Appendix J – Operational Noise and Vibration Assessment (2022)

Victoria Park – Canning
Level Crossing Removal Programme

OPERATIONAL NOISE AND VIBRATION DESIGN REPORT – Interim Detailed Design DA1

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Approval			
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Executive Summary (Based on interim IDD information)

An operational noise and vibration assessment has been undertaken for the Victoria Park - Canning Level Crossing Removal (LXR) Project as part of METRONET. The purpose of which is to indicate the extent of mitigation required to achieve compliance with the Scope of Work and Technical Criteria (SWTC).

This report outlines the design response to the assessment of operational rail noise and vibration modelling during the Reference Design stage of the project.

The scope of the LXR project works, indicative passenger rail alignment and station locations are illustrated in Figure 1.

The assessment detailed herein has demonstrated that:

Predicted Rail Noise Levels

In the unmitigated scenario, predicted future rail noise levels exceed the:

- Daytime design noise level at a total of 28 receiver locations.
- Night-time design noise level at a total of 13 receiver locations.
- Maximum noise criterion at a total of 5 receiver locations.

Therefore, the following acoustic barriers (noise walls) are proposed and as shown in Appendix G which has been updated for Development Application 1 submission and is now based on the interim IDD information which provides a more detailed design and digital ground model including design developments with updated grades and embankment height, changes have been remodelled, which resulted in a slightly reduced noise level in the northern end. Updates to the extent of retaining wall and areas where there is a detrainment wall upstand forming part of the retaining wall that provides acoustic benefits have also been fully integrated in the model which results in low (~1.5m) noise walls in location where there was previously indicated to be a detrainment upstand on a retaining wall.

- NWW-1 is 1.5 metres high (above rail line) and approximately 88 metres long. It runs adjacent to the railway line and Mytilene Drive, Victoria Park, north of Miller Street.
- NWE-1 is 1.5 metres high (above rail line) and approximately 247 metres long. It runs adjacent to the railway line and Rutland Avenue, Lathlain, south of Miller Street.
- NWW-2 is 1.5 metres high (above rail line) and approximately 330 metres long. It runs adjacent to the railway line and Sevenoaks Street, Cannington, from Bent Street to Crawford Street.
- NWE-2 ranges from 1.5 metres high to 2.0 metres high (above rail line) and is approximately 685 metres long, with the 1.5-metre high section being 628 metres long and the 2.0-metre high section being 57 metres long. It runs adjacent to the railway line and Railway Parade, East Cannington, from Gerard Street to Albion Street.

The discussion in the report focuses on an analysis of $L_{Aeq,day}$ noise levels as this has been identified as being the controlling noise criterion for this project. Results for the $L_{Aeq,night}$ and L_{Amax} descriptors have also been included.

In the mitigated scenario, predicted rail noise levels achieve the $L_{Aeq,day}$, $L_{Aeq,night}$ and L_{Amax} at all receivers.

This report only identifies the noise wall heights and extents which are required to achieve compliance with the rail noise criteria. Other project considerations are not addressed or modelled for the purposes of this report. These include:

- The potential retention of existing acoustic barriers.
- Security requirements such as the stipulation of minimum 2.4m height.
- Community considerations such as extending the acoustic barriers to provide visual screening of the rail to residences for which compliance with the criteria does not require noise walls.

Vibration

The vibration criteria for the project from the SWTC are presented in Table 19. The sensitive receptors currently closest to the alignment are primarily single storey residential. These criteria also apply to future buildings which have Development Approval at the time of the procurement contract. Future buildings may include residential buildings, hotels and overnight accommodation along or adjacent to the route.

A semi-analytical model will be used in the next phase of design to predict the differences in vibration and regenerated noise due to the suggested track-based mitigation options compared to the unmitigated ballasted (surface sections of the alignment) and direct fix slab (viaduct sections) tracks:

Corrections will be applied to the vibration levels to account for train speed; the transfer of vibration from the ground into a building; the amplification of vibration on a suspended floor; and the radiation of sound from the vibrating building.

Noise from fixed infrastructure

Fixed infrastructure associated with the passenger rail which are not part of the stations package will consist of the following:

- Power transformers
- Track switching equipment rooms (TSER)
- Communications equipment rooms (CER)
- Overhead line equipment (OLE) infrastructure.

Noise due to all fixed infrastructure will be assessed during the next phase of design against the Western Australia *Environmental Protection (Noise) Regulations* 1997 (EPNR).

1 Introduction

1.1 Project overview

The Armadale Line Upgrade Alliance (ALUA) has been engaged to deliver the Victoria Park - Canning Level Crossing Removal (LXR) Project as part of METRONET on behalf of the Australian and Western Australian Governments.

The LXR Project involves modification to seven (7) kilometres of existing tracks on the existing Armadale Line to remove five (5) level crossings by constructing three new elevated viaduct structures. The viaduct structures are:

- Viaduct 1 (the Mint Street-Oats Street Viaduct) – Mint Street to Oats Street.
- Viaduct 2 (the Welshpool Viaduct) – Existing and future Welshpool Road interchanges.
- Viaduct 3 (the Wharf Street Viaduct) – Hamilton Street to Cannington Station.

The viaducts are interlinked with ballasted track at-grade in between. The Victoria Park - Canning Level Removal Project will create Perth's first major elevated rail designed to improve public transport safety, create new and versatile public spaces for the community and reduce traffic congestion around Perth's inner suburbs.

1.2 Project Location

The project is located southeast of Perth Central Business District (CBD) and spreads across the Local Government Authority (LGA) boundaries of City of Victoria Park and City of Canning. The extent of the LXR project is shown in Figure 1.

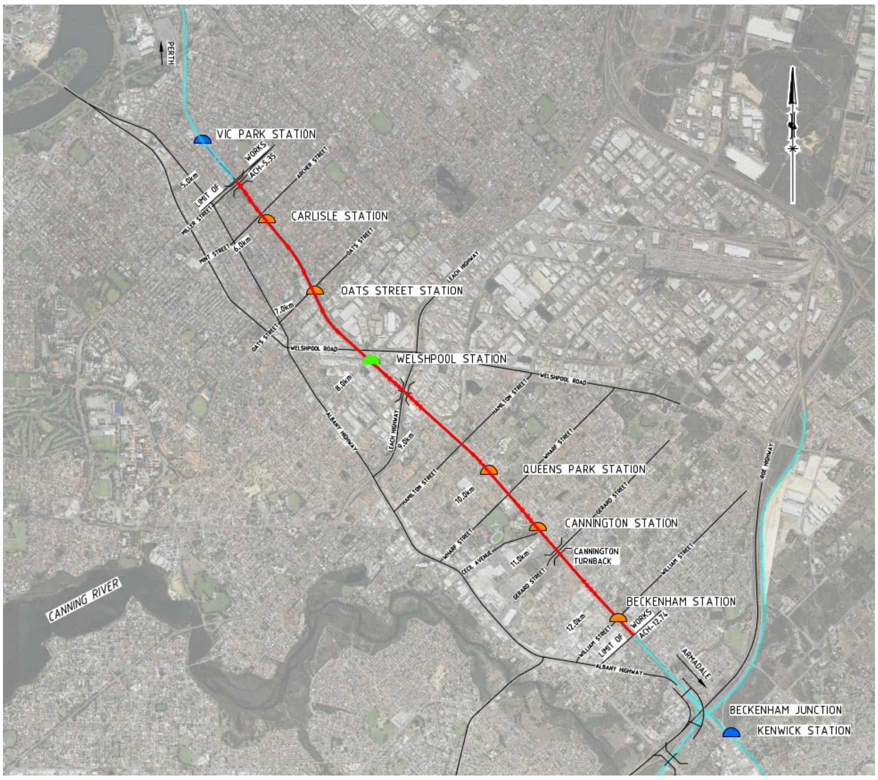

FIGURE 1 LXR OVERVIEW

1.3 Project scope details and boundaries

The overall scope of work for the LXR project is defined within the *Victoria Park-Canning Level Crossing Removal Scope of Work and Technical Criteria*. The project involves the removal of level crossings on the inner section of the Armadale Line, which has been identified as the priority across the Perth metropolitan passenger rail network. The level crossings proposed for removal include:

- Removal of the Mint Street/Archer Street, Oats Street and Welshpool Road level crossings.
- Elevation of the Carlisle and Oats Street stations.
- Future proofing of Welshpool Station.
- Removal of the Wharf Street and Hamilton Street level crossings.
- Elevation of the Queens Park and Cannington stations.
- Construction of a new double-ended centre line turnback between Cannington Station and William Street.

1.4 Audience and Applicability

This report outlines the acoustic design development of the LXR to the stakeholders. The report is intended to supplement an understanding of the design development and how the proposed acoustic solutions were developed for the rail alignment to the respective delivery managers, project managers and engineers.

1.5 Document Applicability

The report is intended to provide information to the Office of Major Transport Infrastructure Delivery (OMTID) and the Public Transport Authority (PTA) to demonstrate that noise and vibration emission from the operational rail is compliant with design standards, specifications, and the SWTC. It highlights some design issues identified in the Reference Design (RD) and which require further assessment in the next design stage.

1.6 Document Exclusions

This report encompasses the acoustic design for the passenger rail and associated infrastructure only. The acoustic assessment for stations is provided in separate reports. The acoustic assessment of road noise and vibration as part of the LXR project is the focus of a separate study.

This report represents the acoustic assessment for the Reference Design phase of the project.

The following items are excluded from this design document, which will be addressed in separate packages:

- Enabling works (Temporary works).
- Construction methodology.
- Construction – Inspection and Test Plans (ITP).
- Commissioning.

1.7 Relevant Design Documents and Packages

This design document shall be read in conjunction with the following documents summarised in Table 1.

TABLE 1 RELEVANT DESIGN DOCUMENTS

DOCUMENT NUMBER	DOCUMENT NAME
	Engineering Management Plan
	Safety Management Plan
	Digital Engineering Management Plan

DOCUMENT NUMBER	DOCUMENT NAME
LXR-MNO-SLR-NV-RPT-0001	Inner Armadale Line Level Crossing Removal Project – Operational Noise and Vibration Assessment

The following design packages interfaces with the acoustic design are summarised in Table 2.

TABLE 2 RELEVANT DESIGN PACKAGES

IDENTIFICATION ID	DESIGN PACKAGE NAME
AB	Abutment
BD	Station Buildings
NW	Noise Walls
RS	Rail Systems
RW	Retaining Walls
TR	Track
UT	Utilities

1.8 Interface with existing non-compliances

None known at this Reference Design project phase.

1.9 Related / interfacing projects

The project interfaces with the following projects:

- Leach Highway and Welshpool Road Interchange (Leach Highway Alliance).
- Duplication and modification of the existing Leach Highway bridge which overpasses the project alignment.
- Victoria Park Station Platform Extension.
- Thornlie Cockburn Link (NEWest Alliance):
  - The Thornlie Cockburn Link (TCL) is currently duplicating the Thornlie Line from Beckenham Junction to Thornlie Station, as well as extending the line to Cockburn Station on the Mandurah Line.
- Byford Rail Extension (MetCONNX Alliance):
  - The Byford Rail Extension is currently extending the Armadale Line 8 kilometres southwards to provide rail services to the Byford area.

1.10 Abbreviations and Acronyms

ABBREVIATION	DESCRIPTION
AD	Alliance Development
AS	Australian Standard
AS / NZS	Australian / New Zealand Standard
CER	Communications Equipment Room
CIVET	Change in Vibration Emitted by Track
CPTED	Crime Prevention through environmental design
DA	Development Application
DJV	Design Joint Venture
DRFI	Design Request for Information
DWER	Department of Water and Environmental Regulation
EPA	Environmental Protection Authority
EPNR	Western Australia *Environmental Protection (Noise) Regulations* 1997

ABBREVIATION	DESCRIPTION
GBN	Ground-borne noise
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
KnR	Kiss-and-Ride
MOTIV	Modelling of Train Induced Vibration
MRWA	Main Roads Western Australia
NATA	National Association of Testing Authorities
NVMP	Noise and Vibration Management Plan
OLE	Overhead Line Equipment
ONVDR	Operational noise and vibration report
OSHR	Western Australia *Occupational Safety and Health Regulations 1996*
PA	Public Address
PER	Power Equipment Room
PnR	Park-and-Ride
PShP	Principal Shared Path
PTA	Public Transport Authority of Western Australia
RING	NSW *Railway Infrastructure Noise Guideline*
SER	Signal Equipment Room
SiD	Safety In Design
SLR	SLR Consulting Australia
SPP 5.4	State Planning Policy 5.4 *Road and Rail Transport Noise and Freight Considerations in Land Use Planning*
SWTC	Scope of Work and Technical Criteria
UBM	Under ballast mat
WAPC	Western Australian Planning Commission
WPC	Western Power Corporation

1.11 Terminologies and Definitions

TERM	MEANING
'A' weighted	Frequency filter applied to measured noise levels to represent how humans hear sounds.
Ambient sound	The all-encompassing sound at a point being a composite of sounds from near and far.
Background sound	The ambient sound in the absence of the sound under investigation.
'C' weighted	Frequency filter which does not discriminate against low frequencies and measures uniformly over the frequency range of 30 to 10,000 Hz
dB	The decibel (dB) is a logarithmic unit of measurement that is commonly used to express sound pressure level. An increase of 3 dB corresponds to an approximate doubling of sound power. When applied to sound, an increase of 10 dB corresponds approximately to a perceived doubling of loudness; typically 0 dB is the threshold of hearing and 120 dB is the threshold of pain.
dB(A)	'A' weighted overall sound pressure level.
Sound power level	The total sound emitted by a source
Sound pressure level	The amount of sound at a specified point
Decibel [dB]	The measurement unit of sound

<table>
<tr><th>TERM</th><th colspan="2">MEANING</th></tr>
<tr><td>A Weighted decibels [dB(A)]</td><td colspan="2">An A weighting filter is applied to measured noise levels to represent how humans hear sounds. The A-weighting filter emphasises frequencies in the speech range (between 1kHz and 4 kHz) which the human ear is most sensitive to and places less emphasis on low frequencies at which the human ear is not so sensitive. When an overall sound level is A-weighted it is expressed in units of dB(A).</td></tr>
<tr><td rowspan="2">Decibel scale</td><td colspan="2">The decibel scale is logarithmic to produce a better representation of the response of the human ear. A 3 dB increase in the sound pressure level corresponds to a doubling in the sound energy. A 10 dB increase in the sound pressure level corresponds to a perceived doubling in volume. Examples of decibel levels of common sounds are as follows:</td></tr>
<tr><td>0 dB(A)
30 dB(A)
40 dB(A)
50 dB(A)
70 dB(A)
80 dB(A)
90 dB(A)
100 dB(A)
110 dB(A)
115 dB(A)
120 dB(A)</td><td>Threshold of human hearing
A quiet country park
Whisper in a library
Open office space
Inside a car on a freeway
Outboard motor
Heavy vehicle pass-by
Jackhammer/Subway train
Rock Concert
Limit of noise permitted in industry
747 take off at 250 metres</td></tr>
<tr><td>Frequency [f]</td><td colspan="2">The repetition rate of the cycle measured in Hertz (Hz). The frequency corresponds to the pitch of the sound. A high frequency corresponds to a high-pitched sound and a low frequency to a low-pitched sound.</td></tr>
<tr><td>Equivalent continuous sound level [L_{eq}]</td><td colspan="2">The constant sound level which, when occurring over the same period, would result in the receiver experiencing the same amount of sound energy.</td></tr>
<tr><td>L_{Aeq}</td><td colspan="2">The A-weighted equivalent continuous sound level.</td></tr>
<tr><td>L_{max}</td><td colspan="2">The maximum sound pressure level measured over the measurement / assessment period.</td></tr>
<tr><td>L_{10}</td><td colspan="2">The sound pressure level exceeded for 10% of the measurement / assessment period. i.e. for 10% of the measurement / assessment period it was louder than the L_{10} value.</td></tr>
<tr><td>L_{90}</td><td colspan="2">The sound pressure level exceeded for 90% of the measurement / assessment period i.e. for 90% of the measurement period it was louder than the L_{90} value.</td></tr>
<tr><td>Ambient noise</td><td colspan="2">The all-encompassing noise at a point composed of sound from all sources near and far.</td></tr>
<tr><td>Background noise</td><td colspan="2">The underlying level of noise present in the ambient noise when extraneous noise (such as transient traffic and dogs barking) is removed. The L_{90} sound pressure level is generally used to quantify background noise.</td></tr>
<tr><td>R_W</td><td colspan="2">The weighted sound reduction performance of a construction material or system. A single number rating method which is used to compare the sound insulating properties of different materials. Note that the R_W rating is based on laboratory test data and is therefore different to the expected in-situ performance.</td></tr>
<tr><td>Day</td><td colspan="2">The period from 0600 to 2200 h (with respect to road and rail noise).</td></tr>
<tr><td>Night</td><td colspan="2">The period from 2200 to 0600 h (with respect to road and rail noise).</td></tr>
<tr><td>N/mm^3</td><td colspan="2">Newtons per cubic millimetre</td></tr>
</table>

1.12 Scope of this report

This report comprises the acoustic deliverable for the operational passenger rail for the Reference Design phase. The contents of the report will serve to:

- Inform the civil design discipline as to appropriate acoustic barrier locations, heights and extents to achieve the required noise emission requirements.
- Inform the utilities discipline as to vibration mitigation measures to achieve the required vibration criteria for buried infrastructure.
- Inform the traffic and civil design disciplines as to noise mitigation requirements to achieve the acoustic standards for roads.
- Inform the project as to controls required to achieve appropriate noise emission from fixed infrastructure to adjacent noise-sensitive premises.

2 Details of Acoustic Personnel

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Author	Details		
Name	Rachel Foster		
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	Bassett Consulting Engineers (Adelaide, South Australia)	Acoustic Engineer	2000 - 2004

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	R. Foster, 'Assessment and regulation of environmental noise – an Australian and New Zealand comparison', Australasian Acoustical Societies' Conference (Christchurch 2006)		
	R. Foster and P. Teague, 'Acoustic assessment of wind farms – A practical perspective', Australasian Acoustical Societies' Conference (Christchurch 2006)		
	R. Foster 'Sounds Good – New Acoustic Standards', Local Government Magazine, New Zealand (December 2008)		

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	AEA Technology Rail/DeltaRail	Consultant	1996 - 2010
	British Rail Research/BRR	Senior Scientific Officer	1989 - 1996
Publications and Technical Papers	Track maintenance from a noise perspective in the context of European legislation, standards and research. Proceedings of Railway Engineering, 2005		
	The influence of vehicle and track condition on the generation of railway ground borne vibration. Proceedings of 7th International Congress on Sound and Vibration, 2000, with BP Temple		
	Practical experience of a model for ground borne noise and vibration from railways. Proceedings of the third European Conference on Noise Control, EuroNoise, 1998, with C Jones		
	Prediction of ground vibration from freight trains. Journal of Sound and Vibration, Volume 193, Number 1, 1996, with C Jones.		

