dB are at the church and at the active recreation Area D.

- During earthworks predicted noise levels indicate high exceedances of more than 20 dB of the NMLs at residential receivers in Area C, D, E and F. Moderate exceedances of more than 10 dB are at the commercial receivers in Area C and at the active recreation Area C.
- Minor exceedances of less than 10 dB are predicted during acoustic shed construction.
- During tunnelling with an acoustic shed there is a high exceedance of the NMLs by more than 20 dB at the residential receivers in Area C, D, and F, and a moderate exceedance in Area E during the daytime, from activities outside the shed. During the night-time there are moderate exceedances of more than 10 dB at the residential receivers in Area C, D, E, and F, and minor exceedances in Area B. An acoustic shed with higher noise insulation would be required to reduce night-time non compliance.
- During fitout compliance is predicted during daytime and evening, with minor exceedances at residences in Areas C and F.

**On Site Night-Time $L_{Amax}$ Truck Noise**

The maximum noise levels associated with on-site truck movements, deliveries by semitrailer and other activities on site can potentially cause awakening reactions (or sleep disturbance) at nearby residential receivers. The $L_{Amax}$ noise levels associated with these events exceed the sleep disturbance screening level during tunnelling with an acoustic shed. During the detailed design night-time 'on site' traffic routes and activities should be reviewed and/or additional mitigation considered, such as increased site perimeter hoarding height.

### 3.4.4 Ground-borne Noise and Human Comfort Vibration Assessment

Where ground-borne noise exceedances are identified then human comfort vibration exceedances would also be present. **Appendix F** illustrates the potential ground borne noise impacts due to vibration intensive construction activities (rock breaking) in this area. In summary the analysis for daytime (no track works are proposed for night-time) indicates:

- Three (3) residences, located to the east of the dive structure, have exceedances of the NML of 20 dB to 25 dB.
- A further seven (7) residences, located to the east and west of the dive structure, have moderate exceedances of the NML of 10 dB to 20 dB. This includes Mowbray House which would form part of the construction site but be retained.
- Minor exceedances of up to 10 dB are predicted at nine (9) residences, located to the east and south of the dive structure.
- A single commercial receiver, located to the west of the dive structure, has a moderate exceedance of 10 dB to 20 dB during the day time.

These exceedances are a direct result of the relative close proximity of receivers to the construction activities and the use of large rock breakers.

### 3.4.5 Vibration Cosmetic Damage Assessment

During construction of the proposed shafts vibration levels are anticipated to remain well below the vibration screening levels associated with minor cosmetic building damage at locations surrounding the works, except for Mowbray House. **Appendix G** illustrates the potential cosmetic damage vibration impacts due to construction activities in this area.

The heritage listed Mowbray House is located on the construction site, and predicted vibration levels for excavation works exceed the 7.5 mm/s vibration screening level. A more detailed assessment of the structure and attended vibration monitoring would be carried out to ensure vibration levels remain below appropriate limits for that structure.

### 3.4.6 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access route to the Chatswood construction site. In this instance the access to the site is via the Pacific Highway, Mowbray Road and Nelson Street. The Pacific Highway and Mowbray Roads are arterial roads with significant daytime flows, whilst Nelson Street is a local road. The RNP base criteria, predicted $L_{Aeq(15hr)}$ daytime and $L_{Aeq(9hr)}$ nighttime noise levels with the development, and the $L_{Aeq}$ increase and sleep disturbance noise levels have been assessed in **Table 24**.

**Table 24 Chatswood Dive Site - Construction Traffic on Public Roads**

| Access Road | Base Criteria Day/Night ($L_{Aeq(15hr/9hr)}$) | Predicted Road Traffic Noise Day/Night | Predicted Road Traffic Noise Increase (dB) | RBL + 15 dB Screening Criterion (dBA) | External LAmax NML Level (dBA) | Predicted $L_{Amax}$ Noise Level (dBA) |
|---|---|---|---|---|---|---|
| Pacific Hwy | 60/55 | 74/68 | 0.1/0.2 | 65 | 65 | 74 |
| Mowbray Rd | 60/55 | 73/67 | 0.1/0.2 | 65 | 65 | 75 |
| Nelson St | 55/50 | 58/52 | n/a[1] | 54 | 65 | 70 |

Note 1: Existing flows are not available for Nelson Street.

**Table 24** indicates that whilst at the Pacific Highway and at Mowbray Road the base criteria are exceeded, the predicted noise level increase ($L_{Aeq}$) associated with construction traffic complies with the 2 dB allowance, therefore sensitive receivers are not likely to notice an increase in the average road traffic noise levels during construction. Nelson Street would be closed, with negligible existing movements as the street would have access at the western end only, and baseline noise levels of daytime 58 dBA and night-time of 52 dBA have been predicted. These levels exceed the RNP baseline criteria of 55 dBA daytime and 50 dBA night-time for local roads.

There are expected to be up to 8 heavy vehicle and 30 light vehicles movements or events per hour during the night and whilst there is an exceedance of the sleep disturbance screening criterion (of up to 10 dB) and external sleep disturbance NML of 65 dBA (by up to 10 dB), the $L_{Amax}$ levels would be similar to other heavy vehicles using the Pacific Highway and Mowbray Road.

At Nelson Street there is an exceedance of the sleep disturbance screening criterion (of up to 16 dB) and external sleep disturbance NML of 65 dBA (by up to 5 dB) resulting in a sleep disturbance risk. Unless compliance with the base road traffic noise criteria can be achieved on Nelson Street, night time heavy vehicle movements at the Chatswood dive site would be restricted to the Pacific Highway and Mowbray Road.

## 3.5 Artarmon Substation Construction Site

### 3.5.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Artarmon Substation construction site and the surrounding receiver areas is provided in **Figure 8** with the nearest noise sensitive receivers identified in **Table 25.**

**Figure 8 Artarmon Substation Construction Site and Receiver Areas**


**Table 25 Nearest Noise Sensitive Receivers - Artarmon Substation Construction Site**

| Receiver Area | Location Relative to Works (m)[1] |
|---|---|
| A - Residential receivers to the north on Butchers Lane | 15 |
| B - Residential receivers to the north east on Reserve Road | 14 |
| C - Residential receivers to the east on Barton Road | 103 |
| D - Commercial receivers to the south on Hotham Parade | 94 |

Note 1: The relative distance to works shown is that from the nearest sensitive receiver to the closest location of construction activity.

### 3.5.2 Site Specific Construction Noise Management Levels

With reference to the ambient noise survey results summarised in **Table 4**, the site specific construction NMLs are presented in **Table 26**.

**Table 26 Artarmon Substation Construction Site Noise Management Levels**

| Receiver Area | Receiver Type | Relevant Monitoring Location | $L_{Aeq(15minute)}$ Construction NMLs (dBA) | | | |
|---|---|---|---|---|---|---|
| | | | Daytime | Daytime OOH | Evening | Night-time |
| A | Residential | B.21 | 59 | 54 | 51 | 46 |
| B | Residential | B.21 | 59 | 54 | 51 | 46 |
| C | Residential | B.21 | 59 | 54 | 51 | 46 |
| D | Commercial | B.21 | 70 | 70 | n/a | n/a |

### 3.5.3 Airborne 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 have been developed to be a subset of those discussed in **Section 3.3.1.1**, and are:

- Enabling works including mobilisation and demolition (one month)
- Earthworks (one month)
- Excavation (nine months)
- Building construction works (12 months)

Calculations of the typical $L_{Aeq(15minute)}$ noise level exceedances of the NMLs at the nearest noise sensitive receivers are provided in **Appendix D** and are summarised in **Table 27**.

**Table 27 Predicted noise level exceedances at Artarmon Substation Construction Site**

| Receiver Area | Scenario | | | |
|---|---|---|---|---|
| | Enabling Works | Earthworks | Excavation | Construction |
| | Day | Day | Day | Day |
| A - Residential receivers to the north on Butchers Lane | 3 | 3 | 3 | 2 |
| B - Residential receivers to the north east on Reserve Road | 3 | 2 | 2 | 2 |
| C - Residential receivers to the east on Barton Road | 2 | 1 | 1 | 1 |
| D – Commercial receivers to the south on Hotham Parade | 1 | 1 | 1 | 0 |

| Legend | | | |
|---|---|---|---|
| Category 0 | Category 1 | Category 2 | Category 3 |
| NML Compliance | NML exceedance of less than 10 dB | NML exceedance of between 10 dB and 20 dB | NML exceedance of more than 20 dB |

**Discussion**

The preliminary findings of the construction noise impact assessment at Artarmon Substation indicate:

- The predicted noise levels for enabling works indicate high exceedances of more than 20 dB of the NMLs at residential receivers in area A and B, and moderate exceedances of more than 10 dB in Area C. These are a direct result of the relative close proximity of receivers to the construction activities and the absence of any appreciable shielding between sites and receivers.
- During earthworks and shaft excavation high exceedances of more than 20 dB at the Area A residential receivers and moderate exceedances of more than 10 dB at the area B residential receivers are predicted during the daytime. There are minor exceedances at the residential receivers in Area C and at the commercial receivers in Area D.
- During construction moderate exceedances of more than 10 dB at the area A and B and minor exceedances in Area C. At the commercial receivers compliance is predicted.

### 3.5.4 Ground-borne Noise and Human Comfort Vibration Assessment

Where ground-borne noise exceedances are identified then human comfort vibration exceedances would also be present. **Appendix F** illustrates the potential ground borne noise impacts due to vibration intensive construction activities (rock breaking) in this area. In summary the analysis for daytime indicates:

- At the nearest residences a minor exceedances of the NML of up 10 dB, and compliance in all other areas.

The potential ground-borne noise impacts associated with the excavation of the tunnels is discussed in **Section 3.16.1**.

### 3.5.5 Vibration Assessment

During rock breaker activities at the Artarmon substation construction site, vibration levels may be perceptible at the nearest residential receivers. On the basis that the nearest buildings are approximately 25 m from the proposed shaft, vibration levels are anticipated to remain well below the vibration screening levels associated with minor cosmetic building damage. **Appendix G** illustrates the potential cosmetic damage vibration impacts due to construction activities in this area.

### 3.5.6 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access routes to the Artarmon substation construction site. In this instance the access to the site is via Reserve Road and Barton Road, which are sub arterial and local roads respectively. Reserve Road has significant daytime flows, and the predicted traffic noise increase is 0.2 dB, complying with the 2 dB allowance criteria.

Barton Road is a cul-de-sac, and does not provide access to residences and as such has negligible existing flows. Therefore traffic noise levels from site only traffic movements have been predicted for comparison with the RNP baseline criteria and are presented in **Table 28**

**Table 28 Artarmon Substation Construction Site - Construction Traffic on Public Roads**

| Site | Access Road | Base Criteria Daytime | Predicted Project Daytime Traffic noise |
|---|---|---|---|
| Artarmon | Barton Rd | 55 | 51 |

**Table 28** shows traffic noise levels from the project comply with the baseline criteria on Barton Road. No night-time activities are proposed at this site.

## 3.6 Crows Nest Station Construction Site

### 3.6.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Crows Nest Station construction site and the surrounding receiver areas is provided in **Figure 9**, with the nearest noise sensitive receivers identified in **Table 29**.

**Figure 9 Crows Nest Station Construction Site and Receiver Areas**

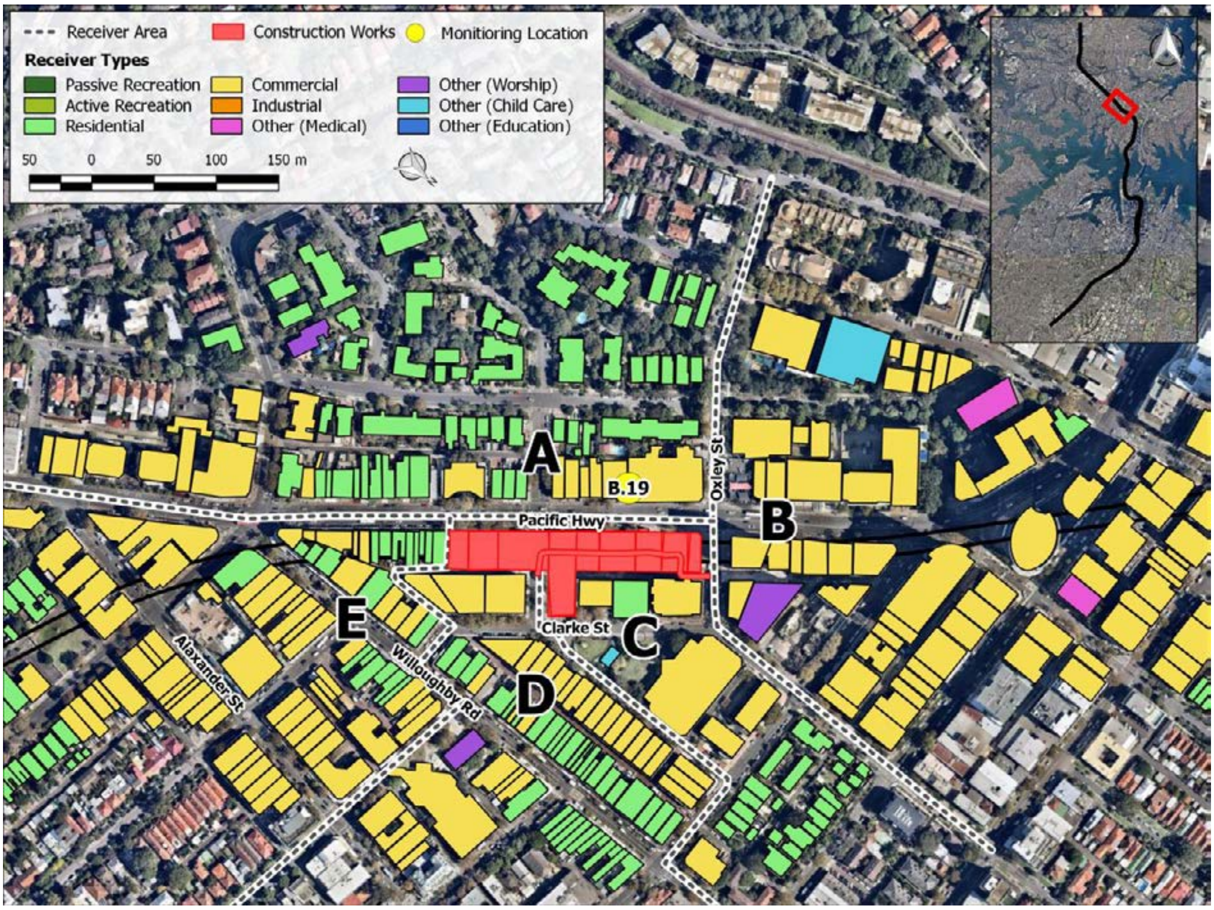



**Table 29 Nearest Noise Sensitive Receivers - Crows Nest Station Construction Site**

| Receiver Area | Location Relative to Works (m)[1] |
|---|---|
| A - Residential receivers to the west on the Pacific Highway | 33 |
| A - Commercial receivers to the west on the Pacific Highway | 28 |
| B - Commercial receivers to the north of Oxley Street | 29 |
| B – North Side Community Church to the north on Oxley St. | 51 |
| C - Residential receivers to the north east on Clarke Street | 5 |
| C - Commercial receivers to the north east on Clarke Street | 2 |
| C - Active recreation receiver to north on Hume Street | 60 |
| D - Residential receivers to the north east on Clarke Street | 69 |

| Receiver Area | Location Relative to Works (m)[1] |
|---|---|
| D - Commercial receivers to the north east on Clarke Street | 5 |
| E - Residential receivers to the south on the Pacific Highway | 4 |
| E - Commercial receivers to the south on the Pacific Highway | 42 |

Note 1: The relative distance to works shown is that from the nearest sensitive receiver to the closest location of construction activity.

### 3.6.2 Site Specific Construction Noise Management Levels

With reference to the ambient noise survey results summarised in **Table 4**, the site specific construction NMLs are presented in **Table 30**.

**Table 30 Crows Nest Station Construction Site Noise Management Levels**

| Receiver Area | Receiver Type | Relevant Monitoring Location | $L_{Aeq(15minute)}$ Construction NMLs (dBA) | | | |
|---|---|---|---|---|---|---|
| | | | Daytime | Daytime OOH | Evening | Night-time |
| A | Residential | B.19 | 69 | 64 | 60 | 55 |
| A | Commercial | B.19 | 70 | 70 | n/a | n/a |
| B | Commercial | B.19 | 70 | 70 | n/a | n/a |
| B | Church | B.19 | 55 | 55 | n/a | n/a |
| C | Residential | B.19 | 69 | 64 | 60 | 55 |
| C | Commercial | B.19 | 70 | 70 | n/a | n/a |
| C | Active Recreation | B.19 | 65 | 65 | n/a | n/a |
| D | Residential | B.19 | 69 | 64 | 60 | 55 |
| D | Commercial | B.19 | 70 | 70 | n/a | n/a |
| E | Residential | B.19 | 69 | 64 | 60 | 55 |
| E | Commercial | B.19 | 70 | 70 | n/a | n/a |

### 3.6.3 Airborne 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 have been developed to be a subset of those discussed in **Section 3.3.1.1**, and are:

- Enabling works including mobilisation and demolition (12 months)
- Earthworks (two months)
- Acoustic shed construction (one month)
- Excavation (three years)
- Station construction (18 months)

Calculations of the typical $L_{Aeq(15minute)}$ noise level exceedances of the NMLs at the nearest noise sensitive receivers are provided in **Appendix D** and are summarised in **Table 31**. The 'sleep' column of the table provides the predicted exceedance of the sleep disturbance screening noise level.

Note that for night-time construction, preliminary modelling indicated that an acoustic shed would be required and was included for the station excavation scenario.

**Table 31 Predicted noise level exceedances at Crows Nest Station Construction Site**

| Receiver Area | Scenario: Enabling Works | Earthworks | Acoustic Shed Construction | Excavation with Shed | | | | | Construction |
|---|---|---|---|---|---|---|---|---|---|
| | Day | Day | Day | Day | DOOH | Even | Night | Sleep | Day |
| A – Residential receivers to the west on the Pacific Highway | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| A – Commercial receivers to the west on the Pacific Highway | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| B – Commercial receivers to the north of Oxley Street | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| B – North Side Community Church to the north on Oxley St. | 2 | 2 | 1 | 1 | 1 | 0 | 0 | 0 | 2 |
| C – Residential receivers to the north east on Clarke Street | 3 | 3 | 1 | 0 | 1 | 1 | 2 | 1 | 2 |
| C – Commercial receivers to the north east on Clarke Street | 3 | 3 | 2 | 1 | 1 | 0 | 0 | 0 | 2 |
| C – Active recreation receiver to north on Hume Street | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| D – Residential receivers to the north east on Clarke Street | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D – Commercial receivers to the north east on Clarke Street | 3 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| E – Residential receivers to the south on the Pacific Highway | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| E – Commercial receivers to the south on the Pacific Highway | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Legend**

| Category 0 | Category 1 | Category 2 | Category 3 |
|---|---|---|---|
| NML Compliance | NML exceedance of less than 10 dB | NML exceedance of between 10 dB and 20 dB | NML exceedance of more than 20 dB |

**Discussion**

The preliminary findings of the construction noise impact assessment at Crows Nest Station indicate:

- The predicted noise levels for enabling works (including mobilisation/demolition) indicate high exceedances of more than 20 dB of the NMLs at residential receivers in Area C and E. Moderate exceedances of more than 10 dB are predicted at residential receivers in Areas A, at the church in Area in B and the active recreation in Area C. At residential receivers in Area D minor exceedances are predicted.

  At the nearest commercial receivers in Areas C and D high exceedances of more than 20 dB of the NMLs are predicted, and at commercial receivers in Areas A and B moderate exceedances of more than 10 dB. Minor exceedances are predicted at commercial receivers in Area E.

- The predicted noise levels for earthworks indicate high exceedances of more than 20 dB of the NMLs at the residential receivers in Area C. Moderate exceedances are predicted at the church in receiver Area B, and the residential receivers in Area E and the active recreation in Area C. Minor exceedances are predicted at the residential receivers in Area A and D.

  At the nearest commercial receivers in Areas C and D high exceedances of more than 20 dB of the NMLs are predicted, and at commercial receivers in Areas A and B moderate exceedances of more than 10 dB.
- During acoustic shed construction moderate exceedances at commercial receivers in Area C, and minor exceedances are predicted at the church in Area B, the residential in Area C and the commercial in Area D.
- During station excavation and structural works minor exceedances of up to 10 dB of the NMLs are predicted at the commercial receivers in Area C, and the church during daytime. With night-time excavation there is a moderate exceedance at residences in Area C, and minor exceedance at residences in Area A. An acoustic shed with higher noise insulation would be required to reduce night-time non compliance.
- During station construction moderate exceedances of more than 10 dB of the NMLs are predicted at the residential receivers in Area C and E, commercial receivers at Area C and D, and at the church in Area B. Minor exceedances are predicted at residential receivers in Area A, and at commercial receivers in Area A and B and the active recreation in Area C.

**On Site Night-Time $L_{Amax}$ Truck Noise**

The maximum noise levels associated with on-site truck movements, deliveries by semitrailer and other activities on site can potentially cause awakening reactions (or sleep disturbance) at nearby residential receivers. The $L_{Amax}$ noise levels associated with these events exceed the sleep disturbance screening level by up to 10 dB during excavation with an acoustic shed. During the detailed design night-time 'on site' traffic routes and activities should be reviewed and/or additional mitigation such as increased site perimeter hoarding height.

### 3.6.4 Ground-borne Noise and Human Comfort Vibration Assessment

Where ground-borne noise exceedances are identified then human comfort vibration exceedances would also be present. **Appendix F** illustrates the potential ground-borne noise impacts due to vibration intensive construction activities (rock breaking) in this area. In summary the analysis indicates:

- During the day seven (7) buildings (four commercial buildings located to the east of the site, one residential building located to the east of the site and two residential buildings located to the south of the site) have ground-borne noise levels potentially higher than 75 dBA for several floors in each building. Where receivers experience day-time internal noise levels greater than 75 dBA more detailed site specific ground borne noise investigation is required. If this investigation finds ground borne noise levels are likely to exceed 75 dBA for extended periods then alternative accommodation would be considered as a mitigation measure.
- During night-time works the analysis shows fifteen (15) residential buildings, located to the east of the site, have regenerated noise levels potentially higher than 45 dBA on one or more floors. Where residential receivers have night-time internal noise levels greater than 45 dBA they would be considered eligible for alternative accommodation (the highest level mitigation measure) as per the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement).

#### 3.6.4.1 Blasting

The use of blasting in the excavation of the station shafts effectively reduces the duration of noise and vibration impacts due to the use of rock breakers, which must be used to some extent before blasting can occur. **Table 32** illustrates the effective reduction in duration of the ground-borne noise (and human comfort vibration) NML exceedances when blasting is used as an alternative excavation methodology. This table also illustrates the effective reduction in duration of these exceedances when blasting is combined with medium rock breakers instead of large rock breakers.

The values in this table represent all exceedances of the NMLs (even those as low as 1 dB to 5 dB). Therefore, the actual requirement for high level mitigation measures is not represented. The information is presented to indicate the benefits in terms of duration of impacts between different excavation methodologies.

**Table 32 No. of Periods Above the NMLs Due to Alternative Construction Methodologies**

| Site | Number of Periods Above NMLs | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Residential | | | | | | | | | Commercial | | |
| | Day | | | Evening | | | Night | | | Day | | |
| | B- Lrg RB | B+ Lrg RB | B+ Med RB | B- Lrg RB | B+ Lrg RB | B+ Med RB | B- Lrg RB | B+ Lrg RB | B+ Med RB | B- Lrg RB | B+ Lrg RB | B+ Med RB |
| Crows Nest | 80 | 30 | 15 | 136 | 45 | 29 | 185 | 60 | 49 | 67 | 27 | 8 |

Note: B- = No Blasting, B+ = With Blasting, Lrg RB = Large Rock Breakers, Med RB = Medium Rock Breakers

The duration of the impacts can be summarised as follows:

**Residential Day**: The use of large rock breakers with no blasting generates 80 daytime periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 30 daytime periods. The inclusion of blasting combined with medium rock breakers reduces the duration of impacts to 15 daytime periods.

**Residential Evening**: The use of large rock breakers with no blasting generates 136 evening periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 45 evening periods. The inclusion of blasting and the use of medium rock breakers reduces the duration of impacts even further to 29 evening periods. Blasting therefore significantly reduces the impacts during the evening.

**Residential Night**: The use of large rock breakers with no blasting generates 185 night-time periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 60 night-time periods. The inclusion of blasting and the use of medium rock breakers reduces the duration of impacts even further to 49 night-time periods. Blasting therefore significantly reduces the impacts during the night.

**Commercial Day**: The use of large rock breakers with no blasting generates 67 daytime periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 27 daytime periods. The inclusion of blasting combined with medium rock breakers reduces the duration of impacts to 8 daytime periods.

With careful planning and positioning of the rock breakers it may be possible to avoid consecutive periods of NML exceedances ie respite periods for receivers could be planned in the construction program through careful rock breaker locations. For any residual exceedances of the NMLs, the processes and mitigation measures identified in the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement) would be implemented.

The potential ground-borne noise impacts associated with the excavation of the tunnels are discussed in **Section 3.16.1**.

### 3.6.5 Vibration Assessment

During construction of the proposed shaft vibration levels are anticipated to exceed the vibration screening levels associated with minor cosmetic building damage. The analysis shows three (3) buildings adjacent to the shaft excavation site (one building located to the east on Clarke Street and two building located to the south of the Pacific Highway) where the screening criteria for cosmetic damage may be exceeded. A more detailed assessment of the structure and attended vibration monitoring would be carried out to ensure vibration levels remain below appropriate limits for those structures. **Appendix G** illustrates the potential cosmetic damage vibration impacts due to construction activities in this area.

### 3.6.6 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access route to the Crows Nest Station sites. In this instance the access to the site is via the Pacific Highway, Oxley Street, Clarke Street and Hume Street. The Pacific Highway is an arterial road with significant daytime flows, and Clarke Street is a local road. No sensitive receivers are located on the sections of Oxley Street and Hume Street proposed to be used as haul routes. Given that traffic movements are proposed during the night-time period, the $L_{Aeq}$ increase and sleep disturbance noise levels have been assessed in **Table 33**.

**Table 33 Crows Nest Station Construction Site - Construction Traffic on Public Roads**

| Access Road | Base Criteria Day/Night ($L_{Aeq(15hr/9hr)}$) | Predicted Road Traffic Noise Day/Night | Predicted Road Traffic Noise Increase (dB) | RBL + 15 dB Screening Criterion (dBA) | External $L_{Amax}$ NML Level (dBA) | Predicted $L_{Amax}$ Noise Level (dBA) |
|---|---|---|---|---|---|---|
| Pacific Hwy | 60/55 | 75/68 | 0.2/0.5 | 65 | 65 | 79 |
| Clarke St | 55/50 | 59/56 | n/a[1] | 66 | 65 | 75 |

Note 1: Existing traffic flows are not available for Clarke Street

**Table 33** indicates that whilst at the Pacific Highway the base criteria are exceeded, the predicted noise level increase ($L_{Aeq}$) associated with construction traffic complies with the 2 dB allowance, therefore sensitive receivers are not likely to notice an increase in the average road traffic noise levels during construction. At Clarke Street the existing movements are not available and baseline noise levels of daytime 59 dBA and night-time of 56 dBA have been predicted. These levels exceed the RNP baseline criteria of 55 dBA daytime and 50 dBA night-time for local roads.

There are expected to be up to 6 heavy vehicle and 2 light vehicles movements or events per hour during the night on the Pacific Highway and whilst there is an exceedance of the sleep disturbance screening criterion (of up to 14 dB) and external sleep disturbance NML of 65 dBA (by up to 14 dB), the $L_{Amax}$ levels would be similar to other heavy vehicles using the Pacific Highway.

At Clarke Street there is an exceedance of the sleep disturbance screening criterion (of up to 9 dB) and external sleep disturbance NML of 65 dBA (by up to 10 dB) with limited existing heavy vehicles expected, resulting in a sleep disturbance risk. Unless compliance with the base road traffic noise criteria can be achieved on Clarke Street, night time heavy vehicle movements at the Crows Nest Station construction site would be restricted to the Pacific Highway, Hume Street and Oxley Street.

## 3.7 Victoria Cross Station Construction Site

### 3.7.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Victoria Cross Station construction site and the surrounding receiver areas is provided in **Figure 10**, with the nearest noise sensitive receivers identified in **Table 34**.

**Figure 10 Victoria Cross Station Construction Site and Receiver Areas**

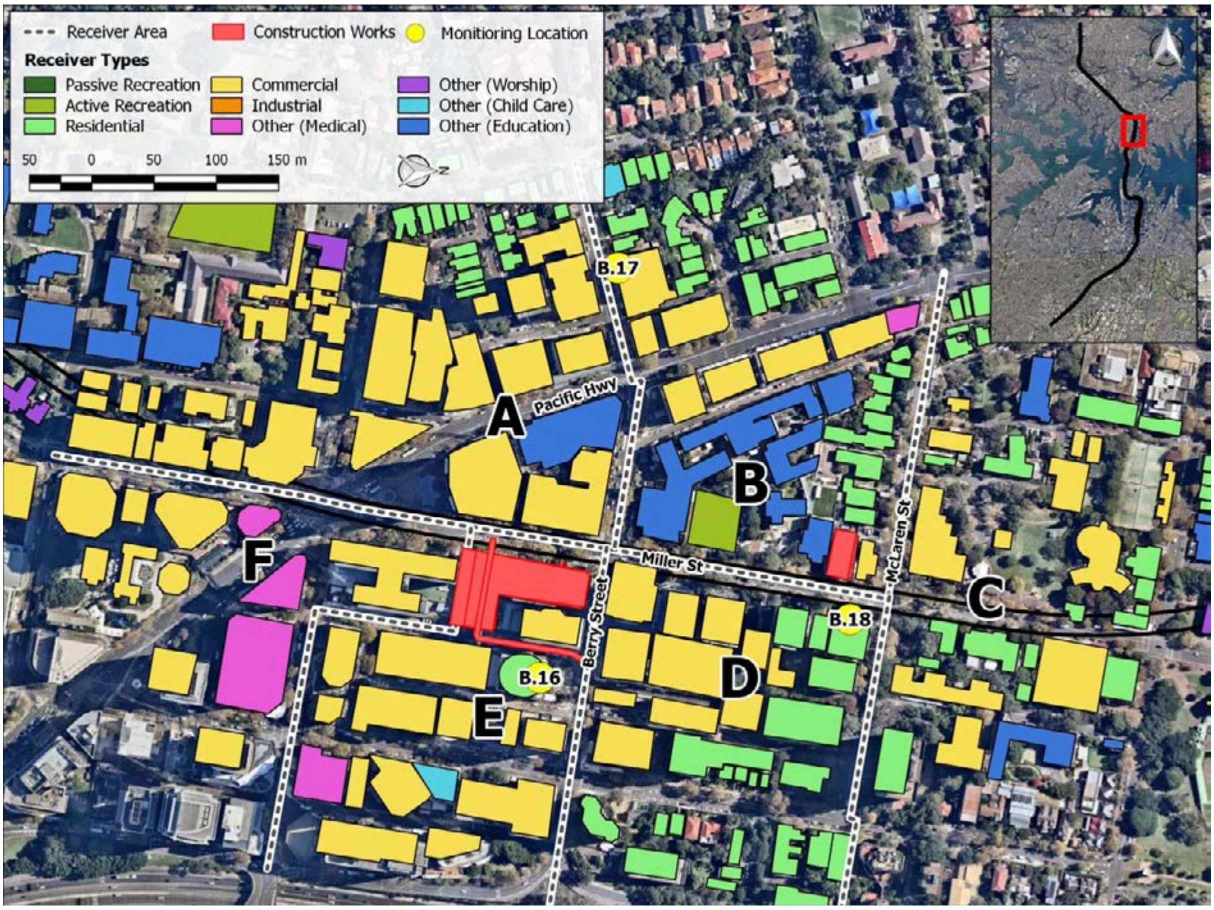



**Table 34 Nearest Noise Sensitive Receivers - Victoria Cross Station Construction Site**

| Receiver Area | Location Relative to Works (m)[1] |
|---|---|
| A - Commercial receivers to the west on Miller Street | 35 |
| A - Educational receivers to the west on the Pacific Highway | 89 |
| B - Commercial receivers to the west on Miller Street | 3 |
| B - Residential receivers to the west on McLaren Street | 11 |
| B - Educational receivers to the west on the Miller Street | 32 |
| C - Residential receivers to the north on McLaren Street | 89 |
| C - Commercial receivers to the north on McLaren Street | 56 |
| D - Residential receivers to the east on Miller Street | 38 |
| D - Commercial receivers to the east on Miller Street | 20 |
| E - Residential receivers to the east on Miller Street | 31 |
| E - Commercial receivers to the east on Miller Street | 7 |
| F - Commercial receivers adjacent to the south | 2 |

Note 1: The relative distance to works shown is that from the nearest sensitive receiver to the closest location of construction activity.

### 3.7.2 Site Specific Construction Noise Management Levels

With reference to the ambient noise survey results summarised in **Table 4**, the site specific construction NMLs are presented in **Table 35**.

**Table 35 Victoria Cross Station Construction Site Noise Management Levels**

| Receiver Area | Receiver Type | Relevant Monitoring Location | $L_{Aeq(15minute)}$ Construction NMLs (dBA) | | | |
|---|---|---|---|---|---|---|
| | | | Daytime | Daytime OOH | Evening | Night-time |
| A | Commercial | B.17 | 70 | 70 | n/a | n/a |
| A | Educational | B.17 | 55 | n/a | n/a | n/a |
| B | Commercial | B.18 | 70 | 70 | n/a | n/a |
| B | Residential | B.18 | 75 | 70 | 62 | 56 |
| B | Educational | B.18 | 55 | n/a | n/a | n/a |
| C | Residential | B.18 | 75 | 70 | 62 | 56 |
| C | Commercial | B.18 | 70 | 70 | n/a | n/a |
| D | Residential | B.18 | 75 | 70 | 62 | 56 |
| D | Commercial | B.18 | 70 | 70 | n/a | n/a |
| E | Residential | B.16 | 75 | 70 | 68 | 57 |
| E | Commercial | B.16 | 70 | 70 | n/a | n/a |
| F | Commercial | B.16 | 70 | 70 | n/a | n/a |

### 3.7.3 Airborne 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 have been developed to be a subset of those discussed in **Section 3.3.1.1**, and are:

- Enabling works including mobilisation and demolition (12 months)
- Earthworks (two months)
- Acoustic shed construction (one month)
- Excavation (three years)
- Station construction (18 months)

Calculations of the typical $L_{Aeq(15minute)}$ noise level exceedances of the NMLs at the nearest noise sensitive receivers are provided in **Appendix D** and are summarised in **Table 36**. The 'sleep' column of the table provides the predicted exceedance of the sleep disturbance screening noise level.

Note that for night-time construction, preliminary modelling indicated that an acoustic shed would be required and was included for the station excavation scenario.

**Table 36 Predicted noise level exceedances at Victoria Cross Station Construction Site**

| Receiver Area | Scenario | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Enabling Works | Earthworks | Acoustic Shed Construction | Excavation with Shed | | | | | Construction |
| | Day | Day | Day | Day | OOHD | Even | Night | Sleep | Day |
| A – Commercial receivers to the west on Miller Street | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| A – Educational receivers to the west on the Pacific Hwy | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| B – Commercial receivers to the west on Miller Street | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| B – Residential receivers to the west on McLaren Street | 2 | 2 | 0 | 0 | 0 | 1 | 2 | 1 | 1 |
| B – Educational receivers to the west on the Miller Street | 3 | 3 | 3 | 2 | 1 | 0 | 0 | 0 | 3 |
| C – Residential receivers to the north on McLaren Street | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C – Commercial receivers to the north on McLaren Street | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D – Residential receivers to the east on Miller Street | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| D – Commercial receivers to the east on Miller Street | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| E – Residential receivers to the east on Miller Street | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| E – Commercial receivers to the east on Miller Street | 3 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 2 |
| F – Commercial receivers adjacent to the south | 3 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 1 |

| Legend | | | |
|---|---|---|---|
| Category 0 | Category 1 | Category 2 | Category 3 |
| NML Compliance | NML exceedance of less than 10 dB | NML exceedance of between 10 dB and 20 dB | NML exceedance of more than 20 dB |

**Discussion**

The preliminary findings of the construction noise impact assessment at Victoria Cross Station indicate:

- The predicted noise levels for enabling works indicate high exceedances of more than 20 dB of the NMLs at educational receivers in Area B and at the commercial receivers in Area B, E and F. Moderate exceedances of more than 10 dB are predicted at commercial receivers in Area A and D, at residential receivers in Area B and educational receivers in Area in A. At residential receivers in Area D and E and commercial receivers in Area C minor exceedances are predicted.
- The predicted noise levels for earthworks indicate high exceedances of more than 20 dB of the NMLs at the educational receivers in Area B and commercial receivers in Area E and F. At the educational receivers in Area A, and the commercial receivers in Area B and D moderate exceedances are predicted.

  At the nearest residential receivers moderate exceedances are predicted in Area B and low exceedances are predicted in Area D and E.

- During acoustic shed construction high exceedances of more than 20 dB are predicted educational receivers in Area B and moderate exceedances of more than 10 dB at commercial receivers in Area E and F.
- During excavation with an acoustic shed there are moderate exceedances at the educational receivers in Area B. For night-time works there is a moderate exceedances at residential receivers in Area B and a minor exceedance is predicted at residential receivers in Area d and E. An acoustic shed with higher noise insulation would be required to reduce night-time non compliance.
- During station construction high exceedances of more than 20 dB are predicted at the educational receivers in Area B, and moderate exceedances of more than 10 dB of the NMLs are predicted at the commercial receivers at Area B and E. Minor exceedances are predicted at residential receivers in Areas B and D, educational receivers in Area A and at commercial receivers in Area A, D and F.

**On Site Night-Time $L_{Amax}$ Truck Noise**

The maximum noise levels associated with on-site truck movements, deliveries by semitrailer and other activities on site can potentially cause awakening reactions (or sleep disturbance) at nearby residential receivers. The $L_{Amax}$ noise levels associated with these events exceed the sleep disturbance screening level during station excavation with an acoustic shed. During the detailed design night-time 'on site' traffic routes and activities should be reviewed and/or additional mitigation such as increased site perimeter hoarding height.

### 3.7.4 Ground-borne Noise and Human Comfort Vibration Assessment

Where ground-borne noise exceedances are identified then human comfort vibration exceedances would also be present. **Appendix F** illustrates the potential ground borne noise impacts due to vibration intensive construction activities (rock breaking) in this area. In summary the analysis indicates:

- During the daytime three (3) buildings immediately adjacent to the at the northern shaft (to the south, west and north) and one (1) building to the east of the southern shaft have regenerated noise levels potentially higher than 75 dBA on several floors in each building. Where receivers experience day-time internal noise levels greater than 75 dBA more detailed site specific ground borne noise investigation is required. If this investigation finds ground borne noise levels are likely to exceed 75 dBA for extended periods then alternative accommodation would be considered as a mitigation measure
- During night-time works the analysis shows five (5) residential buildings at the northern site (to the east and west) and one (1) residential building to the east of the southern site have regenerated noise levels potentially higher than 45 dBA on several floors. Where residential receivers have night-time internal noise levels greater than 45 dBA they would be considered eligible for alternative accommodation (the highest level mitigation measure) as per the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement).

#### 3.7.4.1 Blasting

The use of blasting in the excavation of the station shafts effectively reduces the duration of noise and vibration impacts due to the use of rock breakers which must be used to some extent before blasting can occur. **Table 37** illustrates the effective reduction in duration of the ground-borne noise (and human comfort vibration) exceedances when blasting is used as an alternative excavation methodology. This table also illustrates the effective reduction in duration of these exceedances when blasting is combined with medium rock breakers instead of large rock breakers.

The values in this table represent all exceedances of the NMLs (even those as low as 1 dB to 5 dB). Therefore, the actual requirement for high level mitigation measures is not represented. The information is presented to indicate the benefits in terms of duration of impacts between different excavation methodologies.

**Table 37 No. of Periods Above the NMLs Due to Alternative Construction Methodologies**

| Site | Number of Periods Above NMLs | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Residential | | | | | | | | | Commercial | | |
| | Day | | | Evening | | | Night | | | Day | | |
| | B- Lrg RB | B+ Lrg RB | B+ Med RB | B- Lrg RB | B+ Lrg RB | B+ Med RB | B- Lrg RB | B+ Lrg RB | B+ Med RB | B- Lrg RB | B+ Lrg RB | B+ Med RB |
| Victoria Cross - North | 62 | 32 | 9 | 172 | 71 | 31 | 268 | 101 | 77 | 283 | 131 | 111 |
| Victoria Cross - South | 0 | 0 | 0 | 16 | 8 | 0 | 55 | 22 | 7 | 37 | 22 | 8 |

Note: B- = No Blasting, B+ = With Blasting, Lrg RB = Large Rock Breakers, Med RB = Medium Rock Breakers

The duration of the impacts can be summarised as follows:

**Residential Day**: The use of large rock breakers with no blasting generates 62 daytime periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 32 daytime periods. The inclusion of blasting and the use of medium rock breakers reduces the duration of impacts even further to 9 daytime periods. Blasting coupled with medium rock breaker therefore significantly reduces the impacts during the day.

**Residential Evening**: The use of large rock breakers with no blasting generates 192 evening periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 79 evening periods. The inclusion of blasting and the use of medium rock breakers reduces the duration of impacts even further to 31 evening periods. Blasting therefore significantly reduces the impacts during the evening.

**Residential Night**: The use of large rock breakers with no blasting generates 323 night-time periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 123 night-time periods. The inclusion of blasting and the use of medium rock breakers reduces the duration of impacts even further to 84 night-time periods. Blasting therefore significantly reduces the impacts during the night.

**Commercial Day**: The use of large rock breakers with no blasting generates 324 daytime periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 153 daytime periods. The inclusion of blasting and the use of medium rock breakers reduces the duration of impacts even further to 119 daytime periods. Blasting coupled with medium rock breaker therefore significantly reduces the impacts during the day.

With careful planning and positioning of the rock breakers it may be possible to avoid consecutive periods of NML exceedances ie respite periods for receivers could be planned in the construction program through careful rock breaker locations. For any residual exceedances of the NMLs, the processes and mitigation measures identified in the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement) would be implemented.

The potential ground-borne noise impacts associated with the excavation of the tunnels are discussed in **Section 3.16.1**.

### 3.7.5 Vibration Assessment

During construction of the proposed shafts vibration levels are anticipated to remain well below the vibration screening levels associated with minor cosmetic building damage at all buildings except for three (3) buildings immediately adjacent to the northern site to the south, west and north. The analysis also shows one (1) commercial building to the east of the southern site where the screening criteria for cosmetic damage may be exceeded. Dilapidation surveys, vibration monitoring and more detailed site vibration investigation are therefore recommended for these buildings as a precautionary measure during construction. **Appendix G** illustrates the potential cosmetic damage vibration impacts due to construction activities in this area.

The use of road headers to excavate a low level pedestrian walkway between the northern and southern shafts are not predicted to generate significant vibration levels and will remain below the screening levels associated with minor cosmetic building damage.

### 3.7.6 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access route to the Victoria Cross Station sites. In this instance the access to the site is via McLaren Street, Miller Street and Berry Street which are sub-arterial roads with significant daytime flows, and Denison Street which is a local road. The RNP base criteria, predicted $L_{Aeq(15hr)}$ daytime and $L_{Aeq(9hr)}$ nighttime noise levels with the development, and the $L_{Aeq}$ increase and sleep disturbance noise levels have been assessed in **Table 38**.

