Our ref: SSI-8256-PA-242

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Attention: Dylan Jones, Senior Manager Environment

13 October 2022

Subject: Sydney Metro - Sydenham to Bankstown SSI-8256 - Operational Noise Verification Report

Dear Mr Jones,

I refer to your submission, dated 27 September 2022, of the Operational Noise Verification Report, Revision C dated 29 July 2022 (the ONVR) for approval under Condition E31 of SSI 8256.

I note the ONVR:

- has been prepared in consultation with Inner West Council, Canterbury Bankstown Council and the NSW Environment Protection Authority;
- has been reviewed by Sydney Metro and no issues have been raised with the Department;
- has been endorsed suitably qualified persons; and
- contains the information required by the conditions of approval.

As nominee for the Planning Secretary, I approve the ONVR.

You are reminded that if there are any inconsistencies between the ONVR and the conditions of approval, the conditions prevail.

Please ensure you make the document publicly available on the project website at the earliest convenience.

If you wish to discuss the matter further, please contact Grant Rokobauer at grant.rokobauer@dpie.nsw.gov.au.

Yours sincerely

Grant Brown
A/Team Leader – Rail

As nominee of the Planning Secretary

Operational Noise and Vibration Review (ONVR)

City and Southwest Metro – Sydenham to Bankstown

SMCSW-SMD-1NL-NA-REP-050001 - **July** 2022 | Revision: C

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FUNCTION	POSITION	NAME	DATE
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Amendment Record

DATE	REVISION	AMENDMENT DESCRIPTION	AUTHOR
12/11/21	A	Consolidated draft document including southwest electrical substations	P Shetty
10/6/22	B	Draft amended for comments	P Shetty
29/7/22	C	Updated for comms input and SM comments	P Shetty

Executive Summary

Sydney Metro has prepared this Operational Noise and Vibration Review (ONVR) at the final design stage of the City and Southwest Metro (the 'Project').

The report addresses the operational noise and vibration associated with train operations between Sydenham and Bankstown and from the fixed facilities including 10 existing Sydney Trains stations that are being modified to incorporate metro infrastructure and operations.

The Sydenham to Bankstown (S2B) component was the subject of the Sydenham to Bankstown Environmental Impact Statement (EIS) and the Sydenham to Bankstown Submissions & Preferred Infrastructure Report (SPIR) and was granted planning approval on 12 December 2018. The ONVR is a requirement of Condition E31 of the Project approval.

The noise and vibration assessment in this ONVR is consistent with the assessment undertaken in the EIS and SPIR. The ONVR presents environmental noise and vibration assessments obtained from Project design documentation for the modified railway stations, other fixed facilities and rail operations to demonstrate compliance with the Project's environmental obligations.

Conditions of approval and compliance matrix

This ONVR has been prepared to address the operational noise and vibration conditions outlined in:

- State Significant Infrastructure (SSI) Approval 8256 (dated 12 December 2018)
- Revised Environmental Mitigation Measures (REMMs)

A summary of these conditions and where they have been addressed in this ONVR is provided in the table below. A detailed compliance matrix is given in Appendix A.

ID.	Approval condition	Comments and further Information
A2	The CSSI must be carried out in accordance with all procedures, commitments, preventative actions, performance criteria and mitigation measures set out in the documents listed in Condition A1 unless otherwise specified in, or required under, this approval.	For information
E18	A detailed land use survey must be undertaken to confirm sensitive receivers (including critical working areas such as operating theatres and precision laboratories) potentially exposed to Construction noise and vibration, Construction ground-borne noise and Operational noise. The survey may be undertaken on a progressive basis but must be undertaken in any one area before the commencement of Work which generate Construction or Operational noise, vibration or ground-borne noise in that area. The results of the survey must be included in the Construction Noise and Vibration Impact Statement(s) or Operational Noise and Vibration Review, where relevant.	Land survey information is provided in Appendix B
E31	The Proponent must prepare an Operational Noise and Vibration Review (ONVR) to confirm noise and vibration control measures that would be implemented for the Operation of the CSSI. The ONVR must be prepared as part of the iterative design development and in consultation with the Planning Secretary, relevant council(s), other relevant stakeholders and must:	This document - ONVR
	(a) identify appropriate Operational noise and vibration objectives and levels for surrounding development, including existing sensitive receivers;	The operational noise and vibration objectives and levels for surrounding development objectives are detailed in section 3.2, section 4.2, section 5.1.

	(b) confirm the Operational noise predictions based on the expected final design. Confirmation must be based on an appropriately calibrated noise model (which has incorporated data obtained from noise monitoring).	Airborne noise, ground borne noise and vibration predictions from train operations are presented in section 3.7 and 4.6. Predictions from fixed facilities and substations are presented in section 5.6-5.15, Appendix C, Appendix D and Appendix E
	(c) examine all noise and vibration mitigation measures, with a focus on source control and design;	A summary of mitigation measures (including at-source) is presented in section 3.9, section 4.9 and section 5.5.
	(d) identify specific physical and other mitigation measures for controlling noise and vibration at the source and at the receiver (if relevant) including location, type and timing of mitigation measures;	A summary of mitigation measures is discussed in section 3.9, section 4.7.
	(e) where noise and vibration objectives cannot be achieved, the ONVR must present an analysis of all noise and vibration mitigation measures and the 'best practice' achievable noise and vibration outcome for each activity;	A prediction analysis and a summary of mitigation measures are discussed in section 3.8, section 4.6, and section 4.8.
	(f) fully describe the design, assumptions, calculation process, mitigation strategy, and other relevant factors; and	The calculation methodology, design information and assumptions are described in section 3.4, section 4.5.
	(g) include a consultation strategy to seek feedback from directly affected landowners on the noise and vibration mitigation measures being offered. The ONVR must be verified by a suitably qualified and experienced noise and vibration expert. The ONVR must be undertaken at the Proponent's expense and submitted to the Planning Secretary for approval before the implementation of mitigation measures. The Proponent must implement the identified noise and vibration control measures and make the ONVR publicly available	A summary of the consultation strategy is contained in Section 3.10. Evidence of ONVR verification is contained in the Document Approval Record for this report

E32	Operational noise mitigation measures as identified in Condition E31 that will not be physically affected by Construction, must commence implementation within six (6) months of the commencement of Construction in the vicinity of the impacted receiver(s) to minimise Construction noise impacts, and detailed in an updated Noise and Vibration CEMP Sub-plan for the CSSI Note: For the purpose of Conditions E32 and E33, operational noise mitigation measures refer to at property or other identified non-source controls, the detail of which would broadly be included in the Noise and Vibration CEMP Sub-plan. When detail on the specific mitigation measures is known and before the implementation of the mitigation measures, the CEMP sub-plan must be updated.	Sydney Metro or construction contractor to comply
E33	Where implementation of Operational noise mitigation measures will be physically affected by Construction such that they cannot commence implementation within six (6) months of the commencement of Construction in accordance with Condition E32, the Proponent must submit to the Secretary a report providing justification as to why, along with details of temporary measures that would be implemented to reduce construction noise impacts, until such time that the Operational noise mitigation measures identified in Condition E31 are implemented. The report must be submitted to the ER for review. When the ER is satisfied that the justification and alternative measures are appropriate to address construction noise impacts, and within six (6) months of the commencement of Construction which would affect the identified sensitive receivers, the report must be submitted to the Planning Secretary for information	Not applicable

E34	Within 12 months of the commencement of Operation of the CSSI, the Proponent must undertake monitoring of Operational noise to compare actual noise performance of the CSSI against the noise performance predicted in the review of noise mitigation measures required by Condition E31. The Proponent must prepare an Operational Noise Compliance Report to document this monitoring. The Report must include, but not necessarily be limited to: (a) noise monitoring to assess compliance with the Operational noise levels predicted in the review of Operational noise mitigation measures required under Condition E31; (b) a review of the Operational noise levels in terms of criteria and noise goals established in the NSW Rail Infrastructure Noise Guideline 2013; (c) methodology, location and frequency of noise monitoring undertaken, including monitoring sites at which CSSI noise levels are ascertained, with specific reference to locations indicative of impacts on receivers; (d) details of any complaints and enquiries received in relation to Operational noise generated by the CSSI between the date of commencement of Operation and the date the report was prepared; (e) any required recalibrations of the noise model taking into consideration factors such as noise monitoring; (f) an assessment of the performance and effectiveness of applied noise mitigation measures together with a review and if necessary, reassessment of mitigation measures; and (g) identification of additional measures to those identified in the review of noise mitigation measures required by Condition E31, that are to be implemented with the objective of meeting the criteria outlined in the NSW Rail Infrastructure Noise Guideline 2013 and Noise Policy for Industry (EPA, 2017), when these measures are to be implemented and how their effectiveness is to be measured and reported to the Planning Secretary and the EPA. The Operational Noise Compliance Report must be submitted to the Planning Secretary and the EPA within 60 days of completing the Operational noise monitoring and made publicly available.	Sydney Metro to comply at operational stage

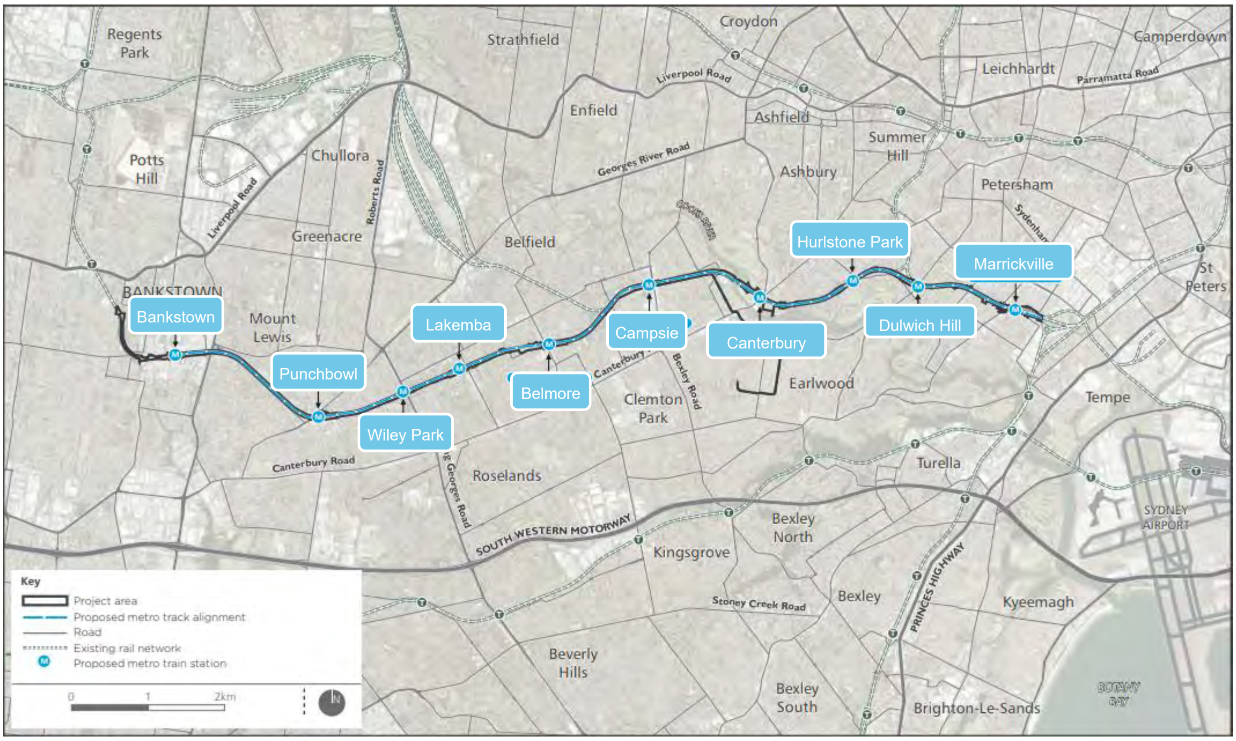
ID.	REMMs	Comments and further Information
NV01	An operational noise and vibration review would be undertaken to guide the approach to identifying reasonable and feasible mitigation measures to incorporate in the detailed design. This would include noise modelling to confirm the results of modelling previously undertaken. Where exceedances of the operational noise objectives in the Rail Infrastructure Noise Guidelines (EPA, 2013) increases noise levels and exceedances are identified, reasonable and feasible mitigation measured would be reviewed.	This document
NV02	The height and extent of noise barriers adjacent to the Project would be confirmed during detailed design with the aim of not exceeding trigger levels from the Rail Infrastructure Noise Guidelines (EPA, 2013). At-property treatments would be offered either on their own or in combination with a noise barrier where there are residual exceedances of the noise trigger levels. Where practicable, operational stage noise mitigation would be installed early to assist with the management of construction noise.	At-property treatments are identified in section 3.9.2. No noise barriers are proposed.
NV03	Operational noise from substations would be minimised by implementing appropriate management measures, such as shielding or enclosures, and specification of equipment selection, to comply with the Industrial Noise Policy (EPA, 2000).	Design requirements and mitigation measures for substations are addressed in section 5.16 - 5.20.

Rail operations overview

Sydney Metro is a new standalone rail network identified in Sydney's Rail Future[1]. The Sydney Metro network consists of Northwest Rail Link (currently in operation) and Sydney Metro City & Southwest. The future Sydney Metro West and Western Sydney Airport Metros (currently in the planning and early design stages) will add to the Sydney Metro Network.

This report addresses operational noise and vibration associated with train operations on sections of track on Metro City and Southwest between Sydenham and Bankstown. This includes the noise emissions from 10 modified at-grade Sydney Trains stations, five new electrical substations and 13 kilometres of rail corridor, from west of Sydenham Station in Marrickville, to west of Bankstown Station in Bankstown.

A map of the Sydney Metro Sydenham to Bankstown alignment is provided below. The map identifies the approximate rail alignment and the locations of the10 train stations.



Map of Sydney Metro Sydenham to Bankstown alignment

The key features of the Project include:

- works to upgrade the 10 stations and station areas between Marrickville and Bankstown (inclusive), to meet the standards required for accessible public transport
- works to meet the standards required for metro services, including:
- station works
- track and rail system facility work
- other works along the rail corridor

[1] Sydney's Rail Future: modernising Sydney's trains (Transport for NSW, June 2012)

Noise and vibration objectives

Fixed facilities

Fixed facilities include station noise sources such as mechanical and electrical services, lifts, public announcement systems, escalators, service buildings as well as separate electrical substations. When they are operational, the cumulative noise emissions from these sources are required to meet the design objectives and compliance requirements of the Project.

The Project approval was generally established on the basis of the Secretary's Environmental Assessment Requirements (SEARs) that existed when the application for approval was submitted. The SEARs, dated March 2017, refers to the NSW Industrial Noise Policy (EPA, 2000) (INP) for compliance requirements for noise from fixed facilities for the Project. This policy was replaced by the Noise Policy for Industry (2017) (NPfI) and was referenced in the Conditions of Approval for the Project, dated December 2018. Therefore NPfI (2017) forms the basis for assessment of noise from fixed facilities for the Project.

Train operations

At opening, six car metro trains would service stations every four minutes during peak periods (averaging around 15 trains per hour in each direction) and every ten minutes during the off-peak periods.

The NSW Environment Protection Authority (EPA) provides guidance for the assessment and management of airborne and ground-borne noise from railways in the *Rail Infrastructure Noise Guideline* (EPA, 2013) (RING). To assess and manage potential noise impacts from rail Projects, the RING provides non-mandatory noise triggers for residential and other sensitive receivers. Where predicted rail noise levels are above the noise triggers, reasonable and feasible noise mitigation measures should be provided to achieve the trigger levels.

The NSW Department of Environment and Conservation (DEC) document *Assessing Vibration: a technical guideline* (2006) provides the compliance requirements for operational rail vibration levels for the Project.

Operational noise and vibration impact prediction and mitigation measures

Train operations

The Nordic Rail Traffic Noise Prediction Method (Kilde Report 130, 1984) implemented in SoundPLAN 8.1 noise prediction software has been used to model the rail operation noise levels for the Project. The Nordic Rail Prediction Method calculates both L_{Aeq} and L_{Amax} levels and is referenced in the RING. More detailed information about the modelling inputs is provided in section 3.4 of this report.

The Project includes control of wheel and rail roughness as a noise reduction element in the base case design for noise mitigation. Further recommended mitigation measures are summarised in section 3.9 of this report.

Fixed facilities

Modelling of noise levels from fixed facilities was undertaken using a 3-dimensional noise model established based on the ISO 9613-2 noise propagation algorithm implemented in the SoundPLAN 8.1 noise modelling software.

Consideration has been given to the design constraints and selection of suitable equipment to determine the feasible and reasonable approach in addressing the residual noise impact in accordance with the NPfI (2017). Details of the noise mitigation measures incorporated into the design are summarised in section 5.5 of this report.

With typical noise mitigation measures incorporated to the mechanical plant design, the noise levels at the existing sensitive receiver locations surrounding the facilities have been predicted to comply with the NPfI noise criteria.

The design incorporates vibration isolation measures that ensure the vibration levels at the relevant internal and external receivers achieve the established vibration criteria.

Consultation and independent verification

This ONVR is to be reviewed by relevant Government agencies and independently verified, as required by the conditions of approval set out in SSI-8256.

A consultation strategy has been prepared and implemented to seek feedback from directly affected landowners on the noise and vibration mitigation measures being offered. A summary of the consultation strategy is contained in Section 3.10.

Table of Contents

Executive Summary 3
Conditions of approval and compliance matrix 3
Rail operations overview 9
Noise and vibration objectives 10
Fixed facilities 10
Train operations 10
Operational noise and vibration impact prediction and mitigation measures 10
Train operations 10
Fixed facilities 10
Consultation and independent verification 11

Table of Contents 12

1 Report overview 16
1.1 Nomenclature 16
1.2 Introduction 17
1.3 Operational noise and vibration assessment approach 18
1.3.1 Legislative and policy context to the assessment 18
1.3.2 Assessment approach 18
1.4 Operational noise and vibration elements 18
1.4.1 Railway operations 18
1.4.2 Fixed facilities 19
1.5 Structure of this report 20

2 Land use survey 21
2.1 Overview of requirements 21
2.2 Receiver classification methodology 21

3 Assessment of train operations – airborne noise 22
3.1 Introduction 22
3.2 Airborne noise objectives 22
3.3 Airborne noise assessment 23
3.4 Modelling methodology 23
3.4.1 Airborne noise predictive model 23
3.4.2 Source noise levels 23
3.4.3 Track features 25
3.4.4 Train speed profile 27
3.4.5 Track alignment and ground terrain 28
3.4.6 Track form and noise level correction 28
3.4.7 Rail traffic data 29
3.4.8 Other model inputs and assumptions 31
3.5 Model validation 31
3.6 Prediction uncertainties 33
3.7 Predicted airborne noise levels 33
3.8 Analysis of predicted airborne noise levels 33
3.8.1 Residential and open space land uses 33
3.8.2 Other non-residential land uses 35
3.9 Summary of mitigation measures 38
3.9.1 Rail and train treatment 38
3.9.2 Property treatment 38
3.10 Consultation Strategy 38

4 Assessment of train operations – ground borne noise and vibration 39
4.1 Introduction 39
4.2 Ground-borne noise objectives 39
4.3 Ground-borne vibration objectives 40
4.4 Ground-borne noise assessment 41
4.5 Modelling methodology 41
4.5.1 Model calibration 42
4.5.2 Source ground-borne noise and vibration levels 42
4.5.3 Vibration Propagation 44
4.5.4 Building vibration coupling loss and attenuation with elevation . 45
4.5.5 Rail traffic data 45
4.5.6 Train speed profile 46
4.5.7 Track alignment, track-form corrections and track feature corrections 46
4.6 Predicted ground-borne noise 46
4.7 Analysis of predicted exceedances 46
4.8 Predicted ground-borne vibration 48
4.8.1 Analysis of predicted exceedances 48
4.9 Summary of mitigation measures 51

5 Assessment of fixed facilities – airborne noise and vibration 52
5.1 Environmental noise objectives 52
5.1.1 NSW Noise Policy for Industry 52
5.1.2 Intrusiveness noise criteria 52
5.1.3 Amenity noise criteria 53
5.1.4 Project-specific noise levels 53
5.1.5 Sleep disturbance 54
5.2 Environmental vibration objectives 54
5.3 Environmental noise assessment 55
5.3.1 Fixed facilities 55
5.3.2 Public address system 56
5.3.3 Electrical substations 60
5.3.4 Emergency operation 60
5.4 Environmental vibration assessment 61
5.5 Summary of mitigation measures 61
5.5.1 Noise 61
5.5.2 Vibration 61
5.6 Marrickville Station 62
5.6.1 Existing and future development 62
5.6.2 Assessment locations 63
5.6.3 Background noise monitoring 63
5.6.4 Measured noise levels 63
5.6.5 Project noise criteria 64
5.6.6 Noise predictions and assessment 64
5.6.7 Emergency 65
5.7 Dulwich Hill Station 65
5.7.1 Existing and future development 65
5.7.2 Assessment locations 66
5.7.3 Background noise monitoring 67
5.7.4 Measured noise levels 67
5.7.5 Project specific criteria 67
5.7.6 Noise predictions and assessment 68
5.7.7 Emergency 68
5.8 Hurlstone Park Station 68
5.8.1 Existing and future development 69
5.8.2 Assessment locations 70
5.8.3 Background noise monitoring 70

5.8.4 Measured noise levels ... 70
5.8.5 Project-specific criteria ... 71
5.8.6 Noise predictions and assessment ... 71
5.8.7 Emergency ... 72
5.9 Canterbury Station ... 72
5.9.1 Existing and future development ... 72
5.9.2 Assessment locations ... 73
5.9.3 Background noise monitoring ... 73
5.9.4 Measured noise levels ... 73
5.9.5 Project-specific noise criteria ... 74
5.9.6 Noise predictions and assessment ... 74
5.9.7 Emergency ... 75
5.10 Campsie Station ... 75
5.10.1 Existing and future development ... 76
5.10.2 Assessment locations ... 76
5.10.3 Background noise monitoring ... 77
5.10.4 Measured noise levels ... 77
5.10.5 Project-specific noise criteria ... 77
5.10.6 Noise predictions and assessment ... 78
5.10.7 Emergency ... 78
5.11 Belmore Station ... 79
5.11.1 Existing and Future Development ... 79
5.11.2 Assessment locations ... 80
5.11.3 Background noise monitoring ... 81
5.11.4 Measured Noise levels ... 81
5.11.5 Project-specific noise criteria ... 82
5.11.6 Noise predictions and assessment ... 82
5.11.7 Emergency ... 82
5.12 Lakemba Station ... 83
5.12.1 Existing and future development ... 84
5.12.2 Assessment locations ... 84
5.12.3 Background noise monitoring ... 85
5.12.4 Measured noise levels ... 85
5.12.5 Project-specific noise criteria ... 85
5.12.6 Noise predictions and assessment ... 86
5.12.7 Emergency ... 86
5.13 Wiley Park Station ... 87
5.13.1 Existing and future development ... 87
5.13.2 Assessment locations ... 88
5.13.3 Background noise monitoring ... 88
5.13.4 Measured noise levels ... 88
5.13.5 Project-specific noise criteria ... 89
5.13.6 Noise predictions and assessment ... 89
5.13.7 Emergency ... 89
5.14 Punchbowl Station ... 90
5.14.1 Existing and future development ... 91
5.14.2 Assessment locations ... 91
5.14.3 Background noise monitoring ... 92
5.14.4 Measured noise levels ... 92
5.14.5 Project-specific noise criteria ... 92
5.14.6 Noise predictions and assessment ... 93
5.14.7 Emergency ... 93
5.15 Bankstown Station ... 94
5.15.1 Existing and future development ... 94
5.15.2 Assessment locations ... 94
5.15.3 Background noise monitoring ... 95

5.15.4 Measured noise levels ... 95
5.15.5 Project-specific noise criteria ... 96
5.15.6 Noise predictions and assessment ... 96
5.15.7 Emergency ... 96
5.16 Dulwich Hill Traction Substation ... 97
5.16.1 Existing and future development ... 97
5.16.2 Background noise monitoring ... 97
5.16.1 Assessment locations ... 98
5.16.2 Project specific noise criteria ... 98
5.16.3 Assessment and prediction ... 99
5.16.4 Vibration Assessment ... 100
5.17 Canterbury Traction Substation ... 100
5.17.1 Existing and future development ... 101
5.17.2 Background noise monitoring ... 101
5.17.3 Assessment locations ... 101
5.17.4 Project specific noise criteria ... 102
5.17.5 Assessment and prediction ... 102
5.17.6 Vibration Assessment ... 103
5.18 Campsie Bulk Infeed and Traction Substation ... 103
5.18.1 Existing and future development ... 104
5.18.2 Background noise monitoring ... 104
5.18.3 Assessment locations ... 104
5.18.4 Project specific noise criteria ... 105
5.18.5 Assessment and prediction ... 106
5.18.6 Vibration Assessment ... 106
5.19 Lakemba Traction Substation ... 106
5.19.1 Existing and future development ... 107
5.19.2 Background noise monitoring ... 107
5.19.3 Assessment locations ... 107
5.19.4 Project specific noise criteria ... 108
5.19.5 Assessment and prediction ... 108
5.19.6 Vibration Assessment ... 109
5.20 Punchbowl Traction Substation ... 109
5.20.1 Existing and future development ... 110
5.20.2 Background noise monitoring ... 110
5.20.3 Assessment locations ... 110
5.20.4 Project specific noise criteria ... 111
5.20.5 Assessment and prediction ... 111
5.20.6 Vibration Assessment ... 112

Appendix A Compliance matrix ... 113

Appendix B – Land use survey maps ... 119

Appendix C – Predicted airborne noise levels ... 120

Appendix D – Predicted ground-borne noise levels ... 121

Appendix E – Predicted ground-borne vibration levels ... 122

Appendix F – Sydney Metro Trains Source Noise Level Measurements ... 123

1 Report overview

This section of the ONVR provides an overview of the report and the assessment approach and sets out the categories and sources of operational noise and vibration which arise from a metro system.

1.1 Nomenclature

Technical Term	Description
Attenuation	A reduction in amplitude of noise or vibration due to increasing distance or other means such as noise barriers, materials or mitigation measures.
Adverse weather	Weather effects that enhance noise (that is, wind and temperature inversions) that occur at a site for a significant period (that is, wind occurring more than 30% of the time in any assessment period in any season and/or temperature inversions occurring more than 30% of the nights in winter).
Airborne noise	Noise that propagates through the air between source and receiver. Most relevant for noise from surface railway tracks or fixed facilities.
Alignment	The position of the railway tracks in three dimensions along their length.
Ambient noise	The all-encompassing noise within a given environment at a given time, usually composed of sound from all sources near and far.
Assessment period	The period in a day over which assessments are made. Assessment periods may be daytime, evening, night-time, 24-hour or busiest 1-hour period (when in use). Time periods associated with each assessment period are defined in the relevant section of this report and differ for rail operations and fixed facilities.
ADIP	Acoustic Design Integration Plan
ADIS	Acoustic Design Integration Strategy
Background noise	Background noise is the term used to describe the underlying level of noise present in the ambient noise, measured in the absence of the noise under investigation, when extraneous noise is removed. It is described as the average of the minimum noise levels measured on a sound level meter and is measured statistically as the A-weighted noise level exceeded for ninety percent of a sample period. This is represented as the L90 noise level (see below).
Chainage	Refers to the distance, along the railway tracks, from Central Station, usually given in kilometres or metres. Down direction refers to trains travelling away from Central Station. Up direction refers to trains travelling towards Central Station.
SPR	Scope and Performance Requirements
SWTC	Scope of Works and Technical Requirements
Decibel (dB)	A unit of measure commonly used to express noise and vibration.
Leq	The average noise energy over a relevant period of noise measurements and takes into account peak and fluctuating noise levels.
LAeq	The A-weighted average noise level over a given period.

LAF90	The A-weighted noise level that is exceeded for 90% of the time over a relevant measurement period using a fast time weighting. The level is typically used to measure the background noise level and derived RBL.
LAmax	The A-weighted maximum sound pressure level of an event using a fast time Weighting
NCC	Noise catchment category: Area of noise sensitive receivers with the same noise amenity levels, defined based on the planning zoning in the relevant local environmental plan and the associated residential receiver categories.
NPfI	Noise Policy for Industry (EPA, 2017)
RBL	The overall single-figure background level representing each assessment period (day/evening/night) over the whole monitoring period.
Sound Power Level (SWL)	The measure of the power of a sound relative to a specified reference level, on a logarithmic dB scale.
Sound Pressure Level (SPL)	The measure of the effective sound pressure of a sound, or level of noise, relative a specified reference level, on a logarithmic dB scale.
dB(A)	A-weighted decibels. The ear is not as effective in hearing low frequency sounds as it is hearing high frequency sounds. That is, low frequency sounds of the same dB level are not heard as loud as high frequency sounds. The sound level meter replicates the human response of the ear by using an electronic filter which is called the “A” filter. A sound level measured with this filter switched on is denoted as dB(A). Practically all noise is measured using the A filter. The following are examples of the decibel readings of everyday sounds: 0dB(A) The faintest sound we can hear 30dB(A) A quiet library or in a quiet location in the country 45dB(A) Typical office space. Ambience in the city at night 60dB(A) CBD mall at lunch time 70dB(A) The sound of a car passing on the street 80dB(A) Loud music played at home 90dB(A) The sound of a truck passing on the street 100dB (A) The sound of a rock band 115dB (A) Limit of sound permitted in industry 120dB (A) Deafening
DP&E	NSW Department of Planning and Environment
INP	NSW Industrial Noise Policy (EPA, 2000)
RING	Rail Infrastructure Noise Guideline (EPA, 2013)

Table 1-1 Nomenclature

1.2 Introduction

The Sydenham to Bankstown component of the City and Southwest Metro was granted approval under SSI approval 8256. Condition E31 of planning approval 8256 requires that an Operational Noise and Vibration Review (ONVR) be produced to confirm the noise and vibration control measures that will be implemented for the Operation of the CSSI.

Sydney Metro has prepared this ONVR to satisfy condition E31 of the planning approval based on the final design stage documentation for the Sydney Metro City and Southwest Metro.

This section covers the operational noise and vibration assessment. An overview of the assessed operational noise and vibration sources is as follows:

- Airborne noise and vibration from rail operations on surface track alignment
- Ground-borne noise and vibration from rail operations on surface track alignment

- Operational noise and vibration from fixed facilities, including station facilities, service buildings and electrical substations.

1.3 Operational noise and vibration assessment approach

1.3.1 Legislative and policy context to the assessment

The guidelines and standards relevant to the operational noise and vibration assessment include:

- Rail Infrastructure Noise Guideline (EPA, 2013) (referred to as RING)
- Assessing Vibration: A Technical Guideline (DEC, 2006) (referred to as the vibration guideline)
- International Standard ISO 14837-1 2005 Mechanical vibration - Ground-borne noise and vibration arising from rail systems - Part 1: General Guidance
- NSW Noise Policy for Industry (EPA,2017) (referred to as NPfI)

1.3.2 Assessment approach

The assessment approach involved:

- Identifying and classifying sensitive receivers
- Determining noise and vibration criteria in accordance with relevant guidelines, and where appropriate, based on the results of ambient noise monitoring (either from the EIS or during design)
- Modelling to quantify the noise and vibration emissions likely to be experienced
- Assessing the significance of noise levels which exceed the relevant guideline values
- Identifying and assessing reasonable and feasible design measures to mitigate any predicted exceedances of the relevant trigger levels and guideline values.

Further information relating to the assessment approach for operational noise and vibration is provided in section 3.3 and 4.4.

1.4 Operational noise and vibration elements

Depending on the nature of the noise or vibration source, and the type of sensitive receiver potentially affected, different sources may need to be considered cumulatively with one another. Noise and vibration are treated differently according to their provenance, which can be split into two categories: railway operations and fixed facilities.

Noise and vibration associated with road traffic and construction activities is not covered by this document.

1.4.1 Railway operations

Noise and vibration emissions associated with railway operations need to be assessed in accordance with the RING (2013) and Assessing Vibration: a technical guideline (2006).

Emissions from railway operations fall into five main categories: airborne noise, ground-borne vibration, ground-borne noise, structure-borne vibration and structure-borne noise.

Airborne noise

Airborne noise propagates between the source and the receiver through the air. This is the primary form of noise that occurs on surface railway tracks and is the most common form of noise experienced by people. The noise arises from:

- Rolling stock mechanical and electrical systems, including air conditioning.
- Wheel-rail interaction, including vibration of train wheels and wheel squeal; and
- Track response, including noise emitted by the running rails when they vibrate.

Ground-borne noise

Train noise in buildings adjacent to rail track where airborne noise does not travel directly to the receiver (such as where the airborne noise transmission path is blocked by a large screen or enclosure) 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. Predictions of ground-borne noise levels have been made for all buildings located adjacent to the proposed rail alignment.

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. 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 vibration levels are predicted for all residential receivers and other sensitive receiver locations above or near to the proposed Project alignment within the Project area.

Structure-borne noise

Structure-borne noise results from the excitation of building fabric or bridge/viaduct structures by structure-borne vibration, which re-radiates as noise. This is typically only an issue where the railway track is supported by a building, such as an underground railway station, or is elevated on a viaduct or bridge. Structure-borne noise is not relevant to the Project area associated with Sydenham to Bankstown section of the City and Southwest Metro.

Structure-borne vibration

Structure-borne vibration is similar to ground-borne vibration, only the transmission path from the railway to receiver does not include the ground. This phenomenon would arise where a development is built directly atop an underground station such that there is a direct path from track or vibrating plant to receiver through the structure of the station and development.

1.4.2 Fixed facilities

Noise from fixed facilities includes sources such as station operations, electrical substations, service facilities and public address systems. The relevant policy governing the assessment of airborne noise emissions from fixed facilities is the NSW NPfI (2017). Additional requirements are introduced through the REMMs and Sydney Metro’s Scope and Performance Requirements (SPRs).

Emissions from fixed facilities covers three main phenomena: airborne noise, structure-borne vibration and structure-borne noise.

Airborne noise

Airborne noise criteria for the operation of stations and ancillary facilities such as traction substations were determined from the noise measurements undertaken in surrounding areas, in accordance with the procedures outlined in the NPfI (2017). Airborne noise sources for fixed facilities include:

- High-voltage transformers and other equipment within electrical substations

- Mechanical and electrical plant within the stations
- Station emergency systems
- Lifts and escalators
- Service buildings
- Public address systems (PA System)

The most significant noise sources for Sydenham to Bankstown stations tend to be station emergency systems and PA system noise spill. There is no tunnel ventilation equipment associated with southwest corridor stations which are all located above ground. The transformers within electrical substations for the southwest corridor are the other principal fixed facilities noise sources.

Structure-borne noise and vibration

Structure-borne noise results from the excitation of building fabric by structure-borne vibration, which re-radiates as noise. This may need to be considered cumulatively with airborne noise.

For fixed facilities, structure-borne vibration is most likely to be caused by equipment with moving components, such as ventilation fans. Although these are mounted on anti-vibration mountings, the possibility of vibration transmitted to adjacent receptors during operations is assessed in this report.

1.5 Structure of this report

This report is structured as follows:

- Section 2 Land use survey.
- Section 3.7 Summary of the predicted airborne noise at sensitive receivers located adjacent to the rail alignment.
- Section 4.6 Summary of the predicted ground-borne noise and vibration at sensitive receivers located adjacent to the rail alignment.
- Section 5.6 - 5.15 Site-by site summary of the predicted airborne noise and vibration at sensitive receivers from the stations.
- Section 5.16 - 5.20 Site-by site summary of the predicted airborne noise and vibration at sensitive receivers from the electrical substations.

2 Land use survey

Prior to construction of the SSI, a detailed land use survey was undertaken to identify potentially critical areas that are sensitive to construction and operational noise (air and ground borne) and vibration impacts. The land use survey for City and Southwest Metro built upon the work presented in Chapter 16 of the EIS, land uses and property using the process described below in Sections 2.1 and 2.2. Information about the land uses and sensitive receivers around the Project are summarised in each section of the report. A land use survey location map for Sydenham to Bankstown corridor is provided in Appendix B.

2.1 Overview of requirements

A land use survey has been undertaken to confirm the location of all sensitive receptors that are potentially impacted by noise and vibration from operation of the Sydenham to Bankstown rail operations. The land use survey was based on:

- Receptors and land use imported from the EIS stage design (Sydney Metro City & Southwest – Sydenham to Bankstown upgrade EIS, December 2018). This consisted of geospatial dataset including building footprints, building heights, preliminary basement information and land use type.
- The Sydney Metro Acoustic Assurance Tool (AAT).
- Desktop review of all receptors above the alignment based on available aerial photography, online Development Authorisation plans, Google Street-view, etc.
- A review of all known sensitive receptors with the Sydney Metro Communications Management team for each package covering all areas above the tunnel.
- On-site inspection of key receptors by the project team and other information available in the public domain.

2.2 Receiver classification methodology

The existing and proposed land use within a corridor extending approximately 100 m either side of the Project rail alignment and typically 200 m from the Project has been 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:

- Residential
- Commercial
- Industrial
- Educational
- Place of Worship
- Childcare
- Hospital (including hospital wards and operating areas)
- Special Sensitive (e.g., areas containing specialist vibration sensitive equipment, such as hospital precision laboratories, recording studios)

The noise and vibration assessment presented in this report considers all receivers within the Project area.