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	AECOM	Consulting and Technology Practice Director, Australia & New Zealand	2018 – Present
	AECOM	Acoustics Practice Leader, Australia & New Zealand	2018 – 2021
	AECOM (formerly Bassett Consulting Engineers)	Senior Acoustic Engineer	2005 – 2007
	Vipac Engineers and Scientists	Acoustic Engineer	1999 – 2005

3 Design Development

3.1 Key Changes

3.1.1 Alliance Design (AD) to Reference Design (RD)

The project Reference Design (RD) has been developed based on the Alliance Design developed previously. The project design development from the AD to the RD is summarised below:

- The temporary tracks alignment has been removed from the project scope, and the reference design.
- Removal of Beckenham Station, Beckenham viaduct and its associated requirements from the project scope.
- A concept quadruplication future track scenario has been produced to the eastern side of the rail corridor:
    - Additional land requirements will be required adjacent to the Queens Park – Cannington Viaduct.
- Revised future Welshpool Station location north of Leach Highway:
    - Future Welshpool Station vertical grade changed from 1.25% (maximum allowable platform grade on embankment) in AD to flat grade in Reference Design.
    - Station box shifted further south closer to the Leach Highway.
- Revised alignment at Welshpool Road locality which include:
    - Reduced clearance to Welshpool Road.
    - Increased south abutment vertical grade to 2.0% compensated.
    - Space provisioning of Future Welshpool Station at-grade.
    - Removed of approach reverse curves.
- A Train Speed Simulation (OPSIM) was undertaken based on the AD phase design alignment to provide expected operating speed for a 'start-stopping' scenario.
- Buffer stop sliding distance has been undertaken for the Cannington Turnback and review against manufacturer's calculations.
- A preliminary ballasted track structure verification calculation has been undertaken
- A preliminary slab track structure design has been undertaken
- A preliminary run-on slab design has been undertaken
- General alignment has been revised as following:
    - Vertical alignment has been reassessed to account for viaduct soffit 'drop' through elevated stations.
    - Station grades have been adjusted based on revised vertical levels and drainage requirements.
    - Transition slabs are now SWTC compliant and are located on tangent tracks instead of previously non-compliant SWTC compliant horizontal curves.
- Carlisle Station has been moved 20 m away from the east kerb of Mint Street. In addition, the clearance to the soffit in the station has been reduced from 6 m to 5 m.
- Adjustments to Cannington Turnback which include:
    - Increased Cannington Turnback length to be compliant with overlapping signalling requirement.

   - Revised track centres between the siding and Down Main to fully comply with PTA's requirements for shunters path.
   - Shift of Cannington Turnback towards countryside to accommodate OLE's requirements for mast placement prior to Gerard Street bridge.
- HAZID and Safety in Design workshops have been undertaken and progressed with additional identification and treatment of risks, including Rail, Rail Systems and Rail Enabling Works.

Specific to the acoustic inputs into the Reference Design, design team meetings have been held weekly through the design process, with interfacing disciplines. This acoustic report addresses the design development from AD to RD associated with:

- Rail operations.
- Fixed infrastructure.

3.1.2 Reference Design (RD) to Interim Design (ID)

Due to a more detailed design and digital ground model including design developments with updated grades and embankment heights, the updated changes have been remodelled, which resulted in a slightly reduced noise level in the northern end. Updates to the extent of retaining wall and areas where there is a detrainment wall upstand forming part of the retaining wall that provides acoustic benefits have also been fully integrated in the model which results in low (~1.5m) noise walls in location where there was previously indicated to be a detrainment upstand on a retaining wall. Refer to Appendix G

- NWW-1 is 1.5 metres high (above rail line) and approximately 88 metres long. It runs adjacent to the railway line and Mytilene Drive, Victoria Park, north of Miller Street.
- NWE-1 is 1.5 metres high (above rail line) and approximately 247 metres long. It runs adjacent to the railway line and Rutland Avenue, Lathlain, south of Miller Street.
- NWW-2 is 1.5 metres high (above rail line) and approximately 330 metres long. It runs adjacent to the railway line and Sevenoaks Street, Cannington, from Bent Street to Crawford Street.
- NWE-2 ranges from 1.5 metres high to 2.0 metres high (above rail line) and is approximately 685 metres long, with the 1.5-metre high section being 628 metres long and the 2.0-metre high section being 57 metres long. It runs adjacent to the railway line and Railway Parade, East Cannington, from Gerard Street to Albion Street.

3.1.3 Interim Design (ID) to Final Design (FD)

This section will be developed following the completion of the Interim Design development.

3.1.4 Final Design (FD) to Issued for Construction (IFC)

This section will be developed following the completion of the Final Design development.

3.2 Critical Issues

3.2.1 Reference Design

The following critical issues identified in the Reference Design (RD) stage in relation to acoustics for the rail operations which require further works are:

- The latest supplied corridor boundary (CONCEPT DESIGN LAND PLAN, LXR-MNO-MET-PN-DWG-0001, REV 3.0, Dated 9th February 2022), currently misaligns with various infrastructures along the alignment, with major changes noted as:
   - CH 8700 to CH 9400 – Reduction in corridor width by approximately 1.4m on the western side of the corridor.

  - CH 8800, CH 8960, CH 9100, CH9420 and CH 9580 – Further reductions in the corridor width on the western side of the corridor due to the rail reserve boundary going around the existing LV/ HV power pole footing's retaining walls.
  - CH 9520 to CH 10200 – Increase in land corridor uptake with the largest increase in corridor width at CH 10400 at an additional 8m increase in corridor width. This occurs adjacent to Queens Park station.
  - The boundary changes are noted as significant, with RFI LXRD-ALUA-RFI-00060 submitted seeking clarification and confirmation on the boundary changes. The updated boundary has not been adopted for the RD design.
- Coordination with Main Cable Route (MCR) temporary and future locations.
- Coordination with embankment and retaining wall design disciplines.

3.2.2 Deviations

No non-compliances with standards in relation to acoustics are currently anticipated.

3.2.3 Departures

No departures from the standards in relation to acoustics are currently anticipated.

3.3 Design Assumptions and Limitations

The following assumptions influencing the acoustic assessment for the operational rail line are:

Permanent Way

- Fastening system (Slab Track) – The fastening system on slab track has been assumed to be Pandrol's VIPA FASTCLIP for the Reference Design (RD). However, the fastening system used is subject to construction procurement.
- Fastening system (Ballasted Track) – The fastening system on ballasted track has been assumed to be Pandrol's e-2000 clips for the Reference Design (RD). However, the fastening system used is subject to construction procurement.

Future Requirement

- Future quadruplication of the rail alignment requires for additional land possession.
- Approximately 3m clearance has been allowed for between the future rail alignment to facilitate construction, adjacent to viaducts.
- The future alignment is assumed to be elevated for the same extent as the project case alignment.
- Construction is allowed to be minimum 2.140m from adjacent track centre lines, where general exemption (GE) barriers are installed.

3.4 Outstanding Items

As interdisciplinary packages are developing concurrently, the following outstanding design inputs are required to finalise the track permanent way design.

Project information

- Survey Data (by the Alliance).
- Survey Data/Design Information of Leach Highway bridge duplication and associated upgrade works.
- Outstanding RFI responses in relation to train types, volumes and speed.

Stations and Places

- Confirmation of elevated station heights.

3.5 Design Constraints

The project alignment corridor consists of various existing infrastructures, such as bridges, utilities. Major constraints which influenced the rail alignment design are outlined below:

- Minimum clearance requirements below elevated stations. These include Carlisle Station, Oats Street Station, Queens Park Station and Cannington Station. The minimum clearance requirements are summarised in Table 3.

TABLE 3 MINIMUM CLEARANCES REQUIRED BELOW STATIONS

Station Name	Minimum Clearance Requirement
Carlisle Station	5.00
Oats Street Station	6.00
Queens Park Station	6.00
Cannington Station	4.75

- The rail corridor boundary width is 40m from the northern tie-in location to approximately Ch 10150 (south of Queens Park Station) where the rail corridor boundary is reduced to 30m wide, from approximately Ch 10150 to Ch 10800 (Cannington Station), where the rail corridor returns to a width of 40m. The corridor boundary reduction is noted as future road widening areas as per the PTA-supplied boundary document.

4 Acoustic Design Standards and Codes

Conditions pertaining to future noise and vibration levels for the project are provided by the *Victoria Park-Canning Level Crossing Removal Scope of Work and Technical Criteria* (SWTC) and are summarised in Table 4.

TABLE 4 SCOPE OF WORK AND TECHNICAL CRITERIA (SWTC CONDITIONS)

Number	Condition	Location where addressed
Book 3A 15.2-1	The NOP shall carry out all investigations and detailed analysis to determine existing and future noise and vibration levels for the operation of the Project (rail and road noise). The NOP, in the investigations and detailed analysis, shall apply best practice methods consistent with the standards, codes of practice and requirements contained in this section.	Existing: Sections 5.2, 5.3, 5.4, 7.2.2 Future: Sections 6, 7
Book 3A: 15.2-2	The NOP shall ensure that the design, construction and operation of the Works complies with the noise and vibration criteria contained in Book 3 - Part A Noise and Vibration Section, design targets in accordance with the modelled Operational Noise and Vibration Assessment (LXR-MNO-SLR-NV-RPT-0001) and the State Planning Policy 5.4: Road and Rail Noise (WAPC, 2019).	Design: Section 6.6, Section 7.2.7 Construction: Refer to the Project's CEMP
Book 3A: 15.2-3	The mechanical services shall be designed on the basis of the criteria specified, and the requirements detailed in Book 4, Noise and Vibration.	Section 8
Book 3A: 15.2-4	The NOP shall design, construct, install, Test and Commission a complete, integrated Permanent Way system to meet all the Technical Criteria requirements of Book 4, Noise and Vibration.	Operation: to be confirmed by post-construction commissioning measurements
Book 3A: 15.2-5	The NOP shall design, construct, install, Test and Commission a complete, the LXR system and associated infrastructure to meet all the Technical Criteria requirements of Book 4, Noise and Vibration.	Section 6.9, Section 7.2.7
Book 3A: 15.3-1	The PTA has prepared a Preliminary Assessment, Operational Noise and Vibration Assessment (LXR-MNO-SLR-NV-RPT-0001).	Note
Book 3A: 15.3-2	The NOP shall undertake a noise and vibration impact assessment for the Project that considers both the current sensitive receivers and future sensitive receivers as identified within approved planning documents as part of development the reference design.	This ONVDR report.
Book 3A: 15.3-3	The NOP shall undertake a noise and vibration impact assessment for the Project as part of developing the reference design.	This ONVDR report

Number	Condition	Location where addressed
Book 3A: 15.3-4	The NOP shall undertake a noise and vibration impact assessment at each subsequent design milestone within the Detailed Design.	OVNDR reports to be issued at Interim Design (ID), Final Design (FD) and Issued for Construction (IFC)
Book 3A: 15.3-5	The NOP shall provide the noise and vibration impact assessment for PTA's review and comment at each stage.	
Book 3A: 15.4-1	The NOP shall submit an Operational Noise and Vibration Design Report (ONDVR) at each stage of the design process for PTA's review and comment.	This ONVDR OVNDR reports to be issued at Interim Design (ID), Final Design (FD) and Issued for Construction (IFC)
Book 3A: 15.4-2	The NOP shall have the ONVDR Independently Verified by the Independent Design Verifier and Validator at each design stage.	Appendix E
Book 3A 15.5-1	The NOP shall carry out operational noise and vibration measurement compliance testing in accordance with Book 3 - Part B Noise and Vibration section. Noise and vibration monitoring shall be undertaken by a suitably qualified person within three months of the opening of the proposal. In addition, noise and vibration monitoring should be undertaken by a suitably qualified person again after 18 months of the opening of the proposal.	Operation: to be confirmed by post-construction commissioning measurements Section 6.9, 7.4
Book 3A 18.0-7	The NOP shall seek to improve or make compliant any non-compliances contained within the concept design where possible, but under no circumstances shall they be made worse than documented at each location.	Section 6.6
Book 3A: 18.1.0-3	Track structure for ballasted track: The NOP shall provide a narrow gauge track structure that complies with the deemed to comply solution in accordance with the requirements shown on Drawing No. 00-C-04-0044 "Standard Trackwork Drawings for Urban Passenger Systems – Typical Track Structure" and the Narrow Gauge Code of Practice. Compliant noise and vibration mitigation measures shall be incorporated as required by the NOPs' noise and vibration study.	Section 7.2.4

Number	Condition	Location where addressed
Book 3A: 18.1.0.4	Track structure shall be ballasted track except on bridges over 40m long and in tunnels.	Section 7.2.4
Book 3A: 18.1.0.5	Track structure for slab track: The NOP shall develop a track structure design suitable for passage of narrow gauge passenger vehicles, work trains and all PTA narrow gauge rollingstock which includes rail, rail fastening systems, rail baseplate systems, baseplate anchoring systems and all other associated trackwork within the section of slab track. Noise and vibration mitigation measures shall be incorporated as required by the NOPs' noise and vibration study.	Section 7.2.4
Book 3A: 18.1.0-7.0-6	Track design shall consider noise reduction measures, Compliant Noise and vibration mitigation measures shall be incorporated into track structures as required by the Noise and vibration study.	Section 7.2.4
Book 3A 18.1.1.0-1.0-1.0-5	The scope of the NOP’s design and detailing of the Permanent Way shall include, as a minimum, the following: Noise and vibration mitigation measures.	Section 6.6, Section 7.2.4
Book 3A 18.1.1.0-5.0-6	Any application of geogrid, ballast mats, noise and attenuation measures shall not compromise overall track structure design, performance and operational requirements stated in code of practice.	Section 7.2.4
Book 3A 18.1.2.0-1.0-5	The NOP shall supply, as a minimum, the following: Lubricators.	Section 7.2.4
Book 3A 18.1.2.0-2.0-16	The NOP shall provide product data sheets, manufacturer warranties and ITPs for the following materials at a minimum: Resilient baseplates (or other resilient components used in the slab track system).	Section 7.2.4
Book 3A 18.1.4-10	The NOP shall design and construct noise walls in accordance with the noise and vibration assessment for the extent of the Works.	Design: Section 6.6.1 Construct: Refer construction documentation
Book 3A 24.11-5	"The NOP shall achieve at least 50 points, a ‘Silver’ Infrastructure Sustainability (IS) 'Design' and 'As Built' rating under version 2.0 of the IS Rating Tool, certified by ISCA at the completion of Final Design and following Practical Completion respectively.	ISCA assessment and documentation will be provided in a

Number	Condition	Location where addressed
		separate document
Book 3B 3.10.0-1	In addition to the testing requirements and acceptance criteria submitted to demonstrate compliance with acceptable noise and vibration levels as part of the detailed design for construction, the NOP shall also develop testing and acceptance criteria to confirm compliance of the Works post construction.	Section 6.9, 7.4
Book 3B 3.10.0-2	The NOP shall carry out:	-
Book 3B 3.10.0-2.0-1	Operational noise and vibration measurement compliance Testing in accordance with Book 4 Noise and Vibration section.	Section 6.9, 7.4
Book 3B 3.10.0-2.0-2	Noise and vibration monitoring shall be undertaken by a suitably qualified person within three months of the opening of the proposal.	Section 6.9, 7.4
Book 3B 3.10.0-2.0-3	Noise and vibration monitoring should be undertaken again after 18 months of the opening of the proposal by a suitably qualified person.	Section 6.9, 7.4
Book 3B 3.10.0-2.0-4	Each monitoring event shall be over a minimum period of seven (7) days at sensitive premises as detailed in the operational NVMP.	Section 6.9, 7.4
Book 3B 3.10.0-2.0-5	Additional monitoring locations shall be added where residential or tenancy areas are developed within and/or adjacent to the proposal prior to the commencement of Project Activities.	Section 6.9, 7.4
Book 3B 3.10.0-2.0-6	Monitoring shall also be undertaken at sensitive receptors where complaints have been received.	Section 6.9, 7.4
Book 3B 3.10.0-2.0-7	The NOP shall allow for one additional round of Testing in the event that earlier Testing identified a requirement for further investigation.	Section 6.9, 7.4
Book 3B 3.10.0-2.0-8	Compliance measurement Reports shall be submitted to the PTA's Representative not later than three weeks after the Tests are completed.	Section 6.9, 7.4
Book 3B 3.10.0-2.0-9	Should a potentially affected building remain incomplete at the time of the compliance measurements, the likely vibration and ground-borne noise levels shall be determined by measurements in the nearest or most similar space, supplemented by calculations, as appropriate.	Section 6.9, 7.4
Book 3B 3.10.0-2.0-1	Operational noise and vibration measurement compliance Testing in accordance with Book 4 Noise and Vibration section.	Section 6.9, 7.4

Number	Condition	Location where addressed
Book 3C 14	Noise and vibration requirements are as per Book 3A.	Section 6.9, 7.4
Book 3C 17	Track Structure for Ballasted Track: The NOP must provide a Narrow gauge track structure that complies with the deemed to comply solution in accordance with the requirements shown on Drawing No. 00-C-04-0044 “Standard Trackwork Drawings for Urban Passenger Systems – Typical Track Structure” and the Narrow Gauge Code of Practice. Compliant Noise and vibration mitigation measures are to be incorporated as required by the NOPs' noise and vibration study. Track Structure for Slab Track: The NOP shall develop a track structure design suitable for passage of narrow gauge and standard gauge passenger vehicles, work trains and all PTA narrow gauge rollingstock which includes rail, rail fastening systems, rail baseplate systems, baseplate anchoring systems and all other associated trackwork within the section of slab track. Noise and vibration mitigation measures shall be incorporated as required by the NOPs' noise and vibration study. Track design shall consider noise reduction measures, Compliant Noise and vibration mitigation measures shall be incorporated into track structures as required by the Noise and vibration study.	Section 6.6, Section 7.2.4
Book 3C 17.1.1	The scope of the NOP’s design and detailing of the Permanent Way includes, as a minimum, the following: Noise and vibration mitigation measures.	Section 6.6, Section 7.2.4
Book 3C 24.1	The PTA has adopted the Infrastructure Sustainability Council of Australia (ISCA) rating scheme for evaluating sustainability and driving sustainability performance across the design, construction and operation of the Project. The PTA has registered the Project with ISCA under version 2.0 of the Rating Tool, excluding any Green Star rated components. PTA is the ISCA registered entity for the Project. The NOP shall achieve at least 50 points, a ‘Silver’ Infrastructure Sustainability (IS) 'Design' and 'As Built' rating under version 2.0 of the IS Rating Tool, certified by ISCA at the completion of Final Design and following Practical Completion respectively	ISCA assessment and documentation will be provided in a separate document
Book 3C 27.5	The NOP shall identify services requiring relocation and protection. All existing services that are impacted but not require relocation shall be protected in accordance with asset owner requirements. The NOP shall relocate or replace all existing services that are impacted where required in accordance with asset owner requirements.	Vibration impacts to buried infrastructure will be provided in a separate document.

