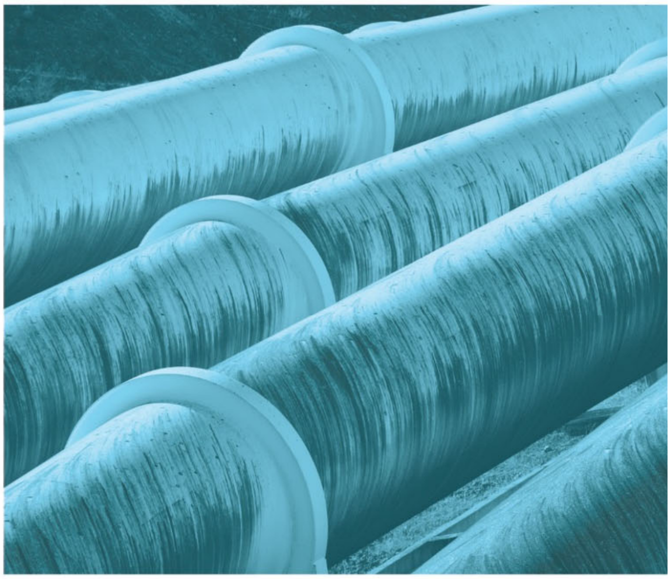



M4-M5 Link Mainline Tunnels

Construction Noise and Vibration Impact Statement - Pyrmont Bridge Road Operations

Prepared for Lendlease Samsung Bouygues Joint Venture
February 2019

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Report Number

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Client

Lendlease Samsung Bouygues Joint Venture

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21 February 2019

This report has been prepared in accordance with the brief provided by the client and has relied upon the information collected at the time and under the conditions specified in the report. All findings, conclusions or recommendations contained in the report are based on the aforementioned circumstances. The report is for the use of the client and no responsibility will be taken for its use by other parties. The client may, at its discretion, use the report to inform regulators and the public.

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1 Introduction

1.1 Context

This Construction Noise and Vibration Impact Statement (CNVIS) has been prepared to identify the noise and vibration impacts from a portion of Stage 1 of the WestConnex 3A – M4-M5 Link Mainline tunnels project (the Project). In addition, this CNVIS also responds to (as required) the various noise and vibration requirements detailed within the Minister's Conditions of Approval (CoA), the WestConnex M4-M5 Link Environmental Impact Statement (EIS), the revised environmental management measures (REMM) listed in the Submissions and Preferred Infrastructure Report (SPIR) and all applicable legislation.

1.2 Background and project description

An EIS (AECOM 2017) assessed the potential impacts of construction and operation of the project on noise and vibration, within Chapter 10.

The EIS identified the potential noise and vibration impacts during construction typically associated with noise intensive construction works. It concluded any potential impacts could be managed by standard mitigation and management measures.

The WestConnex M4-M5 Link project is being constructed in two stages (refer to Figure 1.1):

- Stage 1: (the Project and subject of this document): M4-M5 Link Mainline tunnels.
- Stage 2: Rozelle interchange.

Sydney Motorway Corporation (SMC) has engaged Lendlease Samsung Bouygues Joint Venture (LSBJV) to design and construct Stage 1 of the project (refer Figure 1.1). The key features of the Mainline tunnels project include:

- Twin mainline motorway tunnels between the M4 East at Haberfield and the New M5 at St Peters. Each tunnel would be around 7.5 kilometres long and would generally accommodate up to four lanes of traffic in each direction;
- Connections of the mainline tunnels to the M4 East project, comprising:
  - A tunnel-to-tunnel connection to the M4 East mainline stub tunnels east of Parramatta Road near Alt Street at Haberfield;
  - Entry and exit ramp connections between the mainline tunnels and the Wattle Street interchange at Haberfield (which is currently being constructed as part of the M4 East project); and
  - Minor physical integration works with the surface road network at the Wattle Street interchange including road pavement and line marking;
- Connections of the mainline tunnels to the New M5 project, comprising:
  - A tunnel-to-tunnel connection to the New M5 mainline stub tunnels north of the Princes Highway near the intersection of Mary Street and Bakers Lane at St Peters;
  - Entry and exit ramp connections between the mainline tunnels and the St Peters interchange at St Peters (which is currently being constructed as part of the New M5 project); and

    - Minor physical integration works with the surface road network at the St Peters interchange including road pavement and line marking;

- Construction of tunnel stubs to provide for future underground connection of the mainline tunnels to the Rozelle interchange and Iron Cove Link;
- A motorway operations complex at St Peters (Campbell Road) (MOC5). The types of facilities that would be contained within the motorway operations complexes would include substations, water treatment plants, ventilation facilities and outlets (the Campbell Road ventilation facility), offices, on-site storage and parking for employees;
- Tunnel ventilation systems, including ventilation supply and exhaust facilities, ventilation fans, ventilation outlets and ventilation tunnels;
- Fitout (mechanical and electrical) of part of the Parramatta Road ventilation facility at Haberfield (which is currently being constructed as part of M4 East project) for use by the M4-M5 Link project;
- Drainage infrastructure to collect surface and groundwater for treatment at dedicated facilities;
- Water treatment would occur at the operational water treatment facility at the Campbell Road motorway operations complex (subject to future Modification);
- Ancillary infrastructure and operational facilities for electronic tolling and traffic control and signage (including electronic signage);
- Emergency access and evacuation facilities, including pedestrian and vehicular cross and long passages and fire and life safety systems;
- Utility works, including protection and/or adjustment of existing utilities, removal of redundant utilities and installation of new utilities;
- Temporary construction ancillary facilities to facilitate construction of the project at the following locations:
    - Northcote Street civil and tunnel site (C3a), Haberfield (subject to future Modification);
    - Haberfield civil site (C2b), Haberfield;
    - Parramatta Road East civil site (C3b), Haberfield;
    - Parramatta Road West civil site (C1b), Ashfield;
    - Wattle Street civil and tunnel site (C1a), Haberfield;
    - Pyrmont Bridge Road tunnel site (C9), Camperdown/Annandale;
    - Campbell Road civil and tunnel site (C10), St Peters; and
    - White Bay civil site (C11), Rozelle.

An overview of the project footprint and ancillary facilities is presented in the Construction Environmental Management Plan (CEMP) and Site Environmental Management Plan (SEMP). Further detail of the project description is presented in Section 1.3 of the CEMP.

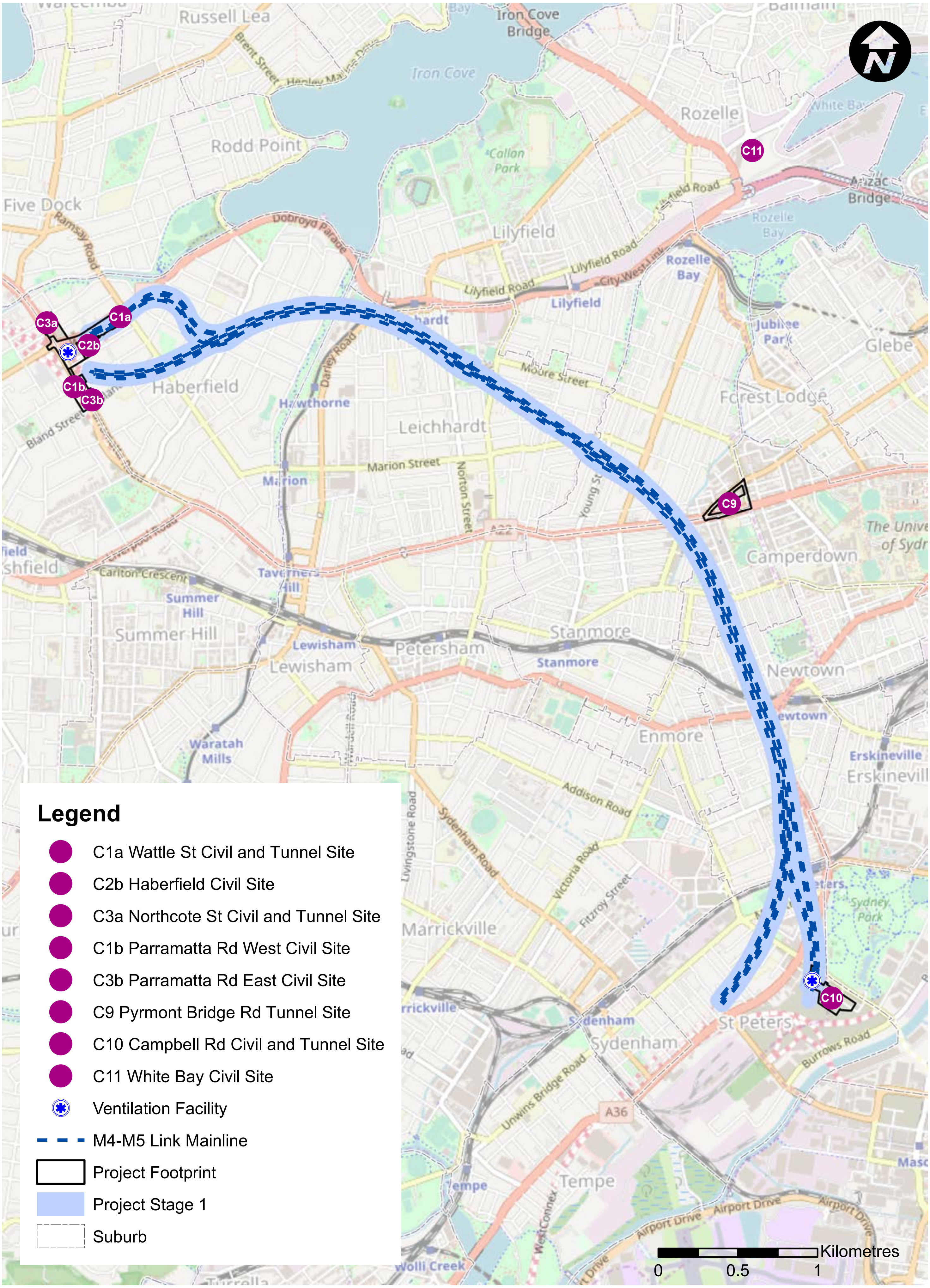


Figure 1-1 Overview of Stage 1 - M4-M5 Link Mainline Tunnels (the Project)

1.3 Scope of this CNVIS

The scope of this CNVIS is to assess potential noise impacts from 24/7 tunnelling activities at the Pyrmont Bridge Road ancillary facility at Camperdown. The site layout is shown in Figure 1.2. The proposed activities at this site assessed in this CNVIS include:

- tunnel excavation and ventilation;
- spoil handling inside an acoustic shed and haulage offsite;
- civil fit out (pavement, concreting works); and
- tunnel lining and support (concreting, shotcrete, deliveries).

The purpose of the CNVIS is to identify potential noise and vibration impacts and to develop feasible and reasonable noise management and mitigation measures where potential impacts are identified.

1.4 Environmental management systems overview

The environmental management system overview is described in Section 1.5 of the CEMP. Noise and vibration impacts are managed through the implementation of the Noise and Vibration Management Plan (NVMP) as required by CoA C4 b).

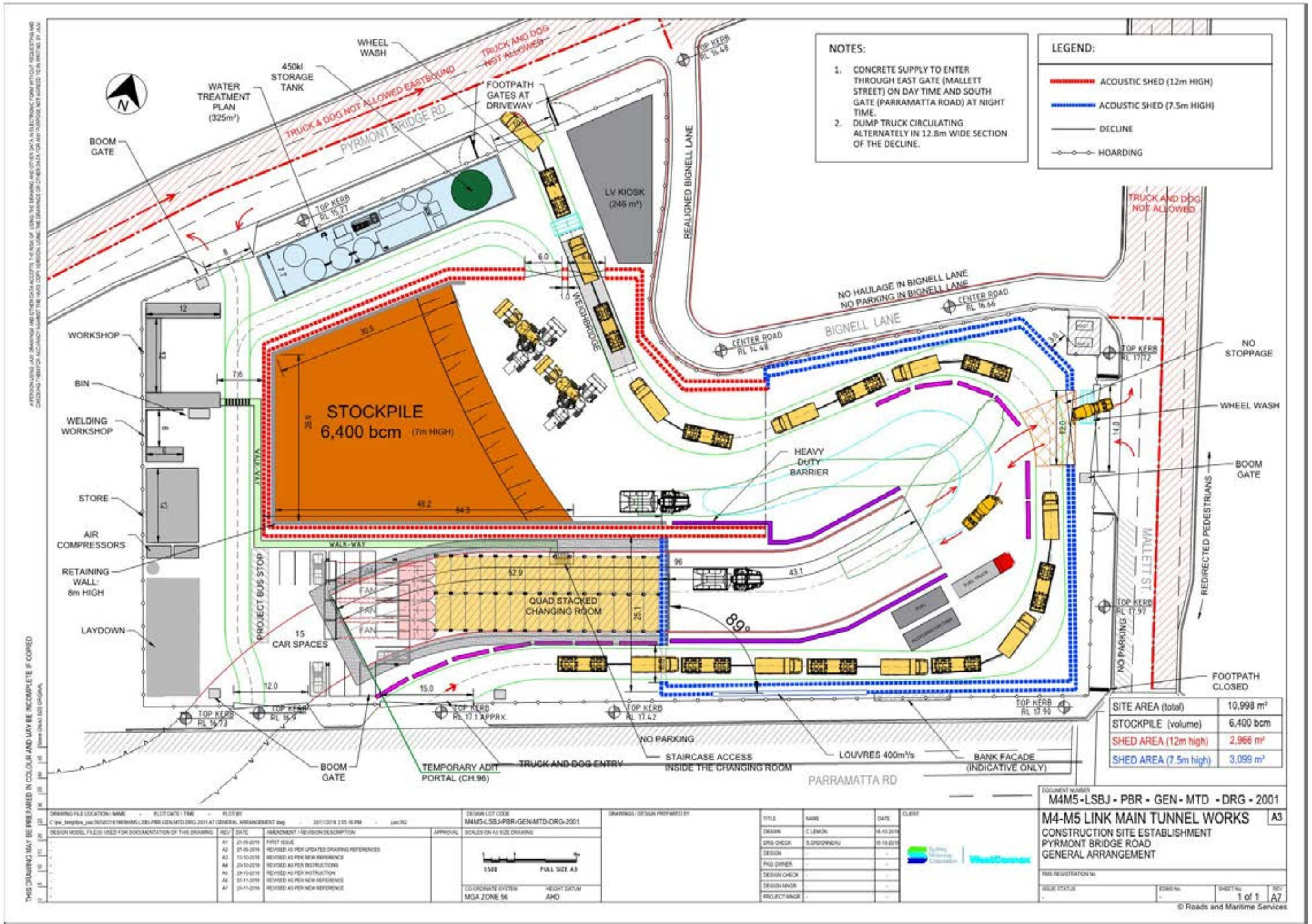


Figure 1.2 Site layout

2 Purpose and objectives

The key objective of the CNVIS is to ensure all CoA, REMM and licence/permit requirements relevant to noise and vibration are described, scheduled and assigned responsibility as outlined in:

- The EIS prepared for WestConnex M4-M5 Link;
- The submissions report prepared for WestConnex M4-M5 Link;
- Conditions of Approval granted to the project on 17 April 2018;
- Roads and Maritime specifications G36;
- The Project's Environmental Protection Licence (EPL); and
- All relevant legislation and other requirements described in Section 3 of this Plan.

3 Environmental requirements

3.1 Legislation

This CNVIS has been prepared in accordance with:

- Environmental Planning and Assessment Act 1979; and
- Protection of the Environment Operations Act 1997 (POEO Act).

3.2 Guidelines

The following guidelines apply to project related construction noise and vibration:

- *NSW Industrial Noise Policy* (INP) 2000*,* Environmental Protection Authority[1];
- *NSW Interim Construction Noise Guideline* (ICNG) 2009, Department of Environment and Climate Change;
- *NSW Road Noise Policy,* Department of Environment 2011, Climate Change and Water;
- *NSW Assessing Vibration – a technical guideline* (AVTG) 2006, Department of Environment and Conservation;
- *NSW Noise Criteria Guideline* (NCG) 2015, Roads and Maritime Services;
- *NSW Noise Mitigation Guideline* (NMG) 2015, Roads and Maritime Services;
- *Construction noise and vibration guideline* (CNVG) 2016, Roads and Maritime Services;
- Australian Standard AS/NZS 2107:2000 *'Acoustics - Recommended design sound levels and reverberation times for building interiors'*;
- Australian Standard 2834-1995 Computer Accommodation, Chapter 2.9 Vibration;
- Australian Standard AS 2187.2 *'Explosives - Storage and use - Part 2 Use of explosives'*;
- Australian Standard AS2436-1981 *'Guide to Noise Control on Construction, Maintenance and Demolition Sites'*;
- British Standard BS 6472-2008, *'Evaluation of human exposure to vibration in buildings (1-80Hz)'*;
- British Standard 7385: Part 2-1993 *'Evaluation and measurement of vibration in buildings'*;
- German Standard DIN4150-1999 *'Structural vibration Part 3: Effects of vibration on Structures'*;
- *Construction Noise Strategy 7TP-ST-157/2.0* (CNS) 2012, Transport for NSW; and
- *Environmental Noise Management Manual* (ENMM) 2001, Roads and Traffic Authority.