**Table 38 Victoria Cross Station Construction Site - Construction Traffic on Public Roads**

| Access Road | Base Criteria Day/Night ($L_{Aeq(15hr/9hr)}$) | Predicted Road Traffic Noise Day/Night | Predicted Road Traffic Noise Increase (dB) | RBL + 15 dB Screening Criterion (dBA) | External $L_{Amax}$ NML Level (dBA) | Predicted $L_{Amax}$ Noise Level (dBA) |
|---|---|---|---|---|---|---|
| McLaren St | 60/55 | 66/62 | 0.6/0.8 | 66 | 65 | 76 |
| Miller St | 60/55 | 66/59 | 0.3/0.7 | 66 | 65 | 72 |
| Berry St | 60/55 | 69/62 | 0.3/0.8 | 67 | 65 | 76 |
| Denison St | 55/50 | 54/50 | n/a[1] | 67 | 65 | 72 |

Note 1: Existing flows are not available for Denison Street

**Table 38** indicates that whilst at McLaren Street, Miller Street and at Berry Street the base criteria are exceeded,the predicted noise level increase ($L_{Aeq}$) associated with construction traffic complies with the 2 dB allowance, therefore sensitive receivers are not likely to notice an increase in the average road traffic noise levels during construction. At Denison Street there are negligible existing movements, and baseline noise levels of daytime 54 dBA and night-time of 50 dBA have been predicted. These levels comply with the RNP baseline criteria for local roads.

There are expected to be up to 6 heavy vehicle and 2 light vehicles movements or events per hour during the night and whilst there is an exceedance of the sleep disturbance screening criterion (of up to 10 dB) and external sleep disturbance NML of 65 dBA (by up to 11 dB), the $L_{Amax}$ levels would be similar to other heavy vehicles using McLaren Street, Miller Street and Berry Street. At Denison Street there are limited existing heavy vehicles resulting in a sleep disturbance risk. Unless compliance with the base road traffic noise criteria can be achieved on Denison Street, night time heavy vehicle movements at the Victoria Cross Station construction site would be restricted to McLaren Street, Miller Street and Berry Street.

## 3.8 Blues Point Temporary Site

### 3.8.1 Site Layout and Proposed Works

An aerial photograph of the proposed Blues Point temporary site and the surrounding receiver areas is provided in **Figure 11**, with the nearest noise sensitive receivers identified in **Table 39**.

**Figure 11 Blues Point Temporary Site and Receiver Areas**

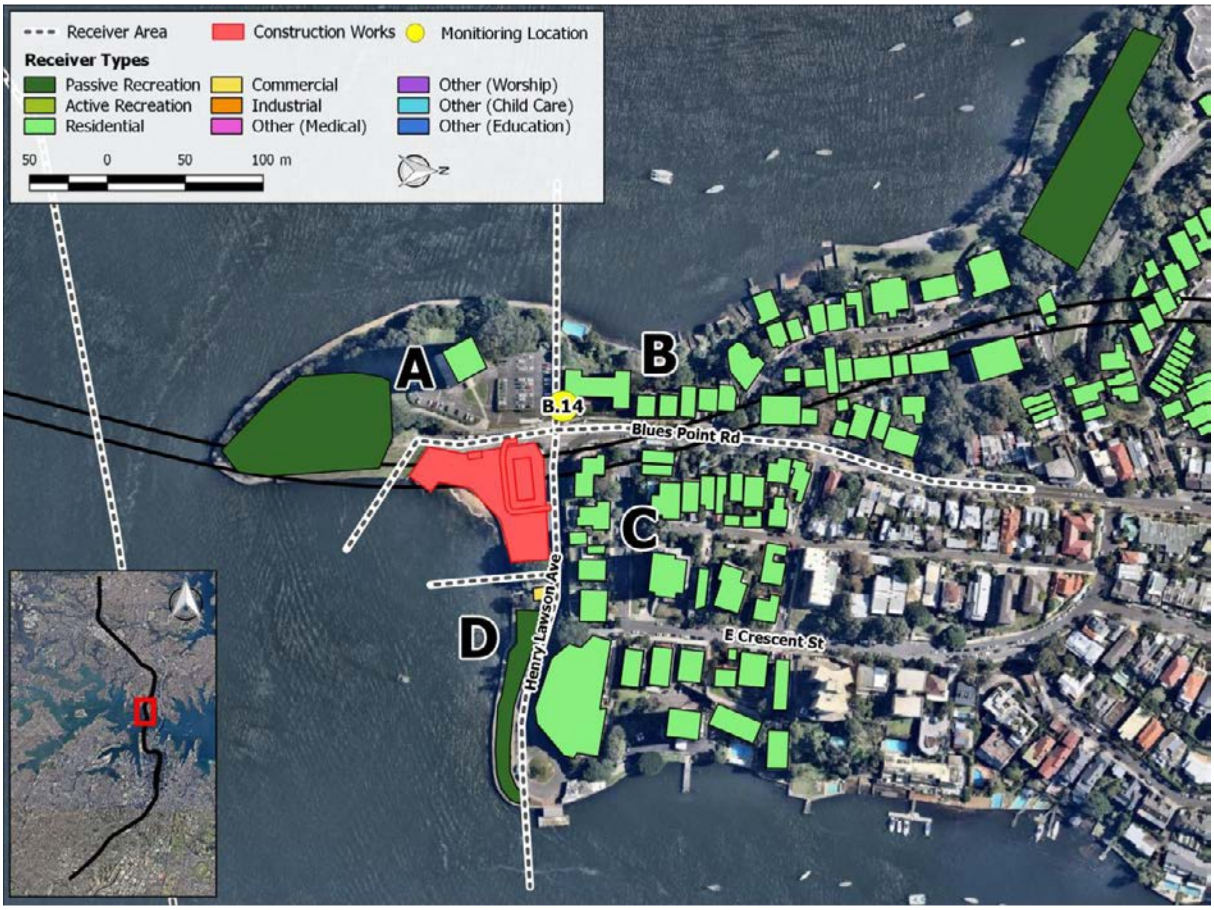



**Table 39 Nearest Noise Sensitive Receivers - Blues Point Temporary Site**

| Receiver Area | Location Relative to Works (m)[1] |
|---|---|
| A - Residential receivers to the west in Blue's Point Tower | 54 |
| A - Passive recreation to the south west | 23 |
| B - Residential receivers to the north, east of Blues Point Road | 36 |
| C - Residential receivers to the north of Henry Lawson Avenue | 22 |
| D - Commercial receiver to the east of Henry Lawson Avenue | 18 |
| D - Passive recreation to the east | 37 |

Note 1: The relative distance to works shown is that from the nearest sensitive receiver to the closest location of construction activity.

### 3.8.2 Site Specific Construction Noise Management Levels

With reference to the ambient noise survey results summarised in **Table 4**, the site specific construction NMLs are presented in **Table 40**.

**Table 40 Blues Point Temporary Site Noise Management Levels**

| Receiver Area | Receiver Type | Relevant Monitoring Location | $L_{Aeq(15minute)}$ Construction NMLs (dBA) | | | |
|---|---|---|---|---|---|---|
| | | | Daytime | Daytime OOH | Evening | Night-time |
| A | Residential | B.14 | 61 | 56 | 54 | 45 |
| A | Recreation | B.14 | 60 | 60 | n/a | n/a |
| B | Residential | B.14 | 61 | 56 | 54 | 45 |
| C | Residential | B.14 | 61 | 56 | 54 | 45 |
| D | Commercial | B.14 | 70 | 70 | n/a | n/a |
| D | Recreation | B.14 | 60 | 60 | n/a | n/a |

### 3.8.3 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 have been developed to be a subset of those discussed in **Section 3.3.1.1**, and are:

- Enabling works including mobilisation and demolition (one month)
- Earthworks (one month)
- Shaft excavation (12 months)
- Site reinstatement (6 months)

At this site, site reinstatement works are proposed to reinstate the park land, jetty, and bus shelter.

Calculations of the typical $L_{Aeq(15minute)}$ noise level exceedances of the NMLs at the nearest noise sensitive receivers are provided in **Appendix D** and are summarised in **Table 41**.

**Table 41 Predicted noise level exceedances at Blues Point Temporary Site**

| Receiver Area | Scenario | | | |
|---|---|---|---|---|
| | Enabling works | Earthworks | Excavation | Site reinstatement |
| | Day | Day | Day | Day |
| A – Residential receivers to the west in Blue's Point Tower | 2 | 2 | 2 | 1 |
| A – Passive recreation to the south west | 2 | 1 | 1 | 1 |
| B – Residential receivers to the north, east of Blues Point Road | 2 | 2 | 2 | 1 |
| C – Residential receivers to the north on Henry Lawson Avenue | 3 | 3 | 3 | 2 |
| D – Commercial receiver to the east Henry Lawson Avenue | 2 | 1 | 1 | 0 |
| D – Passive recreation to the east | 2 | 1 | 1 | 1 |

**Legend**

| Category 0 | Category 1 | Category 2 | Category 3 |
|---|---|---|---|
| NML Compliance | NML exceedance of less than 10 dB | NML exceedance of between 10 dB and 20 dB | NML exceedance of more than 20 dB |

**Discussion**

The preliminary findings of the construction noise impact assessment at Blues Point indicate:

- The predicted noise levels for enabling works indicate high exceedances of more than 20 dB of the NMLs at residential receivers in Area C, and moderate exceedances of more than 10 dB in Area A, B, and D. A moderate exceedance is also predicted in the passive recreation Area A and D, and at the commercial receiver in Area D. These are a direct result of the relative close proximity of receivers to the construction activities and the absence of any appreciable shielding between sites and receivers.
- During earthworks and shaft excavation there are high exceedances of more than 20 dB at the Area C residential receivers, a moderate exceedance at residences in Area A and B and minor exceedances of less than 10 dB at the passive recreation receivers in Area A and D, and the commercial receiver in Area D.
- During site reinstatement moderate exceedances of more than 10 dB are predicted at the residential receivers in Area C. There are minor exceedances in the residential Areas A and B and the passive recreation Areas A and D.

**On Site Night-Time $L_{Amax}$ Truck Noise**

The maximum noise levels associated with on-site truck movements, deliveries by semitrailer and other activities on site can potentially cause awakening reactions (or sleep disturbance) at nearby residential receivers. No night-time activities are proposed with the exception of the four TBM retrieval events.

### 3.8.4 Ground-borne Noise Assessment

Where ground-borne noise exceedances are identified then human comfort vibration exceedances will also be present. **Appendix F** illustrates the potential ground borne noise impacts due to vibration intensive construction activities (rock breaking) in this area. In summary the analysis for daytime (no works are proposed for night-time) indicates:

- At the nearest residences, located on Warung Street, the analysis shows one (1) high exceedance of the NML between 20 dB to 25 dB, and three (3) moderate exceedances of up to 10 dB.

The potential ground-borne noise impacts associated with the excavation of the tunnels are discussed in **Section 3.16.1**.

### 3.8.5 Vibration Assessment

During construction of the proposed shafts vibration levels are anticipated to remain well below the vibration screening levels associated with minor cosmetic building damage. The analysis shows the heritage listed bus stop adjacent to the shaft excavation site where the screening criteria for cosmetic damage may be exceeded. However, this bus stop would be temporarily removed during the construction works. **Appendix G** illustrates the potential cosmetic damage vibration impacts due to construction activities in this area.

### 3.8.6 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access routes to the Blues Point construction site. In this instance the access to the site is via Blues Point Road and Henry Lawson Avenue, which are local roads with low existing daytime flows. Therefore traffic noise levels from site only traffic movements have been predicted for comparison with the RNP baseline criteria and are presented in **Table 42**.

**Table 42 Blues Point Temporary Site - Construction Traffic on Public Roads**

| Site | Access Road | Base Criteria Daytime | Predicted Project Daytime Traffic noise |
|---|---|---|---|
| Blues Point | Blues Point Rd | 55 | 56 |
| | Henry Lawson Avenue | 55 | 52 |

**Table 42** shows traffic noise levels from the project comply with the baseline criteria on Henry Lawson Avenue and exceed by 1 dB on Blues Point Road. No night-time activities are proposed at this site, with the exception of the four TBM retrieval events.

## 3.9 Sydney Harbour ground improvements work

### 3.9.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Sydney Harbour ground improvement works and the surrounding receiver areas is provided in **Figure 12**, with the nearest noise sensitive receivers identified in **Table 43**.

**Figure 12 Sydney Harbour ground improvement works and Receiver Areas**

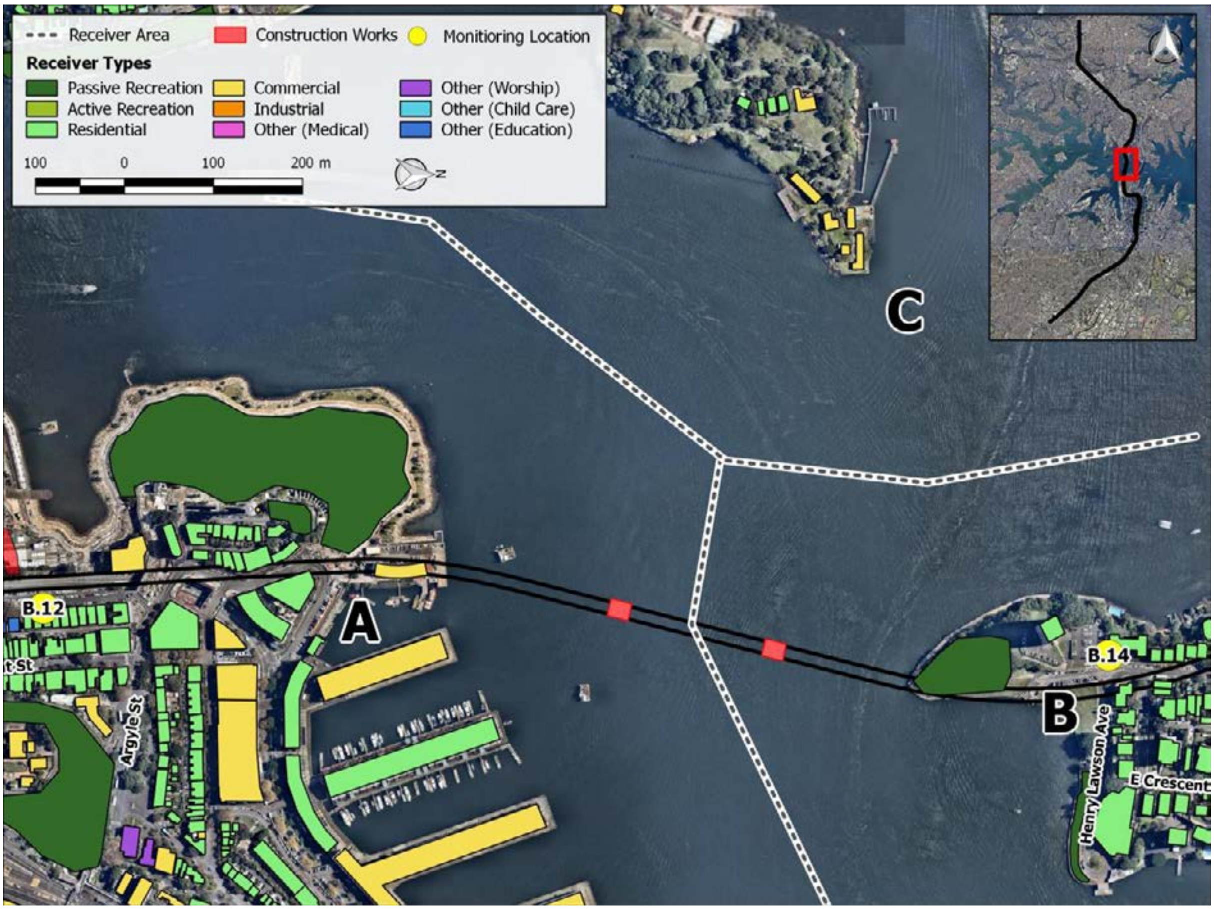



**Table 43 Nearest Noise Sensitive Receivers - Sydney Harbour ground improvement works**

| Receiver Area | Location Relative to Works (m)[1] |
|---|---|
| A - Commercial receivers to the south in Port Authority of NSW building | 240 |
| A - Residential receivers to the south, Hickson Road | 220 |
| A - Passive recreation area receivers to the south in Barangaroo Reserve | 310 |
| B - Passive recreation area receivers south of Blue's point tower | 190 |
| B - Residential receivers to the north in Blue's Point Tower | 350 |
| C - Residential receivers on Goat Island | 680 |
| C - Commercial receivers on Goat Island | 510 |

Note 1: The relative distance to works shown is that from the nearest sensitive receiver to the closest location of construction activity.

### 3.9.2 Site Specific Construction Noise Management Levels

With reference to the ambient noise survey results summarised in **Table 4**, the site specific construction NMLs are presented in **Table 44**.

**Table 44 Sydney Harbour Ground Improvement Works Noise Management Levels**

| Receiver Area | Receiver Type | Relevant Monitoring Location | $L_{Aeq(15minute)}$ Construction NMLs (dBA) | | | |
|---|---|---|---|---|---|---|
| | | | Daytime | Daytime OOH | Evening | Night-time |
| A | Residential | B.12 | 60 | 55 | 50 | 45 |
| A | Commercial | B.12 | 70 | 70 | n/a | n/a |
| A | Recreation | B.12 | 60 | 60 | n/a | n/a |
| B | Recreation | B.14 | 60 | 60 | n/a | n/a |
| B | Residential | B.14 | 61 | 56 | 54 | 45 |
| C | Residential | B.29 | 59 | 54 | 54 | 46 |
| C | Commercial | B.29 | 70 | 70 | n/a | n/a |

### 3.9.3 Airborne 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 have been developed to be a subset of those discussed in **Section 3.3.1.1**, and are:

- Grout barge

Calculations of the typical $L_{Aeq(15minute)}$ noise level exceedances of the NMLs at the nearest noise sensitive receivers are provided in **Appendix D** and are summarised in **Table 45**. The 'sleep' column of the table provides the predicted exceedance of the sleep disturbance screening noise level.

**Table 45 Predicted noise level exceedances at Harbor Crossing Ground Improvement works**

| Receiver Area | Scenario: Grout Barge | | | | |
|---|---|---|---|---|---|
| | Day | DOOH | Even | Night | Sleep |
| A - Commercial receivers to the south in Port Authority of NSW building | 0 | 0 | 0 | 0 | 0 |
| A - Residential receivers to the south, Hickson Road | 0 | 0 | 0 | 1 | 0 |
| A - Passive recreation area receivers to the south in Barangaroo Reserve | 0 | 0 | 0 | 0 | 0 |
| B - Passive recreation area receivers south of Blue's Point tower | 0 | 0 | 0 | 0 | 0 |
| B - Residential receivers to the north in Blue's Point Tower | 0 | 0 | 0 | 0 | 0 |
| C - Residential receivers on Goat Island | 0 | 0 | 0 | 0 | 0 |
| C – Commercial receivers on Goat Island | 0 | 0 | 0 | 0 | 0 |

**Legend**

| Category 0 | Category 1 | Category 2 | Category 3 |
|---|---|---|---|
| NML Compliance | NML exceedance of less than 10 dB | NML exceedance of between 10 dB and 20 dB | NML exceedance of more than 20 dB |

**Discussion**

The preliminary findings of the construction noise impact assessment of the Sydney Harbour Crossing construction site ground improvement works indicates:

- Compliance for the daytime at evening periods at all receiver areas. During night-time there is a minor exceedance of up to 10 dB at residential receivers in Area A.

### 3.9.4 Ground-borne Noise and Human Comfort Vibration Assessment

No ground-borne noise impacts are predicted due to construction activities at this site.

### 3.9.5 Vibration Assessment

No vibration impacts are predicted due to construction activities at this site.

## 3.10 Barangaroo Station Construction Site

### 3.10.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Barangaroo Station construction site and the surrounding receiver areas is provided in **Figure 13**, with the nearest noise sensitive receivers identified in **Table 46**.

**Figure 13 Barangaroo Station Construction Site and Receiver Areas**

**Table 46 Nearest Noise Sensitive Receivers - Barangaroo Station Construction Site**

| Receiver Area | Location Relative to Works (m)[1] |
|---|---|
| A - Commercial receivers to the west (to be constructed) | 2 |
| A - Residential receivers to the west and south (to be constructed) | 18 |
| B - Residential receivers to the north on Bettington Street | 75 |
| B - Passive recreation area receivers to the north in Barangaroo Reserve | 101 |
| C - Residential receivers to the east on High Street | 10 |
| D - Residential receivers to the south on High Street | 12 |
| D - Commercial receivers to the south on Hickson Road | 61 |
| E - Residential receivers to the west in Balmain East | 500 |

Note 1: The relative distance to works shown is that from the nearest sensitive receiver to the closest location of construction activity.

### 3.10.2 Site Specific Construction Noise Management Levels

With reference to the ambient noise survey results summarised in **Table 4**, the site specific construction NMLs are presented in **Table 47**.

**Table 47 Barangaroo Station Construction Site Noise Management Levels**

| Receiver Area | Receiver Type | Relevant Monitoring Location | $L_{Aeq(15minute)}$ Construction NMLs (dBA) | | | |
|---|---|---|---|---|---|---|
| | | | Daytime | Daytime OOH | Evening | Night-time |
| A | Commercial | B.12 | 70 | 70 | n/a | n/a |
| A | Residential | B.12 | 60 | 55 | 50 | 45 |
| B | Residential | B.12 | 60 | 55 | 50 | 45 |
| B | Recreation | B.12 | 60 | 60 | n/a | n/a |
| C | Residential | B.12 | 60 | 55 | 50 | 45 |
| C | Residential | B.12 | 60 | 55 | 50 | 45 |
| D | Commercial | B.12 | 70 | 70 | n/a | n/a |
| E | Residential | B.29 | 59 | 54 | 54 | 46 |

### 3.10.3 Airborne 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 have been developed to be a subset of those discussed in **Section 3.3.1.1**, and are:

- Enabling works including mobilisation and demolition (12 months)
- Earthworks which consists of initial excavation (2 months)
- Acoustic shed construction (one month)
- Excavation and tunnelling with shed (12 months for station excavation, and 18 months for tunnelling)
- Station construction and fitout (18 months)

Calculations of the typical $L_{Aeq(15minute)}$ noise levels at the nearest noise sensitive receivers (at ground floor level) are provided in **Appendix D** and the predicted noise level exceedances are summarised in **Table 48**. The 'sleep' column of the table provides the predicted exceedance of the sleep disturbance screening noise level.

For night-time construction, preliminary modelling indicated that an acoustic shed would be required and was included for the excavation and tunnelling scenarios.

**Table 48 Predicted noise level exceedances at Barangaroo Station Construction Site**

| Receiver Area | Scenario | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Enabling Works | Earthworks | Acoustic Shed Construction | Excavation with Shed | | | | | Construction |
| | Day | Day | Day | Day | DOOH | Eve | Night | Sleep | Day |
| A – Commercial receivers to the east (to be constructed) | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| A – Residential receivers to the west and south (to be constructed) | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 |
| B – Residential receivers to the north on Bettington Street | 2 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 |
| B – Passive recreation area receivers to the north in Barangaroo Reserve | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| C – Residential receivers to the east on High Street | 3 | 2 | 1 | 2 | 1 | 2 | 2 | 1 | 2 |
| D – Residential receivers to the south on High Street | 2 | 2 | 1 | 1 | 1 | 2 | 2 | 1 | 2 |
| D – Commercial receivers to the south on Hickson Road | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E – Residential receivers to the west in Balmain East | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Legend**

| Category 0 | Category 1 | Category 2 | Category 3 |
|---|---|---|---|
| NML Compliance | NML exceedance of less than 10 dB | NML exceedance of between 10 dB and 20 dB | NML exceedance of more than 20 dB |

**Discussion**

The preliminary findings of the construction noise impact assessment at Barangaroo Station indicate:

- The predicted noise levels for enabling works indicate high exceedances of more than 20 dB of the NMLs at residential receivers in Area C and commercial receivers in Area A. Moderate exceedances of more than 10 dB are predicted at residential receivers in Area B and D. Minor exceedances are predicted at residential receivers in Area A, commercial receivers in Area D and passive recreation in Area B. These are a direct result of the relative close proximity of receivers to the construction activities and the absence of any appreciable shielding between sites and receivers.
- During earthworks there is a moderate exceedance at residential receivers in Area C and D. Minor exceedances are predicted at residential receivers in Area A, B, commercial receivers in Areas A and D and passive recreation in Area B.
- During construction of the acoustic shed there are minor exceedances at the residential receivers in Areas C and D.

- During excavation with the acoustic shed there is a moderate exceedance of more than 10 dB at residences in Area C, and a minor exceedance of up to 10 dB at residential receivers in Areas B and D. For operations outside standard construction hours there are moderate exceedances at residential receivers in Area C and D and minor exceedances in Area A and B. An acoustic shed with increased noise insulation is required for night-time compliance.
- During construction there are moderate exceedances at residential receivers in Area C and D and minor exceedances at residences in Area A and B, commercial receivers in Area A and passive recreation in Area B.

**On Site Night-Time $L_{Amax}$ Noise**

The maximum noise levels associated with on-site truck movements, deliveries by semitrailer and other activities on site can potentially cause awakening reactions (or sleep disturbance) at nearby residential receivers. The $L_{Amax}$ noise levels associated with these events exceed the sleep disturbance screening level by up to 10 dB during excavation with an acoustic shed at residential receivers in Area C and D. During the detailed design night-time 'on site' traffic routes and activities should be reviewed and/or additional mitigation such as increased site perimeter hoarding height.

### 3.10.4 Ground-borne Noise and Human Comfort Vibration Assessment

Where ground-borne noise exceedances are identified then human comfort vibration exceedances would also be present. **Appendix F** illustrates the potential ground borne noise impacts due to vibration intensive construction activities (rock breaking) in this area. In summary the analysis indicates:

- During the day one (1) commercial building, located on Hickson Road to the north of the site is predicted to have high exceedances of the NML of 20 dB to 25 dB. The remaining commercial and residential buildings show a moderate exceedance of the NML of 10 dB to 20 dB.
- During night-time fourteen (14) residential buildings, located on High Street and Kent Street to the east of the excavation site, have regenerated noise levels potentially higher than 45 dBA on several floors. Where residential receivers have night-time internal noise levels greater than 45 dBA they should be considered eligible for Alternative Accommodation (the highest level mitigation measure) as per the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement).

#### 3.10.4.1 Blasting

The use of blasting in the excavation of the station shafts effectively reduces the duration of noise and vibration impacts due to the use of rock breakers which must be used to some extent before blasting can occur. **Table 49** illustrates the effective reduction in duration of the ground-borne noise (and human comfort vibration) exceedances when blasting is used as an alternative excavation methodology. This table also illustrates the effective reduction in duration of these exceedances when blasting is combined with medium rock breakers instead of large rock breakers.

The values in this table represent all exceedances of the NMLs (even those as low as 1 dB to 5 dB). Therefore, the actual requirement for high level mitigation measures is not represented. The information is presented to indicate the benefits in terms of duration of impacts between different excavation methodologies.

**Table 49 No. of Periods Above the NMLs Due to Alternative Construction Methodologies**

| Site | Number of Periods Above NMLs | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Residential | | | | | | | | | Commercial | | |
| | Day | | | Evening | | | Night | | | Day | | |
| | B- Lrg RB | B+ Lrg RB | B+ Med RB | B- Lrg RB | B+ Lrg RB | B+ Med RB | B- Lrg RB | B+ Lrg RB | B+ Med RB | B- Lrg RB | B+ Lrg RB | B+ Med RB |
| Barangaroo | 358 | 171 | 63 | >365 | 277 | 174 | >365 | >365 | 295 | 9 | 6 | 1 |

Note: B- = No Blasting, B+ = With Blasting, Lrg RB = Large Rock Breakers, Med RB = Medium Rock Breakers

The duration of the impacts can be summarised as follows:

**Residential Day**: The use of large rock breakers with no blasting generates 358 daytime periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 171 daytime periods. The inclusion of blasting and the use of medium rock breakers reduces the duration of impacts even further to 63 daytime periods. Blasting coupled with medium rock breaker therefore significantly reduces the impacts during the day.

**Residential Evening**: The use of large rock breakers with no blasting generates greater than 365 evening periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 277 evening periods. The inclusion of blasting and the use of medium rock breakers reduces the duration of impacts even further to 174 evening periods. Blasting therefore significantly reduces the impacts during the evening.

**Residential Night**: The use of large rock breakers with no blasting generates greater than 365 night-time periods with exceedances of the NMLs. The inclusion of blasting still results in the duration of impacts being greater than 365 night-time periods. The inclusion of blasting and the use of medium rock breakers reduces the duration of impacts to 295 night-time periods.

**Commercial Day**: The use of large rock breakers with no blasting generates 9 daytime periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 6 daytime periods. The inclusion of blasting and the use of medium rock breakers reduces the duration of impacts even further to 1 daytime period. Blasting coupled with medium rock breaker therefore reduces the impacts during the day.

With careful planning and positioning of the rock breakers it may be possible to avoid consecutive periods of NML exceedances ie respite periods for receivers could be planned in the construction program through careful rock breaker locations. For any residual exceedances of the NMLs, the processes and mitigation measures identified in the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement) would be implemented.

The potential ground-borne noise impacts associated with the excavation of the tunnels are discussed in **Section 3.16.1**.

### 3.10.5 Vibration Assessment

During construction of the proposed shafts vibration levels are anticipated to remain well below the vibration screening levels associated with minor cosmetic building damage at all buildings except for one (1) commercial building adjacent to the north of the site on Hickson Road. A more detailed assessment of the structure and attended vibration monitoring would be carried out to ensure vibration levels remain below appropriate limits for this structure. **Appendix G** illustrates the potential cosmetic damage vibration impacts due to construction activities in this area.

### 3.10.6 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access route to the Barangaroo Station site. In this instance the access to the site is via Hickson Road which is a sub-arterial road with significant daytime flows. The RNP base criteria, predicted $L_{Aeq(15hr)}$ daytime and $L_{Aeq(9hr)}$ nighttime noise levels with the development, and the $L_{Aeq}$ increase and sleep disturbance noise levels have been assessed in **Table 50**.

**Table 50 Barangaroo Station Construction Site - Construction Traffic on Public Roads**

| Access Road | Base Criteria Day/Night ($L_{Aeq(15hr/9hr)}$) | Predicted Road Traffic Noise Day/Night | Predicted Road Traffic Noise Increase (dB) day/night | RBL + 15 dB Screening Criterion (dBA) | External LAmax NML Level (dBA) | Predicted $L_{Amax}$ Noise Level (dBA) |
|---|---|---|---|---|---|---|
| Hickson Rd | 60/55 | 70/64 | 0.6/1.2 | 55 | 65 | 77 |

**Table 50** indicates that whilst at Hickson Road the base criteria are exceeded, the predicted noise level increase ($L_{Aeq}$) associated with construction traffic complies with the 2 dB allowance, therefore sensitive receivers are not likely to notice an increase in the average road traffic noise levels during construction. There are expected to be up to 6 heavy vehicle and 2 light vehicles movements or events per hour during the night and whilst there is an exceedance of the sleep disturbance screening criterion (of up to 22 dB) and external sleep disturbance NML of 65 dBA (by up to 12 dB), the $L_{Amax}$ levels would be similar to other heavy vehicles using Hickson Road.

## 3.11 Martin Place Station Construction Site

### 3.11.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Martin Place Station construction site and the surrounding receiver areas is provided in **Figure 14**, with the nearest noise sensitive receivers identified in **Table 51**.

**Figure 14 Martin Place Station Construction Site and Receiver Areas**

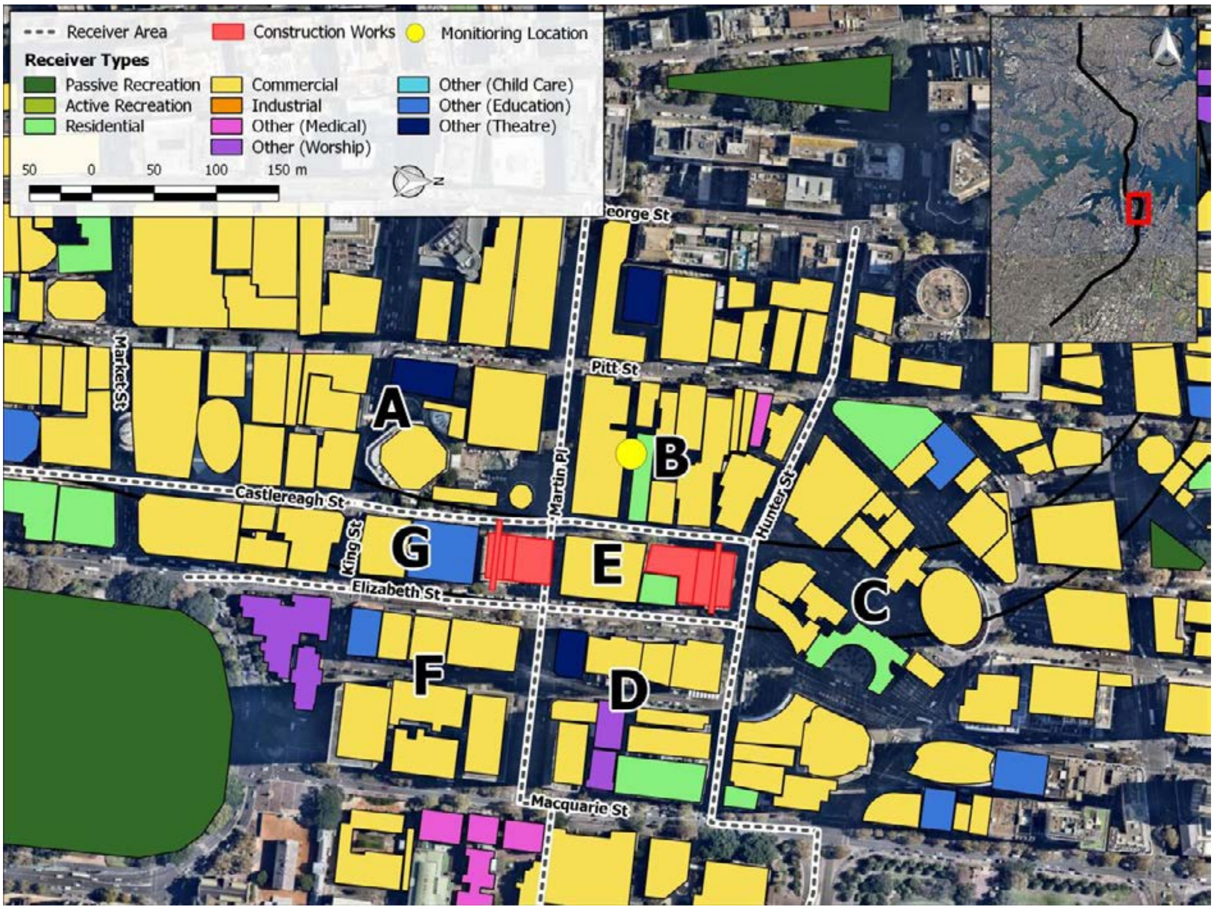



**Table 51 Nearest Noise Sensitive Receivers - Martin Place Station Construction Site**

| Receiver Area | Location Relative to Works (m)[1] |
|---|---|
| A - Commercial receivers to the west, west of Castlereagh Street and south of Martin Place | 27 |
| A - Theatre Royal to the west, west of Castlereagh Street and south of Martin Place | 79 |
| B - Residential receivers to the west, west of Castlereagh Street and north of Martin Place. | 21 |
| B - Commercial receivers to the west, west of Castlereagh Street and north of Martin Place. | 21 |
| C - Residential receivers to the north, north of Hunter Street | |
| C - Commercial receivers to the north, north of Hunter Street. | 25 |
| D - Residential receivers to the east, between Hunter Street and Martin Place | 87 |
| D - Commercial receivers to the east, between Hunter Street and Martin Place | 35 |
| E - Residential receivers between the two construction sites | 3 |
| E - Commercial receivers between the two construction sites | 3 |
| F - Commercial receivers to the east, between King Street and Martin Place. | 42 |

| Receiver Area | Location Relative to Works (m)[1] |
|---|---|
| F - Educational to the east, between King Street and Martin Place | 105 |
| G - Educational receivers to the south, between Castlereagh Street and Elizabeth Street | 10 |
| G - Commercial receivers to the south, between Castlereagh Street and Elizabeth Street | 77 |

Note 1: The relative distance to works shown is that from the nearest sensitive receiver to the closest location of construction activity.

### 3.11.2 Site Specific Construction Noise Management Levels

With reference to the ambient noise survey results summarised in **Table 4**, the site specific construction NMLs are presented in **Table 52**.

**Table 52 Martin Place Station Construction Site Noise Management Levels**

| Receiver Area | Receiver Type | Relevant Monitoring Location | $L_{Aeq(15minute)}$ Construction NMLs (dBA) | | | |
|---|---|---|---|---|---|---|
| | | | Daytime | Daytime OOH | Evening | Night-time |
| A | Commercial | B.11 | 70 | 70 | n/a | n/a |
| A | Special | B.11 | 50 | 50 | 50 | n/a |
| B | Residential | B.11 | 71 | 66 | 61 | 57 |
| B | Commercial | B.11 | 70 | 70 | n/a | n/a |
| C | Residential | B.11 | 71 | 66 | 61 | 57 |
| C | Commercial | B.11 | 70 | 70 | n/a | n/a |
| D | Residential | B.11 | 71 | 66 | 61 | 57 |
| D | Commercial | B.11 | 70 | 70 | n/a | n/a |
| E | Residential | B.11 | 71 | 66 | 61 | 57 |
| E | Commercial | B.11 | 70 | 70 | n/a | n/a |
| F | Commercial | B.11 | 70 | 70 | n/a | n/a |
| F | Educational | B.11 | 55 | n/a | n/a | n/a |
| G | Educational | B.11 | 55 | n/a | n/a | n/a |
| G | Commercial | B.11 | 70 | 70 | n/a | n/a |

### 3.11.3 Airborne 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 have been developed to be a subset of those discussed in **Section 3.3.1.1**, and are:

- Enabling works including mobilisation and demolition (12 months)
- Earthworks (two months)
- Acoustic shed construction (one month)
- Excavation (three years)
- Station construction (18 months)

Calculations of the typical $L_{Aeq(15minute)}$ noise level exceedances of the NMLs at the nearest noise sensitive receivers are provided in **Appendix D** and are summarised in **Table 53**. The 'sleep' column of the table provides the predicted exceedance of the sleep disturbance screening noise level.

For night-time construction, preliminary modelling indicated that an acoustic shed would be required and was included for the station excavation scenario.

**Table 53 Predicted noise level exceedances at Martin Place Station Construction Site**

| Receiver Area | Scenario | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Enabling Works | Earthworks | Acoustic Shed Construction | Excavation with Shed | | | | | Construction |
| | Day | Day | Day | Day | OOHD | Even | Night | Sleep | Day |
| A - Commercial receivers to the west, west of Castlereagh Street & south of Martin Place | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| B - Residential receivers to the west, west of Castlereagh Street & north of Martin Place. | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| B - Commercial receivers to the west, west of Castlereagh Street & north of Martin Place. | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| C - Residential receivers to the north, north of Hunter Street | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C - Commercial receivers to the north, north of Hunter Street. | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| D - Residential receivers to the east, between Hunter Street and Martin Place | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D - Commercial receivers to the east, between Hunter Street and Martin Place | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| E - Residential receivers between the two construction sites | 3 | 2 | 1 | 0 | 0 | 1 | 1 | 0 | 2 |
| E - Commercial receivers between the two construction sites | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| F - Commercial receivers to the east, between King Street and Martin Place. | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| F - Educational to the east, between King Street and Martin Place | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| G - Educational receivers to the south, between Castlereagh Street and Elizabeth Street | 3 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 3 |
| G - Commercial receivers to the south, between Castlereagh Street and Elizabeth Street | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Legend | | | |
|---|---|---|---|
| Category 0 | Category 1 | Category 2 | Category 3 |
| NML Compliance | NML exceedance of less than 10 dB | NML exceedance of between 10 dB and 20 dB | NML exceedance of more than 20 dB |

**Discussion**

The preliminary findings of the construction noise impact assessment at Martin Place Station indicate:

- The predicted noise levels for enabling works (including mobilisation/demolition) indicate high exceedances of more than 20 dB of the NMLs at educational receivers in Area G and the residential receivers in Area E. Moderate exceedances of more than 10 dB are predicted at residential receivers in Areas B and educational receivers in Area F. At residential receivers in area C minor exceedances of less than 10 dB are predicted.

At the nearest commercial receivers in Area E high exceedances of more than 20 dB of the NMLs are predicted, and at commercial receivers in Areas A, B, C and D moderate exceedances of more than 10 dB. Minor exceedances are predicted at commercial receivers in Area F.

- The predicted noise levels for earthworks indicate high exceedances of more than 20 dB of the NMLs at the educational receivers in Area G. At the educational receivers in Area F and residences in Area E moderate exceedances are predicted. At residences in Area B and C minor exceedances of the NMLs are predicted.

  At the nearest commercial receivers in Areas A, B, C, D and E moderate exceedances of the NMLs are predicted, with minor exceedances in Area F.

- During the acoustic shed construction a moderate exceedance is predicted at educational receivers in Area G and minor exceedances at educational receivers in Area F, the residential receivers in Area E, and commercial receivers in Area B.
- During excavation with an acoustic shed a moderate exceedance of more than 10 dB is predicted the educational receivers in Area G, and compliance at all other receivers during daytime. For night-time there are minor exceedances at residences in Area B and E.
- During station construction major exceedances are predicted at the educational receivers in Area G and moderate exceedances at residences in Area E and commercial receivers at Area E. Minor exceedances are predicted at educational receivers in Area F, at residential receivers in Area B and at commercial receivers in Area A, B, C, D and F.
- At the Channel Seven studio on Martin Place noise levels are predicted to be up to 79 dBA, and at the Theatre Royal up to 69 dBA. At both locations these levels would be similar to external noise levels from heavy vehicles on Castlereagh Street, and Pitt Street respectively, and general city noise. The building external to internal noise reduction would therefore adequately attenuate noise from the works to the news room and theatre respectively.

**On Site Night-Time $L_{Amax}$ Truck Noise**

The maximum noise levels associated with on-site truck movements, deliveries by semitrailer and other activities on site can potentially cause awakening reactions (or sleep disturbance) at nearby residential receivers. The $L_{Amax}$ noise levels associated with these events comply with the sleep disturbance screening level.

### 3.11.4 Ground-borne Noise and Human Comfort Vibration Assessment

Where ground-borne noise exceedances are identified then human comfort vibration exceedances would also be present. **Appendix F** illustrates the potential ground borne noise impacts due to vibration intensive construction activities (rockbreaking) in this area. In summary the analysis indicates:

- During the day two (2) commercial buildings (one to the south of the northern site and one to the south of the southern site) are predicted to have ground-borne noise levels potentially higher than 75 dBA for several floors, this correlates to very high NML exceedances of greater than 25 dB.

  A further five (5) commercial buildings, located to the west of both sites, show high exceedances of the NML of 20 dB to 25 dB. The nearest residential receiver, located to the west on Castlereagh Street between Hunter Street and Martin Place, shows a moderate exceedance of the NML of 10 dB to 20 dB. Where receivers experience day-time internal noise levels greater than 75 dBA more detailed site specific ground borne noise investigation is required. If this investigation finds ground borne noise levels are likely to exceed 75 dBA for extended periods then alternative accommodation would be considered as a mitigation measure.

- During night-time one (1) residential building to the west on Castlereagh Street between Hunter Street and Martin Place has regenerated noise levels potentially higher than 45 dBA on one or more floors. Where residential receivers have night-time internal noise levels greater than 45 dBA they should be considered eligible for Alternative Accommodation (the highest level mitigation measure) as per the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement).