Number	Condition	Location where addressed
	The NOP shall be responsible for the design and construction of all services in accordance with asset owner requirements.	
Book 3D 22	The NOP shall design, construct, install, test and commission all structures and associated works, including foundation, substructure, superstructure, earthwork and drainage for the following: iii. Noise wall structures.	Design: Section 6.6 Install: Refer construction documentation Test and Commission: Section 6.9
Book 4 Part 3 13	The NOP must retain an acoustics engineer to provide design input and documentation throughout the design process. The acoustic engineer must have a minimum of ten (10) years' relevant experience. The NOP must design and construct the railway and roads to minimise operational noise and vibration impacts on existing sensitive receptors as far as practicable. The NOP, in their investigations and detailed analysis, must apply Best Industry Practice consistent with standards, codes of practice and requirements contained in this section. The NOP must have Independent Design Verification and Validation undertaken by the appropriate Independent Design Verifier and Validator for each affected Design Package to ensure that: The investigation, detailed analysis and methodology is robust and consistent with the requirements of this section. The NOP must have Independent Design Verification and Validation undertaken by the appropriate Independent Design Verifier and Validator for each affected Design Package to ensure that the uncertainty of noise or vibration measurement, prediction or calculation is suitably determined, stated, and has factored into the design such that compliance with each applicable requirement is demonstrated to the required confidence level.	Section 2
Book 4 Part 3 13.3	The Operational Noise and Vibration Design Report (ONVDR) must include the following as a minimum: Detailed description of the design, assumptions, methodology, baseline testing, extrapolation modelling and calculation process including how each model accounts for: Relevant dynamic and static properties of the trainset rolling stock and supporting structure. Station and associated infrastructure (e.g. bus interchange, car parks, plant rooms etc.)	This ONVDR Table 26

Number	Condition	Location where addressed
	Variation in train length and speed. The source noise and vibration levels and accounts for changes in the selected track form and unique local features such as Turnouts. Vibration losses entering buildings and amplification effects within each floor level. Full detailed description of the design and engineering mitigation strategy, infrastructure elements to address the strategy, maintenance strategy and all other relevant factors. Description and quantification of the accuracy of input parameters and predictions, how any uncertainty will be resolved or have been resolved during the design process. Propagation losses and variation in ground conditions such as stratification in sandy soils. Evidence that the noise and vibration prediction model has been Verified and Validated by a suitably qualified person. The ONVDR must account for the results of baseline noise and vibration monitoring. The NOP must have each stage of the ONVDR Independently Verified by the Independent Design Verifier and Validator.	Stations design reports Table 14 Table 14 Table 21, Table 22 Section 5.5, 6.3, 7.3 Section 7.2.6 Page i Section 5.2, 5.3, 5.4 Page i
Book 4 Part 3 13.4	The PTA has completed a preliminary noise and vibration assessment report for the Project "Byford Rail Extension, Preliminary Assessment, Operational Noise and Vibration Assessment, SLR, 2020". The Report is provided as information to inform the assessments to be carried out by the NOP. Noise and vibration mitigation controls shall be implemented for operational noise and vibration design targets in accordance with a modelled operational noise and vibration assessment and the State Planning Policy 5.4: Road and Rail Noise.	N/A Section 6.6, Section 7.2.4
Book 4 Part 3 13.5	The NOPNOP must prepare an Operational Noise and Vibration Management Plan three months prior to Practical Completion to demonstrate that the operational railway has been designed and constructed to minimise operational noise and vibration impacts on existing sensitive receptors as far as practicable. The Operational Noise and Vibration Management Plan must show the locations and heights of noise walls and provide a summary of the noise and vibration mitigation measures that have been constructed to meet the noise and vibration criteria specified within this section. The Operational Noise and Vibration Management Plan must provide noise and vibration monitoring methodologies and detail the operational noise and vibration compliance test measurements in	TBC

Number	Condition	Location where addressed
	accordance with Book 3 - Part C: Noise and Vibration section. The Operational Noise and Vibration Management Plan must be approved by the PTA prior to the commencement of operational noise and vibration compliance test measurements.	
Book 4 Part 3 13.6	The NOP is responsible for the Detailed Design of the railway and roads and associated noise and vibration mitigation measures to meet the noise and vibration criteria specified within Book 4 - Noise and Vibration. The NOP must consult with residents in the vicinity of any proposed noise walls/barriers and take into account their feedback when determining the location, height, materials, design and colour of noise walls/barriers.	Section 6.6, Section 7.2.4 Refer Community Liaison Team
Book 4 Part 3 13.7	The NOP shall consult with relevant service providers (e.g. ATCO Gas, WPC, Water Corporation, BP, Telstra etc.) to determine acceptable vibration limits for adjacent Assets and design and construct vibration mitigation and / or protection measures as appropriate. The NOP shall design and construct the railway and roads and associated noise and vibration mitigation measures to comply with the noise and vibration criteria specified within Book 4 Part section 13 Noise and Vibration with consideration to relevant Acts, Standards and Codes of Practice.	TBC Design: Section 6.6, Section 7.2.4 Construct: Refer construction documentation

<table>
<tr><th>Number</th><th>Condition</th><th>Location where addressed</th></tr>
<tr><td></td><td>The relevant Acts, Standards and Codes of Practice are listed in <XREF 799653>.
<table>
<tr><th>Reference</th><th>Title</th></tr>
<tr><td>CR NOI TSI</td><td>Technical specification for interoperability relating to the subsystem 'rolling stock – noise' of the trans-European conventional rail system, adopted by the Commission Decision 2011/229/EU, April 2011</td></tr>
<tr><td>SPP 5.4</td><td>State Planning Policy No. 5.4 Road and Rail Noise 2019</td></tr>
<tr><td>Road and Rail Noise Guidelines</td><td>Road and Rail Noise Guidelines, September 2019</td></tr>
<tr><td>DevWA Development Policy 3</td><td>Development Policy 3 – Sound and Vibration Attenuation</td></tr>
<tr><td>NSWRING</td><td>New South Wales Rail Infrastructure Noise Guideline, NSW EPA, May 2013</td></tr>
<tr><td>AS 1742.7-2007</td><td>Manual of Uniform Traffic Control Devices - Railway Crossings</td></tr>
<tr><td>AS 1428.2-1992</td><td>Design for access and mobility Part 2: Enhanced and additional requirements - Buildings and Facilities</td></tr>
<tr><td>AS 2670.1</td><td>Evaluation of human exposure to whole-body vibration - General requirements</td></tr>
<tr><td>AS 2670.2</td><td>Evaluation of human exposure to whole-body vibration - Continuous and shock-induced vibration in buildings (1 to 80 Hz)</td></tr>
<tr><td>BS 6472</td><td>Evaluation of Human Exposure Vibration in Buildings (1 Hz to 80 Hz)</td></tr>
<tr><td>BS 7385.2</td><td>Evaluation and Measurement for Vibrations in Buildings – Part 2 Guide to Damage Levels from Ground-Borne Vibration</td></tr>
<tr><td>DIN 4150.3</td><td>Part 3: Structural Vibration in Buildings: Effects on Structures</td></tr>
<tr><td>ISO GUIDE 98-3</td><td>Uncertainty of measurement — Part 3:Guide to the expression of uncertainty in measurement (GUM:1995)</td></tr>
<tr><td>ISO 3095</td><td>Acoustics - Railway applications - Measurement of noise emitted by railbound vehicles - Third Edition, August 2013</td></tr>
<tr><td>ISO 3381</td><td>Railway applications - Acoustics - Measurement of noise inside railbound vehicles</td></tr>
<tr><td>ISO 8041</td><td>Human response to vibration – Measuring instrumentation</td></tr>
<tr><td>ISO 14837</td><td>Mechanical vibration - Ground-borne noise and vibration arising from rail systems</td></tr>
<tr><td>AS/RISSB 7532:2016</td><td>Railway Rolling Stock - Audible Warning Devices</td></tr>
<tr><td>8190-600-009</td><td>Code of Practice: Design Principles for Active Level Crossing Warning Systems</td></tr>
<tr><td></td><td>Main Roads WA - Railway Crossing Control in Western Australia Policy and Guidelines</td></tr>
<tr><td></td><td>RailCorp Engineering Specification Signals SPG 0723 Level Crossing Equipment</td></tr>
<tr><td></td><td>American Railway Engineering and Maintenance-of-Way Association (AREMA)</td></tr>
</table></td><td></td></tr>
<tr><td>Book 4 Part 3

13.7.1</td><td>The NOP must design and construct the operating passenger railway and any associated noise mitigation controls to meet the requirements of "State Planning Policy No. 5.4 Road and Rail Noise (SPP 5.4)" (WAPC, 2019).

The NOP must design and construct the operating passenger railway to ensure that the L_{Amax} applicable to the 95th percentile train passby event (the level not exceeded in 95% of train passbys) is 80 dB referenced to 20 microPascals (dB re 20μPa) or less at buildings with a noise sensitive use located on noise sensitive premises.

The NOP must design and construct the operating passenger railway to comply with the vibration criteria detailed in <XREF 797686>.</td><td>Design: Section 6.6, Section 7.2.4

Construct: Refer construction documentation</td></tr>
</table>

Number	Condition	Location where addressed

Parameter	Criterion[2]	Value	Basis
Rail Operations – Design Level	Vibration levels from rail operations will be managed as low as is reasonably practicable.	Demonstrated	Industry best practice
Rail Operations Building Vibration Trigger Level	Mitigation of vibration via ground or structural pathways must be considered where the vector		AS2670.2:1990
	Medical clinical treatment, surgery or recovery areas, or facilities operating precision equipment	Curve 1 ($L_{v,RMS,1s}$ 100dB)	ISO2631,
	Residential and hotel accommodation	Curve 2 ($L_{v,RMS,1s}$ 106dB)	ASHRAE[5]
	Commercial premises, public buildings, Churches and community centres and the like	Curve 4 ($L_{v,RMS,1s}$ 112dB)	guidelines
	Light and general industrial buildings	Curve 8 ($L_{v,RMS,1s}$ 118dB)	NSWRING
Rail Operations Regenerated Noise/Ground-Borne Noise Trigger Level	Mitigation of vibration via ground or structural pathways must be considered where the rail operations regenerated noise trigger level is exceeded as applicable to the 95th percentile train passby event and measured at centre of reasonably representative interior space(s) of each building usage.		NSWRING
	Residential and hotel accommodation, 10pm to 6am	L_{ASmax} 35dB	
	Residential and hotel accommodation, 6am to 10pm	L_{ASmax} 40dB	
	Commercial buildings, public buildings, Churches and community centres and the like	L_{ASmax} 45dB	
	Retail and point of sale areas, occupiable light and general industrial buildings	L_{ASmax} 50dB	
	Occupiable light and general industrial buildings	L_{ASmax} 50dB	

[1] Airborne noise criteria are referenced to 20 microPascals (dB re 20µPa).

[2] Vibration criteria are referenced to 1nm/s (dB re 1nm/s), use the subscript 'v' and are assessed on the basis of 1 second root mean square (RMS) values.

[3] ISO 2631-1:1997 Mechanical vibration and shock - Evaluation of human exposure to whole-body vibration - Part 1: General requirements.

[4] AS ISO 2631.2:2014 Mechanical vibration and shock - Evaluation of human exposure to whole-body vibration - Vibration in buildings (1 Hz to 80 Hz).

[5] American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc (ASHRAE), 2011 ASHRAE Handbook - Heating, Ventilating, and Air-Conditioning APPLICATIONS - SI Edition, Atlanta GA http://www.ashrae.org

Number	Condition	Location where addressed
Book 4 Part 3 13.9	The NOP must carry out operational noise and vibration measurement compliance testing in accordance with Book 4 Noise and Vibration section. Noise and vibration monitoring must be undertaken by a suitably qualified person within three months of the opening of the proposal. In addition, noise and vibration monitoring should be undertaken again after 18 months of the opening of the proposal by a suitably qualified person. Each monitoring event must be over a minimum period of seven (7) days at sensitive premises	Section 6.9, 7.4

Number	Condition	Location where addressed
	as detailed in the operational NVMP. Additional monitoring locations must be added where residential areas are developed adjacent to the proposal prior to the commencement of operations. Monitoring must also be undertaken at sensitive receptors where complaints have been received. The NOP must allow for one additional round of testing in the event that earlier testing identified a requirement for further investigation. Compliance measurement Reports must be submitted to the PTA's Representative not later than three weeks after the Tests are completed. Should a potentially affected building remain incomplete at the time of the compliance measurements, the likely vibration and ground-borne noise levels must be determined by measurements in the nearest, or most similar space, supplemented by calculations, as appropriate. The NOP must ensure that the operational noise and vibration measurement compliance testing measurement Reports must be prepared by a specialist acoustics engineer. The Reports must include the following as a minimum: Energy averaged or maximum 1/3 octave band spectral values for each measured passby event, as well as daily overall levels in terms comparable with the criteria in Book 4 - Part A: Noise and Vibration. Spectral values for airborne noise levels must include the range of third octaves with centre frequencies 20 to 10,000 Hz. Spectral values for ground vibration levels must include the range of third octaves, with centre frequencies 10 Hz to 315 Hz and otherwise conform to section 7 of the guidelines to the "State Planning Policy No 5.4 Road and Rail Noise (SPP 5.4)" (WAPC, 2019). Sufficient detail around the methodology and site conditions to enable replication by others, including details of equipment used and calibration processes. The expanded uncertainty of measurement for a 95% confidence interval (U95) determined according to the ISO "Guide to the Expression of Uncertainty in Measurement".	

5 Existing Environment

The following sections describe noise and vibration measurements which have been undertaken in the vicinity of the alignment in order to characterise the existing acoustic environment.

5.1 Sensitive Receivers

Properties adjacent to the rail corridor have been identified based on usage. Residential properties, education centres, child-care centres and health centres have been classified as noise-sensitive receivers. This identification is based on aerial imagery, Google Street View imagery, supplied data and attended site inspections.

In all areas, the existing passenger rail is the controlling noise source, with areas adjacent to Mint Street, Oats Street, and Sevenoaks Street also being influenced by road traffic noised from these roads. Welshpool Road and Leach Highway, while carrying significantly more traffic, are not adjacent to any noise-sensitive receivers associated with the LXR project.

A total of 1471 noise-sensitive receivers have been identified in the LXR project area.

ZONE 1 – MILLER STREET TO CHAINAGE 6600

Between Miller Street and Mint Street, Zone 1 has the East Victoria Park Primary School to the west of the alignment, and residential properties to the east. Between Mint Street and Carlisle Station there are residential properties to the west, with the Goodstart Early Learning Centre, the Carlisle Hotel and several commercial properties to the east.

ZONE 2 – CHAINAGE 6600 TO LEACH HIGHWAY

The area between Chainage 6600 and Oats Street Station is residential to both sides of the rail alignment, with the South Metropolitan T.A.F.E. Carlisle Campus adjacent to the Oats Street Station to the west. Between the Oats Street Station and Leach Highway is predominantly commercial, with a small section of residential and Cuddles Early Learning & Childcare between Oats Street and Cohn Street.

ZONE 3 – LEACH HIGHWAY TO GERARD STREET

The area between Leach Highway and Radium Street is commercial. Between Radium Street and Wharf Street is predominantly residential, with a small pocket of commercial properties and mixed-use properties north of George Street / Mallard Way.

South of George Street / Mallard Way has noise-sensitive receivers either side of the rail alignment – education facilities Goodstart Early Learning Queens Park and Sevenoaks Community College as well as community facilities the Bodhi Siksa Buddhist Society, the Hope Church and the Cannington Leisureplex are also in this area. There is a small pocket of residential area between Gibbs Street and Gerard Street.

ZONE 4 – GERARD STREET TO BECKENHAM STATION

Between Gerard Street and Beckenham Station is a mixture of commercial and residential properties either side of the rail alignment. Albion Park and the Western Power East Cannington Substation are also located in this Zone.

ZONE 5 – BECKENHAM STATION TO WILLIAM STREET

At the time of writing, the project does not include Zone 5.

5.2 Noise Measurements

The ALUA Alliance undertook noise monitoring of the existing rail noise between 17 and 19 May 2022. The full noise and vibration monitoring report will be developed concurrently and issued / referenced in the next phase of design.

Targeted rail noise measurements were undertaken over the three days at two locations, in order to obtain the baseline average and maximum train pass-by noise levels and spectral content to inform the rail noise model.

Noise measurements were taken with a microphone set at a height of 1.2 – 1.5m above ground level. Noise levels were monitored on the 'Slow' response setting and L_{Aeq}, L_{Amax}, L_{A10}, and L_{A90} noise metrics were monitored at each location. One third octave band noise levels were measured to assist with the analysis of noise characteristics.

Noise monitoring was conducted in accordance with the following Standards and Guidelines:

- SPP5.4 guidelines.
- Class 1 Sound level meters with certification as defined in Australian Standard AS IEC-61672.1-2004 were used for all measurements.
- Sound level meters were calibrated before and after each measurement period using a calibrator suitable for a Class 1 instrument, which complied to AS IEC-60942-2004.
- Monitoring guidelines for ground-borne noise from railways as contained in ISO 14837-1.

Approximately 80 trains were observed during the monitoring period. Table 5 below provides airborne noise results at the positions outlined in Figure 2and Figure 3 below.

TABLE 5 MEASURED BASELINE MAXIMUM AIRBORNE NOISE LEVELS

Site Position	Distance (m)	Median SEL dB	Median (50th Perc.) $L_{Smax,Tp}$	L_5 (95th Perc.) $L_{Smax,Tp}$	Comment
N1 – 18/5/2022	10m	94	88	91	A Type Trains
N2 – 19/5/2022	15m	91	85	88	A Type Trains
N2 – 20/5/2022	15m	91	86	89	A Type Trains

FIGURE 2 MEASUREMENT LOCATION – SITE 1

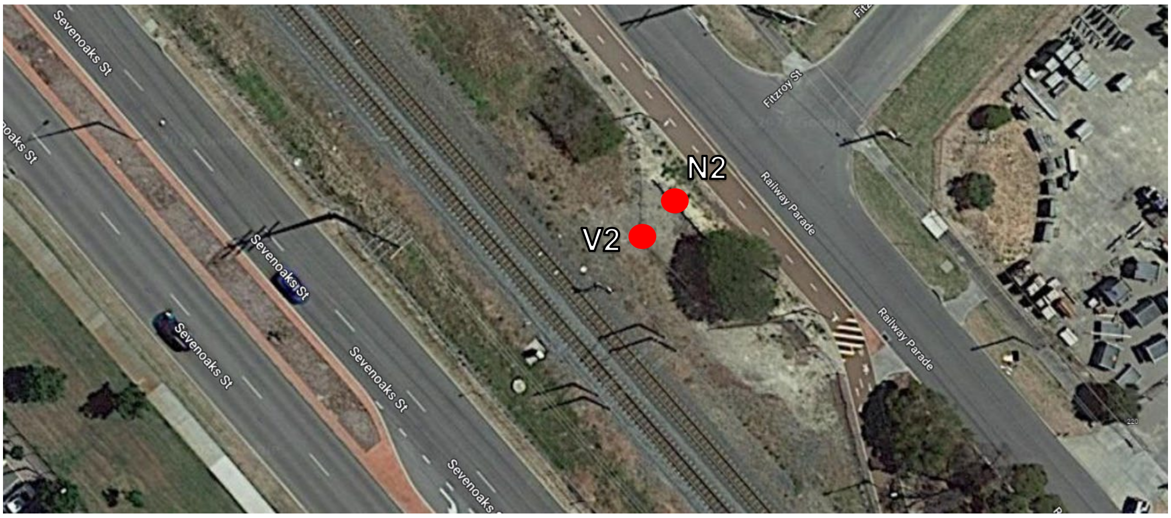

FIGURE 3 MEASUREMENT LOCATIONS – SITE 2

5.3 Vibration Measurements

Vibration monitoring was also conducted concurrently at the two locations and three dates noted above. The full noise and vibration monitoring report will be developed concurrently and issued / referenced in the next phase of design.

The monitoring of vibration was undertaken in accordance with the following Standards and guidelines where relevant:

- SPP 5.4 guidelines.
- Australian Standards; AS 2670, AS 2775 and International Standard ISO 14837-1.

Approximately 80 trains per day were observed during the monitoring period. Table 6 provides vibration monitoring results at the positions outlined above.

TABLE 6 MEASURED BASELINE VIBRATION LEVELS

Site Position	Distance (m)	Direction	Median Lv,RMS,1s	95th Percentile (L5) Lv,RMS,1s
V1 – 18/5/2022	10m	UP and DN	57 dB	66 dB
V2 – 19/5/2022	10m	UP and DN	50 dB	77 dB
V2 – 20/5/2022	10m	UP and DN	40 dB	43 dB

5.4 Validation Measurements

The ALUA Alliance undertook noise monitoring of the existing rail and general ambient noise environment between 17 and 31 May 2022 for the purposes of validating the existing rail noise model.

Four noise loggers were used to take unattended measurements at eight residential locations along the LXR rail corridor. The loggers were deployed for one week of continuous monitoring during standard rail operations. Noise measurements were taken in accordance with those conditions and standards identified in Section 5.2.

Each logger was positioned 1 metre from the nearest residential façade to the rail.

The results are shown in Table 7.

TABLE 7 MEASURED ENVIRONMENTAL NOISE LEVELS

Logger location	$L_{Aeq,day}$ dB(A)	$L_{Aeq,night}$ dB(A)
1 – 132 Rutland Avenue, Carlisle	60	50
2 – 73A Bank Street, East Victoria Park	57	46
3 – 210 Rutland Avenue, Carlisle	61	52
4 – 246A Rutland Avenue, Carlisle	58	52
5 – 96 Railway Parade, Queens Park	62	50
6 – 184 Railway Parade, Queens Park	64	54
7 – 278 Railway Parade, East Cannington	60	49
8 – 325 Sevenoaks Street, Cannington	63	52

A full report of the noise and vibration monitoring will be provided in report LXR-PW-Z0-GN-DT-RPT-0000x, developed concurrently and issued / referenced in the next phase of design

5.5 Accuracy of Noise Measurements

All measured existing noise levels are referenced to 20 microPascals (dB re 20 μPa).