[1] This document has since been superseded by the NSW Noise Policy for Industry (NPfI) 2017. However, the INP remains the relevant policy in accordance with the project's Instrument of Approval and NPfI transitional requirements.

3.3 Conditions of approval

The CoA relevant to this CNVIS are listed in Table 3.1.

Table 3.1 Conditions of Approval for construction noise and vibration

Condition	Key requirement
Land Use Survey	
E66	A detailed land use survey must be undertaken to confirm sensitive receivers (including critical working areas such as operating theatres and precision laboratories) potentially exposed to construction noise and vibration, construction ground-borne noise and operational noise. The survey may be undertaken on a progressive basis but must be undertaken in any one area prior to the commencement of works which generate construction or operational noise, vibration or ground-borne noise in that area. The results of the survey must be included in the Construction Noise and Vibration Management Sub-plan.
Noise Assessments	
E67	All noise and vibration assessment, management and mitigation required by this approval must consider the cumulative noise impacts of approved CSSI and SSI projects. This includes using ambient and background levels which do not include other WestConnex M4 East and New M5 (SSI 6307 and SSI 6788) projects. This condition applies to all works and operation.
Works Hours	
E68	Works must be undertaken during the following hours: a) 7:00 am to 6:00 pm Mondays to Fridays, inclusive; b) 8:00 am to 1:00 pm Saturdays; and c) at no time on Sundays or public holidays.
E69	Notwithstanding **Condition E68**, works may be undertaken between 1:00 pm to 6:00 pm on Saturday.
E70	Notwithstanding **Conditions E68** and **E69** the following works are permitted to be undertaken 24 hours a day, seven days a week: a) tunnelling activities excluding cut and cover tunnelling; b) haulage of spoil and delivery of material; c) works within an acoustic shed; and d) (d) tunnel fit out works. Other surface works associated with tunnelling must only be undertaken in accordance with the requirements of **Condition E73**.
Construction Noise and Vibration – General	
E79	Construction Noise and Vibration Impact Statements must be prepared for construction ancillary facility(s) before any works that result in noise and vibration impacts commence, and include specific mitigation measures identified through consultation with affected sensitive receivers. The Statements must supplement the Construction Noise and Vibration Management Sub-plan or Site Establishment Management Plan(s) and are to be implemented for the duration of the works. The Construction Noise and Vibration Impact Statement for the White Bay Civil Site (C11) must be prepared in consultation with the Port Authority of NSW and NSW Heritage Council.

Table 3.1 Conditions of Approval for construction noise and vibration

Condition	Key requirement
E80	Noise generating works in the vicinity of potentially-affected community, religious, educational institutions and noise and vibration-sensitive businesses and critical working areas (such as theatres, laboratories and operating theatres) resulting in noise levels above the NMLs must not be timetabled within sensitive periods, unless other reasonable arrangements with the affected institutions are made at no cost to the affected institution.
E81	Mitigation measures must be implemented with the aim of achieving the following construction noise management levels and vibration criteria: a) construction 'Noise affected' noise management levels established using the *Interim Construction Noise Guideline* (DECC, 2009); b) vibration criteria established using the *Assessing vibration: a technical guideline* (DEC 2006) (for human exposure); c) Australian Standard AS 2187.2 - 2006 "*Explosives - Storage and Use - Use of Explosives*"; d) BS 7385 Part 2-1993 "*Evaluation and measurement for vibration in buildings Part 2*" as they are "applicable to Australian conditions"; and e) the vibration limits set out in the *German Standard DIN 4150-3: Structural Vibration- effects of vibration on structures* (for structural damage). Any works identified as exceeding the noise management levels and/or vibration criteria must be managed in accordance with the **Construction Noise and Vibration Management Sub-plan.** *Note: The Interim Construction Noise Guideline identifies 'particularly annoying' activities that require the addition of 5 dB(A) to the predicted level before comparing to the construction Noise Management Level.*
Construction Noise Mitigation – Acoustic Sheds	
E86	All acoustic sheds must be erected as soon as site establishment works at the facilities are completed and before undertaking any works which are required to be conducted within the sheds.

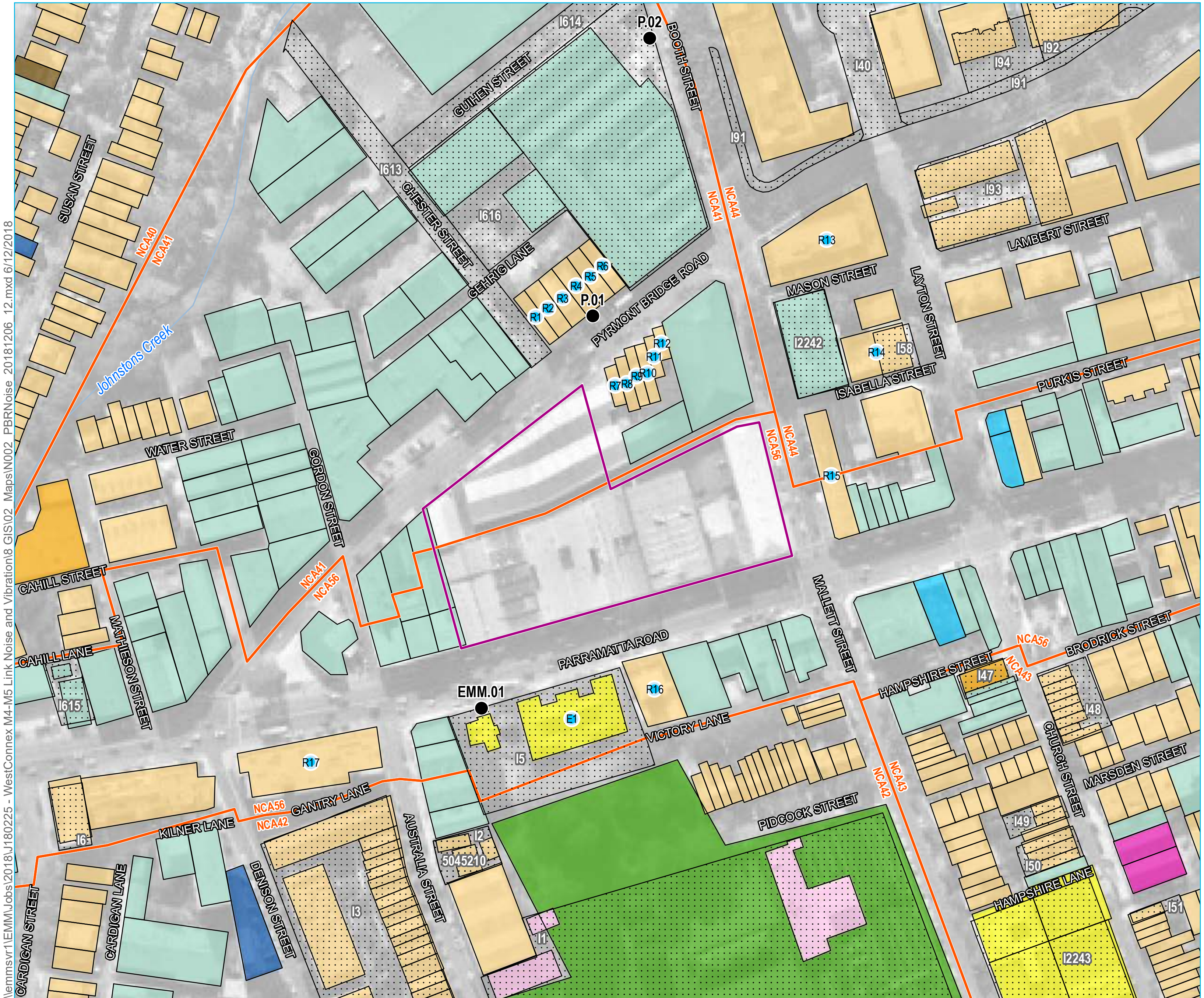
4 Existing environment

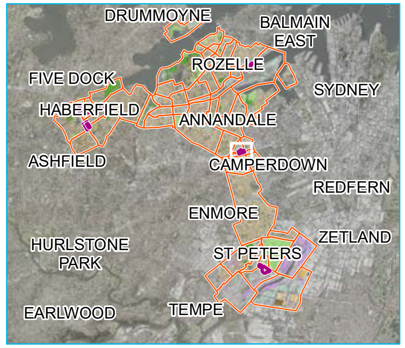
4.1 Noise and vibration sensitive receivers

A detailed land use survey has been undertaken to address E66 of the CoA. The outcomes of the land use survey have been incorporated into this CNVIS. A visual representation of the survey is provided in the NVMP. For the purpose of this assessment, receivers potentially sensitive to noise have been categorised as:

- residential dwellings;
- commercial, retail and industrial properties; and
- other, including:
  - education institutions;
  - childcare centres;
  - medical (hospital wards or other uses including medical centres);
  - places of worship;
  - outdoor open areas (passive and active recreation);
  - aged care;
  - hotel;
  - theatre/auditorium;
  - public building; and
  - recording studio.

The sensitive receivers in proximity to the site is shown in Figure 4.1. Heritage items of importance where vibration emission needs to be considered are also shown.





KEY

- Noise logger location
- Receiver location and ID
- Watercourse / drainage line
- Site boundary
- Noise catchment boundary
- Heritage item (LEP/SHR)

Noise receiver

- Residential
- Commercial
- Other - café/bar
- Other - childcare
- Other - educational
- Other - medical
- Other - outdoor active
- Other - place of worship
- Other - public building
- Other - recording studio

Source: EMM (2018); LendLease (2018); DFSI (2017); DPE (2017)

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Pyrmont Bridge Road - noise catchment areas, receivers and noise monitoring locations

Westconnex M4-M5 Link Tunnels
Construction noise and vibration impact statement – Operations

Figure 4.1

EMM

4.2 Noise catchment areas

The study area has been divided into Noise Catchment Areas (NCAs). NCAs group individual sensitive receivers by common traits such as existing noise environment and location in relation to the works.

In November 2018, EMM conducted unattended noise monitoring to establish a more representative Rating Background Level (RBL) for premises situated along Parramatta Road. A new NCA (NCA56) was subsequently established to represent the noise environment for properties which are more heavily influenced by road traffic noise from Parramatta Road.

The noise catchment areas of relevance to this CNVIS are shown in Figure 4.1 and described in Table 4.1.

Table 4.1 Noise catchment areas relevant to site

NCA	Description
NCA41	North of Parramatta Road between Booth Street/Mallett Street and Johnstons Creek. Land use comprises of a mix of residential and commercial receivers and a place of worship
NCA42	South of Parramatta Road between Mallett Street and Salisbury Road. Land use comprises of a mix of residential and commercial receivers, special use facilities and active and passive recreation areas
NCA43	South of Parramatta Road, east of Mallett Street. Land use comprises of a mix of residential and commercial receivers and special use facilities
NCA44	North of Parramatta Road, east of Booth Street. Land use comprises of a mix of residential and commercial receivers.
NCA56[1]	Representative of receivers adjacent to Parramatta Road.

Notes: Source: M4-M5 Link EIS

1. EMM conducted unattended noise monitoring to establish a more suitable RBL for premises situated along Parramatta Road. NCA56 represents these premises whose background noise environment is dominated by traffic along Parramatta Road.

4.3 Background noise levels

This CNVIS has adopted background noise levels documented in the EIS which are presented in Table 4.2 for each relevant NCA. Representative monitoring locations are shown in Figure 4.1.

The majority of the NCAs surrounding the project are influenced by road traffic noise levels from major roads. In accordance with prescribed methods in the NSW Industrial Noise Policy (Section 3.3) and the NSW Road Noise Policy (Section 2.5.5), the background noise logging data for the Project was reviewed in greater detail to identify potential shoulder periods. Shoulder periods are defined as periods between the standard INP day, evening and night periods where there may be a steady rise or fall in background noise levels and therefore a justification to define an RBL specific to that time period.

It is proposed to adopt shoulder period Noise Management Levels (NMLs) during 5am to 7am (morning shoulder) and 10pm to midnight (evening shoulder) in order to manage noise according to the noise characteristics of the catchments.

It is noted that the Interim Construction Noise Guideline (ICNG) relies on methodologies contained within the NSW Industrial Noise Policy for the establishment of RBLs. Hence, this approach is deemed consistent with the guidance provided by the ICNG.

Table 4.2 Rating background levels

Rep monitoring location	Rating background level (RBL)[1] $L_{A90(15min)}$				
	Daytime	Evening	Night	Morning shoulder (5 am to 7 am)[2]	Evening shoulder (10 pm to 12 am)[3]
P.01	51	49	41	46	45
P.02	53	50	46	49	48
EMM.01	62	59	51	56	55

Notes: 1.ICNG defines daytime period as 7:00am to 6:00pm Monday to Saturday, 8:00am to 6:00 pm Sunday; Evening as 6:00pm to 10:00pm; Night as 10:00pm to 7:00am Monday to Saturday, 10:00pm to 8:00am Sunday.

2. There is a steady rise in background noise levels between 5am and 7am. Hence a shoulder period has been applied in accordance with the INP by taking the mid-point of day and night RBLs.

3. There is a steady fall in background noise levels between 10pm and 12am. Hence a shoulder period has been applied in accordance with the INP by taking the mid-point of evening and night RBLs.

5 Construction noise criteria

5.1 Interim Construction Noise Guideline

The ICNG provides guidelines for the assessment and management of noise from construction works.

Table 5.1 is an extract from the ICNG and provides construction NMLs for residential receivers for both recommended standard construction hours and outside of these periods.

It is noted that the CoA allows extended standard hours of construction during 1pm to 6pm on Saturdays which deviates slightly from ICNG recommended standard hours.

Table 5.1 ICNG residential noise management levels

Time of day	Management level $L_{Aeq,15\ minute}$	How to apply
Recommended standard hours: Monday to Friday 7:00 am to 6:00 pm Saturday 8:00 am to 6:00 pm No work on Sundays or public holidays	Noise affected RBL + 10 dB	The noise affected level represents the point above which there may be some community reaction to noise. • Where the predicted or measured LAeq,15 minute is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level. • The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.
	Highly noise affected 75 dB	The highly noise affected level represents the point above which there may be strong community reaction to noise. • Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account: – times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences; and – if the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside recommended standard hours	Noise affected RBL + 5 dB	• A strong justification would typically be required for works outside the recommended standard hours. • The proponent should apply all feasible and reasonable work practices to meet the noise affected level. • Where all feasible and reasonable practices have been applied and noise is more than 5 dB(A) above the noise affected level, the proponent should negotiate with the community.

1. Noise levels apply at the property boundary that is most exposed to construction noise, and at a height of 1.5 m above ground level. If the property boundary is more than 30 m from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30 m of the residence. Noise levels may be higher at upper floors of the noise affected residence.

Table 5.2 summarises noise management levels for non-residential land uses as defined in the ICNG.

Table 5.2 ICNG noise management levels at other land uses

Land use	Management level, $L_{Aeq,15\ minute}$
Industrial premises	External noise level 75 dB (when in use)
Offices, retail outlets	External noise level 70 dB (when in use)
Classrooms at schools and other educational institutions	Internal noise level 45 dB (when in use)
Hospital wards and operating theatres	Internal noise level 45 dB (when in use)
Places of worship	Internal noise level 45 dB (when in use)
Active recreation areas	External noise level 65 dB (when in use)
Passive recreation areas	External noise level 60 dB (when in use)

Source: ICNG (DECC, 2009).

The ICNG provides further guidance for construction noise levels at commercial and industrial premises as follows:

> Due to the broad range of sensitivities that commercial or industrial land can have to noise from construction, the process of defining management levels is separated into three categories. The external noise levels should be assessed at the most-affected occupied point of the premises:
>
> - Industrial premises: external $L_{Aeq\ (15\ min)}$ 75 dB(A)
> - offices, retail outlets: external $L_{Aeq\ (15\ min)}$ 70 dB(A)
> - other businesses that may be very sensitive to noise, where the noise level is project specific as discussed below.
>
> Examples of other noise-sensitive businesses are theatres and child care centres. The proponent should undertake a special investigation to determine suitable noise levels on a project-by-project basis; the recommended 'maximum' internal noise levels in AS 2107 Acoustics – Recommended design sound levels and reverberation times for building interiors may assist in determining relevant noise levels (Standards Australia 2000).
>
> The proponent should assess construction noise levels for the project, and consult with occupants of commercial and industrial premises prior to lodging an application where required.

During construction, the proponent should regularly update the occupants of the commercial and industrial premises regarding noise levels and hours of work.

5.2 Sleep disturbance at residences

The Site will operate during the night-time period (10pm to 7am). Therefore, the assessment of potential sleep disturbance at residences is required in accordance with the INP application notes. Sleep disturbance is defined as both awakenings and disturbance to sleep stages.

The INP application notes suggests that an $L_{A1(1min)}$ or L_{Amax} level of RBL plus 15 dB is a suitable screening criteria for sleep disturbance for the night-time period. This applies at the most affected façade of a building.