The Theatre Royal (theatre) is located approximately 100 m from the proposed station excavation works. The ground-borne noise levels would be up to $L_{Aeq(15minute)}$ 30 dBA within the theatre during rock breaker works, assuming that a large rock breaker would be utilised, which complies with the 30 dBA criteria.

#### 3.11.4.1 Blasting

The use of blasting in the excavation of the station shafts effectively reduces the duration of noise and vibration impacts due to the use of rock breakers which must be used to some extent before blasting can occur. **Table 54** illustrates the effective reduction in duration of the ground-borne noise (and human comfort vibration) exceedances when blasting is used as an alternative excavation methodology. This table also illustrates the effective reduction in duration of these exceedances when blasting is combined with medium rock breakers instead of large rock breakers.

The values in this table represent all exceedances of the NMLs (even those as low as 1 dB to 5 dB). Therefore, the actual requirement for high level mitigation measures is not represented. The information is presented to indicate the benefits in terms of duration of impacts between different excavation methodologies.

**Table 54 No. of Periods Above the NMLs Due to Alternative Construction Methodologies**

| Site | Number of Periods Above NMLs | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Residential | | | | | | | | | Commercial | | |
| | Day | | | Evening | | | Night | | | Day | | |
| | B- Lrg RB | B+ Lrg RB | B+ Med RB | B- Lrg RB | B+ Lrg RB | B+ Med RB | B- Lrg RB | B+ Lrg RB | B+ Med RB | B- Lrg RB | B+ Lrg RB | B+ Med RB |
| Martin Place - North | 2 | 0 | 0 | 5 | 1 | 0 | 9 | 1 | 1 | 225 | 42 | 22 |
| Martin Place - South | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 32 | 18 | 9 |

Note: B- = No Blasting, B+ = With Blasting, Lrg RB = Large Rock Breakers, Med RB = Medium Rock Breakers

The duration of the impacts can be summarised as follows:

**Residential Day**: The use of large rock breakers with no blasting generates 2 daytime periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to zero (0) daytime periods.

**Residential Evening**: the use of large rock breakers with no blasting generates 5 evening periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 1 evening period.

**Residential Night**: The use of large rock breakers with no blasting generates 9 night-time periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 1 night-time period.

**Commercial Day**: The use of large rock breakers with no blasting generates 257 daytime periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 60 daytime periods. The inclusion of blasting and the use of medium rock breakers reduces the duration of impacts even further to 31 daytime periods. Blasting coupled with medium rock breaker therefore significantly reduces the impacts during the day.

With careful planning and positioning of the rock breakers it may be possible to avoid consecutive periods of NML exceedances ie respite periods for receivers could be planned in the construction program through careful rock breaker locations. For any residual exceedances of the NMLs, the processes and mitigation measures identified in the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement) would be implemented.

The potential ground-borne noise impacts associated with the excavation of the tunnels are discussed in **Section 3.16.1**.

### 3.11.5 Vibration Assessment

During construction of the proposed shafts vibration levels are anticipated to remain well below the vibration screening levels associated with minor cosmetic building damage for all the surrounding buildings except for one (1) commercial building located immediately to the south of the southern shaft. A more detailed assessment of the structure and attended vibration monitoring would be carried out to ensure vibration levels remain below appropriate limits for this structure.**Appendix G** illustrates the potential cosmetic damage vibration impacts due to construction activities in this area.

No exceedance of the 7.5 mm/s screening criteria is predicted at the Commonwealth Bank building which is listed as a heritage building. Despite this finding, as a further precaution a dilapidation survey, vibration monitoring and more detailed site vibration investigation are recommended for the Commonwealth Bank building.

### 3.11.6 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access route to the Martin Place Station site. In this instance the access to the site is via Hunter Street, Castlereagh Street and Elizabeth Street which are sub-arterial roads with significant daytime flows. The RNP base criteria, predicted LAeq(15hr) daytime and LAeq(9hr) nighttime noise levels with the development, and the $L_{Aeq}$ increase and sleep disturbance noise levels have been assessed in **Table 55**.

**Table 55 Martin Place Station Construction Site - Construction Traffic on Public Roads**

| Access Road | Base Criteria Day/Night (LAeq(15hr/9hr) | Predicted Road Traffic Noise Day/Night | Predicted Road Traffic Noise Increase (dB) day/night | RBL + 15 dB Screening Criterion (dBA) | External LAmax NML Level (dBA) | Predicted LAmax Noise Level (dBA) |
|---|---|---|---|---|---|---|
| Hunter St | 60/55 | 70/66 | 0.3/0.4 | 67 | 65 | 78 |
| Castlereagh St | 60/55 | 69/64 | 0.4/0.6 | 67 | 65 | 78 |
| Elizabeth St | 60/55 | 73/69 | 0.2/0.2 | 67 | 65 | 78 |

**Table 55** indicates that whilst at Hunter Street, Castlereagh Street and at Elizabeth Street the base criteria are exceeded, the predicted noise level increase (LAeq) associated with construction traffic complies with the 2 dB allowance, therefore sensitive receivers are not likely to notice an increase in the average road traffic noise levels during construction. There are expected to be up to 6 heavy vehicle and 2 light vehicles movements or events per hour during the night and whilst there is an exceedance of the sleep disturbance screening criterion (of up to 11 dB) and external sleep disturbance NML of 65 dBA (by up to 13 dB), the LAmax levels would be similar to other heavy vehicles using Hunter Street, Castlereagh Street and Elizabeth Street.

## 3.12 Pitt Street Station Construction Site

### 3.12.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Pitt Street Station construction site and the surrounding receiver areas is provided in **Figure 15**, with the nearest noise sensitive receivers identified in **Table 56**.

**Figure 15 Pitt Street Station Construction Site and Receiver Areas**

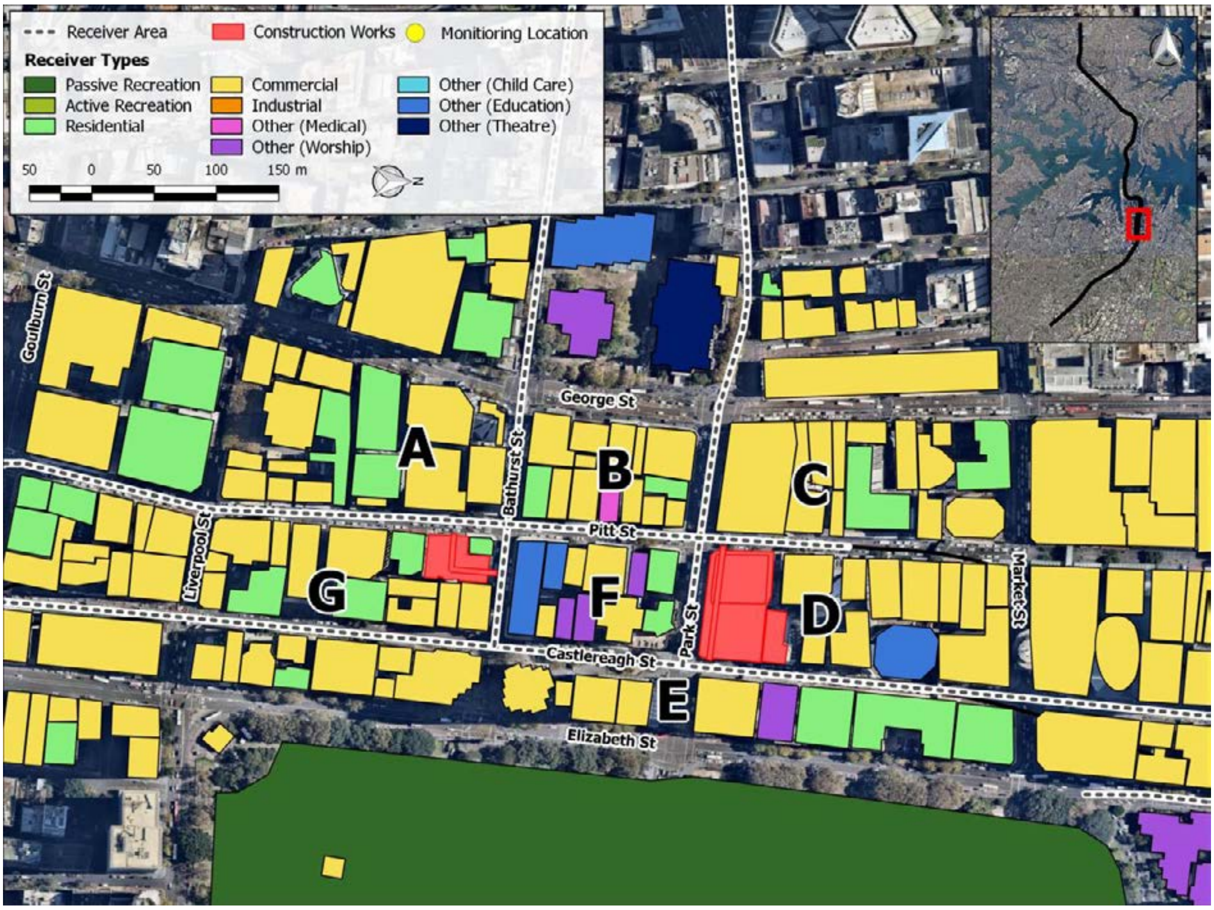



**Table 56 Nearest Noise Sensitive Receivers - Pitt Street Station Construction Site**

| Receiver Area | Location Relative to Works (m)[1] |
|---|---|
| A - Residential receivers to the west, west of Pitt Street and south of Bathurst Street | 45 |
| A - Commercial receivers to the west, west of Pitt Street and south of Bathurst Street | 25 |
| B - Residential receivers to the west, west of Pitt Street and north of Bathurst Street. | 45 |
| B - Commercial receivers to the west, west of Pitt Street and north of Bathurst Street. | 55 |
| C - Residential receivers to the west, west of Pitt Street and north of Park Street. | 76 |
| C - Commercial receivers to the west, west of Pitt Street and north of Park Street. | 19 |

| Receiver Area | Location Relative to Works (m)[1] |
|---|---|
| D - Commercial receivers to the north, between Pitt Street and Castlereagh Street | 2 |
| E - Residential receivers to the east | 50 |
| E - Commercial receivers to the east | 20 |
| F – Residential receivers between Park Street and Bathurst Street. | 24 |
| F - Commercial receivers between Park Street and Bathurst Street. | 58 |
| F - Educational receivers between Park Street and Bathurst Street. | 26 |
| G - Residential receivers to the north and south, between Pitt Street and Castlereagh Street | 2 |
| G - Commercial receivers to the south, between Pitt Street and Castlereagh Street | 2 |

Note 1: The relative distance to works shown is that from the nearest sensitive receiver to the closest location of construction activity.

### 3.12.2 Site Specific Construction Noise Management Levels

With reference to the ambient noise survey results summarised in **Table 4**, the site specific construction NMLs are presented in **Table 57**.

**Table 57 Pitt Street Station Construction Site Noise Management Levels**

| Receiver Area | Receiver Type | Relevant Monitoring Location | $L_{Aeq(15minute)}$ Construction NMLs (dBA) | | | |
|---|---|---|---|---|---|---|
| | | | Daytime | Daytime OOH | Evening | Night-time |
| A | Residential | B.27 | 76 | 71 | 69 | 66 |
| A | Commercial | B.27 | 70 | 70 | n/a | n/a |
| B | Residential | B.27 | 76 | 71 | 69 | 66 |
| B | Commercial | B.27 | 70 | 70 | n/a | n/a |
| C | Residential | B.27 | 76 | 71 | 69 | 66 |
| C | Commercial | B.27 | 70 | 70 | n/a | n/a |
| D | Commercial | B.27 | 70 | 70 | n/a | n/a |
| E | Residential | B.27 | 76 | 71 | 69 | 66 |
| E | Commercial | B.27 | 70 | 70 | n/a | n/a |
| F | Residential | B.27 | 76 | 71 | 69 | 66 |
| F | Commercial | B.27 | 70 | 70 | n/a | n/a |
| F | Educational | B.27 | 55 | n/a | n/a | n/a |
| G | Residential | B.27 | 76 | 71 | 69 | 66 |
| G | Commercial | B.27 | 70 | 70 | n/a | n/a |

### 3.12.3 Airborne 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 have been developed to be a subset of those discussed in **Section 3.3.1.1**, and are:

- Enabling works including mobilisation and demolition (12 months)
- Earthworks (two months)
- Acoustic shed construction (one month)
- Excavation (three years)
- Station construction (18 months)

Calculations of the typical $L_{Aeq(15minute)}$ noise level exceedances of the NMLs at the nearest noise sensitive receivers are provided in **Appendix D** and are summarised in **Table 58**. The 'sleep' column of the table provides the predicted exceedance of the sleep disturbance screening noise level.

For night-time construction, preliminary modelling indicated that an acoustic shed would be required and was included for the station excavation scenario.

**Table 58 Predicted noise level exceedances at Pitt Street Station Construction Site**

| Receiver Area | Scenario | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Enabling Works | Earthworks | Acoustic Shed Construction | Excavation with Shed | | | | | Construction |
| | Day | Day | Day | Day | DOOH | Even | Night | Sleep | Day |
| A – Residential receivers to the west, west of Pitt Street and south of Bathurst Street | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| A – Commercial receivers to the west, west of Pitt Street and south of Bathurst Street | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| B – Residential receivers to the west, west of Pitt Street and north of Bathurst Street. | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B – Commercial receivers to the west, west of Pitt Street and north of Bathurst Street. | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| C – Residential receivers to the west, west of Pitt Street and north of Park Street. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| C – Commercial receivers to the west, west of Pitt Street and north of Park Street. | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| D – Commercial receivers to the north, between Pitt Street and Castlereagh Street | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| E – Residential receivers to the east | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E – Commercial receivers to the east | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| F – Residential receivers between Park Street and Bathurst Street. | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| F – Commercial receivers between Park Street and Bathurst Street. | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| F – Educational receivers between Park Street and Bathurst Street. | 3 | 3 | 2 | 1 | 0 | 0 | 0 | 0 | 3 |
| G – Residential receivers to the south, between Pitt Street and Castlereagh Street | 3 | 2 | 1 | 0 | 0 | 0 | 1 | 0 | 3 |
| G – Commercial receivers to the south, between Pitt Street and Castlereagh Street. | 3 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 3 |

**Legend**

| Category 0 | Category 1 | Category 2 | Category 3 |
|---|---|---|---|
| NML Compliance | NML exceedance of less than 10 dB | NML exceedance of between 10 dB and 20 dB | NML exceedance of more than 20 dB |

**Discussion**

The preliminary findings of the construction noise impact assessment at Pitt Street Station indicate:

- The predicted noise levels for enabling works) indicate high exceedances of more than 20 dB of the NMLs at the residential receivers in Area G and at educational receivers in Area F. At residential receivers in area B and F, minor exceedances are predicted.

  At the nearest commercial receivers in Areas D, and G high exceedances of more than 20 dB of the NMLs are predicted, and at commercial receivers in Areas A, C and E moderate exceedances of more than 10 dB. Minor exceedances are predicted at commercial receivers in Areas B and F.

- The predicted noise levels for earthworks indicate high exceedances of more than 20 dB of the NMLs at the educational receivers in Area F. Minor exceedances of more than 10 dB are predicted at residential receivers in Area G.

  At the nearest commercial receivers in Area G high exceedances of more than 20 dB of the NMLs are predicted, and at commercial receivers in Areas A, C, D and E moderate exceedances of more than 10 dB. Minor exceedances are predicted at commercial receivers in Areas B, and F. During the acoustic shed construction a moderate exceedance is predicted at educational receivers in Area F and commercial receivers in Area G. Minor exceedances at residential receivers in Area G and commercial receivers in Area C and D are predicted.

- During excavation with an acoustic shed a minor exceedance of less than 10 dB is predicted at educational receivers in Area F during the daytime.
- During station construction major exceedances are predicted at residential receivers in Area G, the educational receivers in Area F and the commercial receivers in Area G. Moderate exceedances at commercial receivers at Area D. Minor exceedances are predicted at the residential receivers in Area F, and at commercial receivers in Area A, B, C, E and F.
- At Town Hall external noise levels are predicted to be up to 68 dBA. These levels will be similar to existing noise from heavy vehicles on George Street and other city noise. The buildings external to internal noise reduction will be expected to attenuate noise from the works to levels similar to those from heavy vehicles on George Street to the performance space.

**On Site Night-Time $L_{Amax}$ Noise**

The maximum noise levels associated with on-site truck movements, deliveries by semitrailer and other activities on site can potentially cause awakening reactions (or sleep disturbance) at nearby residential receivers. The $L_{Amax}$ noise levels associated with these events comply with the sleep disturbance screening level during excavation with an acoustic shed.

### 3.12.4 Ground-borne Noise and Human Comfort Vibration Assessment

Where ground-borne noise exceedances are identified then human comfort vibration exceedances would also be present. **Appendix F** illustrates the potential ground borne noise impacts due to vibration intensive construction activities (rock breaking) in this area. In summary the analysis indicates:

- During the day one (1) building adjacent to the northern shaft (to the north on Pitt Street) and the four (4) buildings immediately adjacent to the southern shaft have regenerated noise levels potentially higher than 75 dBA on several floors in each building. Where receivers experience day-time internal noise levels greater than 75 dBA more detailed site specific ground borne noise investigation is required. If this investigation finds ground borne noise levels are likely to exceed 75 dBA for extended periods then alternative accommodation would be considered as a mitigation measure.

- During night-time works the analysis shows three (3) residential buildings at the northern shaft (one to the north on Pitt Street, and two to the south on Park Street) and four (4) residential buildings at the southern shaft (one to the south on Pitt Street, one to the south on Castlereagh Street and two to the west on Pitt Street) have regenerated noise levels potentially higher than 45 dBA on several floors in each building. Where residential receivers have night-time internal noise levels greater than 45 dBA they would be considered eligible for alternative accommodation (the highest level mitigation measure) as per the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement).

#### 3.12.4.1 Blasting

The use of blasting in the excavation of the station shafts effectively reduces the duration of noise and vibration impacts due to the use of rock breakers which must be used to some extent before blasting can occur. **Table 59** illustrates the effective reduction in duration of the ground-borne noise (and human comfort vibration) exceedances when blasting is used as an alternative excavation methodology. This table also illustrates the effective reduction in duration of these exceedances when blasting is combined with medium rock breakers instead of large rock breakers.

The values in this table represent all exceedances of the NMLs (even those as low as 1 dB to 5 dB). Therefore, the actual requirement for high level mitigation measures is not represented. The information is presented to indicate the benefits in terms of duration of impacts between different excavation methodologies.

**Table 59 No. of Periods Above the NMLs Due to Alternative Construction Methodologies**

| Site | Number of Periods Above NMLs | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Residential | | | | | | | | | Commercial | | |
| | Day | | | Evening | | | Night | | | Day | | |
| | B- Lrg RB | B+ Lrg RB | B+ Med RB | B- Lrg RB | B+ Lrg RB | B+ Med RB | B- Lrg RB | B+ Lrg RB | B+ Med RB | B- Lrg RB | B+ Lrg RB | B+ Med RB |
| Pitt Street - North | 48 | 25 | 4 | 123 | 52 | 24 | 181 | 69 | 54 | 41 | 22 | 12 |
| Pitt Street - South | 76 | 33 | 23 | 129 | 53 | 35 | 212 | 83 | 56 | 116 | 60 | 36 |

Note: B- = No Blasting, B+ = With Blasting, Lrg RB = Large Rock Breakers, Med RB = Medium Rock Breakers

The duration of the impacts can be summarised as follows:

**Residential Day**: The use of large rock breakers with no blasting generates 124 daytime periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 58 daytime periods. The inclusion of blasting and the use of medium rock breakers reduces the duration of impacts even further to 27 daytime periods. Blasting coupled with medium rock breaker therefore significantly reduces the impacts during the day.

**Residential Evening**: The use of large rock breakers with no blasting generates 252 evening periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 105 evening periods. The inclusion of blasting and the use of medium rock breakers reduces the duration of impacts even further to 59 evening periods. Blasting therefore significantly reduces the impacts during the evening.

**Residential Night**: The use of large rock breakers with no blasting generates greater than 365 night-time periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 152 night-time periods. The inclusion of blasting and the use of medium rock breakers reduces the duration of impacts even further to 60 night-time periods.

**Commercial Day**: The use of large rock breakers with no blasting generates 157 daytime periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 82 daytime periods. The inclusion of blasting and the use of medium rock breakers reduces the duration of impacts even further to 48 daytime periods. Blasting coupled with medium rock breaker therefore significantly reduces the impacts during the day.

With careful planning and positioning of the rock breakers it may be possible to avoid consecutive periods of NML exceedances ie respite periods for receivers could be planned in the construction program through careful rock breaker locations. For any residual exceedances of the NMLs, the processes and mitigation measures identified in the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement) would be implemented.

The potential ground-borne noise impacts associated with the excavation of the tunnels are discussed in **Section 3.16.1**.

### 3.12.5 Vibration Assessment

During construction of the proposed shafts vibration levels are anticipated to exceed the vibration screening levels associated with minor cosmetic building damage. The analysis shows five (5) buildings at the southern site (the buildings immediately adjacent on Bathurst, Pitt and Castlereagh streets) and one (1) building adjacent to the northern site (to the north on Pitt Street) where the screening criteria for cosmetic damage may be exceeded. A more detailed assessment of the structure and attended vibration monitoring would be carried out to ensure vibration levels remain below appropriate limits for these structures. **Appendix G** illustrates the potential cosmetic damage vibration impacts due to construction activities in this area.

### 3.12.6 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access route to the Pitt Street Station site. In this instance the access to the site is via Pitt Street north and south of the site, Castlereagh Street and Bathurst Street which are sub-arterial roads with significant daytime flows. The RNP base criteria, predicted $L_{Aeq(15hr)}$ daytime and $L_{Aeq(9hr)}$ nighttime noise levels with the development, and the $L_{Aeq}$ increase and sleep disturbance noise levels have been assessed in **Table 60**.

**Table 60 Pitt Street Station Construction Site - Construction Traffic on Public Roads**

| Access Road | Base Criteria Day/Night ($L_{Aeq(15hr/9hr)}$) | Predicted Road Traffic Noise Day/Night | Predicted Road Traffic Noise Increase (dB) day/night | RBL + 15 dB Screening Criterion (dBA) | External LAmax NML Level (dBA) | Predicted $L_{Amax}$ Noise Level (dBA) |
|---|---|---|---|---|---|---|
| Pitt St South | 60/55 | 67/62 | 0.5/0.7 | 76 | 65 | 76 |
| Pitt St North | 60/55 | 65/61 | 0.5/0.4 | 76 | 65 | 76 |
| Castlereagh St | 60/55 | 67/61 | 0.2/0.4 | 76 | 65 | 76 |
| Bathurst St | 60/55 | 70/67 | 0.2/0.2 | 76 | 65 | 76 |

**Table 60** indicates that whilst at Pitt Street, Castlereagh Street and at Bathurst Street the base criteria are exceeded, the the predicted noise level increase ($L_{Aeq}$) associated with construction traffic complies with the 2 dB allowance, therefore sensitive receivers are not likely to notice an increase in the average road traffic noise levels during construction. There are expected to be up to 6 heavy vehicle and 2 light vehicles movements or events per hour during the night and whilst there is compliance with the sleep disturbance screening criterion, there is an exceedance of the external sleep disturbance NML of 65 dBA (by up to 11 dB). The $L_{Amax}$ levels would however, be similar to other heavy vehicles using Pitt Street, Castlereagh Street and Bathurst Street.

## 3.13 Central Station Construction Site

### 3.13.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Central Station construction site and the surrounding receiver areas is provided in **Figure 16**, with the nearest noise sensitive receivers identified in **Table 61**.

**Figure 16 Central Station Construction Site and Receiver Areas**

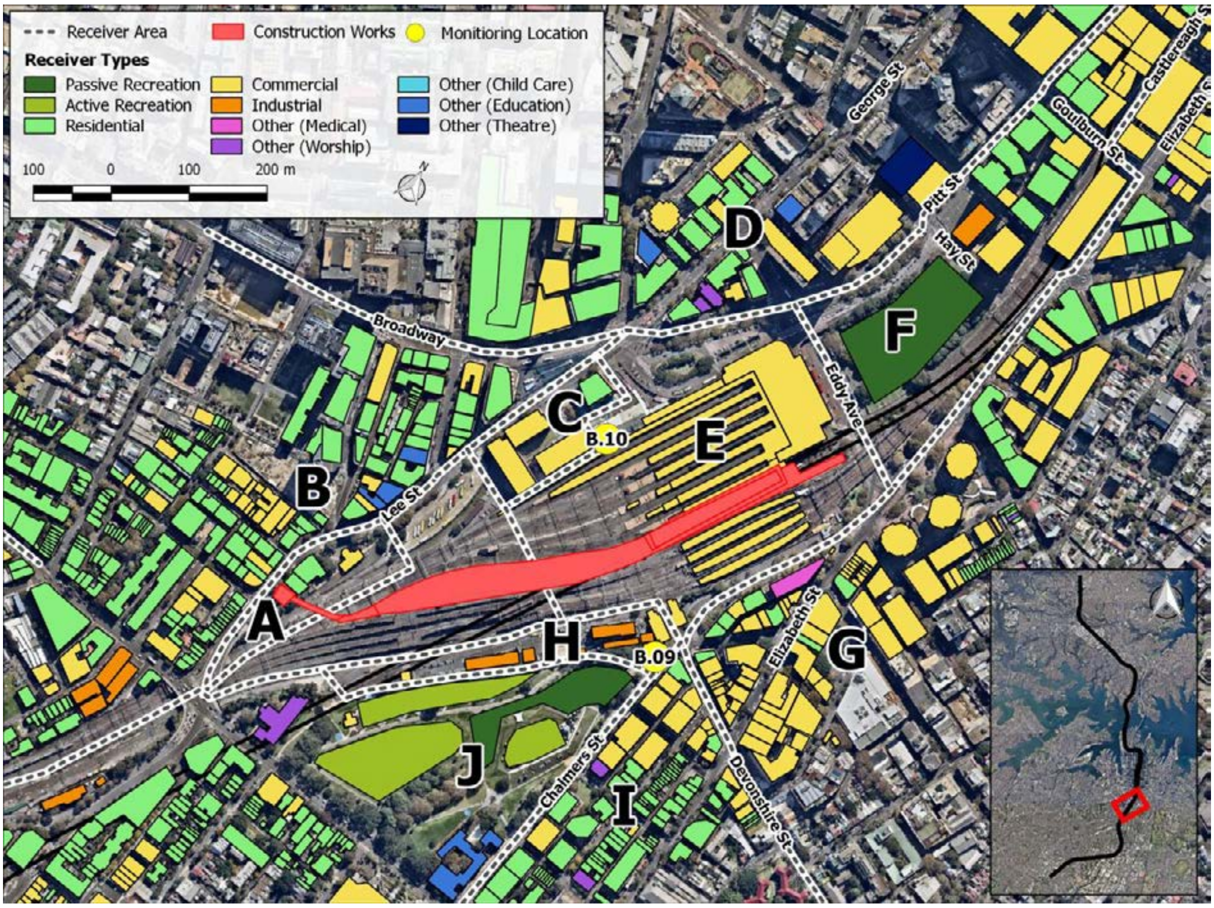



**Table 61 Nearest Noise Sensitive Receivers – Central Station Construction Site**

| Receiver Area | Location Relative to Works (m)[1] |
|---|---|
| A - Residential receivers to the west, east of Regent Street. | 5 |
| B - Residential receivers to the east, west of Regent Street | 20 |
| B - Commercial receivers to the west, east of Lee Street | 20 |
| C - Residential receivers to the east, east of Regent Street | 170 |
| C - Commercial receivers to the east, east of Regent Street | 110 |
| D - Residential receivers to the west, west of Pitt Street | 210 |
| D - Church to the west, west of Pitt Street | 210 |
| E - Commercial receivers surrounding at Central Station | 5 |
| F - Belmore Park to the north | 60 |
| G - Residential receivers to the east, east of Chalmers Street | 95 |
| G – Sydney Dental Hospital to the east, east of Chalmers St. | 95 |

| Receiver Area | Location Relative to Works (m)[1] |
|---|---|
| H - Commercial receivers to the east, west of Prince Alfred Pk. | 65 |
| I - Residential receivers to the east, south of Devonshire St. | 125 |
| I - Commercial receivers to the east, south of Devonshire St. | 140 |
| J - Prince Alfred Park | 110 |

Note 1: The relative distance to works shown is that from the nearest sensitive receiver to the closest location of construction activity.

### 3.13.2 Site Specific Construction Noise Management Levelss

With reference to the ambient noise survey results summarised in **Table 4**, the site specific construction NMLs are presented in **Table 62**.

**Table 62 Central Station Construction Site Noise Management Levels**

| Receiver Area | Receiver Type | Relevant Monitoring Location | $L_{Aeq(15minute)}$ Construction NMLs (dBA) | | | |
|---|---|---|---|---|---|---|
| | | | Daytime | Daytime OOH | Evening | Night-time |
| A | Residential | B.26 | 68 | 63 | 61 | 57 |
| B | Residential | B.26 | 68 | 63 | 61 | 57 |
| B | Commercial | B.26 | 70 | 70 | n/a | n/a |
| C | Residential | B.26 | 68 | 63 | 61 | 57 |
| D | Residential | B.26 | 68 | 63 | 61 | 57 |
| D | Church | B.26 | 55 | 55 | n/a | n/a |
| E | Commercial | B.26 | 70 | 70 | n/a | n/a |
| F | Recreation | B.26 | 60 | 60 | n/a | n/a |
| G | Residential | B.09 | 66 | 61 | 58 | 50 |
| G | Medical | B.09 | 55 | 55 | n/a | n/a |
| H | Commercial | B.09 | 70 | 70 | n/a | n/a |
| I | Residential | B.09 | 66 | 61 | 58 | 50 |
| I | Commercial | B.09 | 70 | 70 | n/a | n/a |
| J | Recreation | B.09 | 60 | 60 | n/a | n/a |

### 3.13.3 Airborne 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 have been developed to be a subset of those discussed in **Section 3.3.1.1**, and are:

- Enabling works including mobilisation and demolition (18 months)
- Earthworks (two months)
- Excavation (three and a half years)
- Station construction (12 months)

Calculations of the typical $L_{Aeq(15minute)}$ noise level exceedances of the NMLs at the nearest noise sensitive receivers are provided in **Appendix D** and are summarised in **Table 63**. The 'sleep' column of the table provides the predicted exceedance of the sleep disturbance screening noise level.

**Table 63 Predicted noise level exceedances at Central Station Construction Site**

| Receiver Area | Scenario | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Enabling Works | Earthworks | Excavation | | | | | Construction |
| | Day | Day | Day | DOOH | Even | Night | Sleep | Day |
| A - Residential receivers to the west, east of Regent Street. | 3 | 3 | 0 | 0 | 0 | 1 | 0 | 0 |
| B - Residential receivers to the east, west of Regent Street | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| B - Commercial receivers to the west, east of Lee Street | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| C - Residential receivers to the east, east of Regent Street | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| C - Commercial receivers to the east, east of Regent Street | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D - Residential receivers to the west, west of Pitt Street | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D - Church to the west, west of Pitt Street | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E - Commercial receivers surrounding at Central Station | 3 | 3 | 2 | 2 | 0 | 0 | 0 | 3 |
| F - Belmore Park to the north | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| G - Residential receivers to the east, east of Chalmers Street | 1 | 1 | 0 | 1 | 1 | 2 | 1 | 0 |
| G - Sydney Dental Hospital to the east, east of Chalmers St. | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 1 |
| H - Commercial receivers to the east, west of Prince Alfred Pk. | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| I - Residential receivers to the east, south of Devonshire St. | 1 | 0 | 0 | 0 | 1 | 2 | 1 | 0 |
| I - Commercial receivers to the east, south of Devonshire St. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| J - Prince Alfred Park | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Legend**

| Exceedance Category 0 | Exceedance Category 1 | Exceedance Category 2 | Exceedance Category 3 |
|---|---|---|---|
| NML Compliance | NML exceedance of less than 10 dB | NML exceedance of between 10 dB and 20 dB | NML exceedance of more than 20 dB |

**Discussion**

The preliminary findings of the construction noise impact assessment at Central Station indicate:

- The predicted noise levels for enabling works (including mobilisation/demolition/earthworks) indicate high exceedances of more than 20 dB of the NMLs at the residential receivers in Area A. Moderate exceedances of more than 10 dB are predicted at residential receivers in Area B, at the Sydney Dental Hospital and at Belmore Park. At residential receivers in area G and I, at the Church in Area D and at Prince Alfred Park minor exceedances are predicted.

  At the nearest commercial receivers in Area E high exceedances of more than 20 dB of the NMLs are predicted. At commercial receivers in Area B moderate exceedances of more than 10 dB are predicted. Minor exceedances are predicted at commercial Areas H.

- The predicted noise levels for earthworks indicate high exceedances of more than 20 dB of the NMLs at the residential receivers in Area A. At residential receivers in Areas B and G, at the Sydney Dental Hospital and at Belmore Park minor exceedances are predicted.

At the nearest commercial receivers in Area E high exceedances of more than 20 dB of the NMLs are predicted. Minor exceedances are predicted at commercial receivers in Areas B, and H.

Compliance during earthworks is predicted at residential receivers in Areas C, D and I, at the Church and at commercial receivers in Areas C, and I.

- During excavation during daytime there is a moderate exceedance of more than 10 dB at commercial receivers in Area E, a minor exceedance at the Sydney Dental Hospital and compliance at all other locations. For excavation during DOOH and evenings there is a minor exceedance of up to 10 dB for residences in Area G, and during DOOH a minor exceedance at the Sydney Dental Hospital

  For night-time excavation works there are moderate exceedances of more than 10 dB at residences in area G and I and minor exceedances of up to 10 dB at residences in area A and C.

- During construction there is a major exceedance at commercial receivers in Area E, a minor exceedance at the Sydney Dental Hospital and compliance at all other areas.

**On Site Night-Time $L_{Amax}$ Noise**

The maximum noise levels associated with on-site truck movements, deliveries by semitrailer and other activities on site can potentially cause awakening reactions (or sleep disturbance) at nearby residential receivers. The $L_{Amax}$ noise levels associated with these events exceed the sleep disturbance screening level during the construction phase. During the detailed design night-time ‘on site’ traffic routes and activities should be reviewed and/or additional mitigation such as increased site perimeter hoarding height.

### 3.13.4 Ground-borne Noise and Human Comfort Vibration Assessment

**Appendix F** illustrates the potential ground borne noise impacts due to vibration intensive construction activities (rock breaking) in this area. In summary the analysis indicates:

- During the day ground borne noise levels inside the adjacent station buildings and on platforms has the potential to exceed 75 dBA during rock breaking activities. However, no mitigation measures are likely to be required for this site because of the existing ambient noise levels from normal operation of the station.
- During the day three (3) commercial buildings, located to the east around the northern corner of Prince Alfred Park, are predicted to have regenerated noise levels potentially higher than 75 dBA on several floors in each building. Where receivers experience day-time internal noise levels greater than 75 dBA more detailed site specific ground borne noise investigation is required. If this investigation finds ground borne noise levels are likely to exceed 75 dBA for extended periods then alternative accommodation would be considered as a mitigation measure.
- During night-time works the analysis shows one (1) residential building, located on the corner of Devonshire and Chalmers streets, has regenerated noise levels potentially higher than 45 dBA on several floors. Where residential receivers have night-time internal noise levels greater than 45 dBA they would be considered eligible for alternative accommodation (the highest level mitigation measure) as per the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement). Other potential mitigation measures would include alternative excavation techniques such as blasting and penetrative cone fracture (PCF).

The potential ground-borne noise impacts associated with the excavation of the tunnels are discussed in **Section 3.16.1**.

### 3.13.5 Vibration Assessment

During construction of the proposed excavation vibration levels are anticipated to exceed the vibration screening levels associated with minor cosmetic building damage. The analysis shows two (2) station platforms where the screening criteria for cosmetic damage may be exceeded. A further three (3) commercial buildings (located to the east around the northern corner of Prince Alfred Park) are predicted to exceed the screening criterion. A more detailed assessment of the structure and attended vibration monitoring would be carried out to ensure vibration levels remain below appropriate limits for these structures. **Appendix G** illustrates the potential cosmetic damage vibration impacts due to construction activities in this area.

### 3.13.6 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access route to the Central Station site. In this instance the access to the site is via Regent Street and Chalmers Street which are sub-arterial roads with significant daytime flows. The RNP base criteria, predicted $L_{Aeq(15hr)}$ daytime and $L_{Aeq(9hr)}$ nighttime noise levels with the development, and the $L_{Aeq}$ increase and sleep disturbance noise levels have been assessed in **Table 64**.

**Table 64 Central Station Construction Site - Construction Traffic on Public Roads**

| Access Road | Base Criteria Day/Night ($L_{Aeq(15hr/9hr)}$) | Predicted Road Traffic Noise Day/Night | Predicted Road Traffic Noise Increase (dB) | RBL + 15 dB Screening Criterion (dBA) | External LAmax NML Level (dBA) | Predicted $L_{Amax}$ Noise Level (dBA) |
|---|---|---|---|---|---|---|
| Regent Street | 60/55 | 74/70 | 0.1/0.2 | 67 | 65 | 78 |
| Chalmers Street | 60/55 | 72/67 | 0.2/0.3 | 60 | 65 | 78 |

**Table 64** indicates that whilst at Regent Street and at Chalmers Street the base criteria are exceeded, the the predicted noise level increase ($L_{Aeq}$) associated with construction traffic complies with the 2 dB allowance, therefore sensitive receivers are not likely to notice an increase in the average road traffic noise levels during construction. There are expected to be up to 6 heavy vehicle and 2 light vehicles movements or events per hour during the night and whilst there is an exceedance of the sleep disturbance screening criterion (of up to 18 dB) and external sleep disturbance NML of 65 dBA (by up to 13 dB), the $L_{Amax}$ levels would be similar to other heavy vehicles using Regent Street and Chalmers Street.

## 3.14 Waterloo Station Construction Site

### 3.14.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Waterloo Street Station construction site and the surrounding receiver areas is provided in **Figure 17**, with the nearest noise sensitive receivers identified in **Table 65**.

**Figure 17 Waterloo Station Construction Site and Receiver Areas**


**Table 65 Nearest Noise Sensitive Receivers – Waterloo Station Construction Site**

| Receiver Area | Location Relative to Works (m)[1] |
|---|---|
| A - Residential receivers north of Raglan Street | 16 |
| B - Residential receivers east of Cope Street | 25 |
| C - Residential receivers south of Buckland Street | 18 |
| C - Commercial receivers south of Buckland Street | 18 |
| D - Residential receivers west of Botany Road | 23 |
| D - Place of worship receivers west of Botany Road | 16 |
| D - Commercial receivers east of Botany Road | 43 |

Note 1: The relative distance to works shown is that from the nearest sensitive receiver to the closest location of construction activity.

### 3.14.2 Site Specific Construction Noise Management Levels

With reference to the ambient noise survey results summarised in **Table 4**, the site specific construction NMLs are presented in **Table 66**.

**Table 66 Waterloo Station Construction Site Noise Management Levels**

| Receiver Area | Receiver Type | Relevant Monitoring Location | $L_{Aeq(15minute)}$ Construction NMLs (dBA) | | | |
|---|---|---|---|---|---|---|
| | | | Daytime | Daytime OOH | Evening | Night-time |
| A | Residential | B.06 | 64 | 59 | 52 | 44 |
| B | Residential | B.06 | 64 | 59 | 52 | 44 |
| C | Residential | B.06 | 64 | 59 | 52 | 44 |
| C | Commercial | B.06 | 70 | 70 | n/a | n/a |
| D | Residential | B.06 | 64 | 59 | 52 | 44 |
| D | Place of Worship | B.06 | 70 | 70 | n/a | n/a |
| D | Commercial | B.06 | 70 | 70 | n/a | n/a |

### 3.14.3 Airborne 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 have been developed to be a subset of those discussed in **Section 3.3.1.1**, and are:

- Enabling works including mobilisation and demolition (12 months)
- Earthworks (two months)
- Acoustic shed construction (one month)
- Excavation (three years)
- Station construction (18 months)

Calculations of the typical $L_{Aeq(15minute)}$ noise level exceedances of the NMLs at the nearest noise sensitive receivers are provided in **Appendix D** and are summarised in

**Table 67**. The 'sleep' column of the table provides the predicted exceedance of the sleep disturbance screening noise level.

Note that for night-time construction, preliminary modelling indicated that an acoustic shed would be required and was included for the station excavation scenario.

**Table 67 Predicted noise level exceedances at Waterloo Station Construction Site**

| Receiver Area | Scenario | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Enabling Works | Earthworks | Acoustic Shed Construction | Excavation with Shed | | | | | Construction |
| | Day | Day | Day | Day | DOOH | Even | Night | Sleep | Day |
| A - Residential receivers north of Raglan Street | 3 | 2 | 1 | 0 | 1 | 1 | 2 | 1 | 1 |
| B - Residential receivers east of Cope Street | 2 | 2 | 1 | 0 | 1 | 1 | 2 | 1 | 2 |
| C - Residential receivers south of Buckland Street | 2 | 2 | 1 | 0 | 0 | 1 | 2 | 1 | 2 |
| C - Commercial receivers south of Buckland Street | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| D - Residential receivers west of Botany Road | 3 | 2 | 1 | 0 | 1 | 1 | 2 | 1 | 1 |
| D - Place of worship receivers west of Botany Road | 3 | 3 | 2 | 1 | 1 | 0 | 0 | 0 | 3 |
| D – Commercial receivers east of Botany Road | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

**Legend**

| Category 0 | Category 1 | Category 2 | Category 3 |
|---|---|---|---|
| NML Compliance | NML exceedance of less than 10 dB | NML exceedance of between 10 dB and 20 dB | NML exceedance of more than 20 dB |

**Discussion**

The preliminary findings of the construction noise impact assessment at Waterloo Street Station indicate:

- The predicted noise levels for enabling works indicate high exceedances of more than 20 dB of the NMLs at the residential receivers in Area A and D, and at place of worship in Area D. Moderate exceedances of more than 10 dB are predicted at residential receivers in Areas B and D.

  At the nearest commercial receivers in Area D, moderate exceedances of more than 10 dB of the NMLs are predicted. Minor exceedances of less than 10 dB are predicted at commercial receivers in Area C.

- The predicted noise levels for earthworks works indicate high exceedances of more than 20 dB of the NMLs at the place of worship in Area D. Moderate exceedances of more than 10 dB are predicted at residential receivers in Areas A, B, C and D.

  At the nearest commercial receivers in Areas C and D, minor exceedances of less than 10 dB of the NMLs are predicted.

- During the acoustic shed construction a moderate exceedance is predicted at the place of worship in Area D. There are minor exceedances at residential receivers in Area A, B, C and D.

- During daytime excavation with an acoustic shed a minor exceedance of less than 10 dB is predicted at the place of worship in Area D. For night-time excavation there are moderate exceedances for residences in Area A, B, C and D. Potential mitigation would be to increase the acoustic shed noise insulation performance, however this would not reduce ground-borne noise at the impacted receivers.
- During station construction high exceedances are predicted at the place of worship in Area D. Moderate exceedances are predicted at residential receivers at Areas B and C. Minor exceedances are predicted at residences in Area A and D, and at commercial receivers in Area C and D.

**On Site Night-Time LAmax Noise**

The maximum noise levels associated with on-site truck movements, deliveries by semitrailer and other activities on site can potentially cause awakening reactions (or sleep disturbance) at nearby residential receivers. The LAmax noise levels associated with these events exceed the sleep disturbance screening level during excavation by up to 10 dB in area A, B, C and D. During the detailed design night-time 'on site' traffic routes and activities should be reviewed and/or additional mitigation such as increased site perimeter hoarding height.