Annex G of ISO 3095: 2013 *Acoustics — Railway applications — Measurement of noise emitted by railbound vehicles* (ISO/IEC Guide 98-3:2008 *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*) provides an estimate of measurement uncertainty. For this project, the estimated uncertainty of existing noise measurements is as shown in Table 8, as described in report *LXR-MNO-SLR-NV-RPT-0001_4*.

TABLE 8 ESTIMATED NOISE AND VIBRATION MEASUREMENT UNCERTAINTY

Noise/Vibration Descriptor	Measurement equipment	U_{95}	Student's t-factor
L_{Aeq}, L_{A10}, L_{A1}, L_{AE}, L_{Amax}	01dB Duo	0.8 dB	2.0
L_{vSmax}	01dB Orion Smart Vibration Monitoring Terminal	5 dB	2.0 dB

U_{95} indicates the 95% confidence interval, representing the estimated range in which the true measurement value lies for 95 out of 100 identical tests. This is considered to be an internationally established acceptable level of risk.

5.6 Noise Model Inputs

The noise model input sources are provided in Table 9.

TABLE 9 EXISTING NOISE MODEL INPUTS

Input	Source
Rail Strings	*LXR-PW-Z0-GN-SV-M3D-LXR_CONSOLIDATED_&_ROADS.dwg* dated 19/4/2022
Rail volumes	'Existing' — Series A (4-car / 2-car) Perth – Armadale (DN): Day:122 (98 / 24) Night: 18 (8 / 10) Armadale – Perth (UP): Day: 125 (104 / 21) Night: 19 (6 / 13) Traffic volumes for the current year are based on 2020 Armadale services timetable
Ground Topography	*LXR-PW-Z0-GN-SV-M3D-LXR_CONSOLIDATED_&_ROADS-unused.*dwg dated 25/6/2021
Ground Absorption	Ground absorption for rail corridor, roads, car parks and significant paved/concrete areas was set to 0.1; all other areas set to 0.5 as being a mixture of hard/soft ground
Buildings and Structures	Identification is based on aerial imagery, Google Street View imagery (last accessed May 2022) and supplied data (*Buildings_WA.shp* accessed 22/10/2020).
Receptor locations	Residential properties have been classified as noise-sensitive receivers. Airborne noise receivers for residential dwellings are represented by a point 1.5 metres above ground level and 1 metre away from the most exposed habitable facade in accordance with SPP 5.4.

<table>
<tr><th>Input</th><th>Source</th></tr>
<tr><td>Noise Sensitive Receivers</td><td>In total, 1471 noise sensitive receivers have been identified along the rail corridor. Achievement of noise and vibration requirements at these first-row receptors would generally indicate that compliance will also be achieved at those located further from the rail corridor.</td></tr>
<tr><td>Track Form</td><td>Rail noise corrections have been applied in accordance with the SPP 5.4 implementation guidelines:
<table>
<tr><th>Situation</th><th>Correction</th></tr>
<tr><td>Turnouts and Crossings</td><td>+6 dB</td></tr>
<tr><td>Tight Radius Curves:</td><td></td></tr>
<tr><td>R<300m</td><td>+8 dB</td></tr>
<tr><td>R>300m <500m</td><td>+3 dB</td></tr>
<tr><td>Diamond Crossings</td><td>+10 dB</td></tr>
<tr><td>Mechanical / uneven joints</td><td>+3 dB</td></tr>
</table></td></tr>
<tr><td>Train Speeds</td><td>Passenger rail UP at 90 km/hr
Passenger rail DOWN at 90 km/hour</td></tr>
<tr><td>Train reference noise levels</td><td>Train noise levels were monitored between 17-19 May 2021. Reference levels utilised are:
<table>
<tr><th colspan="2">Train reference noise levels at 80 km/hr, 15 m distance and 1.5 m height</th></tr>
<tr><th>L_{AE} dB</th><th>L_{Amax}, dB</th></tr>
<tr><td>87</td><td>93</td></tr>
</table></td></tr>
</table>

5.7 Noise Model Validation

The calculated L_{Amax} noise level results for the existing conditions noise model were compared against the existing attended measured noise levels as given in Table 5.

TABLE 10 COMPARISON – MEASURED AND CALCULATED NOISE LEVELS FOR THE EXISTING SCENARIO

Measurement Location	Measured L_{Amax} dB L_5 (95th percentile)	Calculated L_{Amax} dB	Difference
N1	84.7	84.1	0.6
N2	84.7	84.3	0.4

The calculated $L_{Aeq,day}$ and $L_{Aeq,night}$ noise level results for the existing conditions noise model were compared against the measured existing noise levels for Sites 5 to 8 as given in Table 7. Note that the data from Locations 1 – 4 was excluded from this assessment as these locations gave only a small sample of valid data due to weather conditions excluding large portions of measured data.

TABLE 11 COMPARISON – MEASURED AND CALCULATED NOISE LEVELS FOR THE EXISTING SCENARIO

Measurement Location	Measured $L_{Aeq,day}$ dB	Calculated $L_{Aeq,day}$ dB	Difference dB	Measured $L_{Aeq,night}$ dB	Calculated $L_{Aeq,night}$ dB	Difference dB
5	57	54.9	2.1	46	46.9	-0.9
6	62	58.3	3.7	50	50.5	-0.5
7	58	58.6	-0.6	52	50.8	1.2
8	60	60.1	-0.1	50	52.4	-2.4
Average Difference			**1.3**			**-0.6**

A variation of +/- 2 dB is considered to be acceptable (refer also to Section 5.5) and represents a conservative noise model. Therefore, the existing rail noise model is considered to be validated.

5.8 Calculated Noise levels – existing conditions

A detailed noise model has been developed using SoundPLAN version 8.2 to calculate noise from the existing passenger rail line. The Nordic Rail Prediction Method (NORD2000) algorithm was used with corrections made based on Perth rail conditions and the measured noise levels given in Table 5 and Table 7.

The calculated existing noise levels are given in Appendix C; a summary of results is given in Table 12.

TABLE 12 SUMMARY – CALCULATED EXISTING NOISE LEVELS

Descriptor	Number of receivers	Compliant with Design Noise Level	Within 2dB	Exceeds > 2dB
$L_{Aeq,Day}$	1431	1289	119	23
$L_{Aeq,Night}$	1431	1368	58	5
L_{Amax}	1431	1405	20	6

This indicates that approximately 10% of the 1431 receivers adjacent to the rail corridor currently experience average day noise levels above the airborne $L_{Aeq,Day}$ noise design level, approximately 4% currently experience average night noise levels above the airborne $L_{Aeq,Night}$ noise design level, and approximately 2% currently experience noise levels above the airborne L_{Amax} noise design level. The receivers at which these exceedances occur are highlighted in the tabulated results in Appendix C.

6 Operational Noise Assessment

A detailed noise model has been developed using SoundPLAN version 8.2 to calculate noise from the future operational rail line. The Nordic Rail Prediction Method (NORD 2000) algorithm was used with corrections made based on Perth rail conditions.

Noise from the project to station buildings does not form part of this assessment and is addressed in separate reports for each of the Carlisle, Oats Street, Queens Park and Cannington stations.

6.1 Operational Noise Criteria

The *Victoria Park-Canning Level Crossing Removal Scope of Work and Technical Criteria* Book 4 Part 3 Section 13.7.1 states that:

> *The Alliance must design and construct the operating passenger railway and any associated noise mitigation controls to meet the requirements of "State Planning Policy No. 5.4 Road and Rail Noise (SPP 5.4)" (WAPC, 2019).*
>
> *The Alliance must design and construct the operating passenger railway to ensure that the L_{Amax} applicable to the 95th percentile train passby event (the level not exceeded in 95% of train passbys) is 80 dB referenced to 20 microPascals (dB re 20μPa) or less at buildings with a noise sensitive use located on noise sensitive premises.*

Therefore, the operational noise criteria for the project are presented below in Table 13.

TABLE 13 OPERATIONAL RAIL NOISE CRITERIA

Proposal	Noise Targets			
	Outdoor			Indoor
	Day (6 am – 10 pm) $L_{Aeq,day}$ dB	Night (10 pm – 6 am) $L_{Aeq,night}$ dB	L_{Amax} dB	$L_{Aeq,day}$ dB
Upgraded Railways	60	50	80	N/A

6.2 Future Operational Noise Model Inputs

The operational future noise model input sources are provided in Table 14.

TABLE 14 OPERATIONAL FUTURE NOISE MODEL INPUTS

<table>
<tr><th>Input</th><th>Source</th></tr>
<tr><td>Rail Strings</td><td>LXR-PW-Z0-GN-RL-TR-M2D-00049-ALIGN_UP-H1V1.dwg dated 9/6/2021
LXR-PW-Z0-GN-RL-TR-M2D-00050-ALIGN_DN-H1V1.dwg dated 9/6/2021</td></tr>
<tr><td>Rail volumes</td><td><table>
<tr><td rowspan="2">'Build' & 'Build+M' for year 2042</td><td>Perth – Armadale (DN)</td><td rowspan="2">Series B (6-car / 3-car)</td><td>Day: 171 (137 / 34)
Night: 25 (11 / 14)</td><td rowspan="2">Traffic volumes for the design year (year 2042) of the project, estimated as 40% increase from the 2020 Armadale services timetable</td></tr>
<tr><td>Armadale – Perth (UP)</td><td>Day: 175 (146 / 29)
Night: 26 (8 / 18)</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Input</th><th>Source</th></tr>
<tr><td>Ground Topography</td><td>LXR-PW-Z0-GN-RL-TR-M2D-00012-EARTHWORKS.dwg dated 7/6/2022</td></tr>
<tr><td>Ground Absorption</td><td>Ground absorption for rail corridor, roads, car parks and significant paved/concrete areas was set to 0.1; all other areas set to 0.5 as being a mixture of hard/soft ground</td></tr>
<tr><td>Buildings and Structures</td><td>Identification is based on aerial imagery, Google Street View imagery (last accessed May 2022) and supplied data (Buildings_WA.shp accessed 22/10/2020).</td></tr>
<tr><td>Receptor locations</td><td>Residential properties have been classified as noise-sensitive receivers. Airborne noise receivers for residential dwellings are represented by a point 1.5 metres above ground level and 1 metre away from the most exposed habitable facade in accordance with SPP 5.4.</td></tr>
<tr><td>Noise Sensitive Receivers</td><td>In total, 1431 noise sensitive receivers have been identified along the rail corridor. Achievement of noise and vibration requirements at these first-row receptors would generally indicate that compliance will also be achieved at those located further from the rail corridor.</td></tr>
<tr><td>Track Form</td><td>Rail noise corrections have been applied in accordance with the SPP 5.4 implementation guidelines:
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<tr><td>Diamond Crossings</td><td>+10 dB</td></tr>
<tr><td>Mechanical / uneven joints</td><td>+3 dB</td></tr>
</table></td></tr>
<tr><td>Train Speeds</td><td>Passenger rail UP at 90 km/hr
Passenger rail DOWN at 90 km/hour</td></tr>
<tr><td>Train reference noise levels</td><td>Train reference noise levels were monitored between 17-19 May 2021. Reference levels utilised are:
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<tr><th colspan="2">Train reference noise levels at 80 km/hr, 15 m distance and 1.5 m height</th></tr>
<tr><th>L_{AE} dB</th><th>L_{Amax}, dB</th></tr>
<tr><td>87</td><td>93</td></tr>
</table></td></tr>
</table>

6.3 Accuracy of Noise Model Results

U_{95} indicates the 95% confidence interval, representing the estimated range in which the true measurement value lies for 95 out of 100 identical tests. This is considered to be an internationally established acceptable level of risk.

The accuracy of the noise model results is influenced by the following factors:

- Accuracy of existing noise level measurement results (refer to Section 5.5).
- Potential differences between estimated and actual train speeds during existing noise level measurements.
- Actual speed of trains during existing noise measurements as compared against the modelled train speed.
- Actual lengths and consist of trains during existing noise measurements as compared against those assumed within the modelling.
- Actual condition of track during existing noise measurements as compared against that assumed within the modelling.
- Actual condition of rolling stock during existing noise measurements as compared against that assumed within the modelling.
- Actual corrections for rail track features (turnouts, crossings, curves etc.) as compared against those assumed within the modelling (refer to Table 14).
- Actual ground absorption conditions for existing noise measurements as compared against those assumed within the modelling (refer to Table 14).
- Actual meteorological conditions for existing noise measurements as compared against those assumed within the modelling (refer to Table 14).
- Rounding effects on measured and modelled noise levels.
- Actual shielding effects due to topography or local features/barriers/embankments present for existing noise measurements as compared against those assumed within the modelling.

ISO/IEC Guide 98-3:2008 *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*) provides an estimate of noise prediction uncertainty. Table 15 provides a summary of the estimated noise prediction uncertainty for this project, as provided in report *LXR-MNO-SLR-NV-RPT-0001_4*.

TABLE 15 ESTIMATED NOISE PREDICTION UNCERTAINTY

Noise Descriptor	Element	U_{95}	Student's t-factor
$L_{Aeq,day}$, $L_{Aeq,night}$, L_{ASmax}	NORD 2000	4.0 dB	2.00

All calculated existing noise levels are referenced to 20 microPascals (dB re 20 μPa).

6.4 Noise Model Outputs

The predicted noise levels have been separated into three categories:

- Compliant with the design noise level criteria.
- Within 2 dB of the design noise level criteria.
- Exceeds the design noise level criteria by 2dB or more.

A change in noise of less than 2 dB is typically considered indiscernible. In cases where reasonable and practicable noise mitigation options have been exhausted, it can be considered infeasible to provide noise mitigation to achieve compliance for an indiscernible change in noise.

Noise contour maps showing $L_{Aeq,day}$, $L_{Aeq,night}$ and L_{Amax} noise levels throughout the assessment area, for both unmitigated and mitigated (incorporating the refined noise wall design) scenarios, have been calculated and are presented in Appendix D.

6.5 Predicted Future Noise Levels - Unmitigated

Modelling of expected future rail noise levels was completed to predict the number of receivers for which the future noise levels would comply with applicable design noise level criteria with, and without acoustic treatment.

Table 16 provides a summary of the number of receivers at which predicted rail noise levels are compliant with, within 2 dB, and exceeding the design noise criteria by more than 2 dB.

TABLE 16 UNMITIGATED RECEIVER COMPLIANCE - $L_{AEQ,DAY}$, $L_{AEQ,NIGHT}$ AND L_{AMAX}

Descriptor	Number of receivers	Compliant	Within 2dB	Exceeds > 2dB
$L_{Aeq,Day}$	1431	1403	16	12
$L_{Aeq,Night}$	1431	1418	12	1
L_{Amax}	1431	1426	5	0

Compliance with the rail noise criteria is therefore controlled by the day time ($L_{Aeq,Day}$) descriptor. In the unmitigated scenario, predicted rail noise levels exceed daytime noise criterion at a total of 28 receiver locations. 12 of these indicate an exceedance of greater than 2 dB.

6.6 Noise Mitigation Design

The proposed noise mitigation design is discussed in the following sections.

6.6.1 Noise Wall Requirements

State Planning Policy 5.4 - Road and Rail Noise (SPP 5.4) states that noise walls are a solid wall or fence designed to reduce airborne noise.

Noise walls must be continuously airtight and without gaps (between materials or between the base of the wall and the ground) but can be made from a range of materials including precast concrete panels, brickwork, limestone blocks, concrete blockwork, timber, transparent acrylic, fibre cement, recycled plastic, and metal sheeting.

It is generally recommended that walls in close proximity to transport corridors have a minimum surface density of at least 15 kilograms per square metre to effectively reduce the noise passing through the wall.

The noise wall locations have been refined based on discussions with the project team, with noise wall heights refined based on predicted noise levels in previous model iterations, and a detailed review of the predicted

This report only identifies the noise wall heights and extents which are required to achieve compliance with the rail noise criteria. Other project considerations are not addressed or modelled for the purposes of this report. These include:

- The potential retention of existing acoustic barriers.
- Security requirements such as the stipulation of minimum 2.4m height.
- Community considerations such as extending the acoustic barriers to provide visual screening of the rail to residences for which compliance with the criteria does not require noise walls.

6.6.2 At-Property Treatments

The SPP 5.4 *Road and Rail Noise Guidelines* provide noise exposure categories based on the forecast exceedance of the design noise level criteria at residential receivers.

The document details quiet-house packages for each exposure category i.e. example minimum building façade, door, wall, window and roof construction to enable an appropriate internal noise level to be achieved.

Forecast Excess Noise Level, dB	Exposure Category	Policy requirements for noise-sensitive land-use and/or development
0 or less	-	No further measures
1 to 3	A	Noise-sensitive land-use and/or development is acceptable, subject to: Mitigation measures in accordance with an approved noise management plan; or quiet house package as specified
–	*A+	
4 to 7	B	
–	*B+	
8 to 11	C	
–	*C+	
12 to 15	D	Noise-sensitive land-use and/or development is not recommended. There is no default quiet house option due to excessive forecast noise: professional design input is required in order to achieve compliance with relevant criteria. If noise-sensitive land-use and/or development is unavoidable, an approved noise management plan is required to demonstrate compliance with the noise target (see Table 1).
16 +	E	

* Assits to mitigate short term noise events from freight rail.