A detailed maximum noise level event assessment is required if the screening criteria is exceeded. Further guidance in regard to potential impact on sleep is provided in the NSW Road Noise Policy (RNP) (DECCW 2011). The RNP calls upon a number of studies that have been conducted into the effect of maximum noise levels on sleep, and provides the following factors that are key in assessing the extent of impacts on sleep:

- how often high noise events would occur;
- the distribution of likely events across the night-time period and the existing ambient maximum events in the absence of the project;
- whether there are times of day when there is a clear change in the noise environment (such as during early-morning shoulder periods); and
- current scientific literature available at the time of the assessment regarding the impact of maximum noise level events at night.

The RNP also quotes the following internal noise levels with respect to potential sleep disturbance:

- maximum internal noise levels (L_{max}) below 50 to 55 dBA are unlikely to awaken people from sleep; and
- one or two noise events per night, with maximum internal noise levels (L_{max}) of 65 to 70 dBA, are not likely to affect health and wellbeing significantly.

It is commonly accepted by acoustic practitioners and regulatory bodies that a facade of a residential building of standard construction including a partially open window will reduce external noise levels by 10dB. Therefore, external noise levels in the order of 60 to 65 dB L_{Amax} calculated at the facade of a residence are unlikely to cause sleep disturbance affects.

5.3 Project specific NMLs - residential

In accordance with the ICNG and based on the RBLs presented in Table 4.2, Table 5.3 presents the project specific construction noise affected NMLs applicable to residential premises during the proposed work hours. As per the ICNG, these apply to ground floor locations. The highly noise affected NML also applies to all residential receivers during standard hours.

Table 5.3 Project specific NMLs at residential locations

NCA	Rep monitoring location	Standard construction NMLs (RBL + 10 dB) Day[1]	Out of hours NMLs (RBL + 5dB)[1]					Sleep disturbance screening criteria (RBL + 15 dB)[3]
			Morning shoulder (5 am to 7 am)	Day (7 am to 6 pm)	Evening (6 pm to 10 pm)	Evening shoulder (10 pm to 12 am)	Night (12 am to 5 am)	
NCA40	P.01	61	51	56	54	50	46	56
NCA41	P.01	61	51	56	54	50	46	56
NCA42	P.01	61	51	56	54	50	46	56
NCA43	P.01	61	51	56	54	50	46	56
NCA44	P.01	61	51	56	54	50	46	56
R15	P.02[2]	63	54	58	55	53	51	61
NCA56	EMM.01	72	61	67	64	60	56	66

Notes: 1. Noise levels apply at the property boundary that is most exposed to construction noise, and at a height of 1.5 m above ground level. If the property boundary is more than 30 m from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30 m of the residence. Noise levels may be higher at upper floors of the noise affected residence.

2. NMLs have been applied to R15. This receive is located between Pyrmont Bridge Road and Parramatta Road. It is therefore considered more appropriate to assign NMLs based on the RBLs recorded at P.02.

5.4 Project specific NMLs - non-residential

Table 5.4 presents the project specific construction NMLs applicable to non-residential land uses as defined in the NSW ICNG and AS2107.

Table 5.4 Project specific NMLs at non-residential land uses

Land use	Noise management level (when in use), $L_{Aeq,15\ minute}$
Industrial premises	External noise level 75 dB
Offices, retail outlets	External noise level 70 dB
Classrooms at schools and other educational institutions	Internal noise level 45 dB
Hospital wards and operating theatres	Internal noise level 45 dB
Places of worship	Internal noise level 45 dB
Active recreation areas	External noise level 65 dB
Passive recreation areas	External noise level 60 dB
Child care centres[1]	External noise level 65 dB
Aged care[1]	External noise level 65 dB (7am to 10pm) 60 dB (10pm to 7am)
Hotels[1]	External noise level 65 dB (7am to 10pm) 60 dB (10pm to 7am)
Theatre/auditorium[1]	External noise level 45 dB
Recording studio[1]	External noise level 45 dB
Public building[1]	Determined on site specific basis

Notes:

1. NML based on AS2017 recommend maximum internal noise level and the premise that windows and doors for such development would typically remain closed, providing 20 dB of outdoor to indoor construction noise level reduction.
2. Notwithstanding NMLs in this table, Condition E80 states "Noise generating works in the vicinity of potentially-affected community, religious, educational institutions and noise and vibration-sensitive businesses and critical working areas (such as theatres, laboratories and operating theatres) resulting in noise levels above the NMLs must not be timetabled within sensitive periods, unless other reasonable arrangements with the affected institutions are made at no cost to the affected institution

6 Construction vibration criteria

6.1 Overview

Vibration criteria adopted for the works are consistent with those established in the EIS and in accordance with the Instrument of Approval (SSI 7485). Condition E81 of SSI 7485 states that mitigation measures must be implemented with the aim of achieving the following vibration criteria:

- vibration criteria established using the Assessing vibration: a technical guideline (DEC 2006) (for human exposure);
- Australian Standard AS 2187.2 - 2006 “Explosives - Storage and Use - Use of Explosives”;
- BS 7385 Part 2-1993 “Evaluation and measurement for vibration in buildings Part 2” as they are “applicable to Australian conditions”; and
- the vibration limits set out in the German Standard DIN 4150-3: Structural Vibration- effects of vibration on structures (for structural damage).

It is noted that blasting is not part of the scope for works relevant to this CNVIS.

6.2 Human comfort – Assessing vibration: a technical guideline (DEC)

Environmental Noise Management – Assessing Vibration: a technical guideline (DEC 2006) is based on guidelines contained in BS 6472 – 2008, Evaluation of human exposure to vibration in buildings (1-80Hz).

The guideline presents preferred and maximum vibration values for use in assessing human responses to vibration and provides recommendations for measurement and evaluation techniques. At vibration values below the preferred values, there is a low probability of adverse comment or disturbance to building occupants. Where all feasible and reasonable mitigation measures have been applied and vibration values are still beyond the maximum value, it is recommended the operator negotiate directly with the affected community.

The guideline defines three vibration types and provides direction for assessing and evaluating the applicable criteria. Table 2.1 of the guideline provides examples of the three vibration types and has been reproduced in Table 6.1.

Table 6.1 Examples of types of vibration (from Table 2.1 of the guideline)

Continuous Vibration	Impulsive Vibration	Intermittent Vibration
Machinery, steady road traffic, continuous construction activity (such as tunnel boring machinery).	Infrequent: Activities that create up to 3 distinct vibration events in an assessment period, e.g. occasional dropping of heavy equipment, occasional loading and unloading. Blasting is assessed using ANZECC (1990).	Trains, intermittent nearby construction activity, passing heavy vehicles, forging machines, impact pile driving, jack hammers. Where the number of vibration events in an assessment period is three or fewer these would be assessed against impulsive vibration criteria.

Intermittent vibration is representative of activities such as impact hammering, vibratory rolling or general excavation work (such as an excavator tracking) and, as such, is most relevant to this assessment.

Intermittent vibration (as defined in Section 2.1 of the guideline) is assessed using the vibration dose concept which relates to vibration magnitude and exposure time.

Section 2.4 of the Guideline provides acceptable values for intermittent vibration in terms of vibration dose values (VDV) which requires the measurement of the overall weighted RMS (root mean square) acceleration levels over the frequency range 1 Hz to 80 Hz. To calculate VDV the following formula (refer *section 2.4.1* of the guideline) was used:

$$VDV = \left[\int_0^T a^4(t)dt\right]^{0.25}$$

Where VDV is the vibration dose value in $m/s^{1.75}$, *a (t)* is the frequency-weighted rms of acceleration in m/s^2 and *T* is the total period of the day (in seconds) during which vibration may occur.

The Acceptable Vibration Dose Values (VDV) for intermittent vibration are reproduced in Table 5.2.

Table 6.2 Acceptable vibration dose values (VDV) for intermittent vibration ($m/s^{1.75}$)

Location	Daytime		Night-time	
	Preferred value, $m/s^{1.75}$	Maximum value, $m/s^{1.75}$	Preferred value, $m/s^{1.75}$	Maximum value, $m/s^{1.75}$
Critical Areas	0.10	0.20	0.10	0.20
Residences	0.20	0.40	0.13	0.26
Offices, schools, educational institutions and places of worship	0.40	0.80	0.40	0.80
Workshops	0.80	1.60	0.80	1.60

Notes:

1. Daytime is 7 am to 10 pm and night-time is 10 pm to 7 am.
2. These criteria are indicative only, and there may be a need to assess intermittent values against continuous or impulsive criteria for critical areas.

There is a low probability of adverse comment or disturbance to building occupants at vibration values below the preferred values. Adverse comment or complaints may be expected if vibration values approach the maximum values. The Guideline states that activities should be designed to meet the preferred values where an area is not already exposed to vibration.

6.3 Structural vibration criteria

Most commonly specified "safe" structural vibration limits are designed to minimise the risk of threshold or cosmetic surface cracks, and are set well below the levels that have potential to cause damage to the main structure.

6.3.1 Australian Standard AS 2187.2 - 2006

In terms of the most recent relevant vibration damage criteria, Australian Standard AS 2187.2 - 2006 "*Explosives -* Storage *and Use - Use of Explosives*" recommends the frequency dependent guideline values and assessment methods given in BS 7385 Part 2-1993 *"Evaluation and measurement for vibration in buildings Part 2*" be used as they are "applicable to Australian conditions".

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

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

The recommended limits (guide values) for transient vibration to ensure minimal risk of cosmetic damage to residential and industrial buildings are presented numerically in Table 6.3 and graphically in Figure 6.1.

Table 6.3 Transient vibration guide values - minimal risk of cosmetic damage

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

Notes: Source: BS 7385 Part 2-1993.

The standard states that the guide values in Table 5.3 relate predominantly to transient vibration which does not give rise to resonant responses in structures and low-rise buildings.

Where the dynamic loading caused by continuous vibration is such as to give rise to dynamic magnification due to resonance, especially at the lower frequencies where lower guide values apply, then the guide values in Table 5.3 may need to be reduced by up to 50%.

Sheet piling activities (for example) are considered to have the potential to cause dynamic loading in some structures (eg residences) and it may therefore be appropriate to reduce the transient values by 50%.

In the lower frequency region where strains associated with a given vibration velocity magnitude are higher, the guide values for building types corresponding to Line 2 are reduced. Below a frequency of 4 Hz where a high displacement is associated with the relatively low peak component particle velocity value, a maximum displacement of 0.6 mm (zero to peak) is recommended. This displacement is equivalent to a vibration velocity of 3.7 mm/s at 1 Hz. The standard goes on to state that minor damage is possible at vibration magnitudes which are greater than twice those given in Table 5.3, and major damage to a building structure may occur at values greater than four (4) times the tabulated values.

Fatigue considerations are also addressed in the standard and it is concluded that unless calculation indicates that the magnitude and number of load reversals is significant (in respect of the fatigue life of building materials) then the guide values in Table 5.3 should not be reduced for fatigue considerations.

In order to assess the likelihood of cosmetic damage due to vibration, AS2187 specifies that vibration measurements should be undertaken at the base of the building and the highest of the orthogonal vibration components (transverse, longitudinal and vertical directions) should be compared with the criteria curves presented in Figure 6.1.

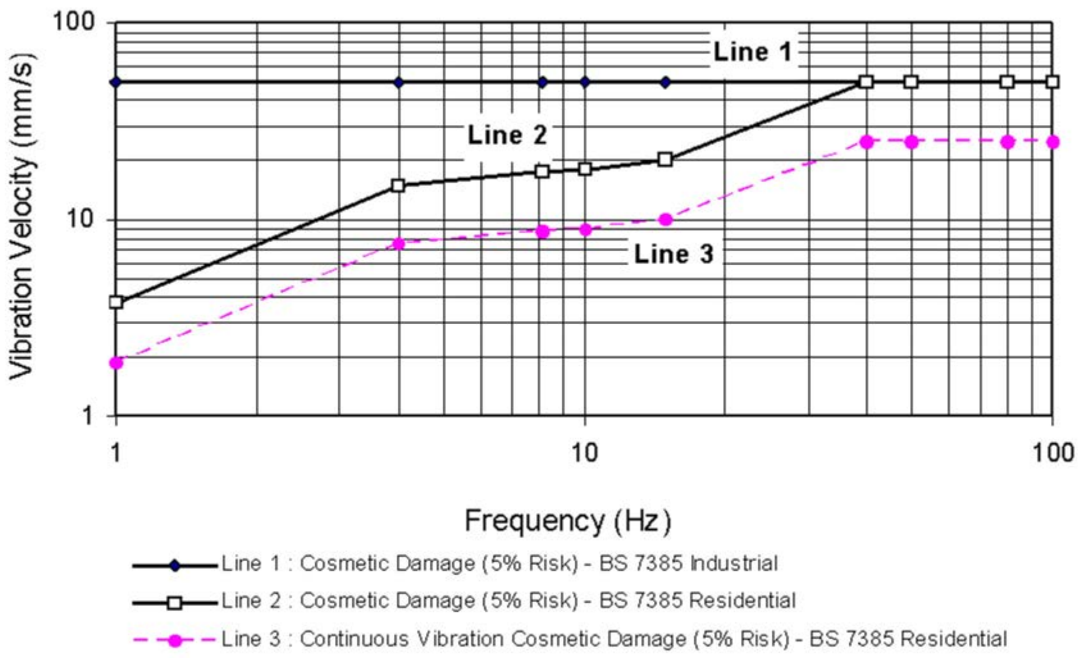


Figure 6.1 Graph of transient vibration guide values for cosmetic damage

It is noteworthy that extra to the guide values nominated in Table 5.3, the standard states that:

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

Also that:

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

A vibration screening criterion of 15 mm/s is recommended for structures surrounding the site for vibration inducing construction. This should be reduced to 7.5mm/s (by 50%) if the vibration activity is continuous and has the potential to cause resonance effects in surrounding structures (eg sheet piling).

6.3.2 German Standard DIN 4150-3:1999

The German Standard DIN 4150 - Part 3: 1999, provides the strictest guideline levels of vibration velocity for evaluating the effects of vibration in structures. The limits presented in this standard are generally recognised to be conservative.

The DIN 4150 values (maximum levels measured in any direction at the foundation, or maximum levels measured in (x) or (y) horizontal directions, in the plane of the uppermost floor), are summarised in Table 6.4 and shown graphically in Figure 5.2.

For residential and commercial type structures, the standard recommends safe limits as low as 5 mm/s and 20 mm/s respectively. These limits increase with frequency values above 10 Hz. The operational frequency of construction plant typically ranges between 10 Hz to 30 Hz, and hence according to DIN4150, the safe vibration guide limit range for dwellings is 5 to 15 mm/s. For reinforced commercial type buildings the limit is as low as 20mm/s, while for heritage or sensitive structures the lower limit is 3 mm/s.

Table 6.4 Structural damage guideline values of vibration velocity – DIN4150

Line*	Type of Structure	Vibration Velocity in mm/s			
		At Foundation at a Frequency of			Plane of Floor of Uppermost Storey
		1 Hz to 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz	All Frequencies
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 to 40	40 to 50	40
2	Dwellings and buildings of similar design and/or use	5	5 to 15	5 to 20	15
3	Structures that because of their particular sensitivity to vibration do not correspond to those listed in Lines 1 or 2 and have intrinsic value (e.g. buildings that are under a preservation order)	3	3 to 8	8 to 10	8

Notes:

1. "Line*" refers to curves in Figure 1 of DIN4150
2. For frequencies above 100Hz the higher values in the 50Hz to 100Hz column should be used

These levels are "safe limits", for which damage due to vibration effects is unlikely to occur. "Damage" is defined in DIN 4150 to include even minor non-structural effects such as superficial cracking in cement render, the enlargement of cracks already present, and the separation of partitions or intermediate walls from load bearing walls.

Should such damage be observed without vibration levels exceeding the "safe limits" then it is likely to be attributable to other causes. DIN 4150 also states that when vibration levels higher than the "safe limits" are present, it does not necessarily follow that damage will occur.

As indicated by the guide levels from DIN 4150 in Figure 5.2, high frequency vibration has less potential to cause damage than lower frequencies. Furthermore, the "point source" nature of vibration from plant causes the vibratory disturbances to arrive at different parts of nearby large structures in an out-of-phase manner, thereby reducing its potential to excite in-phase motion of the low order modes of vibration in such structures.