3 Assessment of train operations – airborne noise

3.1 Introduction

The Project involves upgrade works to the Sydenham to Bankstown line to facilitate replacement of the Sydney Trains rolling stock with Sydney Metro's rolling stock, with trains running every four minutes in peak periods, averaging around 15 trains per hour in each direction. The key elements of the Project are located mainly within the existing rail corridor, from about 800 metres west of Sydenham Station in Marrickville, to about one kilometre west of Bankstown Station in Bankstown.

The Project will use the existing Sydney Trains tracks where possible. In some locations, there may be a need to upgrade/replace the existing track, which would involve replacing the rails, sleepers, fastenings and ballast. The track may need to be replaced because of its condition in some locations.

Once the Project is operational, Sydney Trains services will no longer operate along the T3 Bankstown line between Sydenham and Bankstown stations.

3.2 Airborne noise objectives

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 pass-by the wheel, bogies, rail and rail support system vibrate and transfer this energy to the surrounding environment as airborne noise. The key influences on airborne noise are the train speed, the condition of the wheel and rail, the train length, number of trains pass-by 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.

The NSW EPA provides guidance for the assessment and management of potential airborne noise from railways in the RING. To assess and manage potential noise from rail projects, the RING provides non-mandatory airborne noise triggers for residential and other sensitive receivers. Where predicted rail noise levels are above the noise triggers, reasonable and feasible noise mitigation measures should be provided to achieve the trigger levels.

For redevelopment of an existing heavy rail line, the RING provides airborne noise trigger levels for residential and non-residential land uses as provided in Table 3-1 and Table 3-2 , respectively.

Sensitive land use	Time of the day	External noise trigger levels
Development increases existing $L_{Aeq(period)}$[1] rail noise levels by 2 dB(A) or more, or existing L_{Amax} rail noise levels by 3 dB(A) or more and predicted rail noise levels exceed:		
Residential	Day (7am – 10pm)	65 $L_{Aeq(15h)}$ or 85 L_{Amax}[2]
	Night (10pm – 7am)	60 $L_{Aeq(9h)}$ or 85 L_{Amax}

Table 3-1 Airborne noise criteria for residential receivers

Notes:

1. $L_{Aeq(period)}$ means $L_{Aeq(15h)}$ for the daytime period and $L_{Aeq(9h)}$ for the night-time period.

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.

Sensitive land use	Trigger
Development increases existing rail noise levels by 2 dB(A) or more in L_{Aeq} for that period and resulting rail noise levels exceed:	
Schools, educational institutions, and childcare centres	45 $L_{Aeq(1h)}$ internal
Places of worship	45 $L_{Aeq\ (1h)}$ internal
Hospital wards	40 $L_{Aeq\ (1h)}$ internal
Hospital other uses	65 $L_{Aeq\ (1h)}$
Open space – passive use (parklands, bush reserves)	65 $L_{Aeq\ (15h)}$
Open Space – active use (sports field, golf course)	65 $L_{Aeq\ (15h)}$

Table 3-2 Airborne noise criteria for non- residential receivers

3.3 Airborne noise assessment

The RING requires that the noise from the Project be assessed at Project opening year (2024) and for a future design year, typically ten years or more after opening. The EIS has considered Project opening year as 2024 and future design year as 2034. This assessment has considered Project opening year as 2024, and future design year as 2036 based on the updated rail traffic data that was available (noting that rail traffic volumes are expected to either remain the same or increase from 2034 to 2036, and therefore the assessment provides a conservative outcome). The following operational scenarios have been modelled and assessed:

- ‘no build’ and ‘with build’ for opening year in 2024; and
- ‘no build’ and ‘with build’ for future design year in 2036

3.4 Modelling methodology

3.4.1 Airborne noise predictive model

The Nordic Rail Traffic Noise Prediction Method (Kilde Report 130, 1984) implemented in SoundPLAN 8.1 noise prediction software has been used to model the operational rail airborne noise levels for the Project. The Nordic Rail Prediction Method calculates both L_{Aeq} and L_{Amax} levels as referenced in the RING.

3.4.2 Source noise levels

The noise sources included in the rail operation modelling are:

- Sydney Trains
- Sydney Metro Trains
- Freight trains (locomotives and wagons)

It is noted that the Sydney Light Rail near Dulwich Hill was included in the noise modelling. Considering that the noise contribution from the light rail line was not significant in comparison to the heavy rail lines above, and that the noise contribution did not influence the assessment outcome, the Sydney Light Rail impacts have not been considered further and excluded from further reference in this document.

The noise levels for each train type used in the predictions are provided below. The noise levels are referenced to 80 kilometres/hour train speed, and at 15 metres setback distance from the rail centreline. The noise levels used in the noise modelling assume the rail tracks are in good condition with the running surface of the rail head free of defects; and that the wheel tread conditions of the passenger trains are in good condition.

Sydney Trains source noise levels

A baseline airborne noise survey was conducted along the existing Bankstown Line to determine the aggregate source noise levels for the existing Sydney Trains fleet. This is summarised in the Metron Memorandum “Sydney Metro City and Southwest – Baseline Airborne Noise Survey Results” (the Baseline Survey Report), dated 4 June 2020. The survey included noise measurements of up to 195 train pass-bys taken at five locations adjacent straight sections of rail line (other locations were selected based on the presence of turnouts/ rail curvature and different terrain). The attended noise measurements included a mixture of A, B, C, K and M train sets and were used to derive the representative noise emission levels from the existing Sydney Trains operations.

The noise levels derived from the baseline survey data (summarised in Table 3-3) were used in the operational rail airborne noise model.

Baseline survey results	$L_{Amax\ 95\%}$[1] (dB)	L_{AE}[2] (dB)
Mix of A,B,C,K,M sets	83	85

Table 3-3 Sydney Trains source noise levels

Notes:

1. Calculated based on the 95% percentile of the measured L_{Amax} noise levels in the combined dataset.

2. Calculated based on the logarithmic average of the standardised L_{Aeq} noise levels in the combined dataset.

Sydney Metro train source noise levels

Noise measurements were undertaken for the Alstom Metropolis Trains operating on the recently opened North West Rail Link (NWRL) and the measured data was compared with the manufacturer’s NWRL compliance test measurements to determine the Sydney Metro train source noise levels for input the airborne noise model. Further details of the measurements and comparison are provided in the Metron Report “Sydenham to Bankstown Rail Operation – Airborne Noise Review”, dated 27 November 2020, and included in Appendix F.

Table 3-4 summarises the source noise levels (L_{Amax} and L_{AE}) from the NWRL measurements and the manufacturer test data, referenced to 80 kilometres/hour train speed and at 15 metres setback distance from the rail centreline.

Data source	$L_{Amax\ 95\%}$ (dB)	L_{AE} (dB)
NWRL measurement	82	85
Manufacture test data	80	83

Table 3-4 Sydney Metro train source noise levels

The source noise levels for Sydney Metro trains in the operational rail airborne noise model were based on the NWRL measurements. It is noted that the L_{AE} source noise level for the Sydney Metro trains is the same as the L_{AE} source level for Sydney Trains’ rolling stock as measured and assessed during the Bankstown survey.

Freight train noise levels

The noise levels derived based on the NSW Rail Noise Database have been used in the noise model. The source noise levels are summarised in Table 3-5 and have been validated with measurements in the EIS study.

Freight Train	$L_{Amax\ 95\%}$ (dB)	L_{AE} (dB)
Per locomotive [1]	94	88
Per wagon [2]	90	83

Table 3-5 Freight Train noise levels

Notes:

1. A total of 3 locomotives per train, each locomotive with average 20m length.

2. A total of 45 wagons per train, each wagon with average 18m length.

3.4.3 Track features

Turnout correction

Where a turnout occurs, a correction of +6 dB(A) increase has been applied to the noise level input (both L_{AE} and L_{Amax},95%) 10 metres before and after the point identified.

Curve gain corrections

Curve gain corrections in Table 3-6 have been applied where tight curves occur. The curve locations and applied corrections in the noise model are summarised in Table 3-7.

Curve radius	Passenger train adjustment[1]		Freight train adjustment[2]	
	L_{Aeq} (dB)	L_{Amax} (dB)	L_{Aeq} (dB)	L_{Amax} (dB)
Greater than 500m	0	0	0	0
400m to 500m	3	3	3	3
300m to 400m	8	16	5	5
200m to 300m	8	17	8	8
Less than 200m	8	17	8	8

Table 3-6 Curve gain corrections

Notes:

1. Basutu, L., Hanson, D., Schulten, C.: Modelling Curve Gain in NSW. Acoustics Australia (2015) 43:245-250.

2. Consistent with SCHALL 03 2006, Richtlinie zur Berechnug der Schallimmissionen von Eisenbahnen und Strabenbahnen (Draft, 21.12.2006). EIS have used these values and the noise model has been validated with site measurements.

Curve	Rail line	Approx. chainage	Approx. curve radius (m)	Passenger train		Freight train	
				L_{Aeq} (dB)	L_{Amax}	L_{Aeq} (dB)	L_{Amax}
1	Botany line	5.530 to 6.160	230	-	-	8	8
2	Goods line	8.130 to 8.630	390	8	16	5	5
	Bankstown line	-8.180 to -8.660					

Curve	Rail line	Approx. chainage	Approx. curve radius (m)	Passenger train		Freight train	
				L_{Aeq} (dB)	L_{Amax}	L_{Aeq} (dB)	L_{Amax}
	Metro line	-8.800 to -9.280					
3	Goods line	9.660 to 9.990	420	3	3	3	3
	Bankstown line	-9.690 to -9.990					
	Metro line	-10.310 to -10.610					
4	Goods line	10.540 to 10.890	410	3	3	3	3
	Bankstown line	-10.560 to -10.900					
	Metro line	-11.180 to -11.520					
5	Goods line	11.870 to 12.130	380	8	16	5	5
	Bankstown line	-11.910 to -12.160					
	Metro line	-12.530 to 12.789					
6	Good line	12.290 to 12.560	190	-	-	8	8
7	Meeks line	5.890 to 6.070	190	-	-	8	8
8	Meeks line	-5.530 to -5.890	250	-	-	8	8
9	Bankstown & Metro line	-6.170 to -6.510	310	8	16	-	-
10	Bankstown & Metro line	-16.410 to -16.840	430	3	3	-	-
11	Bankstown line	-17.030 to -17.460	> 500[1]	3	3	-	-
12	Bankstown line	-18.960 to -19.130	320	8	16	-	-

Table 3-7 Curve gain applied corrections

Note: 1 The curvature radius is greater than 500m radius, therefore a correction would typically not be applied. However, a correction has been considered for this curve, for the Sydney Trains operation (i.e. not included for the Sydney Metro operation) based on observations of significant flanging from the older double-deck K-set trains during the baseline survey.

Bridge noise corrections

The corrections applied to account for potential structure-radiated noise from rail bridges are summarised in Table 3-8.

Bridge	Approx. chainage	Rail line	Bridge	
			Construction description	Correction dB(A)
Unwins Bridge Road	-5.300 to -5.340	Goods line	Ballasted, concrete span, no side screens	0
Illawarra line overpass	-5.470 to -5.520	Goods line	Open transom, fabricated steel web, no side screens	+10
Frasier Park bridge	-5.680 to -5.700	Goods line	Ballasted, concrete span, no side screens	0
Victoria Road bridge	-6.310 to -6.340	Goods line Bankstown line Sydney Metro line	Open transom, fabricated steel web, no side screens	+8
Ness Avenue bridge	-8.160 to -8.190	Goods line Bankstown line Sydney Metro line	Ballasted, concrete span, no side screens	0
Foord Avenue bridge	-9.070 to –9.100	Goods line Bankstown line Sydney Metro line	Ballasted, concrete span, no side screens	0
Broughton Street and Cooks River bridge – passenger train	-10.420 to 10.520	Bankstown line Sydney Metro line	Ballasted, concrete span, no side screens	+4
Broughton Street Bridge - Freight train Cooks River Bridge - Freight Train Bridge	-10.420 to -10.520	Goods line	Ballasted, concrete span, no side screens	+4
Nowra Street Bridge	-10.700 to -10.740	Bankstown line Sydney Metro line	Ballasted, concrete span, no side screens	0
Belmore Sportsground Pedestrian Overpass	-12.770 to -12.790	Bankstown line Sydney Metro line	Ballasted, concrete span, no side screens	0
West Terrace Road Bridge	-18.430 to -18.460	Bankstown line Sydney Metro line	Ballasted, concrete span, no side screens	0

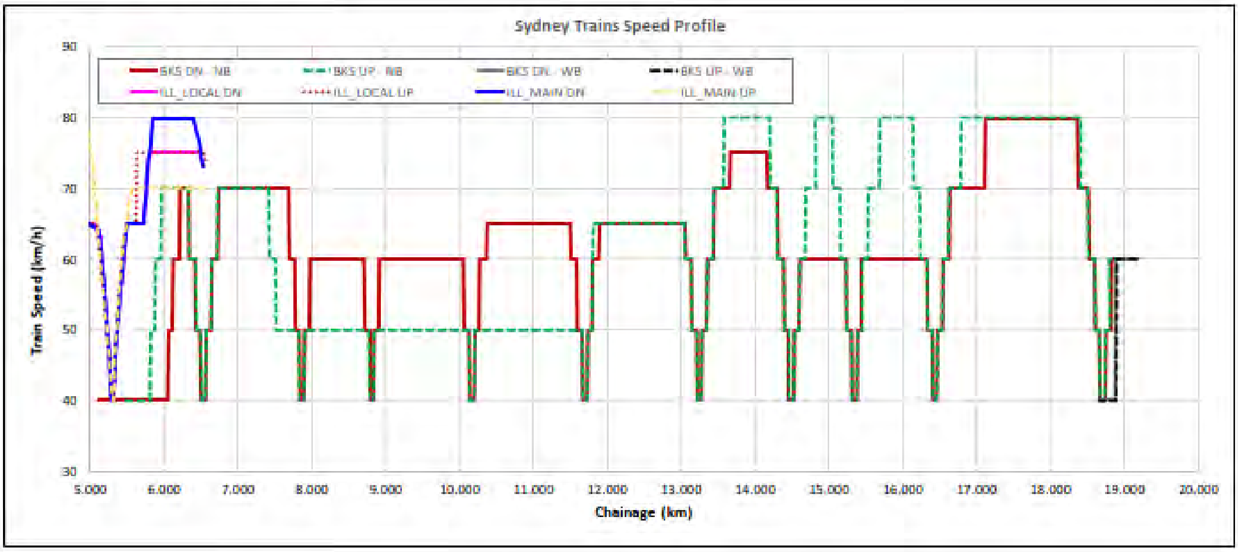
Table 3-8 Bridge noise corrections

3.4.4 Train speed profile

The train speed profiles used for Sydney Trains and Sydney Metro rail operations in the operational noise model for Sydenham to Bankstown are shown in the Figure 3-1 below.

For freight trains, a fixed average speed of 40km/h along the entire freight line was applied. The freight train speed, along with the locomotive notch setting associated with the source noise level in Table 3-5 has been validated with noise measurements in the EIS study.

Sydney Trains Speed Profile



Sydney Metro Speed Profile

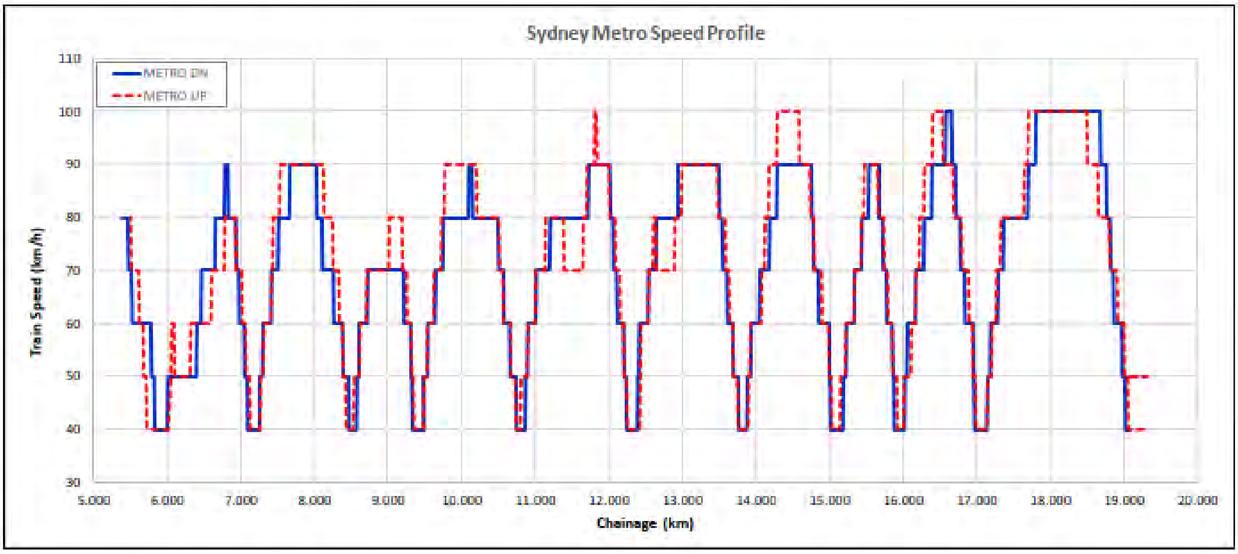


Figure 3-1 Train speed profiles for Sydney Trains and Sydney Metro used in the operational noise model

3.4.5 Track alignment and ground terrain

Minor adjustment has been made to the Sydney Metro track alignment since the EIS. The modelling has been based on the updated track alignment as provided by the Project team. The existing track alignments for the other lines (Sydney Trains and Freight lines) have been based on the EIS model. The digital ground terrain generated during the EIS has been incorporated in the model, which includes cuttings and embankments. The ground terrain for the future build scenario was modified to account for the adjustments made to the Sydney Metro track alignment.

3.4.6 Track form and noise level correction

The slab track is a ‘standard attenuation’ direct fix track with relatively stiff baseplates. A +6 dB(A) adjustment has been adopted for the noise model which is the conservative approach for this type of trackform.

The future Sydney Metro City and Southwest surface track will primarily consist of ballasted track with concrete sleepers, except at the following stations where slab track has been incorporated in the design:

- Marrickville
- Dulwich Hill
- Hurlstone Park
- Canterbury
- Campsie
- Belmore
- Lakemba
- Punchbowl

The slab track form is being installed for the extent of rail (both Up and Down lines) summarised in

Table **3-9**. These chainages represent the lengths of the station platforms, plus an additional allowance of 20 metres for transitions at both ends of the platforms. All other sections of the future Sydney Metro surface tracks and existing tracks (Sydney Trains and freight lines) were modelled as ballasted track with concrete sleepers.

Station	Chainage (Sydney Metro both Down and Up lines line)
Marrickville	- 7.090 to - 7.290
Dulwich Hill	- 8.390 to - 8.600
Hurlstone Park	- 9.320 to - 9.530
Canterbury	- 10.690 to - 10.900
Campsie	- 12.230 to - 12.430

Belmore	- 13.780 to - 13.980
Lakemba	- 15.010 to - 15.220
Punchbowl	- 16.970 to - 17.180

Table 3-9 Chainages modelled as slab track form

3.4.7 Rail traffic data

The number of rail traffic movements for the opening year (2024) and the future year (2036) were obtained from Sydney Metro and Australian Rail Track Corporation (ARTC). The number of train movements per weekday (daytime and night-time) incorporated in the noise model for each rail line are summarised in Table 3-10 below.

Rail line	Scenario	Day		Night	
		Up	Down	Up	Down
Bankstown line (T3)[1]	2024 no	96	91	22	22
	2024 with	0	0	0	0
	2036 no	96	91	22	22
	2036 with	0	0	0	0
Illawarra Locals @ Sydenham (T4, T8, Intercity, Country)[1]	2024 no	32	31	9	9
	2024 with	32	31	10	9
	2036 no	155	155	46	46
	2036 with	155	155	46	46
Illawarra Mains @ Sydenham (T4, Intercity, Country,	2024 no	171	178	34	25
	2024 with	171	178	34	25
	2036 no	328	328	104	104
	2036 with	328	328	104	104
	2024 no	0	0	0	0

Rail line	Scenario	Day		Night	
		Up	Down	Up	Down
Sydney Metro Line[3]	2024 with	225	225	27	27
	2036 no	0	0	0	0
	2036 with	263	263	27	27
Goods Line[2]	2024 no	35	35	21	21
	2024 with	35	35	21	21
	2036 no	45	45	27	27
	2036 with	45	45	27	27
Botany Line @ Sydenham[2]	2024 no	24	24	15	15
	2024 with	24	24	15	15
	2036 no	35	35	21	21
	2036 with	35	35	21	21
Meeks Line[4]	2024 no	11	11	6	6
	2024 with	11	11	6	6
	2036 no	10	10	6	6
	2036 with	10	10	6	6

Table 3-10 Rail traffic data used in the airborne noise model

Source:

1. TfNSW

2. ARTC

3. Sydney Metro

4. Estimated based on ARTC data for Goods Line and Botany Line

Note that there are expected future increases to the Sydney Trains traffic numbers along the existing Illawarra lines (main and local), under the Sydney's Rail Future Plan.

3.4.8 Other model inputs and assumptions

The following summarises the other model inputs and assumptions used in the operational rail airborne noise model:

- Ground type: hard ground
- Receiver height: 1.5 metres above ground (or floor level for multi-storey buildings)
- Floor height: 3 metres per floor level
- Train noise characteristics assumptions:
- Train braking noise is no greater than the pass-by noise levels based on train type acceptance testing data;
- Train traction inverter noise as trains accelerate from standstill at Metro stations is shielded by the station and platform sliding door structures;

- Any existing noise associated with the freight train line such as bunching noise or horn use will not be exacerbated with the project build, as the freight line aspect of the rail corridor will not be changed with the project.

3.5 Model validation

Baseline noise survey measurements have been conducted at 10 locations along the Bankstown Line. The survey included five locations with unobscured line-of-sight to straight sections of the rail line, and five locations near curved sections of the rail line and/or with some portion of the rail line obscured (by ground topography or elevation difference). Rail roughness survey was also undertaken at each baseline noise survey location to characterise the rail surface condition.

The baseline noise survey measurements have been used to validate the Sydney Trains source noise level input and the airborne noise model. The predicted noise levels at the survey locations were compared with the measured noise levels and summarised in Table 3-11.

Baseline survey			Average noise level, L_{Aeq} (dBA) For one Sydney Trains pass-by on each of the Up and Down lines.		
Location ID	**Chainage (km)**	**Distance from track (m)**	**Predicted dB(A)**	**Measured dB(A)**	**Difference (Predicted minus measured) dB(A)**
B N&V01	18.020	16	79.1	78.3	0.8
B N&V02	17.020	16	76.6	77.3	-0.7
B N&V03	15.730	17	76.8	75.6	1.2
B N&V04	14.950	17	76.4	73.9	**2.5**
B N&V05	13.740	17	77.1	76.4	0.7
B N&V06	11.190	18	77.4	78.1	-0.7
B N&V07	9.760	16	71.8	67.7	**4.1**
B N&V08	8.280	18	84.3	87.0	**-2.7**
B N&V09	5.990	16	77.7	76.5	0.8
B N&V010	6.940	13	76.1	76.5	-0.4
All			Average difference		0.6
			Median difference		0.7

Table 3-11 Model validation

The table indicates that the predicted and measured noise levels are generally within 2 dB(A) of each other, except at three locations, B N&V04, B N&V07 and B N&V08 (shown in bold in Table 3-11) which are discussed further below:

- At locations B N&V04 and B N&V07, the predicted noise levels are higher than the measured noise levels. This is due to the simplified noise model underpredicting the excess attenuation of the complex topographical features and ground absorption effects in the area. Considering that the noise model will overpredict the noise levels from both the build and no build scenarios, and that the assessment methodology compares the relative difference between the build and no build noise levels rather than just the absolute levels, the noise model is considered acceptable. The overprediction will not result in more onerous requirements for the Project, or vice versa.

- B N&V 08 is located adjacent to a tight curve in the rail line and the predicted noise levels are lower than the measured noise levels. A review of the baseline measured noise levels indicated that the derived noise levels were significantly influenced by four measurements (out of the total 43 measurements taken) associated with C/K-set trains. The audio recordings taken indicate significant curve squeal as the trains associated with those measurements traverse the curve. The inclusion of these measurements in the dataset increases the overall derived measured L_{Aeq} and $L_{Amax,95\%}$ noise levels at Location B N&V 08 by 3 dB(A) and 7 dB(A), respectively.

The following conclusions are based on the above data and analysis:

- The differences greater than 2 dB(A) between the predicted and measured noise levels are related to the elevated measured noise levels due to the inclusion of the four noise measurement points (associated with the C/K-set train), rather than other factors related to the noise model setup
- The baseline measurements indicate that the curve gain corrections applied to the section of rail near the measurement location are appropriate for most Sydney Trains, except for the C/K train sets where higher corrections factors should be applied.
- The Sydney Metro trains will not be noisier than the newer train types from the Sydney Trains fleet on the Southwest corridor, and therefore the applied curve gain corrections are considered appropriate. A train-borne solid flange lubrication system will be incorporated with the Sydney Metro train (by the manufacturer, Alstom) which will minimise flanging noise around the curve. In addition, rail lubrication will be applied in accordance with the TfNSW Standard for Rail Lubrication to the rail curve near B N&V 08, to minimise potential rail curve noise.
- Considering that the assessment compares the relative difference between the future and existing noise levels, the underprediction of the existing Sydney Trains noise levels will result in a conservative outcome.
- The modelled noise levels are considered to be acceptable for accessing the future impact of Sydney Metro trains without further adjustments.

3.6 Prediction uncertainties

The noise model is considered to be suitable for predicting operational rail noise levels from the Project. Although there are differences between the predicted and measured noise levels at some locations along the rail corridor, the differences are generally within 2 dB(A). Where the variance is greater, further investigation has been conducted and it has been shown that the noise model provides a conservative assessment. The average and median differences between the predicted and measured noise levels at all locations are no greater than 1 dB(A), which is an acceptable margin.

3.7 Predicted airborne noise levels

The predicted noise levels at the external receivers for the ‘no build’ and ‘with build’ scenarios for years 2024 and 2036 are provided in Appendix C.

3.8 Analysis of predicted airborne noise levels

3.8.1 Residential and open space land uses

The noise levels from the rail operation have been predicted to be no greater than the RING external noise trigger levels at all residential and relevant open space receivers, except at three residential receiver locations (1, 103 and 105 Stansfield Avenue, Bankstown). The predicted average noise levels at each of the residential receiver locations where exceedances are predicted are shown in bold in Table 3-12. At these locations, the average noise levels (L_{Aeq}) were predicted to exceed the RING trigger noise levels, whilst the maximum noise levels (L_{Amax}) were compliant. It is noted that exceedances are marginal, being no greater than 2 dB(A) above the trigger levels at receivers.

Receiver	Predicted noise – No build				Effective criteria				Predicted noise – with build			
	2024		2036		2024		2036		2024		2036	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
Residential (RING trigger levels: daytime 65 dB L_{Aeq} | night-time 60 dB L_{Aeq} <u>and</u> an increase of 2dBA)												
1 Stansfield Avenue, Bankstown (Receiver ID 00195)	63	59	63	59	65	61	65	61	65	58	**66**	58
103 Stansfield Avenue, Bankstown (Receiver ID 00375)	60	56	60	56	65	60	65	60	65	58	**66**	58
105 Stansfield Avenue, Bankstown (Receiver ID 00380)	60	56	60	56	65	60	65	60	65	58	**66**	58

Table 3-12 Predicted noise levels ($L_{Aeq, period}$) at residential and open space land use

Further details and consideration of the exceedances at each location above are provided below:

- The receiver at 1 Stansfield Avenue, Bankstown (receiver ID 00195) is a two-storey townhouse block, located near the rail corridor as shown in Figure 3-2. The rail noise levels are predicted to exceed on the upper level of the rear facade closest to the rail corridor. Considering that this is a single isolated receiver (only two townhouses are affected) and the exceedance is at the upper level, at-property noise mitigation is considered the appropriate feasible and reasonable mitigation measure (in lieu of a high noise barrier at the rail corridor). Also, considering that the predicted exceedance is marginal at this receiver (i.e., no greater than 1 dB(A), it is recommended that post-construction noise compliance monitoring be conducted at this location to confirm that there is an exceedance of the RING trigger level at Project opening (or potential future) at this location, prior to noise mitigation being implemented.

Figure 3-2 1 Stansfield Avenue, Bankstown

- The receivers at 103 and 105 Stansfield Avenue, Bankstown (receivers ID 00375 and 00380, respectively) are two-storey dwellings located near the rail corridor as shown in Figure 3-3. The noise levels are predicted to exceed on the upper level of the dwellings at rear facade closest to the rail corridor. These dwellings are located marginally closer to the rail corridor than the adjacent dwellings (where the predicted noise levels are not predicted to exceed the RING trigger levels). Considering that these receivers are isolated, and that the exceedances are at the upper level, at-property noise mitigation is considered to be the appropriate feasible and reasonable mitigation measure (in lieu of a high noise barrier at the rail corridor). Also, considering that the predicted exceedance is marginal at these receivers (i.e., no greater than 1 dB(A), it is recommended that post-construction noise compliance monitoring be conducted at these locations to confirm that there is an exceedance of the RING trigger level at Project opening (or potential for exceedance in the future) at these receivers, prior to noise mitigation being implemented.

Figure 3-3 Receiver 103 and 105 Stansfield Avenue, Bankstown

3.8.2 Other non-residential land uses

The noise levels from the rail operation have been predicted to be no greater than the RING internal noise trigger levels (or equivalent external noise trigger levels) at all sensitive non-residential land uses, except at the six buildings identified as 00363, 00421, 00429, 00434, 01195, and 01206. At these locations, the daytime one-hour average noise levels ($L_{Aeq(1h)}$) were predicted and used to compare with the RING noise trigger levels. The predicted average external noise levels at each of the receiver locations for which exceedances are predicted, are shown in bold in Table 3-13.

External noise trigger levels that are equivalent to the internal noise trigger levels for non-residential receivers were generally established based on the conservative assumption of a 10dB difference between internal and external noise levels to account for open windows (consistent with RING page 10, Table 3, note 6) unless otherwise noted in the following analysis. The façade noise reduction for Punchbowl Boys High School was established by testing. Details of non-residential receiver land uses and buildings are discussed further below.

Receiver	Predicted noise level – No build		Effective criteria		Predicted noise level – With build	
	2024	2036	2024	2036	2024	2036

Bankstown Childcare Academy	Building ID 00363 (70 South Terrace, Punchbowl)	56	56	58	58	**60**	**61**
Punchbowl Boys High School	Building ID 00421	57	57	59	59	**60**	**61**
	Building ID 00429	53	53	55	55	**57**	**58**
	Building ID 00434	53	53	55	55	**56**	**57**
Belmore Community Centre	Building ID 01195 (Afford Belmore Lifestyle Centre)	55	55	57	57	**60**	**61**
	Building ID 01206 (Belmore Early Childhood Health Centre)	52	52	54	54	**56**	**57**

Table 3-13 Predicted ($L_{Aeq,\ 1hr}$) noise levels at non-residential receivers

Further details and consideration of the exceedances at each location above are provided below:

- The building at 70 South Terrace, Punchbowl (receiver ID 00363), is a childcare centre (Bankstown Childcare Academy) shown in Figure 3-4. Considering that this is a single isolated receiver, noise mitigation has been considered at the property rather than a noise barrier at the rail corridor (noting that the internal $L_{Aeq(1hour)}$ 45 dB(A)/outdoor $L_{Aeq(1hour)}$ 55 dB(A) criterion with façade reflection for a childcare centre is more stringent than the daytime criterion for the adjacent residential receivers). The form and extent of the at-property treatment has been determined and advised as part of the Consultation Strategy.

Figure 3-4 Receiver 70 South Terrace, Punchbowl

- The buildings with receiver IDs 00421, 00429 and 00434 are educational buildings at the Punchbowl Boys High School, as shown in Figure 3-5. The predicted exceedances occur at ground and upper levels. To mitigate the noise at the source, a significant noise barrier (4 metres high or greater) would be required along a large portion of the rail corridor (more than 200 metres extent) to block line of sight between the trains and the multi-level receiver points. Given the extent of significant noise barrier that would be required, the feasible and reasonable solution is to apply acoustic treatment at the receiver (i.e., implement architectural treatment to the building facades). A site inspection and noise transfer tests were conducted at the school on 21 January 2020, to identify the uses of the internal spaces where the exceedances were predicted, and to measure the outside-to-inside noise attenuation. The uses of the spaces were noted to be:

- 00421 - Ground level - Classroom, kitchen and woodwork
- 00429 - Level 3 - Classroom
- 00434 - Ground level - Classroom

The measured average outside-to-inside noise attenuation for the spaces above in each building with windows open was as follows:

- 00421 – 11 dB(A) (note the internal spaces had high ceiling, with a large facade area)
- 00429 – 14 dB(A)
- 00434 – 14 dB(A)

With the above measured open window façade attenuation applied to the assessment in lieu of an initial conservative assumption of 10 dB(A), the RING internal noise trigger levels were still exceeded.

To prevent exceedance of the RING trigger levels, the acoustic treatment implemented to the façade has to provide a minimum outside-to-inside attenuation performance improvement of 2 dB(A), resulting in the future noise levels being no greater than 2 dB(A) of the existing levels. Ideally, the treatment will provide improvement of up to 8 dB(A) and achieve the 45 dB(A) noise criterion. The form and extent of the at-property treatment has been determined and advised as part of the Consultation Strategy.

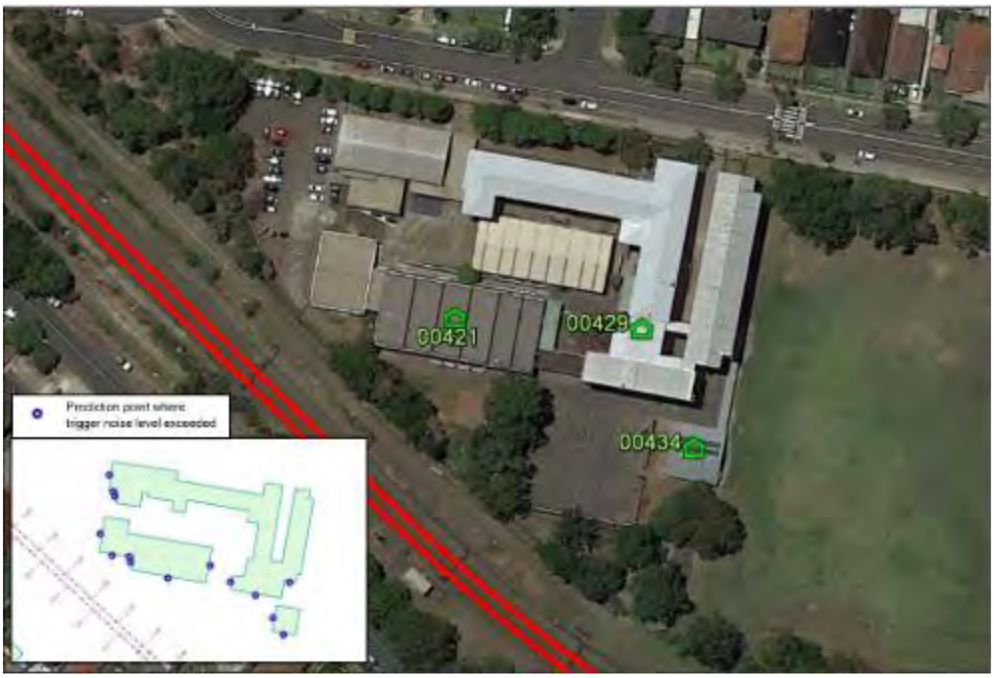


Figure 3-5 Receiver Boys High School, Punchbowl

- The buildings with receiver IDs 01195 and 01206 are located at Belmore Community Centre, as shown in Figure 3-6. These buildings have been identified as healthcare centres (Afford Belmore Lifestyle Centre and Belmore Early Childhood Health Centre, respectively). The assessment of noise impact based on trigger noise levels for a healthcare or hospital ward are considered very conservative. The land uses of these buildings are more aligned with living and/or hospital uses other than wards. The predicted noise levels at these locations achieve the relevant noise trigger levels for both residential and hospital uses other than wards without noise mitigation. Additional noise mitigation was therefore considered not warranted.

Figure 3-6 Receiver Belmore Community Centre

3.9 Summary of mitigation measures

3.9.1 Rail and train treatment

The Project includes control of wheel and rail roughness as a noise reduction element in the base case design for noise mitigation.

To minimise the noise from curve squeal as much as practicable, the following measures have been incorporated in the design:

- Rail lubricant be applied to the extent of rail curves that have a radius of less than 800 metres, in accordance with *the TfNSW Standard for Rail Lubrication (T HR TR 00111 ST)*
- The performance of the train-borne solid flange lubrication system provided by the train manufacturer (Alstom) is established and monitored to ensure that adequate lubrication is occurring and is maintained.
- On-train or rolling stock-based mitigation measures for controlling curve squeal (other than solid flange lubrication) such as shorter bogie wheelbases, modifications to bogie steering and the addition of wheel dampers are not considered to be reasonable given the small numbers of marginal exceedances predicted and the significance of design changes to the rolling stock.