FIGURE 4 FORECAST NOISE EXPOSURE CATEGORIES

Exposure Category	Orientation to corridor	Acoustic rating and example constructions					Mechanical ventilation / air conditioning considerations
		Walls	External doors	Windows	Roofs and ceilings of highest floors	Outdoor living areas	
A **Quiet House A**	Facing	**Bedroom and indoor living and work areas to Rw+Ctr 45dB** • One row of 92mm studs at 600mm centres with: – Resilient steel channels fixed to the outside of the studs; and – 9.5mm hardboard or 9mm fibre cement sheeting or 11mm fibre cement weatherboards or one layer of 19mm board cladding fixed to the outside of the channels; and – 75mm glass wool (11kg/m3) or 75mm polyester (14kg/m3) insulation, positioned between the studs; and – Two layers of 16mm fire-protective grade plasterboard fixed to the inside face of the studs. – Single leaf of 150mm brick masonry with 13mm cement render on each face. – Double brick: two leaves of 90mm clay brick masonry with a 20mm cavity between leaves.	Bedrooms: • Fully glazed hinged door with certified Rw+Ctr 28dB rated door and frame including seals and 6mm glass Other external doors to Rw+Ctr 25dB, e.g. • 35mm solid core timber hinged door and frame system certified to Rw 28dB including seals • Glazed sliding door with 10mm glass and weather seals	Bedrooms: • Total external door and window system area up to 40% of room floor area: Sliding or double hung with minimum 10mm single or 6mm-12mm-10mm double insulated glazing (Rw+Ctr 28 dB). Sealed awning or casement windows may use 6 mm glazing instead. • Up to 60% floor area: as per above but must be sealed awning or casement type windows (Rw+Ctr 31dB). **Indoor living and work areas** • Up to 40% floor area: Sliding, awning, casement or double hung with minimum 6mm single pane or 6mm-12mm-6mm double insulated glazing (Rw+Ctr 25dB). • Up to 60% floor area: As per Bedrooms at up to 40% area (Rw+Ctr 28 dB). • Up to 80% floor area: As per Bedrooms at up to 60% area (Rw+Ctr 31dB).	To Rw+Ctr 35dB • Concrete or terracotta tile or metal sheet roof with sarking and at least 10mm plasterboard ceiling	At least one outdoor living area located on the opposite side of the building from the transport corridor and/or at least one ground level outdoor living area screened using a solid continuous fence or other structure of minimum 2 metres height above ground level.	• Acoustically rated openings and ductwork to provide a minimum sound reduction performance of Rw 40dB into sensitive spaces • Evaporative systems require attenuated ceiling air vents to allow closed windows • Refrigerant-based systems need to be designed to achieve National Construction Code fresh air ventilation requirements • Openings such as eaves, vents and air inlets must be acoustically treated, closed or relocated to building sides facing away from the corridor where practicable
	Side on						
	Opposite		As per 'Facing' above, except Rw+Ctr values may be 3dB less, e.g. glazed sliding door with 10mm glass and weather seals for bedrooms.	As above, except Rw+Ctr values may be 3dB less, or max % area increased by 20%			
			No specific requirements				
A **Quiet House A+**	All	As per Quiet House A, except double leaf masonry / brick construction only.	As per Quiet House A.	As per Quiet House A, except that • 'Side-on' requirements same as 'Facing'. • All windows comprise minimum 6 mm thick laminated or toughened glass in sealed awning or casement frames. Polymer (e.g. uPVC) window framing should be used. Evaporative air conditioning systems are not recommended. • No external doors for bedrooms with entry 'Facing' transport corridor	No specific requirements		
B **Quiet House B**	Facing	**Bedroom and indoor living and work areas to Rw+Ctr 50dB** • Single leaf of 90mm clay brick masonry with: – A row of 70mm x 35mm timber studs or 64mm steel studs at 600mm centres; – A cavity of 25mm between leaves; – 50mm glass wool or polyester cavity insulation (R2.0+) insulation between studs; and – One layer of 10mm plasterboard fixed to the inside face • Single leaf of 220mm brick masonry with 13mm cement render on each face • 150mm thick unlined concrete panel or 200mm thick concrete panel with one layer of 13mm plasterboard or 13mm cement render on each face • Double brick: two leaves of 90mm clay brick masonry with: – A 50mm cavity between leaves – 50mm glass wool or polyester cavity insulation (R2.0+) – resilient ties where required to connect leaves • Double brick: two leaves of 110mm clay brick masonry with a 50mm cavity between leaves and R2.0+ cavity insulation	Bedrooms • Fully glazed hinged door with certified Rw+Ctr 31dB rated door and frame including seals and 10mm glass • Other external doors to Rw+Ctr 28dB, e.g. • As per Quiet House A Bedrooms.	Bedrooms: • Total external door and window system area up to 40% of room floor area: Fixed sash, awning or casement with minimum 6mm single or 6mm-12mm-6mm double insulated glazing (Rw+Ctr 31 dB). • Up to 60% floor area: as per above but must be minimum 10 mm single or 6mm-12mm-10mm double insulated glazing (Rw+Ctr 34dB). **Indoor living and work areas** • Up to 40% floor area: Sliding or double hung with minimum 6mm single pane or 6mm-12mm-6mm double insulated glazing (Rw+Ctr 28dB). Sealed awning or casement windows may use 6 mm glazing instead. • Up to 60% floor area: As per Bedrooms at up to 40% area (Rw+Ctr 31 dB). • Up to 80% floor area: As per Bedrooms at up to 60% area (Rw+Ctr 34dB).	To Rw+Ctr 35dB • Concrete or terracotta tile or metal sheet roof, sarking and at least 10mm plasterboard ceiling, R3.0+ insulation	At least one outdoor living area located on the opposite side of the building from the corridor and/or at least one ground level outdoor living area screened using a solid continuous fence or other structure of minimum 2.4 metres height above ground level	
	Side-on		As per Quiet House A 'Facing' above (Rw+Ctr values may be 3dB less, or max % area increased by 20%).				
	Opposite		As per Quiet House A 'Side-on' above.				
B **Quiet House B+**	All	As per Quiet House B example above, except use double leaf masonry construction only.	As per Quiet House B, except • No external doors for bedrooms with entry 'Facing' or 'Side-on' to transport corridor	As per Quiet House B, except that • 'Side-on' requirements become the same as Quiet House B 'Facing'. • All windows comprise minimum 6 mm thick laminated or toughened glass in sealed awning or casement frames. Polymer (e.g. uPVC) window framing should be used. • Evaporative air conditioning systems are not recommended.	As per Quiet House C (to Rw+Ctr 40dB).		

FIGURE 5 QUIET-HOUSE DESIGN PACKAGES A AND B

Exposure Category	Orientation to corridor	Acoustic rating and example constructions					Mechanical ventilation / air conditioning considerations
		Walls	External doors	Windows	Roofs and ceilings of highest floors	Outdoor living areas	
C **Quiet House C**	Facing	Bedroom and indoor living and work areas to Rw+Ctr 50dB • As per Quiet House B example above	Bedrooms • External doors to bedrooms facing the corridor are not recommended. Other external doors to Rw+Ctr 30dB, e.g. • Fully glazed hinged door with certified Rw+Ctr 31dB rated door and frame including seals and 10mm glass. • 40mm solid core timber frame and door (without glass or with glass inserts not less than 6mm), side hinged with certified Rw 32dB acoustically rated door and frame system including seals	Bedrooms: • Total external door and window system area up to 20% of room floor area: Fixed sash, awning or casement with minimum 6mm single or 6mm-12mm-6mm double insulated glazing (Rw+Ctr 31 dB). • Up to 40% floor area: as per above but must be minimum 10 mm single or 6mm-12mm-10mm double insulated glazing (Rw+Ctr 34dB). **Indoor living and work areas** • Up to 40% floor area: Sliding or double hung with minimum 6mm single pane or 6mm-12mm-6mm double insulated glazing (Rw+Ctr 31dB). Sealed awning or casement windows may use 6 mm glazing instead. • Up to 60% floor area: As per Bedrooms at up to 40% area (Rw+Ctr 34 dB).	To Rw+Ctr 40dB • To all bedrooms, 2 layers of 10mm plasterboard, or one layer 13 mm high density sealed plasterboard (minimum surface density of 12.5 kg/m2), affixed using steel furring channels beneath ceiling rafters / supports. • R3.0+ insulation batts laid in cavity. • Concrete or terracotta tile roof with sarking, or metal sheet roof with foil backed R2.0+ fibre insulation between steel sheeting and roof battens.	As per Quiet House B	• Acoustically rated openings and ductwork to provide a minimum sound reduction performance of Rw 40dB into sensitive spaces • Evaporative systems require attenuated ceiling air vents to allow closed windows • Refrigerant-based systems need to be designed to achieve National Construction Code fresh air ventilation requirements • Openings such as eaves, vents and air inlets must be acoustically treated, closed or relocated to building sides facing away from the corridor where practicable
	Side-on		As per Quiet House B 'Facing' above (Rw+Ctr values may be 3dB less, or max % area increased by 20%).				
	Opposite		As per Quiet House A 'Facing' above.				
C **Quiet House C+**	All	As per Quiet House B example above, except using double leaf masonry construction only. • Double brick: two leaves of 90mm clay brick masonry with: – A 50mm cavity between leaves – R2.0+ cavity insulation – resilient ties where required to connect • Double brick: two leaves of 110mm clay brick masonry with a 50mm cavity between leaves and R2.0+ cavity insulation	As per Quiet House C, except • No external doors for bedrooms with entry 'Facing' or 'Side-on' to transport corridor.	As per Quiet House C, except that • 'Side-on' requirements same as Quiet House C 'Facing'. • All windows into habitable areas comprise minimum 6 mm thick glazing in sealed awning or casement frames. Polymer (e.g. uPVC) window framing and hardware which cannot rattle loose should be used throughout. • Evaporative air conditioning systems are not recommended.	To Rw+Ctr 45dB As per Quiet House C, except • the roof must be concrete or terracotta tile construction with sarking (i.e. no steel sheet roof option). • Ceilings to bedrooms must be constructed from at least 2 overlapping layers of flush plasterboard.		

FIGURE 6 QUIET-HOUSE DESIGN PACKAGES C

6.6.3 Wheel Squeal

There is the potential for wheel squeal to be generated due to the radius of curvature of the track in the vicinity of the Oats Street Station and adjacent to Forward Street, East Vitoria Park, as appropriate. This has been accounted for in the noise modelling by the application of rail noise correction factors as given in Table 14.

There are two mechanisms that generate the phenomenon commonly referred to as "wheel squeal". The first and most common, flange contact noise, is caused by contact between the wheel flange and the side of the rail head and results in a broadband grinding noise.

Flange contact noise is mitigated by:

- Rail grinding to maintain the rail head profile.
- Wheel turning to maintain wheel profiles.
- Lubrication of the contact between the wheel flange and the side of the rail.

The second is more correctly termed as wheel squeal and is caused by the uncontrolled slippage of the inner most wheel. This sets up resonant modes in the wheel web and results in a noise that appears to have a distinct tone to it.

Wheel squeal can be mitigated by:

- Dampers that modify the resonant behaviour of the wheel web.
- Use of friction modifiers on the rail head to maintain a constant level of friction between wheel and the rail at the contact patch.

It is difficult to predict which (or both) of these mechanisms is causing squeal, and trials of lubrication and friction modifiers are the quickest method of determining this. Suppliers of the products are often willing to demonstrate/test their products in a trial.

6.6.4 Noise Mitigation Design Summary

Figure 7 below provides a map of the potential noise wall locations (refer to Table 17 and Appendix H for latest extents).

FIGURE 7 NOISE WALL LOCATION REQUIREMENTS FOR LXR PROJECT

Details of the proposed designed noise walls are given in Table 17 and are depicted in Appendix D.

TABLE 17 PROPOSED NOISE WALL (NW) DETAILS

Noise Wall (NW)	Segment	Height (m)	Length (m)	Chainage From	Chainage To
NWW-1	1	1.5	88	5282	5370
NWE-1	1	1.5	247	5414	5661
NWW-2	1	1.5	330	11360	11690
NWE-2	1	1.5	628	11144	11772
	2	2.0	57	11772	11829

NWW-1

NWW-1 is 1.5 metres high and approximately 88 metres long. It runs adjacent to the railway line and Mytilene Drive, Victoria Park, north of Miller Street.

NWE-1

NWE-2 is 1.5 metres high and approximately 247 metres long. It runs adjacent to the railway line and Rutland Avenue, Lathlain, south of Miller Street.

NWW-2

NWW-2 is 1.5 metres high and approximately 330 metres long. It runs adjacent to the railway line and Sevenoaks Street, Cannington, from Bent Street to Crawford Street.

NWE-2

NWE-3 ranges from 1.5 metres high to 2.0 metres high and is approximately 685 metres long, with the 1.5 metre high section being 628 metres long and the 2.0-metre high section being 57 metres long. It runs adjacent to the railway line and Railway Parade, East Cannington, from Gerard Street to Albion Street.

6.7 Predicted Noise Levels – Mitigated

The following sections provide an assessment of the predicted noise levels following the installation of the mitigation recommended in Section 6.6.

Table 18 provides a summary of the number of receivers at which predicted rail noise levels are compliant with, within 2 dB, and exceeding the design noise criteria by greater than 2 dB.

TABLE 18 MITIGATED RECEIVER COMPLIANCE - $L_{AEQ,DAY}$, $L_{AEQ,NIGHT}$ AND L_{AMAX}

Descriptor	Number of receivers	Compliant	Within 2dB	Exceeds > 2dB
$L_{Aeq,Day}$	1431	1431	-	-
$L_{Aeq,Night}$	1431	1431	-	-
L_{Amax}	1431	1431	-	-

In the mitigated scenario, predicted rail noise levels achieve the day-time, night time and maximum noise criteria at all receiver locations

6.8 Non-Compliant Receiver Locations

In the mitigated scenario, predicted rail noise levels achieve the $L_{Aeq,Day}$, $L_{Aeq,Night}$ and L_{Amax} design noise criteria, and no non-compliant noise-sensitive receiver locations are identified.

6.9 Post-Construction Noise Monitoring

The *Victoria Park-Canning Level Crossing Removal Scope of Work and Technical Criteria* requires the following in Book 3 Part A Section 14.5:

> *The Alliance shall carry out operational noise and vibration measurement compliance testing in accordance with Book 3 - Part B Noise and Vibration section. Noise and vibration monitoring shall be undertaken by a suitably qualified person within three months of the opening of the proposal. In addition, noise and vibration monitoring should be undertaken by a suitably qualified person again after 18 months of the opening of the proposal.*

SWTC Book 3 Part B Section 3.10 requires that the NOP shall carry out:

Operational noise and vibration measurement compliance Testing in accordance with Book 4 Noise and Vibration section.

> *Noise and vibration monitoring shall be undertaken by a suitably qualified person within three months of the opening of the proposal.*
>
> *Noise and vibration monitoring should be undertaken again after 18 months of the opening of the proposal by a suitably qualified person.*
>
> *Each monitoring event shall be over a minimum period of seven (7) days at sensitive premises as detailed in the operational NVMP.*
>
> *Additional monitoring locations shall be added where residential or tenancy areas are developed within and/or adjacent to the proposal prior to the commencement of Project Activities.*
>
> *Monitoring shall also be undertaken at sensitive receptors where complaints have been received.*

> *The NOP shall allow for one additional round of Testing in the event that earlier Testing identified a requirement for further investigation.*
>
> *Compliance measurement Reports shall be submitted to the PTA's Representative not later than three weeks after the Tests are completed.*
>
> *Should a potentially affected building remain incomplete at the time of the compliance measurements, the likely vibration and ground-borne noise levels shall be determined by measurements in the nearest or most similar space, supplemented by calculations, as appropriate.*

While it is not appropriate within this design report to identify specific noise monitoring locations, the outcomes of the acoustic assessment contained within will drive the determination for monitoring locations, and may propose:

a) Locations at which the rail noise criteria are predicted to be marginally exceeded i.e. within the 2 dB tolerance.

b) Locations at which the rail noise criteria are predicted to be exceeded i.e. greater than the 2 dB tolerance.

c) Locations at which a significant change from the existing (pre-project) noise levels is predicted.

d) Comparative locations between areas in which noise mitigation measures have, and have not, been implemented.

Input from the community consultation team will also be sought in relation to locations at which there is justifiable community concern over post-construction noise and vibration levels.

The development of a Noise and Vibration Monitoring Plan, incorporating monitoring locations, monitoring methodology and specific reporting requirements, will be undertaken at later stages of the project.

7 Operational Vibration Assessment

Vibration generated by the trackform is driven by the force of the unsprung mass. This force is transmitted to the rails when the wheels roll on the rail and is highly dependent on the wheel and rail roughness. Smoother wheels and rails would transmit less force and hence generate lower vibration levels.

Vibration generated is also dependent on the stiffness of the trackform, with a higher stiffness trackform typically yielding higher vibration levels. As well as the resilient components in the track (e.g. rail pads, under sleeper pads or ballast mats), the trackform stiffness is dependent on the stiffness of the ballast and the ground below it.

The following sections describe the methodology used to assess vibration and ground-borne noise.

Note that vibration associated with the project to buried infrastructure and to station buildings does not form part of this assessment and is addressed in separate reports.

7.1 Vibration Criteria

The vibration criteria for the project from the SWTC Book 4 Part 3 Section 13.7.1 are presented in Table 19. The receptors currently closest to the alignment are primarily single storey residential, with educational, community and child-care facilities within the project area. Receivers also include commercial and industrial premises. These criteria also apply to future buildings which have Development Approval at the time of the procurement contract. Future buildings may include residential buildings, hotels and overnight accommodation along or adjacent to the route.

The project will consider the use of reasonable and practicable controls if these levels are predicted to be exceeded.

The criteria related to vibration in a building are specified as a vibration velocity level with units of decibels, reference 1 nanometre per second (1e-9 m/s). The $L_{v,RMS,1s}$ metric is the highest average level over a 1-second time period and these levels are equivalent to the lowest base curve levels (vertical axis, rms level) for critical working areas (Curve 1); residential properties during the day (Curve 2); offices (Curve 3); and workshops (Curve 4) from AS 2670.2:1990 (equivalent to ISO 2631.1:1997). These versions of the standards are no longer current and this guidance on criteria has been removed in the subsequent revisions due to the uncertainty associated with determining human response to vibration.

In additional to a limit on the overall vibration level in terms the $L_{v,RMS,1s}$ it is implied that the equivalent spectral criteria are also relevant as described by the multipliers of the base curve, e.g. Curve 2 etc.

The regenerated or ground-borne noise (GBN) criteria are quoted as the maximum 1-second sound pressure level with an A-weighting applied. These originate from the *NSW Railway Infrastructure Noise Guideline* (RING) with the exception of the residential and hotel accommodation night-time level which is stated in the SWTC as 40 dB L_{ASmax}, rather than 35 dB as found in the RING.

TABLE 19 PROJECT RAIL OPERATIONS VIBRATION CRITERIA

Parameter	Criterion	Value	Basis
Rail Operations – Design Level	Vibration levels from rail operations will be managed as low as is reasonably practicable.	Demonstrated	Industry best practice
Rail Operations Building Vibration Trigger Level	Mitigation of vibration via ground or structural pathways must be considered where the vector sum rail operations building vibration trigger level is exceeded as applicable to the 95th percentile train passby event measured at a reasonably representative location of the building		AS2670.2:1990

Parameter	Criterion	Value	Basis
	occupancy, with appropriate use of frequency weightings from ISO 2631.1:1997 as amended or AS ISO 2631.2:2014.		
	Medical clinical treatment, surgery or recovery areas, or facilities operating precision equipment	Curve 1 ($L_{v,RMS,1s}$ 100dB)	ISO2631, ASHRAE guidelines
	Residential and hotel accommodation	Curve 2 ($L_{v,RMS,1s}$ 106dB)	
	Commercial premises, public buildings, Churches and community centres and the like	Curve 4 ($L_{v,RMS,1s}$ 112dB)	
	Light and general industrial buildings	Curve 8 ($L_{v,RMS,1s}$ 118dB)	NSWRING
Rail Operations Regenerated Noise/Ground-Borne Noise Trigger Level	Mitigation of vibration via ground or structural pathways must be considered where the rail operations regenerated noise trigger level is exceeded as applicable to the 95th percentile train passby event and measured at centre of reasonably representative interior space(s) of each building usage.		NSWRING
	Residential and hotel accommodation, 10pm to 6am	L_{ASmax} 35dB	
	Residential and hotel accommodation, 6am to 10pm	L_{ASmax} 40dB	
	Commercial buildings, public buildings, Churches and community centres and the like	L_{ASmax} 45dB	
	Retail and point of sale areas, occupiable light and general industrial buildings	L_{ASmax} 50dB	
	Occupiable light and general industrial buildings	L_{ASmax} 50dB	

7.2 Vibration Modelling

The vibration modelling requirements relating to receivers outside the rail corridor are specified in SWTC Book 4 Part 3 Section 13.3, as follows:

Detailed description of the design, assumptions, methodology, baseline testing, extrapolation modelling and calculation process including how each model accounts for:

- *Relevant dynamic and static properties of the trainset rolling stock and supporting structure.*
- *Variation in train length and speed.*
- *The source noise and vibration levels and accounts for changes in the selected track form and unique local features such as Turnouts.*
- *Vibration losses entering buildings and amplification effects within each floor level.*
- *Propagation losses and variation in ground conditions such as Stratification in sandy soils; and*

Full detailed description of the design and engineering mitigation strategy, maintenance strategy and all other relevant factors.

Description and quantification of the accuracy of input parameters and predictions, how any uncertainty will be resolved or have been resolved during the design process; and

Evidence that the noise and vibration prediction model has been Verified and Validated by a suitably qualified person.

7.2.1 Methodology

An empirical model will be used in the next design phase to predict the vibration and regenerated noise using measured vibration data presented in Section 5.3 and Section 7.2.2.

The measured data was obtained on the ground surface. Thus, corrections to these data will be applied to estimate the vibration in a building and the internal radiation of sound from the building vibration. Where required, corrections to these data will also be made for train speed. These corrections are described in Section 7.2.3.