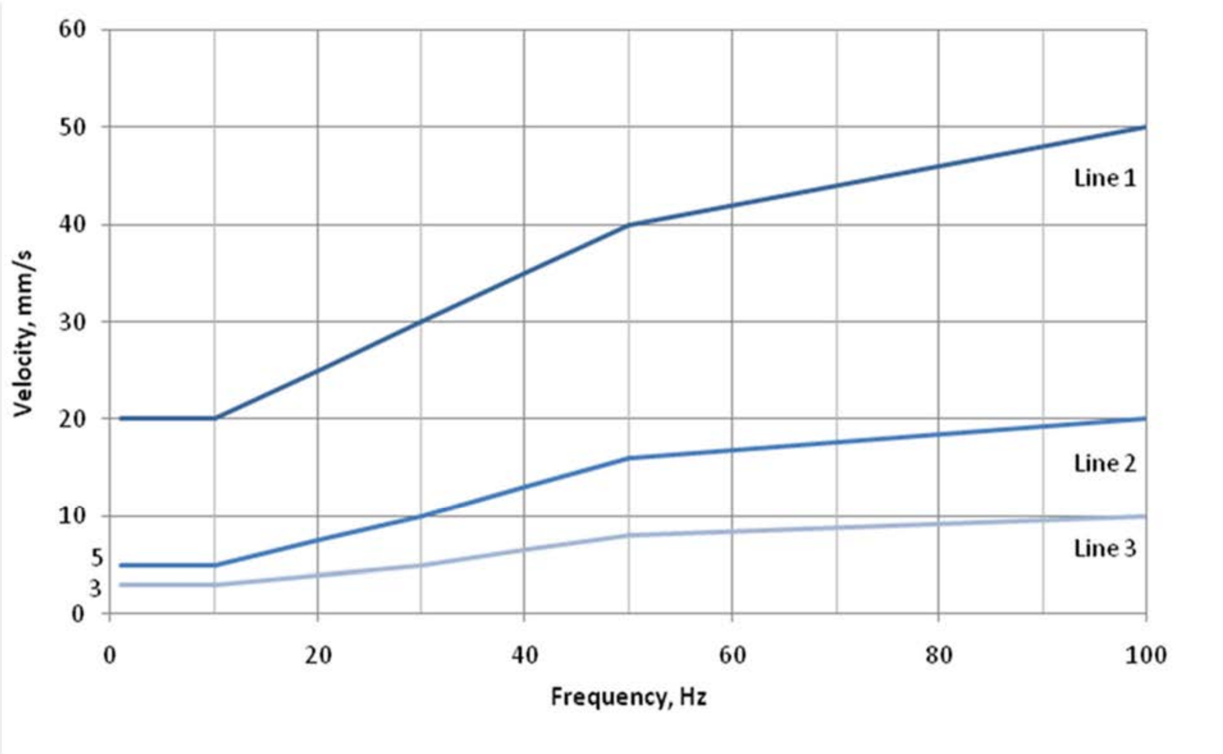


Figure 6.2 DIN4150 structural damage guideline values of vibration velocity

6.3.3 Project specific structural vibration criteria

Condition E81 requires that BS7385-2 and DIN4150-3 are both satisfied. DIN4150-3 is more conservative and provides more information for the assessment of heritage structures. If DIN4150-3 limits are satisfied, the limits in BS7385-2 will also be satisfied.

DIN4150-3 has therefore been adopted as the structural vibration criteria for the project.

7 Construction noise assessment

7.1 Assessment method

The following sections outline the modelling method and key assumptions adopted to assess noise levels from 24 hour / 7 day a week operation of the site in accordance with the ICNG (EPA 2009) and CNVG (RMS 2015) requirements.

7.1.1 Scenarios

i Day (7am to 6pm)

For this period, the following activity was assessed:

- spoil haul trucks entering site from Parramatta Road and exiting onto Pyrmont Bridge Road;
- light vehicles and deliveries entering site from Parramatta Road entrance;
- concrete trucks and delivery trucks entering and exiting the site through the Mallet Street access; and
- plant and equipment within the site compound and acoustic shed working at full capacity as described in Section 7.1.3 and Section 7.1.5.

ii Evening, night, and shoulder periods (6pm to 7am)

For these periods, the following activity was assessed:

- spoil haul trucks entering site from Parramatta Road and exiting onto Pyrmont Bridge Road;
- concrete trucks entering site from Parramatta Road and exiting onto Pyrmont Bridge Road with the Mallet Street access door permanently closed;
- the north deliveries door is kept closed; and
- plant and equipment within the site compound and acoustic shed working at full capacity as described in Section 7.1.3 and Section 7.1.5.

7.1.2 External haul truck and concrete truck movements

The following assumptions have been made in reference to truck movements on-site:

- truck ingress and egress routes as described above and as shown in Figure 7.1;
- concrete trucks were modelled with a sound power level of 105 dBA travelling at 10 km/h; and
- spoil haul trucks were modelled with a sound power level of 103 dBA travelling at 10 km/h.

7.1.3 Inside the acoustic shed

The following assumptions have been made in reference to construction activities occurring inside the acoustic shed:

- The equipment generating noise in the shed consists of:
  - two 24 t front end loaders (FELs);
  - four 30 t articulated dump trucks (ADT);
  - one underground shotcrete agitator;
  - two road concrete agitators;
  - nine truck and dogs for spoil haulage;
  - 20 t excavator; and
  - noise from the decline.
- A worst case reverberant sound pressure level of 86 L_{Aeq} dB has been adopted inside the acoustic shed. This is based on all plant and equipment listed (total sound power level of 120 dBA) above operating in the shed at one time continuously over a 15-minute assessment period. This provides a conservative representation of noise levels inside the shed.

7.1.4 Construction ventilation noise

Noise associated with ventilation for the tunnelling construction activities consists of four axial fans at the location depicted on Figure 7.1, each with a sound power level of 107 dBA inclusive of silencers (specifications shown in Appendix A). The fans will be elevated on a steel structure and will be housed in a shipping container. All ducting extended to the cut and cover will be enclosed to minimise noise breakout.

The acoustic shed is fitted with 10 roof exhaust fans each with an attenuated sound power level of 72 dBA. The attenuation comprises an internally lined 90 degree elbow duct fitted to the fan extract as shown in Appendix B.

7.1.5 Other noise generating site activities

Other noise generating activities and equipment on-site included in modelling consists of:

- compressor (Ingersoll Rand 850 CFM 8 bar or similar) with a sound power level of 100 dBA, $L_{Aeq,15min}$; and
- noise generated from the workshop between 7am and 12am with a nominal worst case sound power level of 104 dBA, $L_{Aeq,15min}$.

The location of this equipment is shown on Figure 7.1.

Figure 7.1 Modelled noise source locations

7.2 Site specific noise mitigation

The following mitigation will require implementation on site to achieve compliance with noise management levels:

1. installation of an acoustic shed over the tunnel shaft and spoil handling sites;
2. ventilation fans and ducting to be contained in an acoustic structure including in-duct fan silencing; and
3. hoardings around the site.

7.2.1 Acoustic shed construction

An acoustic shed is to be constructed with the following dimensions (approximate) over the tunnel shaft and spoil handling areas with properties as follows:

- approximately 130 m long (east and west walls) and 50 m wide (north and south walls);
- 12 m height in the western portion and 8 m height in the eastern portion;
- high level acoustic louvre with dimensions 14 m x 4 m on the north and south facades (total surface area 112 m^2);
- one single width door (Parramatta Road);
  - 6 m wide; and
  - 5 m high.
- two single width doors side-by-side (Pyrmont Bridge Road);
  - 6 m wide; and
  - 5 m high.
- one double width door (Mallet Street access).
  - 12 m wide; and
  - 5 m high.

The predicted noise levels include noise through the open/closed doors (as applicable), walls and roof of the shed, as well as through the acoustic louvres.

i Walls

All shed walls are to be constructed of the following:

- outer skin of 0.48 mm base metal thickness (bmt) sheet metal; and
- 60 mm internal insulation lining walls with perforated foil facing inwards.

The sound transmission loss of the proposed wall is presented in Table 7.1. This table also presents the anticipated reduction in performance due to detailing leaks at junctions.

Table 7.1 Minimum sound transmission loss of shed walls

Shed wall	Description	Octave band centre frequency, minimum transmission loss, dB							Rw	Rw + Ctr
		63	125	250	500	1 k	2 k	4 k		
All walls	In principle performance	6	12	16	21	27	30	40	24	23
	With shed leakage	1	7	11	14	18	22	32	n/a	n/a

ii Roof

The shed roof is to be constructed of the following:

- outer skin of 0.42 mm bmt sheet metal;
- an air gap (with structure) of 202 mm with 50 mm minimum 32 kg/m^3 insulation; and
- inner skin of 0.48 mm bmt sheet metal.

The sound transmission loss of the proposed roof is presented in Table 7.2.

Table 7.2 Minimum sound transmission loss of shed roof

Element	Octave band centre frequency, minimum transmission loss, dB							Rw	Rw + Ctr
	63	125	250	500	1k	2k	4k		
Shed roof	6	9	21	31	31	33	35	38	28

iii Internal reverberation control

The shed roof and all walls will be internally lined with insulation to control reverberation noise build-up and breakout through the open doors. A minimum 90% surface area needs to be covered with a material with minimum absorption coefficient as presented in Table 7.3.

If a greater proportion of insulation is applied to the roof (eg 100%), then the amount applied to the walls could be reduced. This may be more practical if the lower wall zone had to be kept clear for maintenance or to reduce dust build-up in the absorptive material which may accumulate more at lower levels and reduce the effectiveness of the insulation.

Table 7.3 Minimum sound absorption coefficient of internal insulation

Element	Octave band centre frequency, minimum absorption coefficient					
	125	250	500	1 k	2 k	NRC
Shed roof and walls (at least 90% coverage)	0.3	1.0	1.0	1.0	0.9	1.0

Notes: 1. Based on NCX Trelawney compound shed design (WM 2015)

iv Louvre

The minimum required insertion loss of the louvre proposed for the north and south facades of the shed is provided in Table 7.4. This performance can be achieved using a Fantech SBL2 acoustic louvre, or approved equivalent. The exact dimensions and size of the louvres required is subject to final selection and required open area, to be confirmed by the design team.

Table 7.4 Minimum insertion loss acoustic louvre

Element	Octave band centre frequency, insertion loss dB (Hz)						
	63	125	250	500	1 k	2 k	4 k
Acoustic louvre	5	10	14	22	27	25	21

7.2.2 Noise hoarding

The proposed location and height of site hoardings for both scenarios is shown in Figure 7.1.

All hoarding with a height of 3 m or less should comprise a single sheet of 19mm plywood or equivalent providing a minimum Rw + Ctr of 22.

All hoarding of greater than 3 m height should comprise either two sheets of 19 mm plywood with sheet joins opposed, double stacked shipping containers or equivalent providing a minimum Rw + Ctr of 24.

Additional 4 m high hoarding has been recommended along the boundary of the nearest receiver to the north-west of site (receiver R7 in Figure 4.1) due to the potential of sleep disturbance at the second floor.

7.2.3 Construction ventilation noise mitigation

i Performance requirements

Four axial fans as shown in Figure 7.1 will be used to provide supply air to the construction works underground. The following specification is required by the fans and fan enclosure:

- Fan inlet noise level of 67 dBA at 3 m;
- Fan outlet noise level of 89 dBA at 3 m; and
- Fan casing/enclosure breakout noise level of 62 dBA at 3 m.

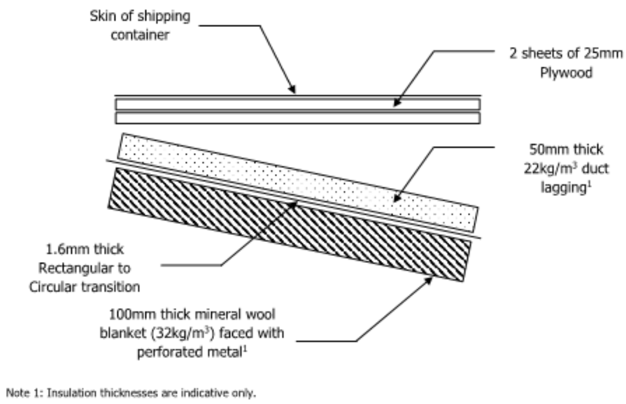
ii Mitigation requirements

It is assumed that the fans used will be similar to those used at the Trelawny tunnelling compound from the NorthConnex project (Appendix A). A notional noise control solution for these fans to achieve the above performance requirements is as follows[2]:

- removal of the Inlet Circular Attenuator, leaving the fan and surrounding housing, henceforth to be referred to as a “fan core” plus the proprietary downstream attenuator. The proprietary downstream attenuator should be placed directly to the underside of the cut and cover structure;

[2] This design is based on the Trelawney site compound ventilation noise mitigation for the Northconnex project (Wilkinson Murray 2015)

- the use of a standard 20-foot-long high cube container to house each fan, with the following assumed internal dimension:
  - length 6 m (Standard 20');
  - width 2.35 m;
  - height 2.697 m (High Cube Container); and
  - the shipping container is to be lined internally or externally with 2 sheets of 19 mm thick Plywood.
- all joints are to be sealed with mastic sealant and an aluminium extrusion or similar is to be in the corner to minimise breakout noise;
- a metal duct (rectangular to circular transition in at least 1.6 mm wall thickness) to be installed between the fan intake and the proposed rectangular attenuator;
- the transition duct is to be lined internally with 100 mm thick mineral wool blanket (32 kg/m^3) faced with perforated metal and is to be externally lagged with 50 mm thick 22 kg/m^3 insulation, as shown in Figure 7.2;



Source: Wilkinson Murray 2015

Figure 7.2 Detail of construction ventilation mitigation

- an enclosure is to be built over the fan housing and ducting to bridge any gap between the container and the cut and cover duct penetration. The duct within the enclosure should be externally lagged with Pyrotek Soundlag 4525C or approved equivalent. This enclosure should have an approximate Rw + Ctr of 23. This could be achieved with 2 sheets of 19 mm thick plywood over a steel frame structure with internal 50 mm insulation (minimum 32 kg/m^3) OR the shed wall system presented in Section 7.2.1i;
- the use of a rectangular attenuator, with the following specification:
  - the rectangular attenuator is to be 50% open area with a semi-circular inlet fairing with tapered discharge profile in order to minimise pressure drop and regenerative noise;
  - the airways shall be straight and parallel;
  - have the limited dimension not exceeding 2.7 m (height) and 2.35 m (width) limited by the internal dimensions of a standard high cube shipping containers;

- have a minimum insertion loss as defined in Table 7.5; and
- have a maximum regenerative noise in Table 7.6.

Table 7.5 Minimum insertion loss of inlet attenuator

Element	Octave band centre frequency, insertion loss dB (Hz)							
	63	125	250	500	1 k	2 k	4 k	4 k
Inlet attenuator	21	28	51	54	61	37	21	22

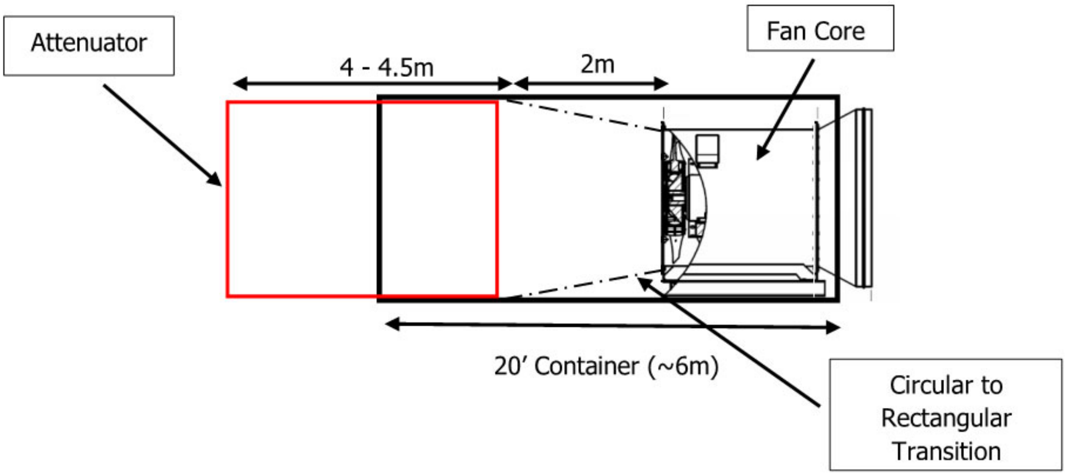
Table 7.6 Maximum regenerated noise of inlet attenuator

Element	Octave band centre frequency, insertion loss dB (Hz)							
	63	125	250	500	1 k	2 k	4 k	4 k
Inlet attenuator	82	69	66	64	63	61	59	52

For access to the fan cores the following could be provided:

- a solid wood door or that constructed from a similar cross section to the hoarding could be installed for access to the fan area through the hoarding; or
- a door constructed from a similar cross section to that of the container could be installed in the wall or roof of the shipping container.

A possible layout in relation to the placement of the container relative to the fan housing is shown in Figure 7.3.



Source: Wilkinson Murray 2015

Figure 7.3 Construction ventilation mitigation cross-section

7.2.4 Cut and cover

The surface cover of the decline is specified to consist of large concrete planks, allowing for work and activities to continue on the surface as well as providing sufficient noise reduction minimizing breakout noise from the shaft. It is required that these planks be fully sealed between each plank, ie no air gaps, in order for the system to be effective in minimising noise breakout from the shaft.

Alternatively, a steel frame over the decline with two sheets of 25 mm thick plywood or three sheets of 17 mm thick plywood with 75 mm thick insulation with perforated foil facing to the underside could be used. The ply sheeting joins on each layer should be opposed. Any gaps or cavity on the perimeter should be filled with insulation and capped with ply sheeting, aluminium extrusion/capping or similar solid material.