### 3.14.4 Ground-borne Noise and Human Comfort Vibration Assessment

Where ground-borne noise exceedances are identified then human comfort vibration exceedances would also be present**. Appendix F** illustrates the potential ground borne noise impacts due to vibration intensive construction activities (rock breaking) in this area. In summary the analysis indicates:

- Moderate (or less) exceedances of the NMLs (10 to 20 dB) are predicted at the nearby commercial and residential receivers.
- During night-time works the analysis shows ten (10) residential buildings have regenerated noise levels potentially higher than 45 dBA on several floors in each building. Where residential receivers have night-time internal noise levels greater than 45 dBA they would be considered eligible for alternative accommodation (the highest level mitigation measure) as per the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement).

#### 3.14.4.1 Blasting

The use of blasting in the excavation of the station shafts effectively reduces the duration of noise and vibration impacts due to the use of rock breakers which must be used to some extent before blasting can occur. **Table 68** illustrates the effective reduction in duration of the ground-borne noise (and human comfort vibration) exceedances when blasting is used as an alternative excavation methodology. This table also illustrates the effective reduction in duration of these exceedances when blasting is combined with medium rock breakers instead of large rock breakers.

The values in this table represent all exceedances of the NMLs (even those as low as 1 dB to 5 dB). Therefore, the actual requirement for high level mitigation measures is not represented. The information is presented to indicate the benefits in terms of duration of impacts between different excavation methodologies.

**Table 68 No. of Periods Above the NMLs Due to Alternative Construction Methodologies**

| Site | Number of Periods Above NMLs | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Residential | | | | | | | | | Commercial | | |
| | Day | | | Evening | | | Night | | | Day | | |
| | B- Lrg RB | B+ Lrg RB | B+ Med RB | B- Lrg RB | B+ Lrg RB | B+ Med RB | B- Lrg RB | B+ Lrg RB | B+ Med RB | B- Lrg RB | B+ Lrg RB | B+ Med RB |
| Waterloo | 251 | 139 | 13 | >365 | 275 | 131 | >365 | >365 | 294 | 14 | 8 | 3 |

Note: B- = No Blasting, B+ = With Blasting, Lrg RB = Large Rock Breakers, Med RB = Medium Rock Breakers

The duration of the impacts can be summarised as follows:

**Residential Day**: The use of large rock breakers with no blasting generates 251 daytime periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 139 daytime periods. The inclusion of blasting and the use of medium rock breakers reduces the duration of impacts even further to 13 daytime periods. Blasting coupled with medium rock breaker therefore significantly reduces the impacts during the day.

**Residential Evening**: The use of large rock breakers with no blasting generates greater than 365 evening periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 275 evening periods. The inclusion of blasting and the use of medium rock breakers reduces the duration of impacts even further to 131 evening periods. Blasting and the use of medium rock breakers significantly reduces the impacts during the evening.

**Residential Night**: The use of large rock breakers with no blasting generates greater than 365 night-time periods with exceedances of the NMLs. The inclusion of blasting and the use of medium rock breakers reduces the duration of impacts 294 night-time periods.

**Commercial Day**: The use of large rock breakers with no blasting generates 14 daytime periods with exceedances of the NMLs. The inclusion of blasting reduces the duration of impacts to 8 daytime periods. The inclusion of blasting and the use of medium rock breakers reduces the duration of impacts even further to 3 daytime periods. Blasting coupled with medium rock breaker therefore reduces the impacts during the day.

With careful planning and positioning of the rock breakers it may be possible to avoid consecutive periods of NML exceedances ie respite periods for receivers could be planned in the construction program through careful rock breaker locations. For any residual exceedances of the NMLs, the processes and mitigation measures identified in the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement) would be implemented.

The potential ground-borne noise impacts associated with the excavation of the tunnels are discussed in **Section 3.16.1**.

### 3.14.5 Vibration Assessment

During construction of the proposed shaft vibration levels are anticipated to remain well below the vibration screening levels associated with minor cosmetic building damage. **Appendix G** illustrates the potential cosmetic damage vibration impacts due to construction activities in this area.

### 3.14.6 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access route to the Waterloo Station site. In this instance the access to the site is via Botany Road and Henderson Road which are sub-arterial roads with significant daytime flows. The RNP base criteria, predicted $L_{Aeq(15hr)}$ daytime and $L_{Aeq(9hr)}$ nighttime noise levels with the development, and the $L_{Aeq}$ increase and sleep disturbance noise levels have been assessed in **Table 69**.

**Table 69 Waterloo Station Construction Site - Construction Traffic on Public Roads**

| Access Road | Base Criteria Day/Night ($L_{Aeq(15hr/9hr)}$) | Predicted Road Traffic Noise Day/Night | Predicted Road Traffic Noise Increase (dB) | RBL + 15 dB Screening Criterion (dBA) | External LAmax NML Level (dBA) | Predicted $L_{Amax}$ Noise Level (dBA) |
|---|---|---|---|---|---|---|
| Botany Rd | 60/55 | 73/68 | 0.1/0.2 | 54 | 65 | 78 |
| Henderson Rd | 60/55 | 72/66 | 0.1/0.3 | 54 | 65 | 76 |

**Table 69** indicates that whilst at Botany Road and at Henderson Road the base criteria are exceeded, the predicted noise level increase ($L_{Aeq}$) associated with construction traffic complies with the 2 dB allowance, therefore sensitive receivers are not likely to notice an increase in the average road traffic noise levels during construction.

There are expected to be up to 6 heavy vehicle and 2 light vehicles movements or events per hour during the night and whilst there is an exceedance of the sleep disturbance screening criterion (of up to 24 dB) and external sleep disturbance NML of 65 dBA (by up to 13 dB), the $L_{Amax}$ levels would be similar to other heavy vehicles using Botany Road and Henderson Road.

## 3.15 Marrickville Dive Site

### 3.15.1 Site Layout and Proposed Construction Works

An aerial photograph of the proposed Marrickville dive site and the surrounding receiver areas is provided in **Figure 18**, with the nearest noise sensitive receivers identified in **Table 70**.

**Figure 18 Marrickville Dive Site and Receiver Areas**

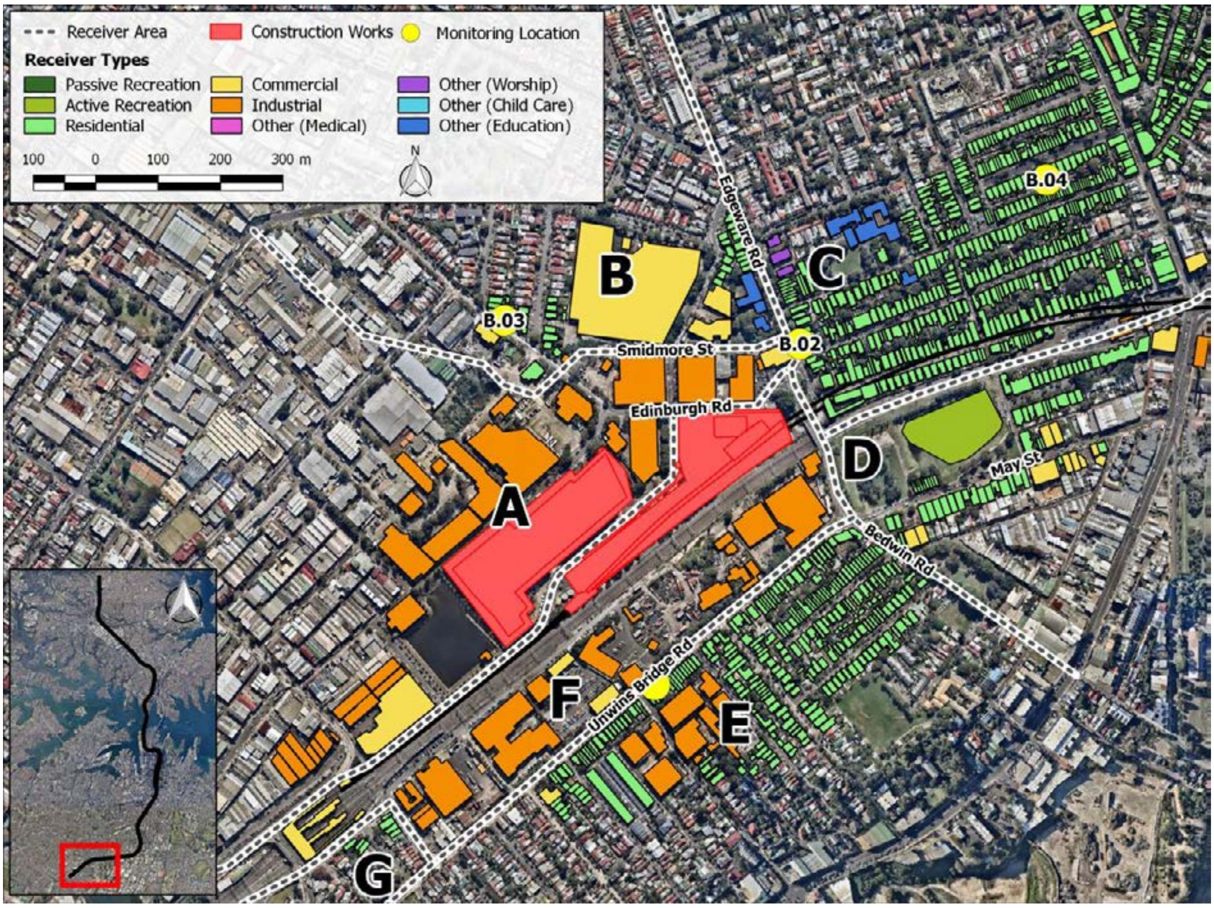


**Table 70 Nearest Noise Sensitive Receivers - Marrickville Dive Site**

| Receiver Area | Location Relative to Works (m)[1] |
|---|---|
| A - Industrial Area to the north | 20 |
| B - Commercial receivers to the north | 160 |
| B - Educational receiver to north | 124 |
| B - Residential receivers to the north on Edinburgh Road | 110 |
| C - Residential receivers to the north, east of Edgeware Road | 65 |
| D - Recreation to the east at Camdenville Park | 70 |
| D - Residential receivers to the east, north and south of May Street | 190 |
| E - Residential receivers to the south–east on Unwins Bridge Road | 160 |
| F - Industrial receivers to the south –east | 45 |
| G - Residential receivers to the south–east on Burrows Avenue | 510 |

Note 1: The relative distance to works shown is that from the nearest sensitive receiver to the closest location of construction activity.

### 3.15.2 Site Specific Construction Noise Management Levels

With reference to the ambient noise survey results summarised in **Table 4**, the site specific construction NMLs are presented in **Table 71**.

**Table 71 Marrickville Dive Site Noise Management Levels**

| Receiver Area | Receiver Type | Relevant Monitoring Location | $L_{Aeq(15minute)}$ Construction NMLs (dBA) | | |
|---|---|---|---|---|---|
| | | | Daytime | Evening | Night-time |
| A | Industrial | B02 | 75 | n/a | n/a |
| B | Commercial | B03 | 70 | n/a | n/a |
| B | Educational | B03 | 55 | n/a | n/a |
| B | Residential | B03 | 62 | 48 | 43 |
| C | Residential | B02 | 68 | 57 | 43 |
| D | Active recreational (field) | B02 | 65 | n/a | n/a |
| D | Residential | B02 | 68 | 57 | 43 |
| E | Residential | B01 | 69 | 58 | 46 |
| F | Industrial | B01 | 75 | n/a | n/a |
| G | Residential | B01 | 69 | 58 | 46 |

### 3.15.3 Airborne 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 have been developed to be a subset of those discussed in **Section 3.3.1.1**, and are detailed as follows:

- Enabling works including mobilisation and demolition (12 months)
- Track works which consists of construction works to the south of the dive site (12 months)
- Earthworks which consist of initial excavation, tunnel dive piling, tunnel dive excavation, tunnel dive lining, laying tunnel dive track (six months)
- Acoustic shed construction (one month)
- Tunnelling and excavation with shed, including the precast factory (18 months)
- Fitout (18 months)

Calculations of the typical $L_{Aeq(15minute)}$ noise level exceedances of the NMLs at the nearest noise sensitive receivers are provided in **Appendix D** and are summarised in **Table 72**. The 'sleep' column of the table provides the predicted exceedance of the sleep disturbance screening noise level.

For night-time construction, preliminary modelling indicates that an acoustic shed would be required and was included for the tunnelling and precast scenarios.

**Table 72 Predicted noise level exceedances at the Marrickville Dive Site**

| Receiver Area | Scenario | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Enabling Works | Track Works | Earthworks | Acoustic Shed Construction | Tunnelling with Shed and Precast Factory | | | | | Fitout | | | | |
| | Day | Day | Day | Day | Day | DOOH | Eve | Night | Sleep | Day | DOOH | Eve | Night | Sleep |
| A – Industrial Area to the north | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B – Commercial receivers to the north | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B – Educational receiver to north | 2 | 2 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B – Residential receivers to the north on Edinburgh Road | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| C – Residential receivers to the north, east of Edgeware Road | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| D – Camdenville Park to the east | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| D – Residential receivers to the east, north and south of May Street | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| E – Residential receivers to the south–east on Unwins Bridge Road | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| F – Industrial receivers to the south –east | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| G – Residential receivers to the south–east on Burrows Avenue | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |

**Legend**

| Category 0 | Category 1 | Category 2 | Category 3 |
|---|---|---|---|
| NML Compliance | NML exceedance of less than 10 dB | NML exceedance of between 10 dB and 20 dB | NML exceedance of more than 20 dB |

**Discussion**

The preliminary findings of the construction noise impact assessment at the Marrickville construction site indicate:

- The predicted noise levels for enabling works indicate moderate exceedances of between 10 dB to 20 dB of the NMLs at the educational receiver in Area B and industrial receivers in Area A. Minor exceedances are predicted at Residential receivers in Area B and C, and commercial and industrial receivers in Area B and F. These are a direct result of the relative close proximity of receivers to the construction activities and the absence of any appreciable shielding between sites and receivers. Enabling works duration is approximately 10 months.
- During track works and earthworks there is a moderate exceedance of between 10 dB to 20 dB of the NML at the educational receiver in Area B. At residential receivers there is a minor exceedance at receivers in Area C.

  At commercial and industrial receivers there is a minor exceedance of up to 10 dB at the industrial area to the south east and compliance elsewhere. Earthworks duration is approximately 6 months.
- During acoustic shed construction compliance is predicted. . Acoustic shed construction duration is approximately 2 months.
- During tunnelling and precast factory operation there is a minor exceedance at educational receiver in Area B, and at the residential receivers in Area B, C, D, E and G during night-time. Tunnelling and precast duration is approximately 22 months.
- During fitout compliance is predicted. Fitout duration is approximately 14 months.

**On Site Night-Time $L_{Amax}$ Noise**

The maximum noise levels associated with on-site truck movements, deliveries by semitrailer and other activities on site can potentially cause awakening reactions (or sleep disturbance) at nearby residential receivers. The $L_{Amax}$ noise levels associated with these events comply with screening level during tunnelling with the precast factory and fitout.

### 3.15.4 Ground-borne Noise and Human Comfort Vibration Assessment

Where ground-borne noise exceedances are identified then human comfort vibration exceedances would also be present**. Appendix F** illustrates the potential ground borne noise impacts due to vibration intensive construction activities (rockbreaking) in this area. The ground-borne noise assessment indicated all receivers would comply with the ground-borne noise NMLs. Dive excavation works at this site are expected to occur during the daytime period only.

The potential ground-borne noise impacts associated with the excavation of the tunnels are discussed in **Section 3.16.1**.

### 3.15.5 Vibration Assessment

During construction of the proposed excavation vibration levels are anticipated to remain well below the vibration screening levels associated with minor cosmetic building damage. **Appendix G** illustrates the potential cosmetic damage vibration impacts due to construction activities in this area.

### 3.15.6 Traffic Noise Assessment

Traffic noise levels have been predicted for residential receivers located on the proposed access route to the Marrickville dive site. In this instance the access to the site is via the Bedwin Road, and May Street which are sub-arterial roads with significant daytime flows. The RNP base criteria, predicted $L_{Aeq(15hr)}$ daytime and $L_{Aeq(9hr)}$ nighttime noise levels with the development, and the $L_{Aeq}$ increase and sleep disturbance noise levels have been assessed in **Table 73**.

**Table 73 Marrickville Dive Site - Construction Traffic on Public Roads**

| Access Road | Base Criteria Day/Night ($L_{Aeq(15hr/9hr)}$) | Predicted Road Traffic Noise Day/Night | Predicted Road Traffic Noise Increase (dB) | RBL + 15 dB Screening Criterion (dBA) | External $L_{Amax}$ NML Level (dBA) | Predicted $L_{Amax}$ Noise Level (dBA) |
|---|---|---|---|---|---|---|
| Bedwin Rd | 60/55 | 68/62 | 0.5/1.8 | 53 | 65 | 69 |
| May St | 60/55 | 72/68 | 0.9/2.4 | 56 | 65 | 79 |

**Table 73** indicates that whilst at Bedwin Road and at May Street the base criteria are exceeded, the the predicted noise level increase ($L_{Aeq}$) associated with construction traffic complies with the 2 dB allowance during the daytime. During the night-time on Bedwin Road the predicted traffic increase complies with the 2 dB allowance, and on May Street is marginally exceeded by 0.4 dB.

There are expected to be up to 18 heavy vehicle and 90 light vehicles movements or events per hour during the night and whilst there is an exceedance of the sleep disturbance screening criterion (of up to 23 dB) and external sleep disturbance NML of 65 dBA (by up to 14 dB), the $L_{Amax}$ levels would be similar to other heavy vehicles using Bedwin Road and May Street.

## 3.16 TBM Tunnel Excavation

Two 15.5 km tunnels would be excavated for the project using Tunnel Boring Machines (TBMs). It is expected that the stations would be excavated concurrently using conventional breakers, excavators and roadheaders.

In addition to the twin tunnels and station excavations, the following underground features would also be excavated using roadheaders:

- Cross passages between the two tunnels would be provided at intervals of about 240 metres to allow for emergency access.
- Stub tunnels from the twin tunnels near Victoria Cross Station and Sydenham to allow for future extensions to the metro network.

It is anticipated that the tunnel boring machines works would occur from three sites incorporating a total of five TBMs. These sites are:

- A tunnel boring machine launch and support site in Chatswood (to the south of Chatswood Station and north of Mowbray Road), referred to as the Chatswood dive site.
- A tunnel boring machine launch and support site north of Sydenham Station (south of Bedwin Road), referred to as the Marrickville dive site.
- A tunnel boring machine launch and support site at the proposed Barangaroo Station construction site for the crossing of Sydney Harbour.

TBM retrieval sites would be at Blues Point for the south going TBMs from Chatswood and for the north going TBMs from Barangaroo and at Barangaroo for the north going TBMs from Marrickville.

The TBMs are proposed to be travelling approximately 20 m per day on a 24 hour per day basis.

### 3.16.1 Ground-borne Noise from Tunnelling

The potential ground-borne noise impacts associated with the construction of the underground tunnels and caverns have been assessed. The assessment includes the excavation of the twin rail tunnels and the underground works associated with the stations, cross passages and stub tunnels.

The assessment is based on available basement information provided by the project team at the time of assessment. It is noted that this is not a complete survey of all existing basements and a survey should be completed at the detailed design stage to confirm that all buildings with basements have been accurately included in the assessment.

#### 3.16.1.1 Excavation of Main Tunnels

**Figure 19** provides an overview chart showing the proposed tunnel depth for the entire alignment and illustrates that the tunnel depth varies from approximately 20 m to 60 m at the shallowest and deepest points respectively.

In the following assessment, where the depth of the alignment is discussed, the distance is noted as being from the existing ground surface height (ground elevation) to the track height (track elevation).

The ground-borne noise assessment is based on the worst-case predicted $L_{Aeq}$ internal ground-borne noise level when the tunnelling works are directly below each receiver and the tunnelling works are at their closest point.

Given the progression rate of the TBM (around 20 m per day), it is anticipated that the worst-case ground-borne noise impacts along the majority of the alignment would only be apparent for a relatively short period of time (ie a few days for each TBM) whilst the tunnelling works are directly beneath a particular receiver.

As the works progress and move away, a particular receiver's exposure to ground-borne noise would notably reduce. This concept is illustrated in **Figure 20**, which shows the likely internal ground-borne noise levels from TBM excavation works as it progresses past a particular location. The figure indicates that the night-time NML of $L_{Aeq(15minute)}$ 35 dBA is likely to be exceeded for up to four days as each TBM passes residential receivers within a slant distance of approximately 40 m from the tunnels.

The progress rate of roadheading is notably less (around 4 m per day), however, the vast majority of the alignment is proposed to be excavated using TBMs and roadheading only at stations, cross passages and stub tunnels.

**Figure 19 Proposed Tunnel Depth and Existing Ground Elevation**

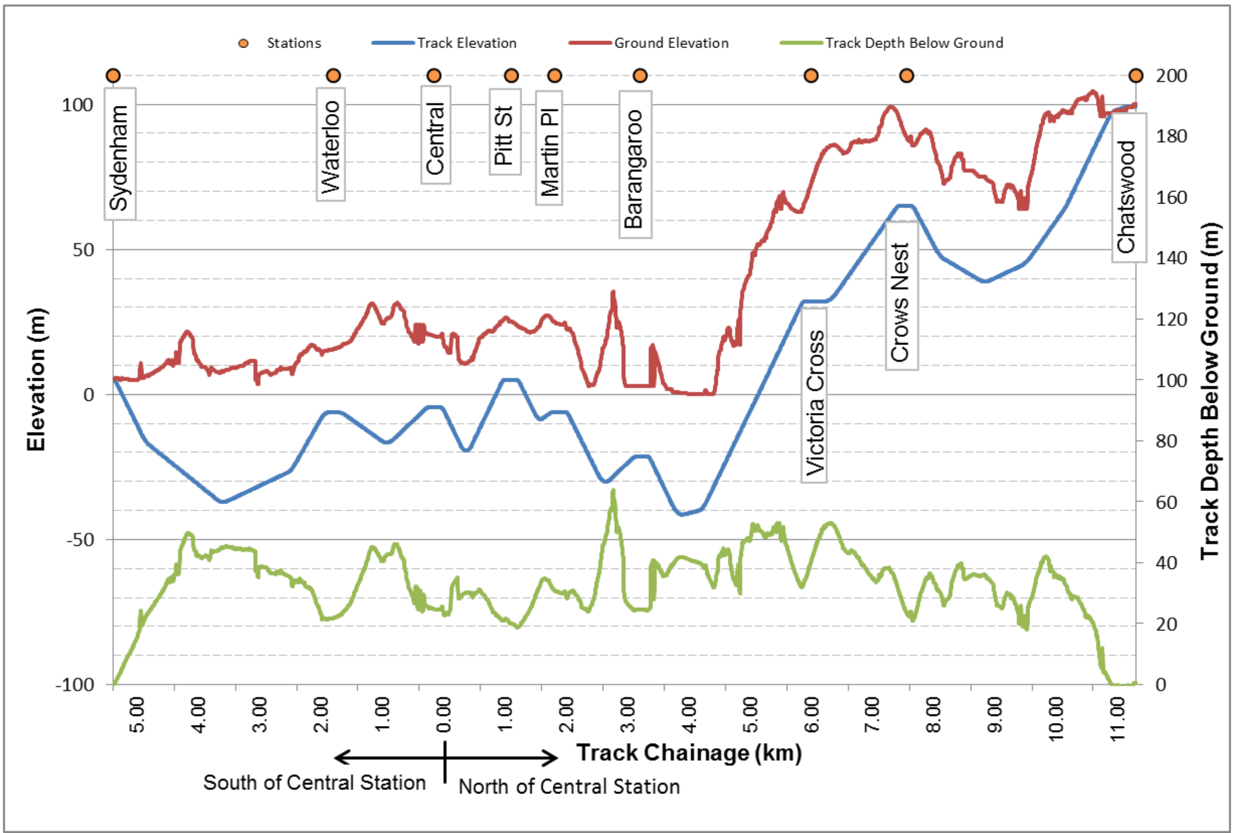
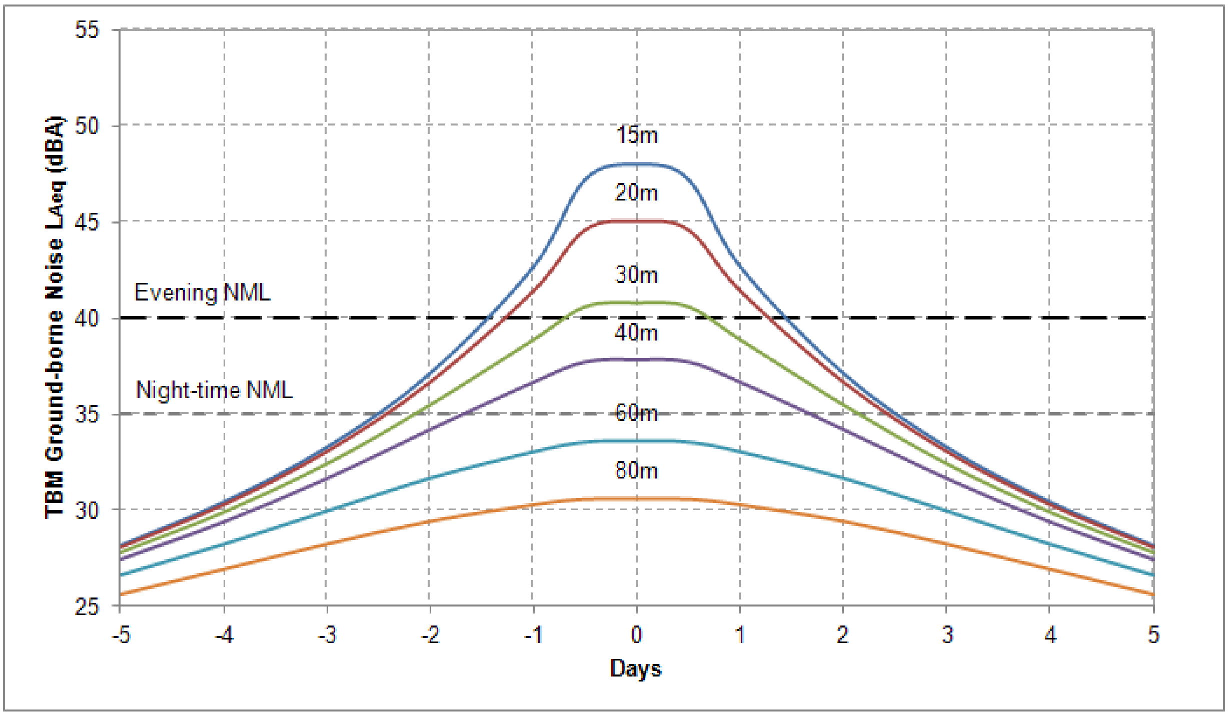



**Figure 20 Ground-borne Noise Levels at Slant Distances from TBM (Progress = 20m/day)**

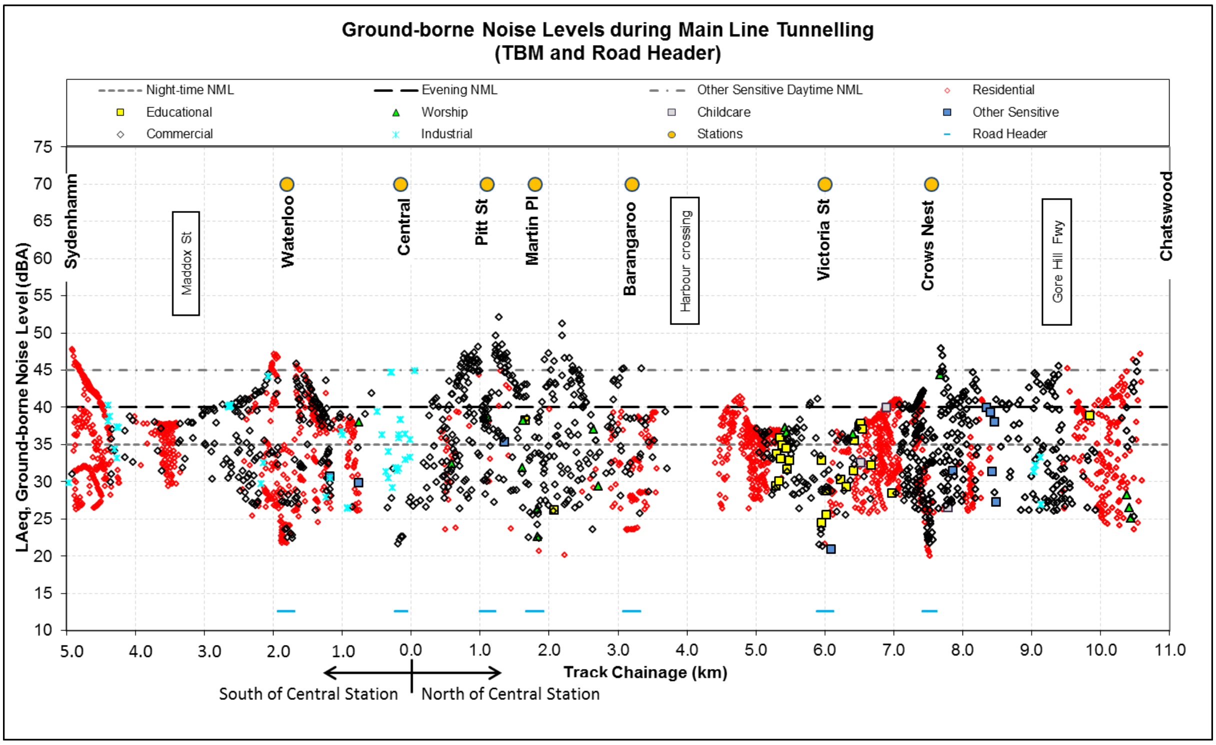


A summary graph showing the maximum predicted ground-borne noise levels from TBM excavation works is presented in **Figure 21**. The predicted maximum ground-borne noise levels from TBM excavation works are also presented on maps in **Appendix E**.

At residential locations greater than a slant distance of approximately 50 m from the nearest tunnel (ie taking into account the tunnel depth and the horizontal offset distance), exceedances of the ground-borne NML of $L_{Aeq(15minute)}$ 35 dBA during night-time periods are unlikely. At several locations, the tunnel depth at receivers directly above the proposed alignment is less than 50 m. The following sections discuss the predicted maximum ground-borne noise levels from TBM excavation works and potential impacts.

At all of the locations, the ground-borne noise predictions are based on the nearest sensitive receivers and most exposed floor (ie ground floor for commercial and lowest habitable floor for residential) above or adjacent to the proposed tunnel alignment. The ground-borne noise impacts would reduce for sensitive receivers further away from the alignment or on floor levels higher up within buildings.

**Figure 21 Ground-borne Noise from Tunnelling**

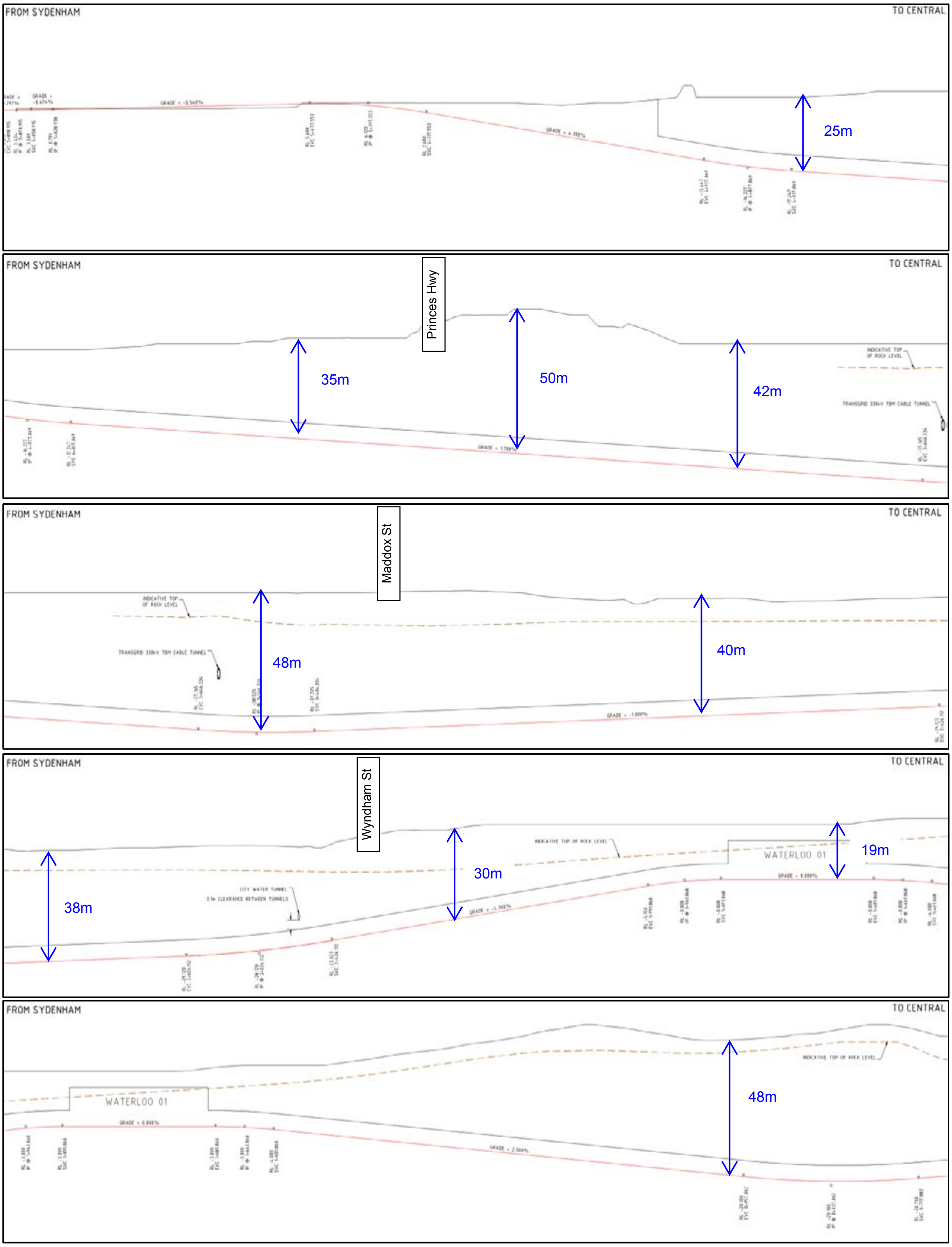


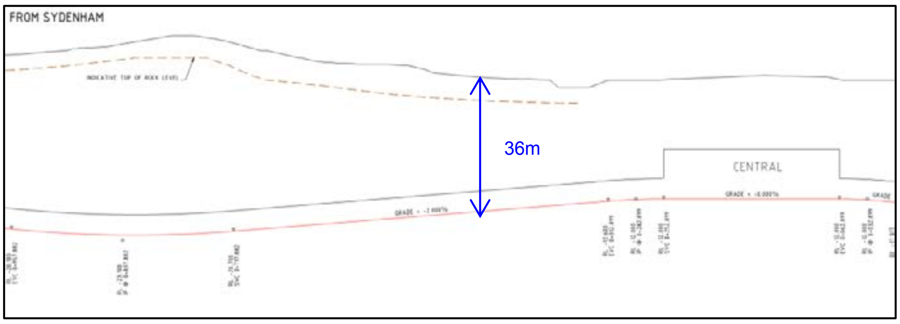

Note: The predictions are for the most exposed floor (ie ground floor for commercial and lowest habitable floor for residential) and would reduce with approximately 2 dB per floor level for higher floors.

#### 3.16.1.1.1 Marrickville Tunnel Portal to Central Station

The long sections for tunnels between the Marrickville portal and Central Station are provided in **Figure 22**.

**Figure 22 Proposed Long Sections for Tunnels – Marrickville Tunnel Portal to Central Station**






Reference to **Figure 22** indicates that the tunnel depth between the Marrickville tunnel portal and Central Station varies from a minimum depth of 19 m at Waterloo Station to a maximum depth of 50 m just west of Princess Highway.

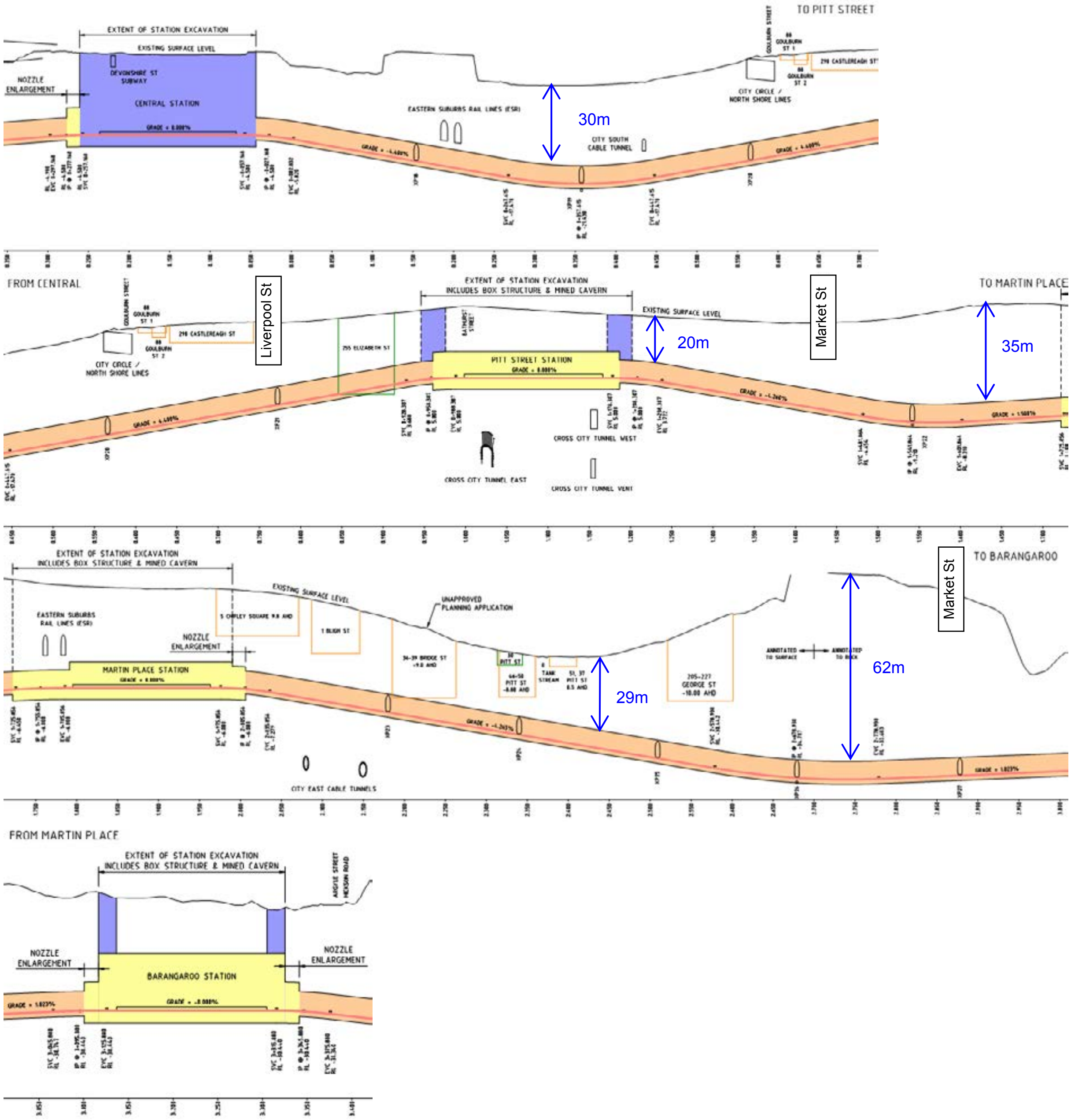
The predicted maximum ground-borne noise levels (refer **Figure 21**) and potential impacts at sensitive receiver locations are discussed below:

- Portal to Princes Highway. This is the initial low depth tunnel just after the portal under a large residential area, with a large number of potentially affected residential receivers. Worst-case exceedances of the $L_{Aeq(15minute)}$ night-time NML of more than 10 dB are predicted during TBM excavation near the portal, where the depth of the alignment is at its shallowest point. It should be noted that these receivers are located adjacent the existing rail line and exposed to high existing background noise levels.
- Princes Highway to Maddox Street. The alignment passes beneath a commercial and residential area at a tunnel depth of approximately 45 m. There are several potentially affected residential receivers. However, the worst-case predicted night-time exceedances are generally less than 3 dB.
- Maddox Street to Wyndham Street. The alignment passes beneath a commercial area with no predicted exceedances.
- Wyndham Street to Waterloo Station. The alignment passes beneath an area of commercial, mixed use and residential receivers. Just south of Waterloo Station the tunnel depth drops to close to 20 m and there are a few potentially affected residential receivers. Worst-case exceedances of the $L_{Aeq(15minute)}$ night-time NML of more than 10 dB are predicted during TBM excavation.
- Waterloo Station to Central Station. The alignment passes beneath an area of commercial, mixed use and residential receivers. Just north of Waterloo Station the tunnel depth is approximately 25 m, however, the depth quickly increase to close to 50 m before entering beneath the existing rail corridor. There are a few potentially affected residential receivers north of Waterloo Station with worst-case exceedances of the $L_{Aeq(15minute)}$ night-time NML of up to 10 dB predicted during TBM excavation.

#### 3.16.1.1.2 Sydney CBD (Central Station to Barangaroo Station)

The long sections for tunnels between the Central Station and Barangaroo Station are provided in **Figure 23**.

**Figure 23 Proposed Long Sections for Tunnels - Sydney CBD (Central Station to Barangaroo Station)**




Reference to **Figure 23** indicates that the tunnel depth for the alignment through Sydney CBD between the Central Station and Barangaroo Station varies from a minimum depth of 20 m around Pitt Street and Barangaroo Stations to a maximum depth of 62 m just south of Kent Street.