3.9.2 Property treatment

At-property treatments have been designed in concept for consideration by the following receivers where exceedance of the RING noise trigger levels has been predicted:

- The facades to be treated at receiver ID 00363 – childcare centre located at 70 South Terrace, Punchbowl.
- The facades to be treated at receiver ID 00363 00421, 00429 and 00434 – school buildings located at Punchbowl Boys High School.

An exceedance of up to 1dB(A) was predicted at the receivers listed below:

- The facades on the upper level at receiver ID 00375 and 00380 – two-storey dwellings located at 103 and 105 Stansfield Avenue, Bankstown. The facades on the upper level at receiver ID 00195 two-storey townhouse block located at 1 Stansfield Avenue, Bankstown.

Considering that the predicted exceedances at 00375, 00380 and 00195 are marginal (i.e., no greater than 1 dB(A)), it is recommended that post-construction noise compliance monitoring be conducted at these receivers prior to further consideration of any at-property treatment at these sites. If the compliance monitoring confirms that there is an exceedance of the RING trigger noise level at these receivers, then at-property treatment shall be considered and implemented as required for compliance with the RING.

3.10 Consultation Strategy

Members of the Sydney Metro Community team made contact with representatives from Punchbowl Boys High School and Bankstown Childcare Academy in December 2020 to explain the property treatment process and organise formal inspections of each property.

Prior to property treatments being installed, Sydney Metro will update its document *Property Treatment Communication Strategy – Sensitive Receivers* to include the project's Sydenham to Bankstown component (currently only Chatswood to Sydenham). The consultation approach for the installation of any treatments will be managed in accordance with this document.

4 Assessment of train operations – ground borne noise and vibration

4.1 Introduction

Train noise impacts on receivers adjacent to surface track are most commonly caused by direct airborne noise transmission, however noise impacts may also be caused by the transmission of ground borne vibration that is re-radiated as noise within buildings.

Rail operations also have the potential to cause impacts due to tactile vibration that may result in disturbance and loss of amenity within receiver buildings.

Figure 4-1 illustrates the difference between airborne noise and ground-borne noise and vibration pathways.

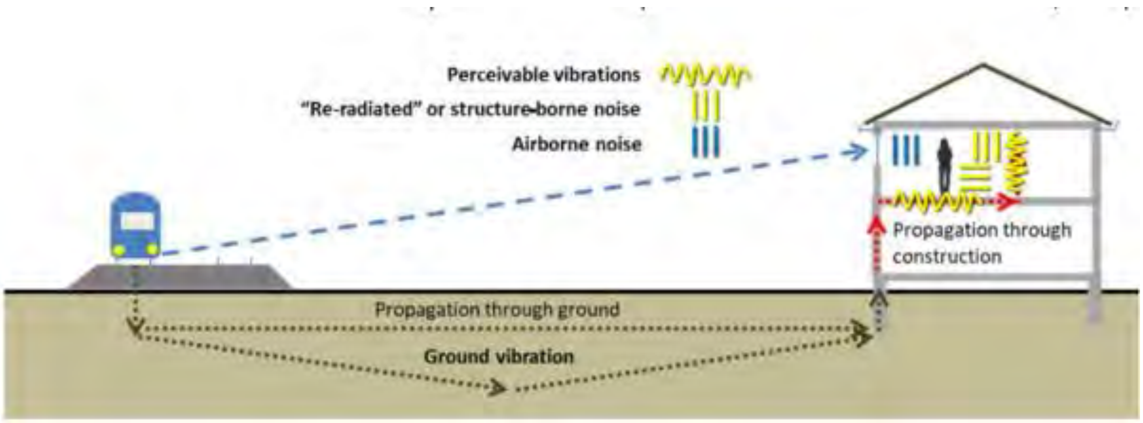


Figure 4-1 Propagation of ground borne noise and vibration

The Project involves the redevelopment of an existing rail corridor and will result in an increase in rail traffic volumes, the use of metro trains in place of the existing Sydney Trains fleet, and in some instances, the introduction of new cross-overs and a realignment of the tracks within the corridor. Ground-borne noise is sensitive to changes in track alignment, cross-over location, train type and train speed, while the vibration metric is sensitive to these factors as well as changes in rail traffic volume and train length.

This section presents the operational ground-borne noise and vibration assessment for the Project, including the ground-borne noise and vibration objectives, modelling methodology, predicted impacts and mitigation measures.

4.2 Ground-borne noise objectives

Ground-borne noise objectives for the Project are provided in Table 4-1.

The "trigger levels" are defined in terms of an L_{ASmax} metric, which refers to the maximum noise level not exceeded for 95 percent of rail pass-by events and is measured using the 'slow' (S) response setting on an analyser.

Sensitive land use	Period	Trigger dB(A)[1, 4]
Development increases existing rail noise levels by more than 3 dB(A) **and** resulting rail noise levels exceed:		
Residential	Day (7am – 10pm)	$L_{Amax(slow)}$ 40

Sensitive land use	Period	Trigger dB(A)[1, 4]
	Night (10pm – 7am)	$L_{Amax(slow)}$ 35
Schools, educational institutions, places of worship	When in use	$L_{Amax(slow)}$ 40 - 45
Medical institutions	When in use	$L_{Amax(slow)}$ 40 - 45[2]
General office area	When in use	$L_{Amax(slow)}$ 45
Private offices and conference	When in use	$L_{Amax(slow)}$ 40
Retail area	When in use	$L_{Amax(slow)}$ 50
Cinemas	When in use	$L_{Amax(slow)}$ 35
Public hall	When in use	$L_{Amax(slow)}$ 35
Lecture theatres	When in use	$L_{Amax(slow)}$ 35
Film/TV/Studio recording	When in use	NR 15[3] refer AZ/NZ 2107
Drama theatres	When in use	NR 25[3] refer AZ/NZ 2107:2000

Table 4-1 Ground borne noise design objectives

Note:

1. The ground-borne noise Design Objectives are based on the maximum LAmax (slow) noise level not to be exceeded for 95% of train pass-bys over any 24 hour period.

2. Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring. These criteria are only indicative, and there may be a need to assess intermittent values against the continuous or impulsive criteria for critical areas. Source: BS 6472–1992

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 20dBA and NR 25 is approximately 30 dBA

4. Ground-borne noise levels are only relevant where they are higher than operational rail airborne noise levels and where they are expected to be or are audible within habitable rooms.

4.3 Ground-borne vibration objectives

The RING refers to Assessing Vibration: a technical guideline, as the means by which vibration impacts on human comfort from operating railways should be assessed in NSW. Vibration from rail operations is assessed using the “Vibration Dose Value” (VDV) metric as train movements are considered to be an intermittent vibration source. The VDV criteria from the vibration guideline that are reflected in the Project Design Objectives are given in Table **4-2**.

The criteria given in the vibration guideline are to be considered as non-mandatory goals that should be sought to be achieved using all feasible and reasonable mitigation measures. The vibration guideline notes that Projects should be designed to meet the VDV levels as follows:

- ‘preferred’ where the area is not already exposed to vibration.
- ‘maximum’ where all feasible and reasonable mitigation measures have been applied.

Sensitive land use	Vibration dose values (m/s$^{1.75}$)			
	Day time (7am – 10pm)		Night-time (10pm – 7am)	
	Preferred	Maximum	Preferred	Maximum
Critical areas[1]	0.10	0.20	0.10	0.20
Residential	0.20	0.40	0.13	0.26
Offices, schools, educational institutions, and places of worship	0.40	0.80	0.40	0.80
Workshops	0.80	1.60	0.80	1.60

Table 4-2 Acceptable Vibration Dose Values for Intermittent Vibration

Note 1 Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring. These criteria are only indicative, and there may be a need to assess intermittent values against the continuous or impulsive criteria for critical areas. Source: BS 6472–1992

4.4 Ground-borne noise assessment

Ground-borne noise is defined in *ISO 14837-1 "Mechanical vibration – ground-borne noise and vibration arising from rail systems*" as noise generated inside a building by ground-borne vibration generated from the pass-by of a vehicle on rails. Ground-borne noise or regenerated noise in buildings is typically only perceptible at receiver locations where the level of ground-borne noise is greater than airborne noise (e.g., in buildings above rail tunnels where the airborne noise is enclosed by the tunnel or in buildings adjacent surfaces tracks where receiver facades are screened from airborne noise).

Ground-borne noise is relevant only where it is higher than the airborne noise from railways and where the ground-borne noise levels are expected to be, or are, audible within habitable rooms. Ground-borne noise objectives for the project are determined in accordance with the RING.

The RING prescribes non-mandatory "trigger levels" which, if exceeded, require the consideration of feasible and reasonable mitigation measures. Note that these trigger levels are only applicable if the predicted ground-borne noise level:

- Increases as a result of the development by more than 3 dB(A)
- Exceeds the airborne rail noise level. The "trigger levels" are prescribed as an L_{ASmax} metric, which refers to the maximum noise level not exceeded for 95 per cent of rail pass-by events and is measured using the 'slow' (S) response setting on an analyser.

4.5 Modelling methodology

Ground-borne noise and vibration was modelled using Sydney Metro's Acoustic Assurance Tool (AAT). The AAT is a broad-scale propagation model that is based on the application of MOTIV software (University of Southampton and Cambridge University) which was used to modify the vibration source spectra for the influence of different train types (Sydney Metro and Sydney Trains) and other parameters such as train speed and the presence of cross-overs and curves. The model was used to generate predicted ground vibration levels, with vibration dose values and ground-borne noise levels at the receiver buildings adjacent to the rail corridor.

4.5.1 Model calibration

The AAT ground-borne noise and vibration propagation model was calibrated for ground vibration propagation in the Southwest Corridor using baseline vibration surveys conducted along the existing Bankstown Line. Vibration source data for Sydney Metro trains was calibrated based on measurements obtained for NWRL operations. The operational rail source vibration levels are described in the following section.

4.5.2 Source ground-borne noise and vibration levels

The vibration sources included in the operational rail ground-borne noise and vibration model are:

- Sydney Trains fleet
- Sydney Metro trains
- Freight trains (locomotives and wagons)

The source vibration levels used in the initial model were based on the assumption that the rail tracks are in good condition with the running surface of the rail head free of defects; and that the wheel tread conditions of the trains are in good condition. These assumptions were then corrected based on measurements to represent actual wheel-rail condition.

The average (L_{eq}) and maximum (L_{ASmax}) vibration source levels were determined from measurement surveys for use in modelling.

The average vibration level from a train pass-by (L_{eq}) was weighted and used to calculate the estimated Vibration Dose Value (eVDV) at each receiver, which was then accumulated over the number of events during the day or night period for comparison with the ground-borne vibration objectives. The 95th percentile slow-weighted vibration level, $L_{max,slow,}$ (the maximum vibration level not exceeded for 95 percent of rail pass-by events), was used to calculate the L_{ASmax} ground-borne noise level for each receiver.

The MOTIV software was used to modify the vibration source spectra for the influence of different trackform types, train speeds and geological conditions.

Sydney trains vibration levels

A baseline vibration and noise survey was conducted along the existing Bankstown Line to determine the aggregate vibration source level from the existing Sydney Trains movements (taking account of existing rail/wheel condition). The survey included vibration measurements of up to 195 train pass-bys taken at five locations located adjacent straight sections of track. Other measurement locations were selected based on the presence of turnouts / rail curvature and different terrain. The attended measurements included a mix of A, B, C, K and M train sets and were used to derive the representative vibration emission levels from the existing Sydney Trains operations, excluding any measurements where a rail defect or rail curvature influenced the measurement results.

Figure 4-2 and Figure 4-3 show the L_{eq} and $L_{max,slow}$ measured vibration spectra for Sydney trains operations on straight sections of ballasted track referenced to a train speed of 80 km/hr and a source-receiver distance of 10 metres. The large variance in measured ground vibration levels relates to the maintenance regime of the wheel/rail interface by Sydney Trains across multiple sites.

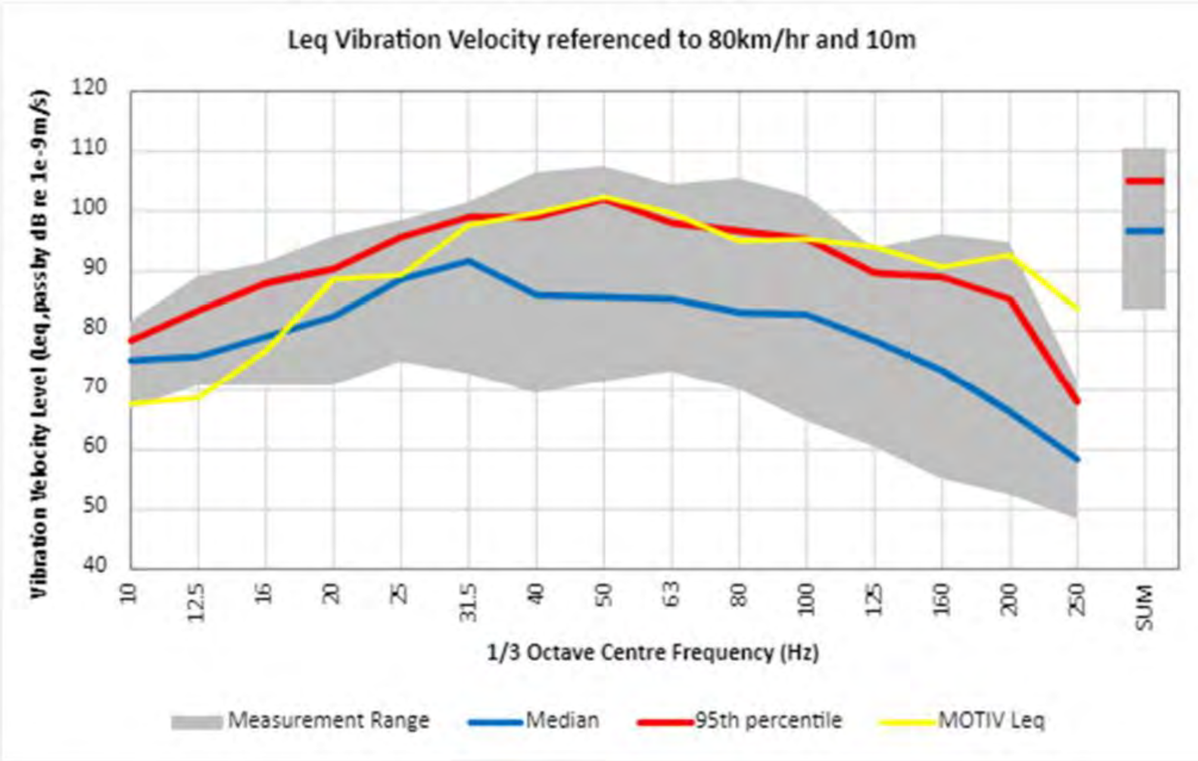


Figure 4-2 Measured Sydney Trains ballasted track Leq vibration @ 10m (referenced to 80 km/hr)

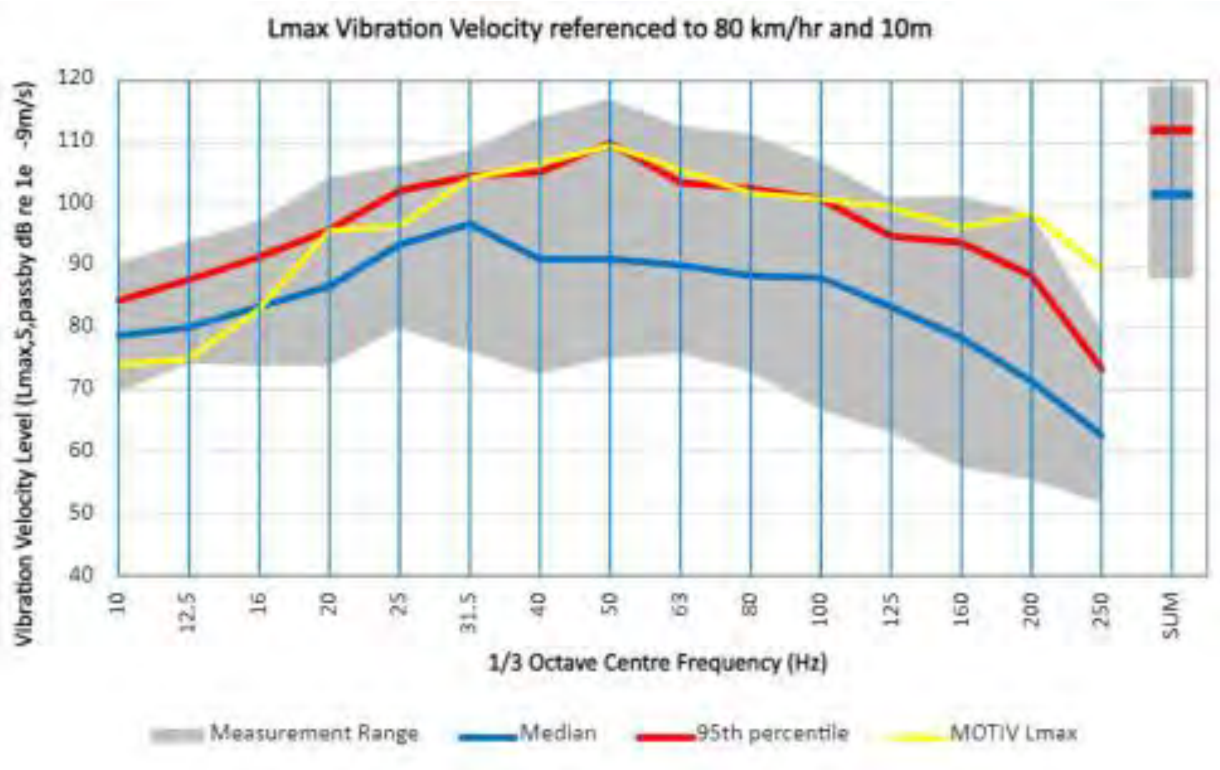


Figure 4-3 Measured Sydney Trains ballasted track Lmax,slow vibration @ 10m (referenced to 80 km/hr)

Sydney metro vibration levels

Figure 4-4 and Figure 4-5 show the source vibration spectra used in the model for Sydney Metro operations along the southwest corridor based on the measurements described in the previous sections.

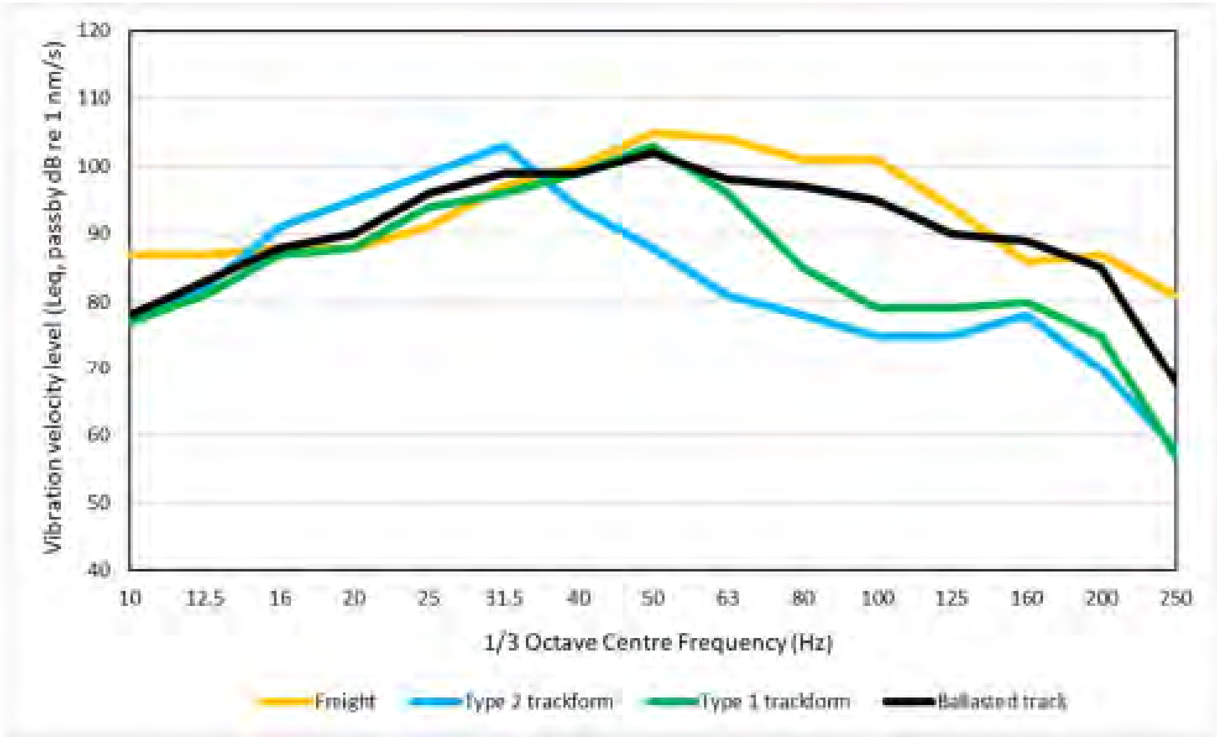


Figure 4-4 Leq vibration source spectra (80km/hr @ 10m) for VDV calculation

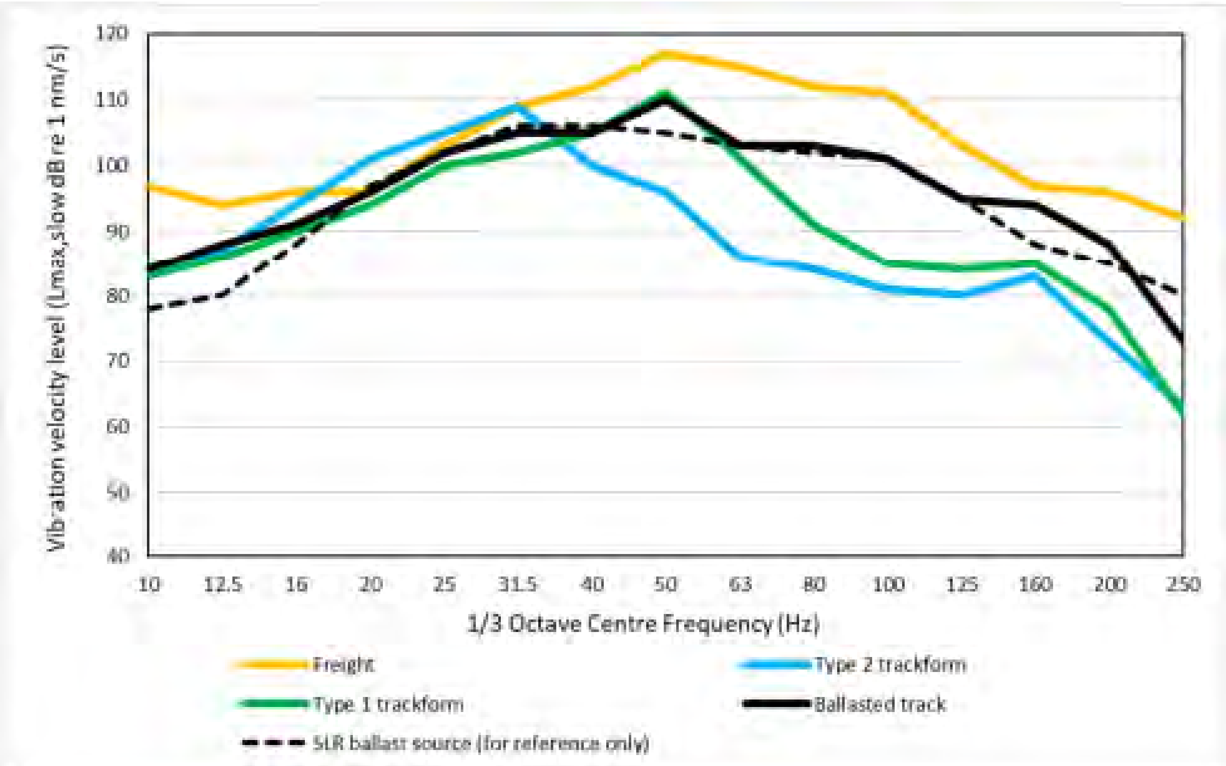


Figure 4-5 Lmax,slow source vibration spectra used for calculation of the ground-borne noise

4.5.3 Vibration Propagation

The broad-scale vibration propagation methodology was based on the principles of BS *ISO 14837-1:2005 'Mechanical vibration -- Ground-borne noise and vibration arising from rail systems --Part 1: General guidance'* and uses ISO 10137:2007 *'Bases for design of structures – Serviceability of buildings and walkways against vibrations*' as a basis for decoupling the components of geometric attenuation and material damping.

A review of geometric spreading coefficients for various source types, wave types and ground types is provided by Amick (1999) in his paper 'A Frequency-Dependent Soil Propagation Model'. Amick provides a geometric spreading coefficient of n = 0 for surface waves (Rayleigh waves) from a line source, and therefore only material damping loss influences reduction of vibration with distance from the rail source.

Material damping loss for the Southwest corridor was determined based on measurements at varying distances from the existing corridor at Punchbowl (Stansfield Avenue), Marrickville (McNeilly Park) and Campsie (South Parade). The material damping used in the predictive model is presented in Figure 4-6 with separate damping loss modelled for distances between 0 and 40 metres, and beyond 40 metres (to account for reduced material damping at low strains).

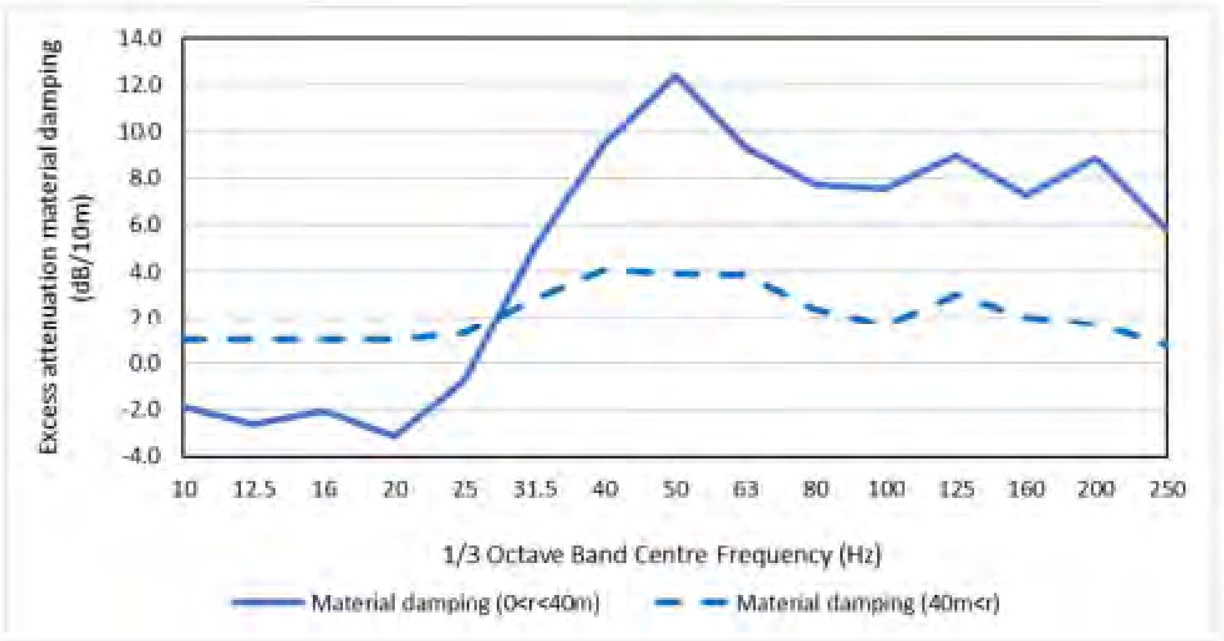


Figure 4-6 Excess attenuation due to material damping (dB per 10m) applied to source vibration spectra

4.5.4 Building vibration coupling loss and attenuation with elevation

Building coupling loss factors used in the vibration and ground-borne noise predictions for receiver buildings of varying height/construction type are based on the *Federal Transit Administration Manual (FTA) Transit Noise and Vibration Impact Assessment Manual*.

A coupling loss corresponding to the most conservative 'Single Family Residential' curve of the FTA has been implemented for all receptors (including residential, commercial, industrial, etc.) along the alignment.

No attenuation or reduction in vibration for floors above the foundation has been implemented in the broad-scale model (i.e. the predicted ground-borne noise and vibration level in the lowest basement of the building is the same as for all other floors/levels).

4.5.5 Rail traffic data

The number of rail traffic movements for the opening year (2024) and the future year (2036) were obtained from Sydney Metro and ARTC and incorporated in the ground-borne noise and vibration model. The rail traffic data is provided in Table 3-10 in Section 3.4.7 as per the airborne noise assessment.

4.5.6 Train speed profile

The train speed profile for the existing Sydney Trains operations and for the Sydney Metro operations associated with the Project are provided in Section 3.4.4 of this report.

4.5.7 Track alignment, track-form corrections and track feature corrections

The track alignment and trackform corrections presented in Section 3.4.5 and 3.4.6 have been considered in the ground-borne noise model.

4.6 Predicted ground-borne noise

The list of predicted operational ground-borne noise levels at all residential and non-residential receivers is provided in Appendix D.

4.7 Analysis of predicted exceedances

The details of the predicted operational ground-borne and airborne noise levels at each of the receiver locations for which exceedances are predicted are provided in Table 4-3

Address	GBN Criteria dB(A)	GBN no build dB(A)	GBN with build dB(A)	ABN internal future dB(A)	GBN increase dB(A)
37 South Parade Campsie	35	38	44	42	6
61-63 Bankstown City Plaza	40	56	59	37	3
58-60 Bankstown City Plaza	35	56	59	38	3
36 South Parade Campsie	35	39	45	41	6
35 South Parade Campsie	35	39	45	44	6
31 South Parade Campsie	35	39	44	43	5
25 Hurlstone Avenue Hurlstone Park	35	43	46	45	3

Table 4-3 Details of predicted exceedances in ground-borne noise level at sensitive receivers

The results presented in Table 4-3 indicate that there are predicted to be ground-borne noise exceedances at a relatively small number of receivers. Ground-borne noise targets are predicted to be marginally exceeded at the Bankstown and Campsie cross-overs as well as at a remote residence along-side the corridor where the speed changed significantly. Based on a detailed review of these sites and considering that the quantum of the predicted exceedances together with the probable benefits and costs of mitigation, it was considered that mitigation was not warranted. The specific details of each of the predicted exceedances are discussed below.

- At 31, 35, 36 and 37 South Parade Campsie shown in Figure 4-7 (Chainage ~12,000); Near the Campsie cross-over there is no existing cross-over/points at this location. The introduction of a new cross-over will increase both airborne and ground-borne noise levels. The predicted airborne noise levels are expected to exceed the ground borne noise level, typically by about 1-2 dB(A), noting that the ground-borne noise level is predicted to the closest point on the façade while the airborne noise is the façade most shielded and the furthest from the corridor. There is potential to introduce ground-borne noise mitigation for a ballasted track using a ballast mat (subject to engineering review), however, given the marginal exceedance, the cost, and the very small benefit available from this potential mitigation measure, it was recommended that ground-borne noise mitigation not be applied at this site.

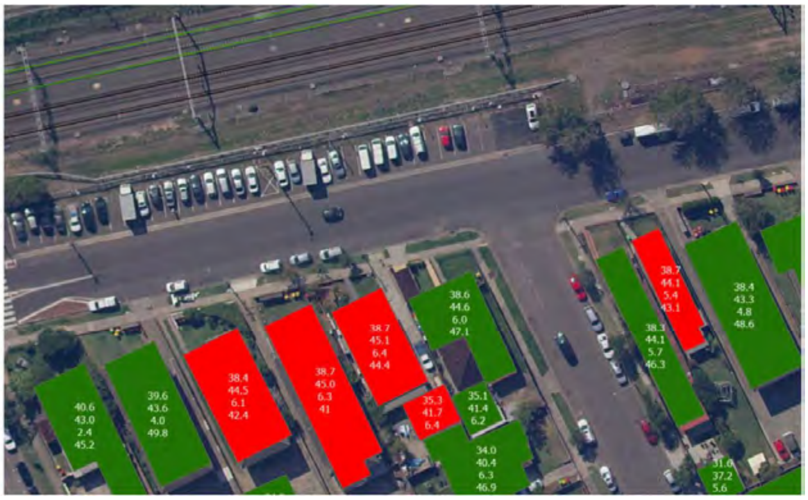


Figure 4-7 Predicted exceedances at South Parade residential properties at Campsie

- At 58-60 and 61-63 Bankstown City Plaza as shown in Figure 4-8 (Chainage ~19,000) the introduction of cross-over/points with the metro lines is predicted to increase the ground-borne noise levels by 3.3 dB(A). This exceeds the 3 dB(A) trigger level for a change in ground-borne noise for these two properties, a residential property and a commercial property. Given that only one residential property is impacted and that the predicted change in ground-borne noise level only marginally exceeds the 3 dB(A) trigger level this does not warrant the introduction of mitigation (likely a ballast mat under the new cross-over).

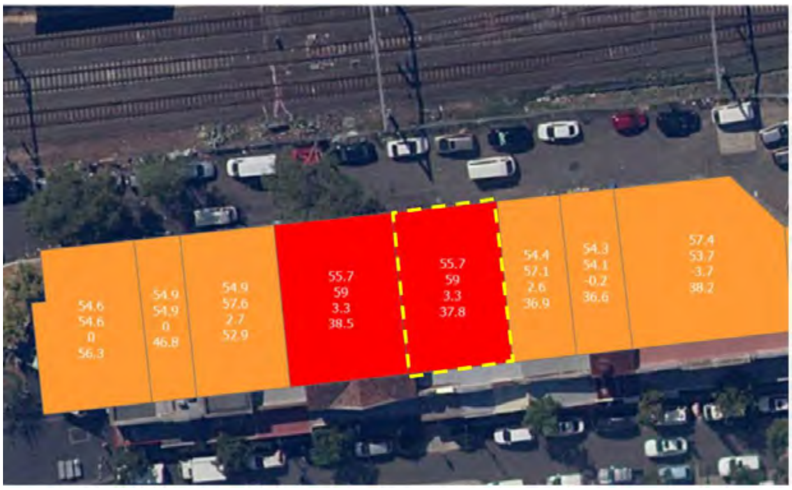


Figure 4-8 Predicted exceedances at Bankstown City Plaza

- At 25 Hurlstone Avenue Hurlstone Park as shown in Figure 4-9 (Chainage ~10,000) the train speed increases from 60 kph to 90 kph due to the Project are predicted to result in the ground-borne noise level increasing by 3.5 dB(A) to 46.6 dB(A) and exceeding the airborne noise level of 45.2 dB(A) (conservatively determined based on the rear facade from the rail corridor). Given that this is an isolated receiver and that the predicted exceedance of the 3 dB(A) trigger level and predicted airborne noise level at the rear façade is marginal, mitigation is not recommended at this site.

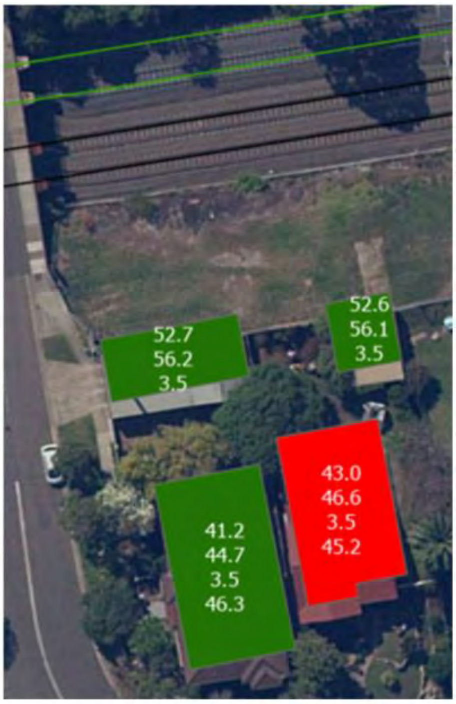


Figure 4-9 Predicted exceedances at Hurlstone Park Avenue

Ground-borne noise targets were marginally exceeded at the Bankstown and Campsie cross-overs as well as at a remote residence along-side the corridor where the speed changed significantly. Given the impact, mitigation was not warranted.

4.8 Predicted ground-borne vibration

The predicted ground-borne vibration levels at all sensitive receivers for the design year, 2036, (with Project) are provided in Appendix E. The vibration levels expressed in terms of VDVs have been separated into day-time and night-time limits for both residential and other receiver types.

4.8.1 Analysis of predicted exceedances

Predicted ground-borne vibration VDVs at residential and other land uses are shown graphically in Figure 4-10 to Figure 4-13 below for day-time and night-time periods. Some predicted exceedances of the VDV objectives are apparent based on the data shown in the figures. These predicted exceedances are discussed below.

Residential

- A marginal exceedance (approximately 25 per cent) of the “preferred” daytime VDV target 0.2 m/s$^{1.75}$ is noted, primarily as a result of the increase in train movements due to Sydney Metro operations, but also due to the addition of new cross-overs and a minor track re-alignment. the predicted vibration levels are well below the “maximum” daytime VDV target of 0.4 m/s$^{1.75}$.
- A marginal exceedance of the “preferred” night-time VDV target of 0.13 m m/s$^{1.75}$ is noted, primarily as a result of future predicted freight movements. the predicted vibration levels are well below the “maximum” night-time VDV target of 0.26 m/s$^{1.75}$.