7.3 Noise predictions

Noise emissions from the site were modelled using Bruel & Kjær proprietary modelling software, Predictor. Predictor allows prediction under the ISO9613-2 “*Acoustics – Attenuation of Sound during Propagation Outdoors – general method”* algorithm. This algorithm is accepted by the EPA. Features which affect the predicted noise level that are considered in the noise modelling include:

- equipment sound power levels and locations;
- screening from structures;
- receiver locations;
- ground topography;
- noise attenuation due to geometric spreading;
- ground absorption; and
- atmospheric absorption.

For all scenarios, it has been assumed that all plant and equipment operate simultaneously. This is considered to be a conservative representation of a typical worst case scenario.

In addition, a comparison has been produced by comparing noise level predictions at receivers when the number of trucks within a 15-minute period are varied from 2 to 8, with half of these being spoil haulage and half being concrete agitators.

This comparison assumes that the Mallet Street access door would be open and used by concrete agitators between 7am and 6pm only. The Parramatta Road and Pyrmont Bridge Road access will be used at other times.

7.3.1 Results

Noise level predictions to the nearest representative sensitive receivers are provided in Table 7.7Pre (refer Figure 4.1 for receiver locations). The noise modelling demonstrates these locations have the highest predicted noise levels of all residential receivers. Therefore, predicted noise levels at other residential receivers will be equal to or less than those presented in Table 7.7, for the respective areas.

Predictions for each period are presented with comparison to relevant NMLs as outlined in Section 5. The noise level predictions are based on operational noise sources outlined in Section 7.1 and with noise mitigation applied as outlined in Section 7.2.

Table 7.7 Predicted noise level above NML, $L_{Aeq,15min}$ dB

Receiver	Day										Evening					Evening shoulder					Night					Morning shoulder				
	NML (standard)	Trucks[1]				NML (OOH)	Trucks[1]				NML (OOH)	Trucks[1]				NML	Trucks[1]				NML	Trucks[1]				NML	Trucks[1]			
		2	4	6	8		2	4	6	8		2	4	6	8		2	4	6	8		2	4	6	8		2	4	6	8
E1	65	0	0	0	0	65	0	0	0	0	65	0	0	0	0	65	0	0	0	0	65	0	0	0	0	65	0	0	0	0
R1	61	0	0	0	0	56	0	0	0	0	54	0	0	0	0	50	0	0	0	0	46	2	2	3	3	51	0	0	0	0
R2	61	0	0	0	0	56	0	0	0	0	54	0	0	0	0	50	0	0	0	0	46	1	2	2	3	51	0	0	0	0
R3	61	0	0	0	0	56	0	0	0	0	54	0	0	0	0	50	0	0	0	0	46	1	1	2	2	51	0	0	0	0
R4	61	0	0	0	0	56	0	0	0	0	54	0	0	0	0	50	0	0	0	0	46	0	0	1	1	51	0	0	0	0
R5	61	0	0	0	0	56	0	0	0	0	54	0	0	0	0	50	0	0	0	0	46	0	0	0	0	51	0	0	0	0
R6	61	0	0	0	0	56	0	0	0	0	54	0	0	0	0	50	0	0	0	0	46	0	0	0	0	51	0	0	0	0
R7	61	0	0	0	0	56	0	0	0	0	54	0	0	0	0	50	0	0	0	0	46	0	0	1	1	51	0	0	0	0
R8	61	0	0	0	0	56	0	0	0	0	54	0	0	0	0	50	0	0	0	0	46	1	1	1	1	51	0	0	0	0
R9	61	0	0	0	0	56	0	0	0	0	54	0	0	0	0	50	0	0	0	0	46	0	0	0	0	51	0	0	0	0
R10	61	0	0	0	0	56	0	0	0	0	54	0	0	0	0	50	0	0	0	0	46	0	0	0	0	51	0	0	0	0
R11	61	0	0	0	0	56	0	0	0	0	54	0	0	0	0	50	0	0	0	0	46	0	0	0	0	51	0	0	0	0
R12	61	0	0	0	0	56	0	0	0	0	54	0	0	0	0	50	0	0	0	0	46	0	0	0	0	51	0	0	0	0
R13	61	0	0	0	0	56	0	0	0	0	54	0	0	0	0	50	0	0	0	0	46	0	0	0	0	51	0	0	0	0
R14	61	0	0	0	0	56	0	0	0	0	54	0	0	0	0	50	0	0	0	0	46	0	0	0	0	51	0	0	0	0
R15	63	1	1	1	1	58	6	6	6	6	55	0	0	0	0	53	0	0	0	0	51	0	0	0	0	54	0	0	0	0
R16	72	0	0	0	0	67	0	0	0	0	64	0	0	0	0	60	0	0	0	0	56	0	0	0	0	61	0	0	0	0
R17	72	0	0	0	0	67	0	0	0	0	64	0	0	0	0	60	0	0	0	0	56	0	0	0	0	61	0	0	0	0

Notes: 1. Assumes 50% spoil haul trucks and 50% concrete agitators

In summary, noise level predictions comply at most sensitive receiver locations for all possible worst case operational scenarios. The exceptions to this are described below.

Predicted noise levels at PBR receivers located north of the site are compliant with NMLs throughout all periods except for between 12am and 5am where an exceedance of up to 3 dB has been identified (R1 and R2 only), predominantly caused by spoil haul and concrete agitator truck movements. This predicted exceedance will be limited 1 to 2 dB based on no more than 4 trucks arriving and leave site in a 15-minute period which is representative for this time period. A 1 to 2 dB exceedance is classified by the EPA and DPE as negligible after all feasible and reasonable noise mitigation and management has been applied (refer to the NPfI (EPA 2017) and Voluntary Land Acquisition and Mitigation Policy (VLAMP) (DPE 2017)).

For R15, predicted noise levels:

- comply with the evening, night and shoulder period NMLs;
- are marginally above the standard day NML by 1 dB; and
- are above the day OOH NML by 6 dB.

The exceedances during the standard and OOH day period are due to the Mallet Street access door being open which is otherwise closed between 6pm and 7am.

Notwithstanding the above, the following points are applicable to the actual potential for noise impact during OOH day periods at this property (ie Sunday and Public Holidays from 8am to 6pm):

- the boundary of this property is directly on the pedestrian footpath on Mallet Street. The ground floor is commercial with the top floor residential. The potential for external amenity to be affected by construction noise is considered irrelevant as there no external spaces associated with the top floor residential dwelling; and
- existing energy average (L_{Aeq}) noise levels during the day are estimated to be 65 dBA (based on P.02 data), largely due to road traffic noise. Given this level of external road traffic noise, it is anticipated that the windows fronting Mallet Street would be closed during the day, if occupants wanted to mitigate the existing external noise environment, and hence construction noise is likely to be ameliorated.

A noise level of 52 dB is predicted at the educational facility to the south of the site (E1) during the day time with site at maximum capacity. The NML for classrooms in Table 5.4 specifies an internal level of 45dB. A typical building facade partially including windows would provide a transmission loss of at least 10dB. Accounting for this, an external level of 52 dB at the façade, and therefore a likely internal noise level of 42 dB, is predicted to satisfy this requirement.

Predicted noise levels from tunnelling activity are expected to satisfy NMLs at all other sensitive receiver locations across all time periods.

Consultation on proposed works and mitigation measures will be undertaken with receivers identified to have exceedances of NMLs outside Standard Construction Hours (ie 'affected sensitive receivers'), where no other consultation or at receiver mitigation strategies are implemented.

7.3.2 Sleep disturbance

Sleep disturbance impacts from onsite trucking movements has been assessed at residential receivers. The predicted maximum noise levels at the nearest representative receivers are provided in Table 9.2 and apply to the upper most floor.

Table 7.8 Maximum noise level predictions, dB

Receiver	Sleep disturbance screening criteria (RBL + 15 dB)	Predicted noise level (L_{max})
R1	56	**68**
R2	56	**67**
R3	56	**65**
R4	56	**64**
R5	56	**63**
R6	56	**64**
R7	56	**62**
R8	56	**60**
R9	56	**57**
R10	56	**58**
R11	56	52
R12	56	51
R13	56	50
R14	56	45
R15	56	50
R16	66	**67**
R17	66	**57**

Notes: 1. Predictions in bold indicate exceedances of screening criteria

Maximum noise levels above the sleep disturbance screening criteria are predicted at 12 representative locations.

Notwithstanding, with the exception of locations R1, R2 and R16, predicted maximum noise levels are below levels expected to cause awakenings of 60 to 65 dB L_{max} external (equating to 50 to 55 dB L_{max} internal) as referenced in the RNP (EPA 2011).

The existing maximum noise levels are mostly generated by traffic movements on Parramatta Road, Pyrmont Bridge Road and Mallet Street, which are similar in nature to the maximum noise level events that will be generated by the site at night. An analysis of unattended noise monitoring data at P.01 demonstrated that 99% of 15-minute logger data featured L_{max} events that exceeded this upper criteria of 65 dB by more than 5 dB, and 82% of data featured events that exceeded it by more than 10 dB. The relative impact of truck movements compared to the existing noise environment is therefore similar, albeit with additional events.

The predicted level at receiver R7 is representative of the southern facade at the second storey and takes into account the proposed 4 m hoarding at the receiver boundary which is required to mitigate maximum noise levels to below 65 dBA. If preferred, at property acoustic treatment will be implemented to reduce the risk of sleep disturbance at this property. This will reduce the height requirement of this wall or remove the need for the wall altogether for noise control purposes.

Maximum noise level events will be managed during the night-time period in accordance with the Construction Environment Management Plan (CEMP).

7.3.3 Road traffic noise

Road traffic noise impacts due to increased truck movements on public roads generated by 24/7 tunnelling activities will be assessed in the project's haulage CNVIS.

8 Construction vibration assessment

No vibration impacts from the PBR ancillary facility are expected apart from those generated during site establishment works and by tunnelling activity. Vibration impacts from these project aspects have been assessed in the Site Establishment CNVIS (EMM 2018) and Tunnelling CNVIS (EMM 2018), respectively.

9 Noise mitigation and management

9.1 General

The EPA’s NSW ICNG requires that construction noise levels are assessed against NMLs.

Noise levels above NMLs have been predicted with the incorporation of noise mitigation measures. It is not uncommon for construction projects to exceed NMLs. For this reason, they are not considered as noise criteria, but as a trigger for all feasible and reasonable noise mitigation and management to be considered, once exceeded.

Noise mitigation and management for the site that has been described in detail in Section 7.2. Other mitigation and management measures that can be implemented on site are provided in the following sections.

9.2 Work practices

Work practice methods include:

- the Mallet Street shed access door will be closed between 6 pm and 7 am;
- regular reinforcement (such as at toolbox talks) of the need to minimise noise and vibration;
- regular identification of noisy activities and adoption of improvement techniques;
- avoiding the use of portable radios, public address systems or other methods of site communication that may unnecessarily impact upon nearby residents;
- develop routes for the delivery of materials and parking of vehicles to minimise noise;
- where possible, avoid the use of equipment that generates impulsive noise;
- minimise the movement of materials and plant and unnecessary metal-on-metal contact;
- minimise truck movements; and
- schedule respite periods for intensive works as determined through consultation with potentially affected neighbours (eg a daily respite period for a minimum of one hour at midday).

9.3 Plant and equipment

Additional measures for plant and equipment include:

- where possible, choose quieter plant and equipment based on the optimal power and size to most efficiently perform the required tasks;
- operate plant and equipment in the quietest and most efficient manner; and
- regularly inspect and maintain plant and equipment to minimise noise and vibration level increases, to ensure that all noise and vibration reduction devices are operating effectively.

9.4 Quantifying noise reductions

Approximate noise reductions provided by some of these measures are provided in Table 9.1.

Table 9.1 Relative effectiveness of various forms of noise control

Noise control	Nominal noise reduction possible, in total A-weighted sound pressure level, dB
Increase source to receiver distance[1]	approximately 6 dB for each doubling of distance
Reduce equipment operating times or turn off idling machinery[2]	approximately 3 dB per halving of operating time
Operating training on quiet operation[2]	Up to 3 to 5 dB
Screening (eg noise barrier)[1]	normally 5 dB to 10 dB, maximum 15 dB
Enclosure (eg shed/building)[1]	normally 15 dB to 25 dB, maximum 50 dB
Silencing (eg exhaust mufflers) [1]	normally 5 dB to 10 dB, maximum 20 dB

Notes:

1. Sourced from AS2436-2010
2. Based on EMM's measurement experience at construction and mining sites

9.5 Additional noise mitigation measures – Construction Noise and Vibration Guideline

In many instances, impacts from construction noise and vibration are unavoidable where works are undertaken in relatively close proximity to surrounding receivers. The CNVG includes a list of additional mitigation measures which aim to manage the potential noise impacts. Additional mitigation measures from the CNVG that have been adopted for the project are summarised in Table 9.2.

Table 9.2 CNVG additional noise mitigation measures

ID	Name	Description
N	Notification (letterbox drop or equivalent)	Advanced warning of works and potential disruptions can assist in reducing the impact to the community. The notification may consist of a letterbox drop (or equivalent) detailing work activities, time periods over which these will occur, impacts and mitigation measures. Notification should be a minimum of seven calendar days prior to the start of works. The approval conditions for projects may also specify requirements for notification to the community about works that may impact on them.
SN	Specific notifications	Specific notifications are letterbox drops (or equivalent) to identified stakeholders no later than seven calendar days ahead of construction activities that are likely to exceed the noise objectives. The specific notification should provide additional information to that covered in the general notifications and be targeted at highly affected receivers.
RO	Respite offers	Respite Offers should be considered and or adopted where there are high noise and vibration generating activities near receivers. As a guide work should be carried out in continuous blocks that do not exceed three hours each, with a minimum respite period of one hour between each block. The actual duration of each block of work and respite should be flexible to accommodate the usage of and amenity at nearby receivers. The purpose of such an offer is to provide residents with respite from an ongoing impact. This measure is evaluated on a project-by-project basis, and may not be applicable to all projects.

Table 9.2 CNVG additional noise mitigation measures

ID	Name	Description
R1	Respite period 1	Out of hours construction conducted during the OOHW period 1 (Monday to Friday 6 pm to 10 pm, Saturday 7 am to 8 am and 1 pm to 10 pm, Sunday/Public Holiday 8 am to 6 pm) shall be limited to no more than three consecutive evenings per week except where there is a duration respite. For night work these periods of work should be separated by not less than one week and no more than six evenings per month.
R2	Respite period 2	Night time construction in OOHW period 2 (Monday to Friday 10 pm to 7 am, Saturday 10 pm to 8 am, Sunday/Public Holiday 6 pm to 7 am) shall be limited to two consecutive nights except for where there is a Duration Respite. For night work these periods of work should be separated by not less than one week and six nights per month. Where possible, high noise generating works shall be completed before 11 pm.
AA	Alternative accommodation	Alternative accommodation options may be offered to residents living in close proximity to construction works that are likely to experience highly intrusive noise levels (refer to Tables C1-C3 of the CNVG). The specifics of the offer will be identified on a project-by-project basis. Additional aspects for consideration shall include whether the highly intrusive activities occur throughout the night or before midnight.
DR	Duration respite	Respite offers and respite periods 1 and 2 may be counterproductive in reducing the impact on the community for longer duration projects. In this instance and where it can be strongly justified that it may be beneficial to increase the work duration, number of evenings or nights worked through Duration Respite so that the project can be completed more quickly The project team should engage with the community where noise levels are expected to exceed the NML to demonstrate support for Duration Respite Where there are few receivers above the NML each of these receivers should be visited to discuss the project to gain support for Duration Respite.
V	Verification	Refer to Appendix F of the CNVG for more details about verification of noise and vibration levels as part of routine checks of noise levels or following reasonable complaints. This verification should include measurement of the background noise level and construction noise. Note this is not required for projects less than three weeks unless to assist in managing complaints.

The level of additional mitigation is then assigned based on the impact classification (ie predicted noise level above NML) and the list of measures in Table 9.3.

Table 9.3 Additional mitigation measures matrix – airborne construction noise

Predicted airborne $L_{Aeq(15min)}$ noise level at receiver			Additional mitigation measures	
Perception	**dBA above RBL**	**dBA above NML**	**Type**	**Mitigation levels**
All hours				
75 dBA or greater			N, V, RO	HA
Standard hours: Mon - Fri (7 am – 6 pm), Sat (8 am – 1 pm), Sun/Pub Hol (Nil)				
Noticeable	5 to 10	0	-	NML
Clearly audible	10 to 20	<10	-	NML
Moderately intrusive	20 to 30	10 to 20	N, V	NML + 10
Highly intrusive	>30	> 20	N, V	NML + 20
OOHW Period 1: Mon – Fri (6 pm – 10 pm), Sat (7 am – 8 am & 1 pm – 10 pm), Sun/Pub Hol (8 am – 6 pm)				
Noticeable	5 to 10	<5	-	NML
Clearly audible	10 to 20	5 to 15	N, R1, DR	NML +5
Moderately intrusive	20 to 30	15 to 25	V, N, R1, DR	NML + 15

Table 9.3 Additional mitigation measures matrix – airborne construction noise

Predicted airborne $L_{Aeq(15min)}$ noise level at receiver			Additional mitigation measures	
Perception	**dBA above RBL**	**dBA above NML**	**Type**	**Mitigation levels**
Highly intrusive	>30	>25	V, N, SN, R2, DR	NML + 25
OOHW period 2: Mon - Fri (10 pm – 7 am), Sat (10 pm – 8 am), Sun/Pub Hol (6 pm – 7 am)				
Noticeable	5 to 10	<5	N	NML
Clearly audible	10 to 20	5 to 15	V, N, R2, DR	NML + 5
Moderately intrusive	20 to 30	15 to 25	V, N, SN, R2, DR	NML + 15
Highly intrusive	>30	>25	AA, V, N, SN, R2, DR	NML + 25

Note:

1. The following abbreviations are used: Alternative Accommodation (AA), Respite Period 1 (R1), Verification (V), Specific Notifications (SN), Notification drops (N), Respite Period 2 (R2), Negotiated Respite (NR), Highly Affected (HA), Respite Offer (RO), Duration Respite (DR).