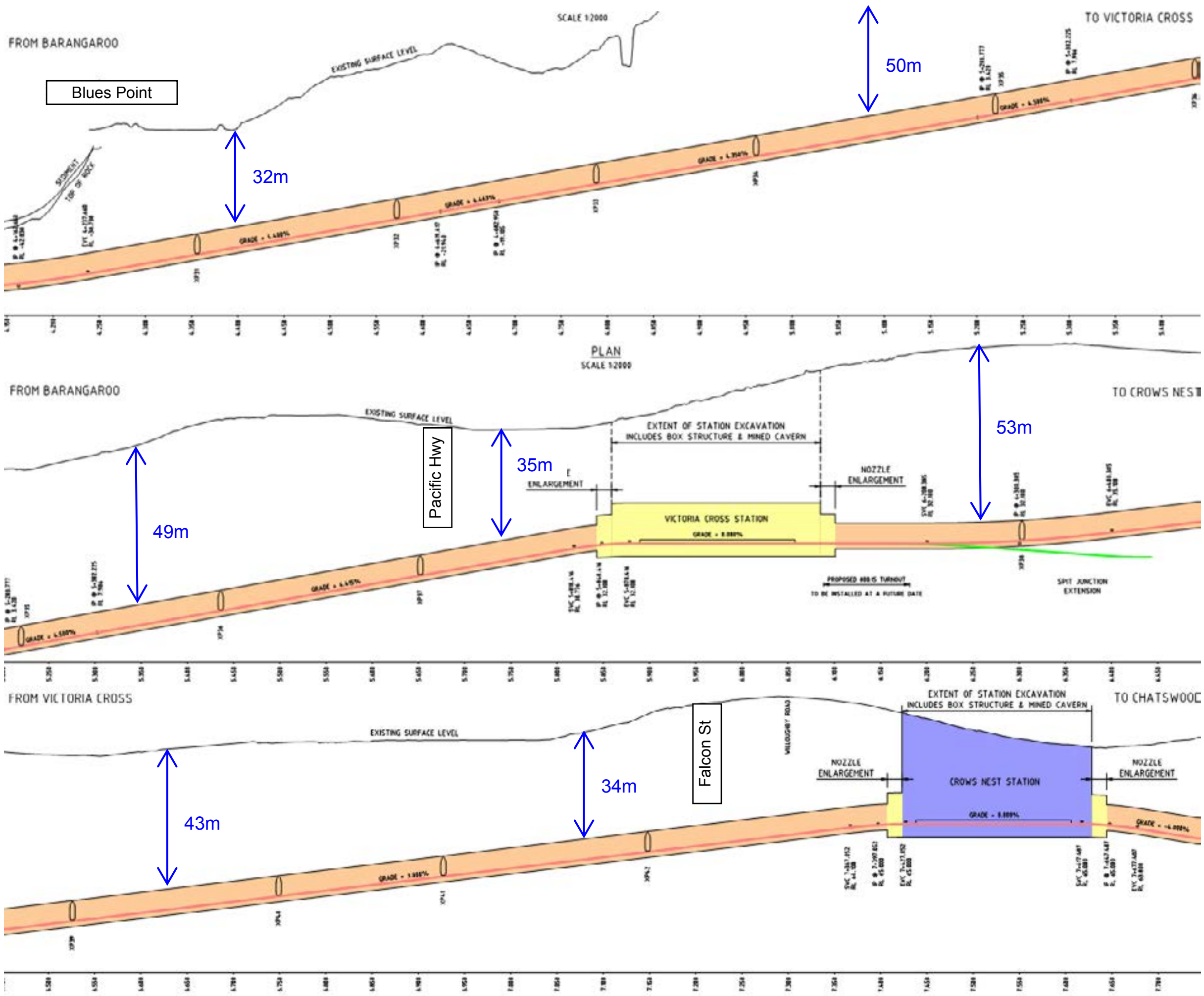
The predicted maximum ground-borne noise levels (refer **Figure 21**) and potential impacts at sensitive receiver locations are discussed below:

- Pitt Street Station and Martin Place Station. The alignment passes beneath mostly commercial and some mixed use receivers (ie commercial or retail on ground floor with residential higher up in the building) at depth of approximately 30 m. A few residential receivers (Hilton Hotel amongst these) have predicted worst-case exceedances of the $L_{Aeq(15minute)}$ night-time NML of up to 10 dB during TBM excavation near Pitt Street Station. There are also a large number of commercial receivers, with predicted ground-borne noise that would be audible. However, only one receiver is predicted to exceed the $L_{Aeq(15minute)}$ daytime NML of 50 dBA, due to the close proximity to the alignment and having 5 basement levels.
- Just north of Martin Place Station. The alignment passes beneath mostly commercial receivers at depth of between 25 m and 30 m. There are several buildings with identified basements in this area which increases the ground-borne noise transmitted into the buildings. There is one residential receiver (the Sofitel Sydney Wentworth Hotel) with predicted worst-case exceedances of the $L_{Aeq(15minute)}$ night-time NML of up to 5 dB during TBM excavation near Martin Place Station. There are several commercial receivers, with predicted ground-borne noise that would be audible. However, only one receiver is predicted to exceed the $L_{Aeq(15minute)}$ daytime NML of 50 dBA, due to the close proximity to the alignment and having 6 basement levels.
- Barangaroo Station. The alignment passes beneath a few residential receivers just before and after the Barangaroo Station at depth of approximately 20 m. There are worst-case exceedances of the $L_{Aeq(15minute)}$ night-time NML of up to 5 dB during TBM excavation.

#### 3.16.1.1.3 North Sydney (Blues Point to Crows Nest Station)

The long sections for tunnels between Blues Point and Crows Nest Station are provided in **Figure 24**.

**Figure 24 Proposed Long Sections for Tunnels - North Sydney (Blues Point to Crows Nest Station)**




Reference to **Figure 24** indicates that the tunnel depth for the alignment through North Sydney between the Blues Point and Crows Nest Station varies from a minimum depth of 32 m near the North Shore to a maximum depth of 53 m just north of Victoria Cross Station.

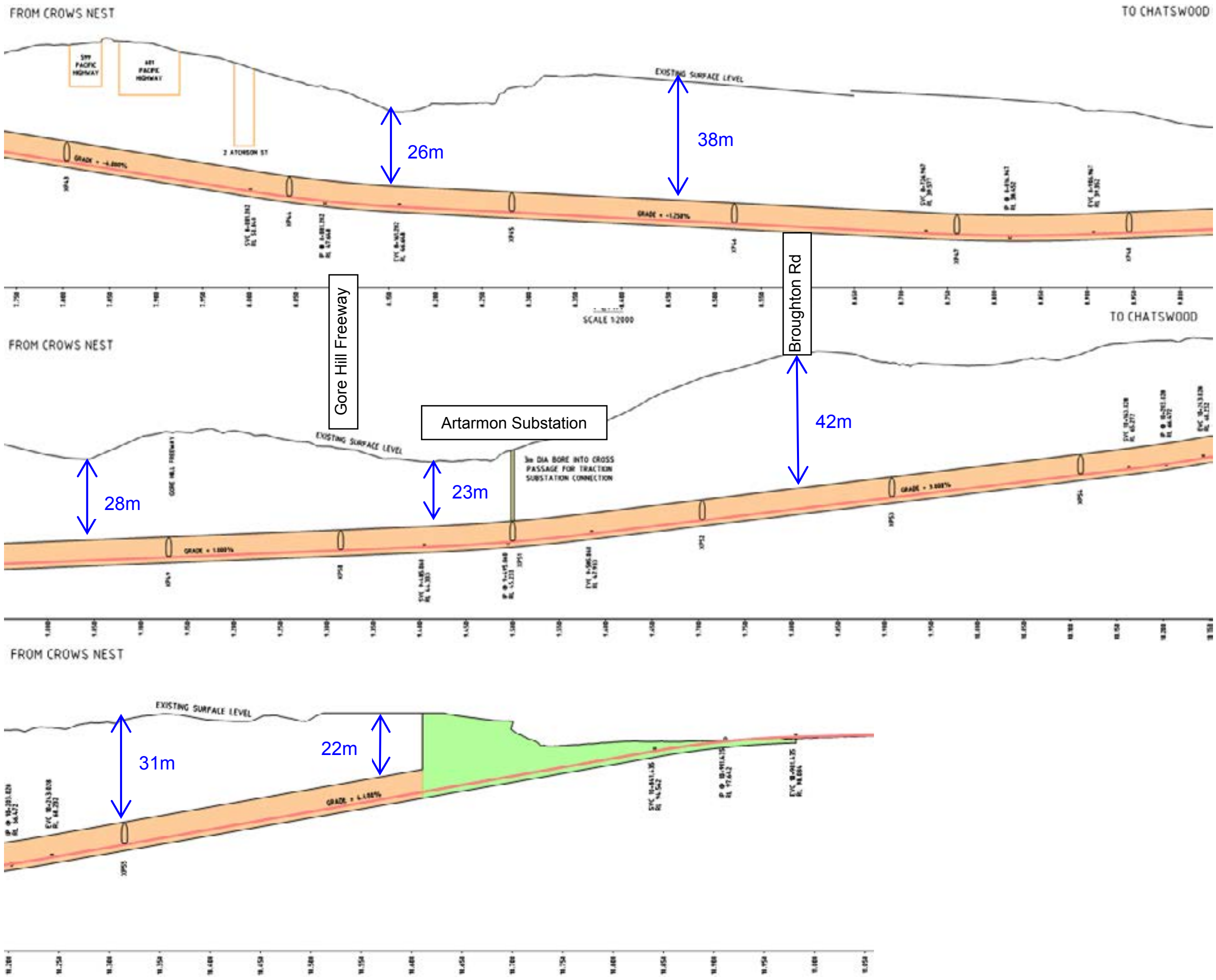
The predicted maximum ground-borne noise levels (refer **Figure 21**) and potential impacts at sensitive receiver locations are discussed below:

- Blues Point. The alignment passes beneath a residential area at depth of between 32 m and 52 m. There are a few number of residential receivers with predicted worst-case exceedances of the $L_{Aeq(15minute)}$ night-time NML of up to 8 dB close to the north shore before chainage 4.8 km (south of Princess Street). From Princess Street to just after the existing North Sydney Station there are a large number of residential receivers with a marginal predicted worst-case exceedances of the $L_{Aeq(15minute)}$ night-time NML of up to 3 dB.
- Victoria Cross Station to Crows Nest Station. The alignment passes beneath a large residential area with some educational and a place of worship at depth of between 34 m and 53 m. There are a large number of residential receivers with predicted worst-case exceedances of the $L_{Aeq(15minute)}$ night-time NML of up to 5 dB. The educational receivers and place of worship is below the $L_{Aeq(15minute)}$ NML (other sensitive receivers).

#### 3.16.1.1.4 Connection to Chatswood (Crows Nest Station to Chatswood tunnel portal)

The long sections for tunnels between Crows Nest Station and the Chatswood portal just south of Chatswood are provided in **Figure 25**.

**Figure 25 Proposed Long Sections for Tunnels - Connection to Chatswood (Crows Nest Station to Chatswood tunnel portal)**




Reference to **Figure 25** indicates that the tunnel depth for the alignment through the northern suburbs of Sydney between the Crows Nest Station to the Chatswood tunnel portal just south of Chatswood varies from a minimum depth of 23 m around the Artarmon Substation to a maximum depth of 42 m at Broughton Road.

The predicted maximum ground-borne noise levels (refer **Figure 21**) and potential impacts at sensitive receiver locations are discussed below:

- Crows Nest Station to Gore Hill Freeway. The alignment passes beneath mostly commercial receivers with a few residential receivers and the Royal North Shore Hospital at depth of between 32 m and 52 m. There are commercial receivers just north of Crows Nest Station with predicted ground-borne noise levels that would be audible, but not exceeding the $L_{Aeq(15minute)}$ daytime NML of 60 dBA. There are a few number of residential receivers with predicted worst-case exceedances of the $L_{Aeq(15minute)}$ night-time NML of up to 6 dB. The Royal North Shore Hospital is below the $L_{Aeq(15minute)}$ NML (other sensitive receivers).

- Gore Hill Freeway to Chatswood tunnel portal. The alignment passes beneath a residential area with one educational receiver at depth of between 30 m and 42 m (decreasing to 22 m just before the portal). There are a large number of residential receivers with predicted worst-case exceedances of the $L_{Aeq(15minute)}$ night-time NML of up to 10 dB. The educational receiver is below the $L_{Aeq(15minute)}$ daytime NML (other sensitive receivers).

#### 3.16.1.2 Cross Passages

Cross passages between tunnels would be spaced at regular intervals of approximately 240 m and are proposed to be excavated with roadheaders, with niches and rooms by hydraulic rock breaker.

The anticipated duration of the excavation works is 80 working days for each cross passage. During the excavation works, the potential ground-borne noise impacts would be dependent on the tunnel depth and potential basement levels for adjacent buildings. The $L_{Aeq(15minute)}$ night-time NML of 35 dBA is predicted to be exceeded at slant distances of less than approximately 30 m (which generally occurs near the tunnel portals and around Crows Nest Station, Barangaroo Station, Martin Place Station, Pitt Street Station, Central Station and Waterloo Station) for roadheading and 70 m (which would be the case for the majority of the tunnel alignment) for rock hammering. Rock hammering for cross passages and niches between 10:00 pm and 7:00 am would be precluded except where there would be no exceedances of the applicable noise management level at sensitive receivers.

#### 3.16.1.3 Stub Tunnels

Short sections of stub tunnels would be excavated adjacent to the main tunnels, located adjacent to Darley and Wells Street north of the Marrickville tunnel portal and just north of Victoria Cross Station.

The stub tunnels are expected to be excavated by roadheaders. During the excavation works for the stub tunnels, lower ground-borne noise levels compared to those during the main tunnel excavation by TBM is expected. If excavation with rock breakers is required, rock hammering for the stub tunnels between 10:00 pm and 7:00 am would be precluded except where there would be no exceedances of the applicable noise management level at sensitive receivers.

#### 3.16.1.4 Use of Rock Breakers

Rock breakers may be required at each of the above sites in situations where hard rock is encountered. Rock hammering within the tunnels between 10:00 pm and 7:00 am would be precluded except where there would be no exceedances of the applicable noise management level at sensitive receivers. If out of hours works are required, approval would need to be sought on a case by case basis with noise and vibration management mitigation measures being managed in accordance with the procedures in the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement).

### 3.16.2 Ground-borne Vibration from Tunnelling

During tunnelling works, construction related vibration levels at sensitive receivers from TBM and roadheaders would be much lower than the 7.5 mm/s screening level (relating to the threshold where minor cosmetic damage may occur).

Vibration levels may, however, be noticeable within surface buildings which are located close to the main tunnel alignment. The impacts at these locations would only be apparent for a relatively limited period (ie one or two days) as the TBMs pass by a particular location. Human comfort vibration impacts from tunnelling works would be managed in accordance with the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement).

### 3.16.3 Ground-borne Noise from Construction Work Trains

As discussed in **Section 3.2.7**, it is currently assumed that work trains would be required during construction to transport labour and materials between the TBM support sites and the work front within the tunnels.

Whilst the speed of these work trains is typically limited to approximately 10 km/h (for safety reasons), the temporary nature of the activities does not facilitate the installation of a low noise and vibration track design consistent with the requirements for passenger train operations.

On the basis that work trains are anticipated to operate during the night-time period and would have similar characteristics to train operations (in terms of the temporal characteristics), it is considered appropriate to compare the ground-borne noise levels with the operational noise trigger levels in the RING. For train operations, the following noise trigger levels are provided for residential receivers:

- Daytime (7:00 am to 10:00 pm) 40 dBA $L_{Amax}$, (slow)
- Night-time (10:00 pm to 7:00 am) 35 dBA $L_{Amax}$, (slow)

For schools, educational institutions and places of worship, the ground-borne noise trigger levels are 40 dBA to 45 dBA $L_{Amax}$, (slow), when in use.

Consistent with the requirements in RING, feasible and reasonable mitigation measures would be considered at locations where there is a risk that the ground-borne noise and / or vibration trigger levels would be exceeded. Such measures are only likely to be required at locations where the tunnel depth is relatively shallow, and may include the following:

- Use of rubber-tyred vehicles in lieu of work trains.
- Slowing down work trains at locations where the ground-borne noise and vibration trigger levels are exceeded.
- Installation of resilient layer between the track and tunnel formation (either in the form of resilient rail fasteners or ballast mat, rubber pads or similar materials placed below the sleepers).
- Grinding of uneven joints in the rail sections.

At this stage in the assessment process, there is insufficient information to undertake a thorough assessment of the potential ground-borne noise and vibration impacts associated with work train movements within the tunnels. An assessment of the potential impacts associated with the proposed construction technique would be undertaken as part of the construction environmental management documentation.

### 3.16.4 Tunnelling Ground-borne Noise Management and Mitigation Measures

Tunnelling activities are anticipated to occur on 24 hour per day basis and up to 7 days per week. At any particular receiver location, the potential ground borne noise impacts from tunnelling are anticipated to occur only for short periods of time (up to approximately 4 nights) when each TBM passes by.

There are multi storey residences and hotels in the Sydney CBD that exceed the night-time NML, however the noise predictions are for the lowest habitable floor and the noise level would be lower higher up in the buildings. As a guide, ground-borne noise levels attenuate by approximately 2 dB per floor for the first 4 floors and by approximately 1 dB per floor thereafter.

The following management strategies would be implemented where feasible and reasonable to minimise the impact of the TBM tunnelling works:

- Ground-borne noise and vibration monitoring to be undertaken at the commencement of tunnelling to refine the source data utilised for this assessment.
- Comprehensive advance notice as well as educating the public of intended tunnelling activities in the localities near the tunnel alignment. Part of the consultation process should include information regarding the monitoring program. A thorough education program will assist to allay fears of the tunnelling process.
- Slow down the progress rate of the TBM during night-time to generate less ground-borne noise levels.

Further details of management and mitigation measures are outlined in the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement).

### 3.16.5 Noise from construction of power supply routes

The ICNG suggests a qualitative noise assessment method for works which are unlikely to affect an individual or sensitive land use for more than three weeks in total. As the construction work associated with the power supply routes are not expected to affect any individual receivers for more than 3 weeks, and these receivers would be minimally impacted by the long term works of the project, a qualitative noise assessment has been carried out for these works.

Work along the power supply routes would take place generally within the road corridor and therefore would be close to receivers. In some cases the closest residential receiver would be within 10 metres of the proposed works. The following sections provide a qualitative discussion in relation to the types of activities and potential noise impacts.

#### 3.16.5.1 Trenching

Receivers along the power supply route are expected to experience elevated noise levels during periods when the trenching work is in their vicinity. The initial phase of trenching is likely to involve the use of a concrete saw to remove road pavement. This would be followed by excavation using a small excavator or bobcat.

During these works, especially during the use of concrete saws, the closest receivers could experience noise levels in excess of 75 dB(A). Additionally, as the works are located within road reserves, a substantial portion of the works may be required to be carried out outside of standard daytime construction hours. The excavation work is anticipated to progress at about 30 metres per day and it is likely that a receiver would be affected for up to two consecutive days at most.

Due to these potential high noise levels, feasible and reasonable mitigation measures would be implemented to minimise impacts to receivers. This would include:

- Carrying out works during the daytime period when in the vicinity of residential receivers, where feasible and reasonable
- Where out of hours works are required, scheduling the noisiest activities to occur in the evening period (up to 10 pm)
- Use of portable noise barriers around particularly noisy equipment such as concrete saws
- Provision of additional mitigation measures in accordance with the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement).

#### 3.16.5.2 Under-boring

Where works cross major roads or other infrastructure under-boring may be used instead of trenching. Drilling equipment would typically result in elevated noise levels which, at some receivers, could exceed 75 dB(A). It is anticipated that under boring would generally be restricted to daytime works and would be carried out for up to two weeks in any single location.

#### 3.16.5.3 Cable installation

Cable installation work is expected to be carried out during standard daytime construction hours and is not expected to cause significant noise impacts. The estimated work rate is around 500 metres per day and therefore any single receivers would only be affected for about one day.

#### 3.16.5.4 Road and footpath re-instatement

Road and footpath re-instatement works have the potential to cause elevated noise levels in the vicinity of sensitive receivers. Additionally, these works are likely to occur outside of standard daytime construction hours to minimise traffic impacts. Re-instatement works are expected to progress at about 30 metres per day and therefore any single receiver would likely be affected for up to about two days.

# 4 OPERATIONAL NOISE AND VIBRATION ASSESSMENT

This section covers the operational noise and vibration assessment. An overview of the assessed operational noise and vibration sources is as follows:

- Ground-borne noise and vibration from trains operating within the project tunnels.
- Airborne noise from metro trains operating between the Chatswood tunnel portal and just south of Chatswood Station, suburban and intercity trains operating between Brand Street, Atarmon and just south of Chatswood Station, and metro trains operating immediately outside the Marrickville tunnel portal
- Airborne noise from mechanical plant and tunnel ventilation systems at stations and other ancillary facilities.

## 4.1 Ground-borne Vibration - Train Operations

### 4.1.1 Introduction

Rail vibration is generated by dynamic forces at the wheel-rail interface and occurs, to some degree, even with continuously welded rail and smooth wheel and rail surfaces (due to the moving loads, finite roughness and elastic deformation of the surfaces). Higher vibration levels occur in the presence of rail and wheel surface irregularities.

This vibration propagates via the rail mounts into the ground or track support structures. It then travels through the ground or structures and in some circumstances may sometimes be felt as tactile vibration by the occupants of buildings. If the levels of vibration are sufficiently high (ie in buildings very close to rail tracks), then 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 an 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 4.2**.

### 4.1.2 Ground-borne Vibration Goals

#### 4.1.2.1 Human Perception of Vibration

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.

The thresholds of perception for continuous whole-body vibration vary widely among individuals. Approximately half the people in a typical population, when standing or seated, can perceive a vertical weighted peak acceleration of 0.015 $m/s^2$ as stated in Annex C of AS 2670.1:2001 '*Evaluation of human exposure to whole-body vibration - Part 1: General requirements*[xvi] (AS2670.1). Converted to vibration velocity, the perception threshold is approximately 0.1 mm/s Root Mean Square (RMS).

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 continuous vibration include generators, compressors and other continuous operating plant. Examples of impulsive vibration events include the vibration generated by blasting, or dropping of heavy equipment. Examples of intermittent vibration events include vibration generated by train passbys, vibratory roller passbys, drilling and materials handling.

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 is the case for continuous vibration. As such, higher vibration goals are usually applicable for short term, intermittent and impulsive vibration activities than for continuous sources.

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 4.1.3**.

#### 4.1.2.2 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 are the human comfort goals. It is therefore not necessary to set separate design objectives for this environmental impact statement in relation to the effect of rail 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 generic vibration criteria within commonly referenced sources in the literature[1].

#### 4.1.2.3 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 rail vibration, as compliance with the human comfort design objectives would ensure compliance with any criteria related to potential structural damage.

[1] *ANC Guidelines - Measurement and Assessment of Ground-borne Noise & Vibration,* Association of Noise Consultants (2012) and *Vibration Control Design of High Technology Facilities*, Journal of S & V, Ungar, Sturtz & Amick (1990).

### 4.1.3 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* (2006)[xvii]
- British Standard BS 6472-1992 - *Evaluation of Human Exposure Vibration in Buildings (1 Hz to 80 Hz)*[xviii]
- *Assessing Vibration: A Technical Guideline* (DEC, 2006)[xix].

The following discussion expresses root mean square (RMS) 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 has been withdrawn, however there is no new replacement and it has still been referred to due to the long history of application on Australian projects. The 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 project operations.

*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.

#### 4.1.3.1 Proposed Vibration Design Objectives

The proposed project vibration design objectives for residential receivers are in line with those applied for the Sydney Metro Northwest and are based on the continuous vibration levels in AS 2670 and *Assessing Vibration: A Technical Guideline*.

The proposed design objectives for residential and other sensitive receiver categories are listed in **Table 74**. 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 74 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 rail tunnels, the ground-borne noise trigger levels presented in **Section 4.2.3** almost always require lower vibration levels than the vibration objectives indicated in **Table 74**. Hence other than at specific specialist facilities with particularly high sensitivity to vibration, compliance with the ground-borne noise trigger levels would ensure that the vibration design objectives is achieved.

The generic vibration criterion curve C (Colin G. Gordon - 28 September 1999) is used as a trigger level for further investigation for identified receivers likely to have highly vibration sensitive equipment. The VC-C curve 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 (refer further discussion in **Section 3.1.10**).

### 4.1.4 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*[xx] provides relevant guidance 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 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 project 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.

#### 4.1.4.1 Modelling Approach

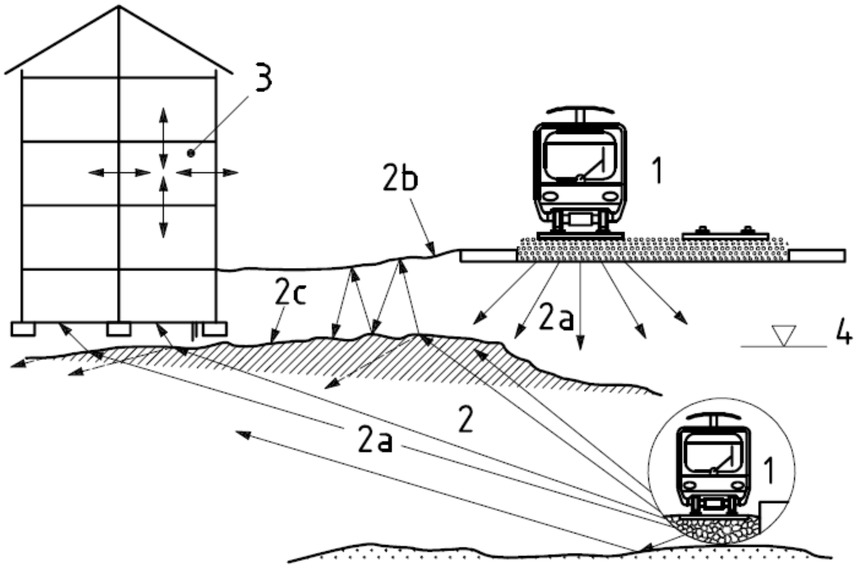
The prediction of ground-borne noise and vibration from rail systems is a complex and developing technical field. Whilst much research has been undertaken into various aspects associated with ground-borne impacts from rail systems, there are currently no commercially available modelling software packages.

The modelling for the project was therefore carried out using a modelling process for the core calculations developed by SLR. 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 whilst a test train was operating in the tunnel under controlled conditions. As part of this testing, SLR 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 project assessment.

An overview of the ground-borne noise and vibration modelling approach is illustrated in **Figure 26**. 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 the propagation of vibration within the building elements (3).

**Figure 26 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.

#### 4.1.4.2 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 expected similarities of the project to the ECRL (in terms of tunnel diameter, geology, concrete lining, slab track design, etc), the source vibration levels for the new fleet of single deck, metro 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.

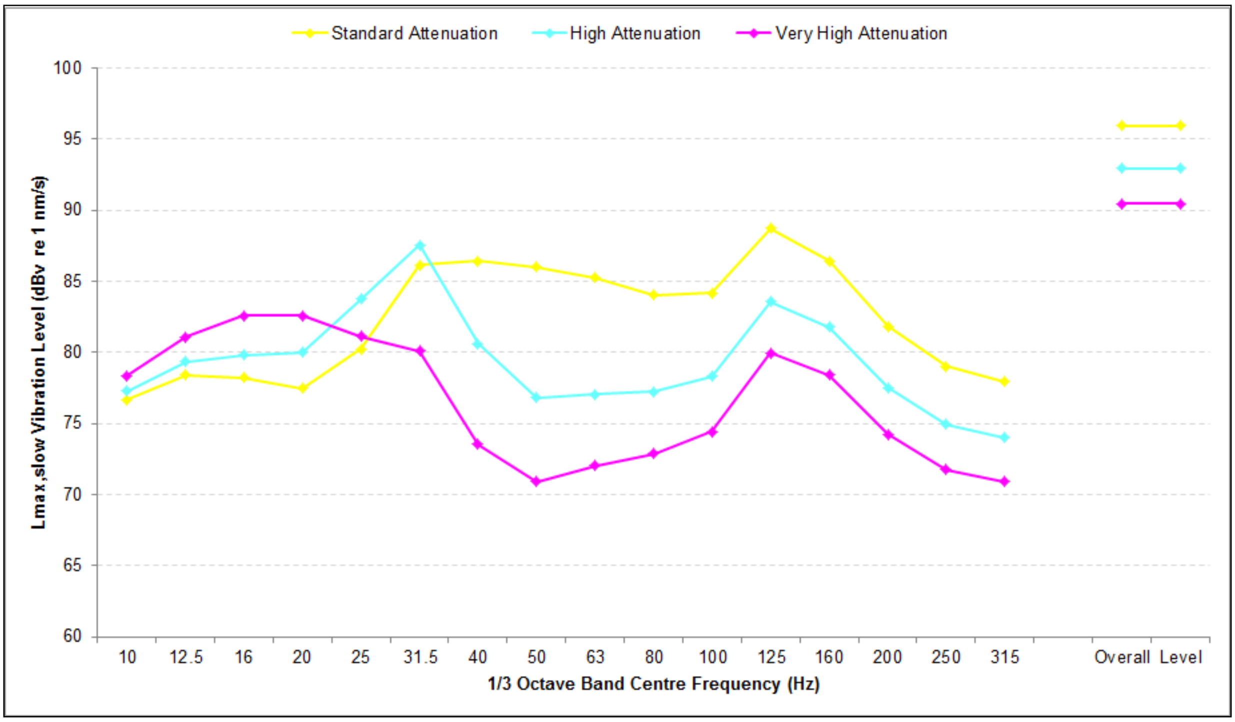
In the absence of specific measured data relating to the proposed single-deck trains, source vibration levels have been assumed to be equivalent to A-Set (Waratah) trains, which are the most modern trains currently operating on the Sydney rail network. This assumption is considered to be slightly conservative 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 75** and **Figure 27**. These track forms are project-specific, taking into account the relevant design factors described below under the Track Form Design heading.

**Table 75 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 Hz | 12 Hz | 16 Hz | 20 Hz | 25 Hz | 31.5 Hz | 40 Hz | 50 Hz | 63 Hz | 80 Hz | 100 Hz | 125 Hz | 160 Hz | 200 Hz | 250 Hz | 315 Hz | |
| 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 27 Reference Source Vibration Levels (Tunnel Wall at 80 km/h) - Lmax,slow,95%**




#### 4.1.4.2.1 Route Alignment

The proposed tunnel alignment was guided primarily by the general location of metro stations. However, in order to reduce proximity to sensitive receivers, the project alignment has, where practicable, been located below or near to major roads and existing surface rail corridors including the Pacific Highway, Miller Street, Castlereagh Street and Pitt Street.

From a ground-borne noise and vibration perspective this is advantageous because the nearest sensitive receivers have existing noise exposure from road and rail traffic (which often masks the effects of ground-borne noise) or are commercial or industrial in nature and therefore less susceptible to ground-borne noise and vibration emissions. In other sections, the proposed alignment runs beneath suburban residential areas not directly adjacent to 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 track radii less than approximately 600 m, measurements undertaken by SLR on the Singapore Circle Line indicated that there is a general increase in source vibration levels of approximately 5 dB. On this basis, 5 dB has been added to the source vibration levels at the locations identified in **Table 76**.

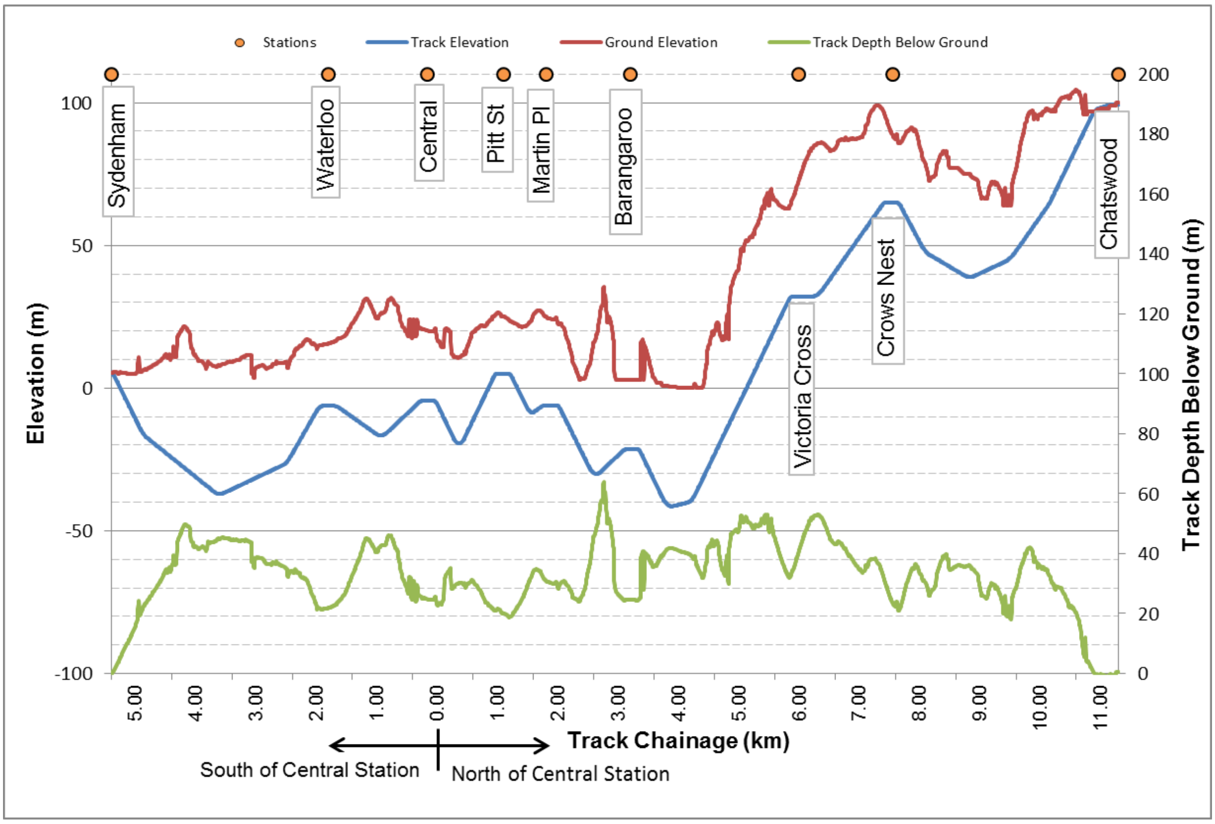
**Table 76 Location of Curve Radii Less than 600 m**

| Chainage (m) | | Curve Radius (m) | Chainage (m) | | Curve Radius (m) |
|---|---|---|---|---|---|
| **Start of Curve** | **End of Curve** | | **Start of Curve** | **End of Curve** | |
| **North of Central Station** | | | | | |
| **Up Track (Southbound)** | | | **Down Track (Northbound)** | | |
| 1,370 | 1,440 | 600 | 170 | 600 | 550 |
| 1,630 | 1,690 | 600 | 760 | 860 | 400 |
| 2,050 | 2,515 | 280 | 1,365 | 1,450 | 250 |
| 2,675 | 3,060 | 260 | 1,550 | 1,760 | 575 |
| 3,640 | 3,740 | 600 | 2,070 | 2,470 | 250 |
| 4,790 | 5,105 | 400 | 2,615 | 3,020 | 274 |
| 6,270 | 6,840 | 514 | 4,220 | 4,490 | 600 |
| 7,175 | 7,315 | 500 | 4,740 | 5,075 | 414 |
| 9,805 | 10,355 | 600 | 6,220 | 6,780 | 500 |
| | | | 7,120 | 7,260 | 500 |
| **South of Central Station** | | | | | |
| **Down Track (Southbound)** | | | **Up Track (Northbound)** | | |
| | | | 2,020 | 2,990 | 600 |

Note: The chainage is defined as increasing away from Central Station. Tracks traveling away from Central Station are called Down Track and tracks traveling to Central Station are called Up Track.

The tunnel depth (i.e. rail track level) along the project alignment is shown in **Figure 28**. It can be seen that the rail tracks under the Sydney CBD (chainage 0 m to 3,600 m) are between 20 m and 40 m underground. There are no tunnel sections with the rail tracks less than 20 m below ground.

**Figure 28 The Project Tunnel Depth vs Chainage**




Note: The chainage is defined as increasing away from Central Station. Tracks traveling away from Central Station are called Down Track and tracks traveling to Central Station are called Up Track.

#### 4.1.4.2.2 Rolling Stock Design

The proposed rolling stock to be utilised on the project would comprise modern, single-deck, metro trains. The trains would be approximately 160 m to 170 m long in an 8-car configuration (6-car trains would be used at opening and increased to 8-car trains as demand increases). 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.

#### 4.1.4.2.3 Rail Type

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

#### 4.1.4.2.4 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 rail lines.

The broad principles of vibration isolation for rail lines consist of a reduction in the dynamic stiffness of the track support and an 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.[2]

[2] *ANC Guidelines - Measurement and Assessment of Ground-borne Noise & Vibration,* Association of Noise Consultants (2012), Page209.

Mitigation of ground-borne noise and vibration levels in buildings near rail 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 29** 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 30**.

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.

The final track form design and associated mitigation measures would be addressed in the detailed design to be undertaken by the successful contractor. The track form design assessed as part of this environmental impact statement identifies one option for achieving the ground-borne noise and vibration objectives.

**Figure 29 Generic Track Forms to Mitigate Ground-borne Noise and Vibration on Slab Track**

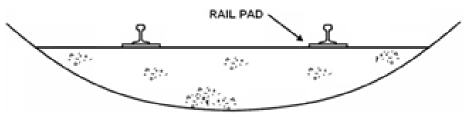
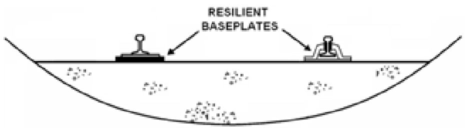
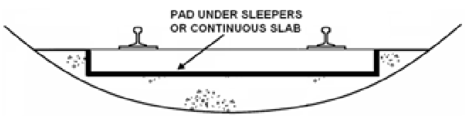
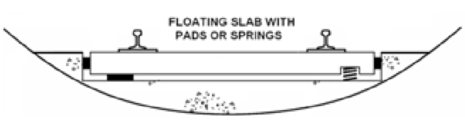
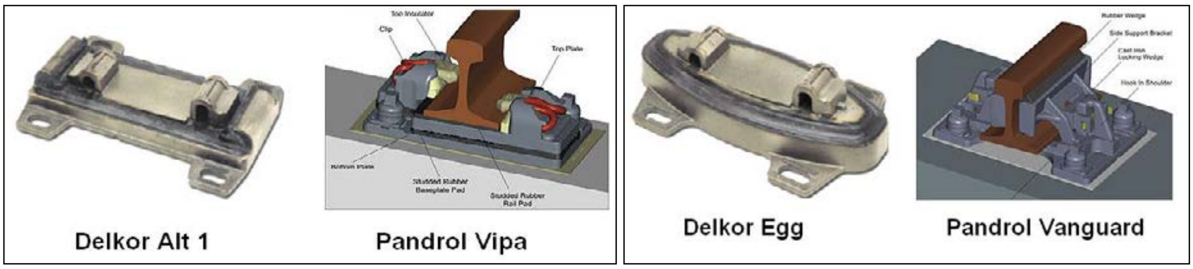
| ***Generic Track Form Layouts*** | ***Acoustic Performance*** | ***Description*** |
|---|---|---|
|   | | *Direct fixation with standard rail foot pads (eg HDPE)* |
|   | | *'Hard' resilient baseplates (eg, Delkor Alt 1, Pandrol Vipa, Pandrol Double Fastclip)* |
| | ***Increasing Ground-borne Noise and Vibration Reduction*** | *'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 30 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 stiffness properties for a number of different track forms are provided in **Table 77**.

**Table 77 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 would 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 may require further investigation 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 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 would 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).

#### 4.1.4.2.5 Track Forms

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 project design assumes a rail fastener spacing of 700 mm for all track form options.

In the project 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 the base case 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 75** and **Figure 27**.

#### 4.1.4.2.6 Turnouts

There are no proposed turnouts or crossovers within the tunnels. There are however two future potential tunnel extensions and associated turnouts south of Central Station and just north of Victoria Cross Station.

As there is a discontinuity in the rail running surface at these turnouts, vibration levels would be higher than on smooth continuous track. 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's experience on previous projects.

The potential increase in ground-borne vibration and noise from the future turnouts would be designed and mitigated as part of these future projects. If required, mitigation could include specification of alternative turnouts (such as swingnose) and/or higher attenuation track form fasteners for a section adjacent to the turnouts.

#### 4.1.4.2.7 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 approximately 6 m has been evaluated for the project design.

#### 4.1.4.2.8 Construction Tolerances

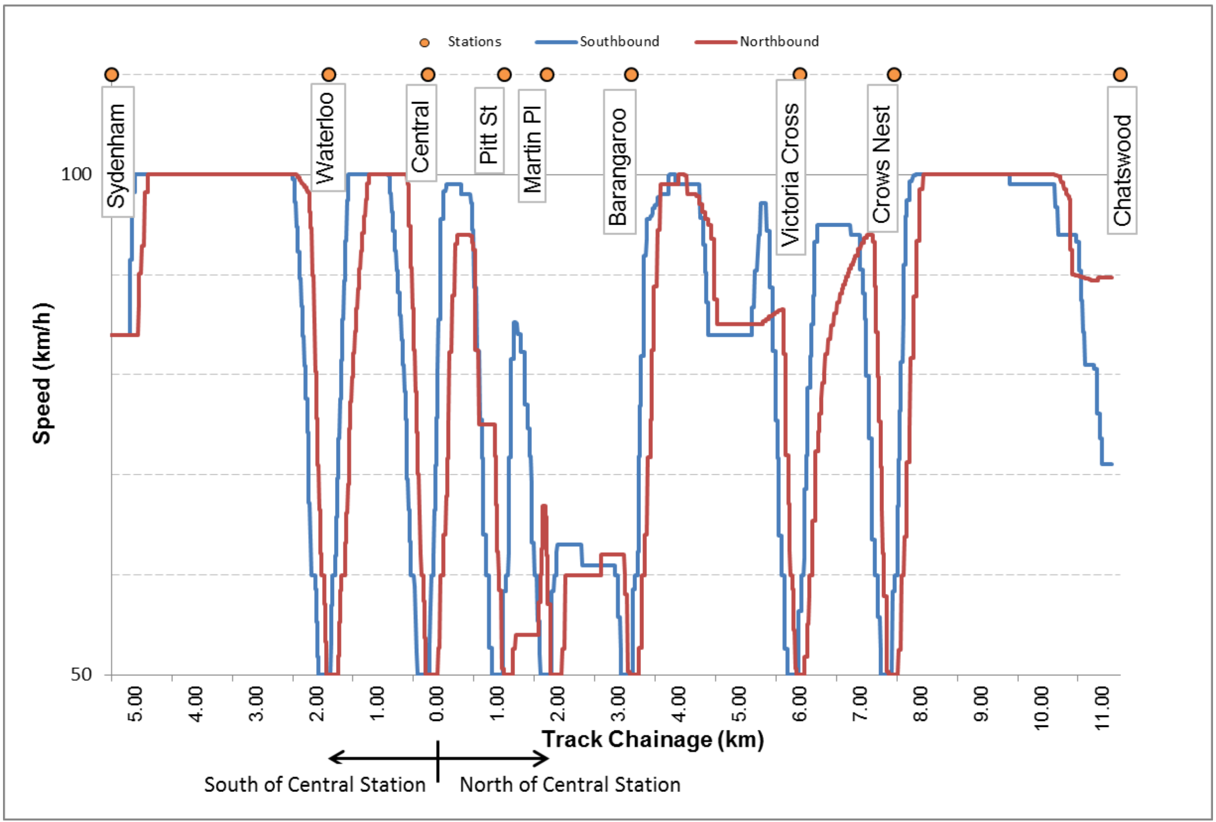
Construction tolerances refer to factors such as the variation in stiffness values between rail fasteners, the quality of the track construction and any change in stiffness values with time.

The potential effect of construction tolerances has not been evaluated as part of the assessment and will be required to be addressed in the detailed design and procurement processes. Control of these effects is anticipated to be feasible, and therefore construction tolerances are not considered further in this assessment.

#### 4.1.4.2.9 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 31**. For the purpose of the ground-borne noise and vibration modelling, a minimum speed of 50 km/h has been assumed at the stations.

**Figure 31 Speed Profile**




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 on other projects (including ECRL) and has therefore been adopted for the modelling.

The reference vibration levels adopted in the modelling process are for a train speed of 80 km/h (refer to **Table 75**). The maximum train speeds proposed for the project is 100 km/h. **Figure 31** 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:

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

The potential impact of simultaneously passing trains at particular receiver locations on a regular basis has not been evaluated in detail as part of the 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.

#### 4.1.4.2.10 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. Additional information on rail roughness management as applied to the ECRL may be found in Vegh et. al. *Acoustic rail grinding - measures of long term effectiveness: Epping to Chatswood Rail Link case study* [xxi].

The source vibration levels are also based on the 95th percentile (highest 5%) of train vibration levels observed, as required by the RING. The project would include wheel condition monitoring systems and a wheel lathe at the Sydney Metro Trains Facility (part of Sydney Metro Northwest). 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 incorporation of anti-skid braking systems in the design. If wheel flats or other wheel defects do occur, 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.

#### 4.1.4.2.11 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.

### 4.1.4.3 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.

#### 4.1.4.3.1 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:

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

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

#### 4.1.4.3.2 Vibration Attenuation due to Material Damping

The indicated ground geology along the proposed alignment is predominantly Hawkesbury sandstone and Ashfield shale.