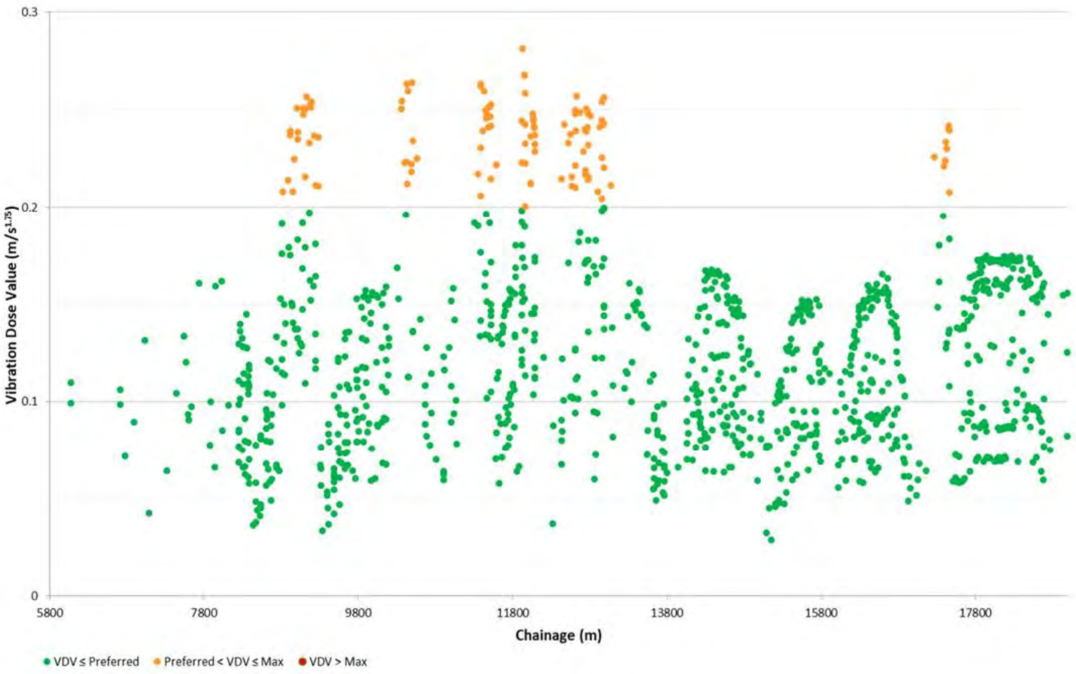


Figure 4-10 Residential Receiver – Predicted Daytime Vibration Dose Values (“preferred” = 0.2 m/s$^{1/75}$ “maximum”= 0.4 m/s$^{1/75}$)

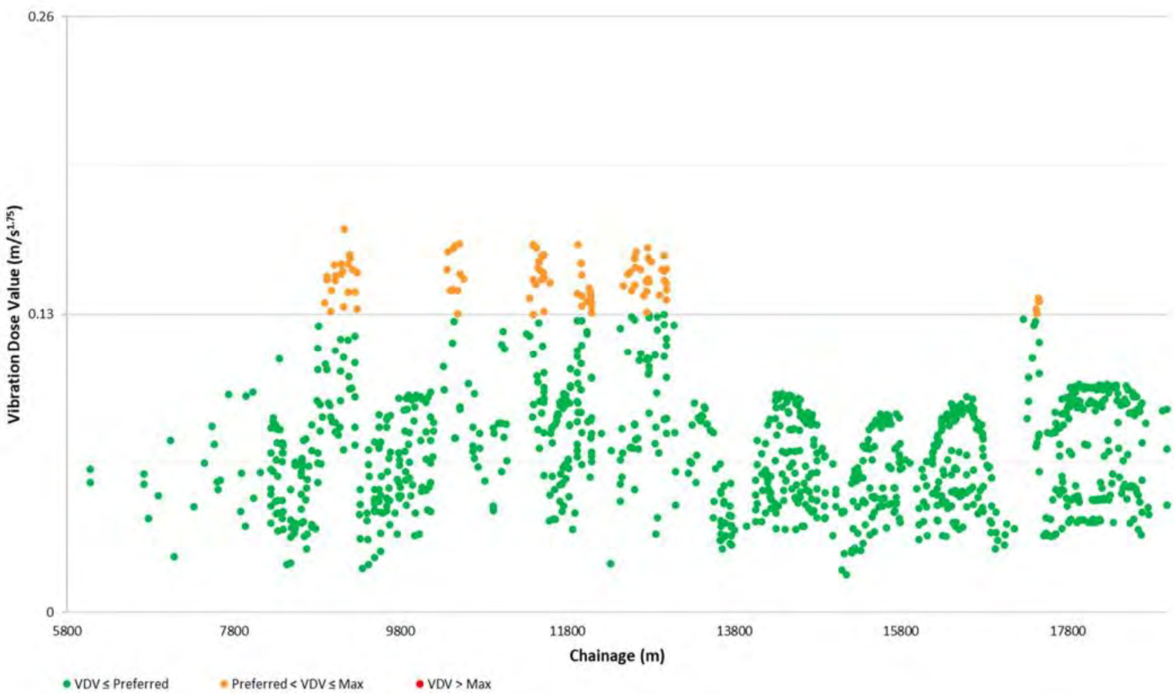


Figure 4-11 Residential Receiver – Predicted Night-time Vibration Dose Values (“preferred” = 0.13 m/s$^{1/75}$ “maximum”= 0.26 m/s$^{1/75}$)

Other land uses

The only VDV exceedances relating to non-residential or ‘other’ land uses are for commercial properties within station buildings located over the track.

Given that the predicted VDVs due to the Project are less than 50% above the “preferred” target and are below the “maximum” target, and that the VDVs are predicted to exceed the “preferred” target even without the Project, it is not considered feasible or reasonable to mitigate vibration at these receivers.

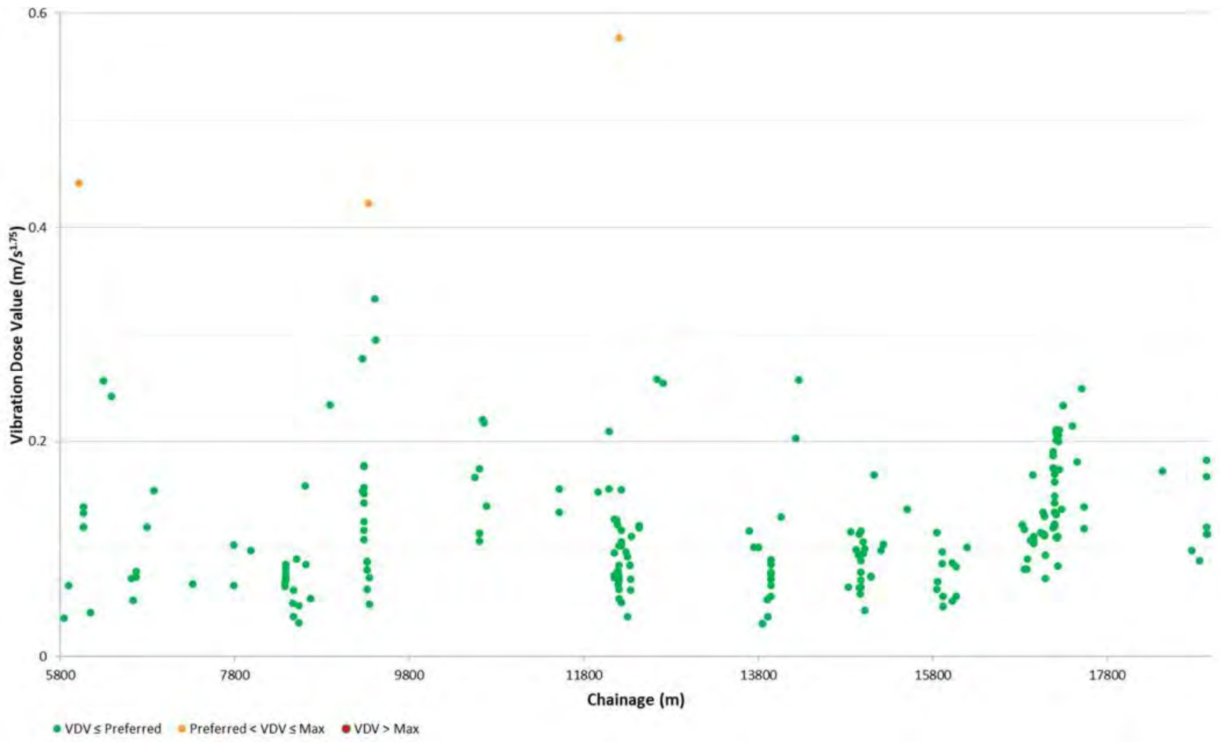


Figure 4-12 Other Land Uses – Predicted Daytime Vibration Dose Values (“preferred” = 0.4 $m/s^{1/75}$ “maximum”= 0.8 $m/s^{1/75}$)

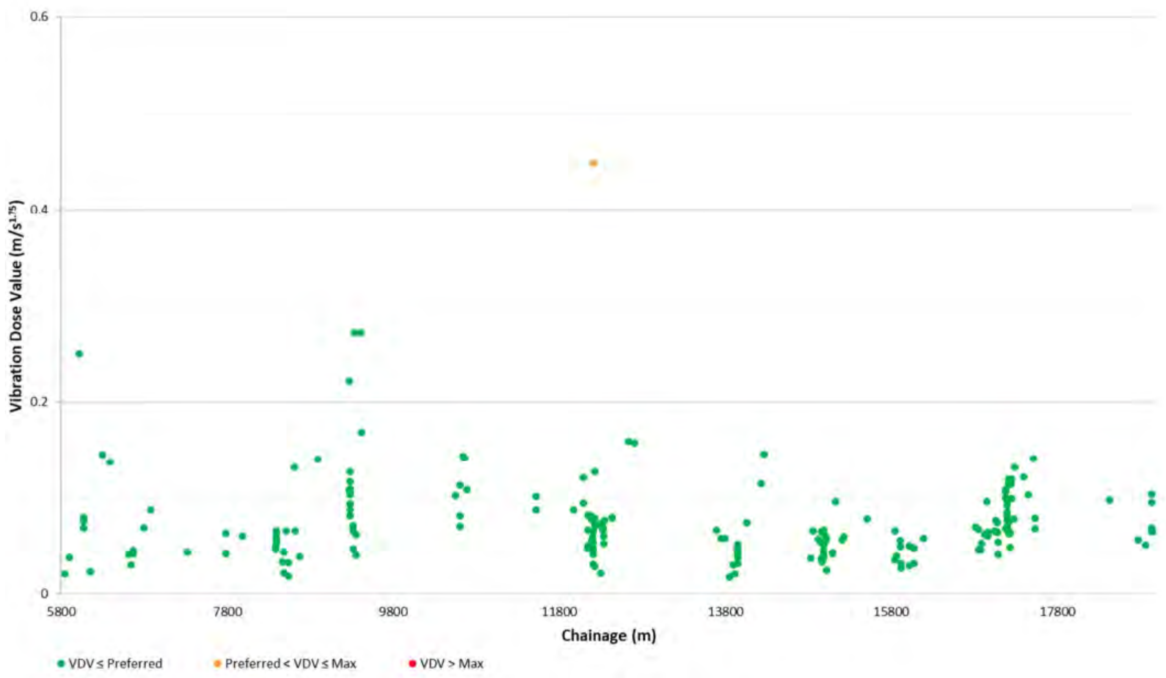


Figure 4-13 Other Land Uses – Predicted Night-time Vibration Dose Values (“preferred” = 0.4 $m/s^{1/75}$ maximum”= 0.8 $m/s^{1/75}$)

There are relatively few potentially feasible and reasonable ground-borne noise and vibration mitigation measures to address residual vibration impacts in the Southwest Corridor. The mitigation measures that have been considered are documented below. On the basis of this assessment it is considered that all feasible and reasonable mitigation measures have been exhausted.

Operational Measures

Operational rail ground-borne noise and vibration are influenced by train speeds with vibrations increasing with increasing train speed. Reducing train speed would have the effect of reducing vibration and ground-borne noise and VDV levels.

The potential to reduce trains speeds has been explored and is not considered to be feasible due to its impact on the CSWM operational performance.

Wheel and Rail Maintenance

Vibrations and ground-borne noise are initiated by rolling contact between slightly irregular wheel and rail surfaces. These surface irregularities can take the form of randomly distributed surface waviness or wheel and rail surface defects such as wheel flats, rail squats and dipped joints (special causes).

Sydney Metro has specified best practice wheel and rail condition management to be formalised in the wheel-rail interface strategy for the CSWM. An appropriate level of wheel and rail maintenance has been included in the operational vibration model and is reflected in the predicted receiver vibration levels.

Track design

Examples of track mitigation include the provision of ballast mat, resilient rail fasteners, booted sleepers and Under Sleeper Pads (USPs).

The use of trackform mitigation measures has been explored and it has been determined that the only form of track-based mitigation that is feasible to install on a ballasted track is USPs. USPs have been tested in the ground-borne noise and vibration model and found not to be effective in reducing receiver vibration and ground-borne noise levels. The use of USPs in the Southwest Corridor is therefore not recommended.

Path and receiver isolation

Vibration mitigation methods such as path isolation by installing deep trenches and vibration isolation of receiver buildings have limited effectiveness and are considered to be impractical (not feasible).

4.9 Summary of mitigation measures

There are no mitigation measures specifically included within the design for the purpose of mitigating ground-borne noise and vibration.

5 Assessment of fixed facilities – airborne noise and vibration

This assessment considers the airborne noise and vibration impact at external receiver locations from the operation of new service buildings and associated mechanical and electrical systems that will service the Sydney Metro operation between Sydenham and Bankstown.

5.1 Environmental noise objectives

The airborne noise criteria at external receivers are provided by the NPfI (2017), which establishes the Project noise trigger levels based on two components of noise impact: intrusive noise impact and amenity impact. The lower of the noise trigger values established for the two types of noise impacts is applied to the Project as the noise objective at residential receivers.

To determine the existing ambient noise levels within the Project area, unattended ambient noise measurements were undertaken. Noise measurements were performed in the vicinity of all stations between Sydenham and Bankstown which are being upgraded for Metro operation and in the vicinity of the five new electrical substations.

The noise trigger levels for the intrusiveness and amenity impacts are considered for the different assessment periods (day, evening or night), based on the average noise level (L_{Aeq}), however the averaging period for the two types of noise impact differs.

For the Project intrusiveness noise level, the L_{Aeq} is determined over a 15-minute period, whilst for the Project amenity noise level, the L_{Aeq} is determined over the assessment period (day, evening or night). To standardise the time periods for the intrusiveness and amenity noise levels, the NPfI assumes $L_{Aeq,15min} = L_{Aeq\ period} + 3$ dB(A), unless robust evidence can be provided for an alternative approach.

5.1.1 NSW Noise Policy for Industry

The intrusiveness and amenity noise criteria established using the NPfI are determined based on the land uses around each of the fixed facilities. These criteria are to be met at the most-affected boundary of the receiver property. The more stringent of these two criteria defines the proposal specific noise levels at residences. At other non-residential receivers (e.g. educational, place of worship, commercial), the amenity noise criteria applies. 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 has been considered, however, given that the fixed facilities noise sources are continuous, sleep disturbance considerations do not govern noise requirements for fixed facilities between Sydenham and Bankstown.

At locations where the fixed facilities are expected to produce annoying noise characteristics such as tonality, intermittency, irregularity or dominant low-frequency content, adjustments are applied to the predicted noise levels prior to comparison with the noise criteria, as outlined in the NPfI. Based on the nature of the noise from typical operation of mechanical plant and equipment, adjustments for noise characteristics from Sydney Metro fixed facilities sites are not expected to be applicable. It is a condition of procurement for mechanical plant and equipment for the Project that it does not exhibit tonal noise characteristics, when considered at the closest sensitive receiver location.

5.1.2 Intrusiveness noise criteria

To provide for protection against intrusive noise, the NPfI states that the L_{Aeq} noise level of the source, measured over a period of 15 minutes, should not be more than 5 dB(A) 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.

5.1.3 Amenity noise criteria

To provide protection against impacts on amenity, the NPfI specifies suitable maximum noise levels for particular land uses and activities during the daytime, evening and night-time periods. For the assessment, the existing residences in the vicinity of the stations and ancillary facilities are considered to be 'Urban' or 'Suburban'.

According to the NPfI, an 'Urban' area is characterised by an acoustic environment dominated by 'urban hum' or industrial source noises, through traffic with characteristically heavy and continuous traffic flows during peak hours, located near commercial districts or industrial districts and "Suburban" is described as an area that has local traffic with characteristically intermittent traffic flows or some limited commerce or industry. The "Suburban" area has a characteristic of evening ambient noise levels defined by the natural environment and human activity.

The NPfI external amenity noise criteria applicable to the Project are presented in Table 5-1.

Type of Receiver	Indicative Noise Amenity Area	Time of the Day	Recommended L_{Aeq} Noise level dB(A)	
			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	65	70
Active recreation area	All	When in	55	60
Educational	All	When in	55[1]	60[1]
Place of worship	All	When in use	60[1]	65[1]

Table 5-1 Industrial Noise Policy Amenity Noise levels

Note:

1. External levels, based on the internal levels specified in the NPfI plus 10 dB(A) (assuming open windows)

5.1.4 Project-specific noise levels

The applicable airborne noise criteria at residential receivers for noise from fixed facilities are taken as the lower of the intrusiveness and amenity noise criteria. At non-residential receivers, the amenity noise criteria are applicable.

5.1.5 Sleep disturbance

The approach taken to assessing the potential for sleep disturbance based on the NPfI was to apply initial screening criteria and then undertake additional analysis if the screening criteria cannot be achieved. The screening criteria considered at residential locations are as follows:

- $L_{Aeq,15min}$ 40 dB(A) or the prevailing RBL plus 5 dB, whichever is the greater, and/or
- L_{AFmax} 52 dB(A) or the prevailing RBL plus 15 dB, whichever is the greater.

The sleep disturbance screening criteria apply outside bedroom windows during the night-time period. Where the screening criteria cannot be met, the additional analysis should consider the level of any exceedance as well as factors such as:

- how often high noise events would occur.
- the time of day (normally at night-time 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).

Considering the main noise sources associated with the fixed facilities (mechanical and electrical plant) will typically operate continuously during the night without any significant modulation, maximum noise level events are not expected to be a significant feature of the plant noise impact. Further, compliance with the night-time project-specific noise level will satisfy the initial noise screening $L_{Aeq,15min}$ criterion. Noise from the PA system is predicted to achieve both screening criteria. Therefore, additional analysis to assess potential sleep disturbance impact was not necessary.

5.2 Environmental vibration objectives

The Project environmental objectives for continuous vibration sources associated with fixed facilities are derived from the NSW vibration guideline for the assessment of vibration for human comfort.

The vibration guideline provides preferred and maximum vibration objectives for human amenity for continuous vibration in terms of RMS vibration velocity, as summarised in Table **5-2** for different receiver locations (or land uses).

Location	Time	Vibration Velocity Level, RMS mm/s	
		Preferred	Maximum
Residences	Day time	0.20	0.40
	Night-time	0.14	0.28
Offices	All	0.40	0.80
Workshops	All	0.80	1.60
Critical working areas	All	0.10	0.20

Table 5-2 Vibration objective for fixed facilities

Impacts on vibration sensitive equipment are assessed using the vibration curves identified in *ASHRAE Noise and Vibration Control 2011 handbook (Chapter 48) for sensitive equipment*. There is no vibration sensitive equipment at the station sites and therefore this requirement is not relevant at internal receivers. At external receivers, the recommended criteria shown in

Figure 5-1 have been considered, in the absence of any sensitive equipment at nearby receivers.

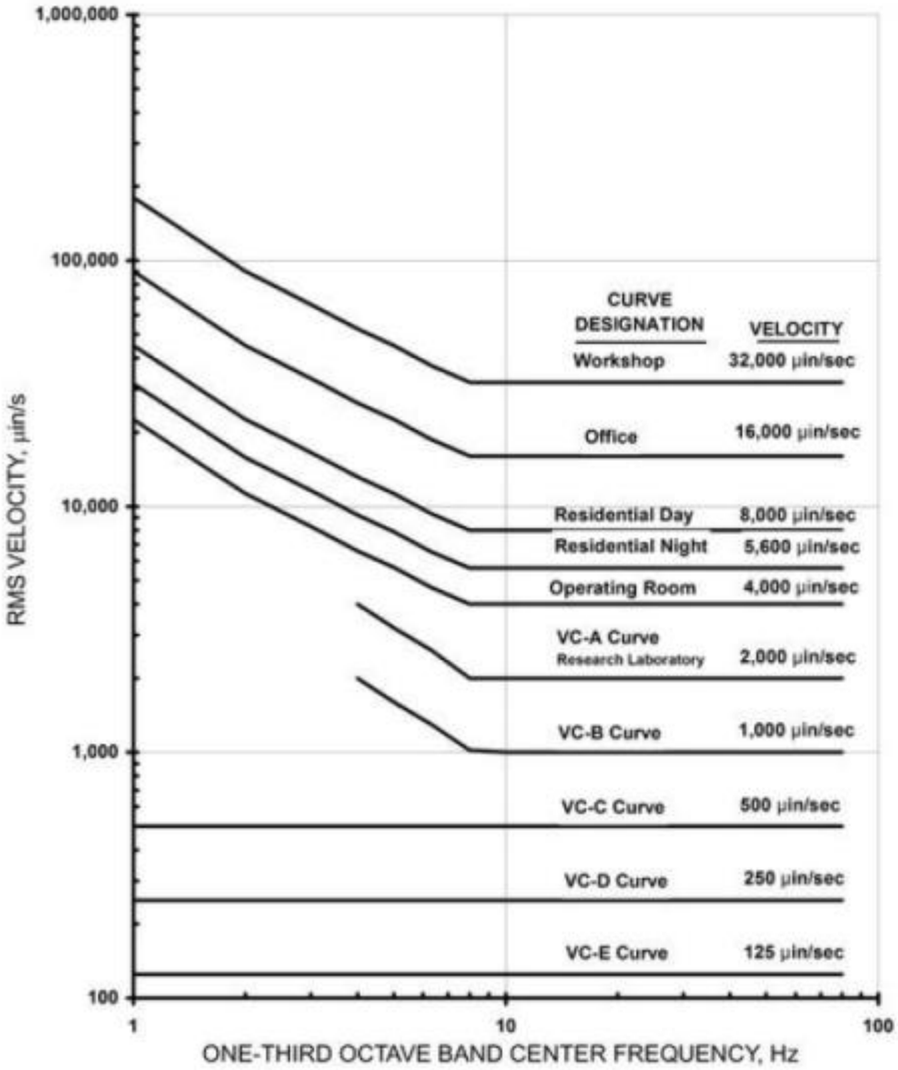


Figure 5-1 ASHRAE recommended vibration criteria in buildings

5.3 Environmental noise assessment

5.3.1 Fixed facilities

Environmental noise from fixed facilities noise sources (mechanical and electrical plant) has been predicted to the relevant closest noise sensitive receivers using a 3-dimensional noise model established based on the ISO 9613-2 noise propagation algorithm implemented in the SoundPLAN 8.1 noise modelling software.

The ISO 9613-2 methodology considers meteorological conditions that are consistent with the noise-enhancing meteorological conditions described in Fact Sheet D of the NPfI. Therefore, the predictions provide the expected worst-case (highest) noise levels.

Other assumptions in the noise model include hard ground cover to the entire area as a conservative approach, and all plant and equipment (on duty) operating continuously and concurrently.

5.3.2 Public address system

An analysis of the acoustic performance of the Public Address system at each of the stations was carried out using the EASE ray tracing software package to predict sound pressure levels and speech intelligibility on platforms and concourses. The output from this analysis formed the basis for determining the PA noise 'spill' at nearby receiver locations.

The methodology to assess the PA noise spill takes into account the worst case scenario during day, evening and night-time periods with PA announcements during train approach and departure. The assessment predicts the impact from the PA announcements for the worst case 15-minute period. The EASE ray tracing software package was utilised for the predictions which involved 3-dimensional modelling of each of the Southwest corridor stations with loudspeakers operating on the platform. Below are the assumptions taken into account for the assessment.

- Maximum number of rail movements (worst case) for each assessment period. 5/5/3 (Day/Evening/Night) train pass-bys during a 15-minute duration.
- Duration of 15 seconds per announcement each time during approach and departure (total 30 sec).
- Maximum $L_{Aeq\ (1\ sec)}$ is predicted from the EASE model and time weighted based on assumptions above.
- The background noise level assumed within the platform area during train approach/ departure is 60 dBA for day, evening and night-time periods. This is a conservative approach as the background noise during the night-time will be at least 5 dB lower than the daytime period (based on the measured background noise near the stations).
- Loudspeakers on the platform operate at -15dB SPL. This provides a total SPL (maximum) of 70 dBA at the platform with a Signal to noise ratio of ≥10 dB.
- 5 dB/10 dB (site specific) noise attenuation due to barrier effects has been assumed within the model where appropriate.
- Typical 50% ground absorption has been assumed.

The station PA acoustic analysis was completed for each of the stations and compliance was assessed against the established noise design criteria at the closest and most sensitive receivers. The summary of sound pressure levels at the boundary of the receivers is presented in Table 5-3.

Station	Period	Nearest residential receiver for the NCA*	Noise Design Criteria dB(A)	PA contribution dB(A)
Sydenham (SYD)	Day (7am-6pm)	30 Hogan Ave, Sydenham	53	41
	Eve (6pm-10pm)		51	41
	Night (10pm-7am)		44	39
Marrickville (MKV)	Day (7am-6pm)	Urban Residential	40	39
	Eve (6pm-10pm)		40	39

Station	Period	Nearest residential receiver for the NCA*	Noise Design Criteria dB(A)	PA contribution dB(A)
	Night (10pm-7am)	359 Illawarra Rd, Marrickville, NSW	35	35
	Day (7am-6pm)	Suburban Residential 3 Leofrene Avenue, Marrickville	40	36
	Eve (6pm-10pm)		40	36
	Night (10pm-7am)		35	34
Dulwich Hill (DHL)	Day (7am-6pm)	Urban Residential 1 Bedford Crescent, Dulwich Hill 1 Ewart Lane, Dulwich Hill NSW	43	37
	Eve (6pm-10pm)		43	37
	Night (10pm-7am)		36	34
	Day (7am-6pm)	Suburban Residential 9 Keith Lane, Dulwich Hill NSW	43	36
	Eve (6pm-10pm)		40	36
	Night (10pm-7am)		35	33
Hurlstone Park (HRL)	Day (7am-6pm)	Urban Residential 46 Floss Street, Hurlstone Park NSW	40	34
	Eve (6pm-10pm)		40	34
	Night (10pm-7am)		36	32
	Day (7am-6pm)	Suburban Residential 101-103 Duntroon St, Hurlstone Park NSW	40	37
	Eve (6pm-10pm)		40	37
	Night (10pm-7am)		35	35
	Day (7am-6pm)		45	39

Station	Period	Nearest residential receiver for the NCA*	Noise Design Criteria dB(A)	PA contribution dB(A)
Canterbury (CBY)	Eve (6pm-10pm)	Urban Residential 2&2A Charles St, Canterbury NSW	45	39
	Night (10pm-7am)		38	37
	Day (7am-6pm)	Suburban Residential 3 Broughton Street, Canterbury	45	37
	Eve (6pm-10pm)		40	37
	Night (10pm-7am)		35	35
Campsie (CMP)	Day (7am-6pm)	Urban Residential 13-15 Anglo Road, Campsie NSW 3 Wilfred Avenue, Campsie	46	41
	Eve (6pm-10pm)		44	41
	Night (10pm-7am)		37	37
Belmore (BMO)	Day (7am-6pm)	Urban Residential 30 Redman Parade, Belmore NSW	43	29
	Eve (6pm-10pm)		43	29
	Night (10pm-7am)		37	27
	Day (7am-6pm)	Suburban Residential 1 Acacia Street, Belmore	43	30
	Eve (6pm-10pm)		40	30
	Night (10pm-7am)		35	28
Lakemba (LAK)	Day (7am-6pm)	Urban Residential 52 Railway Parade, Lakemba 17 Croydon St, Lakemba	52	34
	Eve (6pm-10pm)		45	34
	Night (10pm-7am)		40	32

Station	Period	Nearest residential receiver for the NCA*	Noise Design Criteria dB(A)	PA contribution dB(A)
		63 The Boulevarde, Lakemba		
Wiley Park (WLY)	Day (7am-6pm)	Urban Residential	46	40
	Eve (6pm-10pm)	1A Shadforth Street, Wiley Park	45	40
	Night (10pm-7am)	89 King Georges Rd, Wiley Park NSW	40	38
	Day (7am-6pm)	Suburban Residential	46	19
	Eve (6pm-10pm)	2A Cornelia Street, Wiley Park	40	19
	Night (10pm-7am)	118 The Boulevarde, Wiley Park	35	16
Punchbowl (PUN)	Day (7am-6pm)	Urban Residential	49	40
	Eve (6pm-10pm)	279A The Boulevarde, Punchbowl	45	40
	Night (10pm-7am)	695-697 Punchbowl Road, Punchbowl	40	38
	Day (7am-6pm)	Suburban Residential	49	25
	Eve (6pm-10pm)	41 Urunga Parade, Punchbowl	40	25
	Night (10pm-7am)		35	23
Bankstown (BNK)	Day (7am-6pm)	Urban Residential	55	28
	Eve (6pm-10pm)	8 Bankstown City Plaza,	45	28

Station	Period	Nearest residential receiver for the NCA*	Noise Design Criteria dB(A)	PA contribution dB(A)
	Night (10pm-7am)	Bankstown NSW 2 West Terrace.	40	25

Table 5-3 Predicted noise from public announcement systems

The summary of results presented in Table 5-3 shows that the PA noise spill is predicted to be within the noise design criteria allowed for PA noise at receivers adjacent to Southwest corridor stations. The noise design criteria for the PA systems at stations were set so as to enable the overall Project noise objectives at nearby receivers to be met when the balance of noise contributed by fixed facilities sources is considered.

5.3.3 Electrical substations

There are four new electrical substations associated with the Southwest corridor component of the Project. The noise and vibration sources associated with normal operation of the Southwest Corridor Substations addressed are:

- Mechanical equipment serving the modular buildings
- Electrical equipment including Bulk Power Supply, HV Reticulation System and Traction Power System

Electrical substations are fixed facilities and airborne noise emissions from the substations was assessed using the NPfI as described in Section 5.1. The vibration criteria given in Section 5.2 were considered as part of the assessment, however, all of the mechanical and electrical equipment associated with the substations is vibration isolated and/or is sufficiently separated from receivers to ensure that there will be negligible vibration from electrical substations at receiver locations. The individual substation noise assessments are presented in Sections 5.16 to 5.20.

5.3.4 Emergency operation

The noise performance criteria provided by the NPfI apply to mechanical systems that can operate continuously during the day and night, and therefore are considered overly stringent for mechanical systems that only operate on rare occasions for a short period of time (e.g., the gas suppression system during a fire).

During an emergency event, some of the normal duty plant and equipment would cease operation, and additional emergency systems would commence operation. The noise from plant and equipment that operates during an emergency event forms part of Environmental Control Systems (ECS) and is assessed in accordance with noise criteria that are less stringent than those in the NPfI, derived as follows:

> The intrusiveness noise levels or the total amenity noise levels, whichever are greater, plus 10 dB(A) for the daytime noise level and plus 5 dB(A) for the evening and night-time noise levels.

Considering that an emergency event can occur at any time during the day or night, the resultant night-time noise criteria are most relevant to the assessment given that they are more stringent. The resultant night-time noise criteria are 45 dB(A) at receivers in suburban residential areas and 50 dB(A) at receivers in the urban residential areas.

It is noted that emergency mechanical systems are only proposed for the Services Building. The noise criteria above have been considered at the closest receivers to the Services Building.

5.4 Environmental vibration assessment

The vibration levels at the external receivers from the fixed facilities sources such as fans are expected to be well below the levels for human perception and will easily achieve the vibration criteria due to the following factors:

- The significant separation distances between the station and the external receivers
- The vibration isolation measures that are implemented for the mechanical systems.

5.5 Summary of mitigation measures

5.5.1 Noise

The following design related mitigation measures have been applied at each station to minimise the noise impacts within the stations as well as to meet the noise criteria at external receivers surrounding the stations:

- Use of standard acoustic mitigation measures such as shielding and attenuators.
- The plant and equipment are positioned or angled away from sensitive receivers to improve the performance of the acoustic shielding or attenuators.
- The inclusion of noise limits in the mechanical specification that are consistent with the assumptions used in the acoustic models for stations and services buildings.
- Noise from the mechanical and electrical equipment to be procured has been specified so as not to exhibit tonal noise characteristics when considered at the closest sensitive receiver location.
- As per measures implemented on the existing Sydney Trains platforms to control PA noise spill, the SPL for all of the platform Public Address loudspeakers close to residential properties will be reduced by 15 dBA relative to the baseline speaker specification. The speaker SPL is dynamically adjusted using automatic gain control during train approach / departure to achieve this outcome while maintaining the PA performance on the platforms. Relatively low background noise levels on the platforms at night (compared to daytime when the PA needs to be louder) enables the PAS noise spill to be controlled during the worst case night-time period.

5.5.2 Vibration

The design of mechanical systems within railway stations, services buildings and electrical substations incorporates vibration isolation measures which are consistent with the recommendation of *ASHRAE Noise and Vibration Control handbook*. The measures include:

- Supporting all rotating or reciprocating equipment with vibration absorbing mounts or hangers using neoprene or spring hanger having minimum 95% vibration isolation efficiency.
- Providing neoprene pads or waffle pads for all static equipment located on the slab floor.
- Providing plinths for all floor mounted equipment.
- Ensuring all connections to rotating equipment or assemblies containing rotating equipment are rendered flexible by flexible connections or by anti-vibration hangers supporting ductwork and pipework.

- Incorporating neoprene hangers or mounts for ductwork supported from concrete soffit or fixed to walls.
- Incorporating neoprene sleeves between pipework and the supports/brackets.
- Ensuring all rotating plant is statically and dynamically balanced to meet compliance with the requirements of AS 1360 “Rotating electrical machines of particular types or for particular application” and AS 2625 “Mechanical vibration – Evaluation of machine vibration by measurement on non-rotating parts”.

With the vibration isolation measures incorporated, the potential vibration from mechanical plant will achieve the recommended vibration criteria at the relevant internal receivers. Consequently, given the significant separation distances between the plant and the external receivers (greater than 10 metres), the potential vibration from mechanical and electrical plant will not be perceptible at the receivers and will easily achieve the relevant vibration criteria.

5.6 Marrickville Station

Marrickville Station is located east of the Illawarra Road overbridge. The station area is bounded to the north by a multi-storey residential apartment building located on the corner of Illawarra Road and Byrnes Street, to the south by Station Street and residential dwellings fronting Leofrene Avenue, and to the west by Illawarra Road. The station entrance is on Illawarra Road. The layout of the station and surrounds is shown in Figure 5-2.

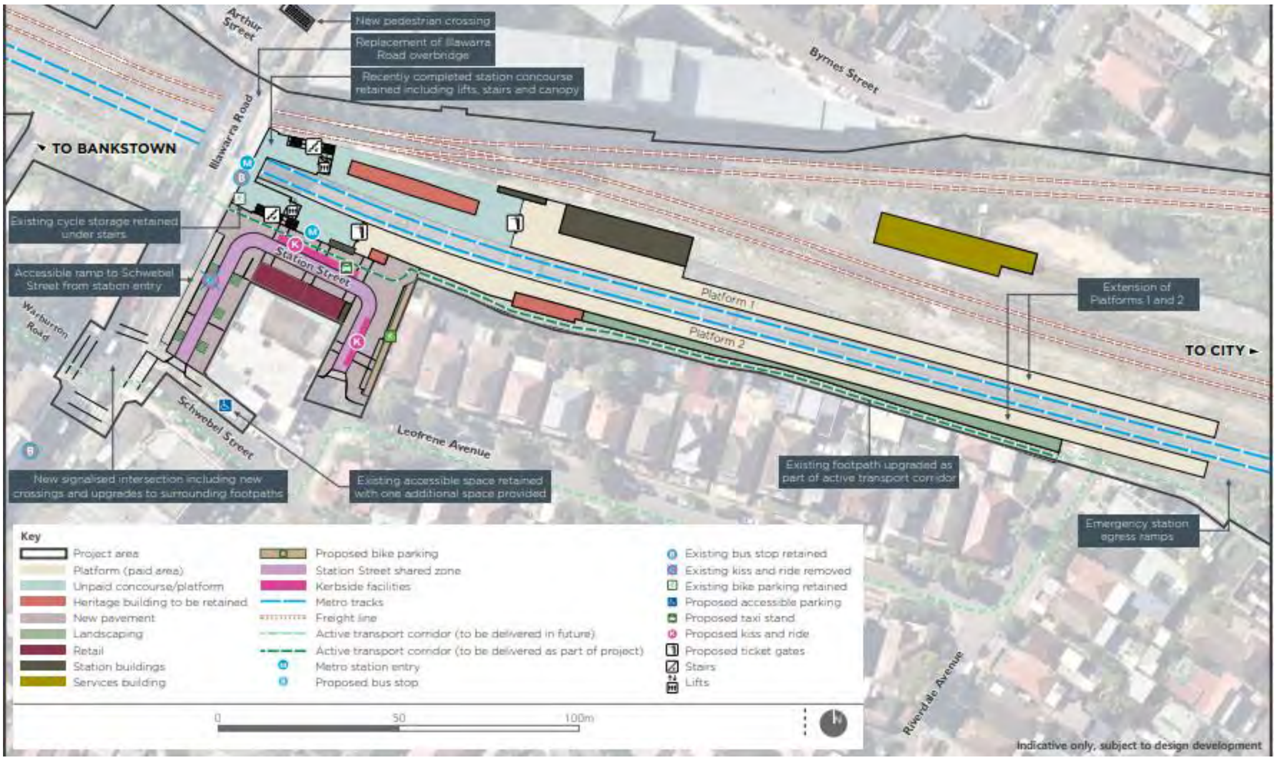


Figure 5-2 Marrickville Station indicative layout map

5.6.1 Existing and future development

The closest sensitive receiver to Marrickville Station Building is the residential building block at 359 Illawarra Road, whilst the closest sensitive receiver to the Services Building is the dwelling at 19 Cavey Street. The existing land uses, and the closest sensitive receivers are shown on Figure 5-3, which has been reproduced from the EIS.