The measured data was obtained from trains operating on ballasted track. In order to assess the effects of track-based mitigation, frequency-dependent corrections were predicted for the different trackforms and applied to the measured data using a semi-analytical model (Section 7.2.6).

Both ground vibration levels and regenerated noise will be assessed at stations and noise-sensitive premises adjacent to the rail corridor.

7.2.2 Measured Data

Section 5.3 describes the vibration measurements from passenger trains at two locations on the LXR rail corridor.

Spectral data was also obtained from the measurements. A summary is provided in Table 20 and shown graphically in Figure 8.

TABLE 20 SPECTRUM DISTRIBUTION – VIBRATION MEASUREMENTS

1/3 Octave Band Centre Frequency	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
	Maximum Lv,RMS,1s dB			95th Percentile (L5) Lv,RMS,1s dB		
4	44	38	-	44	38	-
5	49	38	-	49	38	-

1/3 Octave Band Centre Frequency	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
	Maximum Lv,RMS,1s dB			95th Percentile (L5) Lv,RMS,1s dB		
6	47	40	-	46	40	-
8	55	57	55	54	56	54
10	60	62	57	60	61	57
12	59	55	52	59	55	52
16	61	59	57	60	58	56
20	62	67	61	60	62	59
25	65	73	66	64	71	65
31	75	79	78	75	78	74
40	78	75	71	75	75	69
50	73	72	67	73	71	65
63	78	71	70	76	71	64
80	76	75	71	75	75	62
100	73	75	75	71	75	57
120	67	77	76	67	77	57
160	65	60	56	63	58	47
200	56	54	52	54	52	47
250	53	52	54	50	51	47
315	49	53	51	49	52	45
400	52	53	51	51	52	45

This graph also shows that the highest levels of vibration occur at frequencies below 125 Hz. The magnitude of vibration at these low frequencies is due to the characteristics of the ground through which the vibration propagates and this has implications for mitigation (Section 7.2.4).

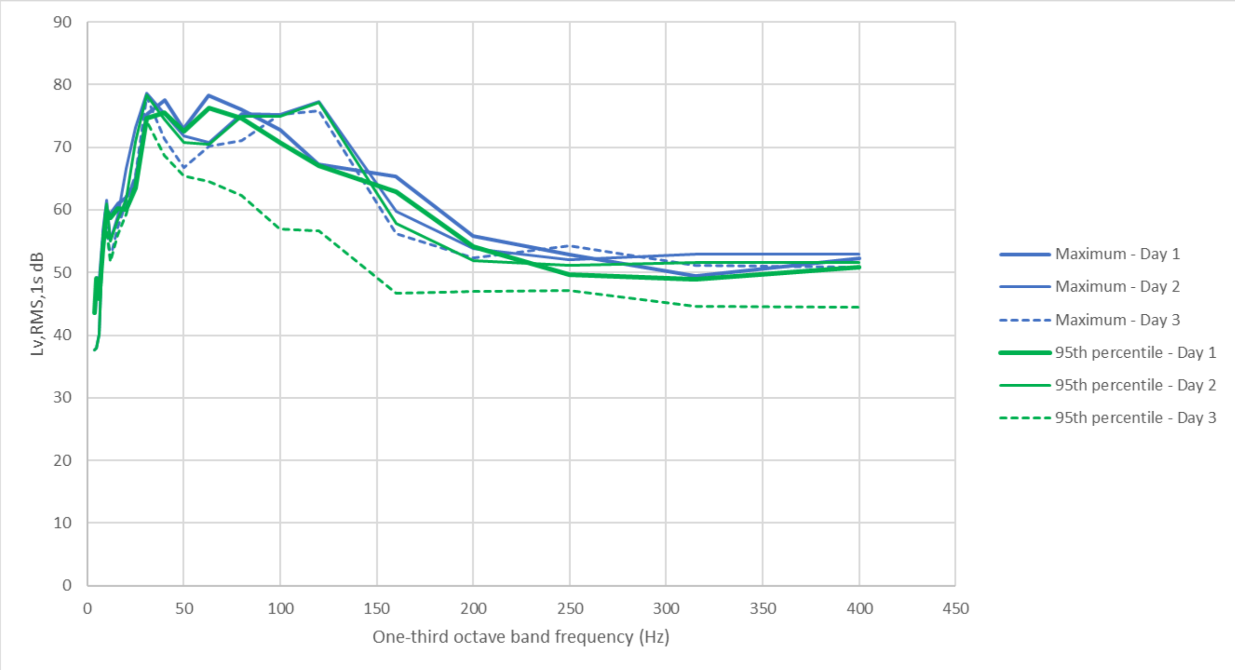

FIGURE 8 SPECTRAL COMPOSITION OF MEASURED VIBRATION LEVELS

7.2.3 Applied Corrections

The following sections describe corrections which are to be made to the data to account for transmission of vibration into buildings, the conversion of vibration to sound and for changes in train speed.

7.2.3.1 Ground to Building

When vibration passes from one medium to another, there is a reduction in vibration which is referred to as a coupling loss. This may occur between the ground and a structure and between subsequent floors. Also, there may be an increase in noise and vibration due to amplification of incoming source levels in which the structural response at any location within the building will depend on the structural rigidity of the element.

Adjustments to received vibration within structures is presented in Table 21, as given in *LXR-MNO-SLR-NV-RPT-001_4*.

TABLE 21 GROUND COUPLING LOSS

Aspect	Scenario	Third octave band centre frequency, Hz																		
		5	6.3	8	10	12	16	20	25	31.5	40	50	63	80	100	125	160	200	250	315
Coupling loss between structure and groundsoil	Large Masonry on Piles	-6	-6	-6	-6	-7	-7	-7	-8	-9	-10	-11	-12	-13	-13	-14	-14	-15	-15	-15
	Large Masonry on Spread Footings	-11	-11	-11	-11	-12	-13	-14	-14	-15	-15	-15	-15	-14	-14	-14	-14	-13	-12	-11
	2-4 Storey Masonry on Spread Footings	-5	-6	-6	-7	-9	-11	-11	-12	-13	-13	-13	-13	-13	-12	-12	-11	-10	-9	-8
	1-2 Storey Commercial	-4	-5	-5	-6	-7	-8	-8	-9	-9	-9	-9	-9	-9	-8	-8	-8	-7	-6	-5
	Single Residential	-3	-3	-4	-4	-5	-5	-6	-6	-6	-6	-6	-6	-6	-5	-5	-5	-5	-5	-5
Floor to floor adjustment (per floor above ground)	1st floor	-1	-1	-1	-1	-1.5	-1.5	-1.5	-2	-2	-2	-3	-3	-3	-2	-2	-2	-3	-3	-3
	2nd and above	-1	-1	-1	-1	-1.5	-1.5	-1.5	-2	-2	-2	-2	-2	-2	-3	-3	-3	-3	-3	-3
Amplification adjustment	Floor / wall vibration	+10	+10	+10	+10	+10	+10	+10	+11	+11	+11	+10	+9	+9	-	-	-	-	-	-
	Amplification, ground borne noise	-	-	-	-	-	-	+6	+7	+7	+8	+8	+7	+7	+5	+4	+3	+2	+1	+1

In addition, the vibration on suspended floors may be amplified by the response of the floor. The frequency-dependent coupling loss associated with this is presented in Table 22. This was determined by measurements taken within Perth (*TCYAD-SLR-EN-RPT-00003.6.0.IFI*).

TABLE 22 BUILDING COUPLING LOSS

One-third octave band centre frequency (Hz)	Coupling loss dB
8	0.7
10	5.7
12.5	1.7
16	0.3
20	-3.0
25	-8.5
31.5	-11.4
40	-13.4
50	-15.3
63	-13.5
80	-11.5
100	-7.6
125	-4.3
160	-4.4
200	5.7
250	-5.4
315	-2.3

7.2.3.2 Vibration to sound

A vibrating building radiates sound from the walls, floors and ceilings, resulting in regenerated or ground-borne noise. This typically only applies to situations where the airborne sound from a railway is effectively screened, for example, by a tunnel or deep cutting. A correction of -27 dB will be used between the vibration velocity in the building (in dB re 1 nm/s) and the radiated sound (in dB re 20 μPa).

7.2.3.3 Speed

As the speed of the train changes, the vibration generated changes. Typically, an increase in speed results in increased vibration. In this assessment a speed vibration correction of 4 dB per doubling of train speeds will be used. This has been determined by measurements on other projects.

7.2.4 Mitigation

The SWTC Book 3 Part A Section 17.1 stipulates the installation of "*Ballast mats for protection of structures where ballast would otherwise contact a structural element. For example (but not limited to) structural approach / transition slabs or ballasted bridge structures.*"

The SWTC Book 3 Part A Section 17.1.1 stipulates that "*Any application of geogrid, ballast mats, noise and attenuation measures shall not compromise overall track structure design, performance and operational requirements stated in code of practice.*"

Under ballast mats (UBM) are often used to mitigate regenerated noise as they typically mitigate vibration at frequencies of 40 Hz and above. As shown in Figure 8, the highest levels of vibration from the existing trains occur at frequencies of 125 Hz and below. The impact of any such ballast matting will therefore be considered in the next design phase.

7.2.5 Assumptions

The following assumptions will be made in this assessment:

- The new tracks will have the same or better rail roughness and vertical track geometry compared to that found on the tracks used for the vibration measurements (Section 5.3 and Section 7.2.2).
- The train speed profiles have been requested from the PTA; current data is that track speeds are 90 km/hr for both UP and DOWN directions.

7.2.6 Vibration Model and Parameters

7.2.6.1 CIVET

The CIVET (*Change In Vibration Emitted by Track*) model will be used to calculate the change in vibration due to a change in the track type (e.g. ballasted track on grade versus slab track on embankments versus slab track on the viaducts). This model is presented diagrammatically in Figure 9 in which the track is shown as the idealisation of a simple directly fixed track (rail, rail-pad, concrete slab).

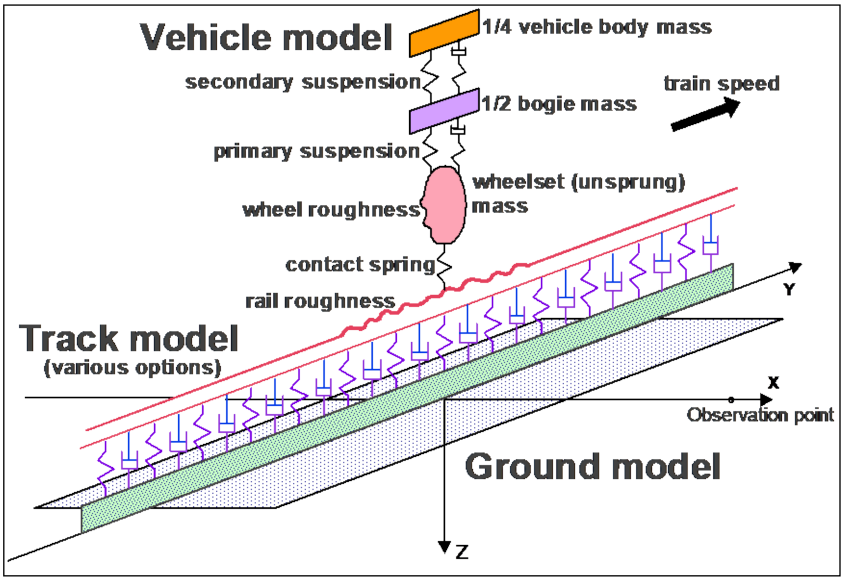

FIGURE 9 DIAGRAMMATIC REPRESENTATION OF THE CIVET MODEL

A full description of the model is given in "*Ground borne noise from new railway tunnels*" (Jones, Proceedings of Internoise 96).

The model allows several different sets of variables to be modified, giving options for track type, vehicle type, and the condition of the interface. For the vehicle, different unsprung masses and different suspension designs can be considered.

For the track, a complete range of different trackforms can be represented, using various combinations of layers as components, including ballasted (with sleeper-soffit pads, under-ballast mats and floating ballasted troughs) and non-ballasted (with directly fastened, resilient baseplates, booted sleepers and floating slab designs).

7.2.6.2 Parameters

The CIVET input parameters are detailed in Table 23to Table 25**.** These include the mitigation options:

- Ballast mats for ballasted track sections as per Section 7.2.4; and
- Pandrol e-Clips to slab tracks on viaducts.

A number of the parameters for these mitigation measures have been obtained from suppliers. If an alternative supplier is used, the assessment results will be the same provided the characteristics of the products are similar, such as the stiffness and damping of the resilient elements. Products with different characteristics will result in changes of the vibration and regenerated noise.

Some input parameters will be taken from the database of the MOTIV vibration modelling package. The MOTIV Project (https://motivproject.co.uk/motiv-software/) was a collaborative research project between the University of Southampton, Institute of Sound and Vibration Research (ISVR), and the University of Cambridge, Dynamics and Vibration Research Group (DVRG) with the aim to provide a good understanding of the generation and propagation of vibration from operational railways and its effects on nearby buildings.

The accuracy of input parameters determines the confidence in the predicted results. For the ground (Table 23), the primary parameter is the Young's modulus.

For the track (Table 24 for surface tracks and Table 25 for viaduct sections), the critical input parameters are the stiffnesses of the resilient elements, e.g. rail pads, baseplate pads; and ballast mats. These parameters have been sourced from data provided by the METRONET project and will be confirmed with the Project Rail Design Team and pad/mat manufacturers.

For the vehicle (Table 26), the most important parameter is the unsprung mass. This is the mass of the wheelset and any axle mounted traction motors which is below the primary suspension. In the absence of specific project data on this parameter the MOTIV standard value for this type of rolling stock has been used.

Confirmation that these conform to PTA-specific values and AS 1085 *Railway Track Materials* is being sought.

TABLE 23 GROUND PARAMETERS

Parameter	Value	Source
Soil density (kg/m^3)		Bassendean Sand
Soil damping loss factor		
Young's modulus (MN/m^2)		
Poisson ratio		
Soil density (kg/m^3)		Gnangara Sand
Soil damping loss factor		
Young's modulus (MN/m^2)		
Poisson ratio		
Soil density (kg/m^3)		Guilford Formation
Soil damping loss factor		
Young's modulus (MN/m^2)		
Poisson ratio		

TABLE 24 TRACK PARAMETERS – SURFACE RAILWAY (BALLASTED TRACK)

Parameter	Value	Source
Rail mass per unit length (kg/m)	50	METRONET Project Team
Rail moment of inertia (cm^4)	2940	
Rail Young's modulus (GPa)	1.13	
Rail fastener spacing (m)	0.7	
Rail fastener stiffness (kN/mm)	130	Standard value from MOTIV library for ballasted track
Rail fastener damping loss factor	0.1	
Sleeper mass (kg)	352	
Ballast mass per unit length (kg/m)	1740	
Ballast stiffness per unit length (MN/m^2)	4640	
Ballast damping loss factor	0.04	
Parameters for ballast mat H80 (20 mm) as part of the mitigated ballasted track:		
Ballast mat bedding modulus (N/mm^3)	0.067	Pandrol datasheet TDS-UBM-H80-S-20210216-EN
Ballast mat damping loss factor	0.2	AECOM database
Ballast mat width (m)	2.5	METRONET Project team
Parameters for ballast mat H100 (15 mm) as part of the mitigated ballasted track:		
Ballast mat bedding modulus (N/mm^3)	0.089	Pandrol datasheet TDS-UBM-H100-S-20210216-EN
Ballast mat damping loss factor	0.2	AECOM database
Ballast mat width (m)	2.5	METRONET Project team
Parameters for ballast mat Tiflek FC907C (25 mm) as part of the mitigated ballasted track:		
Ballast mat bedding modulus (N/mm^3)	0.022	Tiflex datasheet Trackelast DS FC907C
Ballast mat damping loss factor	0.2	AECOM database
Ballast mat width (m)	2.5	METRONET Project team

TABLE 25 TRACK PARAMETERS – VIADUCT RAILWAY (SLAB TRACK)

Parameter	Value	Source
Rail mass per unit length (kg/m)	50	METRONET Project team
Rail moment of inertia (cm^4)	2940	
Rail Young's modulus (GPa)	1.13	
Rail fastener spacing (m)	0.7	
Rail fastener stiffness (kN/mm)	130	Standard value from MOTIV library for ballastless track
Rail fastener damping loss factor	0.1	
Slab width (mm)	5300	METRONET Project Team
Slab depth – average across one track (mm)	1100	
Parameters for VIPA SP A baseplate as part of mitigated slab track:		
Baseplate mass (kg)	28	AECOM database
Baseplate pad stiffness (kN/mm)	12.5	Pandrol VIPA SP baseplate technical specification
Baseplate pad damping loss factor	0.15	AECOM database
Parameters for VIPA SP C/D baseplate as part of mitigated slab track:		
Baseplate mass (kg)	28	AECOM database
Baseplate pad stiffness (kN/mm)	23	Pandrol VIPA SP baseplate technical specification
Baseplate pad damping loss factor	0.15	AECOM database

TABLE 26 ROLLING STOCK PARAMETERS

Parameter	Value	Source
Car body mass (kg)	51,000	METRONET Project team
Car body pitching moment of inertia (kgm^2)	160,000	Standard value from MOTIV library for metro or suburban train on monoblock wheels
Bogie mass (kg)	8,000	AECOM - A-series EMU review
Bogie pitching moment of inertia (kgm^2)	3,600	Standard value from MOTIV library for metro or suburban train on monoblock wheels
Unprung mass (kg)	900	
Primary suspension stiffness (kN/m)	3,400	
Primary suspension viscous damping (kNs/m)	30	
Secondary suspension stiffness (kN/m)	1,600	
Secondary suspension viscous damping (kNs/m)	20	
Wheel radius (m)	0.3	
Wheelset centre spacing (m)	2.5	
Bogie centre spacing (m)	17	
Overall vehicle length (m)	24	Total length of 144 m divided by 6 cars
Speed of train (km/h)	Varies	METRONET Project team

Parameter	Value	Source
Number of vehicles	6	METRONET Project team

7.2.7 Vibration Model Validation

A regression analysis of the measured vibration data will be used to determine the source levels on the ground surface near to the line (i.e. an 'empirical' model). The measurements have been made on the existing alignment. Therefore, the empirical 'source' model will not require validation.

The corrections to be applied to the source data are all based on measurements made in similar situations (e.g. houses in Perth for the coupling loss). Therefore, these do not require validation.

Demonstrations of validation of the CIVET model can be found in *RENVIB II Final Report Phase 1 and Phase 2 (ERRI 2000)*.

7.3 Accuracy of Vibration Model Results

The U_{95} metric indicates the 95% confidence interval which represents the estimated range in which the true measurement value lies for 95 out of 100 identical tests. This is an internationally established acceptable level of risk.

The accuracy of the vibration model results is influenced by the following factors:

- The accuracy of the existing vibration measurement data.
- The potential differences between estimated and actual train speeds during the existing vibration measurements.
- The speed correction used.
- The length and consist of the trains during the existing vibration measurements as compared to those assumed to operate once the project is operational.
- The condition of track during existing vibration measurements as compared to that during operation of the project.
- The condition of rolling stock during the existing vibration measurements as compared to that which will operate on completion of the project.

ISO/IEC Guide 98-3:2008 *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*) provides an estimate of vibration prediction uncertainty, as presented in the METRONET assessment reporting (Table 27).

TABLE 27 ESTIMATED VIBRATION PREDICTION UNCERTAINTY

Vibration Descriptor	Element	U_{95}	Student's t-factor
$L_{v,RMS,1s}$	Measurements, modelling, corrections	6.0 dB	2.01

7.4 Post-Construction Vibration Monitoring

In accordance with the SWTC Book 3 Part A Section 14.5, Book 3 Part B Sections 3.10.0-2.0-2 and 3.10.0-2.0-2, and Book 4 Part 3 Section 13.9, post-construction noise and vibration compliance monitoring is to be undertaken over a period of seven days within 3 months, and again at 18 months, of the project's opening.