Based on the noise level predictions in Section 7.3.1, no additional noise mitigation measures in accordance with the CNVG are required.

Notwithstanding, LSBJV will actively consult with the residents at upper floors of neighbouring properties to confirm the level of impact is acceptable and where appropriate apply additional reasonable and feasible mitigation.

Consultation on proposed works and mitigation measures will be undertaken with receivers identified to have exceedances of NMLs outside Standard Construction Hours (ie 'affected sensitive receivers'), where no other consultation or at receiver mitigation strategies are implemented.

9.6 Community consultation and complaints handling

Community consultation and complaints handling will be undertaken in accordance with the project's Community Communication Strategy (CCS).

10 Conclusion

EMM has completed a construction noise and vibration impact statement to review potential noise and vibration impacts from proposed activities at the PBR ancillary facility to support 24-hour tunnelling.

The site will be extensively mitigated and will be managed to reduce noise emissions, most importantly during the night time period. The mitigation and management applied at site follows the reasonable and feasible approach as outlined in the ICNG (EPA 2009) and CNVG (RMS 2015) as required by the conditions of approval.

The assessment identified that noise level predictions comply at most sensitive receivers for all possible worst case scenarios. The predicted noise levels at Pyrmont Bridge Road receivers located north of the site are compliant with NMLs throughout all periods except for the night (12 am to 5 am) where a 1 to 2 dB exceedance is predicted. A 1 to 2 dB exceedance is classified by the EPA and DPE as negligible after all feasible and reasonable noise mitigation and management has been applied - such a noise level above NML would be imperceptible compared to a noise level that was predicted to meet NML.

For R15, predicted noise levels comply with the evening, night and shoulder period NMLs, are marginally above the standard day NML by 1 dB and are above the day OOH NML by up to 6 dB (this NML applies to 8 am to 6 pm on Sundays and Public Holidays only).

Notwithstanding the above, the boundary of this property is directly on the pedestrian footpath on Mallet Street. The ground floor is commercial with the top floor residential. The potential for external amenity to be affected by construction noise is considered irrelevant as there no external space associated with the top floor residential dwelling. Further, predicted construction noise levels are similar to the existing energy average (L_{Aeq}) noise levels

Further, the predicted noise levels in this CNVIS are considerably lower than those presented for the mitigated scenario in the EIS. A comparison of predicted noise levels above night NMLs is summarised as follows:

- 28 properties in the EIS versus 6 in this CNVIS with noise levels at 1 to 10 dB above NML; and
- 1 property in the EIS versus 0 properties in this CNVIS with noise levels at 11 to 20 dB above NML.

Maximum noise levels above the sleep disturbance screening criteria are predicted at 12 representative locations. Notwithstanding, with the exception of three locations, predicted maximum noise levels are below levels expected to cause awakenings of 60 to 65 dB L_{max} external (equating to 50 to 55 dB L_{max} internal) as referenced in the RNP (EPA 2011). For the three remaining receiver locations, internal noise levels are predicted at up to 58 dBA which is moderately above internal levels that are likely to disturb sleep as referenced in the RNP (EPA 2011). Notwithstanding, the predicted maximum noise levels from site are mostly less than existing maximum noise level events recorded surrounding the site as displayed in unattended noise logging data from the EIS stage. Mitigation measures have been proposed, including increased hoarding and noise barriers to reduce maximum noise level events below levels which are likely to generate awakenings as referenced in the RNP (EPA 2011).

Other noise and vibration assessment aspects of the site such as construction vibration and traffic movements on public roads have been assessed in the project's Site Establishment CNVIS, Tunnelling CNVIS and Haulage CNVIS.

Appendix A

Tunnel air supply fan specifications and attenuators

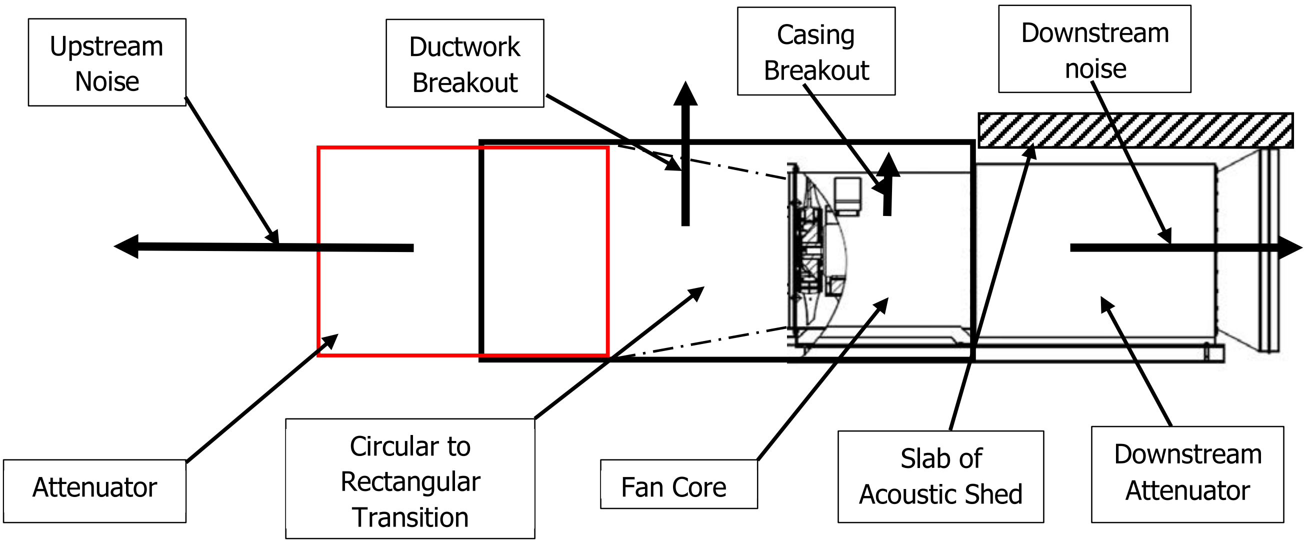
Ventilation Noise Sources

The main noise transmission paths are:

- Noise emanating from the inlet;
- Noise emanating from the outlet down into the shaft; and
- Noise breakout through the fan casing and ductwork.

Downstream noise into the shaft and ductwork breakout into the acoustic shed are not detailed in the below assessment as they form part of the reverberant level inside the acoustic shed.

Figure C- 1 Approximate Locations of Noise Sources



Sound Power Levels (SWLs) are taken from the supplied manufacturer's dataset provided in Appendix C.

Two 250kW fans (Fans 1 & 2) and two 200kW fans (Fans 3 & 4) are to be used at Trelawney Compound. Due to space concerns the inlet circular attenuator as supplied by Cogemacoustic is to be removed, with the Sound Power Level stated in *Table C- 1* being for the Fan only.

Table C- 1 Sound Power Level of the Construction Ventilation Fans

	63	125	250	500	1K	2K	4K	8K	Level (dBL)	Level (dBA)
Sound Power Level Fans 1 & 2	101	107	118	113	113	111	106	100	121	**119**
Sound Power Level Fans 3 & 4	99	105	116	111	111	109	105	98	119	**116**

Upstream Noise Mitigation

As detailed in Section 5.3, the mitigation of the upstream noise from each fan ventilation system is to be achieved through the specification of a large rectangular attenuator. This is to be connected to the fan inlet by the means of rectangular to circular transition duct lined with insulation as shown in Figure 5-6. The following is therefore proposed:

The use of a rectangular attenuator, with the following specification:

- The rectangular attenuator is to be 50% open area with a semi-circular inlet fairing with tapered discharge profile in order to minimise pressure drop and regenerative noise;
- The airways shall be straight and parallel;
- Have the limited dimension not exceeding 2.7m (Height) and 2.35m (Width) limited by the internal dimensions of a standard high cube shipping containers;
- Have a minimum insertion loss as defined *Table C- 2*; and Have a maximum Regenerative Noise in Table C-3;

The use of transition duct, with the following specification:

- The transition duct is to be lined internally with 100 mm thick mineral wool blanket (32 kg/m^3) faced with perforated metal and is to be externally lagged with 50mm thick 22kg/m^3 insulation, as shown in Figure 5-6.

Table C- 2 Minimum Insertion loss of Inlet Rectangular Attenuator

Octave Band Insertion Loss (dB)							
63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
21	28	51	54	61	37	21	22

Table C- 3 Maximum Regenerative Noise

Octave Band Insertion Loss (dB)							
63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
82	69	66	64	63	61	59	52

The effect of lining the transition duct has not been included. Wood's method provides only an indicative order of magnitude solution and the inclusion of lining is intended to alleviate the increased aerodynamic noise caused by the transition and non-ideal inlet conditions.

The calculation of the modelled SWL is provided in Figure C- 2.

Figure C- 2 Construction Ventilation SWL with Attenuation outlined in Section 5.3

	Item / Description		Rating/Broadband/Input Rating	dB	dB(A)	31.5	Octave Band Centre Frequency, Hz 63	125	250	500	1k	2k	4k	8k
1	Fan SWL	Trelawney F1 & F2		121.0	117.8 (A)		101.0	107.0	118.0	113.0	113.0	111.0	106.0	100.0
2														
3	Attentuaor Insertion Loss	As specified in Table 5-6	3000 mm				-21.0	-28.0	-51.0	-54.0	-61.0	-37.0	-21.0	-22.0
4	Attenuator Regenerated Noise, As Supplied by NAP	As specified in Table 5-7	2300 mm	2600 mm	190 Pa		82.0	69.0	66.0	64.0	63.0	61.0	59.0	52.0
5														
6	Linear Sum	Row 1 + 3		87.7	86.8 (A)		80.0	79.0	67.0	59.0	52.0	74.0	85.0	78.0
7	Attn. Level with Regen Noise	Log Sum 4 & 6		88.8	86.9 (A)		84.1	79.4	69.5	65.2	63.3	74.2	85.0	78.0

Duct Break-out

An enclosure is to be built around each of the Ventilation fans to control duct breakout. This is proposed to be constructed using a lined standard high cube shipping container, in reference to transmission loss the following has been assumed:

- The shipping Container is constructed from steel with a skin thickness of 1.6mm;
- The shipping container is to be lined internally or externally with 2 sheets 25mm Plywood;

The sound transmission loss of the wall and roof sections of the ship container is provided in *Table C-4*.

Table C- 4 Transmission Loss of Enclosure to be constructed around Ventilation

Enclosure Around Ventilation Fan Transmission Loss	Minimum Octave Band Sound Transmission Loss, dB							Rw + Ctr
	63Hz	125Hz	250Hz	500Hz	1kHz	2khz	4kHz	
	25	29	28	26	28	34	41	28

As outlined in section 5.3 any space between the acoustic enclosure and acoustic shed is to be bridged with a nominal construction of 2 sheets of 25mm plywood or 3 sheets of 17mm plywood and sealed with mastic sealant and an aluminium extrusion or similar is to be in the corner to minimise breakout

Additionally the fan casing and the circular to rectangular transition duct provide additional transmission loss to the external environment. *Table C- 5* details the assumed fan casing transmission loss and

*Table C- **6*** details the transmission loss the transition duct.

No room loss has been assumed for the space between the fan casing/transition duct and the outer wall of the shipping container.

Table C- 5 Assumed Fan casing Transmission Loss

Transmission Loss	Minimum Octave Band Sound Transmission Loss, dB						
	63Hz	125Hz	250Hz	500Hz	1kHz	2khz	4kHz
	10	25	29	28	27	28	19

Table C- 6 Assumed Transition Duct Transmission Loss

Transmission Loss	Minimum Octave Band Sound Transmission Loss, dB						
	63Hz	125Hz	250Hz	500Hz	1kHz	2khz	4kHz
	4	10	16	22	28	34	34

Structure Borne Noise Mitigation

The acoustic enclosure is to be placed on a concrete slab on ground, which is not directly coupled to any sensitive receiver. Furthermore the vibration emission of such a piece of equipment is considered insignificant with respect to structure borne noise at the receivers.

In regards to vibration isolation to the acoustic enclosure, a vibration isolator mount similar to Mason's NDC, loaded to provide approx. 6mm deflection in the operating condition is to be placed between the Fan Core and acoustic enclosure. Details of the suggested vibration mount are provided in appendix C.

Although not shown on Figure 5-5, a rubber coupling is to be placed between the fan core and the downstream attenuator / transition duct to isolate the fan from the structure, such that the mounts work as intended.

Predicted Noise Levels for Ventilation

Table C- 7 details the predicted noise level at the most affected receivers for ventilation noise.

This considers the following noise sources:

- Noise emanating from the inlet, with the following assumptions:
    - SWL as detailed in Figure C- 2;
    - Emission over the entire face of the ventilation enclosure detailing an area of 2.35m by 2.69m for each fan;
- Break-out emanating from each ventilation enclosure, with the following assumptions:
    - Internal SWL as detailed in Figure C- 2;
    - Transmission losses as detailed in *Table C- 4*, *Table C- 5* and *Table C- **6***;
    - Emission over the entire roof and walls of each ventilation enclosure, detailing an area of 2.69 by 6m for the walls and 2.35m by 6m for the roof;

In reference to global noise source emissions, this forms only a partial level at the most affected receivers, with compliance for global site noise emission demonstrated for various truck movements in Section 6, with predicted noise levels for non-compliance receivers provided in detail in Appendix G.

COGEMACOUSTIC®

Sound Data - Trelawney - F1 & F2 (standard silencers)

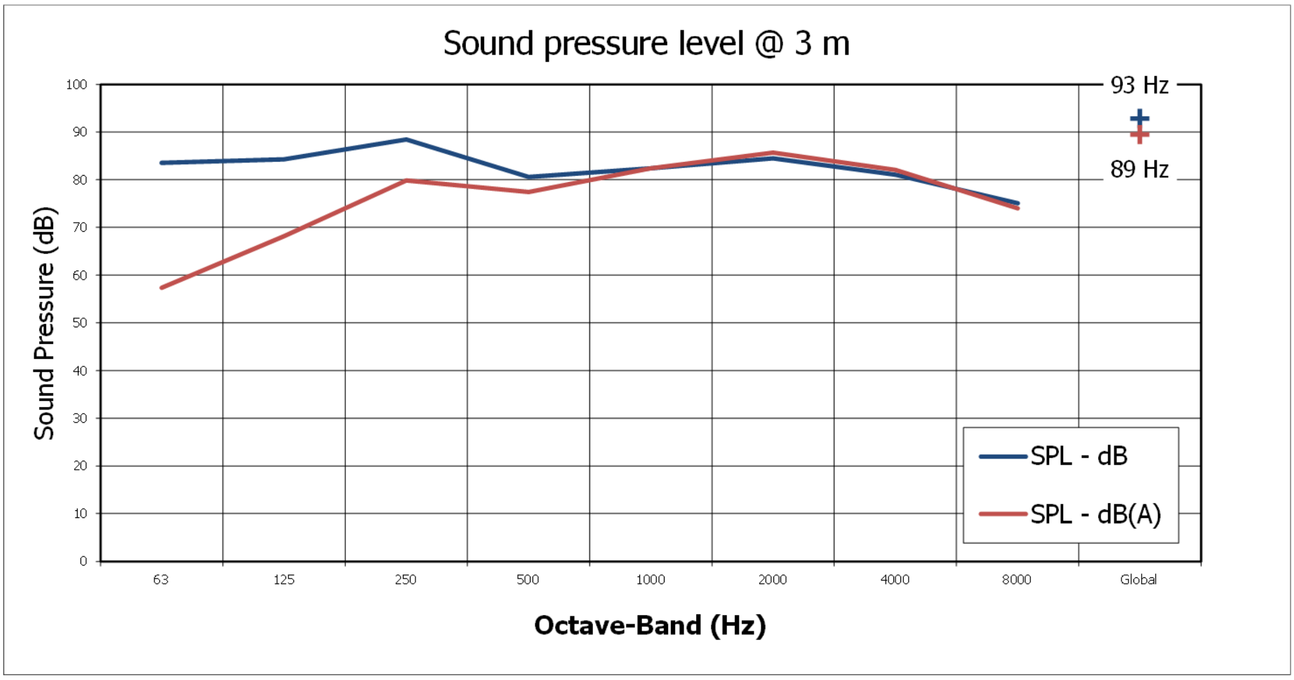
Fan	**Ø1800 250 kW**
Airflow	74.7 m³/s
Total Pressure	2540 Pa
Number of stages	1
Nominal diameter	1800 mm
Number of blades	9
Fan/hub ratio	C1
Hub Diameter	1000 mm
Frequency	48 Hz
Rotational speed	1423 rpm