The excess attenuation due to material damping for the project was based on bore hole vibration testing undertaken by SLR as part of the Sydney Metro Northwest project and the now abandoned 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.

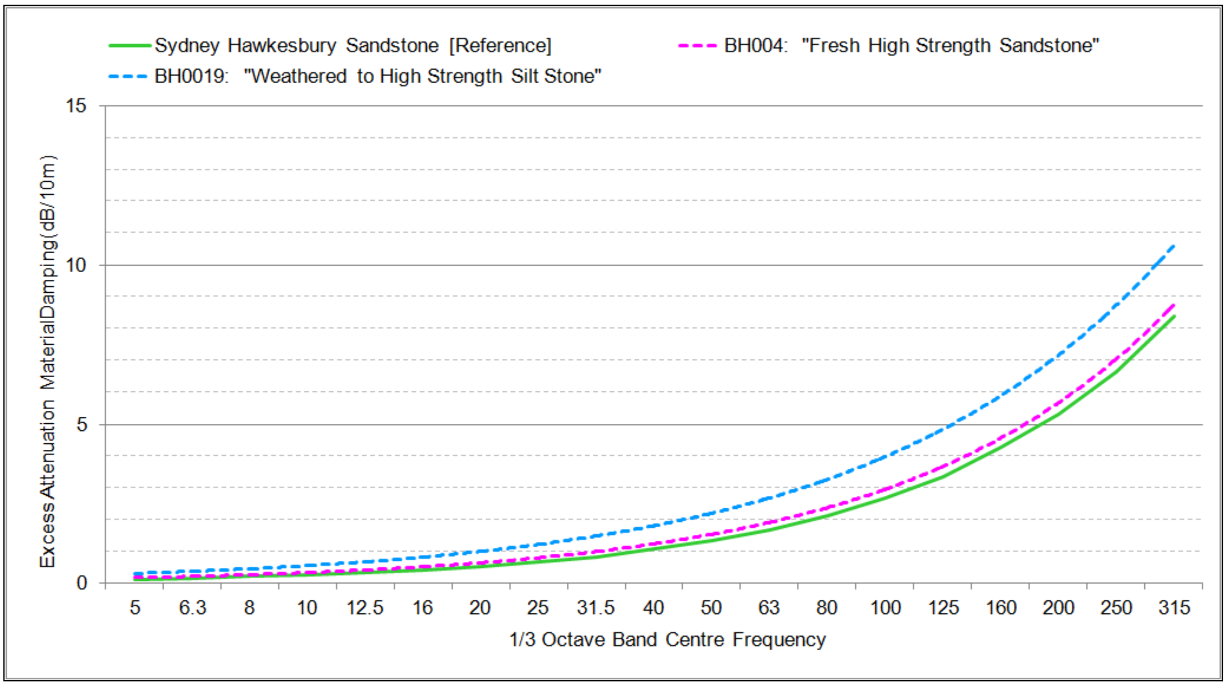
These excess attenuation levels (shown by the green line in **Figure 32**) were adopted on the basis that they provided a good conservative estimate of the measured damping properties for Hawkesbury sandstone and Ashfield shale, which are the predominant ground types through which the project alignment passes.

The measured excess attenuation due to material damping for Hawkesbury sandstone (pink dashed line in **Figure 32**) was found to be consistent with previous measurement data for this ground type. The measurements for Ashfield shale (blue dashed line in **Figure 32**) found slightly higher excess attenuation values compared to Hawkesbury sandstone.

A conservative estimate of the excess attenuation according to values presented in **Figure 32** has therefore been implemented for the length of the project 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 whole alignment.

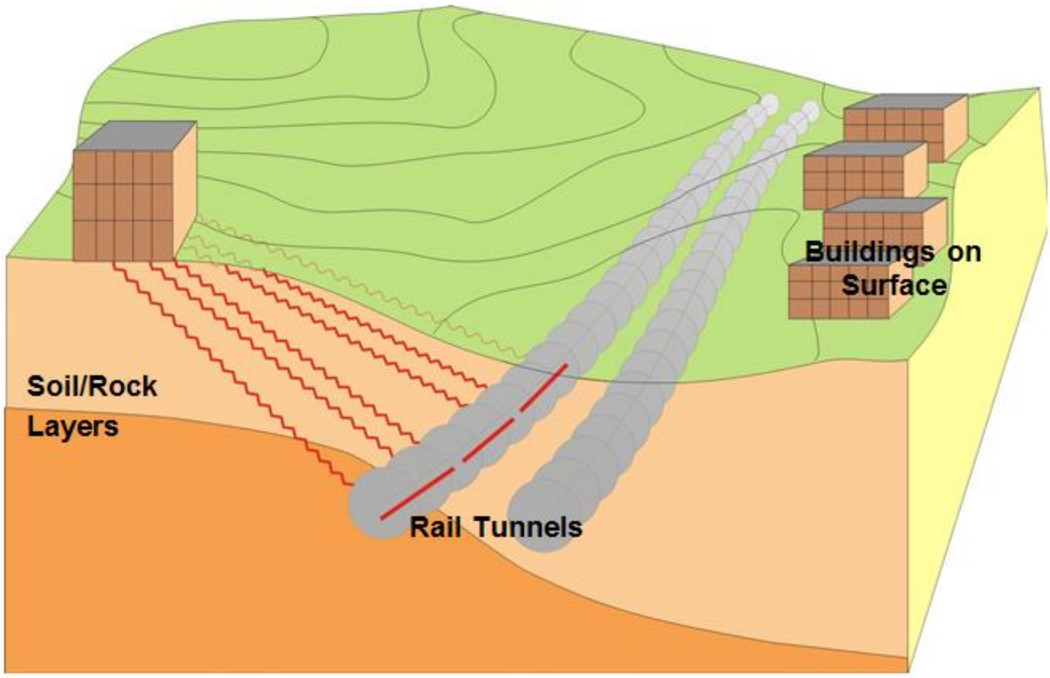
**Figure 32 Excess Attenuation Due to Material Damping**



#### 4.1.4.3.3 Three-Dimensional Modelling

The importance of undertaking three-dimensional modelling is illustrated in **Figure 33**. 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 33 Possible Propagation Paths from Train in Tunnel to Surface Buildings**




### 4.1.4.4 Receivers

#### 4.1.4.4.1 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 constructions.

For many buildings situated near to the project alignment, it is likely that the building footings will be founded in the underlying bedrock. 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 78** together with typical coupling loss data for common building structures.

At this stage of the project only limited information regarding basements is available and modelling would be refined during the detailed design to incorporate all basement levels for potentially impacted buildings.

**Table 78 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 the project | 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[3] and have been extrapolated to include frequency bands below 16 Hz.

#### 4.1.4.4.2 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 79**, which are also based on data presented by Nelson (1987), 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.

**Table 79 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).

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

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 80** 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[4]. The values below have been adopted in the project model for all receivers.

**Table 80 Amplification within Buildings Values**

| Floor Level Above Grade | Floor-to-Floor Amplification (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.

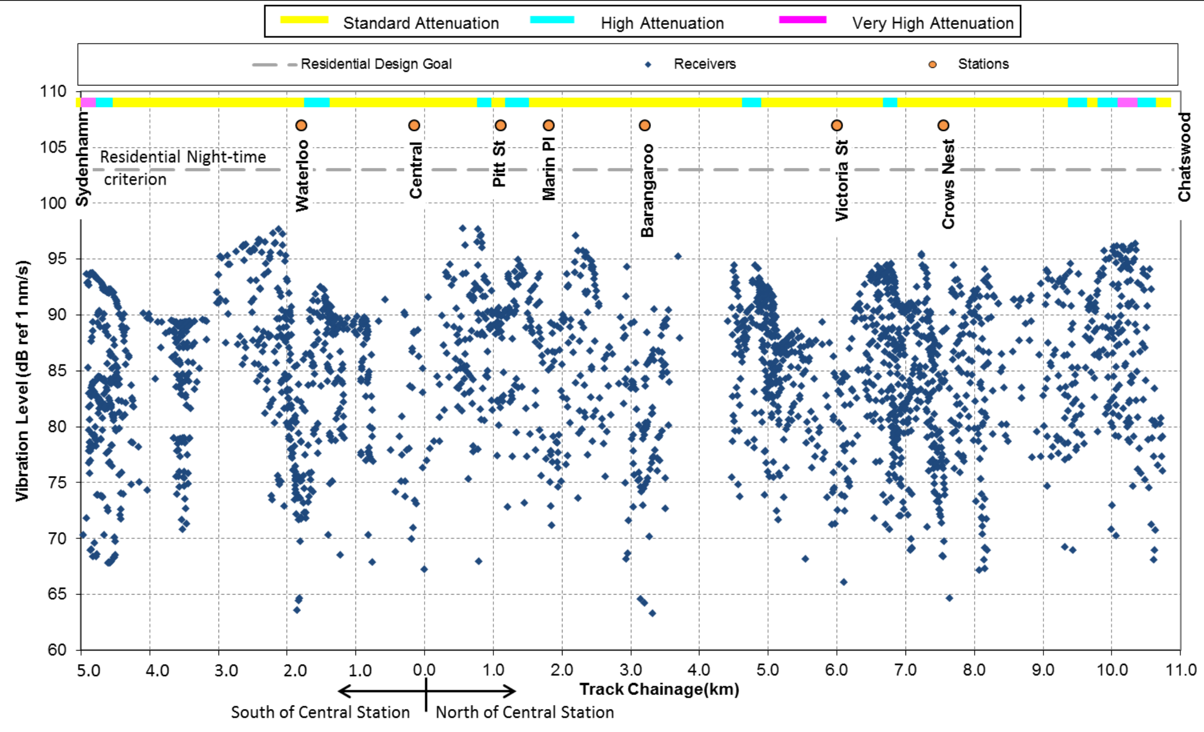
### 4.1.5 Ground-borne Vibration Predictions

**Figure 34** 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 **Section 4.2.7**) and represent the maximum mid-floor vibration levels within multi-storey buildings.

[4] *ANC Guidelines - Measurement and Assessment of Ground-borne Noise & Vibration,* Association of Noise Consultants (2012).

**Figure 34 Predicted Ground-borne Vibration Levels (Proposed Track Form)**




#### 4.1.5.1 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 (within approximately 150 m of the alignment) medical (with MRI or imaging facilities) and special research facilities may contain highly sensitive equipment such as lithography or optical/electronic inspection equipment with high resolution (down to 1 micron). **Table 81** presents predicted ground-borne vibration levels for special facilities that are located in proximity to the proposed alignment.

**Table 81 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 |
| Royal North Shore Hospital | 8.46 | 82 | **74** |
| Health Care Imaging Services | 1.00 | | **75** |

### 4.1.6 Surface Track Ground-borne Vibration Predictions

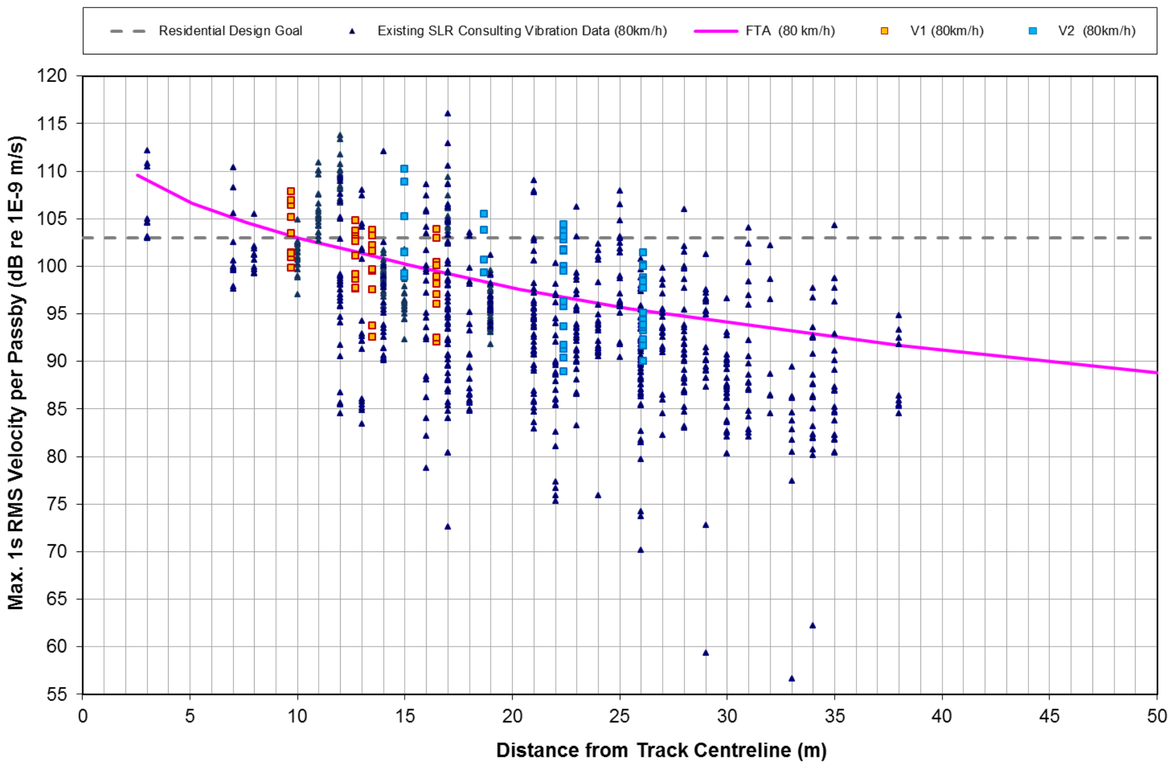
Vibration measurements of passenger train passbys on surface track were undertaken in the Sydney Metro project area at two locations (as described is **Section 2.4.4**).

Vibration propagation characteristics can be highly variable depending on the ground conditions at a given location. The US Federal Transit Administration's (FTA's) Transit Noise and Vibration Impact Assessment report provides indicative vibration levels versus distance for a variety of transport systems, including metro style rail systems. The base curve, shown in **Figure 35** shows the typical ground surface vibration levels assuming rolling stock and rail in good condition and a train speed of 80 km/h. At other speeds, the change in vibration level is approximately proportional to 20 x log(speed/80 km/h), however the manual notes that sometimes the speed relationship has been observed to be as low as 10 to 15 x log(speed/80 km/h).

The vibration measurement results for passenger train passbys in the Sydney Metro project area are presented in **Figure 35** for comparison with the FTA vibration vs distance base curve (adjusted for speed to represent the 80 km/h reference).

Vibration measurements undertaken adjacent to the Sydney metropolitan network on other projects undertaken by SLR Consulting are also included in **Figure 35** to demonstrate the variability of results according to train and location characteristics. The vibration levels are expressed in terms of the RMS vibration velocity level in dB (re 10-9 m/s). The measurement data obtained as part of the current study represent the maximum vibration levels observed during each train passby.

**Figure 35 Ground Surface Vibration Levels Versus Distance (adapted from Figure 10-1 in FTA's Transit Noise and Vibration Impact Assessment Report)**



From the measurement results taken within the Sydney Metro project area it is evident that the vibration levels at locations V1 and V2 are typically consistent with that predicted by the FTA base curve with some measurements higher on average and others lower on average. The variation in measured vibration levels from the FTA base curve is likely to be due to the local ground conditions at the measurement locations and the propagation path from the tracks into the ground.

Section B2.3 of the DECC vibration guideline indicates that the threshold of perception for most people is approximately 103 dB RMS (0.14 mm/s). From the measurement results presented in **Figure 35**, it is anticipated that for some train passbys, vibration levels may be perceptible at times where buildings are located within approximately 20 m from the nearest track. It is noted that the observed average train speeds for Sydney Trains operations on the T1 North Shore Line in the vicinity of the Chatswood dive are approximately 20 km/h lower than the 80 km/h line speeds for this region. Therefore the average vibration impacts are likely to be approximately 2.5 dB lower than the FTA base curve displayed in **Figure 35**.

Some residential buildings located immediately adjacent the surface rail track in the vicinity of the Chatswood dive may experience an increase in train passby vibration levels. Residential receivers located on the eastern side of the surface rail corridor in between Mowbray Road and Gordon Avenue, Chatswood are located approximately 11 m (horizontally) from the nearest existing rail track (T1 North Shore Line Up track). As a result of the track realignment associated with the project, the nearest track would be located approximately 8 m (horizontally) from the nearest residential receiver. According to the FTA base curve displayed in **Figure 35**, this change in track to receiver distance equates to a change in vibration level of approximately 2 dB. This level of change in vibration level is expected to be barely perceptible to most people.

Train passby vibration levels may exceed the night-time 103 $dB_V$ vibration criteria at residential receivers located within 10 m of the design alignment. This includes four residential receivers located on the Up side of the surface rail corridor between Mowbray Road and Gordon Avenue, Chatswood.

However, the maximum predicted VDV value is 0.1 $m/s^{1.75}$ during the day and 0.07 $m/s^{1.75}$ during the night, which is well below the VDV criterion of 0.2 $m/s^{1.75}$ during the day and 0.1 $m/s^{1.75}$ during the night in accordance with BS 6472.

When taking into account the above levels and the duration and frequency of train passbys adjacent to the realigned T1 North Shore Line Up track, no adverse vibration impacts are anticipated adjacent to the project surface rail sections.

### 4.1.7 Summary of Ground-borne Vibration Assessment

As discussed in **Section 4.1.2**, 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 other sensitive receiver locations above or near to the proposed project alignments.

There are no anticipated vibration impacts adjacent to project related surface rail tracks.

## 4.2 Ground-borne Noise Train Operations

### 4.2.1 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 Sydney Trains 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.

For most new rail lines, the track design 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 rail 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 rail line is underground.

### 4.2.2 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 (ie 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.

### 4.2.3 Operational Ground-borne Noise Objectives

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

The ground-borne noise trigger levels for residential and other sensitive receiver locations are provided in **Table 82**.

**Table 82 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 82** 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 (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 between 5 dB and 10 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.

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 in Table 4 … 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 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 ground-borne noise design objective of 40 dBA to 45 dBA $L_{Amax,slow,95\%}$. Even though the guideline does not include specific criteria for medical institutions, it has for this assessment been assumed that the ground-borne noise design objective of 40 dBA to 45 dBA $L_{Amax,slow,95\%}$ is also applicable to medical institutions (except patient wards that are assessed as residential).

For commercial receivers, shopping centres and industrial buildings, RING does not provide guidance on acceptable levels. On other projects including Sydney Metro Northwest, SLR 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 83** is a summary of the proposed ground-borne noise design objectives for the project for these other receiver types.

**Table 83 Ground-borne Noise Design Objectives for Other 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 |
| Medical institutions | 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 that patient wards are assessed as residential receivers.

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.

### 4.2.4 Ground-borne Noise Modelling Methodology

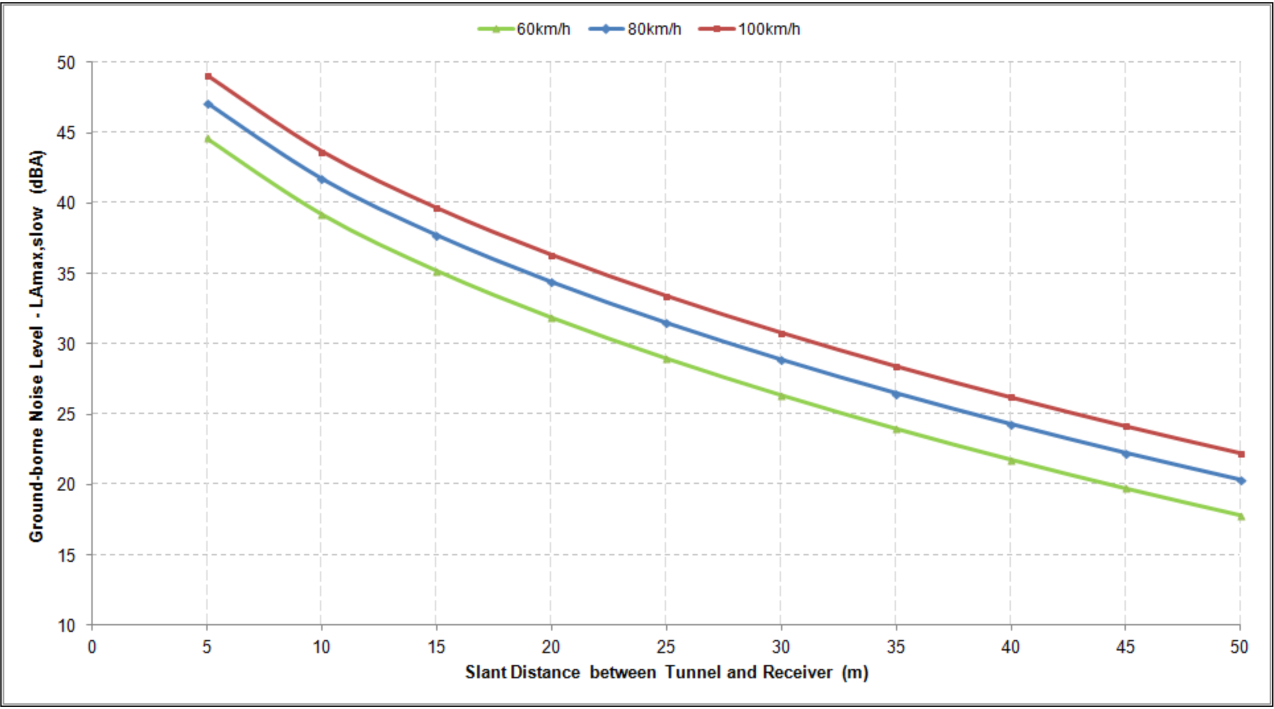
The ground-borne noise and vibration modelling methodology is discussed in **Section 4.1.4**, with the addition of two final steps to account for the conversion of surface vibration into noise.

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. The employed relationship is conservative and the latest version of the ANC guideline (2012) has moved to recommend a conversion factor of -32 (rather than -27).

### 4.2.5 Ground-borne Noise Prediction Curve

On the basis of the ground-borne noise and vibration modelling assumptions discussed in **Section 4.1.4** and **Section 4.2.4**, **Figure 36** presents a summary of the indicative ground-borne noise levels at various distances from the proposed rail tunnels for train speeds of 60 km/h, 80 km/h and 100 km/h, assuming a Standard Attenuation track form design.

**Figure 36 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.

### 4.2.6 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 4.1.4.2.4** 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 and rail lines. 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 rail 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 project 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 ground-borne noise and vibration modelling, it has been assumed that the condition of the wheels and rails would be maintained within specified limits, using similar processes to those that have been implemented successfully on ECRL. Additional information on rail roughness management as applied to the ECRL may be found in Vegh et. al. *Acoustic rail grinding – measures of long term effectiveness: Epping to Chatswood Rail Link case study.*

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.

### 4.2.7 Ground-borne Noise Predictions

On the basis of the speed profile for the project (shown in **Figure 31**), the proposed alignment 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 4.1.4.2.5**.

On the basis of the predicted ground-borne noise levels for the different track forms, **Table 84** provides a summary of the likely extent of the various track forms in each tunnel that are required to achieve compliance with the ground-borne noise design objectives at all sensitive receiver locations. The extents of the proposed track forms are illustrated in **Figure 37**.

The final track form design and associated mitigation measures would form part of the detailed design. The track form design assessed as part of this Environmental Impact Statement 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 (refer **Table 84**) identifies that 91 percent and 93 percent of the southbound and northbound tracks respectively would achieve the ground-borne noise design objectives with the standard attenuation track form. 9 percent and 7 percent of the southbound and northbound tracks respectively would require high attenuation track form to achieve the ground-borne noise design objectives. Only two short sections of the southbound track and two short section of the northbound track were predicted to require the very high attenuation track form to achieve the ground-borne noise design objectives.

The assessment currently assumes that the ground-borne noise objectives can be achieved with a slab track design incorporating direct fixation baseplates. Where required the baseplates need to be a soft resilient type such as Delkor Egg and Pandrol Vanguard. Other systems could also be adopted as part of detailed design to achieve the same outcomes with baseplate designs from other suppliers or via various floating slab track designs.

**Table 84 Proposed[1] Track form Extent**

| Southbound Track [2] | | | Northbound Track [3] | | |
|---|---|---|---|---|---|
| **Chainage (km)** | **Extent (m)** | **Track form** | **Chainage (km)** | **Extent (m)** | **Track form** |
| North of Central Station | | | | | |
| 10.935 - 10.58 | 345 | Standard | 10.90 - 10.535 | 365 | Standard |
| 10.58 - 10.315 | 275 | High | 10.535 - 10.49 | 45 | High |
| 10.315 - 10.16 | 155 | Very High | 10.49 - 10.325 | 165 | Standard |
| 10.16 - 9.87 | 290 | High | 10.325 - 10.12 | 205 | High |
| 9.87 - 9.585 | 285 | Standard | 10.12 - 9.485 | 635 | Standard |
| 9.585 - 9.495 | 90 | High | 9.485 - 9.44 | 45 | High |
| 9.495 - 6.82 | 2,675 | Standard | 9.44 - 4.835 | 4,605 | Standard |
| 6.82 - 6.75 | 70 | High | 4.835 - 4.69 | 145 | High |
| 6.75 - 1.455 | 5,295 | Standard | 4.69 - 0.915 | 3,775 | Standard |
| 1.455 - 1.25 | 205 | High | 0.915 - 0.84 | 75 | High |
| 1.25 - 0 | 1,250 | Standard | 0.84 - 0 | 840 | Standard |
| South of Central Station | | | | | |
| 0 - 1.445 | 1,445 | Standard | 0 – 1.915 | 1,915 | Standard |
| 1.445 - 1.680 | 235 | High | 1.915 - 1.995 | 80 | High |
| 1.680 - 4.595 | 2,915 | Standard | 1.995 - 2.050 | 55 | Very High |
| 4.595 - 4.845 | 250 | High | 2.050 - 2.120 | 70 | High |
| 4.845 - 4.930 | 85 | Very High | 2.120 - 2.245 | 125 | Standard |
| 4.930 - 5.400 | 470 | Standard | 2.245 - 2.370 | 125 | High |
| | | | 2.370 - 4.565 | 2,195 | Standard |
| | | | 4.565 - 4.875 | 310 | High |
| | | | 4.875 - 4.920 | 45 | Very High |
| | | | 4.920 - 5.400 | 480 | Standard |
| **Total** | 16,335 | | | 16,300 | |
| **Track form Percentages** | 14,835 (91%) | Standard | | 15,100 (93%) | Standard |
| | 1,415 (9%) | High | | 1,100 (7%) | High |
| | 240 (1.5%) | Very High | | 100 (0.6%) | Very High |

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 4.1.4.2.5**.

Note 2: Southbound track is Up Track north of Central Station and Down Track south of Central Station.

Note 3: Northbound track is Down Track north of Central Station and Up Track south of Central Station.

**Figure 37 Extent of Proposed Track Forms - Crows Nest Station to Chatswood Tunnel Portal**

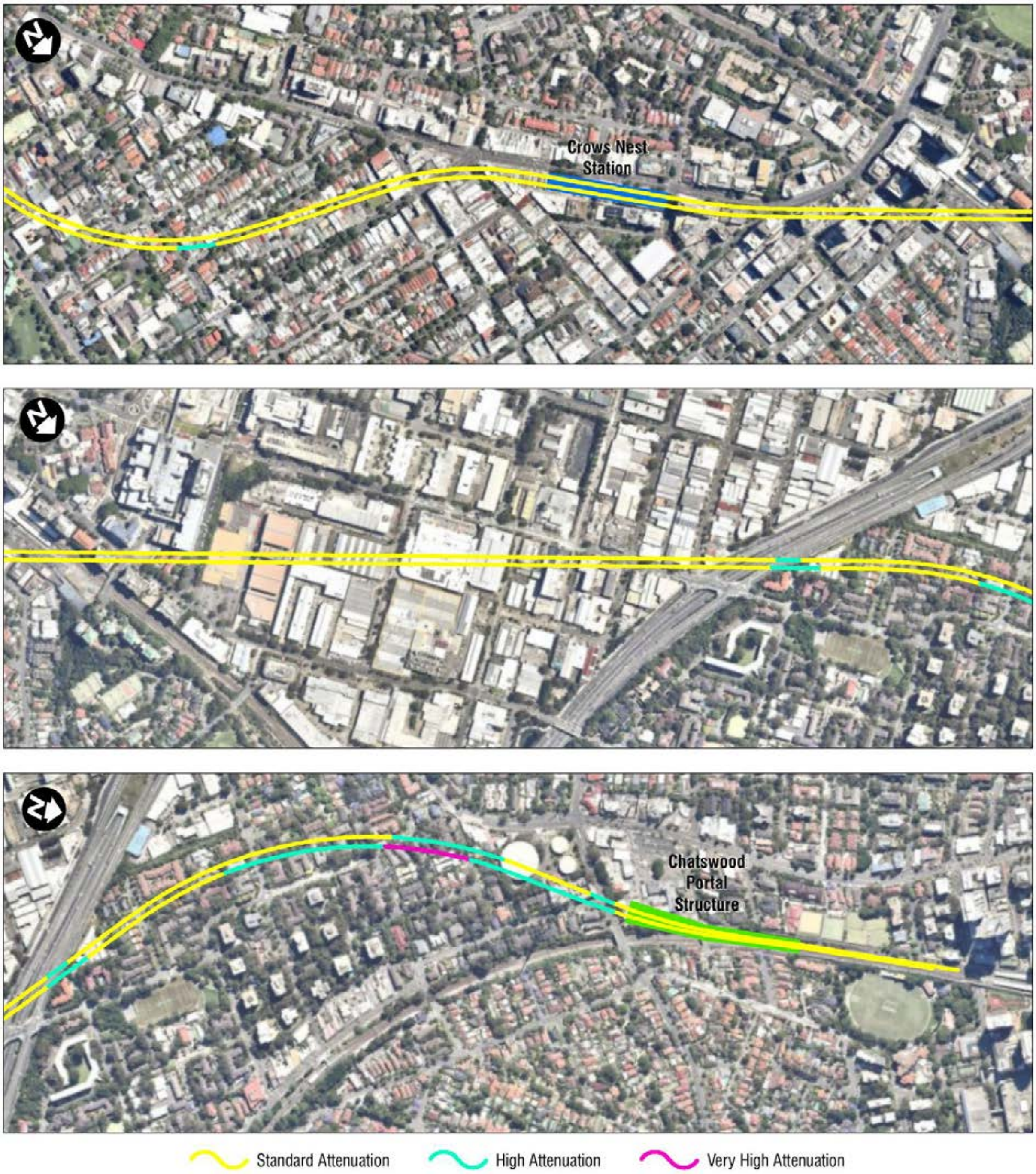


**Figure 38 Extent of Proposed Track Forms - Pitt Street Station to Victoria Cross Station**

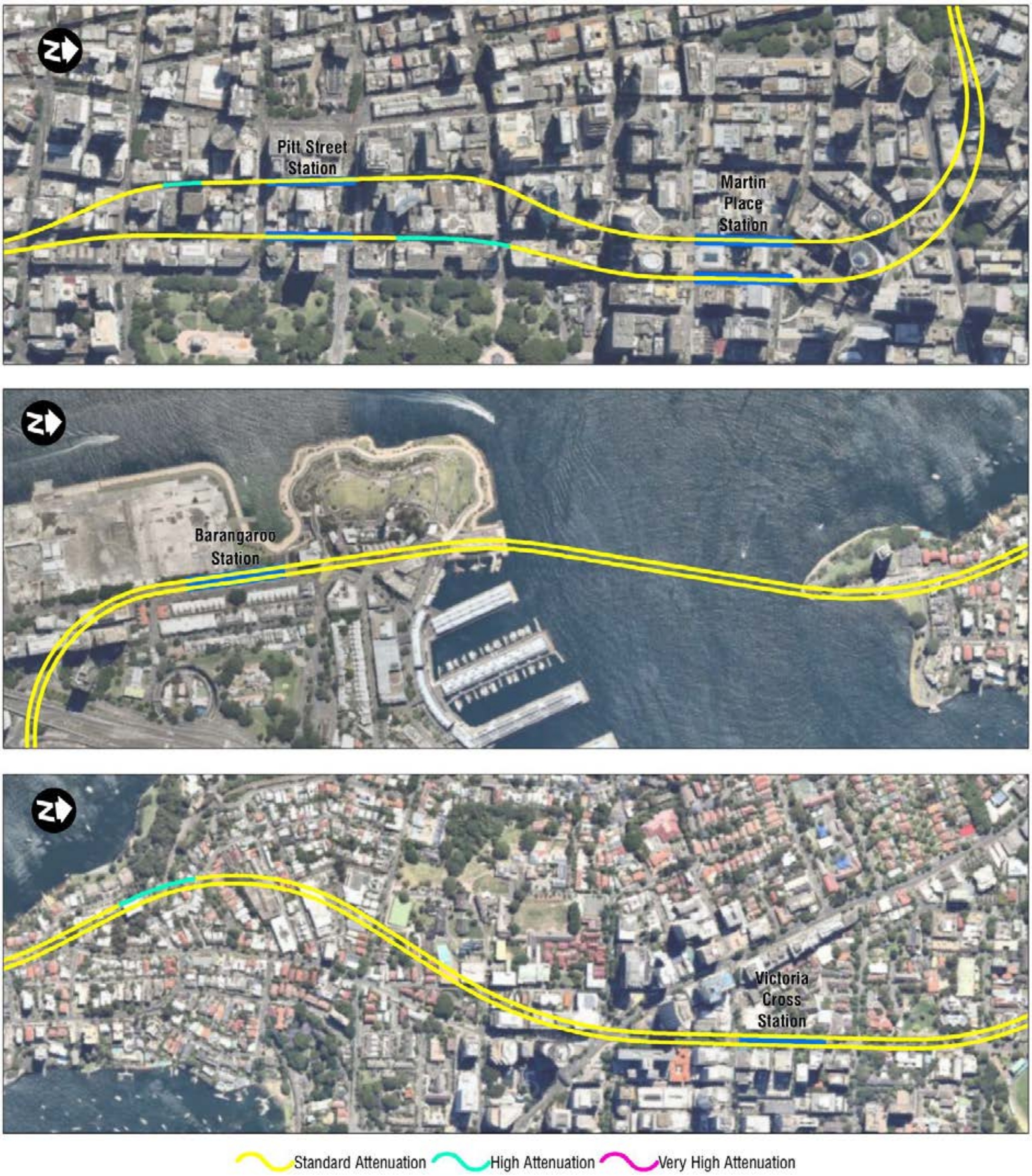
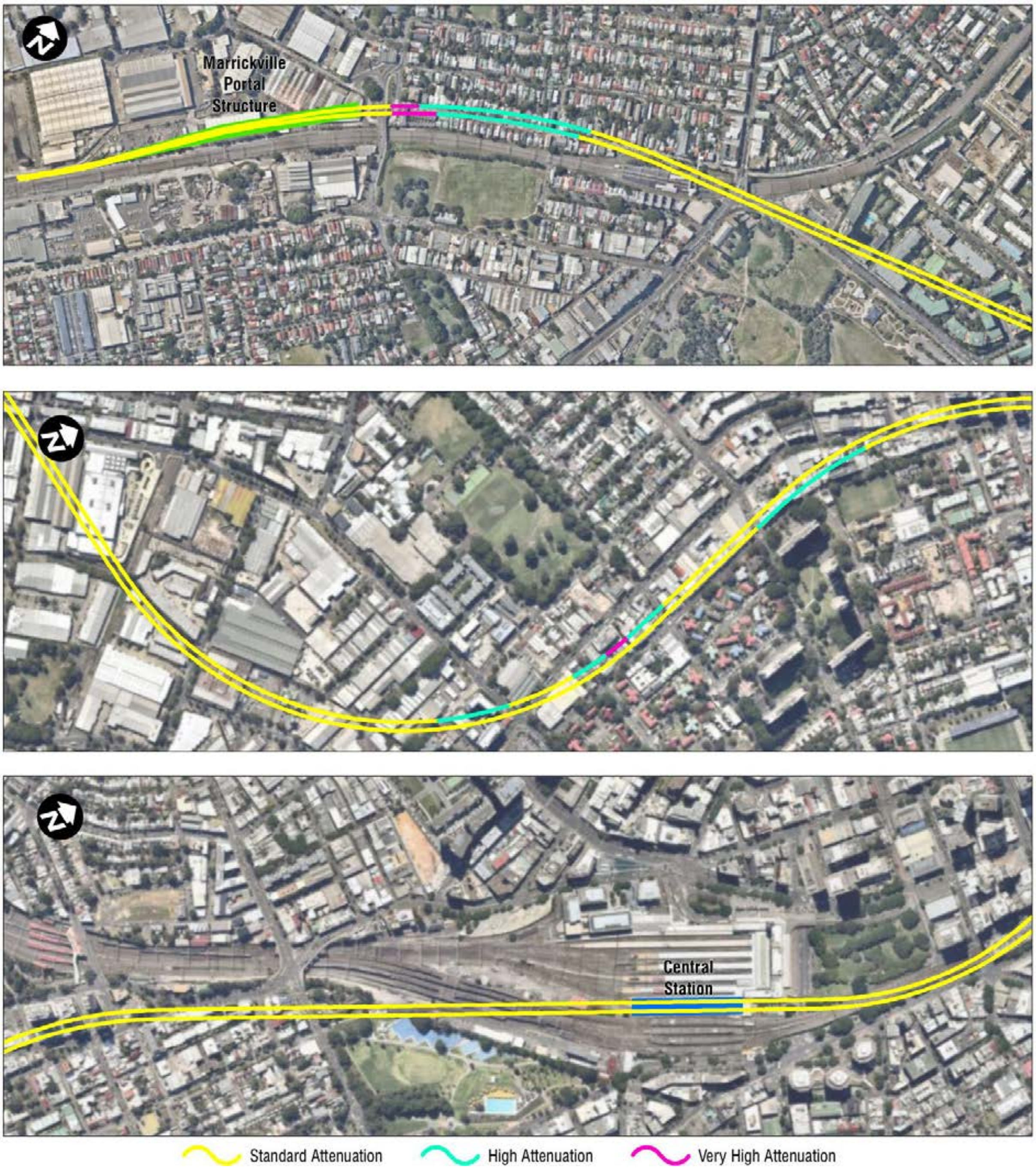


**Figure 39 Extent of Proposed Track Forms - Marrickville Tunnel Portal to Central Station**

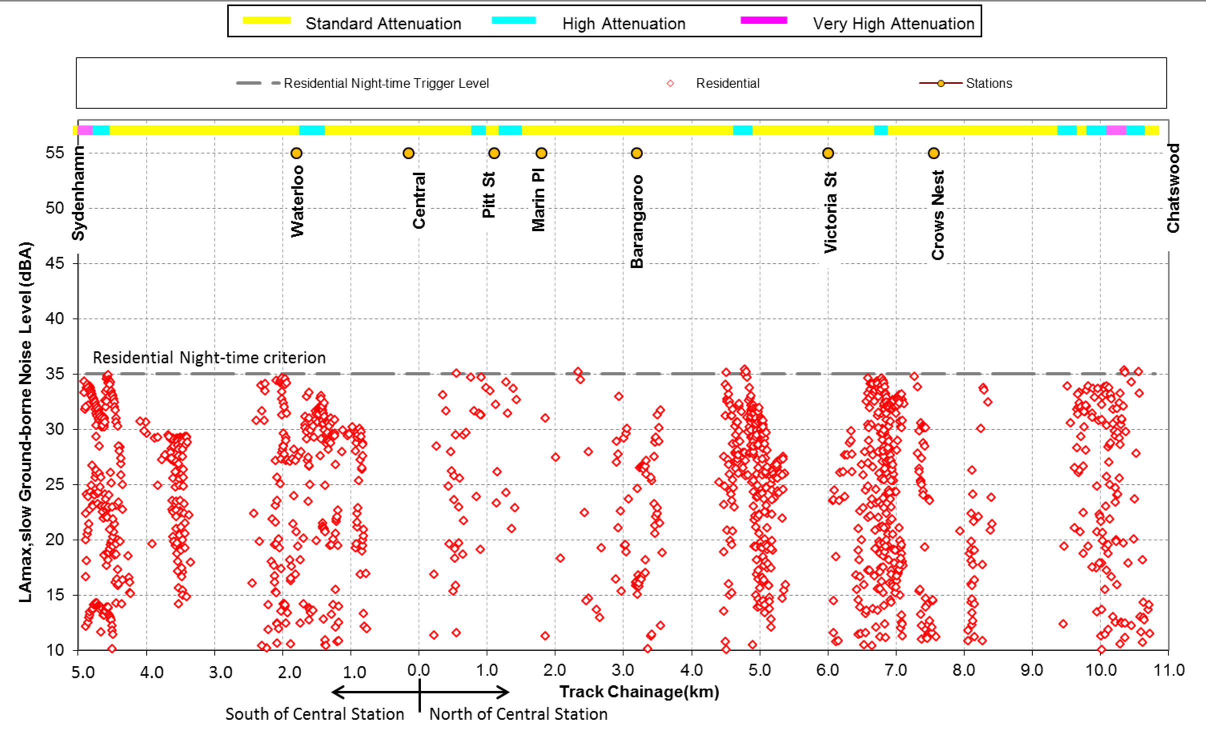



#### 4.2.7.1 Residential Receivers

The ground-borne noise predictions for the residential receivers along the alignment (with the above proposed track form) are provided in **Figure 40**. The predicted ground-borne noise levels for residential receivers are also shown on maps in **Appendix E**.

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 would be much lower.

**Figure 40 Predicted Ground-borne Noise Levels - Residential Receivers**




#### 4.2.7.2 Other Sensitive Receivers

The assessment of ground-borne noise for other sensitive receivers near to the project alignment is presented in **Figure 41**. A summary of the ground-borne noise predictions at non-residential sensitive receivers are provided in **Table 85**. The predicted ground-borne noise levels for commercial and other sensitive receivers are also shown on maps in **Appendix E**.