Proposed residential development is expected to increase by 2036 with 6,000 new dwellings around the station.

5.6.2 Assessment locations

The sensitive receivers have been separated into two noise catchment categories (NCCs) according to the planning zoning and the expected level of noise amenity in the area of the receiver. The closest residential receivers and their approximate distances to the main project buildings in each NCC are indicated in Figure 5-3.

Figure 5-3 Assessment locations – Marrickville Station

5.6.3 Background noise monitoring

Noise monitoring of the existing noise levels in the area was conducted as part of the EIS between 21 and 30 June 2016, at a representative receiver location near the station, at 10 Leofrene Avenue, Marrickville.

It is noted that the monitoring location is shielded and located further away from the rail and/or main road in comparison to the closest sensitive receivers to the site. As such, the monitoring results are expected to be conservative estimates of the existing noise levels at the receivers that are closer and have direct line of sight to the rail/road. Using the monitoring results expected to provide a conservative assessment.

5.6.4 Measured noise levels

The results of the noise monitoring are summarised in Table 5-4.

Noise monitoring location	RBL L_{A90}, dB(A)			Intrusiveness noise criteria $L_{Aeq(15\ min)}$, dB(A)		
	Day	Evening	Night	Day	Evening	Night
10 Leofrene Avenue, Marrickville	38	38	33	43	43	38

Table 5-4 Measured background noise at Marrickville Station

5.6.5 Project noise criteria

The resultant project-specific noise criteria based on section 5.1.4 are summarised in Table **5-5**.

Location	$L_{Aeq(15min)}$ noise criteria, dB(A)		
	Day	Evening	Night
Dwellings close to Station Building			
Suburban residential (NCC2)	40	40	35
Urban Residential (NCC1)	40	40	35
Dwellings close to Service Building			
Suburban residential (NCC2)	43	43	38
Urban Residential (NCC1)	43	43	38

Table 5-5 Project specific criteria – Marrickville Station

Since the noise criteria are lowest during the night-time period and all noise sources are considered to be continuous, the night-time project-specific criterion has been used to compare with the noise predictions. Note the noise criteria for dwellings close to the Station Building have been reduced by 3 dB to allow for noise contribution from the PA system (refer section 5.3.2).

5.6.6 Noise predictions and assessment

Noise predictions in Table **5-6** indicate that the noise levels at external receivers from operation of new noise sources associated with mechanical systems at Marrickville Station will achieve the established noise criteria.

Location	Criterion Night, dB(A)	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)
Dwellings close to Station Building		
3 Leofrene Avenue	35	33
359 Illawarra Road	35	35
Dwellings close to Service Building		
19 Cavey Street	38	38
359 Illawarra Road	38	32

Table 5-6 Predicted noise levels – Marrickville Station

5.6.7 Emergency

The noise from the emergency mechanical systems designed for the Services Building has been predicted at the closest sensitive receivers. The highest predicted noise levels at the receivers have been compared with the relevant noise criteria, as summarised in Table 5-7.

Location	Criteria Night, dB(A)	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)
19 Cavey Street	45	42
359 Illawarra Road	50	36

Table 5-7 Predicted noise levels from emergency equipment

The noise predictions for operation of emergency systems presented in Table 5-7 meet the criteria for the night-time period, which governs requirements for the Project.

5.7 Dulwich Hill Station

Dulwich Hill Station is located west of the Wardell Road overbridge. The station area is bounded by Bedford Crescent to the north, Ewart Lane to the south, and Wardell Road to the east. The station entrance is on Wardell Road.

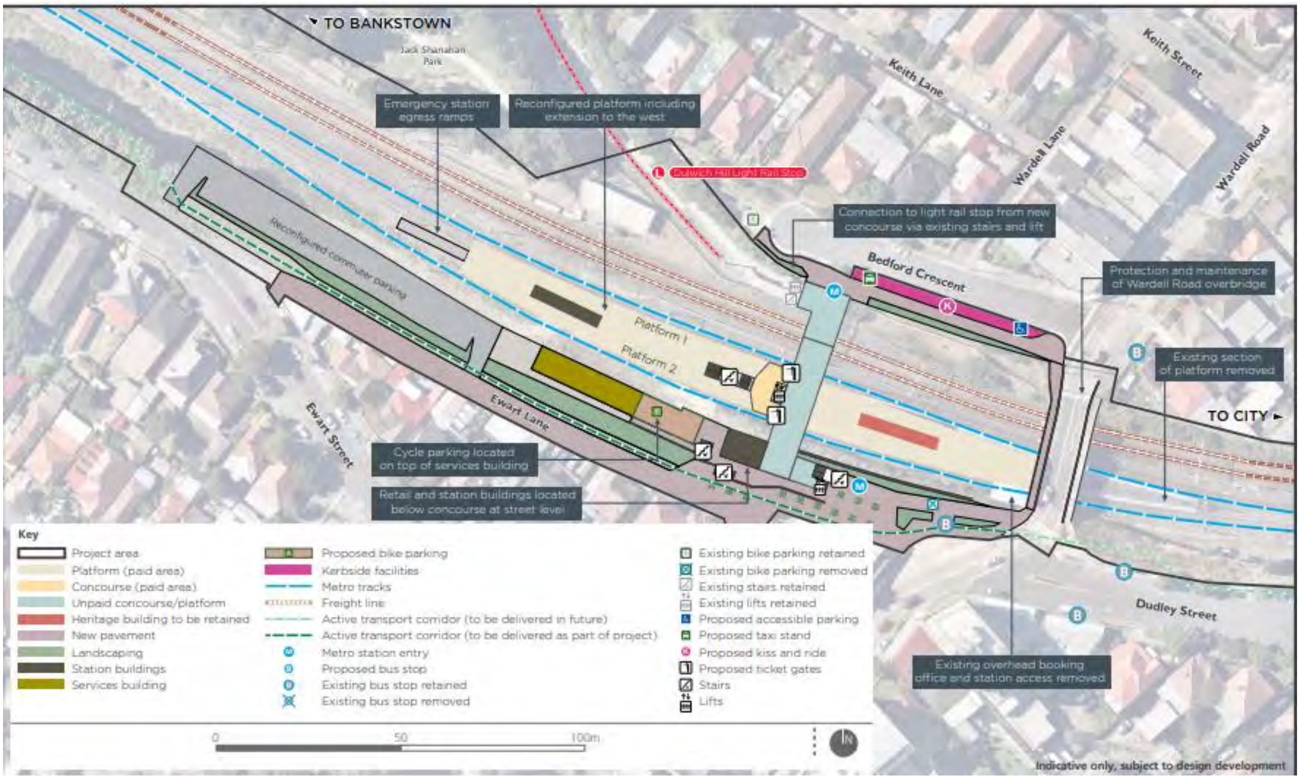


Figure 5-4 Dulwich Hill Station indicative layout map

5.7.1 Existing and future development

The closest sensitive receivers to the Services Building are the dwellings fronting Ewart Street, with the nearest dwelling located at 71 Ewart Street. The closest sensitive receivers to Dulwich Hill Station buildings are the dwellings fronting Bedford Crescent, Ewart Lane and Wardell Road, with the nearest dwelling located at 1 Bedford Crescent.

Proposed residential development is expected to increase by 2036 with 2,000 new dwellings around the station. The existing land uses, and the closest sensitive receivers are shown on Figure 5-5, which has been reproduced from the EIS.

Figure 5-5 Land use around Dulwich Hill Station

5.7.2 Assessment locations

The sensitive receivers have been separated into two noise catchment categories (NCCs) according to the planning zoning and the expected level of noise amenity in the area of the receivers. The closest residential receivers in each NCC and their approximate distances to the main Project buildings are indicated on Figure 5-6.

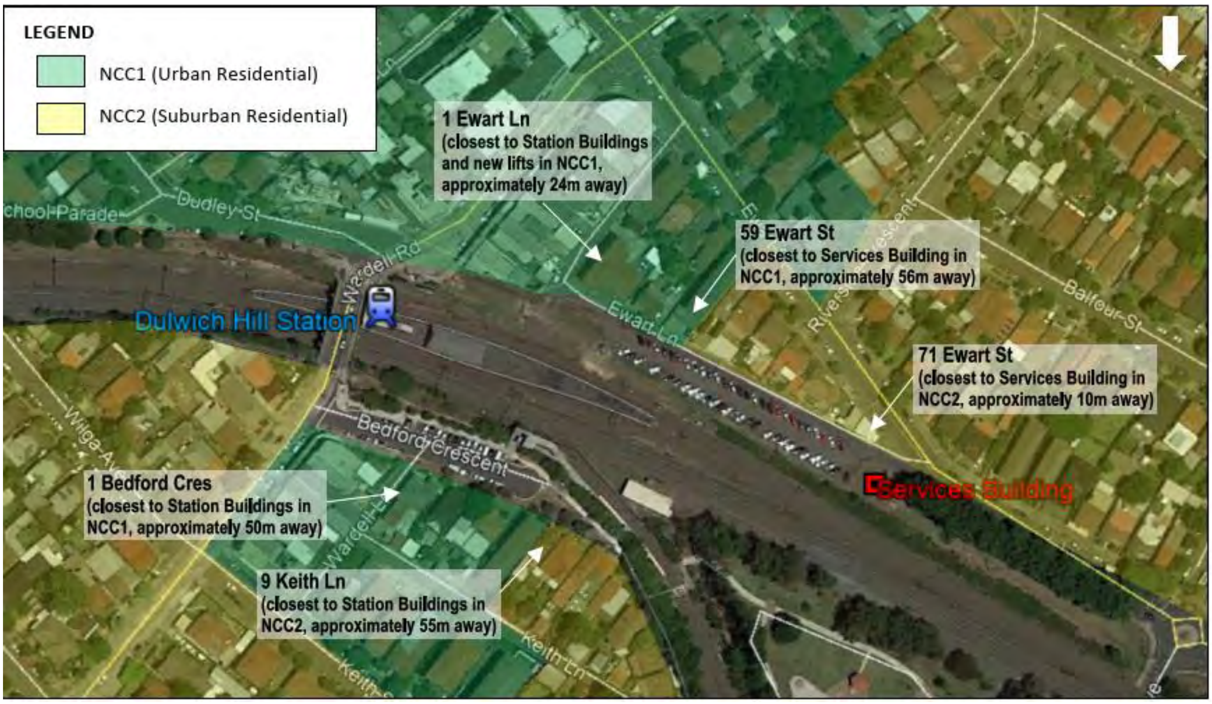


Figure 5-6 Assessment locations – Dulwich Hill Station

5.7.3 Background noise monitoring

Noise monitoring of the existing noise levels in the area was conducted as part of the EIS between 21 and 30 June 2016, at a representative receiver location near the station at 15 Bedford Crescent, Dulwich Hill.

The monitoring location and the closest sensitive receivers to the station are located at a similar proximity to the rail corridor. However, the monitoring location is located further away from the main road (Wardell Road) and therefore the measured noise levels are expected to be conservative for the closest sensitive receivers to the station.

5.7.4 Measured noise levels

The results of the noise monitoring are summarised in Table 5-8.

Noise monitoring location	RBL L_{A90}, dB(A)			Intrusiveness noise criteria $L_{Aeq(15\ min)}$, dB(A)		
	Day	Evening	Night	Day	Evening	Night
15 Bedford Crescent, Dulwich Hill	41	41	34	46	46	39

Table 5-8 Measured noise levels at Dulwich Hill Station

5.7.5 Project specific criteria

The resultant project-specific noise criteria based on section 5.1.4 are summarised in Table **5-9**.

Location	$L_{Aeq(15min)}$ noise criteria, dB(A)		
	Day	Evening	Night
Dwellings close to Station Building			
Suburban residential (NCC2)	43	40	35
Urban Residential (NCC1)	43	43	36
Dwellings close to Service Building			
Suburban residential (NCC2)	46	43	38
Urban Residential (NCC1)	46	46	39

Table 5-9 Project-specific criteria – Dulwich Hill Station

Note the noise criteria for dwellings close to the Station Building have been reduced by 3 dB to allow for noise contribution from the PA system (refer section 5.3.2).

5.7.6 Noise predictions and assessment

Noise predictions in

Location	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)		
	Day	Evening	Night
Dwellings close to Station Building			
1 Bedford Crescent (NCC1 urban residential)	40	40	35
1 Ewart Lane (NCC1 urban residential)	40	40	35
9 Keith Lane (NCC2 suburban residential)	34	34	31
Dwellings close to Service Building			
59 Ewart Street (NCC1 urban residential)	32	32	31
71 Ewart Street (NCC2 suburban residential)	38	38	38

Table **5-10** indicate that the noise levels at external receivers from operation of new noise sources associated with mechanical systems at Dulwich Hill Station will achieve the established noise criteria.

Location	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)		
	Day	Evening	Night
Dwellings close to Station Building			
1 Bedford Crescent (NCC1 urban residential)	40	40	35
1 Ewart Lane (NCC1 urban residential)	40	40	35
9 Keith Lane (NCC2 suburban residential)	34	34	31
Dwellings close to Service Building			
59 Ewart Street (NCC1 urban residential)	32	32	31
71 Ewart Street (NCC2 suburban residential)	38	38	38

Table 5-10 Predicted noise levels – Dulwich Hill Station

5.7.7 Emergency

The noise from the emergency mechanical systems designed for the Services Building has been predicted at closest sensitive receivers. The highest predicted noise levels at the receivers have been compared with the relevant noise criteria, as summarised in Table 5-11.

Location	Criteria Night, dB(A)	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)
59 Ewart Street (NCC1 urban residential)	45	30
71 Ewart Street (NCC2 suburban residential)	50	35

Table 5-11 Predicted noise levels from emergency equipment

The noise predictions for operation of emergency systems presented in Table 5-11 meet the criteria for the night-time period, which governs requirements for the Project.

5.8 Hurlstone Park Station

Hurlstone Park Station is located to the west of the Crinan Street overbridge. The station area is bounded by Crinan and Floss Streets and residential dwellings to the north, Duntroon Street and residential dwellings to the south, and Crinan Street to the west (on the bridge). The station entrance is on the overbridge.

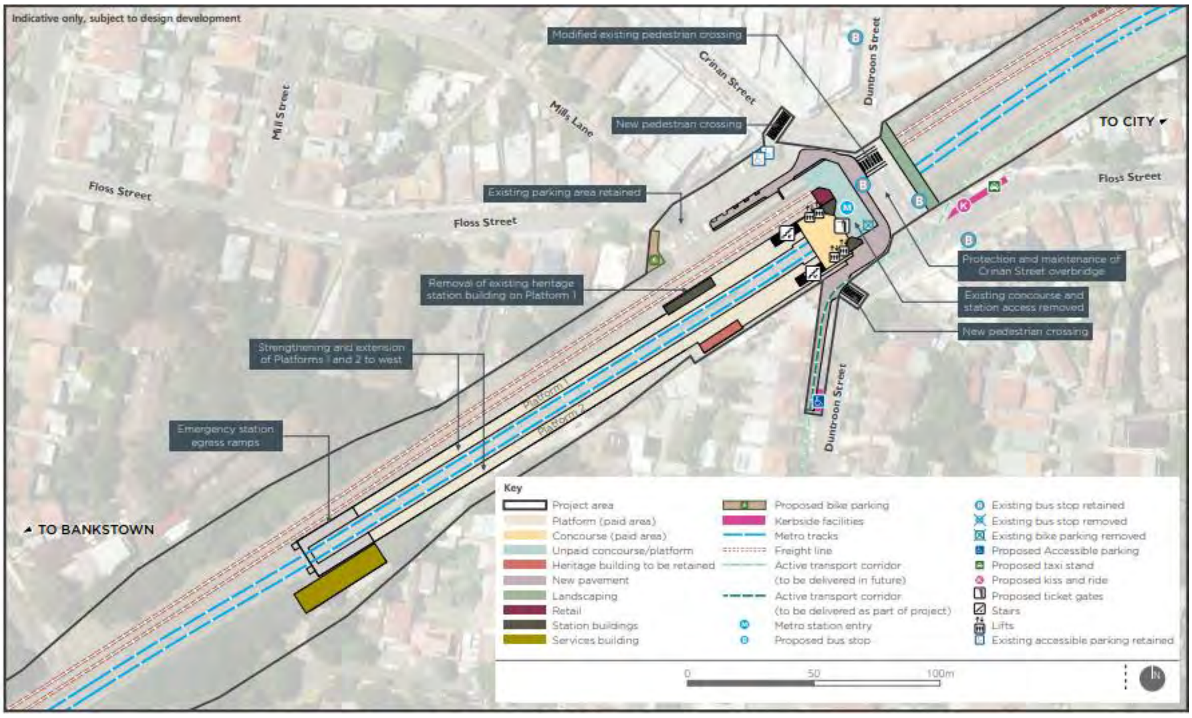


Figure 5-7 Hurlstone Park Station indicative layout map

5.8.1 Existing and future development

The closest sensitive receivers to Hurlstone Park Station buildings are the dwellings at 46 Floss Street and 101 - 103 Duntroon Street, whilst the closest sensitive receivers to the Services Building are the dwellings at 5 Railway Street and 74 Floss Street.

Proposed residential development is expected to increase by 2036 with 100 new dwellings around station. The existing land uses and the closest sensitive receivers to the site are shown on Figure 5-8 which is reproduced from the EIS.

Figure 5-8 Land uses around Hurlstone Park Station

5.8.2 Assessment locations

The sensitive receivers have been separated into two noise catchment categories (NCCs) according to the planning zoning and the expected level of noise amenity in the area of the receiver. The closest residential receivers and their approximate distances to the main Project buildings in each NCC are indicated in Figure 5-9.

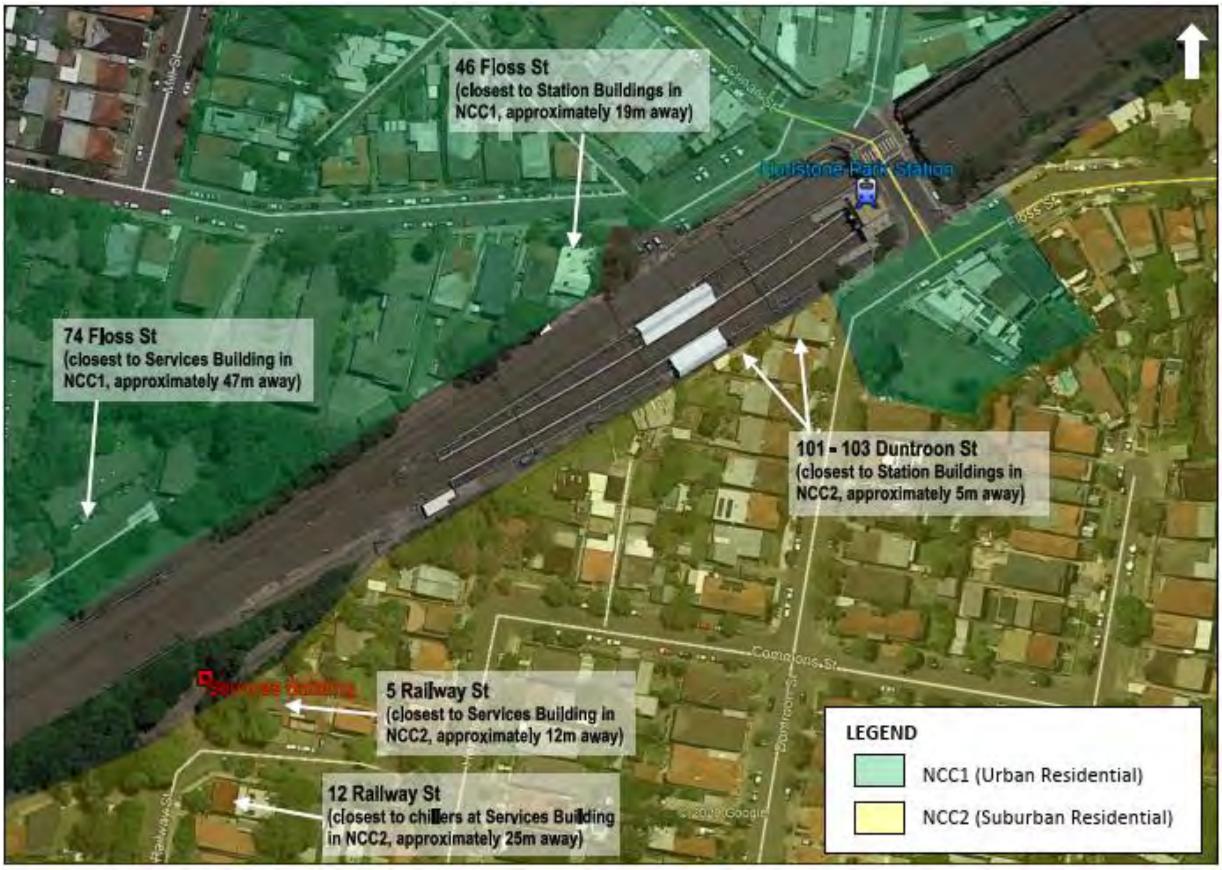


Figure 5-9 Assessment locations – Hurlstone Park Station

5.8.3 Background noise monitoring

Noise monitoring of the existing noise levels in the area was conducted as part of the EIS between 21 and 30 June 2016 at a representative receiver location near the station at 3 Commons Street, Hurlstone Park.

5.8.4 Measured noise levels

The results of the noise monitoring are summarised in Table 5-12.

Noise monitoring location	RBL L_{A90}, dB(A)			Intrusiveness noise criteria $L_{Aeq(15\ min)}$, dB(A)		
	Day	Evening	Night	Day	Evening	Night
3 Commons Street, Hurlstone Park	38	38	34	43	43	39

Table 5-12 Measured noise levels – Hurlstone Park Station

5.8.5 Project-specific criteria

The resultant project-specific noise criteria based on section 5.1.4 are summarised in Table **5-13**.

Location	$L_{Aeq(15min)}$ noise criteria, dB(A)

	Day	Evening	Night
Dwellings close to Station Building			
Suburban residential (NCC2)	40	40	35
Urban Residential (NCC1)	40	40	36
Dwellings close to Service Building			
Suburban residential (NCC2)	43	43	38
Urban Residential (NCC1)	43	43	39

Table 5-13 Project-specific criteria – Hurlstone Park Station

Note the noise criteria for dwellings close to the Station Building have been reduced by 3 dB to allow for noise contribution from the PA system (refer section 5.3.2).

5.8.6 Noise predictions and assessment

Noise predictions in Table **5-14** indicate that the noise levels at external receivers from the operation of new noise sources associated with mechanical systems at Hurlstone Park Station will achieve the established noise criteria.

Location	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)		
	Day	Evening	Night
Dwellings close to Station Building			
101-103 Duntroon Street (Suburban residential - NCC2)	38	38	35
46 Floss Street (Urban Residential - NCC1)	35	35	34
Dwellings close to Service Building			
5 Railway Street (Suburban residential - NCC2)	36	36	35
12 Railway Street (Suburban residential - NCC2)	38	38	38
74 Floss Street (Urban Residential - NCC1)	25	25	24

Table 5-14 Projected noise levels – Hurlstone Park Station

5.8.7 Emergency

The noise from the emergency mechanical systems designed for the Services Building has been predicted at the closest sensitive receivers. The highest predicted noise levels at the receivers have been compared with the relevant noise criteria, as summarised in Table 5-15.

Location	Criteria Night , dB(A)	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)
5 Railway Street (Suburban residential - NCC2)	45	37
12 Railway Street (Suburban residential - NCC2)	45	39
74 Floss Street (Urban Residential - NCC1)	50	28

Table 5-15 Predicted noise levels from emergency operations

The noise predictions for operation of emergency systems presented in Table 5-15 meet the criteria for the night-time period, which governs requirements for the Project.

5.9 Canterbury Station

Canterbury Station is located to the north-west of the Canterbury Road overbridge. The station area is bounded by Broughton Street to the north, a large mixed use development fronting Charles Street to the south, and Canterbury Road to the east. The station entrance is on Canterbury Road.

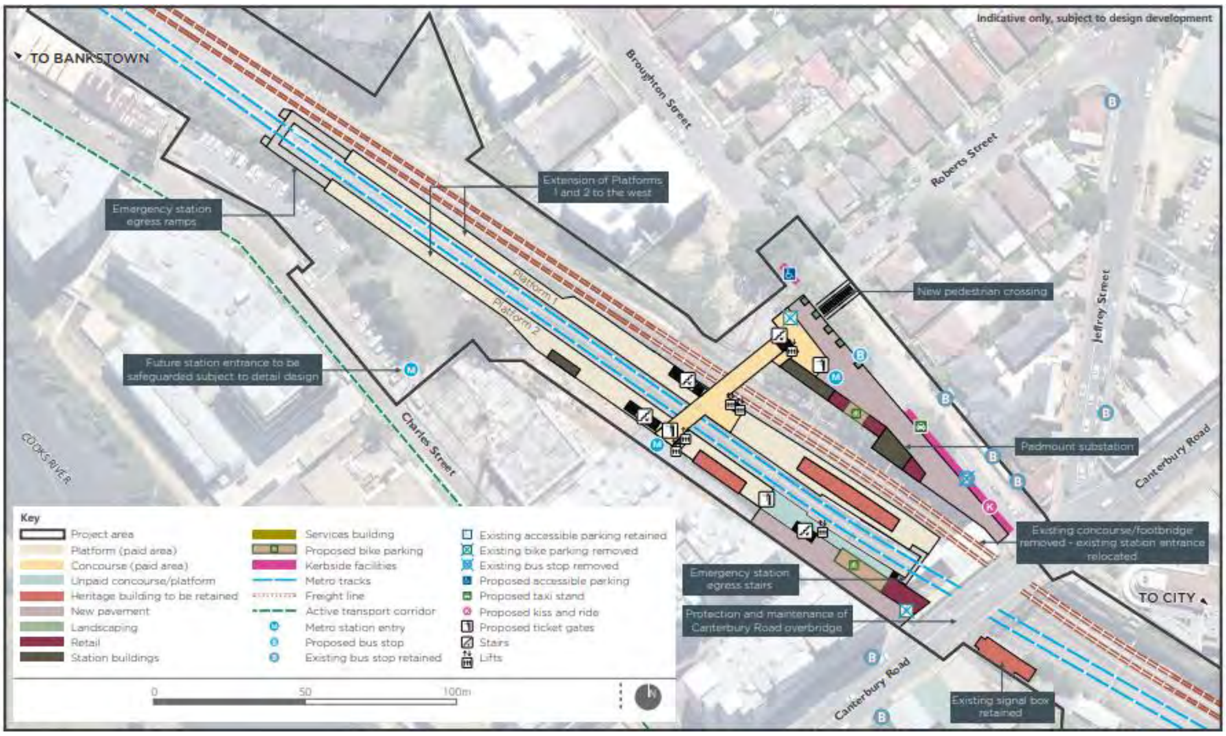


Figure 5-10 Canterbury Station indicative layout map

5.9.1 Existing and future development

The closest sensitive receivers to the Canterbury Station building are the residential apartments at 2 & 2A Charles Street and the dwellings fronting Broughton Street and Canterbury Road, whilst the closest sensitive receivers to the Services Building are the residential apartments to the southeast and southwest, at 10B Charles Street and 11-15 Charles Street, respectively.

Proposed residential development is expected to increase by 2036 with 4000 new dwellings around station.

5.9.2 Assessment locations

The sensitive receivers have been separated into two noise catchment categories (NCCs) according to the planning zoning and the expected level of noise amenity in the area of the receiver. The residential receivers and their approximate distances to the main Project buildings in each NCC are indicated on Figure 5-11.

Figure 5-11 Assessment locations – Canterbury Station

5.9.3 Background noise monitoring

Noise monitoring of the existing noise levels in the area was conducted as part of the EIS between 22 and 30 June 2016, at a representative residential location near the station at 23 Tincombe Street, Canterbury. The monitoring location is located further away from the rail corridor and the main road than some of the closest sensitive receivers to the site, and therefore the monitoring results are likely to provide lower estimates of the existing noise levels at these sensitive receivers. Use of the EIS monitoring results is expected to provide a conservative assessment approach.

5.9.4 Measured noise levels

The results of the noise monitoring are summarised in Table 5-16.

Noise monitoring location	RBL L_{A90}, dB(A)			Intrusiveness noise criteria $L_{Aeq(15\ min)}$, dB(A)		
	Day	Evening	Night	Day	Evening	Night
23 Tincombe Street, Canterbury	43	43	36	48	48	41

Table 5-16 Measured noise levels at Canterbury Station

5.9.5 Project-specific noise criteria

The resultant project-specific noise criteria based on section 5.1.4 are summarised in Table **5-17**.

Location	$L_{Aeq(15min)}$ noise criteria, dB(A)		
	Day	Evening	Night
Dwellings close to Station Building			
Suburban residential (NCC2)	45	40	35
Urban Residential (NCC1)	45	45	38
Dwellings close to Service Building			
Suburban residential (NCC2)	48	43	38
Urban Residential (NCC1)	48	48	41

Table 5-17 Project-specific criteria – Canterbury Station

Note the noise criteria for dwellings close to the Station Building have been reduced by 3 dB to allow for noise contribution from the PA system (refer section 5.3.2).

5.9.6 Noise predictions and assessment

Noise predictions in Table **5-18** indicate that the noise levels at external receivers from operation of new noise sources associated with mechanical systems at Canterbury Station will achieve the established noise criteria.

Location	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)		
	Day	Evening	Night
Dwellings close to Station Building			
3 Brought Street (Suburban residential - NCC2)	33	33	29
2 & 2A Charles Street (Urban Residential - NCC1)	45	45	35
193A Canterbury Road (Urban Residential - NCC1)	38	38	35
Dwellings close to Service Building			
19 Brought Street (Suburban residential - NCC2)	34	34	34
10B Charles Street (Urban Residential - NCC1)	40	40	40
11-15 Charles Street (Urban Residential - NCC1)	41	41	41

Table 5-18 Predicted noise levels – Canterbury Station

5.9.7 Emergency

The noise from the emergency mechanical systems designed for the Services Building has been predicted to closest sensitive receivers. The highest predicted noise levels at the receiver have been compared with the relevant noise criteria, as summarised in Table 5-19.

Location	Criterion Night, dB(A)	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)
19 Brought Street (Suburban residential - NCC2)	46	39
10B Charles Street (Urban Residential - NCC1)	50	42
11-15 Charles Street (Urban Residential - NCC1)	50	40

Table 5-19 Predicted noise levels from emergency operations

The noise predictions for operation of emergency systems presented in Table 5-19 meet the criteria for the night-time period, which governs requirements for the Project.

5.10 Campsie Station

Campsie Station is located to the west of the Beamish Street overbridge. The station area is bounded by Lilian Lane/South Parade to the south, Wilfred Avenue/North Parade to the north, and Beamish Street to the east. The station entrance is located on the overbridge.

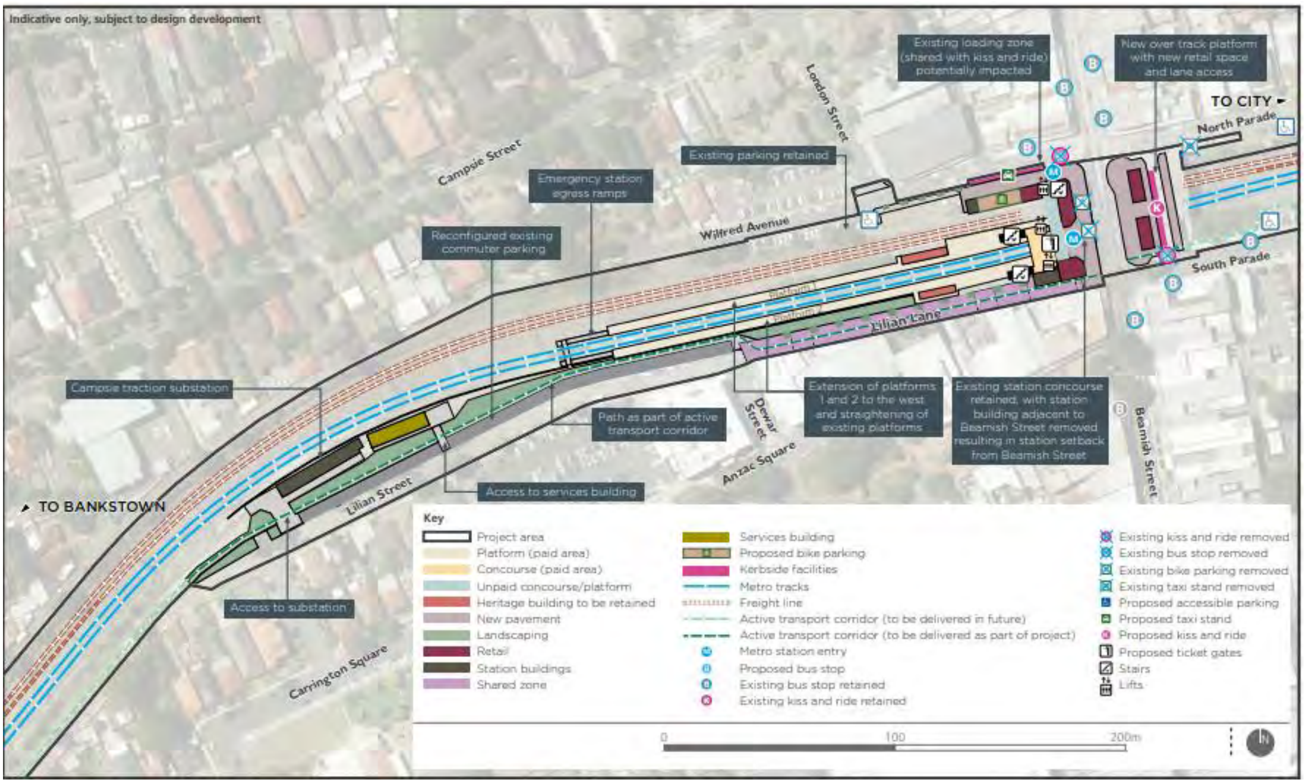


Figure 5-12 Campsie Station indicative layout map

5.10.1 Existing and future development

The closest sensitive receivers to Campsie Station buildings are the residential apartments at 13-15 Anglo Road, whilst the closest sensitive receivers to the Services Building are the dwellings fronting Wilfred Avenue and Assets Street, with the nearest dwelling located at 1

Assets Street. The existing land uses, and the closest sensitive receivers are shown on Figure 5-13, which has been reproduced from the EIS.

Proposed residential development is expected to increase by 2036 with 6000 new dwellings around station.

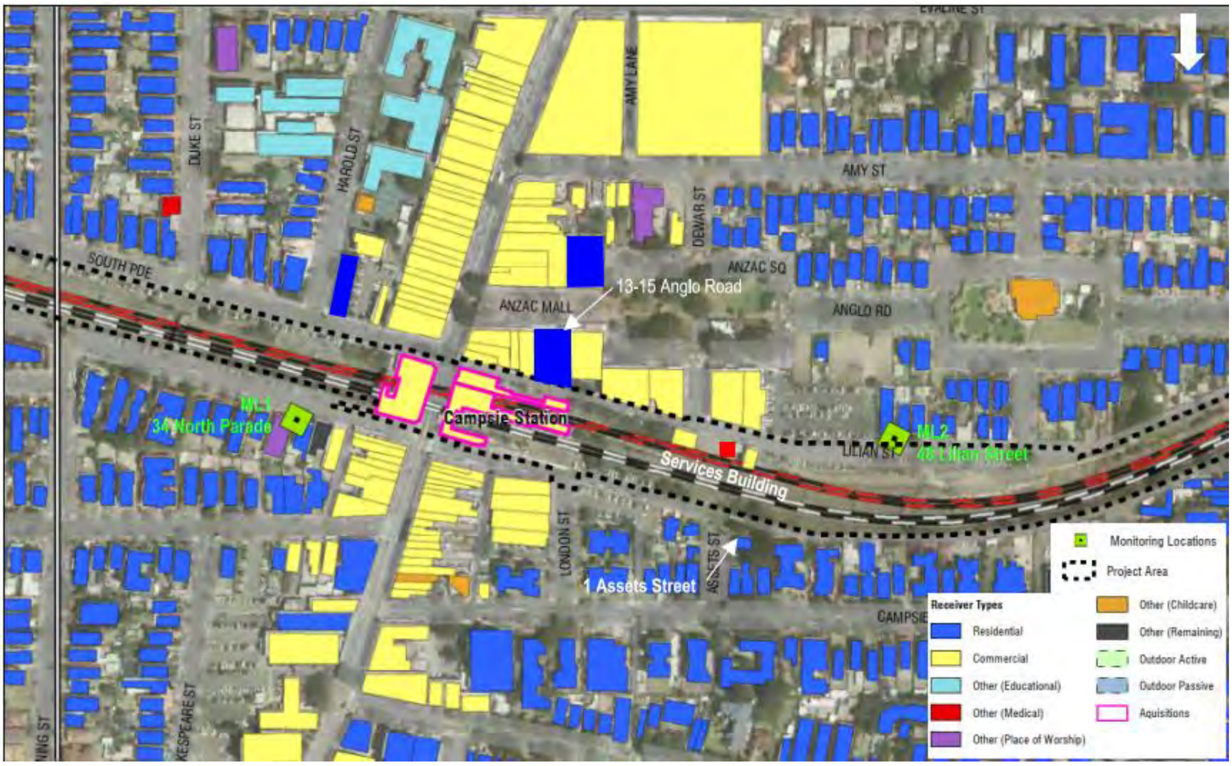


Figure 5-13 Land uses around Campsie Station

5.10.2 Assessment locations

The sensitive receivers have been separated into two noise catchment categories (NCCs) according to the planning zoning and the expected level of noise amenity in the area of the receivers. The closest residential receivers in each NCC and their approximate distances to the main Project buildings are indicated on Figure 5-14.