Silencers	
Length	1.5D
Pod	Yes
Inlet section	2.54 m²
Inlet speed	29.4 m/s

Acoustic pressure mesurements	
Distance	3 m
Q	2
Lw - Lp	-17.5 dB

Fan

Basic Sound Power	**dB**	**121**							
Octave-Band	Hz	63	125	250	500	1000	2000	4000	8000	Global
A weighting	dB	-26	-16	-9	-3	0	1	1	-1	0
Blade frequency correction	dB	0	0	6.5	0	0	0	0	0	
Strouhal number	-	0.8	1.7	3.4	6.7	13	27	54	107	
Spectrum correction	dB	-20	-14	-10	-8	-8	-10	-14	-21	
Octave power level (stage)	dB	101	107	118	113	113	111	106	100	121
Octave power level (fan)	dB	101	107	118	113	113	111	106	100	121
Octave power level	dB(A)	75	91	109	110	113	112	107	99	118
Silencers										
Attenuation	dB	-6.0	-7.0	-12.0	-17.0	-14.0	-9.0	-8.0	-7.5	-20.8
Regeneration	dB	100	97	94	94	93	89	83	73	103
Octave power level	dB	101	102	106	98	100	102	99	93	**110**
Sound Pressure										
Sound pressure level @ 3 m	dB	84	84	88	81	82	84	81	75	93
Sound pressure level @ 3 m	dB(A)	57	68	80	77	82	86	82	74	**89**



COGEMACOUSTIC®

Sound Data - Trelawney - F3 & F4

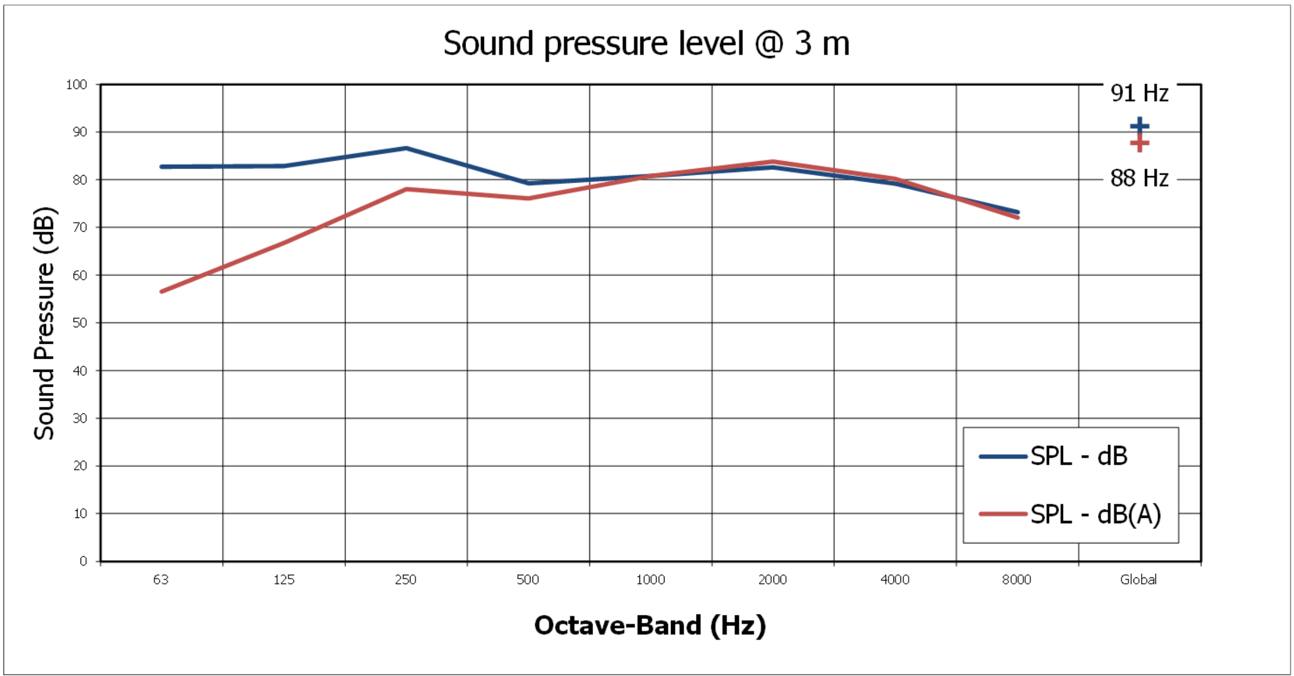
Fan	**Ø1800 200 kW**
Airflow	73.3 m³/s
Total Pressure	2051 Pa
Number of stages	1
Nominal diameter	1800 mm
Number of blades	9
Fan/hub ratio	C1
Hub Diameter	1000 mm
Frequency	48 Hz
Rotational speed	1427 rpm

Silencers	
Length	1.5D
Pod	Yes
Inlet section	2.54 m²
Inlet speed	28.8 m/s

Acoustic pressure mesurements	
Distance	3 m
Q	2
Lw - Lp	-17.5 dB

Fan

Basic Sound Power	**dB**	**119**								
Octave-Band	Hz	63	125	250	500	1000	2000	4000	8000	Global
A weighting	dB	-26	-16	-9	-3	0	1	1	-1	0
Blade frequency correction	dB	0	0	6.5	0	0	0	0	0	
Strouhal number	-	0.8	1.7	3.3	6.7	13	27	54	107	
Spectrum correction	dB	-20	-14	-10	-8	-8	-10	-14	-21	
Octave power level (stage)	dB	99	105	116	111	111	109	105	98	119
Octave power level (fan)	dB	99	105	116	111	111	109	105	98	119
Octave power level	dB(A)	73	89	107	108	111	110	106	97	116
Silencers										
Attenuation	dB	-6.0	-7.0	-12.0	-17.0	-14.0	-9.0	-8.0	-7.5	-20.8
Regeneration	dB	99	96	93	93	92	88	82	72	103
Octave power level	dB	100	100	104	97	98	100	97	91	**109**
Sound Pressure										
Sound pressure level @ 3 m	dB	83	83	87	79	81	83	79	73	91
Sound pressure level @ 3 m	dB(A)	57	67	78	76	81	84	80	72	**88**



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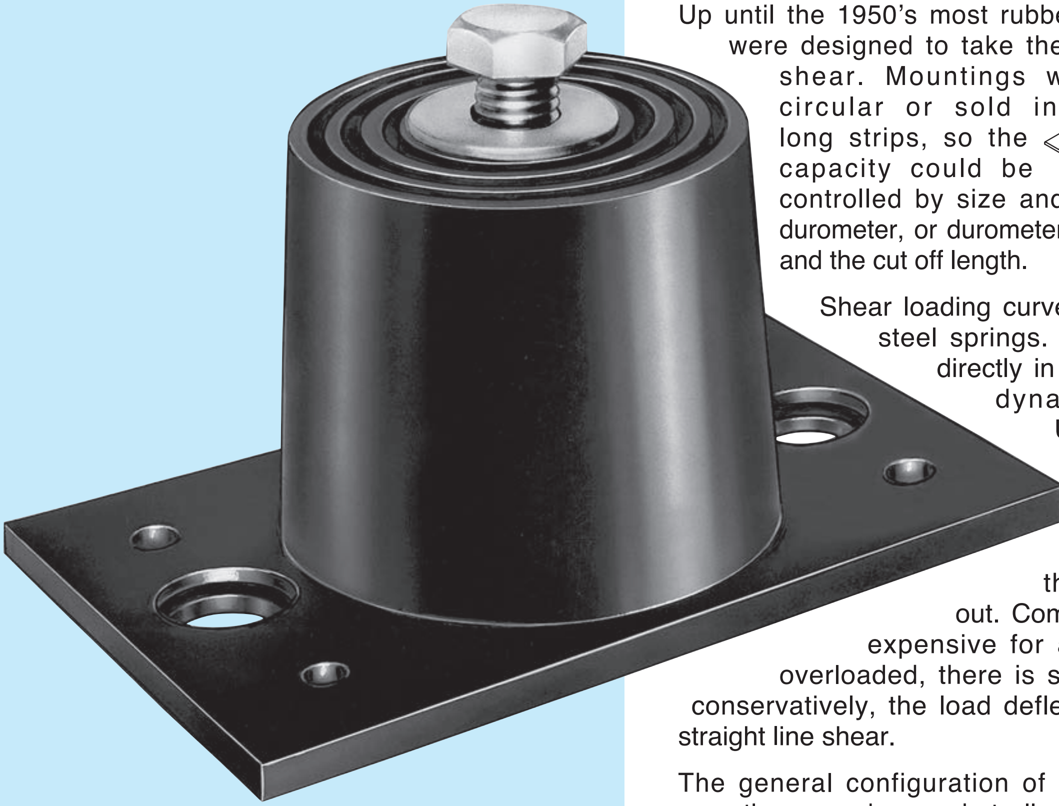
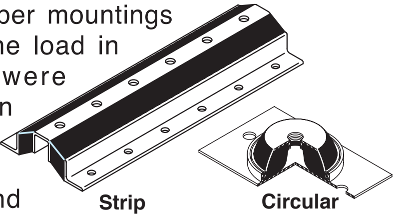
DOUBLE DEFLECTION NEOPRENE MOUNT

ND

BULLETIN ND-26-1



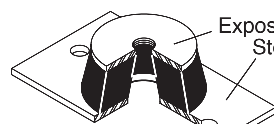
Up until the 1950's most rubber mountings were designed to take the load in shear. Mountings were circular or sold in long strips, so the capacity could be controlled by size and durometer, or durometer and the cut off length.



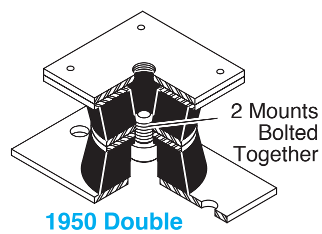
Older style mounts

Shear loading curves are straight line similar to steel springs. The deflection can be used directly in the frequency equation after dynamic stiffness correction. Unfortunately, shear mountings could and did fail because of bond failure between the rubber and metal. When overloaded, the mountings would bottom out. Compression mountings are less expensive for a given capacity and when overloaded, there is still a cushion. When loaded conservatively, the load deflection curve is similar to the straight line shear.

The general configuration of our N mountings was known, but all mountings were manufactured as at the right and seldom taller than 1". Both the base plate and the upper tapped washer were exposed and they corroded. As foolish as it seems now, we cemented a rubber pad to the baseplate to provide friction. Since greater efficiency can only be accomplished by increasing deflection, when double deflection was needed, two mountings were bolted together. This was another makeshift arrangement.

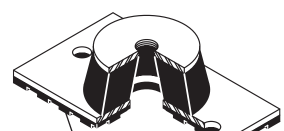


Typical 1950 Design



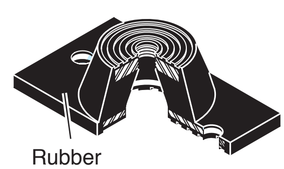
1950 Double Deflection Design

Mason started in 1958. When we did not offer a completely new product, we always improved existing designs. The first thought was bonding the bottom rubber pad, so it was always there.



In some applications no bolting would be needed if there were friction on top so we added the top rubber washer too.

Our next concern was corrosion, so bringing the rubber over the baseplate and up over the top insert was the final improvement. This design has been copied all over the world without people knowing the history.



(continued on back page)

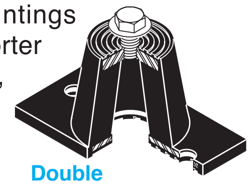
ND Mounts

- All mounts are double deflection
- Offer more than three times the deflection of pads
- Prevent noise and high frequency vibration
- Isolate a wide range of equipment
- Supplied with cap screw and washer

Exclusive Features

- Bottom friction surface makes bolting unnecessary in most installations
- Neoprene covering prevents corrosion of steel parts
- Molded in commercial Neoprene
- Bridge bearing Neoprene, Natural Rubber or other elastomers available

Rather than bolting two mountings together, we decided to do this properly and started manufacturing two mountings using the same base and top plates. The shorter Type N for single deflection; the taller ND, double deflection. We include capscrews and washers, to eliminate the nuisance of our customers finding proper bolts.



Double Deflection ND Mount

Since rubber mountings are inexpensive, we now sell only the ND, so there is always the benefit of the better product.

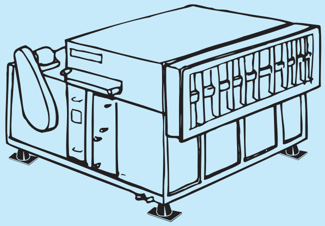
It is not necessary to bolt these mountings to the floor on most installations. They can be used under flat bases that have no bolt holes in much the same manner as rubber pads. When the equipment has a flush drain pan or tank on the bottom, the mounting may be inverted so that the rectangular rubber covered steel base plate provides support over a large area.

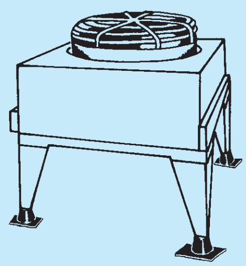
Inverted

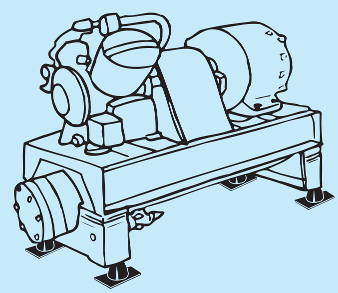
Standard mountings are furnished in oil resistant Neoprene. Since we mold these products ourselves, bridge bearing quality Neoprene, Natural Rubber or other elastomers are readily available to meet your requirements.

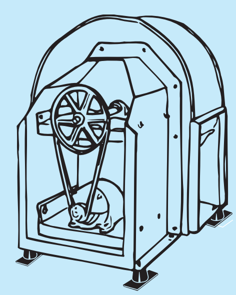
SPECIFICATION

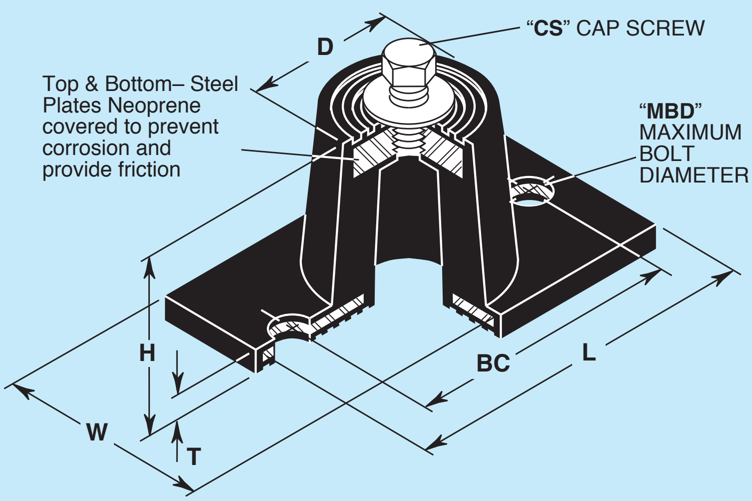
Neoprene mountings shall have a minimum static deflection of 0.35" (9mm). All metal surfaces shall be Neoprene covered to prevent corrosion and have friction pads, both top and bottom. Bolt holes shall be provided on the bottom and a tapped hole with capscrew and washer on top. Mountings shall be Type ND, as manufactured by Mason Industries, Inc.