**Figure 41 Predicted Ground-borne Noise Levels - Commercial and Other Sensitive Receivers**

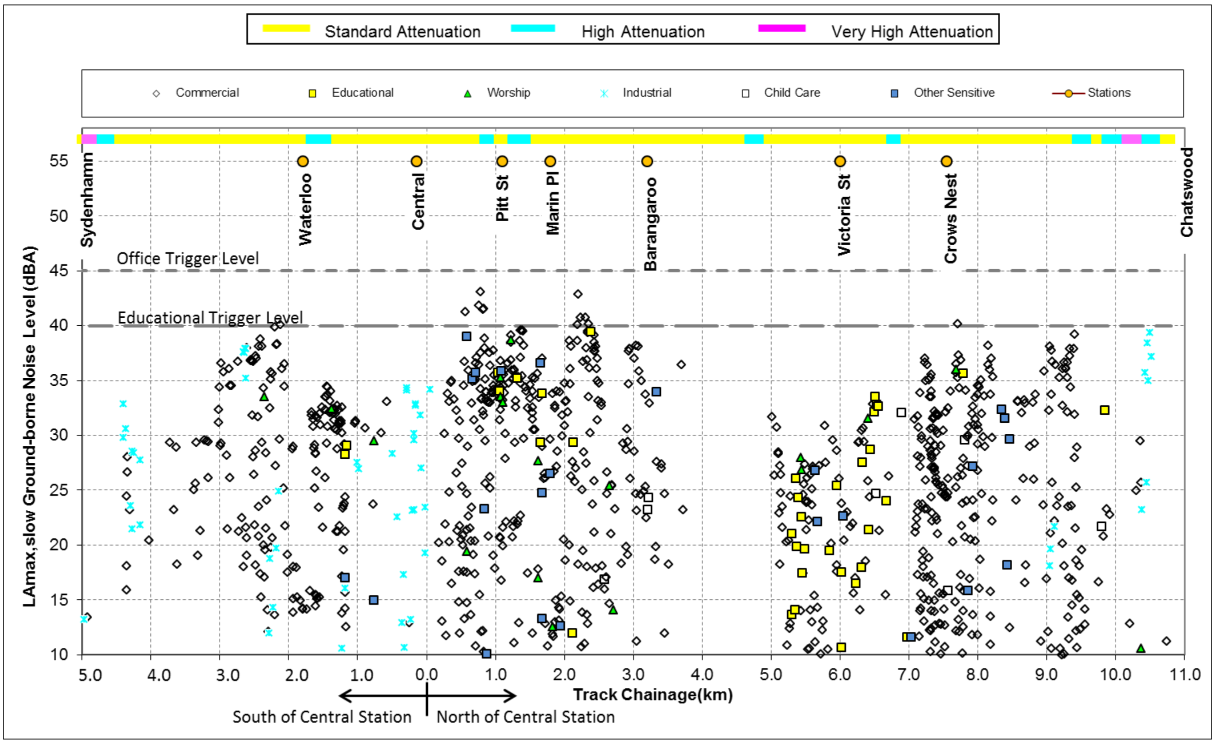



**Table 85 Predicted Ground-borne Noise Levels - Other Sensitive Receivers**

| Receiver | North of Central Station Chainage (km) | Ground-borne Noise Level - LAmax,slow,95% (dBA) | |
|---|---|---|---|
| | | Design Objective | Predicted |
| ***Educational*** | | | |
| Jansen Newman Institute | 7.79 | 40 to 45 | 36 |
| Public Reserve And Recreation | 6.68 | | 24 |
| North Sydney Girls High School | 6.98 | | Less than 20 |
| Marist College North Shore | 6.51 | | 34 |
| Williams Business College | 6.33 | | 28 |
| Wenona School | 6.24 | | Less than 20 |
| Monte Sant' Angelo Mercy College | 5.96 | | 25 |
| School of Physiotherapy Australian Catholic University | 5.85 | | 20 |
| Raffles College of Design and Commerce | 5.68 | | Less than 20 |
| Shore-Sydney Church of England Grammar School | 5.4 | | 26 |
| Macquarie Graduate School of Management | 2.39 | | 40 |
| ELS Universal English College | 2.14 | | 29 |
| Sydney Mechanics' School of Arts | 1.06 | | 34 |
| ***Child Care*** | | | |
| Willoughby Lane Cove Family Day Care | 9.85 | 40 to 45 | 33 |

| Receiver | North of Central Station Chainage (km) | Ground-borne Noise Level - $L_{Amax,slow,95\%}$ (dBA) | |
|---|---|---|---|
| | | Design Objective | Predicted |
| Nicky's Kids Town | 9.8 | | 22 |
| Goodstart Early Learning St Leonards Pacific Highway | 7.81 | | 30 |
| Kelly's Place Children's Centre | 7.57 | | Less than 20 |
| Crows Nest Kindergarten | 6.9 | | 32 |
| Jacaranda Cottage | 6.53 | | 25 |
| KU Lance Preschool and Children's Centre | 3.23 | | 24 |
| Sydney Cove Children's Centre | 2.58 | | Less than 20 |
| Cheeky Monkey Corporation | 1.89 | | 34 |
| ***Worship*** | | | |
| Northside Community Church Sydney | 7.68 | 40 to 45 | 36 |
| St Mary's North Sydney | 6.41 | | 32 |
| St Peter's Presbyterian Church | 5.43 | | 28 |
| St Philips Church | 2.71 | | Less than 20 |
| St Patricks Catholic Church | 2.66 | | 25 |
| St Stephens Church | 1.84 | | Less than 20 |
| St James Church | 1.62 | | 28 |
| Great Synagogue | 1.23 | | 39 |
| Uniting Church | 1.12 | | 38 |
| Church Of Scientology | 1.08 | | 35 |
| Martin Luther Church | 0.59 | | Less than 20 |
| ***Medical*** | | | |
| Royal North Shore Hospital | 8.46 | 40 to 45 | 32 |
| Crows Nest Medical Practice and The Exercise Clinic | 7.04 | | Less than 20 |
| Miller Street Medical Practices | 6.05 | | 23 |
| Sydney Premier Medical & Health Centre | 1.09 | | 36 |
| ***Other Sensitive*** | | | |
| City Recital Hall - Angel Place | 1.9 | 35 | Less than 20 |
| Channel 7 | 1.8 | NR 25[5] | Less than NR 23 |
| Theatre Royal | 1.68 | 35 | 25 |

[5] SLR was involved in the design of the Channel 7 TV studios. The studio was designed to NR 25.

| Receiver | South of Central Station Chainage (km) | Ground-borne Noise Level – $L_{Amax,slow,95\%}$ (dBA) | |
|---|---|---|---|
| | | **Design Objective** | **Predicted** |
| ***Educational*** | | | |
| Redfern Primary School | 1.54 | 40 to 45 | Less than 20 |
| ***Worship*** | | | |
| Yiu Ming Temple | 2.4 | 40 to 45 | 34 |
| Waterloo Congregational Church | 1.83 | | 32 |
| St Luke's Presbyterian Church | 1.38 | | 32 |
| Cathedral of The Annunciation of our Lady | 0.76 | | 30 |
| ***Medical*** | | | |
| Sydney Dental Hospital | 0.025 | 40 to 45 | Less than 20 |
| ***Other Sensitive*** | | | |
| Sydney Film School | 1.56 | 40 to 45 | 33 |
| Cleveland Street Theatre | 0.76 | NR25 | Less than NR15 |

### 4.2.8 Summary of Ground-borne Noise Assessment

On the basis of the proposed alignments, the modelling assumptions described in the previous sections and the proposed track form in **Table 84**, ground-borne noise levels are predicted to comply with the ground-borne noise design objectives at all residential and other sensitive receiver locations.

## 4.3 Airborne Noise - Rail Operations

### 4.3.1 Introduction

The primary source of airborne noise from rail operations is the wheel-rail interface, as a result of surface irregularities on the wheel and/or rail running surfaces and interaction forces. During a train passby the wheel, bogies, rail and rail support system vibrate and transfer this energy to the surrounding environment as airborne noise.

The key influencers of airborne noise are the train speed, the condition of the wheel and rail, the train length, number of train passby events and the design of the train and track. The level of airborne noise experienced at a receiver is dependent upon the distance to the track and the presence of natural or man-made barriers between the rail and the receiver which can impede the propagation of noise.

### 4.3.2 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 RING, $L_{Amax}$ 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 (ie A-weighted).

### 4.3.3 Operational Noise Trigger Levels

The NSW EPA provides guidance for the assessment and management of potential airborne noise from rail lines in the *Rail Infrastructure Noise Guideline* (RING). To assess and manage potential noise from rail projects the guideline provides non-mandatory airborne noise trigger levels for residential and other sensitive receivers. Where rail noise levels are above the noise triggers the noise assessment is to identify feasible and reasonable mitigation to achieve a desired objective of airborne noise within the trigger levels.

The RING requires noise to be assessed at proposal opening and for a future design year, typically ten years after opening. For this proposal the two timeframes assessed are the at-opening scenario in 2024 and a future scenario based on forecasts for operations in 2034.

The project related surface track sections are categorised as a redevelopment of an existing rail line as described by the RING according to the following classification:

> *"Redevelopment of a heavy rail line occurs where any rail infrastructure project is to be developed on land that:*
>
> - *Is located within an existing and operational rail corridor is or has been operational; or*
> - *Is immediately adjacent to an existing operational rail line which may result in widening of an existing rail corridor."*

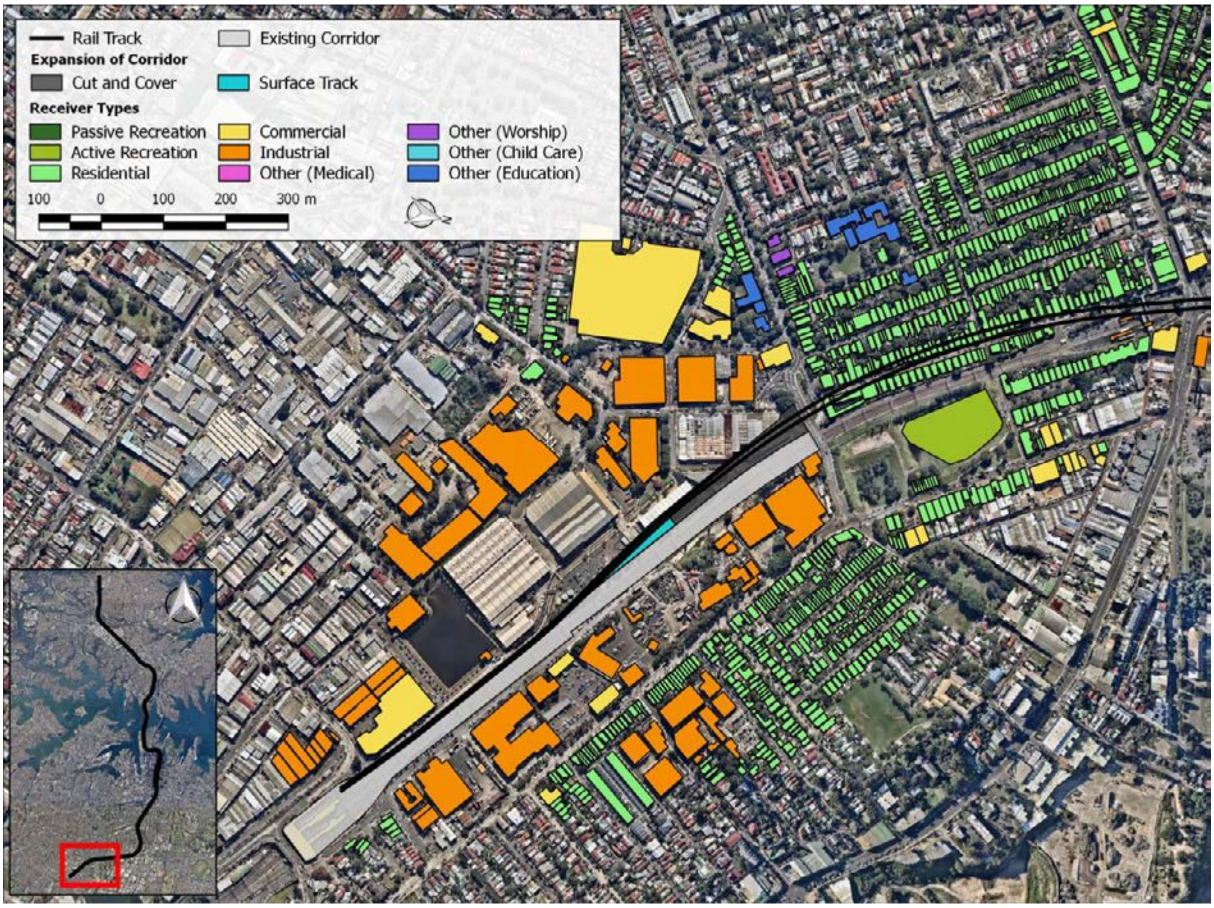
The RING identifies that where the track is moved sufficiently outside the existing corridor to allow new noise mitigation options to be considered that would not have been considered feasible otherwise, the realigned track section should be categorised as 'New' rather than "Redeveloped".

The northern surface track works are generally contained within the confines of the existing T1 North Shore Line rail corridor. Some limited widening of the corridor boundary in the vicinity of the tunnel portal is proposed as displayed in **Figure 42**. The expansion of the rail corridor in this locality is completely comprised of cut and cover tunnel track. Receivers located immediately adjacent the rail noise sources in this area are positioned directly adjacent the existing rail corridor, and closer to the existing rail lines than the new rail lines. No new opportunities for noise mitigation are anticipated to be provided by the limited widening proposed in this area. Therefore, the realigned track section is categorised as a redevelopment under the RING.

**Figure 42 Corridor Widening Near Chatswood Tunnel Portal**


The Marrickville dive structure is situated directly parallel to existing surface track. The project involve new metro rail tracks within the Marrickville dive structure located on the Up-side (north-western side) of the existing corridor from Bedwin Road and extending approximately 450 m south west as displayed in **Figure 43**. The expansion of the rail corridor in the area of the alignment closest to sensitive receivers (Bedwin Road) is comprised of cut and cover tunnel track which is not anticipated to generate airborne operational rail noise. All residential receivers located nearest the surface track sections within the Marrickville dive are located on the Down-side of the rail corridor (south-eastern side) which is the opposite side of the corridor to the widening works, so new opportunities for noise mitigation are not anticipated to be provided by the corridor widening in this area, and works in this area remain categorised as a redevelopment under the RING.

**Figure 43 Corridor Widening Near Marrickville Tunnel Portal**




In summary, the expansion of the surface rail corridors at both the northern and southern extremities of the project area are considered to be "redevelopments" under the RING. The relevant airborne noise trigger levels for residential land uses surrounding the proposed surface track are presented in **Table 86**.

**Table 86 Airborne Rail Noise Triggers for Residential Land Use**

| Sensitive Land Use | Noise Trigger Level (dBA) | |
|---|---|---|
| | **Day time 7:00 am to 10:00 pm** | **Night-time 10:00 pm to 7:00 am** |
| Redevelopment of existing rail line | Development increases existing $L_{Aeq(period)}$[1] rail noise levels by 2 dB or more, or existing $L_{Amax}$[2] rail noise levels by 3 dB or more<br>AND<br>Resulting rail noise levels exceed: | |
| | 65 $L_{Aeq(15hour)}$ and<br>85 $L_{Amax}$ | 60 $L_{Aeq(9hour)}$ and<br>85 $L_{Amax}$ |

Note 1: $L_{Aeq(period)}$ means $L_{Aeq(15hour)}$ for the day-time period and $L_{Aeq(9h)}$ for the night-time period

Note 2: $L_{Amax}$ refers to the maximum noise level not exceeded for 95 per cent of rail pass-by events and is measured using the 'fast' response setting on a sound level meter.

The RING noise triggers for non-residential sensitive receivers in **Table 87** are applicable when the building or premise is in use. All noise trigger levels are external levels except where otherwise stated. Commercial receivers are not considered sensitive to operational airborne noise impacts.

**Table 87 Airborne Rail Noise Triggers for Sensitive Land Uses Other than Residential**

| Sensitive Land Use | Noise Trigger Level dBA (when in use) |
|---|---|
| | Development increases existing rail noise levels by 2.0 dB or more in $L_{Aeq}$ in any hour<br>AND<br>Resulting rail noise levels exceed: |
| Schools, educational institutions and child care centres | 45 $L_{Aeq(1hour)}$ Internal |
| Places of worship | 45 $L_{Aeq(1hour)}$ Internal |
| Hospital wards | 40 $L_{Aeq(1hour)}$ Internal |
| Hospital other uses | 65 $L_{Aeq(1hour)}$ |
| Open space – passive use (e.g. parkland, bush reserves) | 65 $L_{Aeq(15hour)}$ |
| Open space – active use (e.g. sports field, golf course) | 65 $L_{Aeq(15hour)}$ |

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. A facade reflection correction is included for all external noise levels, except the “Open space” in **Table 87** which is assessed as free field.

For sensitive receivers such as schools, child care centres and places of worship, the trigger levels presented in **Table 87** are based on internal noise levels. Any “internal noise level” refers to the noise level at the centre of the habitable room that is most exposed to the noise source. Depending on the location and existing noise sources in the area (ie road, rail, commercial or industry), the building may be fitted with ventilation or air-conditioning to allow for closed windows and indoor acoustic amenity. In other situations open windows may be relied upon to provide adequate ventilation. Depending on building facade and openings, the outside-to-inside attenuation would typically be between 10 and 20 dB, but could also be significantly more.

### 4.3.4 Operational Noise Modelling

#### 4.3.4.1 Introduction to Noise Modelling

SoundPLAN Version 7.1 has been used to calculate rail 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.

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.

#### 4.3.4.2 Source Noise Levels

The future track forms in above ground sections consist primarily of ballast track on concrete sleepers. The only sections of track that are not expected to be ballasted are the Sydney Metro dive structures and the T1 North Shore Line bridge over the Chatswood dive structure. These sections would have a slab track with direct fixation rail fasteners.

The *Handbook of Railway Vehicle Dynamics*[6] 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 depends on the starting noise level. Measurements on the ECRL (on similar track to that proposed for the Sydney Metro) found a benefit of 4 dB from the installation of rail dampers[7].

The reference noise levels used for the noise modelling are shown in **Table 88**. These levels are consistent with the source noise levels applied for modern passenger trains by SLR Consulting on other Sydney Metro projects, with the following adjustments to account for the higher noise emissions from slab track compared to ballasted track.

- While noise emissions from the rail would be approximately 4 dB higher with slab track as the result of softer rail fasteners and less damping, this increase in noise could potentially be controlled where required by application of source mitigation in the form of rail dampers, potentially providing a net change of 0 dB in both $L_{AE}$ and $L_{Amax}$ compared to ballast track.
- An increase of 2 dB in $L_{AE}$ and $L_{Amax}$ is included, to account for increased reflection (reduced absorption) from slab track compared to ballast track.

The source noise levels used in the noise modelling are at the upper end of the range of noise levels in the NSW rail noise database for existing double-deck Sydney trains. This approach is considered conservative, since at this stage the rail roughness in the project area is unknown; there is no measured noise data is available for the new Sydney Metro single-deck trains; and the mix of rolling stock on the existing lines may vary. In the event that the new Sydney Metro rolling stock has lower noise emissions than assumed here, the impacts of the project would be less than predicted in this report (both the overall wayside noise levels, and the increase due to the project).

**Table 88 Rolling Stock Reference Noise Levels (8-car trains)**

| Train Types | Track form | Source Mitigation | Reference Conditions | $L_{Amax,95\%}$ | $L_{AE}$ |
|---|---|---|---|---|---|
| Double-deck Sydney Trains | Ballast | None | 15 m, 80 km/h | 85 dBA | 88 dBA |
| Single-deck Sydney Metro Trains | Ballast | None | 15 m, 80 km/h | 85 dBA | 88 dBA |
| Single-deck Sydney Metro Trains | Slab Track | Rail Damper Mitigation | 15 m, 80 km/h | 87 dBA | 90 dBA |
| Single-deck Sydney Metro Trains | Slab Track | Without Rail Dampers | 15 m, 80 km/h | 91 dBA | 94 dBA |

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

7 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.

#### 4.3.4.3 Track Feature Corrections

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. **Table 89** identifies the locations of the crossovers in the future alignment designs.

**Table 89 Rail Track Crossovers**

| Line | Track | Chainage |
|---|---|---|
| T1 North Shore Line | Main Down | 11.340 km |
| | Main Up | 11.330 km |
| | ECRL Down | 11.470 km |
| | ECRL Up | 11.380 km |
| | | 11.450 km |
| T3 Bankstown Line | Main Up | 5.450 km |
| | Main Down | 5.480 km |
| | | 5.530 km |
| T4 Illawarra Line | Local Up | 5.010 km |
| | | 5.120 km |
| | | 5.160 km |
| | | 5.550 km |
| | | 5.640 km |
| | | 5.760 km |
| | Local Down | 4.990 km |
| | | 5.020 km |
| | | 5.140 km |
| | | 5.670 km |
| | | 5.730 km |
| | | 5.760 km |
| | Main Up | 4.960 km |
| | | 4.990 km |
| | | 5.690 km |
| | | 5.720 km |
| | Main Down | 4.960 km |
| | | 5.690 km |

The modelling includes allowances for localised increases in noise emission from turnouts. A correction of +6 dB for turnouts has been applied in the noise model over a 20 m track distance.

In areas where there are tight radius curves, flanging noise or curve squeal may also increase the levels of noise emission. No surface track sections within the project area have curves of less than 500 m radius, and therefore no corrections for squeal or flanging have been included in the airborne noise predictions.

#### 4.3.4.4 Bridge Noise

Structure-radiated noise from some types of rail bridges (especially open-transom steel bridges) may also increase the overall levels of track noise. The form of the new Sydney Metro rail bridges are currently proposed to comprise concrete beams with concrete deck, which are inherently quieter than steel or composite constructions. Concrete bridges that incorporate solid parapets or side screens are typically quieter than standard (reference) ballasted track at grade, due to the shielding provided by the parapets.

A rail bridge is proposed to carry the T1 North Shore Down-track across the metro rail lines in the vicinity of the Chatswood dive. For modelling purposes, there is no change to the $L_{Amax}$ and $L_{AE}$ noise emissions for a concrete span bridge with ballasted track and no side screens compared to at grade noise emissions from ballasted track.

Corrections applied to rail bridges within the project area are listed in **Table 90**.

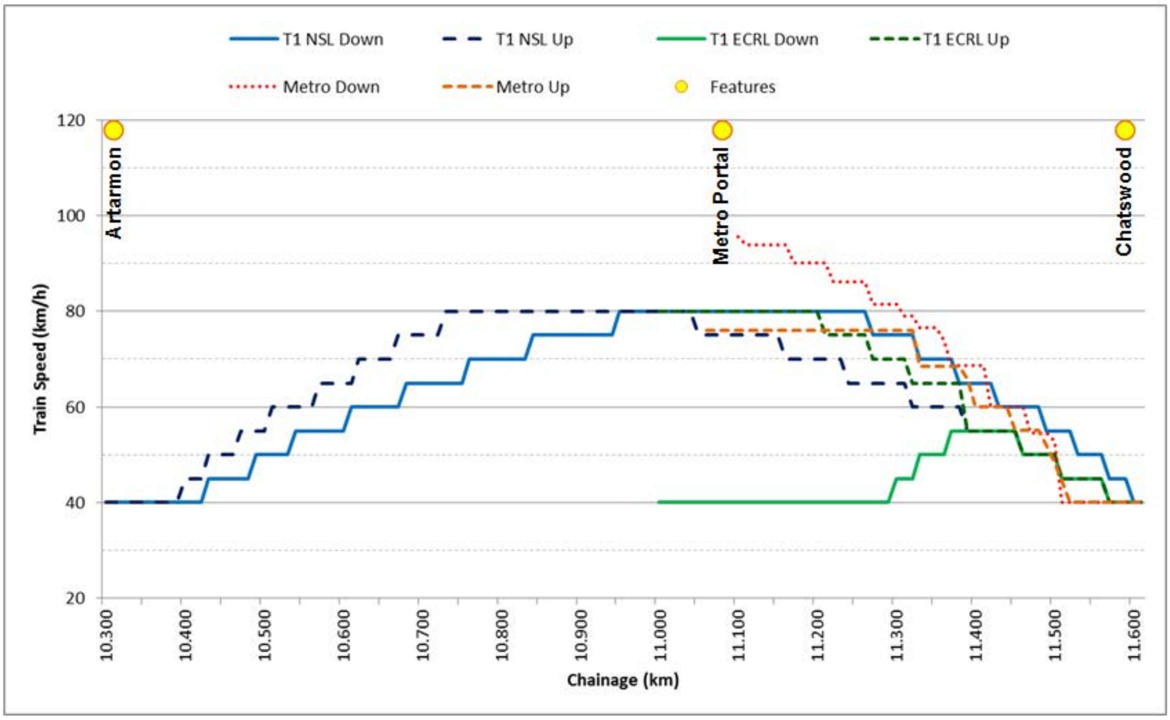
**Table 90 Rail Bridge Corrections**

| Bridge | Approx. Chainage | Existing Bridge | | Proposed Bridge | |
|---|---|---|---|---|---|
| | | Construction Description | Correction | Construction Description | Correction |
| Albert Avenue | 10.540 - 10.570 km | Concrete trackbed, concrete box girder, with side screens | -2 dB | Concrete trackbed, concrete box girder, with side screens | -2 dB |
| Chatswood Dive bridge | 10.990 - 11.070 km | None | - | Concrete trackbed, concrete box girder | 0 dB |

#### 4.3.4.5 Speed Profile

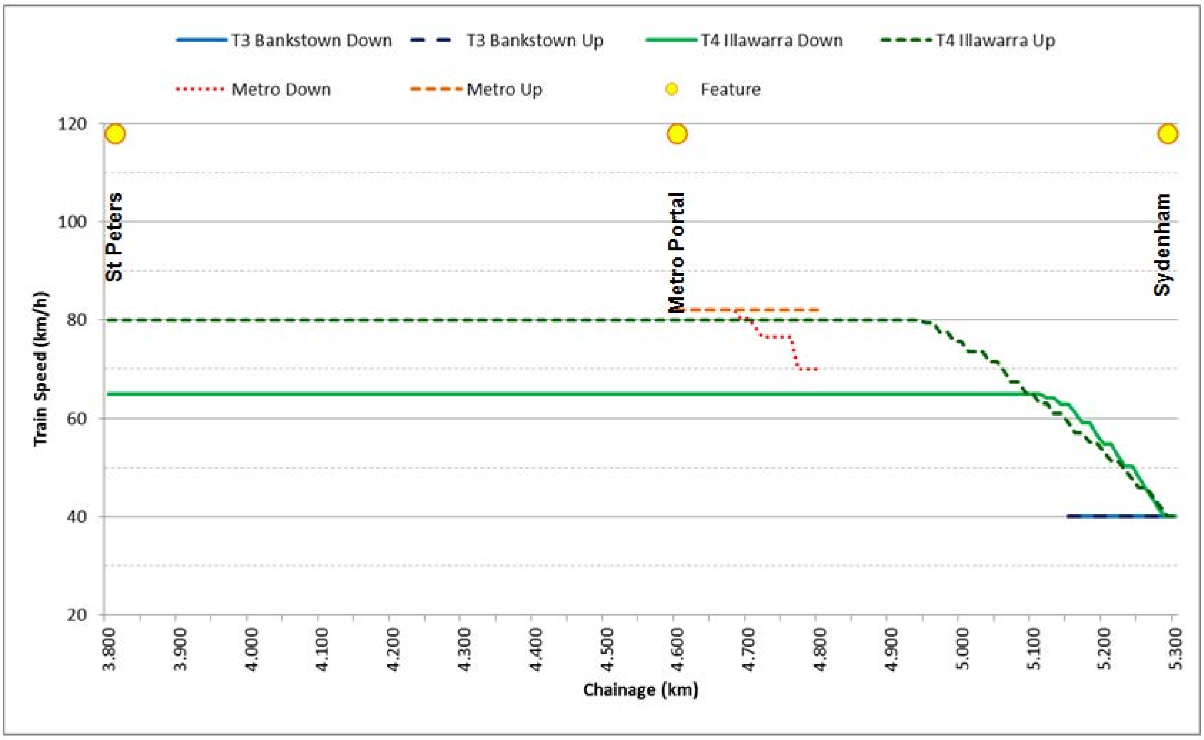
The speed profiles for noise and vibration assessment purposes through the future surface track sections are shown in **Figure 44** and **Figure 45** for the Chatswood and Marrickville dives respectively.

**Figure 44 Sydney Metro Speed Profile for Noise and Vibration Assessment - Chatswood Dive**




Note: "T1 NSL" represents T1 North Shore Line
Note: "T1 ECRL" represents T1 Epping to Chatswood Rail Line

**Figure 45 Sydney Metro Speed Profile for Noise and Vibration Assessment - Marrickville Dive**




As shown in **Figure 44** and **Figure 45**, the minimum modelled train speed through stations is 40 km/h.

#### 4.3.4.6 Track Alignment and Ground Terrain

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

The ground terrain was based on LiDAR data of the project area, modified to incorporate the project alignments and realignment of existing tracks, including cuttings or embankments where necessary.

#### 4.3.4.7 Rail Traffic Data

The RING 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 91**. The train numbers in **Table 91** are indicative only, with consideration given to the estimated passenger demand, minimum service levels and the upper design limit of Sydney Metro service frequencies for future peak times.

**Table 91 Rail Traffic Scenarios for Noise Assessment Purposes**

| Rail Line | Scenario | Train Type | Trains Per Weekday Period | | | |
|---|---|---|---|---|---|---|
| | | | Day 7:00 am to 10:00 pm | | Night 10:00 pm to 7:00 am | |
| | | | Up | Down | Up | Down |
| T1 North Shore Line including future Metro Services | Existing 2015 | A/H/M/T-Set | 186 | 190 | 44 | 47 |
| | Prior to Opening 2024 | A/H/M/T-Set | 186 | 190 | 44 | 47 |
| | After Opening 2024 | A/H/M/T-Set | 186 | 190 | 44 | 47 |
| | | Metro Train | 202 | 202 | 27 | 27 |
| | Future 2034 | A/H/M/T-Set | 186 | 190 | 44 | 47 |
| | | Metro Train | 222 | 222 | 30 | 30 |
| | Future 2034 Without Project (‘no build option’) | A/H/M/T-Set | 186 | 190 | 44 | 47 |
| | | Metro Train | 0 | 0 | 0 | 0 |
| T2 Airport Line | Existing 2015 | A/H/M/T-Set | 6 | 8 | 0 | 1 |
| | Prior to Opening 2024 | A/H/M/T-Set | 6 | 8 | 0 | 1 |
| | After Opening 2024 | A/H/M/T-Set | 6 | 8 | 0 | 1 |
| | Future 2034 | A/H/M/T-Set | 6 | 8 | 0 | 1 |
| | Future 2034 Without Project (‘no build option’) | A/H/M/T-Set | 6 | 8 | 0 | 1 |
| T3 Bankstown Line including future Metro Services | Existing 2015 | A/H/M/T-Set | 78 | 84 | 17 | 20 |
| | Prior to Opening 2024 | A/H/M/T-Set | 78 | 84 | 17 | 20 |
| | After Opening 2024 | A/H/M/T-Set | 78 | 84 | 17 | 20 |
| | | Metro Train | 184 | 184 | 27 | 27 |
| | Future 2034 | A/H/M/T-Set | 78 | 84 | 17 | 20 |
| | | Metro Train | 202 | 202 | 30 | 30 |
| | Future 2034 Without Project (‘no build option’) | A/H/M/T-Set | 78 | 84 | 17 | 20 |
| | | Metro Train | 0 | 0 | 0 | 0 |

| Rail Line | Scenario | Train Type | Trains Per Weekday Period | | | |
|---|---|---|---|---|---|---|
| | | | Day 7:00 am to 10:00 pm | | Night 10:00 pm to 7:00 am | |
| | | | Up | Down | Up | Down |
| T4 Eastern Suburbs and Illawarra Line | Existing 2015 | A/H/M/T-Set | 96 | 85 | 26 | 23 |
| | | C/K/S/R-Set | 9 | 8 | 2 | 2 |
| | Prior to Opening 2024 | A/H/M/T-Set | 105 | 93 | 28 | 25 |
| | After Opening 2024 | A/H/M/T-Set | 105 | 93 | 28 | 25 |
| | Future 2034 | A/H/M/T-Set | 105 | 93 | 28 | 25 |
| | Future 2034 Without Project ('no build option') | A/H/M/T-Set | 105 | 93 | 28 | 25 |

#### 4.3.4.8 Noise Modelling Outputs and Assessment Parameters

The operational noise model predicts facade noise levels at each floor for each 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 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.

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 $L_{Aeq(period)}$ noise parameter is determined by the number of trains during the relevant daytime or night-time period. The night-time $L_{Aeq(9hour)}$ noise trigger levels are 5 dB lower (ie more stringent) than the daytime $L_{Aeq(15hour)}$ noise trigger levels.

For other receivers with noise trigger levels defined on the basis of the $L_{Aeq(1hour)}$ assessment parameter, the maximum number of services per hour within the project area has been used to calculate the $L_{Aeq(1hour)}$ using the values in **Table 92**. Service frequencies in **Table 92** represent the combination of both Up and Down rail traffic per line.

**Table 92 Maximum Service Frequencies - Trains per Hour**

| Line | 2024 Maximum Trains Per Hour | | 2034 Maximum Trains Per Hour | |
|---|---|---|---|---|
| | Day | Night | Day | Night |
| T1 Epping to Chatswood Line Main | 13 | 5 | 13 | 5 |
| T1 North Shore Line Main | 37 | 17 | 37 | 17 |
| T3 Bankstown Line Main | 17 | 9 | 17 | 9 |
| T4 Illawarra Line Local | 4 | 3 | 4 | 3 |
| T4 Illawarra Line Main | 14 | 11 | 14 | 11 |
| Sydney Metro Marrickville Dive | 40 | 12 | 44 | 13 |
| Sydney Metro Chatswood Dive | 40 | 12 | 44 | 13 |

#### 4.3.4.9 Potentially Reasonable and Feasible Base Case Noise Mitigation Options

The project proposes to include several noise abatement elements in the base case design. Base case noise mitigation elements are described below.

##### 4.3.4.9.1 Rail Dampers on 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. This increase in noise due to softer rail supports may be countered through the use of rail dampers.

Where slab track is to be constructed in surface track sections (Chatswood and Marrickville dives) the $L_{Aeq}$ and $L_{Amax}$ noise levels from the surface track in these regions is anticipated to be approximately 6 dB higher than for typical ballast track with concrete sleepers.

Measurements on the ECRL (on similar track to that proposed for the Sydney Metro) found a benefit of 4 dB from the installation of rail dampers[8]. Slab track regions with rail dampers would therefore have $L_{Aeq}$ and $L_{Amax}$ noise levels approximately 2 dB higher than typical ballast track.

The proposed Chatswood dive track alignment is located adjacent several existing multi-storey residential buildings. Rail dampers are included in this assessment as a base case noise mitigation option to address slab track noise emission levels within the Chatswood dive.

##### 4.3.4.9.2 Deck Absorption

Generally slab track is constructed with a concrete deck spanning between the rails (4-foot), and extending between the tracks (6-foot), and also to the edges of the dive. This concrete deck provides less noise absorption compared to typical ballast track, and can increase noise in areas of slab track such as the dive structures.

The installation of noise absorptive material to the 4-foot would likely provide approximately 2 dB of attenuation and potentially more if the area of absorptive material can be increased, for example by application to the dive walls and/or 6-foot.

The combination of rail dampers and deck absorption is expected to reduce the noise emissions from slab track to approximately match the emissions from typical ballast track.

Deck absorption is included in this assessment along with rail dampers as a base case noise mitigation option to address slab track noise emission levels within the Chatswood dive.

##### 4.3.4.9.3 Conventional Noise Barriers

Increasing the height of several existing noise barriers on the up and down sides of the Chatswood dive track has been identified as being likely to be feasible and reasonable in the course of this study. Increased barrier height has therefore been included in the base case design at several locations where noise modelling indicates the project noise goals may exceed the RING noise trigger levels in the absence of mitigation.

The existing 3 m high noise barriers between Nelson Street and Chapman Avenue on the Up side of the corridor would be increased in height by 1 m as part of the base case noise mitigation design. The increase in wall height in this region (NCA02 and NCA03) is likely be considered feasible as the existing wall is planned to be relocated as part of the project scope, therefore providing an opportunity to reconstruct the noise barrier at a greater height.

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[8] 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 existing 3 m high noise barriers between Nelson Street and Gordon Avenue on the Down side of the corridor would be increased in height by 1 m as part of the base case noise mitigation design. While this height of noise barrier would generally be considered reasonable, the feasibility of increasing the height of the existing barrier would require an assessment of constructability constraints. Further consideration of the feasibility of noise barriers in this location should be made during the detailed design stage of the project.

The existing 3 m high noise barriers between the Frank Channon Walk pedestrian underpass and Albert Avenue on the Down side of the corridor would be increased in height by 1 m as part of the base case noise mitigation design. This would require modifications to the barrier over a length of approximately 160 m.

A new 2 m high conventional noise barrier located at the edge of the retaining wall on the Down side of the rail corridor in NCA04 is included in the base case noise mitigation design. The feasibility of this mitigation option is dependent on the detailed design of the civil works in this area. Feasibility and effectiveness of the proposed base case conventional noise barriers in this area would be confirmed when more detailed information pertaining to the civil designs in this area is available.

A summary of the conventional noise barrier modifications included in the base case noise mitigation design is presented in **Table 93**.

**Table 93 Base Case Noise Mitigation Design - Conventional Noise Barriers**

| Area | Side | Mitigation | Description |
|---|---|---|---|
| NCA02 | Up | Increase height of relocated noise barrier to 4 m between Chapman Avenue and Nelson Street. | Noise barrier relocation included as part of the proposed design. Exact height and design of relocated noise barriers to be determined during the detailed design stage of the project when detailed civil designs are available. |
| | Down | Increase existing noise barriers by 1 m between Frank Channon Walk pedestrian underpass and Albert Avenue | Increase existing 3 m high noise barriers by 1 m. Exact height and design of noise barriers to be determined during the detailed design stage of the project when detailed civil designs are available. |
| NCA03 | Up | Increase height of relocated noise barrier to 4 m between Chapman Avenue and Nelson Street. | Noise barrier relocation included as part of the proposed design. Increase existing 3 m high noise barriers by 1 m. Exact height and design of relocated noise barriers to be determined during the detailed design stage of the project when detailed civil designs are available. |
| | Down | Increase existing noise barriers by 1 m between Nelson Street and Gordon Avenue. | Increase existing 3 m high noise barriers by 1 m. Exact height and design of relocated noise barriers to be determined during the detailed design stage of the project when detailed civil designs are available. |
| NCA04 | Down | 2m noise barrier at edge of cutting | 2 m high conventional noise barrier located at the edge of the retaining wall. Feasibility and effectiveness of conventional noise barrier in this area would be confirmed when more detailed information pertaining to the civil designs in this area is available. |

### 4.3.5 Noise Model Validation

To validate the noise model, receiver points representing the measurement locations described in **Section 2.4.3** were established in the model. The model was then used to calculate noise levels at these locations. **Table 94** presents the comparison between the model results and the attended noise measurements at the two locations described in **Section 2.4**.

Noise model validation outputs include $L_{Aeq}$ noise levels and $L_{Amax}$ noise levels. The $L_{Aeq}$ noise levels provide a validation of the assumed $L_{AE}$ train source levels and the number of trains assumed for a given period. The $L_{Amax}$ noise levels provide a validation of the assumed maximum train source levels.

**Table 94 Modelling Predictions and Measured Noise Levels**

| Location | Noise Level (dBA) | | | | | |
|---|---|---|---|---|---|---|
| | $L_{Aeq(24hour)}$ | | | $L_{Amax}$ | | |
| | Measured | Modelled | Difference | Measured | Modelled | Difference |
| Attended N1 | 64 | 64 | -0.6 | 85 | 85 | +0.6 |
| Attended N2 | 55 | 57 | +2.6 | 77 | 78 | +1.1 |

The agreement between the model results and the measurements is within 2 dB at location N1 for $L_{Aeq(24hour)}$ and $L_{Amax}$ noise levels, and at location N2 for $L_{Amax}$ noise levels. At location N2, the model results in a slight over prediction of $L_{Aeq(24hour)}$ relative to the attended measurements.

As discussed in **Section 2.4.3.2** the measured noise levels on the Illawarra Up and Down Main tracks at location N2 were less than expected from typical track, and less than observed on the Local tracks at the same location. Approximately 77% of the rail movements at this location use the Illawarra Up and Down Main tracks. As a result, the $L_{Aeq(24hour)}$ noise levels derived from measurements at this location are lower than noise levels typically observed across the wider network, and lower than the modelled noise levels since the same source levels were used for both sets of tracks. Rail roughness levels at this location have not been investigated in detail at this stage, but it is possible that the measured Main track noise levels may increase over time with a change in rail roughness. For example, maintenance track grinding can increase the roughness and hence rail noise in the area. For this reason, the modelled $L_{Aeq(24hour)}$ noise levels are considered acceptable, with the slight over prediction of 2.6 dB representing a reasonable degree of conservatism.

Overall the model is considered to be suitable for predicting the rail noise levels from the project.

The modelling process inherently requires a number of assumptions to be made. Whilst every effort has been made to correlate predicted noise levels with measured noise data, it is important to regard the overall absolute predicted noise levels within the generally accepted modelling accuracy of +/- 2 dB.

### 4.3.6 Predicted Operational Airborne Noise Levels

To assist the interpretation of operational noise impacts, noise level contours have been calculated with a grid spacing of 10 m. The contour plots for the daytime, night-time and maximum noise levels are calculated for the 2034 with project scenario, at a height of 4.5 m above the local ground level, over a grid spaced at 10 m intervals (see **Appendix I**).

The second floor noise levels are representative of the typically most exposed floor level for the majority of existing receivers. Noise levels at single-storey buildings would 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.

Contours are shown for the 2034 scenario only as this scenario is representative of the future noise levels with the maximum forecast train numbers.

#### 4.3.6.1 Predicted Operational Airborne Noise Levels - Chatswood Dive

Operational airborne noise predictions undertaken for the Chatswood surface track include the noise modelling inputs reviewed in **Section 4.3.4** and base case noise mitigation design discussed in **Section 4.3.4.9**.

##### 4.3.6.1.1 Residential Receivers

A summary of the highest residential rail noise levels for the 2024 and 2034 scenarios are presented in **Table 95** for receivers with a predicted exceedance of the RING noise trigger levels. The results are shown as the worst-case prediction for the receiver potentially most affected by the project in each NCA within the areas surrounding the Chatswood dive. Where exceedance of the RING trigger levels was not predicted within a NCA, the highest overall residential rail noise levels are displayed for non-triggered residential receivers.

**Table 95 Summary of Most Potentially Project Affected Residences - Chatswood Dive**

| NCA | Side | Worst-case Predicted Noise Level (dBA) | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Scenario Year 2024 | | | | | | | | | Scenario Year 2034 | | | | | | | | | | |
| | | Without Project | | | With Project | | | Noise Level Increase | | RING Triggers | Without Project | | | With Project | | | Noise Level Increase | | RING Triggers | | |
| | | LAeq(15h) | LAeq(9h) | LAmax | LAeq(15h) | LAeq(9h) | LAmax | LAeq | LAmax | | LAeq(15h) | LAeq(9h) | LAmax | LAeq(15h) | LAeq(9h) | LAmax | LAeq | LAmax | | | |
| NCA01 | Up | 50 | 46 | 68 | 52 | 47 | 68 | 1.3 | -0.1 | 0 | 50 | 46 | 68 | 52 | 47 | 68 | 1.6 | -0.1 | 0 | | |
| | Down | 61 | 58 | 80 | 62 | 58 | 81 | 1.0 | 0.5 | 0 | 61 | 58 | 80 | 63 | 58 | 81 | 1.2 | 0.5 | 0 | | |
| NCA02 | Up | **68** | 64 | **86** | **70** | **65** | **86** | 1.6 | -0.3 | 0 | **68** | 64 | **86** | **70** | **65** | **86** | 1.9 | -0.3 | 0 | | |
| | Down | 64 | 62 | 84 | **67** | **63** | **85** | 3.3 | 1.3 | 1 | 64 | 60 | 84 | **67** | **62** | **85** | 3.5 | 1.3 | 1 | | |
| NCA03 | Up | **67** | 63 | **86** | **68** | **64** | **87** | 0.6 | 0.8 | 0 | **67** | 63 | **86** | **68** | **64** | **87** | 0.7 | 0.8 | 0 | | |
| | Down | 63 | 59 | 81 | 64 | 60 | 81 | 1.6 | 0.7 | 0 | 63 | 59 | 81 | 65 | 60 | 81 | 1.8 | 0.7 | 0 | | |
| NCA04 | Up | **69** | 65 | **87** | **69** | **65** | **87** | 0.3 | 0.0 | 0 | **69** | 65 | **87** | **69** | **65** | **87** | 0.3 | 0.0 | 0 | | |
| | Down | **68** | 64 | **85** | **68** | **64** | **85** | 0.1 | 0.0 | 0 | **68** | 64 | **85** | **68** | **64** | **85** | 0.1 | 0.0 | 0 | | |

Note1: **Red bold** indicates exceedances of the RING absolute noise trigger levels.

Note 2: "RING Triggers" refers to the number of locations where the RING noise trigger levels are predicted to be exceeded. For reference, the RING noise trigger levels are: development increases existing LAeq(period) rail noise levels by 2 dB or more, or existing LAmax rail noise levels by 3 dB or more ***and*** predicted rail noise levels exceed: daytime: 65 LAeq(15hour) or 85 LAmax, night-time: 60 LAeq(9hour) or 85 LAmax.