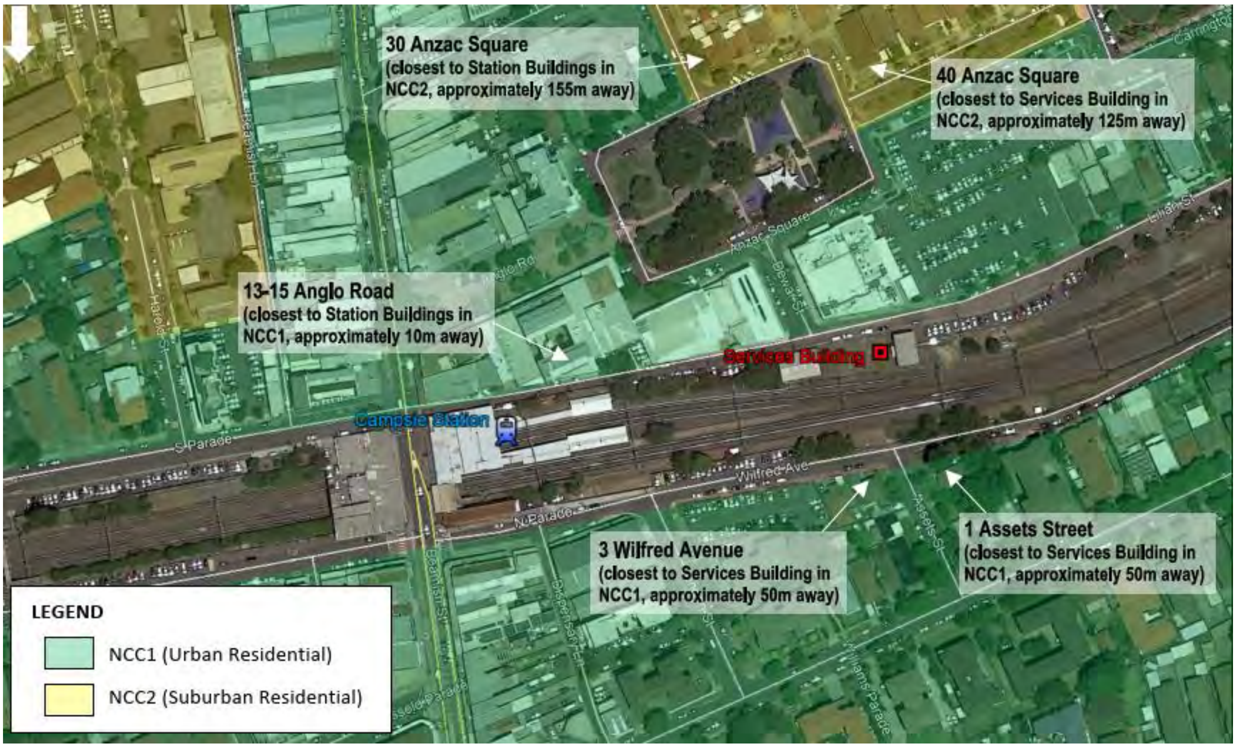


Figure 5-14 Assessment locations – Campsie Station

5.10.3 Background noise monitoring

Noise monitoring of the existing noise levels in the area was conducted as part of the EIS between 21 and 30 June 2016, at two representative receiver locations surrounding the station at 34 North Parade and 48 Lilian Street.

5.10.4 Measured noise levels

The results of the noise monitoring are summarised in Table 5-20.

Noise monitoring location	RBL L_{A90}, dB(A)			Intrusiveness noise criteria $L_{Aeq(15\ min)}$, dB(A)		
	Day	Evening	Night	Day	Evening	Night
34 North Parade	45	42	35	49	47	40
48 Lilian Street	44	44	40	49	49	45

Table 5-20 Measured noise levels at Campsie Station

5.10.5 Project-specific noise criteria

The resultant project-specific noise criteria based on section 5.1.4 are summarised in Table **5-21**.

Location	$L_{Aeq(15min)}$ noise criteria, dB(A)		
	Day	Evening	Night
Suburban residential NCC2	46	40	35
Urban Residential NCC1	46	44	37

Table 5-21 Project-specific criteria – Campsie Station

Since the noise criteria are lowest during the night-time period and all noise sources are considered to be continuous, the night-time project-specific criterion has been used to compare with the noise predictions. Note the noise criteria have been reduced by 3 dB to allow for noise contribution from the PA system (refer section 5.3.2).

5.10.6 Noise predictions and assessment

Noise predictions in Table **5-22** indicate that the noise levels at external receivers from operation of new noise sources associated with mechanical systems at Campsie Station will achieve the established noise criteria.

Location	Criterion Night, dB(A)	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)
1 Assets Street (Urban Residential NCC1)	37	37
3 Wilfred Avenue (Urban Residential NCC1)	37	36
13 – 15 Anglo Road (Urban Residential NCC1)	37	35
40 Anzac Square (Suburban Residential NCC2)	35	27
30 Anzac Square (Suburban Residential NCC2)	35	17

Table 5-22 Predicted noise levels – Campsie Station

5.10.7 Emergency

The noise from the emergency mechanical systems designed for the Services Building has been predicted to closest sensitive receivers. The highest predicted noise levels at the receiver have been compared with the relevant noise criteria, as summarised in Table 5-23.

Location	Criterion Night, dB(A)	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)
13 – 15 Anglo Road (Urban Residential NCC1)	50	35
1 Assets Street (Urban Residential NCC1)	50	29
3 Wilfred Avenue (Urban Residential NCC1)	50	29

Location	Criterion Night, dB(A)	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)
40 Anzac Square (Suburban Residential NCC2)	45	19
30 Anzac Square (Suburban Residential NCC2)	45	13

Table 5-23 Predicted noise level from emergency operations

The noise predictions for operation of emergency systems presented in Table 5-23 meet the criteria for the night-time period, which governs requirements for the Project.

5.11 Belmore Station

Belmore Station is located to the east of the Burwood Road overbridge. To the north and south, the station area is bounded by commuter car parks fronting Redman Parade and Tobruk Avenue respectively. To the west, the station area is bounded by Burwood Road. The existing station entrance is located on the Burwood Road overbridge.

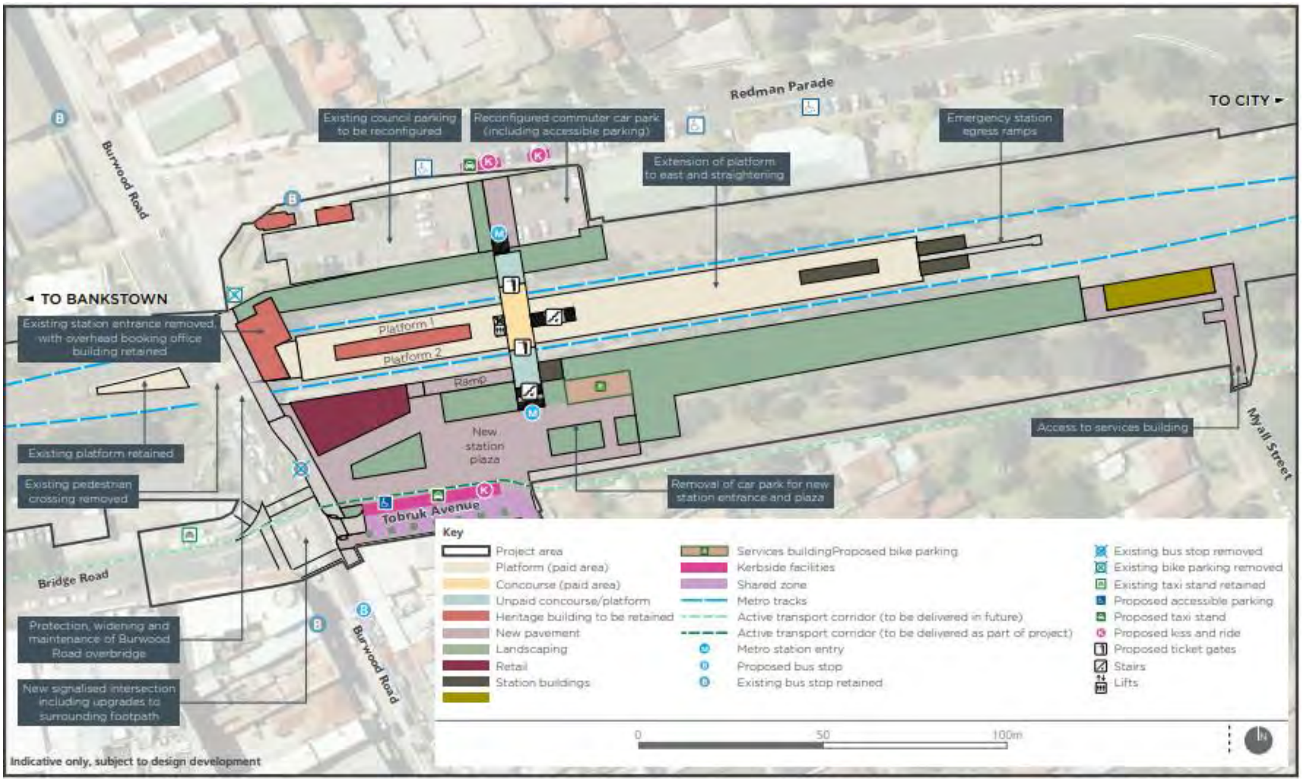


Figure 5-15 Belmore Station indicative layout map

5.11.1 Existing and Future Development

The existing land uses surrounding the Belmore Station site, mainly comprising residential and commercial land uses, have been identified based on the EIS report. The closest surrounding sensitive receivers to Belmore Station buildings are the dwellings at 30 Redman Parade and 1 Acacia Street, whilst the closest surrounding sensitive receivers to the Services Building are the residential block at 4 Sudbury Street and the dwellings at 23 Redman Parade, 1 Myall Street and 2 Acacia Street. The existing land uses and the closest sensitive receivers to the site are shown on Figure 5-16, which has been reproduced from the EIS.

Proposed residential development is expected to increase by 2036 with 3000 new dwellings around station.

Figure 5-16 Land uses around Belmore Station

5.11.2 Assessment locations

The sensitive receivers have been separated into two noise catchment categories (NCCs) according to the planning zoning and the expected level of noise amenity in the area of the receivers. The closest residential receivers in each NCC and their approximate distances to the main Project buildings are indicated on Figure 5-17.

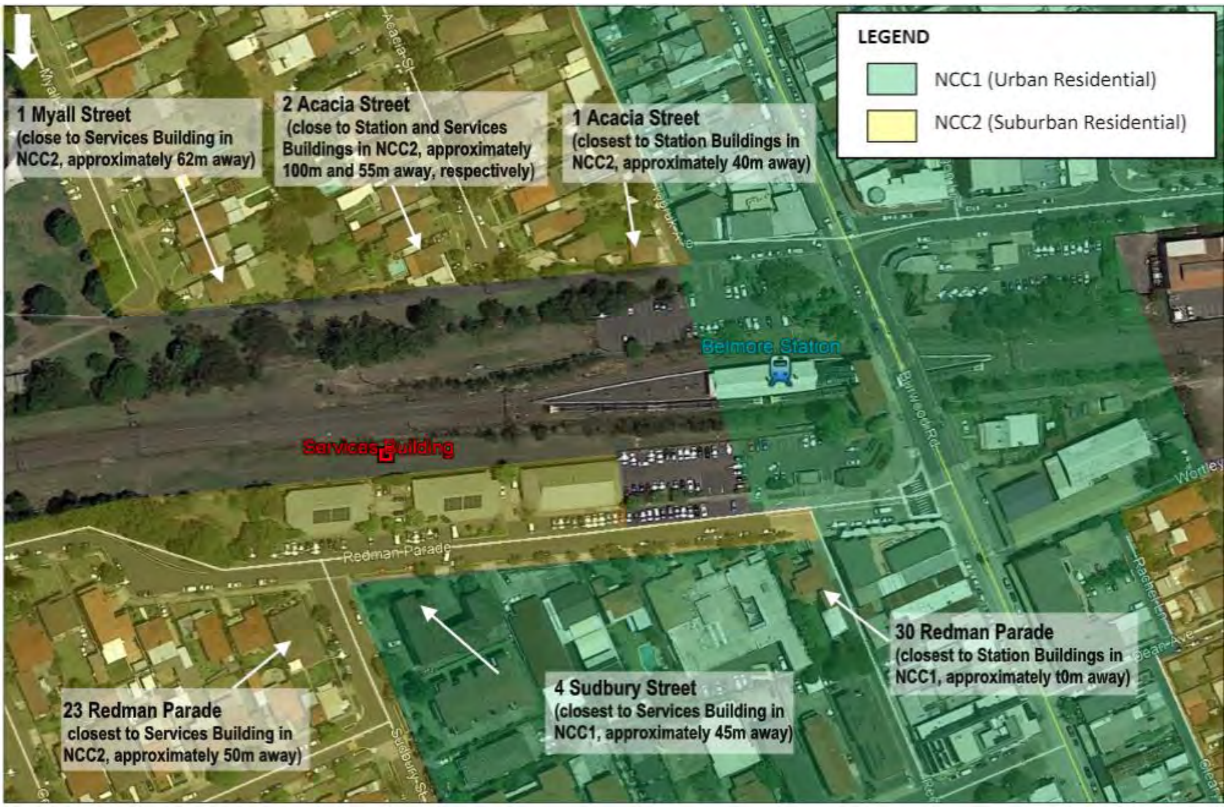


Figure 5-17 Assessment locations – Belmore Station

5.11.3 Background noise monitoring

Noise monitoring of the existing noise levels in the area was conducted in accordance with Noise Policy for Industry 2017, as part of the EIS between 22 and 30 June 2016, at a representative receiver location near the station, at 10 Acacia Street, Belmore. It is noted that the monitoring location is located further away and partially shielded from the rail and/or main roads, in comparison to the closest sensitive receivers to the site.

5.11.4 Measured Noise levels

The results of the noise monitoring are summarised in Table **5-24**.

Noise monitoring location	RBL L_{A90}, dB(A)			Intrusiveness noise criteria $L_{Aeq(15\ min)}$, dB(A)		
	Day	Evening	Night	Day	Evening	Night
10 Acacia Street, Belmore	41	41	35	46	46	40

Table 5-24 Measured noise levels at Belmore Station

5.11.5 Project-specific noise criteria

The resultant project-specific noise criteria based on section 5.1.4 are summarised in Table **5-25**.

Location	$L_{Aeq(15min)}$ noise criteria, dB(A)		
	Day	Evening	Night
Suburban residential	43	40	35
Urban Residential	43	43	37

Table 5-25 Project-specific noise criteria – Belmore Station

Since the noise criteria are lowest during the night-time period and all noise sources are considered to be continuous, the night-time project-specific criterion has been used to compare with the noise predictions. Note the noise criteria have been reduced by 3 dB to allow for noise contribution from the PA system (refer section 5.3.2).

5.11.6 Noise predictions and assessment

Noise predictions in Table **5-26** indicate that the noise levels at external receivers from operation of new noise sources associated with mechanical system at Belmore Station will achieve the established noise criteria.

Noise monitoring location	Criterion Night, dB(A)	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)
30 Redman Parade (NCC1 – Urban Residential)	37	31
4 Sudbury Street (NCC1 – Urban Residential)	37	35
1 Acacia Street (NCC2 – Suburban Residential)	35	30
2 Acacia Street (NCC2 – Suburban Residential)	35	31
1 Myall Street (NCC2 – Suburban Residential)	35	35
23 Redman Street (NCC2 – Suburban Residential)	35	32

Table 5-26 Predicted noise levels – Belmore Station

5.11.7 Emergency

The noise from the emergency mechanical systems designed for the Services Building has been predicted to closest sensitive receivers. The highest predicted noise levels at the receiver have been compared with the relevant noise criteria, as summarised in Table 5-27.

Location	Criterion Night, dB(A)	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)
30 Redman Parade (NCC1 – Urban Residential)	50	31
4 Sudbury Street (NCC1 – Urban Residential)	50	43
1 Acacia Street (NCC2 – Suburban Residential)	45	35
2 Acacia Street (NCC2 – Suburban Residential)	45	35
1 Myall Street (NCC2 – Suburban Residential)	45	30
23 Redman Street (NCC2 – Suburban Residential)	45	39

Table 5-27 Predicted noise levels from emergency operations

The noise predictions for operation of emergency systems presented in Table 5-27 meet the criteria for the night-time period, which governs requirements for the Project.

5.12 Lakemba Station

Lakemba Station is located about 60 metres to the west of the Haldon Street overbridge. The station area is bounded by Railway Parade to the north and The Boulevarde to the south. Access to the station is provided off Railway Parade and The Boulevarde.

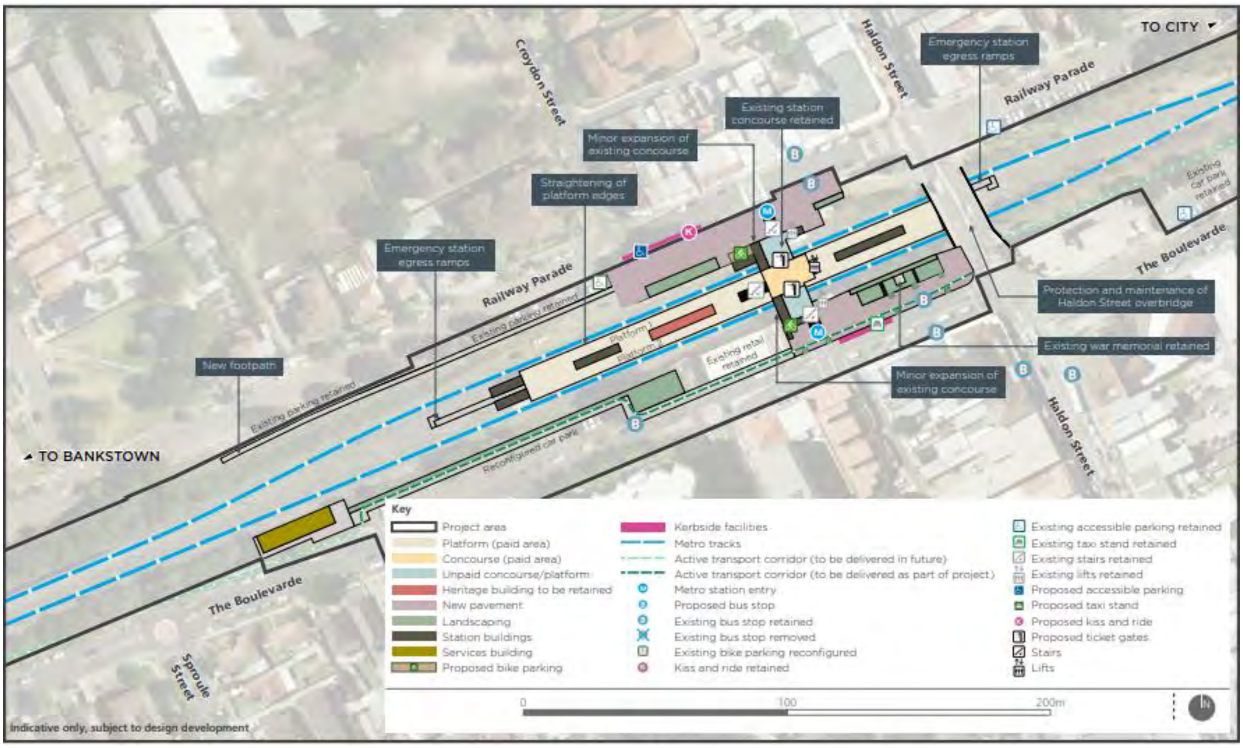


Figure 5-18 Lakemba Station indicative layout map

5.12.1 Existing and future development

The closest sensitive receivers to the Lakemba Station building are the residential units above the ground level shop lots fronting Railway Parade (the closest at 52 Railway Parade), whilst the closest sensitive receivers to the Services Building are the units at the 3-storey apartment block at 17 Croydon Street.

Proposed residential development is expected to increase by 2036 with 3000 new dwellings around station.

The existing land uses and the closest sensitive receivers to the site are shown on Figure **5-19**, which has been reproduced from the EIS.

Figure 5-19 Land uses around Lakemba Station

5.12.2 Assessment locations

The sensitive receivers have been separated into two noise catchment categories (NCCs) according to the planning zoning and the expected level of noise amenity in the area of the receivers. The closest residential receivers in each NCC and their approximate distances to the Project are indicated on Figure 5-20.

Figure 5-20 Assessment locations – Lakemba Station

5.12.3 Background noise monitoring

Noise monitoring of the existing noise levels in the area was conducted as part of the EIS between 21 and 30 June 2016, at a representative receiver location near the station at 63 The Boulevarde, Lakemba.

5.12.4 Measured noise levels

The results of the noise monitoring are summarised in Table 5-28.

Noise monitoring location	RBL L_{A90}, dB(A)			Intrusiveness noise criteria $L_{Aeq(15\ min)}$, dB(A)		
	Day	Evening	Night	Day	Evening	Night
63 The Boulevarde, Lakemba	50	50	43	55	55	48

Table 5-28 Measured noise levels at Lakemba Station

5.12.5 Project-specific noise criteria

The resultant project-specific noise criteria based on section 5.1.4 are summarised in Table **5-29**.

Location	$L_{Aeq(15min)}$ noise criteria, dB(A)		
	Day	Evening	Night
Suburban residential (NCC2)	50	40	35
Urban Residential (NCC1)	52	45	40

Table 5-29 Project specific criteria – Lakemba Station

Since the noise criteria are lowest during the night-time period and all noise sources are considered to be continuous, the night-time project-specific criterion has been used to compare with the noise predictions. Note the noise criteria have been reduced by 3 dB to allow for noise contribution from the PA system (refer section 5.3.2).

5.12.6 Noise predictions and assessment

Noise predictions in Table **5-30** indicate that the noise levels at external receivers from operation of new noise sources associated with mechanical systems at Belmore Station will achieve the established noise criteria.

Noise monitoring location	Criterion Night, dB(A)	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)
54 Railway Parade (NCC1 – Urban Residential)	40	40
52 Railway Parade (NCC1 – Urban Residential)	40	38
17 Croydon Street (NCC1 – Urban Residential)	40	37
63 The Boulevarde Croydon Street (NCC1 – Urban Residential)	40	38
20 Croydon Street (NCC1 – Urban Residential)	35	18

Table 5-30 Predicted noise levels – Lakemba Station

5.12.7 Emergency

The noise from the emergency mechanical systems designed for the Services Building has been predicted to closest sensitive receivers. The highest predicted noise levels at the receiver have been compared with the relevant noise criteria, as summarised in Table 5-31 below.

Location	Criteria Night, dB(A)	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)
54 Railway Parade (NCC1 – Urban Residential)	37	34
52 Railway Parade (NCC1 – Urban Residential)	37	38
17 Croydon Street (NCC1 – Urban Residential)	35	39

Location	Criteria Night, dB(A)	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)
63 The Boulevarde Croydon Street (NCC1 – Urban Residential)	35	40
20 Croydon Street (NCC1 – Urban Residential)	35	19

Table 5-31 Predicted noise levels from emergency operations

The noise predictions for operation of emergency systems presented in Table 5-31 meet the criteria for the night-time period, which governs requirements for the Project.

5.13 Wiley Park Station

Wiley Park Station is located to the west of the King Georges Road overbridge. The station area is bounded by Stanlea Parade walkway to the north, by King Georges Road to the east and The Boulevarde to the south. The station entrance is located on the overbridge.

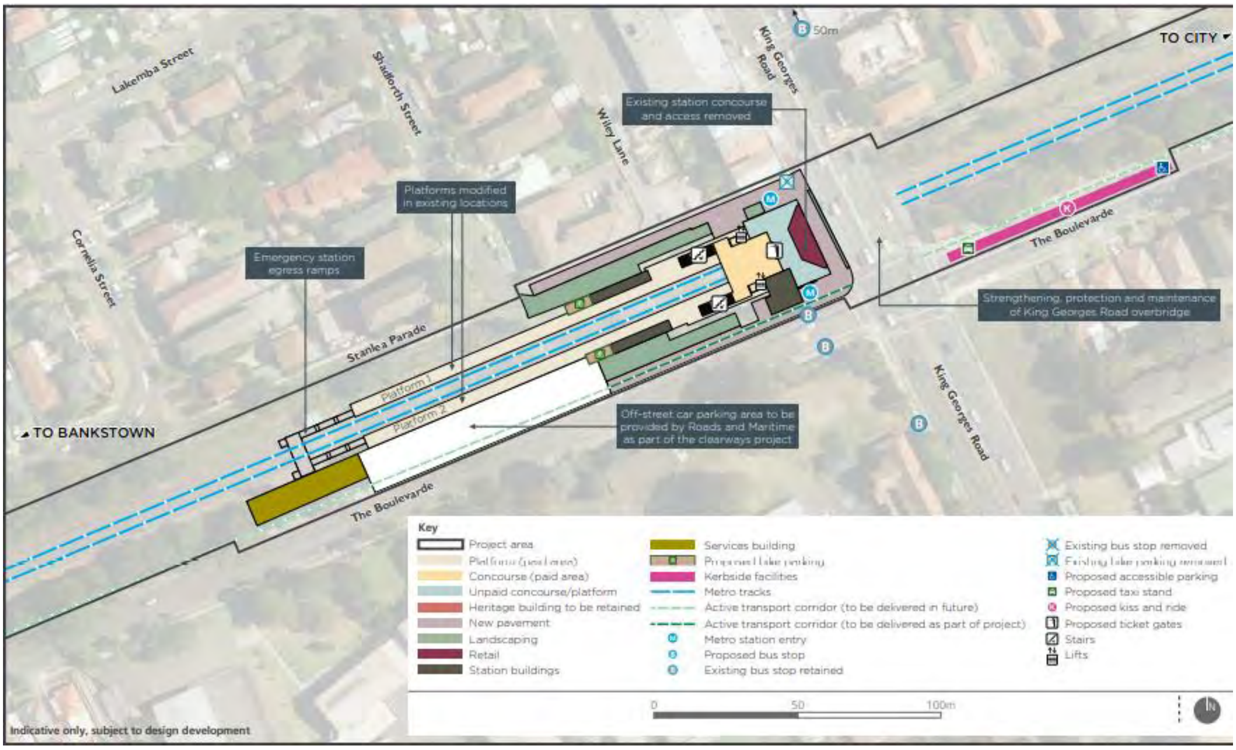


Figure 5-21 Wiley Park Station indicative layout map

5.13.1 Existing and future development

The site is in Canterbury-Bankstown Local Government Area and within the Canterbury Local Environmental Plan 2012. The closest sensitive receivers to Wiley Park Station buildings are the residential apartments at 1A Shadforth Street and the residential units above the commercial land uses fronting King Georges Road (at 89 King Georges Road and the adjacent buildings). The closest sensitive receivers to the Services Building are the residential apartments at 1 Cornelia Street, and the dwellings at 2A Cornelia Street and 118 The Boulevarde.

Proposed residential development is expected to increase by 2036 with 2400 new dwellings around station.

5.13.2 Assessment locations

The sensitive receivers have been separated into two noise catchment categories (NCCs) according to the planning zoning and the expected level of noise amenity in the area of the receivers. The closest residential receivers in each NCC and their approximate distances to the main Project buildings are indicated on Figure 5-22.

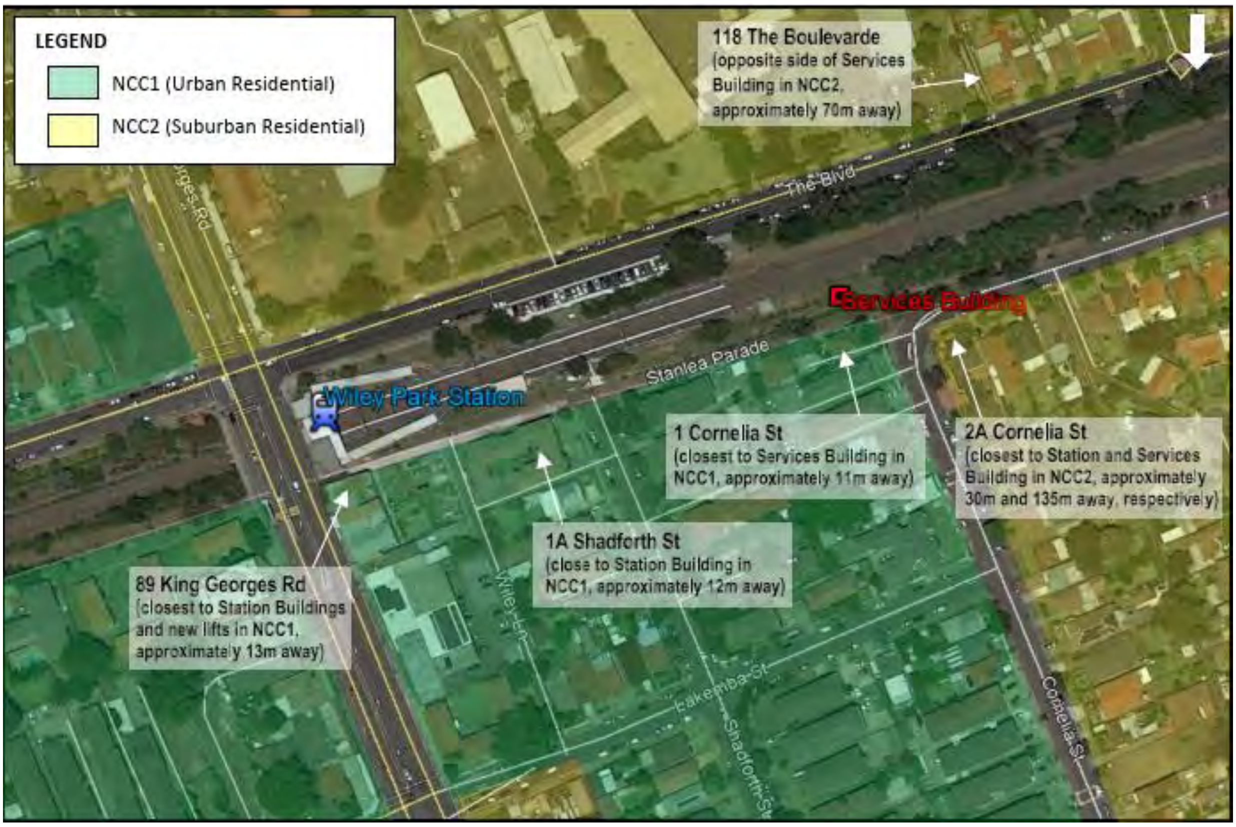


Figure 5-22 Assessment locations – Wiley Park Station

5.13.3 Background noise monitoring

Noise monitoring of the existing noise levels in the area was conducted as part of the EIS between 21 and 30 June 2016, at a representative receiver location near the station at 5 Shadforth Street, Wiley Park.

It is noted that the monitoring location is located further away and partially shielded from the rail and/or main roads, in comparison to the closest sensitive receivers to the site. As such, the monitoring results are expected to be conservative estimates of the existing noise levels at the receivers that are closer to and have full sight to the rail and/or front the main roads. Using the monitoring results in the assessment is expected to provide a conservative approach.

5.13.4 Measured noise levels

The results of the noise monitoring are summarised in Table 5-32.

Noise monitoring location	RBL L_{A90}, dB(A)			Intrusiveness noise criteria $L_{Aeq(15 min)}$, dB(A)		
	Day	Evening	Night	Day	Evening	Night
5 Shadforth Street, Wiley Park	44	44	41	49	49	46

Table 5-32 Measured noise levels at Wiley Park Station

5.13.5 Project-specific noise criteria

The resultant project-specific noise criteria based on section 5.1.4 are summarised in Table **5-33**.

Location	$L_{Aeq(15min)}$ noise criteria, dB(A)		
	Day	Evening	Night
Suburban residential (NCC2)	46	40	35
Urban Residential (NCC1)	46	45	40

Table 5-33 Project-specific criteria Wiley Park Station

Note the noise criteria have been reduced by 3 dB to allow for noise contribution from the PA system (refer section 5.3.2).

5.13.6 Noise predictions and assessment

Noise predictions in Table **5-34** indicate that the noise levels at external receivers from operation of new noise sources associated with mechanical systems at Wiley Park Station will achieve the established noise criteria.

Location	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)		
	Day	Evening	Night
1A Shadforth Street (NCC1 – Urban Residential)	38	38	38
1 Cornelia Street (NCC1 – Urban Residential)	29	29	34
89 King Georges Road (NCC1 – Urban Residential)	45	45	31
2A Cornelia Street (NCC2 – Suburban Residential)	18	18	35
118 The Boulevarde (NCC2 – Suburban Residential)	15	15	26

Table 5-34 Predicted noise levels – Wiley Park Station

5.13.7 Emergency

The noise from the emergency mechanical systems designed for the Services Building has been predicted to closest sensitive receivers. The highest predicted noise levels at the receiver have been compared with the relevant noise criteria, as summarised in Table 5-35.

Location	Criteria Night, dB(A)	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)
1A Shadforth Street (NCC1 – Urban Residential)	51	39
1 Cornelia Street (NCC1 – Urban Residential)	51	41
89 King Georges Road (NCC1 – Urban Residential)	51	32
2A Cornelia Street (NCC2 – Suburban Residential)	51	36
118 The Boulevarde (NCC2 – Suburban Residential)	51	33

Table 5-35 Predicted noise levels from emergency operations

The noise predictions for operation of emergency systems presented in Table 5-35 meet the criteria for the night-time period, which governs requirements for the Project.

5.14 Punchbowl Station

Punchbowl Station is located to the east of the Punchbowl Road overbridge. The station area is bounded by commercial land uses and a car park fronting The Boulevarde to the south, Warren Reserve and Urunga Parade to the north, and Punchbowl Road to the west. The station entrances are located on Punchbowl Road (via Warren Reserve) to the north, and The Boulevarde to the south.

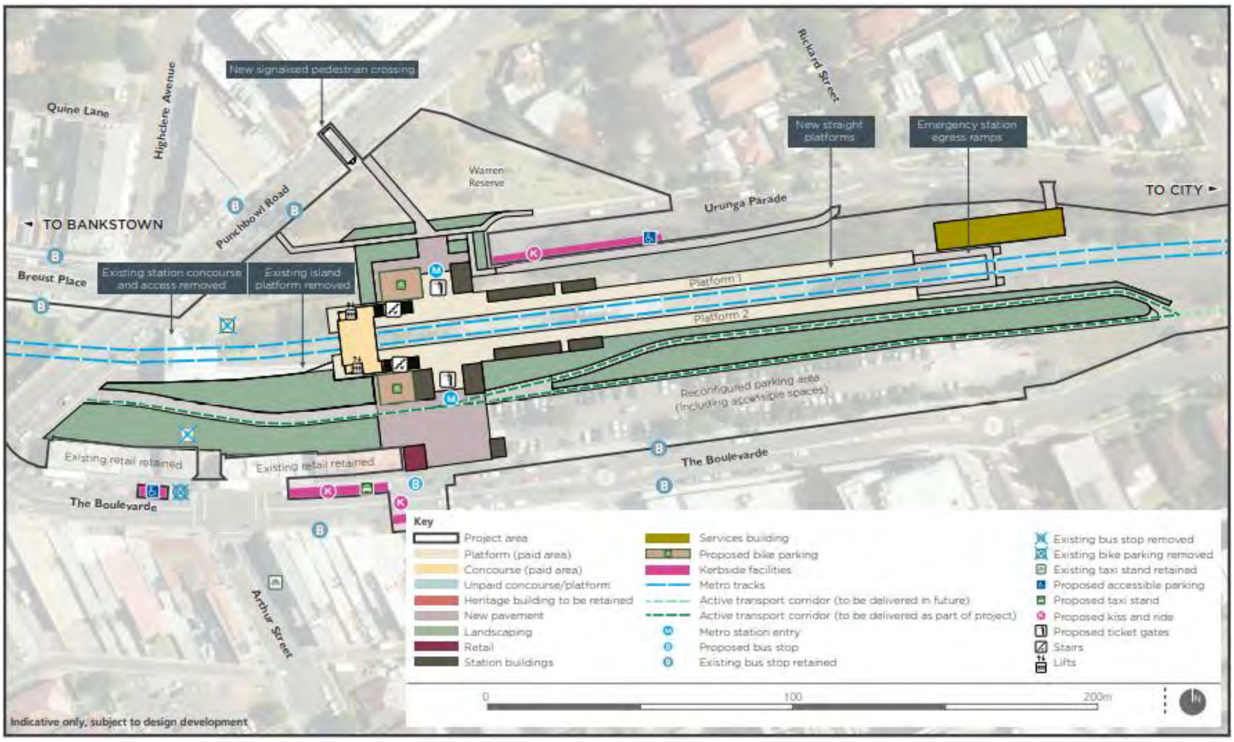


Figure 5-23 Punchbowl Station indicative layout map

5.14.1 Existing and future development

The site is in Canterbury-Bankstown Local Government Area and within the Canterbury Local Environmental Plan 2012. The land use zones for the area are shown in Figure 5-24.