This operational noise and vibration testing is to be undertaken in accordance with the NVMP, which will be developed during the next phase of the project, and which will identify monitoring locations. In addition to these monitoring locations, the SWTC also requires:

- Additional monitoring locations shall be added where residential or tenancy areas are developed within and/or adjacent to the proposal prior to the commencement of Project Activities.
- Monitoring shall also be undertaken at sensitive receptors where complaints have been received.
- The NOP shall allow for one additional round of Testing in the event that earlier Testing identified a requirement for further investigation.
- Compliance measurement Reports shall be submitted to the PTA's Representative not later than three weeks after the Tests are completed.

While it is not appropriate within this design report to identify specific additional vibration monitoring locations, the outcomes of the acoustic assessment contained within will drive the determination for any supplementary monitoring locations, and may propose:

a) Locations at which the rail vibration criteria are predicted to be exceeded.
b) Locations at which a significant change from the existing (pre-project) vibration levels is predicted.
c) Comparative locations between areas in which vibration mitigation measures have, and have not, been implemented.

Input from the community consultation team will also be sought in relation to locations at which there is justifiable community concern over post-construction vibration levels.

The development of a NVMP, incorporating monitoring locations, monitoring methodology and specific reporting requirements, will be developed at later stages of the project.

8 Noise from Fixed Plant

Fixed infrastructure associated with the new passenger rail and relocated freight rail consists of the following:

- Power transformers
- Air conditioning units
- Signal equipment rooms (SER)
- Track-side equipment rooms (TSER)
- Power equipment rooms (PER)
- Communications equipment rooms (CER)
- Overhead line equipment (OLE) infrastructure

Noise from other project noise sources such as station passengers, public address announcements and from vehicle movements associated with the station car parks and bus movements do not form part of this assessment and are addressed in the following reports:

- Queens Park Station: LXR-PW-Z3-QP-SN-EN-RPT-00001
- Oats Street Station: LXR-PW-Z2-OT-SN-EN-RPT-00001
- Carlisle Station: LXR-PW-Z1-CR-SN-EN-RPT-00001
- Cannington Station: LXR-PW-Z3-CN-SN-EN-RPT-00001

8.1 Equipment Details

8.1.1 Air conditioning units, Power Transformers, SER, PER and CER Rooms

Data for air conditioning units is included in the stations design packages. Refer to individual stations reports as follows:

- Queens Park Station: LXR-PW-Z3-QP-SN-EN-RPT-00001 Section 5.1.1
- Oats Street Station: LXR-PW-Z2-OT-SN-EN-RPT-00001 Section 5.1.1
- Carlisle Station: LXR-PW-Z1-CR-SN-EN-RPT-00001 Section 5.1.1
- Cannington Station: LXR-PW-Z3-CN-SN-EN-RPT-00001 Section 5.1.1

8.1.2 TSER Rooms

Noise sources are expected to be air conditioning equipment servicing these rooms. Data for this equipment has not been confirmed at this stage of design, and will be addressed during the next design phase.

8.1.3 OLE Infrastructure

OLE infrastructure does not generate noise.

8.2 Criteria

The setting of noise emission criteria is intended to protect the acoustical amenity of nearby sensitive receivers.

Environmental noise impacts resulting from the Carlisle Station are addressed through the Environmental Protection Act 1986 with the prescribed standards detailed in the Western Australia *Environmental Protection (Noise) Regulations* 1997 (EPNR) as shown in Table 28. The regulations are based on maximum allowable noise levels termed the ‘assigned noise level’. The regulations require that:

> *Noise emitted from any premises when received at other premises must not cause, or significantly contribute to, a level of noise which exceeds the assigned level in respect of noise received at premises of that kind.*

A noise emission is taken to ‘significantly contribute to’ a level of noise if the noise emission exceeds a value which is 5 dB below the assigned level at the point of reception.

TABLE 28 ASSIGNED LEVELS BY THE WESTERN AUSTRALIAN ENVIRONMENTAL PROTECTION (NOISE) REGULATION 1997

Type of premises receiving noise	Time of Day	Environmental Emission Criterion Level dB(A)		
		$L_{A,10}$	$L_{A,1}$	$L_{A,max}$
Nearest noise sensitive receiver: highly sensitive area	0700 to 1900 hours Monday to Saturday	45 + influencing factor	55 + influencing factor	65 + influencing factor
	0900 to 1900 hours Sunday and public holidays	40 + influencing factor	50 + influencing factor	65 + influencing factor
	1900 to 2200 hours all days	40 + influencing factor	50 + influencing factor	55 + influencing factor
	2200 hours on any day to 0700 hours Monday to Saturday and 0900 hours Sunday and public holidays	35 + influencing factor	45 + influencing factor	55 + influencing factor
Noise sensitive premises: any area other than highly sensitive area	All hours	60	75	80
Commercial Premises	All hours	60	75	80
Industrial premises	All hours	65	80	90

The regulations also apply penalties on noise levels that contain annoying characteristics such as tonal components. Where these characteristics do exist and cannot be practicably removed, then the measured levels are adjusted according to the penalties as follows:

- Where tonality is present: +5 dB.
- Where modulation is present: +5 dB.
- Where impulsiveness is present: +10 dB.

The noise adjustments apply up to a maximum cumulative total of 15 dB.

The influencing factor is applied to account for higher noise areas as a result of nearby industrial and commercial areas and major roads. The influencing factor is determined by considering the land use within two circles having radii of 100 m and 450 m from the noise sensitive premises of concern and proximity to major and minor roads as defined in the EPNR.

Transport factors of 6 dB(A) and 2 dB(A) are also applied to noise sensitive receivers if major roads are located within 100 m and 450 m respectively. A transport factor of 2 dB(A) is applied to noise sensitive receivers if a secondary road is located within 100 m.

A major road is defined as having vehicle traffic flows in excess of 15,000 vehicles per day. A secondary road is defined as having traffic flows of 6,000 to 15,000 vehicles per day.

The environmental noise criteria for noise-sensitive receivers in the vicinity of fixed infrastructure are outlined in the stations reports; namely:

- Queens Park Station: LXR-PW-Z3-QP-SN-EN-RPT-00001 Section 4.1
- Oats Street Station: LXR-PW-Z2-OT-SN-EN-RPT-00001 Section 4.1
- Carlisle Station: LXR-PW-Z1-CR-SN-EN-RPT-00001 Section 4.1
- Cannington Station: LXR-PW-Z3-CN-SN-EN-RPT-00001 Section 4.1

8.3 Assessment

8.3.1 Air conditioning units, Power Transformers, SER, PER and CER Rooms

Noise associated with this equipment will be addressed as part of the Stations design packages. Refer to individual stations reports as follows:

- Queens Park Station: LXR-PW-Z3-QP-SN-EN-RPT-00001 Section 5.1.1
- Oats Street Station: LXR-PW-Z2-OT-SN-EN-RPT-00001 Section 5.1.1
- Carlisle Station: LXR-PW-Z1-CR-SN-EN-RPT-00001 Section 5.1.1
- Cannington Station: LXR-PW-Z3-CN-SN-EN-RPT-00001 Section 5.1.1

8.3.2 OLE Infrastructure

OLE infrastructure does not generate noise and is therefore not assessed.

9 Risks and opportunities

A list of risks and opportunities identified in the RD alignment were noted in an alliance wide register.

10 Systems Engineering

10.1 Safety in design

Safety in Design and Hazard Workshops for RD are held as the design progresses. A list of Safety in Design workshops is summarised in Table 29. The purpose of the workshops is to identify and eliminate preliminary risks during the RD phase arising from the station design, that may result in hazards to personnel in the Construction and O&M phases; and if it is not reasonably practicable to eliminate risk, to minimise those risks so far as is reasonably practicable (SFAIRP).

TABLE 29 SAFETY IN DESIGN WORKSHOPS

SiD Session	Safety in Design
HAZID and Analysis Workshop 01 – Stations – RD (11th May, 2022)	Safety in Design (SiD) and Hazard Identification (HAZID) / analysis for RD Stations.

10.2 Reliability, Availability and Maintainability RAMS

Reliability, Availability and Maintainability (RAM) analysis is a systems engineering process in place to ensure that the design life, durability, maintenance and progressive degradation of permanent works items are adequate.

RAM analysis does not form part of the Acoustic scope of works.

10.3 Human Factors

Human Factors (HF) integration does not form part of the Acoustic scope of works.

11 Quality Management

Design verification has been undertaken with the requirements outlined in the Engineering Management Plan (LXR-ALUA-EA-PLN-00001).

11.1 Design Review Process

The design review process for the Reference Design is summarised in Table 30.

TABLE 30 DESIGN REVIEW PROCESS

Review Process	Duration [working day(s)]	Dates (close of business)
Verification	10	21st June 2022
IDC	Day 10	5th July 2022
Update	3	8th July 2022
IV/ISA	10	22nd July 2022
Comment Closeout	3	27th July 2022

Appendix A - STATEMENT OF COMPLIANCE

Internal verification of requirements from SWTC Books 3A and 4.

Appendix B - RECEIVER LOCATIONS

ARMADALE LINE UPGRADE ALLIANCE

DATUM GDA 1994, PROJECTION MGA ZONE 55

0 37.5 75 150

metres

N

1:3,500 (when printed at A3)

Proposed Alignment

Community and Places of Worship

House ID

House ID

Education

Armadale Line
Level Cross Removal Project
Scenario: Build for Year 2042
Post Mitigation

Day Period (6am - 10pm)

PROJECT ID 60676692
CREATED BY JZ
LAST MODIFIED JZ - 21/07/2022

ARMADALE LINE UPGRADE ALLIANCE

DATUM GDA 1994, PROJECTION MGA ZONE 55

0 37.5 75 150

metres

N

1:3,500 (when printed at A3)

Proposed Alignment

Community and Places of Worship

House ID

House ID

Education

Armadale Line
Level Cross Removal Project
Scenario: Build for Year 2042
Post Mitigation

Day Period (6am - 10pm)

PROJECT ID 60676692
CREATED BY JZ
LAST MODIFIED JZ - 21/07/2022

ARMADALE LINE UPGRADE ALLIANCE

DATUM GDA 1994, PROJECTION MGA ZONE 55
0 37.5 75 150
metres
N
1:3,500 (when printed at A3)

Proposed Alignment

House ID

House ID

Community and Places of Worship

Education

Armadale Line
Level Cross Removal Project
Scenario: Build for Year 2042
Post Mitigation

Day Period (6am - 10pm)

PROJECT ID 60676692
CREATED BY JZ
LAST MODIFIED JZ - 21/07/2022

ARMADALE LINE UPGRADE ALLIANCE

DATUM GDA 1994, PROJECTION MGA ZONE 55

0 37.5 75 150

metres

N

1:3,500 (when printed at A3)

Proposed Alignment **Community and Places of Worship**

House ID **Education**

House ID

Armadale Line
Level Cross Removal Project
Scenario: Build for Year 2042
Post Mitigation

Day Period (6am - 10pm)

PROJECT ID 60676692
CREATED BY JZ
LAST MODIFIED JZ - 21/07/2022

ARMADALE LINE UPGRADE ALLIANCE

DATUM GDA 1994, PROJECTION MGA ZONE 55

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metres

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1:3,500 (when printed at A3)

Proposed Alignment

Community and Places of Worship

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Level Cross Removal Project
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Post Mitigation

Day Period (6am - 10pm)

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metres

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1:3,500 (when printed at A3)

Proposed Alignment

Community and Places of Worship

House ID

House ID

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Armadale Line
Level Cross Removal Project
Scenario: Build for Year 2042
Post Mitigation

Day Period (6am - 10pm)

PROJECT ID 60676692
CREATED BY JZ
LAST MODIFIED JZ - 21/07/2022

Appendix C - PREDICTED NOISE LEVELS

(to be updated with final IDD Report)

Appendix D - NOISE MAPS

(to be updated with final IDD Report)

Appendix E- THIRD PARTY VERIFICATION REPORT

(To be attached when available.)

Victoria Park - Canning Level Crossing Removal
Armadale Line Upgrade Alliance

Design Pkg Title:	ONVDR_Rev A	Design package	
Design Report No.:		Rev B	
Reviewer/ Verifier:	Select	REVIEW OUTCOME (LEAD REVIEWER TO ASSIGN):	Select
Design Stage:	A1 - RD Internal/IV Review		

REVIEWER COMMENT CLASSIFICATION:
O - Observation / Designer to acknowledge
P - Potential Non-Compliance: Moderate issue requires response from Designer
N - Non-Compliance: Significant design deficiencies requires immediate action
D - Deferred to next stage

REVIEW COMMENT/RESPONSE STATUS
O - Open
C - Closed
CA - Closed AGAINST this package (but open in other package)
CS - Closed SUBJECT TO additional action / information

Item	Reviewer (N. Last Name)	Reference (Dwg or Doc.)	Revision	Classification (O, P, N, D)	Reviewer Comment	Date	Comment Accepted?	Designer / Design Consult Response	Design Lead (N. Lastname)	Date	Response Status (O, C, CA, CS)	Reviewer Comment on Response	Date
<------ Reviewer to Fill ------>							<------ Designer to Complete ------>				<------ Reviewer to Complete ------>		
RD DETAILED DESIGN REVIEW													
1	L. Zoontjens	Sections 5.3 and 7.2.2, LXR-PW-Z0-GN-RL-NW-RPT-00001 Package 007 Operational Noise and Vibration Design report	A01	P	Levels reported are vastly (30+ dB) below that expected, can this be checked and more information please be provided to verify - not enough detail to reproduce. Series A trains have 5th percentile values are typically measured in the range Lv,RMS,1s 105 to 115 dB at 10-15 metres in groundsoil.	29-Aug-2022	Accepted	This is a mismatch between the actual data measured (which closely aligns to Lv,RMS,1s 105 to 110 dB at 10-15m) and that reported - we will re-interrogate the raw data and update the reported values. The acutal data used in our assessment is the correct data. This will be updated/confirmed in the next stage of reporting/assessment.	Rachel Foster	07-Sep-2022			
2	L. Zoontjens	Section 5.4, LXR-PW-Z0-GN-RL-NW-RPT-00001 Package 007 Operational Noise and Vibration Design report	A01	P	Location 6 is quite near a vehicle crossing which would sound as the train passes through. How was the influence of these bells addressed?	29-Aug-2022	Accepted	The operational rail noise model (existing) is calibrated against the attended noise measurements and those unattended noise measurement locations for which there is minimal influence of extraneous sources (significant road traffic, stations, crossing signals etc). Location 6 is not included in the rail noise	Rachel Foster	07-Sep-2022			
3	L. Zoontjens	Section 5.5, LXR-PW-Z0-GN-RL-NW-RPT-00001 Package 007 Operational Noise and Vibration Design report	A01	O	Generally measurement uncertainty is a function of the measurement system (equipment) and procedures used. Given ALUA are using different equipment and methods, the stated uncertainty may be different to that quoted in the SLR report.	29-Aug-2022	Accepted	Will call Luke Z to discuss.	Rachel Foster	07-Sep-2022			
4	L. Zoontjens	Section 5.6 Table 9, LXR-PW-Z0-GN-RL-NW-RPT-00001 Package 007 Operational Noise and Vibration Design report	A01	N	At 15 metres, Table 5 indicates a median SEL of 91 dB which aligns to historical targets. However, in Table 9, the modelled SEL at 15 m is 87 dB, or 4 dB quieter. Why are the trains modelled as 4 dB quieter than that measured on site?	29-Aug-2022	Accepted	As per Item 1, this is a mismatch between the actual data measured and that reported, predominantly due to the complexities of the NORD2000 model inputs. The acutal data used in our assessment is the correct data. This will be updated/confirmed in the next stage of reporting/assessment.	Rachel Foster	07-Sep-2022			
5	L. Zoontjens	Section 5.6 Table 9, LXR-PW-Z0-GN-RL-NW-RPT-00001 Package 007 Operational Noise and Vibration Design report	A01	N	The ONVDR notes that the project involves a combination of slab track and ballasted track. Due to differences in trackform and pad stiffnesses (Table 25 shows this to be a ~10:1 ratio), the emission rates are substantially different. Slab track is generally substantially (>5 dB) louder due to softer pads and no ballast to provide sound absorption. However, in Table 9,	29-Aug-2022	Accepted	Will be confirmed in conjuntion with the vibration assessment (as per Item 1)	Rachel Foster	07-Sep-2022			
6	L. Zoontjens	Section 5.7, LXR-PW-Z0-GN-RL-NW-RPT-00001 Package 007 Operational Noise and Vibration Design report	A01	P	The validation here looks great but is suspected to change given items 2, 4 and 5 above. If it is the case that to match that measured, source levels are reduced but the environmental (ground and building shielding) assumptions are made more conservative, then an elevated viaduct	29-Aug-2022	Accepted	As identified in previous items, the actual data used in the noise modelling reflects the actual meaured data. Will be confirmed in the next phase of assessment.	Rachel Foster	07-Sep-2022			
7	L. Zoontjens	LXR-PW-Z0-GN-RL-NW-RPT-00001 Package 007 Operational Noise and Vibration Design report	A01	P	Could the report please include a table or figure showing the modelled track slab extents and also the modelled speed profile (speed versus chainage) in each direction.	29-Aug-2022	Accepted	Will be included in the next phase of reporting.	Rachel Foster	07-Sep-2022			
8	L. Zoontjens	Section 7.2.6.2, LXR-PW-Z0-GN-RL-NW-RPT-00001 Package 007 Operational Noise and Vibration	A01	P	Table 23 is empty.	29-Aug-2022	Accepted	Will be included/amended in the next phase of reporting.	Rachel Foster	07-Sep-2022			
9	L. Zoontjens	Section 7.2.6.2, LXR-PW-Z0-GN-RL-NW-RPT-00001 Package 007 Operational Noise and Vibration	A01	D	It's unclear whether the rail fastener stiffnesses for Table 24 and 25 are static or suitable dynamic, could this please be clarified.	29-Aug-2022	Accepted	Will be included in the next phase of reporting.	Rachel Foster	07-Sep-2022			
10	L. Zoontjens	Section 6.6.4 & Appendices, LXR-PW-Z0-GN-RL-NW-RPT-00001 Package 007 Operational Noise and Vibration Design report	A01	D	Text in various figures is unreadable, can these please be updated with high resolution images. Some of the maps present text results and colouring of individual houses - this is welcome however these numbers often do not correlate with the legends in the figure. Please correct in future updates.	29-Aug-2022	Accepted	Will be included/amended in the next phase of reporting.	Rachel Foster	07-Sep-2022			
11	L. Zoontjens	Appendix C, LXR-PW-Z0-GN-RL-NW-RPT-00001 Package 007 Operational Noise and Vibration	A01	O	Can Appendix C please list the street address and chainage of each receiver, or the labels in Appendix B be text searchable rather than a raster image. It is difficult to verify / compare	29-Aug-2022	Accepted	Will be included in the next phase of reporting.	Rachel Foster	07-Sep-2022			
12	L. Zoontjens	Section 6.6.4, LXR-PW-Z0-GN-RL-NW-RPT-00001 Package 007 Operational Noise and Vibration	A01	D	Check Figure 7 and the appendices, may need to be relabelled.	29-Aug-2022	Accepted	Will be included/amended in the next phase of reporting.	Rachel Foster	07-Sep-2022			
13	L. Zoontjens	Section 6.6.4, LXR-PW-Z0-GN-RL-NW-RPT-00001 Package 007 Operational Noise and Vibration Design report	A01	N	There does not appear to be a section which predicts incident vibration levels at individual receivers, as required by ID 1124263. Given item 1, the vibration assessment should be reviewed and updated.	29-Aug-2022	Accepted	As per precvious items, this will be included in the next phase of assessment / reporting.	Rachel Foster	07-Sep-2022			
14	L. Zoontjens	Section 7, LXR-PW-Z0-GN-RL-NW-RPT-00001 Package 007 Operational Noise and Vibration Design report	A01	N	There does not appear to be a section which predicts incident vibration levels at individual receivers, as required by IDs 1124263 and 1129044. Given item 1, the vibration assessment should be reviewed and updated.	29-Aug-2022	Accepted	As per precvious items, this will be included in the next phase of assessment / reporting.	Rachel Foster	07-Sep-2022			