The results presented in **Table 95** for residential receivers surrounding the Chatswood dive indicate that operational noise levels in 2024 and 2034 without the project are generally already close to, or exceeding, the RING $L_{Aeq}$ and $L_{Amax}$ overall noise trigger levels due to the existing rail operations within the rail corridor.

Comparing the 'with project' and 'without project' highest residential $L_{Aeq}$ noise levels within each assessment timeframe in **Table 95**, the 'with project' noise levels are approximately the same as the 'without project' noise levels in the 2024 and 2034 scenarios. This is primarily due to the noise abatement provided by the base case noise mitigation described in **Section 4.3.4.9**.

Reference to the 'without project' predictions shows that there is essentially no change in impacts between the 2024 and 2034 timeframes. This is because the 'without project' scenarios only consider Sydney Trains related noise impacts. These impacts are not anticipated to change over time as these lines are already operating at capacity (refer **Section 4.3.4.7**).

A detailed presentation of the residential airborne noise predictions is provided by NCA in Sections **4.3.6.2.1** through **4.3.6.2.4**.

#### 4.3.6.1.2 Other Sensitive Receivers

A summary of the highest overall rail noise levels for the 2024 and 2034 scenarios are presented in **Table 96** for other sensitive receivers where a noise level increase trigger is predicted. The results are shown as the worst-case prediction in each NCA within the areas surrounding the Chatswood dive. Where an exceedance of the RING trigger levels is not predicted within a NCA, the highest overall rail noise levels are displayed for non-triggered other sensitive receivers.

**Table 96 Summary of Highest Other Sensitive Noise Triggers - Chatswood Dive**

| NCA | Side | Worst-case Predicted Noise Level (dBA) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Scenario Year 2024 | | | | | | Scenario Year 2034 | | | | | |
| | | Without Project | | With Project | | Noise Level Increase | RING Triggers | Without Project | | With Project | | Noise Level Increase | RING Triggers |
| | | LAeq(1h) Day | LAeq(1h) Night | LAeq(1h) Day | LAeq(1h) Night | LAeq(1h) | | LAeq(1h) Day | LAeq(1h) Night | LAeq(1h) Day | LAeq(1h) Night | LAeq(1h) | |
| NCA01 | Up | 59 | 55 | 61 | 56 | 1.9 | 0 | 59 | 55 | 61 | 56 | 2.2 | 0 |
| | Down | 61 | 58 | 62 | 58 | 1.0 | 0 | 61 | 58 | 62 | 58 | 1.2 | 0 |
| NCA02 | Up | - | - | - | - | - | 0 | - | - | - | - | - | 0 |
| | Down | 66 | 62 | 69 | 63 | 3.0 | 0 | 66 | 62 | 69 | 63 | 3.2 | 0 |
| NCA03 | Up | - | - | - | - | - | 0 | - | - | - | - | - | 0 |
| | Down | 63 | 59 | 64 | 60 | 1.6 | 0 | 63 | 59 | 64 | 60 | 1.8 | 0 |
| NCA04 | Up | - | - | - | - | - | 0 | - | - | - | - | - | 0 |
| | Down | 68 | 64 | 68 | 64 | 0.1 | 0 | 68 | 64 | 68 | 64 | 0.1 | 0 |

Note 1: Noise predictions are external. A conservative outside-to-inside attenuation of 10 dB has been applied.

Note 2: “RING Triggers” refers to the number of locations where the RING noise trigger levels are predicted to be exceeded.

The results presented in **Table 96** indicate that there are no exceedances of the RING trigger levels for other sensitive receivers in the vicinity of the Chatswood dive.

#### 4.3.6.2 Predicted Base Case Noise Impacts by Noise Catchment Area - Chatswood Dive

In the following sections, the predicted base case overall rail noise levels are discussed for each of the NCAs adjacent the Chatswood Dive. Tables showing the noise level predictions at all sensitive receivers are provided in **Appendix J**.

In each figure below, receiver buildings with red or orange fill indicates that the property is predicted to exceed the RING trigger levels based on either the 2024 or 2034 modelling scenario.

Where exceedances of the noise trigger levels are apparent, the RING requires additional noise mitigation to be considered. Noise mitigation options are discussed in **Section 4.3.7**.

##### 4.3.6.2.1 Predicted Noise Impacts NCA01

There are no exceedances of the operational noise trigger levels in NCA01 and hence no requirement to consider additional noise mitigation in this catchment. This results from rail operations in the vicinity of NCA01 being relatively slow in speed as services approach, stop, and depart Chatswood Station.

##### 4.3.6.2.2 Predicted Noise Impacts NCA02

Many of the most potentially affected receivers in NCA02 receive noise abatement in the ‘with project’ scenarios through the inclusion of the base case noise mitigation design. This includes the installation of rail dampers and deck absorption within the Chatswood dive structure, and an increase in the height of the existing noise barriers by 1 m.

The remaining sensitive receivers in NCA02 that are triggered for consideration of noise mitigation are shown in **Figure 46**.

**Figure 46 NCA02 Locations Triggered for Consideration of Noise Mitigation**


Exceedances of the noise trigger levels are predicted at one residential receiver building situated on the Down side of the alignment at address 1-3 Gordon Avenue, Chatswood. This residential receiver is a multi-storey apartment building and would consist of several dwellings. The upper floors of this receiver would have an unobstructed view of the rail tracks over the noise barrier, even with the proposed increase in barrier height. To break line of sight at the triggered receivers on the upper floor of this building would require a noise barrier in excess of 6 m high. Noise barriers of this height are unlikely to be considered reasonable and may not be feasible, particularly since the barrier would need to be located in close proximity to the building facade. .

#### 4.3.6.2.3 Predicted Noise Impacts NCA03

The most potentially affected receivers in NCA03 would benefit from the base case noise mitigation design, in the form of dive track source noise mitigation and the increased height of existing noise barriers. As a result, no exceedances of the operational noise trigger levels are predicted in NCA03 and there is no requirement to consider additional noise mitigation in this catchment.

#### 4.3.6.2.4 Predicted Noise Impacts NCA04

The most affected receivers in NCA04 would benefit from the proposed base case noise mitigation measures. These measures include the installation of a 2 m noise barrier at the edge of the cutting on the Up side of the corridor. As a result, there are no predicted exceedances of the operational noise trigger levels in NCA04 and hence no requirement to consider additional noise mitigation in this catchment.

#### 4.3.6.3 Potential Noise Impacts - Proposed Developments Adjacent Chatswood Dive

Commercial receivers located between Nelson Street and Mowbray Road in NCA03 are proposed to be acquired as part of the project. Detailed plans for future land use for this site are not currently available. However, potential future land uses on this site may include several multi-storey residential developments overlooking the rail corridor.

These developments may be exposed to levels of operational airborne rail noise in excess of the RING absolute noise level criteria. Accordingly any future developments on this site should adequately address the noise criteria in the Infrastructure State Environment Planning Policy (SEPP).

#### 4.3.6.4 Predicted Operational Airborne Noise Levels – Marrickville Dive

##### 4.3.6.4.1 Residential Receivers

A summary of the highest residential rail noise levels for the 2024 and 2034 scenarios are presented in **Table 97** for receivers where a RING noise level trigger is predicted. The results are shown as the worst-case prediction for the receiver potentially most affected by the project in each NCA within the areas surrounding the Marrickville dive. Where a RING trigger is not predicted within a NCA, the highest overall residential rail noise levels are displayed for non-triggered residential receivers.

**Table 97 Summary of Most Potentially Project Affected Residences - Marrickville Dive**

| NCA | Side | Worst-case Predicted Noise Level (dBA) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Scenario Year 2024 | | | | | | | | | Scenario Year 2034 | | | | | | | | |
| | | Without Project | | | With Project | | | Noise Level Increase | | RING Triggers | Without Project | | | With Project | | | Noise Level Increase | | RING Triggers |
| | | LAeq(15h) | LAeq(9h) | LAmax | LAeq(15h) | LAeq(9h) | LAmax | LAeq | LAmax | | LAeq(15h) | LAeq(9h) | LAmax | LAeq(15h) | LAeq(9h) | LAmax | LAeq | LAmax | |
| NCA32 | Up | **67** | 63 | **99** | **67** | **63** | **99** | 0.0 | 0.0 | 0 | **67** | 63 | **99** | **67** | **63** | **99** | 0.0 | 0.0 | 0 |
| | Down | **68** | 64 | **93** | **68** | **64** | **93** | 0.0 | 0.0 | 0 | **68** | 64 | **93** | **68** | **64** | **93** | 0.0 | 0.0 | 0 |
| NCA33 | Up | 41 | 38 | 55 | 50 | 44 | 68 | 9.1 | 13.5 | 0 | 41 | 37 | 55 | 50 | 45 | 68 | 9.5 | 13.5 | 0 |
| | Down | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 0 |
| NCA34 | Up | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 0 | n/a | n/a | n/a | n/a | n/a | n/a | n/a | n/a | 0 |
| | Down | 58 | 54 | 76 | 58 | 54 | 76 | 0.0 | 0.0 | 0 | 58 | 54 | 76 | 58 | 54 | 76 | 0.0 | 0.0 | 0 |

Note1: **Red bold** indicates exceedances of the RING absolute criteria levels.

Note 2: Note 2: "RING Triggers" refers to the number of locations where the RING noise trigger levels are predicted to be exceeded.

For reference, the RING trigger levels are "development increases existing LAeq(period) rail noise levels by 2 dB or more, or existing LAmax rail noise levels by 3 dB or more ***and*** predicted rail noise levels exceed: daytime: 65 LAeq(15hour) or 85 LAmax, night-time: 60 LAeq(9hour) or 85 LAmax.

The results presented in **Table 97** for residential receivers surrounding the Marrickville dive indicate that residential noise levels in NCA32 for design years 2024 and 2034 without the project are generally already close to or above, the RING $L_{Aeq}$ and $L_{Amax}$ noise criteria levels.

Comparing the 'with project' and 'without project' highest residential $L_{Aeq}$ noise levels within each assessment timeframe in **Table 97**, the 'with project' noise levels are generally the same for the 2024 and 2034 scenario. Project noise level increases are more evident in NCA33 on the up side of the corridor, and NCA04 on the down side of the corridor where the distance to the dive tracks is shortest. However the predicted noise levels in these areas are below the RING absolute noise level criteria.

Reference to the 'without project' predictions shows that there is essentially no change in impacts between the 2024 and 2034 timeframes. This is because the 'without project' scenarios only consider Sydney Trains related noise impacts which would not change over time since the lines are already at capacity (refer **Section 4.3.4.7**).

From the results presented in in **Table 97** it can be seen that there are no exceedances of the RING noise trigger levels for residential receivers surrounding the Marrickville dive for design years 2024 or 2034.

#### 4.3.6.4.2 Other Sensitive Receivers

A summary of the highest overall rail noise levels for the 2024 and 2034 scenarios are presented in **Table 98** for other sensitive receivers where a noise level increase trigger is predicted. The results are shown as the worst-case prediction in each NCA within the areas surrounding the Marrickville dive. Where a RING trigger is not predicted within a NCA, the highest overall rail noise levels are displayed for non-triggered other sensitive receivers.

**Table 98 Summary of Highest Other Sensitive Noise Levels - Marrickville Dive**

| NCA | Side | Worst-case Predicted Noise Level (dBA) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Scenario Year 2024 | | | | | | Scenario Year 2034 | | | | | |
| | | Without Project | | With Project | | Noise Level Increase | RING Triggers | Without Project | | With Project | | Noise Level Increase | RING Triggers |
| | | LAeq(1h) Day | LAeq(1h) Night | LAeq(1h) Day | LAeq(1h) Night | LAeq(1h) | | LAeq(1h) Day | LAeq(1h) Night | LAeq(1h) Day | LAeq(1h) Night | LAeq(1h) | |
| NCA32 | Up | 67 | 63 | 67 | 63 | 0.0 | 0 | 67 | 63 | 67 | 63 | 0.0 | 0 |
| | Down | 68 | 64 | 68 | 64 | 0.0 | 0 | 68 | 64 | 68 | 64 | 0.0 | 0 |
| NCA33 | Up | 51 | 49 | 55 | 51 | 4.6 | 0 | 51 | 49 | 55 | 51 | 4.8 | 0 |
| | Down | 0 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0 |
| NCA34 | Up | 69 | 64 | 69 | 64 | 0.0 | 0 | 69 | 64 | 69 | 64 | 0.0 | 0 |
| | Down | 68 | 64 | 68 | 64 | 0.0 | 0 | 68 | 64 | 68 | 64 | 0.0 | 0 |

Note 1: Noise predictions are external. An outside-to-inside attenuation of 10 dB has been applied.

Note 2: “RING Triggers” refers to the number of locations where the RING noise trigger levels are predicted to be exceeded.

The results presented in **Table 98** indicate that consideration of noise mitigation for other sensitive receivers in the vicinity of the Marrickville dive is not triggered in either the 2024 or 2034 scenarios.

#### 4.3.6.5 Potential Noise Impacts - Proposed Developments Adjacent to Marrickville Dive

Commercial receivers located on the Up side of the corridor in NCA34 are proposed to be acquired as part of the project. Detailed plans for future land use for this site are not currently available. Potential future land uses on this site are likely to comprise commercial and industrial developments. If residential developments are considered for this site, such developments should adequately address the noise criteria in the Infrastructure State Environment Planning Policy (SEPP).

#### 4.3.6.6 Summary of Locations Triggered for Consideration of Noise Mitigation

**Table 99** provides a summary of the locations where residual exceedances of the RING trigger levels are predicted.

**Table 99 Summary of Locations Triggered for Consideration of Noise Mitigation**

| Project Zone | NCA | SIDE | Number of Exceedances of RING Trigger Levels[1] | | | | Comments |
|---|---|---|---|---|---|---|---|
| | | | Residential Receivers | | Other Sensitive Receivers | | |
| | | | 2024 | 2034 | 2024 | 2034 | |
| Chatswood Dive | NCA01 | Up | 0 | 0 | 0 | 0 | n/a |
| | | Down | 0 | 0 | 0 | 0 | n/a |
| | NCA02 | Up | 0 | 0 | 0 | 0 | n/a |
| | | Down | 1 | 1 | 0 | 0 | Multistorey residential apartment building. |
| | NCA03 | Up | 0 | 0 | 0 | 0 | n/a |
| | | Down | 0 | 0 | 0 | 0 | n/a |
| | NCA04 | Up | 0 | 0 | 0 | 0 | n/a |
| | | Down | 0 | 0 | 0 | 0 | n/a |
| Marrickville Dive | NCA32 | Up | 0 | 0 | 0 | 0 | n/a |
| | | Down | 0 | 0 | 0 | 0 | n/a |
| | NCA33 | Up | 0 | 0 | 0 | 0 | n/a |
| | | Down | 0 | 0 | 0 | 0 | n/a |
| | NCA34 | Up | 0 | 0 | 0 | 0 | n/a |
| | | Down | 0 | 0 | 0 | 0 | n/a |
| | **TOTAL** | | **1** | **1** | **0** | **0** | |

Note 1: The number of locations triggered counts buildings once only, in the event that more than one facade or floor of the building is triggered. This number may be less than the number of individual dwellings triggered, for example where buildings contain multiple apartments.

### 4.3.7 Airborne Noise Mitigation Options

The noise modelling results indicate that future rail noise levels exceed the RING trigger levels at existing receivers in one residential building in Chatswood. It is therefore appropriate to assess additional feasible and reasonable noise mitigation measures for this location.

Appendix 6 of the RING provides the following guidance in relation to determining feasible and reasonable mitigation measures:

> *"A **feasible** mitigation measure is a noise-abatement measure that can be engineered and is practical to build, given proposal constraints such as safety, maintenance and reliability requirements. It may also include options such as amending operational practices (e.g. changing timetable schedules) to achieve noise reduction.*
>
> *Selecting **reasonable** measures from those that are feasible involves judging whether the overall noise benefits outweigh the overall adverse social, economic and environmental effects, including the cost of the abatement measure. To make such a judgement, consider the following.*
>
> - *Noise impacts*
> - *Noise mitigation benefits*
> - *Cost effectiveness of noise mitigation*
> - *Community views"*

A summary of potential airborne operational noise mitigation options along the proposal corridor is provided in **Table 100**, 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 receivers 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 100 Summary of Additional Operational Noise Mitigation Options**

| Description | Estimated Noise Reduction | Comments on Feasibility and Reasonableness |
|---|---|---|
| **Source Control Measures** | | |
| Reduce speeds | A 20% reduction in maximum speed would reduce $L_{Amax}$ noise levels by 2.5 dB and $L_{Aeq}$ noise levels by 1.5 dB | The speeds as proposed are required to meet service frequency demands during peak periods. Potentially feasible and reasonable outside of peak periods, for example at night. |
| Reduce overall number of train passbys | No change in $L_{Amax}$<br>1 dB in $L_{Aeq}$ for 20% reduction<br>2 dB in $L_{Aeq}$ for 35% reduction | Not feasible as train numbers are required to meet service frequency demands. |
| Reduce train lengths | Negligible change in $L_{Amax}$<br>1.3 dB reduction in $L_{Aeq}$ for 6-car trains in lieu of 8-car trains<br>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. |

| Description | Estimated Noise Reduction | Comments on Feasibility and Reasonableness |
|---|---|---|
| Minimise wheel and rail roughness | Limited by whether rail roughness or wheel roughness dominates the combined system | The specifications for the Sydney Metro operations include requirements for maintaining the rail surface (via rail grinding) and train wheel condition (via wheel lathe) in accordance with defined acceptance standards. |
| Minimise train source noise levels via specifications | N/A | Trains are locked in as specified for the Sydney Metro Northwest, and this assessment assumes similar source levels. Additional source noise reduction is not an option for this project. |
| Track design measures - rail dampers | Rail dampers provide 4 dB reduction to LAeq and LAmax for typical slab track. No benefit on ballast track. | Only applicable to slab track in the dives and tunnels. Included on Chatswood Dive slab track as base case noise mitigation. No significant benefit for ballast track. |
| Deck Absorption | Provides 2 dB reduction to LAeq and LAmax for typical slab track. No benefit on ballast track. | Absorption located in between the rails and directly adjacent the rails. Benefit to LAmax noise levels depends on origin of maximum noise. Included on Chatswood Dive slab track as base case noise mitigation. |
| Exclude “noisy” individual trains from Sydney Metro | Negligible | The operation of the Sydney Metro will include a maintenance strategy to identify and repair noisy trains. |
| **Path Control Measures** | | |
| Noise barriers - conventional at rail corridor boundary | Significant noise reduction possible (ie >5 dB) where source to receiver line-of-sight is broken by barrier. | Existing and relocated noise barriers along existing rail tracks adjacent to Chatswood Dive. Existing noise barrier increased in height as base case noise mitigation. Effectiveness limited by multi-storey dwellings. |
| Noise barriers - low profile “platform 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 train. Little benefit to tracks other than the immediately adjacent track. | Could result in high noise reduction with low visual impact. Design would need to consider rolling stock loading gauge and track maintenance requirements including safe access. Feasibility at locations with multiple tracks may be limited. |
| **Receiver Control Options** | | |
| 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 predicted to exceed the trigger levels.<br>Several receivers triggered for mitigation are modern constructions which likely include ventilation and facades with high acoustic performance in line with the requirements of the SEPP. |

### 4.3.8 Potentially Reasonable and Feasible Mitigation Options

Of the additional noise mitigation options listed in **Table 100**, those which may be feasible and reasonable for reducing the impact of operational noise at the existing receivers with identified exceedances of the trigger levels are discussed below.

#### 4.3.8.1 Low Profile Noise Barriers

Even with the inclusion of base case noise mitigation in the form of rail dampers, deck absorption, and increased noise barrier heights, it is anticipated that receivers on the down side of the corridor adjacent to the Chatswood dive would experience residual operational airborne noise impacts.

Noise from the wheel-rail interface is dominant in the region of the Chatswood dive and can be targeted directly by screening in close proximity to the source through use of low profile noise barriers. Low-profile barriers would need to be installed as close as possible to the tracks, but outside the zone in which there is the potential for them to be struck by a train or by maintenance equipment such as automated ballast cleaning machines.

There are many potential designs for low-height barriers in various situations. “Platform” profile barriers have been in use at Woollahra cutting on the Eastern Suburbs rail line since the 1970’s. Other examples of low height barrier designs are shown in **Figure 47**. The low barrier examples in **Figure 47** are installed on only one side of the tracks in most cases. The example with another barrier on the far side incorporates gaps in the low concrete barrier to permit a refuge or egress point. From an acoustic perspective, a barrier with an absorptive facing is preferred.

Safety and maintenance considerations control the detail of the design of a low-height barrier close to the track. Safety and maintenance risks can affect the feasibility of low profile noise barriers and would be considered in greater detail during the detailed design stage of the project.

Low profile noise barriers would potentially reduce noise from metro services at adjacent receivers by up to 8 dB to 10 dB. The actual benefit that can be achieved depends on the geometry of the barrier relative to the train, and the size of the residual gap. If installed on the metro tracks, low profile barriers would be unlikely to effectively address noise from the existing tracks. This mitigation option therefore would not address the total noise from all rail noise services in the corridor.

**Figure 47 Examples of Low-Height Barriers**

#### 4.3.8.2 Conventional Noise Barriers

Unlike low profile noise barriers which only mitigate noise from directly adjacent rail track sources, well designed conventional noise barriers can potentially mitigate noise emissions originating from all sources within the rail corridor.

Conventional noise barriers are generally only considered where more than three closely grouped properties require noise mitigation. In circumstances with multi-unit dwellings, the density of individual dwellings is considered when judging the potential suitability of noise barriers.

A benefit of noise barriers (both conventional and low profile) is that they maximise the noise mitigation benefits to all residents in the area, including those that have noise impacts below the RING trigger levels. Barriers also improve external amenity for all receiver types, including parks and playing fields. Conventional barriers can be constructed to greater heights than low barriers close to the tracks.

Conventional noise barriers do not necessarily satisfy all expectations. Residents may also possibly be affected by negative aspects of conventional barriers such as:

- Loss of open aspect and breezes
- Potential for vandalism and need for graffiti removal
- Reduction in visual amenity of urban landscape and potential for overshadowing
- Loss of views and vistas
- Removal of vegetation

In some cases, transparent barriers have been used in an attempt to reduce overshadowing and loss of visual amenity, but have also attracted vandalism including etching which is difficult to remove.

Conventional noise barriers are typically well suited to mitigating the mid to high frequency noise generated by steel wheels rolling on steel rails.

The primary acoustic limitation of conventional noise barriers is the requirement to break the line of sight between the noise source and receiver. In the case of the multi-storey residential receivers directly adjacent the Chatswood dive rail corridor boundary, this would require a substantial increase in existing noise barrier height.

Residual impacts at the multi-storey residential receiver building at 1-3 Gordon Avenue, Chatswood would persist even if the existing 3 m high noise barrier height were increased to 6 m. This illustrates the limited capability of noise barriers to provide effective mitigation when line of site to the rail source cannot be obstructed. Increasing the existing noise barrier height in the region of this receiver to higher than that included in the base case noise mitigation design is not likely to be a feasible mitigation option.

#### 4.3.8.3 Property Treatments

Treatments to building facades usually involve higher performance windows, doors and seals to keep noise out. Facade treatments effectively require occupants to keep their windows and doors closed and hence alternative ventilation is usually required to maintain adequate air flow.

Building treatments are generally considered as a noise mitigation option only as a final measure. If windows are closed as a noise mitigation measure, the resulting noise reductions are likely to be clearly beneficial from a quantitative and subjective perspective. If heavier glazing, laminated glazing or double glazing is provided, the additional noise benefit (quantitative and subjective) could be beneficial in some circumstances, depending on the overall facade construction of individual dwellings.

The scope and suitability of property facade treatments would depend on the existing conditions at each property and consultation with the affected receivers.

### 4.3.9 Recommended Airborne Noise Mitigation

Base case noise mitigation in the form of rail dampers, deck absorption, and increased noise barrier heights has been included in this assessment. Residual operational airborne noise impacts have been identified at one multi-storey residential receiver on the down side of the corridor adjacent to the Chatswood dive. Airborne noise levels are dominated by wheel rail noise from rail operations.

Noise barriers are unlikely to be effective at the multi-storey residential receiver located immediately adjacent the rail corridor in NCA02 on the Down side of the corridor since the line of sight from the receiver to the tracks cannot be obstructed by a conventional noise barrier.

Low profile noise barriers would potentially be effective in reducing noise from metro services at adjacent receivers but are unlikely to effectively address noise from the neighbouring T1 North Shore Line tracks. The ability of low profile noise barriers to significantly reduce noise emissions from targeted wheel-rail sources may be investigated further during the detailed design stage of the project, with consideration of the safety and maintenance risks.

Residual impacts at the multistorey residential apartment building may therefore require consideration of property treatments if detailed design studies determine the above controls are not sufficient.

## 4.4 Operational Noise from Stations and Ancillary Facilities

This section provides an assessment of the potential operational noise impacts associated with the project stations and ancillary facilities.

### 4.4.1 Nearest Receivers and Unattended Noise Monitoring Results

To determine the existing ambient noise climate within the project area, unattended ambient noise measurements were undertaken (this process is described in detail in **Chapter 1**). Measurements were performed in the vicinity of all proposed stations.

### 4.4.2 Noise Criteria

The Industrial Noise Policy (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. The more stringent of these two criteria usually defines the proposal specific noise levels. For both amenity and intrusiveness, night-time criteria are more stringent than daytime or evening criteria.

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).

Public Address system announcements at the underground stations are not anticipated to generate any audible noise emissions at sensitive receivers above ground.

#### 4.4.2.1 Industrial Noise Policy Criteria for Intrusive Noise

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), measured during the daytime, evening and night-time periods at the nearest sensitive residential receivers. In this case, the intrusiveness criteria are determined from the RBLs in **Table 4** at sensitive receiver locations nearest to the facilities.

#### 4.4.2.2 Industrial Noise Policy Criteria for Amenity

To provide protection against impacts on amenity, the INP specifies suitable maximum noise levels for particular land uses and activities during the daytime, evening and night-time periods. For this assessment, the existing residences in the vicinity of the stations and ancillary facilities are considered to be ‘Urban’. According to the INP, an ‘Urban’ area is characterised by an acoustic environment dominated by ‘urban hum’ or industrial source noise, through traffic with characteristically heavy and continuous traffic flows during peak hours, located near commercial districts or industrial districts.

According to the INP, where existing transportation $L_{Aeq}$ noise levels exceed the 'Acceptable' noise level by 10 dB or more, and the existing noise level is unlikely to decrease in future, the noise criteria should be taken to be the existing noise level minus 10 dB. This approach is also applicable to areas with high traffic noise.

The relevant INP external amenity noise criteria are presented in **Table 101**.

**Table 101 Industrial Noise Policy Amenity Noise Levels**

| Type of Receiver | Indicative Noise Amenity Area | Time of Day | Recommended $L_{Aeq}$ Noise Level (dBA) | |
|---|---|---|---|---|
| | | | Acceptable | Recommended Maximum |
| Residence | Suburban | Day | 55 | 60 |
| | | Evening | 45 | 50 |
| | | Night | 40 | 45 |
| Residence | Urban | Day | 60 | 65 |
| | | Evening | 50 | 55 |
| | | Night | 45 | 50 |
| Commercial | All | when in use | 65 | 70 |
| Active recreation area | All | when in use | 55 | 60 |
| Educational | All | when in use | 55[1] | 60[1] |
| Place of worship | All | when in use | 60[1] | 65[1] |

Note 1: External levels, based on the internal levels specified in the INP plus 20 dB (assuming open windows).

#### 4.4.2.3 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. No modifying factors have been assumed applicable for the stations and ancillary facilities.

#### 4.4.2.4 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 would occur
- The time of day (normally between 10:00 pm and 7:00 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 additional advice relating to potential sleep disturbance impacts should also be considered, including the 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.

#### 4.4.2.5 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 102**.

**Table 102 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 Sydney Metro Northwest, Epping to Chatswood Rail Line (ECRL) and Sydney Airport Rail Line.

### 4.4.3 Noise Goal Summary Mechanical and Electrical Services and Stations

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 in general the most stringent for residential receivers and are therefore the controlling design criteria at most residential locations.

“Commercial” and “active recreation area” receivers have acceptable amenity noise levels of 65 dBA and 55 dBA $L_{Aeq}$ respectively (when in use).

The locations of sensitive receivers at each station and ancillary facility and their corresponding industrial noise criteria, determined using the procedures defined within the INP (refer **Section 4.4.2**), are presented in **Table 103**.

The operational noise criteria at the nearest sensitive receivers at each station and ancillary facility, determined using the procedures defined within the INP, are presented in **Table 103**.

**Table 103 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] |
|---|---|---|---|---|---|---|
| Artarmon Substation | Traction substation | Residential | 12-14 Millner Rd, Artarmon | 25 m | B21 | 45 |
| Crows Nest Station | N Service building | Commercial | 22-28 Clarke Street, Crows Nest | 10 m | N/A | 65 |
| | S Service building | Commercial | 6-8 Clarke Street, Crows Nest | 10 m | N/A | 65 |

| Location | Operational Noise Source | Nearest Receiver Type | Address | Distance to Nearest Boundary or Facade | Reference[2] | External Noise Criteria (dBA)[1] |
|---|---|---|---|---|---|---|
| Victoria Cross Station | N Service building | Residential | 31 Mclaren Street, North Sydney | 40 m | B18 | 56 |
| | | Commercial | 194 Miller Street, North Sydney | 20 m | N/A | 65 |
| | S Service building (incl Traction substation) | Commercial | 65 Berry Street, North Sydney | <10 m | N/A | 65 |
| Barangaroo Station | N Service building and ventilation risers | Residential | 14-16 High St, Millers Point | 20 m | B12 | 45 |
| | S Service building and ventilation risers | Residential | 66 High St, Millers Point | 20 m | B12 | 45 |
| | Traction Substation and minor ventilation risers | Residential | New proposed developments | 10 m | B12 | 45 |
| Martin Place Station | N Service building | Commercial | Macquarie Bank; 48 Castlereagh St, Sydney | <10 m | N/A | 65 |
| | | Commercial | 15 Castlereagh St, Sydney | 20 m | N/A | 65 |
| | S Service building | Commercial | 43 Castlereagh St Sydney | 25 m | N/A | 65 |
| Pitt Street Station | N Service building | Hotel (Residential) | Park8 Hotel Sydney; 256 Pitt St, Sydney | <10 m | B27 | 58 |
| | | Commercial | 50 Park St, Sydney | 20 m | N/A | 65 |
| | S Service building (incl Traction substation) | Commercial | 120 Bathurst St, Sydney | 25 m | N/A | 65 |
| Central Station | Service Building | Hotel (Residential) | Central Hotel; 17 Randle Street, Surry Hills | 135 m | B09 | 50 |
| | | Commercial | 101 Chalmers Street, Chippendale | 70 m | N/A | 65 |
| Waterloo Station | N Service building (incl Traction substation) | Residential to the west | 69-83 Botany Rd, Waterloo | 25 m | B06 | 44 |
| | | Residential to the east | 209 Cope St, Waterloo | 30 m | B06 | 44 |
| | S Service building | Residential | 219 Cope St, Waterloo | 30 m | B06 | 44 |
| | | Worship | 103 Botany Rd, Waterloo | 20 m | N/A | 60 |

| Location | Operational Noise Source | Nearest Receiver Type | Address | Distance to Nearest Boundary or Facade | Reference[2] | External Noise Criteria (dBA)[1] |
|---|---|---|---|---|---|---|
| Southern services facility | Water Treatment Plant | Residential | 80 Unwins Bridge Road, St Peters | 220 m | B01 | 46 |
| | | Commercial | 15 Unwins Bridge Road, St Peters | 130 m | N/A | 65 |
| | Traction substation | Residential | 80 Unwins Bridge Road, St Peters | 220 m | B01 | 46 |
| | | Commercial | 15 Unwins Bridge Road, St Peters | 160 m | N/A | 65 |

Note 1: As discussed in **Section 4.4.3**, 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 in accordance with the INP.

Note 2: The reference location refers to the nearest unattended noise logging location in **Table 4**.

### 4.4.4 Predicted Noise Levels - Stations and Ancillary Facilities

#### 4.4.4.1 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 project 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. 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.

#### 4.4.4.2 Assessment of Mechanical and Electrical Plant and Ventilation Systems

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 104**.

**Table 104 Maximum Acceptable Noise Emissions from Station Services**

| Site Location | Ancillary Locations | Maximum Acceptable Sound Power Level (dBA) |
|---|---|---|
| Artarmon Substation | Traction substation | 78 |
| Crows Nest Station | N Service building | 90 |
| | S Service building | 90 |
| Victoria Cross Station | N Service building | 93 |
| | S Service building (incl Traction substation) | 90 |

| Site Location | Ancillary Locations | Maximum Acceptable Sound Power Level (dBA) |
|---|---|---|
| Barangaroo Station | N Service building | 76 |
| | S Service building | 76 |
| | Traction substation | 70 |
| Martin Place Station | N Service building | 90 |
| | S Service building | 98 |
| Pitt Street Station | N Service building | 83 |
| | S Service building(incl Traction substation) | 98 |
| Central Station | Service building | 98 |
| Waterloo Station | N Service building (incl Traction substation) | 77 |
| | S Service building | 79 |
| Southern services facility | Water Treatment Plant | 98 |
| | Traction Substation | 98 |

Note: Mechanical services located underground at stations and not anticipated to contribute to above ground noise emissions.

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 104** have been compared to plant and equipment selections associated with the ECRL project to determine the feasibility of achieving the project noise criteria.

#### 4.4.4.2.1 Traction Substations

Traction substations are proposed at Artarmon (next to the Gore Hill Freeway), southern services facility, Victoria Cross Station, Pitt Street Station, Barangaroo Station and Waterloo Station.

The substations would generally be 30 m to 50 m long and 10 m to 20 m wide and would be enclosed on all sides with a removable roof to allow installation, maintenance and repair works when required. The facade of the substations would generally be masonry with acoustic louvres if required for noise reduction purposes.

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 receivers, noise from traction substations can be reduced to levels below the maximum levels provided in **Table 104**.

#### 4.4.4.2.2 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 platform 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. 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. Three 40 $m^3$/s track way exhaust fans are proposed to be installed at each end of the underground stations. However, only two of the three fans are expected to be operating under normal conditions.

Overhead tunnel impulse fans are also proposed to be mounted in each tunnel at the two portal locations.

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). Similar fan and attenuator selection was assumed for the Sydney Metro Northwest and is also likely be used for this project. The tunnel ventilation fans may however 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 would 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 and 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 stations.

Careful design consideration would be required at Barangaroo, Pitt Street and Waterloo stations to minimise noise 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, acoustic louvers on ventilation discharges that noise emission from fans can be mitigated to comply with the design criteria. Such measures would be developed in the detailed design stage of the project.

#### 4.4.4.3 Assessment of Train Noise Breakout from Draught Relief Shafts

Although the proposed rail line would operate underground, 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 105**, based on noise measurements undertaken within the ECRL tunnels for a train speed of 80 km/h.

**Table 105 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.

The draught relief shafts are typically of 20 $m^2$ cross section located at each end of the station. The shafts are typically 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 draught relief shaft. The insertion loss provided by these attenuators (assuming 50% open area) would 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.

#### 4.4.5 Summary of Impacts and Mitigation Measures

The maximum allowable mechanical and electrical services sound power levels emitted at each station and ancillary facility have for detailed design purposes been calculated and range from 70 dBA to 98 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, acoustic enclosures and the strategic positioning of critical plant and vent discharges away from sensitive receivers.

# 5 SUMMARY OF NOISE AND VIBRATION MITIGATION MEASURES

## 5.1 Construction

The NSW EPA's ICNG sets out ways to deal with the impacts of construction noise on residential receivers 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 Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement) 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.

**Table 106** provides a summary of the site specific noise mitigation measures to be implemented as part of the project.

**Table 106 Summary of Site Specific Construction Noise and Vibration Mitigation Measures**

| Reference | Mitigation measure | Applicable sites[1] |
|---|---|---|
| NV1 | The Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement) would be implemented with the aim of achieving the noise management levels where feasible and reasonable.<br>This would include the following example standard mitigation measures where feasible and reasonable:<br>• Provision of noise barriers around each construction site<br>• Provision of acoustic sheds at Chatswood dive site, Crows Nest, Victoria Cross, Barangaroo, Martin Place, Pitt Street, Waterloo and Marrickville dive site<br>• The coincidence of noisy plant working simultaneously close together would be avoided<br>• Offset distances between noisy plant and sensitive receivers would be increased<br>• Residential grade mufflers would be fitted to all mobile plant<br>• Dampened rock hammers would be used<br>• Non-tonal reversing alarms would be fitted to all permanent mobile plant<br>• High noise generating activities would be scheduled for less sensitive periods considering the nearby receivers<br>• The layout of construction sites would consider opportunities to shield receivers from noise. | All |
| NV2 | Unless compliance with the relevant traffic noise criteria can be achieved, night time heavy vehicle movements at the Chatswood dive site, Crows Nest Station and Victoria Cross Station sites would be restricted to:<br>• The Pacific Highway and Mowbray Road at the Chatswood dive site<br>• The Pacific Highway, Hume Street and Oxley Street at the Crows Nest Station construction site<br>• McLaren Street, Miller Street and Berry Street at the Victoria Cross station construction site. | CDS, CN, VC |
| NV3 | Where vibration levels are predicted to exceed the screening criteria, a more detailed assessment of the structure and attended vibration monitoring would be carried out to ensure vibration levels remain below appropriate limits for that structure.<br>For heritage items, the more detailed assessment would specifically consider the heritage values of the structure in consultation with a heritage specialist to ensure sensitive heritage fabric is adequately monitored and managed. | All except metro rail tunnels |
| NV4 | Feasible and reasonable measures would be implemented to minimise ground-borne noise where exceedences are predicted. | All |
| NV5 | Feasible and reasonable mitigation measures would be implemented where power supply works would result in elevated noise levels at receivers. This would include:<br>• Carrying out works during the daytime period when in the vicinity of residential receivers<br>• Where out of hours works are required, scheduling the noisiest activities to occur in the evening period (up to 10 pm)<br>• Use of portable noise barriers around particularly noisy equipment such as concrete saws. | PSR |

*[1] STW: Surface track works; CDS: Chatswood dive site; AS: Artarmon substation; CN: Crows Nest Station; VC: Victoria Cross Station; BP: Blues Point temporary site; GI: Ground improvement works; BN: Barangaroo Station; MP: Martin Place Station; PS: Pitt Street Station; CS: Central Station; WS: Waterloo Station; MDS: Marrickville dive site; Metro rail tunnels: Tunnel not related to other sites (eg TBM works); PSR: Power supply routes.*

In addition to the above measures, the following sections provide information on control measures and strategies, consistent with the Sydney Metro CNVS (refer to Appendix E of the Environmental Impact Statement), which also provides the process to develop site specific construction noise impact statements.

#### 5.1.1.1 Source Noise Control

Source control measures should be adopted and these include:

- The minimising of noise emissions from mobile plant by fitting residential grade mufflers on all mobile plant utilised on Sydney Metro construction projects.
- The use of damped hammers is recommended such as the 'City' model Rammer hammers. These reduce the 'ringing' of the rock pick, cylinder and excavator arm that is commonly associated with rock breaking works.
- Air brake silencers should be installed and fully operational for any heavy vehicle that uses any Sydney Metro construction site.
- Heavy vehicle vehicles using the sites should have RMS compliant mufflers to control engine breaking noise.
- Non-tonal reversing alarms should be used for all permanent mobile plant operating on Sydney Metro construction projects. Whilst the use of non-tonal reversing alarms is suggested to ensure noise impacts are minimised, it is noted that OH&S requirements must also be fully satisfied.
- Regular maintenance of all plant and machinery used for the project will assist in minimising noise emissions, including the reporting of the results.
- Acoustic enclosure of plant items, if required, as identified during compliance monitoring.

#### 5.1.1.2 Noise Management Strategies

- Construction hours should be in accordance with the ICNG, and project approvals, except where otherwise specified in an approved noise management plan.
- When working adjacent to schools, medical facilities and childcare centres, particularly noisy activities should be scheduled outside normal working hours, where feasible and reasonable.
- When working adjacent to churches and places of worship particularly noisy activities should be scheduled outside services, where feasible and reasonable.
- Avoiding the coincidence of noisy plant working simultaneously close together and adjacent to sensitive receivers will result in reduced noise emissions.
- Where feasible and reasonable, the offset distance between noisy plant items and nearby noise sensitive receivers should be as great as possible.
- Regular compliance checks on the noise emissions of all plant and machinery used for the project would indicate whether noise emissions from plant items were higher than predicted. This also identifies defective silencing equipment on the items of plant.
- Ongoing noise monitoring during construction at sensitive receivers during critical periods (ie times when noise emissions are expected to be at their highest - eg piling and hammering) to identify and assist in managing high risk noise events.
- Where feasible and reasonable heavy vehicle movements should be limited to daytime hours.
- Provide training and induction for employees, contractors and subcontractors on standard mitigation measures, permissible hours of work and other aspects of the project to minimise impacts.
- Engage community consultation and the maintenance of positive, cooperative relationships with schools, local residents and building owners and occupiers assists in managing impacts from noisier operations.

#### 5.1.1.3 Vibration Management Strategies

Attended vibration measurements are required at the commencement of vibration generating activities to confirm that vibration levels satisfy the criteria for that vibration generating activity. Where there is potential for exceedances of the criteria further vibration site law investigations should be undertaken to determine the site-specific safe working distances for that vibration generating activity. Continuous vibration monitoring with audible and visible alarms should be conducted at the nearest sensitive receivers whenever vibration generating activities need to take place inside the applicable safe-working distances.

#### 5.1.1.4 Blasting Management Strategies

Attended vibration and overpressure measurements are required at the commencement of any blasting activities to confirm that vibration levels satisfy the blasting criteria. Regular vibration site law investigations would be undertaken to determine the site-specific offset distances and maximum instantaneous charge sizes to satisfy the blasting criteria at various horizontal and vertical offset distances as excavation progresses. Blasting would be planned during hours which would cause the least disruption and disturbance to the nearest sensitive receivers. For example, at sites with commercial receivers, the most appropriate period may not be the daytime period. Notification protocols prior to blasting for the nearest sensitive receivers would be established as part of environmental management documentation.

## 5.2 Operation

**Table 107** provides a summary of the site specific noise mitigation measures to be implemented as part of the project.

**Table 107 Summary of Operational Noise and Vibration Mitigation Measures**

| Reference | Mitigation measure | Applicable sites[1] |
|---|---|---|
| OpNV1 | The height and extent of noise barriers adjacent to the northern surface track works would be confirmed during detailed design with the aim of not exceeding trigger levels from the *Rail Infrastructure Noise Guidelines* (Environment Protection Authority, 2013).<br>At property treatments would be offered where there are residual exceedances of the trigger levels. | STW |
| OpNV2 | Track form would be confirmed during the detailed design process in order to meet the relevant ground-borne noise and vibration criteria from the *Rail Infrastructure Noise Guidelines* (EPA, 2013) and the *Interim Guideline for the Assessment of Noise from Rail Infrastructure Projects* (DECC, 2007). | Metro rail tunnels |
| OpNV3 | Stations and ancillary facilities including train breakout noise from draught relief shafts would be designed to meet the applicable noise criteria derived from the *Industrial Noise Policy* (EPA, 2000). | All except metro rail tunnels |

*[1] STW: Surface track works; CDS: Chatswood dive site; AS: Artarmon substation; CN: Crows Nest Station; VC: Victoria Cross Station; BP: Blues Point temporary site; GI: Ground improvement works; BN: Barangaroo Station; MP: Martin Place Station; PS: Pitt Street Station; CS: Central Station; WS: Waterloo Station; MDS: Marrickville dive site; Metro rail tunnels: Tunnel not related to other sites (eg TBM works); PSR: Power supply routes.*

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