The closest sensitive receivers to Punchbowl Station buildings are the residential units above the commercial premises fronting The Boulevarde, with the nearest unit to the station located at 279A The Boulevarde. The closest sensitive receivers to the Services Building are the dwellings fronting Urunga Parade, with the nearest dwelling to the building located at 41 Urunga Parade.

Proposed residential development is expected to increase by 2036 with 2400 new dwellings around station.

Figure 5-24 Land uses around Punchbowl Station

5.14.2 Assessment locations

The sensitive receivers have been separated into two noise catchment categories (NCCs) according to the planning zoning and the expected level of noise amenity in the area of the receivers. The closest residential receivers in each NCC and their approximate distances to the main Project buildings are indicated on Figure 5-25.

Figure 5-25 Assessment locations – Punchbowl Station

5.14.3 Background noise monitoring

Noise monitoring of the existing noise levels in the area was conducted as part of the EIS between 21 and 30 June 2016, at a representative receiver location near the station at 42 Urunga Parade, Punchbowl.

5.14.4 Measured noise levels

The results of the noise monitoring are summarised in Table 5-36.

Noise monitoring location	RBL L_{A90}, dB(A)			Intrusiveness noise criteria $L_{Aeq(15\ min)}$, dB(A)		
	Day	Evening	Night	Day	Evening	Night
42 Urunga Parade, Punchbowl	47	47	41	52	52	46

Table 5-36 Measured noise levels – Punchbowl Station

5.14.5 Project-specific noise criteria

The resultant project-specific noise criteria based on section 5.1.4 are summarised in Table **5-37**.

Location	$L_{Aeq(15min)}$ noise criteria, dB(A)		
	Day	Evening	Night
Suburban residential (NCC2)	49	40	35
Urban Residential (NCC1)	49	45	40

Table 5-37 Project-specific criteria – Punchbowl Station

Note the noise criteria have been reduced by 3 dB to allow for noise contribution from the PA system (refer section 5.3.2).

5.14.6 Noise predictions and assessment

Noise predictions in Table **5-38** indicate that the noise levels at external receivers from operation of new noise sources associated with the mechanical systems at Punchbowl Station will achieve the established noise criteria.

Location	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)		
	Day	Evening	Night
279A The Boulevarde (NCC1 – Urban Residential)	45	45	37
695-697 Punchbowl Road (NCC1 – Urban Residential)	34	34	31
200 The Boulevarde (NCC1 – Urban Residential)	29	29	28
41 Urunga Parade (NCC2 – Suburban Residential)	36	36	35

Table 5-38 Predicted noise levels – Punchbowl Station

5.14.7 Emergency

The noise from the emergency mechanical systems designed for the Services Building has been predicted to closest sensitive receivers. The highest predicted noise levels at the receiver have been compared with the relevant noise criteria, as summarised in Table 5-39.

Location	Criteria Night, dB(A)	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)
279A The Boulevarde (NCC1 – Urban Residential)	51	36
695-697 Punchbowl Road (NCC1 – Urban Residential)	51	31
200 The Boulevarde (NCC1 – Urban Residential)	51	28
41 Urunga Parade (NCC2 – Suburban Residential)	51	33

Table 5-39 Predicted noise levels from emergency operations

The noise predictions for operation of emergency systems presented in Table 5-39 meet the criteria for the night-time period, which governs requirements for the Project.

5.15 Bankstown Station

Bankstown Station is located to the east of the Punchbowl Road overbridge. The station area is bounded by commercial land uses and a car park fronting The Boulevarde to the south, Warren Reserve and Urunga Parade to the north, and Punchbowl Road to the west. The station entrances are located on Punchbowl Road (via Warren Reserve) to the north, and The Boulevarde to the south.

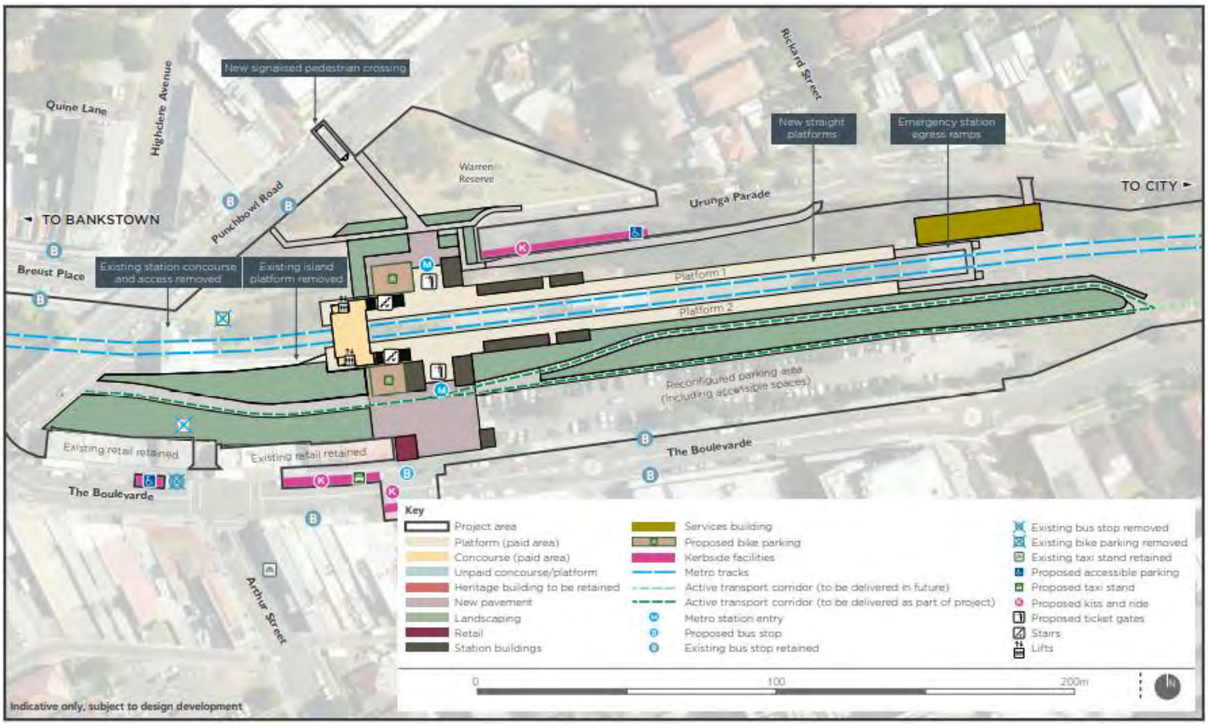


Figure 5-26 Bankstown Station indicative layout map

5.15.1 Existing and future development

The site is in Canterbury-Bankstown Local Government Area and within the Bankstown Local Environmental Plan 2015.

The closest sensitive receivers to Bankstown Station buildings are the residential units above the commercial premises fronting Bankstown City Plaza, with the nearest unit to the station located at 8 Bankstown City Plaza.

Proposed residential development is expected to increase by 2036 with 6000 new dwellings around station.

5.15.2 Assessment locations

The closest sensitive receivers to Bankstown Sydney Metro Station are the units at multi-storey residential building at 2 West Terrace. The existing land uses and the closest sensitive receivers are shown on Figure 5, which has been reproduced from the EIS. The approximate distances of the closest sensitive receivers to the main Project buildings are also indicated on Figure 5-27. The closest sensitive receivers are located within a B4 Mixed Use planning zone in the Bankstown Local Environmental Plan 2015

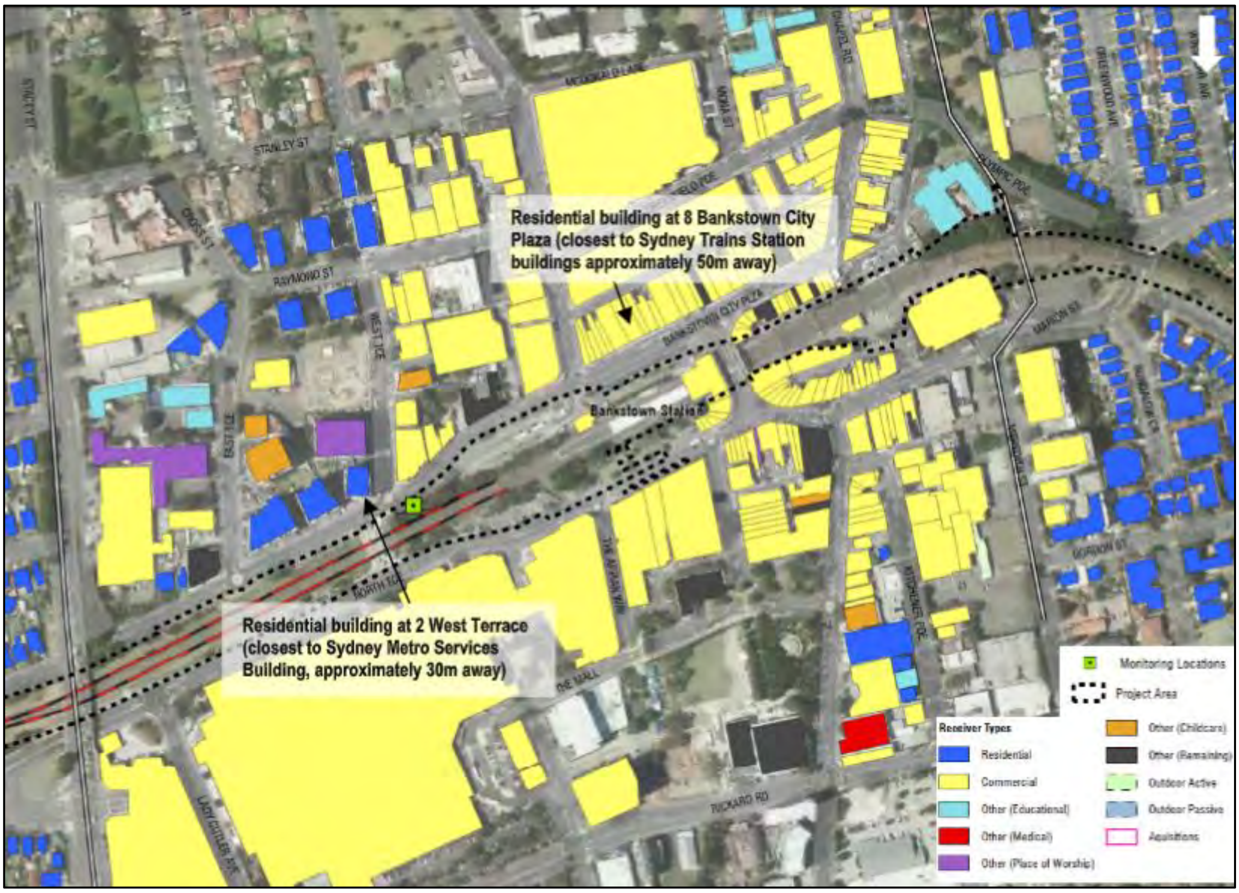


Figure 5-27 Assessment locations – Bankstown Station

5.15.3 Background noise monitoring

Noise monitoring of the existing noise levels in the area was conducted as part of the EIS between 27 June 2016, and 4 July 2016, at a location representative of the receivers surrounding the station, near 258 South Terrace, Bankstown. The EIS indicated that overall ambient noise levels in the area were mainly influenced by road traffic. Considering that the monitoring location was at a similar proximity to the main roads as the closest receivers, the results of the noise monitoring are considered to be representative of noise levels at the closest receivers. The assessment has considered the noise levels and potential vibration impact at the closest sensitive receivers to the Sydney Trains Station Buildings and Sydney Metro Station Buildings.

5.15.4 Measured noise levels

The results of the noise monitoring are summarised in Table **5-40**.

Noise monitoring location	RBL L_{A90}, dB(A)			Intrusiveness noise criteria $L_{Aeq(15\ min)}$, dB(A)		
	Day	Evening	Night	Day	Evening	Night
258 South Terrace, Bankstown	54	51	42	59	56	47

Table 5-40 Measured noise levels at Bankstown Station

5.15.5 Project-specific noise criteria

The resultant project-specific noise criteria based on section 5.1.4 are summarised in Table **5-41**.

Location	$L_{Aeq(15min)}$ noise criteria, dB(A)		
	Day	Evening	Night
Residential receivers	55	45	40

Table 5-41 Project specific criteria – Bankstown Station

Since the noise criteria are lowest during the night-time period and all noise sources are considered to be continuous, the night-time project-specific criterion has been used to compare with the noise predictions. Note the noise criteria have been reduced by 3 dB to allow for noise contribution from the PA system (refer section 5.3.2).

5.15.6 Noise predictions and assessment

Noise predictions in Table **5-42** indicate that the noise levels at external receivers from operation of new noise sources associated with mechanical systems at Bankstown Station will achieve the established noise criteria.

Location	Criterion Night, dB(A)	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)
8 Bankstown City Plaza	40	34
2 West Terrace	40	40

Table 5-42 Predicted noise levels – Bankstown Station

5.15.7 Emergency

The noise from the emergency mechanical systems designed for the Services Building has been predicted to closest sensitive receivers. The highest predicted noise levels at the receiver have been compared with the relevant noise criteria, as summarised in Table 5-43.

Location	Criterion Night, dB(A)	$L_{Aeq(15min)}$ Predicted noise levels, dB(A)
8 Bankstown City Plaza	52	37
2 West Terrace	52	49

Table 5-43 Predicted noise levels from emergency operations

The noise predictions for operation of emergency systems presented in Table 5-43 meet the criteria for the night-time period, which governs requirements for the Project.

5.16 Dulwich Hill Traction Substation

The proposed Dulwich Hill substation is located on the southern side of the existing railway tracks (T2 and T3 Lines). It is predominantly bounded by residential premises. The substation will be constructed as a part of the SMCSW Sydenham to Bankstown project. An aerial photograph identifying the Dulwich Hill Traction Substation is provided in Figure 5-28 below.

Figure 5-28 Dulwich Hill Traction Substation (TDH) location

5.16.1 Existing and future development

The land use survey has found that Southwest Corridor Substations are surrounded by predominately residential premises.

At this stage, it is understood that there is no current proposal to construct noise-sensitive land uses in close proximity to Southwest Corridor Substations. However, should such land uses be proposed in the future, the layout and design of such developments are required to comply with the requirements of the Inner West Council's Marrickville Development Control Plan (DCP) 20115, City of Canterbury-Bankstown Council's Canterbury DCP 20126 and Bankstown DCP 20157, the Infrastructure SEPP8 and the associated Development Near Rail Corridors and Busy Roads Interim Guideline.

5.16.2 Background noise monitoring

The operational noise criteria have been established from the baseline noise measurements in the Environmental Impact Statement (EIS)10 (SLR Report). The background noise levels in the SLR Report are considered appropriate for establishing the operational noise objectives.

The long-term noise monitoring methodology and noise level-vs-time graphs of the data can be found in the SLR Report.

5.16.1 Assessment locations

A summary of long-term noise monitoring locations and time frames are described in Table 5-44 and measurement locations are shown in Figure 5-29.

Receiver location	Intrusiveness noise levels $L_{Aeq(15min)}$, dB(A)			Amenity noise criteria $L_{Aeq(15min)}$, dB(A)		
	Day	Evening	Night	Day	Evening	Night
Residence A, B & C (Both sides of railway track)	43	43	38	63	53	48

Table 5-44 Measured noise levels near Dulwich Hill Traction Substation

Figure 5-29 Dulwich Hill Traction Substation (TDH) location and nearest receivers

5.16.2 Project specific noise criteria

In accordance with the NPfI the project noise trigger levels, which are the lower (i.e. more stringent) value of the project intrusiveness noise level and project amenity noise level, have been determined as shown in Table 5-45 below.

Receiver location	Project noise trigger levels $L_{Aeq(15min)}$, dB(A)		
	Day	Evening	Night
Residence A, B & C (Both sides of railway track)	43	43	38

Table 5-45 Project Specific Noise levels near Dulwich Hill Substation

5.16.3 Assessment and prediction

The noise and vibration sources associated with normal operation of the Southwest Corridor Substations addressed in this assessment include:

- Mechanical equipment serving the modular buildings
- Electrical equipment including Bulk Power Supply, HV Reticulation System and Traction Power System

The noise predictions were carried out in accordance with International Standard ISO9613, as implemented within the CadnaA 3D noise modelling software (Version 2021 MR 1). The software takes into account sound radiation patterns, acoustic shielding and potential reflections from intervening building elements, and noise attenuation due to distance.

The predicted noise levels at the nearest sensitive receivers are provided in Table 5-46 compared with the most stringent project noise trigger levels for the given receivers being the night-time period (10:00pm to 7:00am) since the noise criteria are lowest during the night-time period and all noise sources are steady.

Receiver ID	Location	Land Use	Distance (m)	Project noise trigger levels $L_{Aeq(15min)}$, dB(A)	Predicted noise levels $L_{Aeq(15min)}$, dB(A)	Comments
Res A	20 Randall St, Marrickville	Res	<5	38	40[2]	Up to 2dB exceedance
Res B	19. 21 and 23 Albermarle St, Marrickville	Res	<5	38	40[2]	Up to 2dB exceedance
Res C	41 Challis Ave, Dulwich Hill	Res	43	38	36[2]	Complies

Table 5-46 Predicted noise levels at nearest sensitive receiver – Dulwich Hill Traction Substation

The predicted noise levels comply with the project noise trigger levels at all receivers during the night-time period when the project noise trigger levels are the most stringent, with the exception of:

- Four residential dwellings around the Substation. Three of these are to the south including the granny flats along Albermarle Street and one to the east along Randall Street.

The predicted noise levels comply with the project noise trigger levels at all receivers during the day and evening periods. In accordance with Table 4.1 of the NPfI, the significance of residual noise levels is considered to be negligible if the exceedances are 2 dB(A) or less.

[2] With a +2dB positive adjustment for low frequency noise

Therefore, at the four residential dwellings around the Dulwich Hill Traction Substation with negligible exceedances, no further consideration of noise mitigation measures is required.

5.16.4 Vibration Assessment

Given the separation distance from any of the Southwest Corridor Substations, vibration levels are expected to be well below the vibration objectives. The potential vibration sources are from the plant and equipment installed within the various rooms and that the predicted levels at relevant locations are well below the relevant criteria. The risk of vibration impacts is therefore considered negligible. Vibration associated with train movements is predicted to be well below the vibration goals for satisfactory operation of sensitive equipment within the modular buildings.

5.17 Canterbury Traction Substation

The proposed Canterbury Traction Substation is located on the southern side of the existing railway tracks (T2 and T3 Lines). It is predominantly bounded by residential premises. The substation will be constructed as a part of the SMCSW Sydenham to Bankstown project. An aerial photograph identifying the Canterbury Traction Substation is provided in Figure 5-30 below.

Figure 5-30 Canterbury Traction Substation location

5.17.1 Existing and future development

The land use survey has found that Southwest Corridor Substations are surrounded by predominately residential premises.

At this stage, it is understood that there is no current proposal to construct noise-sensitive land uses in close proximity to Southwest Corridor Substations. However, should such land uses be proposed in the future, the layout and design of such developments are required to comply with the requirements of the Inner West Council's Marrickville Development Control Plan (DCP) 20115, City of Canterbury-Bankstown Council's Canterbury DCP 20126 and Bankstown DCP 20157, the Infrastructure SEPP8 and the associated Development Near Rail Corridors and Busy Roads Interim Guideline.

5.17.2 Background noise monitoring

The operational noise criteria have been established from the baseline noise measurements in the Environmental Impact Statement (EIS)10 (SLR Report). The background noise levels in the SLR Report are considered appropriate for establishing the operational noise objectives. The long-term noise monitoring methodology and noise level-vs-time graphs of the data can be found in the SLR Report.

5.17.3 Assessment locations

A summary of long-term noise monitoring locations and time frames are described in Table 5-47 and measurement locations are shown in Figure 5-31.

Receiver location	Intrusiveness noise levels $L_{Aeq(15min)}$, dB(A)			Amenity noise criteria $L_{Aeq(15\ min)}$, dB(A)		
	Day	Evening	Night	Day	Evening	Night
Residence A & B (Both sides of railway track)	45	45	40	63	53	48
REC (Boar House – Passive recreation)	-	-	-	53 when in use		

Table 5-47 Measured noise levels near Canterbury Traction Substation (TCR)

Figure 5-31 Canterbury Traction Substation (TCR) location and nearest receivers

5.17.4 Project specific noise criteria

In accordance with the NPfI the project noise trigger levels, which are the lower (i.e. more stringent) value of the project intrusiveness noise level and project amenity noise level, have been determined as shown in Table 5-48 below.

Receiver location	Project noise trigger levels $L_{Aeq\ (15min)}$, dB(A)		
	Day	Evening	Night
Residence A & B (Both sides of railway track)	45	45	40
REC	53 when in use		

Table 5-48 Project Specific Noise levels near Canterbury Traction Substation (TCR)

5.17.5 Assessment and prediction

The noise and vibration sources associated with normal operation of the Southwest Corridor Substations addressed in this assessment include:

- Mechanical equipment serving the modular buildings
- Electrical equipment including Bulk Power Supply, HV Reticulation System and Traction Power System

The noise predictions were carried out in accordance with International Standard ISO9613, as implemented within the CadnaA 3D noise modelling software (Version 2021 MR 1). The software takes into account sound radiation patterns, acoustic shielding and potential reflections from intervening building elements, and noise attenuation due to distance.

The predicted noise levels at the nearest sensitive receivers are provided in Table 5-49 compared with the most stringent project noise trigger levels for the given receivers being the night-time period (10:00pm to 7:00am) since the noise criteria are lowest during the night-time period and all noise sources are steady.

Receiver ID	Location	Land Use	Distance (m)	Project noise trigger levels $L_{Aeq(15min)}$, dB(A)	Predicted noise levels $L_{Aeq(15min)}$, dB(A)	Comments
Res A	6 Hutton St, Hurlstone Park	Res	22	40	40[2]	Complies
Res B	2 Canberra St, Hurlstone Park	Res	46	40	37[2]	Complies
REC	Boat Harbour (When in use)	REC	45	53	33[2]	Complies

Table 5-49 Predicted noise levels at nearest sensitive receiver (TCR)

The predicted noise levels comply with the project noise trigger levels at all receivers during the night-time period when the project noise trigger levels are the most stringent.

5.17.6 Vibration Assessment

Given the separation distance from any of the Southwest Corridor Substations, vibration levels are expected to be well below the vibration objectives. The potential vibration sources are from the plant and equipment installed within the various rooms and that the predicted levels at relevant locations are well below the relevant criteria. The risk of vibration impacts is therefore considered negligible. Vibration associated with train movements is predicted to be well below the vibration goals for satisfactory operation of sensitive equipment within the modular buildings.

5.18 Campsie Bulk Infeed and Traction Substation

The proposed Campsie Bulk Infeed and Traction Substation is located on the southern side of the existing railway tracks (T2 and T3 Lines). It is predominantly bounded by residential premises. The substation will be constructed as a part of the SMCSW Sydenham to Bankstown project. An aerial photograph identifying the Canterbury substation is provided in Figure 5-32 below.

Figure 5-32 Campsie Bulk Infeed and Traction Substation (TCS) location

5.18.1 Existing and future development

The land use survey has found that Southwest Corridor Substations are surrounded by predominately residential premises.

At this stage, it is understood that there is no current proposal to construct noise-sensitive land uses in close proximity to Southwest Corridor Substations. However, should such land uses be proposed in the future, the layout and design of such developments are required to comply with the requirements of the Inner West Council's Marrickville Development Control Plan (DCP) 2011[5], City of Canterbury-Bankstown Council's Canterbury DCP 2012[6] and Bankstown DCP 2015[7], the Infrastructure SEPP[8] and the associated Development Near Rail Corridors and Busy Roads Interim Guideline.

5.18.2 Background noise monitoring

The operational noise criteria have been established from the baseline noise measurements in the Environmental Impact Statement (EIS)[10] (SLR Report). The background noise levels in the SLR Report are considered appropriate for establishing the operational noise objectives. The long-term noise monitoring methodology and noise level-vs-time graphs of the data can be found in the SLR Report.

5.18.3 Assessment locations

A summary of long-term noise monitoring locations and time frames are described in Table 5-50 and measurement locations are shown in Figure 5-33.

Receiver location	Intrusiveness noise levels $L_{Aeq(15min)}$, dB(A)	Amenity noise criteria $L_{Aeq(15 min)}$, dB(A)

	Day	Evening	Night	Day	Evening	Night
Residence A & B (Both sides of railway track)	49	49	45	58	48	45
COM (Campsie RSL Club)	-	-	-	63 (External) when in use		

Table 5-50 Measured noise levels near Campsie Bulk Infeed and Traction Substation (TCS)

Figure 5-33 Campsie Bulk Infeed and Traction Substation (TCS) location and nearest receivers

5.18.4 Project specific noise criteria

In accordance with the NPfI the project noise trigger levels, which are the lower (i.e. more stringent) value of the project intrusiveness noise level and project amenity noise level, have been determined as shown in Table 5-51 below.

Receiver location	Project noise trigger levels $L_{Aeq(15min)}$, dB(A)		
	Day	Evening	Night
Residence A & B (Both sides of railway track)	49	48	45
COM	63 (external) when in use		

Table 5-51 Project Specific Noise levels near Campsie Bulk Infeed and Traction Substation (TCS)

5.18.5 Assessment and prediction

The noise and vibration sources associated with normal operation of the Southwest Corridor Substations addressed in this assessment include:

- Mechanical equipment serving the modular buildings
- Electrical equipment including Bulk Power Supply, HV Reticulation System and Traction Power System

The noise predictions were carried out in accordance with International Standard ISO9613, as implemented within the CadnaA 3D noise modelling software (Version 2021 MR 1). The software takes into account sound radiation patterns, acoustic shielding and potential reflections from intervening building elements, and noise attenuation due to distance.

The predicted noise levels at the nearest sensitive receivers are provided in Table 5-52 compared with the most stringent project noise trigger levels for the given receivers being the night-time period (10:00pm to 7:00am) since the noise criteria are lowest during the night-time period and all noise sources are steady.

Receiver ID	Location	Land Use	Distance (m)	Project noise trigger levels $L_{Aeq(15min)}$, dB(A)	Predicted noise levels $L_{Aeq(15min)}$, dB(A)	Comments
Res A	49-51 Anglo Road, Campsie (L3 fronting Lilian St)	Res	27	45	45[3]	Complies
Res B	48-50 Campsie St, Campsie (L1)	Res	43	45	34	Complies
COM	Campsie RSL Club (when in use)	COM	78	63	31	Complies

Table 5-52 Predicted noise levels at nearest sensitive receivers (TCS)

The predicted noise levels comply with the project noise trigger levels at all receivers during the night-time period when the project noise trigger levels are the most stringent.

5.18.6 Vibration Assessment

Given the separation distance from any of the Southwest Corridor Substations, vibration levels are expected to be well below the vibration objectives. The potential vibration sources are from the plant and equipment installed within the various rooms and that the predicted levels at relevant locations are well below the relevant criteria. The risk of vibration impacts is therefore considered negligible. Vibration associated with train movements is predicted to be well below the vibration goals for satisfactory operation of sensitive equipment within the modular buildings.

5.19 Lakemba Traction Substation

The proposed Lakemba Traction Substation is located on the southern side of the existing railway tracks (T2 and T3 Lines). It is predominantly bounded by residential premises. The substation will be constructed as a part of the SMCSW Sydenham to Bankstown project. An

[3] FAT data for the Harmonic Filters, 33kV/11kV Transformer and Auxiliary Transformers are pending

aerial photograph identifying the Lakemba Traction Substation is provided in Figure 5-34 below.

Figure 5-34 Lakemba Traction Substation (TLS) location

5.19.1 Existing and future development

The land use survey has found that Southwest Corridor Substations are surrounded by predominately residential premises.

At this stage, it is understood that there is no current proposal to construct noise-sensitive land uses in close proximity to Southwest Corridor Substations. However, should such land uses be proposed in the future, the layout and design of such developments are required to comply with the requirements of the Inner West Council's Marrickville Development Control Plan (DCP) 2011[5], City of Canterbury-Bankstown Council's Canterbury DCP 2012[6] and Bankstown DCP 2015[7], the Infrastructure SEPP[8] and the associated Development Near Rail Corridors and Busy Roads Interim Guideline.

5.19.2 Background noise monitoring

The operational noise criteria have been established from the baseline noise measurements in the Environmental Impact Statement (EIS)[10] (SLR Report). The background noise levels in the SLR Report are considered appropriate for establishing the operational noise objectives. The long-term noise monitoring methodology and noise level-vs-time graphs of the data can be found in the SLR Report.

5.19.3 Assessment locations

A summary of long-term noise monitoring locations and time frames are described in Table 5-53 and measurement locations are shown in Figure 5-35.

Receiver location	Intrusiveness noise levels $L_{Aeq\,(15min)}$, dB(A)			Amenity noise criteria $L_{Aeq(15\,min)}$, dB(A)		
	Day	Evening	Night	Day	Evening	Night
Residence A & B (Both sides of railway tracks)	52	52	46	63	51	48

Table 5-53 Measured noise levels near Lakemba Traction Substation (TLS)

Figure 5-35 Lakemba Traction Substation (TLS) location and nearest receivers

5.19.4 Project specific noise criteria

In accordance with the NPfI the project noise trigger levels, which are the lower (i.e. more stringent) value of the project intrusiveness noise level and project amenity noise level, have been determined as shown in Table 5-54 below.

Receiver location	Project noise trigger levels $L_{Aeq(15min)}$, dB(A)		
	Day	Evening	Night
Residence A & B (Both sides of railway tracks)	52	51	46

Table 5-54 Project Specific Noise levels near Lakemba Traction Substation (TLS)

5.19.5 Assessment and prediction

The noise and vibration sources associated with normal operation of the Southwest Corridor Substations addressed in this assessment include:

- Mechanical equipment serving the modular buildings
- Electrical equipment including Bulk Power Supply, HV Reticulation System and Traction Power System

The noise predictions were carried out in accordance with International Standard ISO9613, as implemented within the CadnaA 3D noise modelling software (Version 2021 MR 1). The software takes into account sound radiation patterns, acoustic shielding and potential reflections from intervening building elements, and noise attenuation due to distance.

The predicted noise levels at the nearest sensitive receivers are provided in Table 5-55 compared with the most stringent project noise trigger levels for the given receivers being the night-time period (10:00pm to 7:00am) since the noise criteria are lowest during the night-time period and all noise sources are steady.

Receiver ID	Location	Land Use	Distance (m)	Project noise trigger levels $L_{Aeq(15min)}$, dB(A)	Predicted noise levels $L_{Aeq(15min)}$, dB(A)	Comments

Res A	13 The Boulevarde, Lakemba	Res	21	46	42[2]	Complies
Res B	14 Railway Parade, Lakemba	Res	55	46	33[2]	Complies

Table 5-55 Predicted noise levels at nearest sensitive receiver (TLS)

The predicted noise levels comply with the project noise trigger levels at all receivers during the night-time period when the project noise trigger levels are the most stringent.

5.19.6 Vibration Assessment

Given the separation distance from any of the Southwest Corridor Substations, vibration levels are expected to be well below the vibration objectives. The potential vibration sources are from the plant and equipment installed within the various rooms and that the predicted levels at relevant locations are well below the relevant criteria. The risk of vibration impacts is therefore considered negligible. Vibration associated with train movements is predicted to be well below the vibration goals for satisfactory operation of sensitive equipment within the modular buildings.

5.20 Punchbowl Traction Substation

The proposed Punchbowl substation is located on the southern side of the existing railway tracks (T2 and T3 Lines). It is predominantly bounded by residential premises. The Punchbowl Traction Substation will be constructed as a part of the SMCSW Sydenham to Bankstown project. An aerial photograph identifying the Punchbowl Traction Substation is provided in Figure 5-36 below.

Figure 5-36 Punchbowl Traction Substation (TPS) location

5.20.1 Existing and future development

The land use survey has found that Southwest Corridor Substations are surrounded by predominately residential premises.

At this stage, it is understood that there is no current proposal to construct noise-sensitive land uses in close proximity to Southwest Corridor Substations. However, should such land uses be proposed in the future, the layout and design of such developments are required to comply with the requirements of the Inner West Council’s Marrickville Development Control Plan (DCP) 20115, City of Canterbury-Bankstown Council’s Canterbury DCP 20126 and Bankstown DCP 20157, the Infrastructure SEPP8 and the associated Development Near Rail Corridors and Busy Roads Interim Guideline.

5.20.2 Background noise monitoring

The operational noise criteria have been established from the baseline noise measurements in the Environmental Impact Statement (EIS)10 (SLR Report). The background noise levels in the SLR Report are considered appropriate for establishing the operational noise objectives. The long-term noise monitoring methodology and noise level-vs-time graphs of the data can be found in the SLR Report.

5.20.3 Assessment locations

A summary of long-term noise monitoring locations and time frames are described in Table 5-56 and measurement locations are shown in Figure 5-37.

Receiver location	Intrusiveness noise levels $L_{Aeq(15min)}$, dB(A)			Amenity noise criteria $L_{Aeq(15\ min)}$, dB(A)		
	Day	Evening	Night	Day	Evening	Night
Res A & B (Both sides of the railway tracks)	52	52	44	63	52	48
CHC (Bankstown Childcare Academy – Classroom)	-	-	-	38 (internal) noisiest 1-hr period when in use OR 48 (external) noisiest 1-hr period when in use		
SCH (Punchbowl Boys High School – Classroom)	-	-	-	38 (internal) noisiest 1-hr period when in use OR 48 (external) noisiest 1-hr period when in use		

Table 5-56 Measured noise levels near Punchbowl Traction Substation (TPS)

Figure 5-37 Punchbowl Traction Substation (TPS) location and nearest receivers

5.20.4 Project specific noise criteria

In accordance with the NPfI the project noise trigger levels, which are the lower (i.e. more stringent) value of the project intrusiveness noise level and project amenity noise level, have been determined as shown in Table 5-57 below.

Receiver location	Project noise trigger levels $L_{Aeq(15min)}$, dB(A)		
	Day	Evening	Night
Residence A & B (Both sides of railway tracks)	52	52	44
CHC	38 (internal) noisiest 1-hr period when in use OR 48 (external) noisiest 1-hr period when in use		
SCH	38 (internal) noisiest 1-hr period when in use OR 48 (external) noisiest 1-hr period when in use		

Table 5-57 Project Specific Noise levels near Punchbowl Traction Substation (TPS)

5.20.5 Assessment and prediction

The noise and vibration sources associated with normal operation of the Southwest Corridor Substations addressed in this assessment include:

- Mechanical equipment serving the modular buildings

- Electrical equipment including Bulk Power Supply, HV Reticulation System and Traction Power System

The noise predictions were carried out in accordance with International Standard ISO9613, as implemented within the CadnaA 3D noise modelling software (Version 2021 MR 1). The software takes into account sound radiation patterns, acoustic shielding and potential reflections from intervening building elements, and noise attenuation due to distance.

The predicted noise levels at the nearest sensitive receivers are provided in Table 5-58 compared with the most stringent project noise trigger levels for the given receivers being the night-time period (10:00pm to 7:00am) since the noise criteria are lowest during the night-time period and all noise sources are steady.

Receiver ID	Location	Land Use	Distance (m)	Project noise trigger levels $L_{Aeq(15min)}$, dB(A)	Predicted noise levels $L_{Aeq(15min)}$, dB(A)	Comments
Res A	66 South Terrace, Punchbowl	Res	20	44	42[2]	Complies
Res B	105 Stansfield Avenue, Bankstown	Res	47	44	35[2]	Complies
CHC	Bankstown Childcare Academy (Classroom, noisiest 1-hr when in use)	CHC	21	48[4]	41[2]	Complies
SCH	Punchbowl Boys high School (Classroom, noisiest 1-hr when in use)	SCH	118	48[4]	31[2]	Complies

Table 5-58 Predicted noise levels at nearest sensitive receivers (TPS)

The predicted noise levels comply with the project noise trigger levels at all receivers during the night-time period when the project noise trigger levels are the most stringent.

5.20.6 Vibration Assessment

Given the separation distance from any of the Southwest Corridor Substations, vibration levels are expected to be well below the vibration objectives. The potential vibration sources are from the plant and equipment installed within the various rooms and that the predicted levels at relevant locations are well below the relevant criteria. The risk of vibration impacts is therefore considered negligible. Vibration associated with train movements is predicted to be well below the vibration goals for satisfactory operation of sensitive equipment within the modular buildings.