Victoria Park - Canning Level Crossing Removal
Armadale Line Upgrade Alliance

Design Pkg Title:	ONVDR_Rev A		**Design package**	
Design Report No.:			Rev B	
Reviewer/ Verifier:	Select			**REVIEW OUTCOME (LEAD REVIEWER TO ASSIGN):** Select
Design Stage:	A1 - RD Internal/IV Review			

REVIEWER COMMENT CLASSIFICATION:
O - Observation / Designer to acknowledge
P - Potential Non-Compliance: Moderate issue requires response from Designer
N - Non-Compliance: Significant design deficiencies requires immediate action
D - Deferred to next stage

REVIEW COMMENT/RESPONSE STATUS
O - Open
C - Closed
CA - Closed AGAINST this package (but open in other package)
CS - Closed SUBJECT TO additional action / information

Item	Reviewer (N. Last Name)	Reference (Dwg or Doc.)	Revision	Classification (O, P, N, D)	Reviewer Comment	Date	Comment Accepted?	Designer / Design Consult Response	Design Lead (N. Lastname)	Date	Response Status (O, C, CA, CS)	Reviewer Comment on Response	Date
15	L. Zoontjens	Section 6, LXR-PW-Z0-GN-RL-NW-RPT-00001 Package 007 Operational Noise and Vibration Design report	A01	P	There does not appear to be any consideration of noise radiated by vibration of the viaduct. There are considered risks in that the individual span T-Roff design can generate significant low frequency noise from train movements. Can the report please include the basis on which such structural	29-Aug-2022	Accepted	As per precvious items, this will be included in the next phase of assessment / reporting.	Rachel Foster	07-Sep-2022			
16													
17													

IDD DETAILED DESIGN REVIEW

Appendix F - IDR CLOSEOUT RECORD LOG / DRN AND IDR REGISTER

Interdisciplinary Check Certificate

Supplier Details

Supplier Organisation:	ALUA	SEM Name:	John Selfridge
Contract Name:	TBD	Contract Number:	TBD

Project Details

Project Name:	Victoria Park-Canning Level Crossing Removal	PTA Project Number:	200140
CPE Name:	Steven Moran	Project Manager Name:	Binu Stanley
EM4P Phase:	Reference Design		

Deliverables Submitted

Deliverables Package Title and Description:	Reference Design – Noise and Vibration (ONVDR) Report Rev A		
Deliverables Package Reference Number:	N/A	Date Deliverables Submitted to PTA:	Wednesday, 7 September 2022
Description and List of Deliverables Being Reviewed		List of Deliverables Attached:	Yes

RD Deliverables:

Report:

ALUA Document Number	PTA Document Number
LXR-PW-Z0-GN-DT-RPT-00001	LXR-ALUA-NV-RPT-00005

Issues, Comments or Actions to be Addressed

1) Mike Sooi – Can Table 17 be added to the Exec Summary
2) Mike Sooi – Need to liaise with other disciplines (CPTED, Civil, etc) to help inform the final placement, type and height of the noise walls. Rachel – noted, we will liaise with those disciplines.
3) Kristen M – Temp and Perm MCR route will need to be taken into consideration with the final noise wall placement. Construction staging may also inform this (note the temp MCR will be one of the first things built). Rachel – noted, to be further coordinated in detailed design.
4) Mike Sooi – Could you please add the distance from track into table 17? Rachel – we can discuss this, but it will still be in flux until later in the design.
5) Flynn W – if the earthworks levels change, will the noise model need to be re-run? Rachel – yes, this will be iterative as the design matures.

Interdisciplinary Check Certificate

Interdisciplinary Check Details

Declaration: We, the undersigned, certify that the deliverables described with respect to the above project and/or contract, have been the subject of an interdisciplinary check in accordance with Procedure – Engineering Management for Projects (8110-100-013) and Procedure – Deliverables Review (8103-000-005). This check verifies that design checks and approvals have been carried out by competent personnel in accordance with the relevant standards and best practice.

PARTICIPANTS

Name	Discipline	SRE or Other Role Title	Signature
Wolfram Schwarz	Other Subject Area	Viaduct SRE / PE	
Ben Marshall	Other Subject Area	Station Structures SRE / PE	
John Paul Davies	Other Subject Area	Architecture SRE / PE	
Ian Thornely	Signals	Signalling SRE/PE	
Flynn Watervoort	Civil	Civil Corridor SRE / PE	
Stuart Ellis	Other Subject Area	Geotech SRE / PE	
Adarash Dhar	Mechanical	Mechanical SRE/PE	
Ian Woodhead	Other Subject Area	HV / TP SRE / PE	
Sean Sarenac	Track	Track SRE / PE	
Gina Zebreiro	Electrification	OLE SRE / PE	
Trevor Gross	Operational Technology	Comms and OT SRE / PE	
Rachel Foster	Noise & Vibration SME	Noise & Vibration SME	
Kristen Meling	Other Subject Area	Line-wide Package Manager	
Jenny Han	Other Subject Area	Fire & Life Safety SRE/PE	

Interdisciplinary Check Certification

As the appointed Supplier's Engineering Manager (SEM), I certify that: • all reasonable, professional skill and care have been used in the IDC described above; and • the staff who have carried out the review described above are suitably qualified and competent to carry out these duties.			
Submitted on behalf of the Supplier by:			
SEM Name:	John Selfridge		
Signature:		Date:	7/09/2022
Note: Only to be signed by the appointed SEM.			

Victoria Park Canning Level Crossing Removal

IDC/IDR Comment Sheet

Date 11/08/2022

Review task title:	Track Reference Design IDC	**Review task number** (where allocated):	IDC-DP05-001
Project name:	Victoria Park-Canning Level Crossing Removal	**Review activity code** (TR1,TR2, TR3, TR4, TR5, TR6):	TR2
Project number / phase:	200140 - Reference Design	**Review activity code description:**	
Review Co-ordinator	Kristen Meling	**Review budget hours allocation** (where allocated):	
Description of package to be reviewed and review activity required:	Viaduct and Welshpool Road PSP bridge Reference Design - Interdisciplinary Design Review with all ALUA SREs and OMTID Design Leads to interrogate the 2D and 3D design for clashes.		

Review participants

Reference/Item	IDC Reviewer	Discussion Item	IDC Reviewer comment (refer attached sheets where applicable)	SRE/Deisgn Lead//Originator response	PE Response	Comment Closeout	Status	Carry to IDR
OPERATIONAL NOISE AND VIBRATION REPORT – REFERENCE DESIGN	Kristen Meling.	Cover sheet page 1.	This is not the correct ALUA cover sheet. Please fix.	Fixed	Closed.	No action required.	Closed.	N
	David Peoples	Page 6.	Fix.	Fixed	Closed.	No action required.	Closed.	N
	David Peoples	Page 6.	Grammar correction.	Gramar fixed.	Closed	No action required.	Closed	N
	David Peoples	Page 33 - Figure 2	Fix (the image isn't showing on screen for me).	The Originator is on leave and the image does not appear to be on file. Therefore, Figure 2 has been removed. The same information is contained within the text so this is a minor change.	Closed	No action required.	Closed	N
	David Peoples	Page 35.	Fix (the image isn't showing on screen for me).	Fixed	Closed.	No action required.	Closed.	N
	David Peoples	Page 38.	I'm pretty sure it's just "01dB Duo" – no "Orion" for the noise monitor.	Names Fixed.	Closed.	No action required.	Closed.	N
	David Peoples	Page 38.	I think it's "01dB Orion Smart Vibration Monitoring Temrinal".	Names Fixed.	Closed.	No action required.	Closed.	N
	David Peoples	Page 39.	Don't forget to fill this table in.	Fixed	Closed.	No action required.	Closed.	N
	David Peoples	Page 46	Better to say "2 dB or more", as it makes more sense, and it what you've gone with in Section 6.5.	Fixed	Closed.	No action required.	Closed.	N
	David Peoples	Page 50.	Fix.	Fixed	Closed.	No action required.	Closed.	N
	David Peoples	Page 58 - Figure 9	This graph doesn't compare the levels to the criterion.	Fixed - graph title updated	Closed.	No action required.	Closed.	N
	David Peoples	Page 60.	It might be worth pointing out here that such mats can have a detrimental impact on the outcome and that analysis might reveal that mats aren't the way to go.	Comment rejected with justification from the originator, as follows: *I specifically didn't want to discuss this at this point in the design, until James has had a really good look at the model results. We are currently going through this on TCL and it would have been far simpler not to have raised the issue until a formal, calculated position had been arrived at.*	Closed.	No action required.	Closed.	N
	David Peoples	Page 60.	What?	Fixed	Closed.	No action required.	Closed.	N
	Kristen Meling.	Page 72.	Speak to Benny Tschorn for the SWTC extract (Verifier to complete the verification against this).	To be completed. The relevant SWTC clauses are reproduced in Table 4 of the report along with details of the report section where each clause is addressed.	Oustanding.	To be completed	Oustanding.	Y
	David Peoples	Appendix C Predicted Noise	Put in a description of the colours, e.g. red means non-compliant, bold means...	Colours implemented.	Closed.	No action required.	Closed.	N
	Kristen Meling.	Appendix F	Template to use:	Comment sheet completed	Closed.	No action required.	Closed.	N

Record of task completion and agreement of comments

Reviewer - The review task as described above has been undertaken and the package has been reviewed to be appropriate and correct for the scope of the review undertaken.		**Designer / originator - The above review comments have been addressed and incorporated or**	
Review Co-ordinator:	Kirsten Meling	**Designer / originator:**	Rachel Foster.
Organisation:	ALUA	**Organisation:**	ALUA
Signature:	[signature]	**Signature:**	[signature]
Date:		**Date:**	11-Aug-22

Page 1 of 1
Date Printed: 11/08/2022

Victoria Park Canning Level Crossing Removal		
IDC_IDR Review Comment Sheet		07-Sep-22

Review task title:	ONVDR (LXR-PW-Z0-GN-DT-RPT-00001) Rev A	**Review task number** (where allocated):	
Project name:	Victoria Park-Canning Level Crossing Removal	**Review activity code** (TR1,TR2, TR3, TR4, TR5, TR6):	TR2
Project number / phase:	200140 - Reference Design	**Review activity code description:**	
Review Co-ordinator	Kristen Meling	**Review budget hours allocation** (where allocated):	
Description of package to be reviewed and review activity required:	**ONVDR Report - Rev A**		

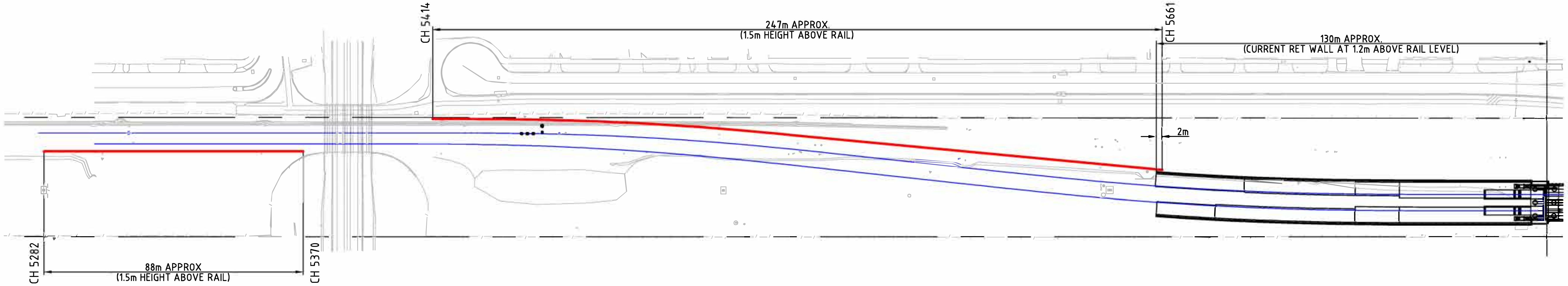
Review participants

Reference/Item	IDC Reviewer	Discussion Topic / Item	IDC/ Reviewer Comment (refer attached sheets where applicable)	SRE/Deisgn Lead//Originator Response	PE Review Comments	Response / Comments Closeout	COMMENTS CATEGORY (1,2,3)	Status	Carry to IDR
Reference Design - Internal Review and IDC Comments									
Traction Power and E&B PE:									
C.1.10 C.2.7	Ian Woodhead	DC Stray Current	The Section makes reference to Stray Current Induced Corrosion and DC Traction Currents. Armadale is a 25kV AC Railway. Please can you remove all reference to DC Stray Currents from this report? AC Railways have leakage current, which is return current, glowing in bonded strutures, into the mass of earth, and back into the nearest conded structure. This is a well known and documented behaviour of AC traction return current, which does not cause corrosion due to DC stray current.	Rachel Foster - I will set up a meeting to discuss this in more detail so the wording can be updated in Rev B.	Rachel Foster - As per column E.		1	O	N
Design Considerations	Ian Woodhead	DC Stray Current	Mentions Stray Current Corrosion	Rachel Foster – noted.	Rachel Foster - No action needed.	Closed	1	C	N
Table 4	Ian Woodhead	DC Stray Current	Book 4 makes reference to Stray Currents and presumably has a DOORS reference to it 920124 and 1128554. Please can these requirements be addressed as it will be impossible to address this as the earthing and bonding of a DC railway is the opposite to the E&B of an AC railway. If not addressed, then this will be a nightmare to deal with at a later stage.		Rachel Foster - As per column E.		1	O	N
Structures & Viaduct PE:									
IDC	Mike Sooi / Wolfram Schwarz	Report	Can Table 17 be added to the Exec Summary	Rachel Foster – Yes, will add in the next revision.	Rachel Foster - As per column E.		1	O	N
IDC	Mike Sooi / Wolfram Schwarz	Noise Wallls	Need to liaise with other disciplines (CPTED, Civil, etc) to help inform the final placement, type and height of the noise walls.	Rachel Foster – noted, we will liaise with those disciplines for detailed design.	Rachel Foster - As per column E.		1	O	N
IDC	Mike Sooi / Wolfram Schwarz	Report	Could you please add the distance from track into table 17?	Rachel Foster – we can discuss this, but it will still be in flux until later in detailed design.	Rachel Foster - As per column E.		1	O	N
Package Manager:									
IDC	Kristen Meling	MCR interface	Temp and Perm MCR route will need to be taken into consideration with the final noise wall placement. Construction staging may also inform this (note the temp MCR will be one of the first things built).	Rachel Foster – noted, to be further coordinated in detailed design.	Rachel Foster - As per column E.		1	O	N
Civil Corridor PE:									
IDC	Flynn Watervoort	Earthworks / noise walls	If the earthworks levels change, will the noise model need to be re-run?	Rachel Foster – yes, this will be iterative as the design matures. We will work with you to ensure changes are re-modelled as needed.	Rachel Foster - As per column E.		1	O	N
Signalling PE:									
IDC	Ian Thornely (Signalling PE/SRE)	Report	No comments related to signalling.	Rachel Foster - Noted.	Rachel Foster - No action needed.	Closed	1	C	N
Track PE:									
IDC	Sean Sarenac Track SRE PE	Report	No comments related to track.	Rachel Foster - Noted.	Rachel Foster - No action needed.	Closed	1	C	N
LV Electrical PE:									
IDC	Shafir Ahamed _ Electrical SRE/PE	Report	No comments for LV	Rachel Foster - Noted.	Rachel Foster - No action needed.	Closed	1	C	N
FLS PE:									
IDC	Jenny Han _ FLS SRE/PE	Report	No comments related to Fire & Life Safety	Rachel Foster - Noted.	Rachel Foster - No action needed.	Closed	1	C	N
Station Structures PE:									
IDC	Ben Marshall PE	Report	No comments related to Station Structures	Rachel Foster - Noted.	Rachel Foster - No action needed.	Closed	1	C	N
Architecture PE:									

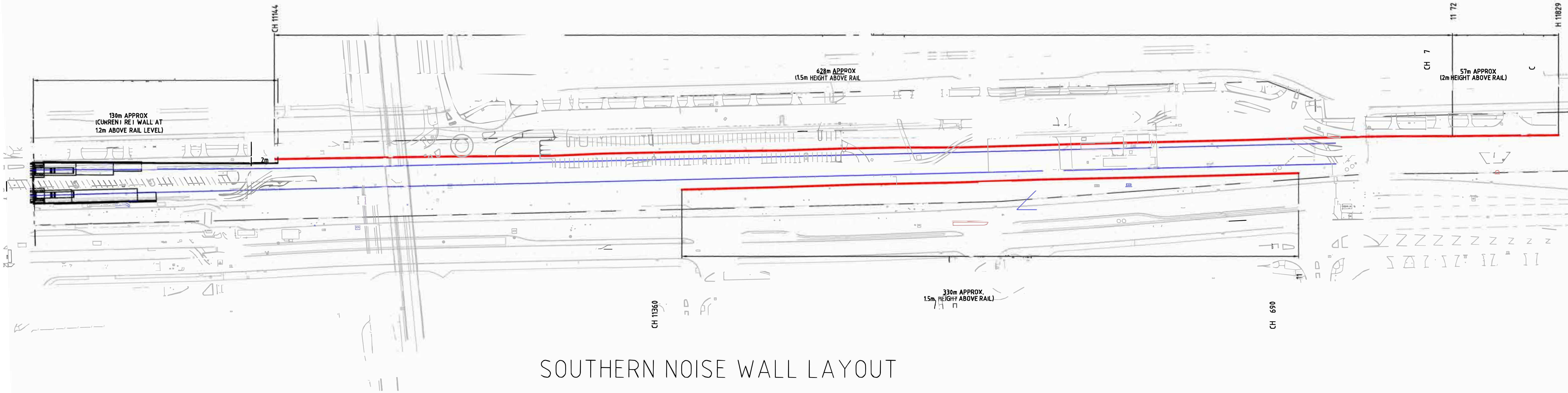
IDC	John-Paul Davies (Station Architecture SRE/PE)	Report	No comments related to Architecture.	Rachel Foster - Noted.	Rachel Foster - No action needed.	Closed	1	C	N
Mechanical PE:									
IDC	Adarash Dhar - Mechanical SRE/PE	Report	No comments related to Mech.	Rachel Foster - Noted.	Rachel Foster - No action needed.	Closed	1	C	N
Hydraulics PE:									
IDC	Rodney Wilson	Report	No comments related to Hydraulics.	Rachel Foster - Noted.	Rachel Foster - No action needed.	Closed	1	C	N
Geotech PE:									
IDC	Stuart Ellis PE	Report	No comments related to Geotech.	Rachel Foster - Noted.	Rachel Foster - No action needed.	Closed	1	C	N
Comms & OT PE:									
IDC	Trevor Gross PE	Report	No comments related to Comms & OT.	Rachel Foster - Noted.	Rachel Foster - No action needed.	Closed	1	C	N
Civil Roads PE:									
IDC	Yaqoob Siddiqui PE	Report	No comments related to Civil Roads.	Rachel Foster - Noted.	Rachel Foster - No action needed.	Closed	1	C	N
Final Design PE Review and IDC/IDR									
Final Design - Internal Review and IDC Comments									

Record of task completion and agreement of comments			
Reviewer - The review task as described above has been undertaken and the package has been reviewed to be appropriate and correct for the scope of the review undertaken.		**Designer / originator - The above review comments have been addressed and incorporated or responded to as appropriate.**	
Review Co-ordinator:	Kristen Meling	**Designer / originator:**	Rachel Foster
Organisation:	ALUA	**Organisation:**	ALUA
Signature:		**Signature:**	
Date:	07-Sep-22	**Date:**	08-Sep-22

Appendix G– LATEST INTERIM DESIGN NOISE WALL EXTENTS



NORTHERN NOISE WALL LAYOUT



SOUTHERN NOISE WALL LAYOUT