TYPE ND RATINGS

Size (Color Mark)	Durometer	Rated Capacity Range (lbs)	Rated Capacity Range (kgs)	Max Rated Defl (in)	Max Rated Defl (mm)
ND-A-Black	30	15-45	7-20		
ND-A-Green	40	30-75	13-34	0.35	9
ND-A-Red	50	60-125	27-57		
ND-B-Black	30	50-100	23-45		
ND-B-Green	40	75-150	34-68		
ND-B-Red	50	110-235	50-107	0.40	10
ND-B-White	60	180-380	82-172		
ND-B-Yellow	70	300-600	136-272		
ND-C-Green	40	140-260	64-118		
ND-C-Red	50	200-400	91-181	0.50	13
ND-C-White	60	310-600	141-272		
ND-C-Yellow	70	520-1000	236-454		
ND-D-Yellow	70	1060-2100	481-953	0.50	13
ND-DS-Yellow	70	2200-4300	998-1950	0.50	13

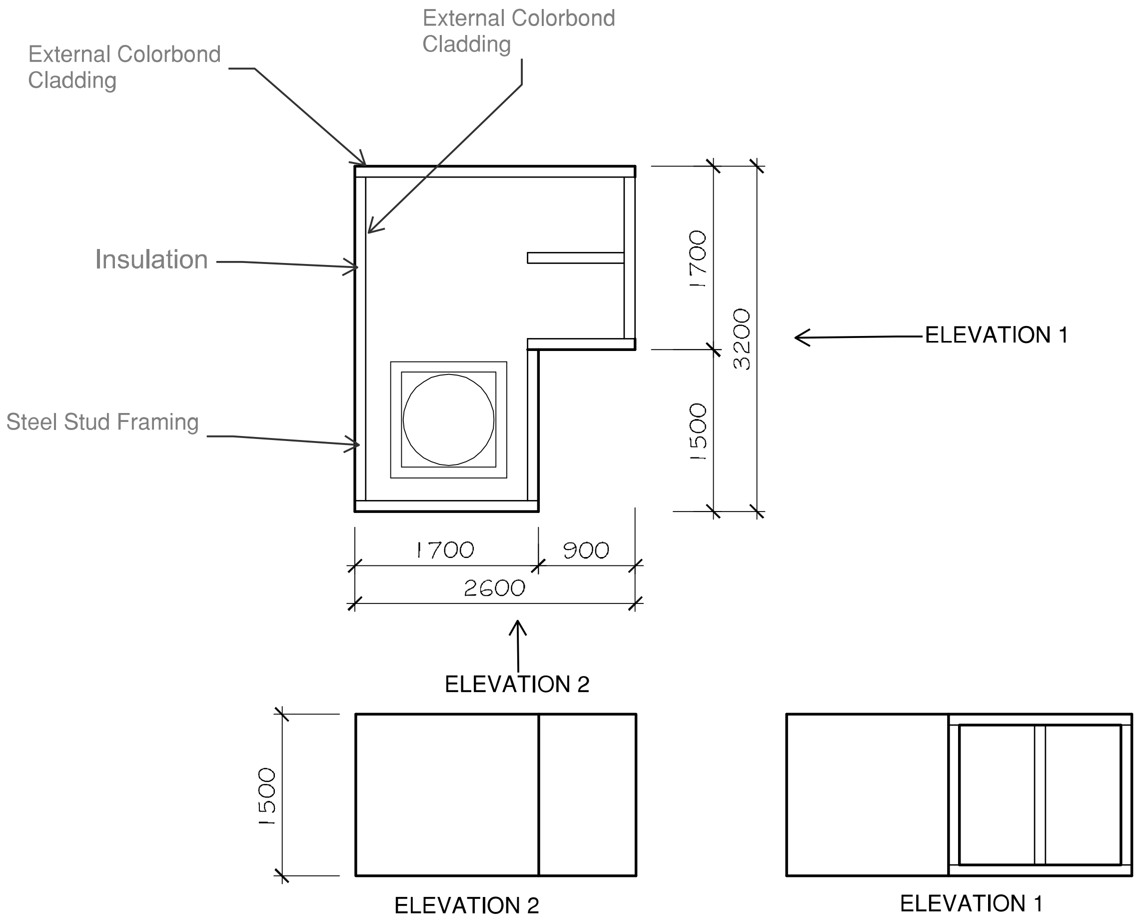
Mounts have straight line deflection curves.

TYPE ND DIMENSIONS (inches mm)

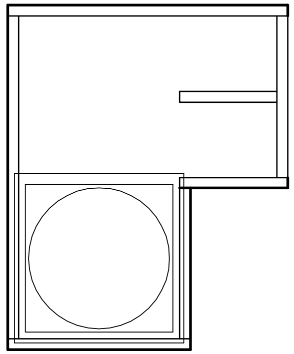
Size	D (in)	D (mm)	H (in)	H (mm)	L (in)	L (mm)	T (in)	T (mm)	W (in)	W (mm)	BC (in)	BC (mm)	CS (in)	CS (mm)	MBD (in)	MBD (mm)
ND-A	1 3/16	30	1 1/2	38	3 3/16	81	3/16	5	1 5/8	41	2 3/8	60	5/16 -18 x 3/4"	x 19	5/16	8
ND-B	1 3/4	44	1 7/8	48	3 7/8	98	1/4	6	2 5/16	59	3	76	3/8 -16 x 1"	x 25	5/16	8
ND-C	2 9/16	65	2 3/4	70	5 1/2	140	1/4	6	3 5/16	84	4 1/8	105	1/2 -13 x 1"	x 25	1/2	13
ND-D	3 3/8	86	2 3/4	70	6 1/4	159	5/16	8	4	102	5	127	1/2 -13 x 1"	x 25	1/2	13
ND-DS	3 3/8	86	2 3/4	70	6 3/4	171	5/16	8	4 3/8	111	5 1/2	140	1/2 -13 x 1"	x 25	1/2	13

Appendix B

Acoustic shed roof fan specifications



ATTENUATOR BOX WITH 800DIA FAN SHOWN



ATTENUATOR BOX WITH 1250DIA FAN SHOWN

Rev. No.	Date	Comments	Drn.	CLIENT:	PBS Drawing No.	Revision No.
1	09/15	Construction		LLBJV	PBS - SK 03	1

xxxxxxxx Drawing No.

DRAWING TITLE
ACOUSTIC SHEDS - ROOF FANS
ATTENUATOR DETAILS
PLANS AND ELEVATIONS

PROJECT:
NorthConnex

Drawn:	Approved:	Date:	Scale:
W.W.		MAY 2014	NTS

PROTECTOR
BUILDING SYSTEMS PTY LTD
Unit 16, 12-18 Clarendon Street, Artarmon NSW 2064
Ph (02) 9437 6505 Fax (02) 9439 1589
Email: admin@protectbuild.com.au

Represented by:
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Huntingwood NSW 2148
Telephone: +61 (02) 8811 0400
Facsimile: +61 (02) 9831 3676
E-mail: ftnsw@fantech.com.au

FANTECH

Quotation N0915-189
Fans

Project: PROTECTOR BUILDING SYSTEMS - VARIOUS SITES

Date: 09/09/2015 **Consulting Engineer:**

Notes: DELIVERY COSTS WILL BE DIVIDED PER CONSIGNMENT:
$400 - 6 OFF FANS allow 4 weeks lead time
$300 - 4 OFF FANS allow 3-4 weeks lead time
$300 - 4 OFF FANS allow 3-4 weeks lead time

Location	
Designation	
Catalogue Code	RVE1258CP6/29
Description	Vertical exhaust axial roof unit
Nominal Diameter (mm)	1250
Hub Size (mm)	350
Impeller	Axial, GRP
Notes	
Volume (L/s)	12000
Static Pressure (Pa)	100
ABS/LL Power (kW)	2.83 / 2.83
Fan Speed (r/s)	12
Outlet Velocity (m/s)	9.81
Sound Pressure (dB(A))	69 @ 3m
Fan Weight (kg)	265.0
Motor Power	3.30kW (AOM)
Electric Supply	415V 3ph 50Hz
FLC/Start (A)	7.70 / 42.00
Motor Frame	D132M
Motor Type	Standard
Motor Speed	8 pole
Number off	14
Price Per Unit	
Total	
GST	

Total price for 14 Fans & Anc.
Total GST
Total (inc GST)

Yours faithfully

Paul Scotto

Represented by:
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Quotation N0915-189

Fans

Project: PROTECTOR BUILDING SYSTEMS - VARIOUS SITES

Date: 09/09/2015 **Consulting Engineer:**

Location	Designation	Catalogue No.	Description	Qty.	Vol. (L/s)	Press (Pa)	Speed (r/s)	Motor Power	Motor Type	Electrical Supply	Inlet Sound Spectra(dBW) 63	125	250	500	1K	2K	4K	8K	SPL (dBA)
		RVE1258CP6/29	Vertical exhaust axial roof unit	14	12000	100	12	3.30kW (AOM)	Standard	415V 3ph 50Hz	90	86	84	83	83	84	81	71	69@ 3m

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E-mail: ftnsw@fantech.com.au

Technical Data for Fan Model RVE1258CP6/29

Location:

Please Note: Data shown is nominal - enter more criteria for accurate detail

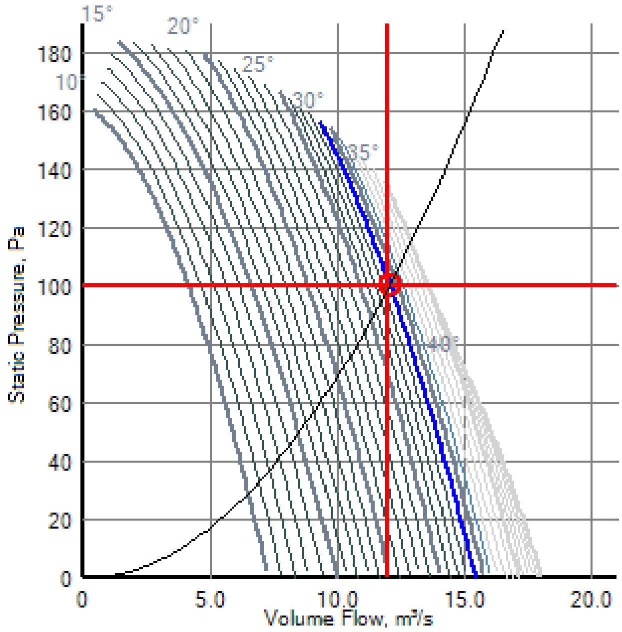
Designation:

Performance - Required

Air Flow:	12000 L/s
Static Pressure:	100 Pa
Selection Pressure:	100 Pa
Installation Type:	TYPE -
Air Density:	1.204 kg/m³
Atmos. Temp.:	20 °C
Altitude: m	0 m
Humidity:	0.0 %

Actual

Air Flow:	12041 L/s
Static Pressure:	101 Pa
Total Pressure:	159 Pa

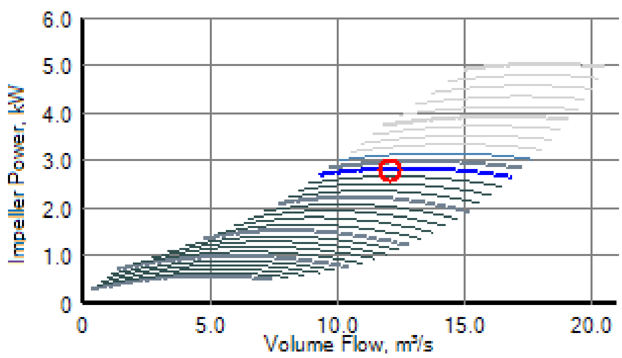


Fan Data

Catalogue Code:	RVE1258CP6/29 (RVE1258CP6B030)		
Description:	Vertical exhaust axial roof unit		
Diameter:	1250 mm	Hub:	350 mm
Impeller Type:	Axial	Pitch:	29°
Blade Material:	GRP	Blades:	6
Speed:	720 RPM	Running:	50 Hz
Power, Abs:	2.83	Peak:	2.83
Efficiency Total:	67.5%	Static:	42.9%
Fan Weight:	265.0 kg		

Motor Data (at STP)

Motor Type:	Standard	
Electrical Supply:	415V 3ph 50Hz	
Motor Frame:	D132M	
Motor Power:	3.30kW (AOM)	(3.00kW IEC)
FLC/Start:	7.70A (AOM) / 42.00A	(7.00A FL IEC)
Motor Speed:	8 pole	
Motor Efficiency:	85.6%	



Energy Efficiency, NCC/BCA Vol. 1, Table J5.2 compliant

+ 2006 - 2009
+ 2010 - 2012
+ 2013 - 2014

Sound Data

Spectrum (Hz):	63	125	250	500	1K	2K	4K	8K	dBW	dB(A) @ 3m
Inlet (dB):	90	86	84	83	83	84	81	71	94	69
Outlet (dB):	93	85	83	81	81	82	79	69	95	67

Sound levels are quoted as in-duct values. dB(A) values are average spherical free-field for comparative use only.
Sound levels for fans running at non-standard speeds are estimated.

Energy Sustainability Data

Hours per Day ($):	24	Annual Electricity Cost ($):	4216.3
Days per Year:	366	Annual GH Gas (Tonnes):	38.7
CO2 per kWh (kg):	1.467	Annual Carbon Usage (Tonnes):	10.5
Cost per kWh ($):	0.16		

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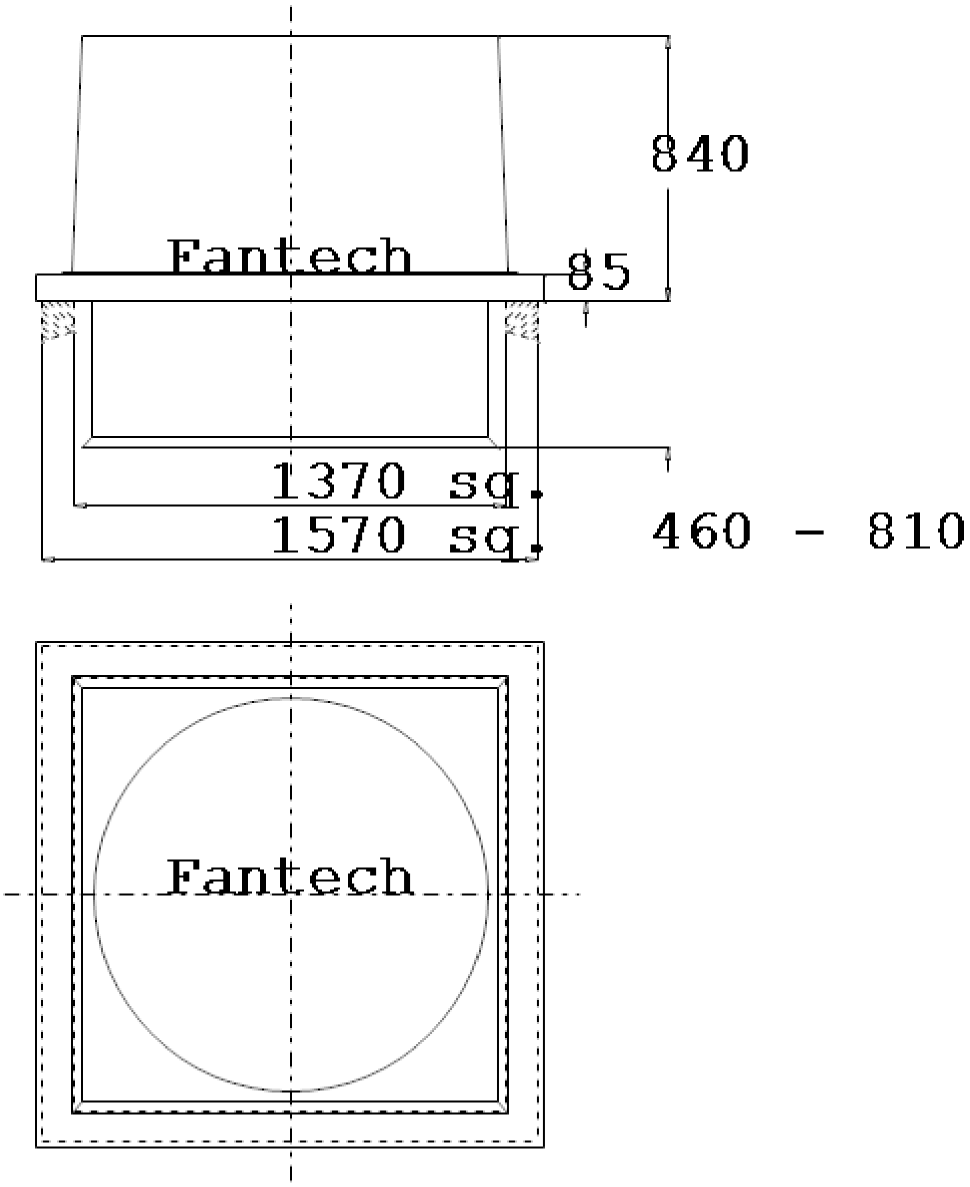
E-mail: ftnsw@fantech.com.au

Version 5.3.9

Drawing for Fan Model RVE1258CP6/29

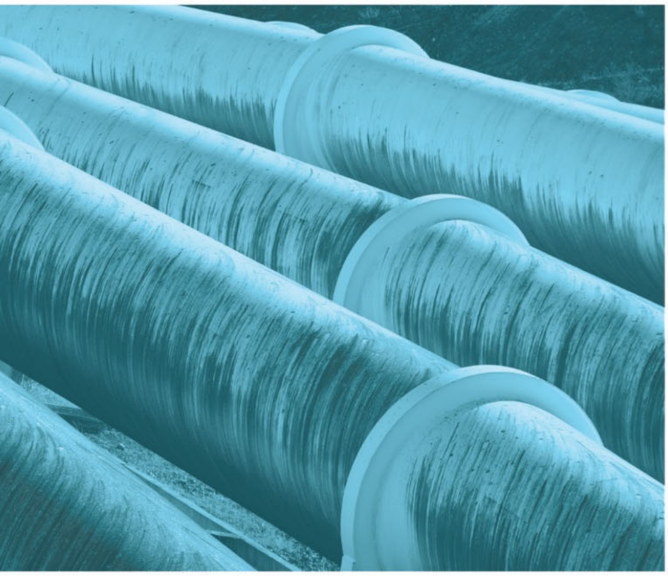
Location:

Designation:



On-going product improvements may result in dimensional changes without notice.



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