[4] Conversion of noise criteria from internal to external for educational facility assumes 10 dB(A) loss from outside to inside through open windows.

Appendix A Compliance matrix

Source	No	Requirement	Report section
SSI Approval 8256		Ministers Conditions of Approval	Refer to Executive Summary
Submissions Report		Revised environmental mitigation measures	Refer to Executive Summary
Scope and performance requirements			
SPR App44	2.1 (a)	OpCo2 must as part of its review obligations during design development of the Foundation Infrastructure Works and its system integration obligations under SPR Appendix 63, work with the Acoustic Engineering Lead in its preparation of an Operational Noise and Vibration Review (ONVR). The objectives of the ONVR are to evaluate and assess the operational compliance of Sydney Metro City & Southwest with the planning approval, identify appropriate noise and vibration objectives, and examine all feasible and reasonable noise and vibration mitigation measures. In addition to the requirements detailed in section 3.3, the ONVR must address the following: • ground-borne noise and vibration • airborne noise and vibration.	This report sets out the categories of operational noise and vibration which arise from a metro system, the sources of noise and vibration and how they contribute to the functioning of the system and the categories of sensitive receiver.
	2.2.2 (a)	The ONVR must • take into account the parameters listed in ISO14837-1; and • include verification and justification that the mitigation and maintenance measures nominated are feasible as defined in the rail noise guidelines	International Standard ISO 14837-1 2005 Mechanical vibration is considered for assessment of ground-borne noise and vibration arising from rail systems. Summary of mitigation measures outlined in:

<table>
<tr><td></td><td></td><td>referred to in Planning Approvals and demonstrate that these measures have been used in other locations effectively</td><td>Section 3.9 (airborne noise)
Section 4.6 – 4.7 (ground borne noise)
Section 4.8 (ground borne vibration)
Section 5.5 (fixed facilities)</td></tr>
<tr><td></td><td>2.2.2 (b)</td><td>In addition to the requirements of the Planning Approvals, the ONVR must ensure that Sydney Metro City & Southwest meets the following ground-borne noise trigger levels as provided in Table 1.

Table 1 Ground-borne noise trigger levels
<table>
<tr><th>Location</th><th>Trigger</th></tr>
<tr><td>General office areas</td><td>$L_{Amax\ (slow)}$ 45dBA (when in use)</td></tr>
<tr><td>Private offices and conference rooms</td><td>$L_{Amax\ (slow)}$ 40 dBA (when in use)</td></tr>
<tr><td>Retail areas</td><td>$L_{Amax\ (slow)}$ 50 dBA (when in use)</td></tr>
<tr><td>Cinemas</td><td>$L_{Amax\ (slow)}$ 35dBA (when in use)</td></tr>
<tr><td>Public halls</td><td>$L_{Amax\ (slow)}$ 35dBA (when in use)</td></tr>
<tr><td>Lecture theatres</td><td>$L_{Amax\ (slow)}$ 35dBA (when in use)</td></tr>
</table></td><td>Section 4.2 details the trigger values adopted for the assessment and section 4.6 provides details of the predicted noise levels</td></tr>
</table>

<table>
<tr>
<td></td>
<td></td>
<td>
<table>
<tr><td>Film/TV/sound recording studios</td><td>NR15 (refer AS/NZS2107:2000)</td></tr>
<tr><td>Medical institutions</td><td>$L_{Amax\ (slow)}$ 40 dBA (when in use)</td></tr>
<tr><td>Drama theatres</td><td>NR 25 (refer AS/NZS2107:2000)</td></tr>
<tr><td>Other critical spaces</td><td>Satisfactory levels in AS/NZS2107:2000</td></tr>
</table>
</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.2.2 (d)</td>
<td>In addition to the requirements of the Planning Approvals, the ONVR will ensure that Sydney Metro City & Southwest meets the following ground-borne vibration goals

Table 2 Ground-borne vibration goals
<table>
<tr><th>Location</th><th>Trigger</th></tr>
<tr><td rowspan="2">Residential</td><td>Day: 106 dB_V (0.2 mm/s)</td></tr>
<tr><td>Night: 103 dB_V (0.14 mm/s)</td></tr>
<tr><td>Commercial</td><td>112 dB_V (0.4 mm/s)</td></tr>
</table>
</td>
<td>Section 4.3 and section 5.2 detail the trigger values adopted for the assessment. Section 4.8 and Section 5.4 provide details of the predicted vibration levels. The ground-borne vibration goals in Table 2 of 2.2.2(d) have been applied to constant vibration sources at fixed facilities. VDV goals have been applied to rail operations as per the Planning Approval.</td>
</tr>
</table>

<table>
<tr>
<td></td>
<td></td>
<td>
<table>
<tr><td>Educational</td><td>112 dB_V (0.4 mm/s)</td></tr>
<tr><td>Place of Worship</td><td>112 dB_V (0.4 mm/s)</td></tr>
<tr><td>Industrial</td><td>118 dB_V (0.8 mm/s)</td></tr>
<tr><td>Theatres</td><td>106 dB_V (0.2 mm/s)</td></tr>
<tr><td>Other critical spaces</td><td>Generic Vibration Criterion (VC) curves in Institute of Environmental Sciences and Technology (IEST) industry Standard IEST-RP-CC012.1 Considerations in Clean Room Design (2007).</td></tr>
</table>
</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.2.3 (a)</td>
<td>The ONVR must:
• include verification and justification that the mitigation and maintenance measures nominated are feasible and have been used in other equivalent systems effectively; and
• for Train operations on surface track, meet the ground-borne vibration goals which are the “vibration dose” (preferred values) in Assessing Vibration: a technical guideline (DECC, 2006).</td>
<td>The rail lubrication treatments listed in section 3.9.1 reference existing standards and are widely applied on rail networks in Sydney. Only conventional mitigation measures (e.g. attenuators and screening and at-property treatments) are listed within this report.

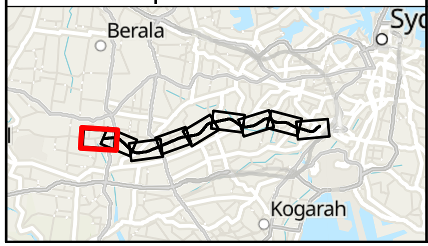
VDV ‘preferred’ values have been applied as vibration goals where appropriate – section 4.3. VDV ‘maximum’ values have been considered where all feasible and reasonable mitigation has been applied</td>
</tr>
</table>

			as per Assessing Vibration: a technical guideline (DECC, 2006)
	2.2.4 (a)	Where background data is not provided or available in environmental documents, the Acoustic Engineering Lead must undertake any and all additional noise and vibration measurements required to determine the applicable noise and vibration criteria at sensitive receivers for the land-use assessment.	Noise levels from background noise monitoring conducted as part of the EIS has been used baseline for the assessment of noise from fixed sources at each station.
	3.2 (a)	In addition to the requirements of Planning Approvals, the land use report will identify the land use category and the associated construction and operational noise and vibration criteria at all existing and proposed (identified at the time of the relevant Planning Approval) sensitive receivers potentially impacted by the OTS2 Works	Section 2, Appendix B – land use survey information
	3.3 (a)	In addition to the requirements in Planning Approvals, the ONVR must include: • a tabulation of where all sensitive receivers will be positioned where they are within 100 m of the nearest track (or within 200m of the nearest stationary facility), and/or where the predicted ground-borne noise or vibration levels are within 5dB of the applicable criteria; and • a tabulation that includes a unique identification nomenclature for each receiver, with its planned distance to the nearest track (or stationary facility), receiver type, applicable criteria and predicted ground-borne noise and vibration levels, to be recorded	Predicted airborne noise, ground borne noise and vibration levels at all external receivers adjacent to the project are provided in Appendix C, Appendix D and Appendix E respectively
	3.3 (b)	The ONVR report must fully describe the design, assumptions, calculation process, mitigation strategy, maintenance strategy and other relevant factors to enable the ONVR to be independently verified by a noise and vibration expert.	Assessment approach and methodology is detailed in section 3.4, 4.5 and 5.3
	3.3 (c)	The ONVR report must describe and quantify the accuracy of the input parameters and predictions, how any inaccuracies are proposed to be resolved or have been resolved during the design process	Assessment approach and methodology is detailed in sections 3.4, 4.5 and 5.3.

	3.3 (d)	The ONVR report must provide evidence that the noise and vibration prediction model has been validated via measurement and prediction on other rail projects	Model validation is provided in sections 3.5 and 4.5
	3.3 (e)	For the ground-borne noise assessment, the prediction model must be validated via measurements undertaken within the existing Epping to Chatswood Rail Line (ECRL) tunnels and on the ground surface for existing train operations. However, measurements and predictions of ground-borne noise and vibration from other projects will be accepted if their relevancy can be established by the Acoustic Engineering Lead.	The ground borne vibration model was validated against measurements taken on the NWRL and ECRL as well as the ground vibration survey results for the Southwest corridor for existing Sydney Trains operations.

Appendix B – Land use survey maps

Location Map



Legend

- Sydney Trains
- Metro - Type 1
- Metro - Ballast
- Goods - Ballast

Building Use

Active Rec	Garage	Residential
Child Care	Industrial	Station
Commercial	Library	Worship
Courts	Medical	Mixed Use
Education	Medical (SENS)	Public Hall

Sydney Metro South West Corridor

Building Use

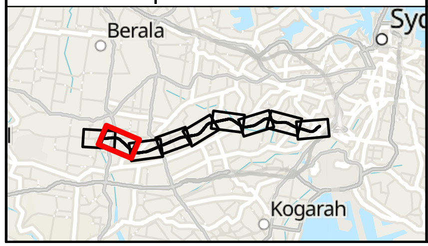
Scale: 1:7,000 at A4

0 250 500 Metres

GDA 1994 MGA Zone 56
Map Export Date: 30/07/2021

Basemap (Location Map) : ESRI World Topographic Map, Basemap (Map) SIX Maps Public NSW Imagery (Map Server)

Location Map



Legend

- Sydney Trains
- Metro - Type 1
- Metro - Ballast
- Goods - Ballast

Building Use

Active Rec	Garage	Residential
Child Care	Industrial	Station
Commercial	Library	Worship
Courts	Medical	Mixed Use
Education	Medical (SENS)	Public Hall

Sydney Metro South West Corridor

Building Use

Scale: 1:7,000 at A4

0 250 500 Metres

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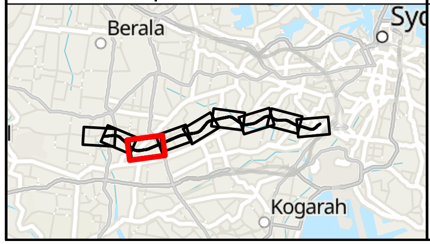
Location Map



Legend

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- Metro - Type 1
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Building Use

Active Rec	Garage	Residential
Child Care	Industrial	Station
Commercial	Library	Worship
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Building Use

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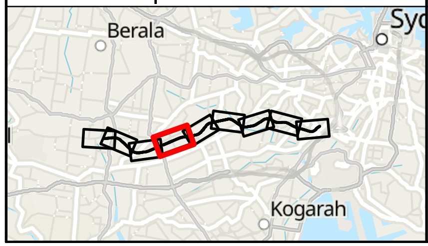

Legend

- Sydney Trains
- Metro - Type 1
- Metro - Ballast
- Goods - Ballast

Building Use

- Active Rec
- Child Care
- Commercial
- Courts
- Education
- Garage
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- Medical
- Medical (SENS)
- Residential
- Station
- Worship
- Mixed Use
- Public Hall

Sydney Metro South West Corridor

Building Use

Scale: 1:7,000 at A4

0 250 500 Metres

GDA 1994 MGA Zone 56

Map Export Date: 30/07/2021

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Location Map

Legend

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- Worship
- Mixed Use
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Sydney Metro South West Corridor

Building Use

Scale: 1:7,000 at A4

0 250 500 Metres

GDA 1994 MGA Zone 56

Map Export Date: 30/07/2021

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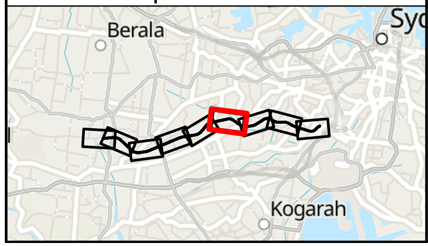
Location Map



Legend

- Sydney Trains
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- Goods - Ballast

Building Use

Active Rec	Garage	Residential
Child Care	Industrial	Station
Commercial	Library	Worship
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Sydney Metro South West Corridor

Building Use

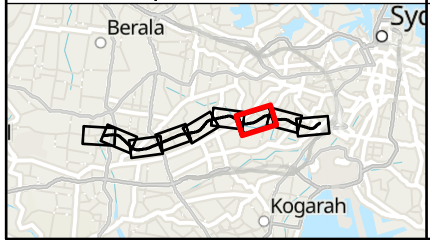
Scale: 1:7,000 at A4

0 250 500 Metres

GDA 1994 MGA Zone 56
Map Export Date: 30/07/2021

Basemap (Location Map) : ESRI World Topographic Map, Basemap (Map) SIX Maps Public NSW Imagery (Map Server)

Location Map



Legend

- Sydney Trains
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- Metro - Ballast
- Goods - Ballast

Building Use

Active Rec	Garage	Residential
Child Care	Industrial	Station
Commercial	Library	Worship
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Sydney Metro South West Corridor

Building Use

Scale: 1:7,000 at A4

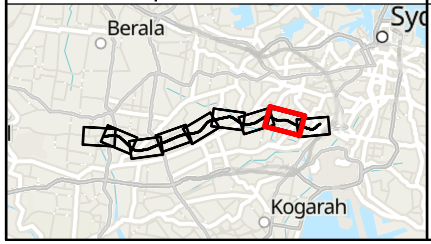
0 250 500 Metres

GDA 1994 MGA Zone 56

Map Export Date: 30/07/2021

Basemap (Location Map) : ESRI World Topographic Map, Basemap (Map) SIX Maps Public NSW Imagery (Map Server)

Location Map



Legend

- Sydney Trains
- Metro - Type 1
- Metro - Ballast
- Goods - Ballast

Building Use

Active Rec	Garage	Residential
Child Care	Industrial	Station
Commercial	Library	Worship
Courts	Medical	Mixed Use
Education	Medical (SENS)	Public Hall

Sydney Metro South West Corridor

Building Use

NSW GOVERNMENT | sydney METRO

Scale: 1:7,000 at A4

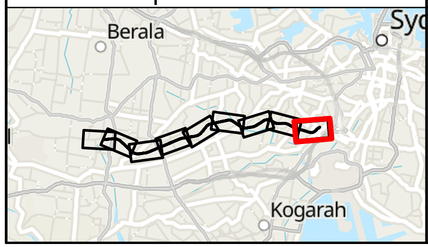
0 250 500 Metres

GDA 1994 MGA Zone 56

Map Export Date: 30/07/2021

Basemap (Location Map) : ESRI World Topographic Map, Basemap (Map) SIX Maps Public NSW Imagery (Map Server)

Location Map



Legend

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- Metro - Ballast
- Goods - Ballast

Building Use

- Active Rec
- Child Care
- Commercial
- Courts
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- Library
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- Medical (SENS)
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- Worship
- Mixed Use
- Public Hall

Sydney Metro South West Corridor

Building Use

NSW GOVERNMENT | sydney METRO

Scale: 1:7,000 at A4

0 250 500 Metres

GDA 1994 MGA Zone 56
Map Export Date: 30/07/2021

Basemap (Location Map) : ESRI World Topographic Map, Basemap (Map) SIX Maps Public NSW Imagery (Map Server)

Appendix C – Predicted airborne noise levels

Data to be provided upon request

Appendix D – Predicted ground-borne noise levels

Data to be provided upon request

Appendix E – Predicted ground-borne vibration levels

Data to be provided upon request

Appendix F – Sydney Metro Trains Source Noise Level Measurements

Appendix F – Sydney Metro Trains - Source Noise Levels

Noise surveys and a review of the noise measurement data of the Alstom Metropolis Trains (Metro train) operating on the Sydney Metro North West Rail Link (NWRL) have been conducted to determine the Metro trains source noise levels for use in the airborne noise modelling of the Sydney Metro City & Southwest Project.

Noise measurements have been conducted by Alstom, METRON and Acoustic Studio along the at-grade straight section of the ballasted rail track between Rouse Hill Station and Tallawong Station, as indicated blue in Figure 20.

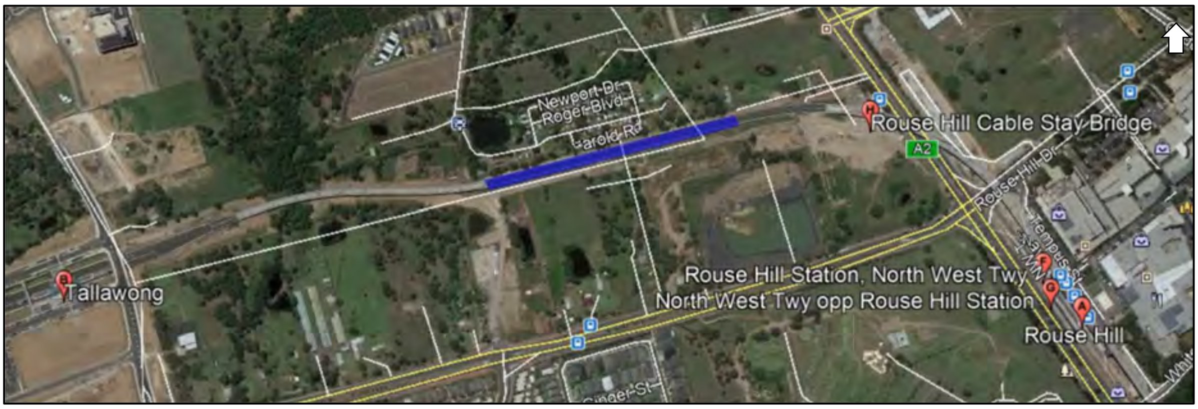


Figure 20: Location of noise measurements.

Alstom Noise Measurements

Compliance noise measurements of the Metro trains operating on the NWRL were conducted by Alstom in December 2018 with the results summarised in the *NORTHWEST RAPID TRANSIT - Test Report For SJV-TP-38 Train Level Group 05.02 – Dynamic Noise Type Test* (Compliance Report, NWRLOTS-NRT-SWD-PT-CTR-133038-A, dated 16 Mar 2019).

The noise measurements were performed with the trains running at 70km/h, 80km/h and 90km/h. The measured noise levels, L_{pAFmax}, at 7.5m from the track centre line and 1.5m above head of the rail, are summarised in Table 16. The measurement location was away from any significant reflecting surfaces that could have influenced the measurements.

As part of the compliance test, rail roughness and track decay rates were also measured. The results provided in the Compliance Report are reproduced below (refer to Figure 21):

- No adjustment was made for rail roughness (wheel roughness was not measured). Interestingly the left-hand (LH) and right-hand (RH) rails of the down-track (DT) in the range of wavelengths affecting wheel/rail noise (6.3mm to 25mm, as will be seen below) are quite different.
- It is considered unusual that the track decay rates are so low (particularly in the vertical direction) for a stiff base plate on a ballasted sleeper. If these results are accurate it is likely to contribute to higher low frequency noise levels than would otherwise be expected on ballasted surface track.

6.5.1 Rail roughness

Rail roughness has been measured on track section where exterior noise was measured as per EN 15610:2011 at free field environment condition. Below figure shows the comparison of measured roughness of both the rails and ISO 3381:2011 requirements. Measured roughness of LH rail is not meeting the ISO 3381:2011 requirements at higher wavelengths and influences exterior noise levels.

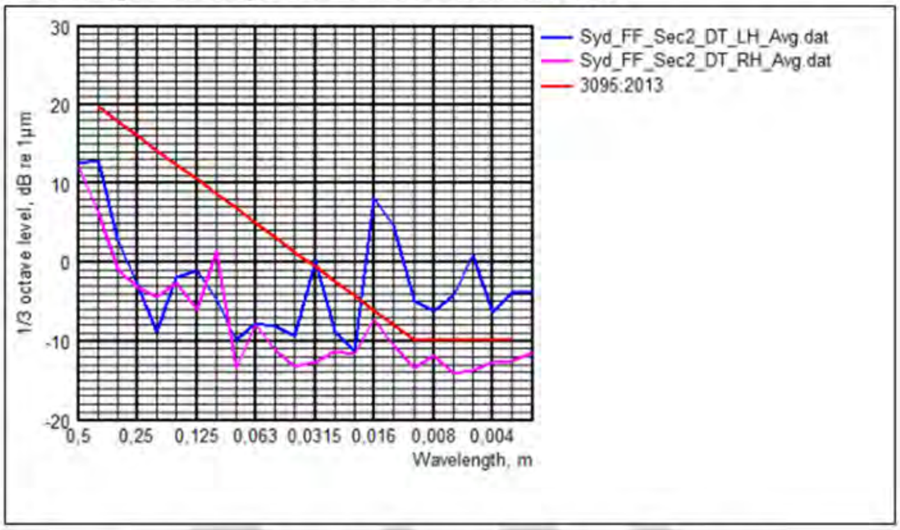


Figure 11: Free-field At-Grade ballasted track rail roughness levels

6.5.2 Track decay rate

The dynamic properties of the track, track decay rate has been measured according to EN 15461:2008 to evaluate if lower limit of track decay rates in ISO 3095:2013 has been met. Track decay rate measurements have been measured on test track section where exterior noise measured at free field environment condition.

Measured track decay rates in vertical and lateral is not meeting ISO 3095:2013 and this influence the exterior noise levels.

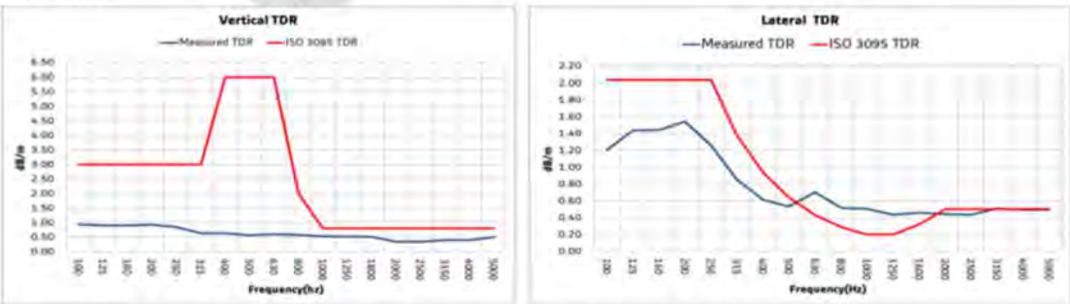


Figure 12: Free-Field track vertical and lateral TDR levels

Figure 21 Excerpts from the NWRL compliance report

Table 16: Measured noise levels (at 7.5m from track centreline and 1.5m above head of the rail).

Measurement	Measured Noise Levels (LpAFmax), dB(A)		
	70 km/h	80 km/h	90km/h
Run 1	79.5	81.2	82.5
Run 2	80.1	81.3	82.9
Run 3	80.0	81.2	82.9

The measured noise levels with the trains running at 90km/h are shown in Figure 22.

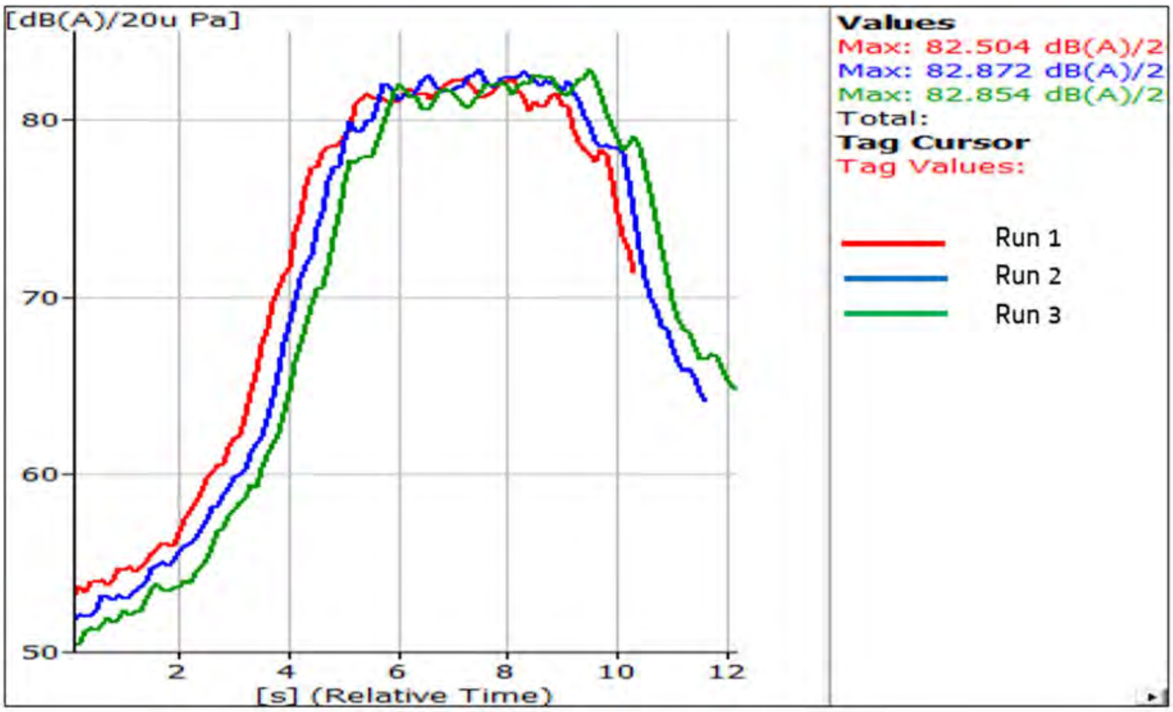


Figure 22: Measured noise levels while train running at 90km/h.

The measured noise levels in Table 16 have been used to derive the average extrapolation factor to calculate the noise levels at other train speeds. The derived average extrapolation factor is 26.5 (as provided in the Compliance Report). The measured average noise level with the trains running at 90km/h (i.e. 82.8 dB(A)) has been to derived noise levels at other train speeds.

For comparison with other measurements, the Alstom measurements have been converted to noise levels referenced at 15m and 80km/h train speed. The conversion steps are shown in Table 17.

The resultant noise levels (referenced at 15m and 80km/h train speed) are as follows:

- 83 dB(A) L_{AE}
- 80 dB(A) $L_{AFmax,95\%}$

Table 17: Alstom measurement conversions, referenced at 15m from track centreline and 80 km/h.

Step	Measurement Distance (m)	Train Speed (km/h)	Train Length (m)	Pass-by Time, T_p (t)	Noise Levels, dB(A)			
					L_{pAFmax}	$L_{pAFmax,95\%}$	L_{pAeq}	L_{AE}
1	7.5	90	132.5	5.3	82.8	85.8	80.8	88.8
2	7.5	80	132.5	6.0	81.4	84.4	79.4	87.2
3	15	80	132.5	6.0	77.4	80.4	75.4	83.1

Notes:

1. $L_{pAFmax,95\%} = L_{pAFmax} + 3$ dB
2. $L_{pAeq} = L_{pAFmax} - 2$ dB
3. $L_{pAFmax,15m} = L_{pAFmax,7.5m} + 13.5 \log (7.5/15)$
4. $L_{pAFmax,90km/h} = L_{pAFmax,80km/h} + 26.5 \log (80/90)$
5. $L_{AE} = L_{pAeq} + 10 \log (T_p)$

METRON Noise Measurements

METRON conducted noise measurements of the existing Metro trains operating on the NWRL on 12 March 2020, at a central position along the extent of track shown blue on Figure 20. The works included measurement of rail surface roughness using a CAT (Corrugation Analysis Trolley as per "EN 15610:2009: "*Railway applications - Noise emission - Rail roughness measurement related to rolling noise generation*") as well as combined wheel and rail roughness and track decay rate using an accelerometer fixed to the underside of the track (as per CEN/TR 16891:2016 "*Railway applications – Acoustics - Measurement method for combined roughness, track decay rates and transfer functions*").

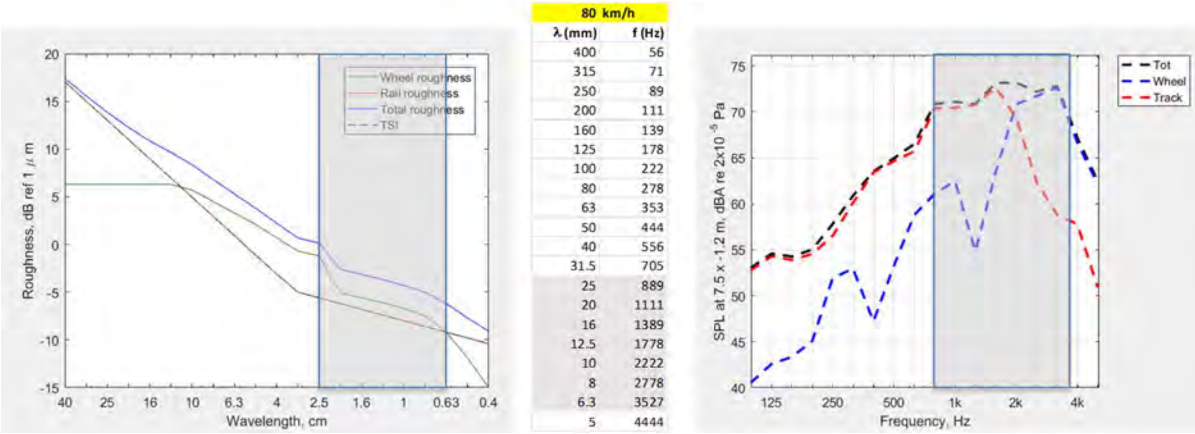
The measurement site was compromised by a retaining wall behind the corridor (acting as a reflection plane) and a concrete edge beam to retain the ballast (also acting as a structure-borne noise source). The measured noise levels varied significantly between train movements on the up and down track, and also from the compliance measurements by Alstom (NWRLOTS-NRT-SWD-PT-CTR-133038-A "*NORTHWEST RAPID TRANSIT - Test Report For SJV-TP-38 Train Level Group 05.02 – Dynamic Noise Type Test*", 16 Mar 2019). A photograph of the measurement site showing the retaining wall behind the corridor and the concrete edge beam is provided as Figure 23.

Figure 23 Image of measurement site.

Given that there were low frequency effects observed in the measurement data associated with train movements on the down track (from the concrete edge beam near to the down track), the measurements of train movements on the down track were removed and only train movements on the up track were considered.

The influence of sound reflections off the retaining wall on the noise measurements has been considered and estimated based on a detailed noise model of the test site using the SoundPlan prediction software. For train movements on the up track, the noise model estimated a noise level increase of 2 dB(A) due to sound reflections off the retaining wall (which is in the order of magnitude that would be expected). The measured noise levels have been adjusted to remove the influence of the retaining wall reflection (i.e. 2 dB(A) subtracted from the measurements).

The influence of track surface roughness on the measured noise levels for the section of track at the test site has been considered. The surface roughness measurements have been reviewed to determine the adjustment factor that should be applied to the measurements to obtain normalised source noise levels for train and rail conditions that are compliant with ISO 3381:2005. The critical region of influence for a train moving at 80km/h are wavelengths between 6.3mm to 25mm with corresponding frequencies between about 900Hz and 3.5kHz. In this region the wheel roughness is likely to exceed the rail roughness, with both the wheel and rail radiating equally contributing to sound generation.



80 km/h	
λ (mm)	f (Hz)
400	56
315	71
250	89
200	111
160	139
125	178
100	222
80	278
63	353
50	444
40	556
31.5	705
25	889
20	1111
16	1389
12.5	1778
10	2222
8	2778
6.3	3527
5	4444

Figure 24 Effects of wheel and rail roughness on wheel/rail noise generation

Measurements of rail surface roughness were carried out in accordance with EN 15610:2019 (using a CAT) and combined wheel and rail roughness in accordance with CEN/TR 16891:2016 (using an accelerometer fixed to the underside of the rail). Measurements were carried out on the left-hand rail of the down track (combined wheel/rail) and both tracks (rail roughness with a CAT) as this rail was closest to the corridor fence for monitoring during train movements and both tracks/rails exhibited the same rail surface roughness when measured using a CAT.

Figure 25 shows a comparison between the measured rail surface roughness at the test site (orange line - *Rail (CAT)*); the measured combined wheel/rail roughness (yellow line - *Surface*); and the ISO 3381:2005 rail surface roughness reference curve (grey line – *ISO 3381*). The shaded area shows the range of critical wavelength/frequencies most relevant to rail/wheel radiated noise.

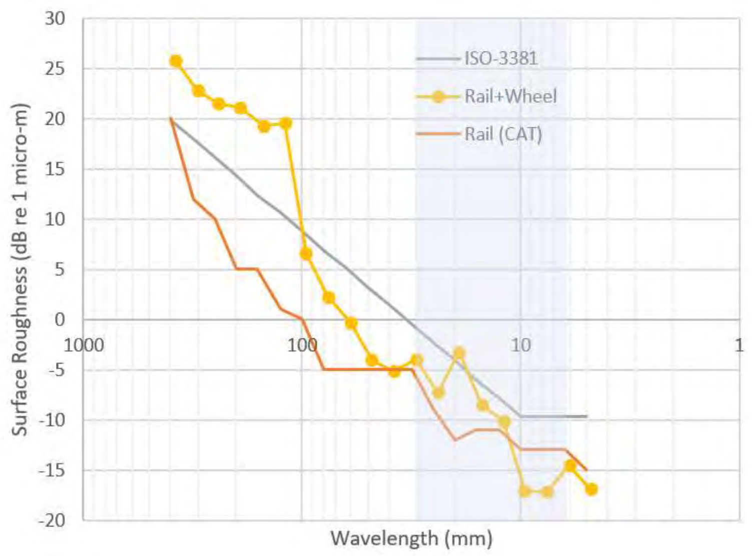


Figure 25 Wheel/Rail roughness measurements and comparison with ISO 3381:2005 reference curve

Based on Figure 25, an adjustment of + 2dB(A) to the measured noise levels is considered appropriate, to account for the smooth track surface conditions at the test site (i.e. the measured track surface roughness lower than the ISO 3381:2005 reference curve at the critical frequencies).

The measured noise levels, reference at 15m from the track centreline and 80km/h train speed, and the adjustments applied to them for reflections and track surface roughness conditions are summarised in Table 18.

Table 18: METRON measurements (referenced at 15m and 80 km/h train speed) and the applied adjustments.

Step	Description	Noise Levels, dB(A)	
		$L_{pAFmax,95\%}$	L_{AE}
1	Measured noise levels from UP track	81.7	85.3
2	Measurements adjusted for retaining wall reflections, - 2 dB(A)	79.7	83.3
3	Measurements adjusted for track surface roughness, + 2 dB(A)	81.7	85.3

The resultant noise levels (referenced at 15m and 80km/h train speed) are as follows:

- 85 dB(A) L_{AE}
- 82 dB(A) $L_{AFmax,95\%}$

Acoustic Studio Noise Measurements

Acoustic Studio have conducted noise measurements of Metro train movements on 7 April 2020, at the same measurement position that METRON conducted their noise measurements.

Like the METRON noise measurements, low frequency effects were observed in the measurement data associated with train movements on the down track, and therefore only the noise measurements associated with train movements on the up track were considered.

Adjustments for reflections off the retaining wall and track surface roughness were also considered for the measurements, as discussed above for the METRON measurements. The measured noise levels from the up track train movements, referenced at 15m from the track centreline and 80km/h train speed, and adjusted for the retaining wall reflections and track surface roughness conditions are summarised in Table 19.

Table 19: Acoustic Studio measurements (referenced at 15m and 80 km/h train speed) and the applied adjustments.

Step	Description	Noise Levels, dB(A)	
		$L_{pAFmax,95\%}$	L_{AE}
1	Measured noise levels from UP track	81.9	85.1
2	Measurements adjusted for retaining wall reflections, - 2 dB(A)	79.9	83.1
3	Measurements adjusted for track surface roughness, + 2 dB(A)	81.9	85.1

The resultant noise levels (referenced at 15m and 80km/h train speed) are as follows:

- 85 dB(A) L_{AE}
- 82 dB(A) $L_{AFmax,95\%}$

Summary of Results

Table 20 summarises the Metro Train source noise levels, referenced at 15m and 80km/h train speed, which have been derived from three different dataset measured from the existing NWRL operation.

Table 20: Metro Trains source noise levels.

Data Source	$L_{Amax,95\%}$	L_{AE}
Manufacturer test data	80 dB(A)	83 dB(A)
METRON measurements	82 dB(A)	85 dB(A)
Acoustic Studio measurements	82 dB(A)	85 dB(A)

Based on Table 20, source noise levels of 85 dB(A) L_{AE} and 82 dB(A) $L_{AFmax,95\%}$ are considered appropriate for the noise modelling works. The source noise levels are consistent with those for the Sydney Trains rolling stock as measured and assessed during the Bankstown survey. However it is noted that they are 3 dB(A) less than the level considered in the Project's EIS noise modelling, which conservatively assumed noise source levels associated with the double-deck C,K,S sets (from the NSW Rail Noise Database).

Critical to achieving these source noise levels is the wheel/rail maintenance strategy which defines condition monitoring requirements for the wheels and rails.