Appendix M

Noise and vibration assessments

Construction assessment - Wilkinson Murray

Operational assessment - ARUP

Ausgrid / Investa

City East Zone Substation and Integrated Commercial Development - 33 Bligh Street

Operational Acoustic Project Application Report

REP/222054/R01

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Contents

Executive Summary

This report presents acoustic input to the Stage 2A(ii) Project Application submission for the new City East Zone Substation and integrated commercial development building at 33 Bligh Street, Sydney, subsequently referred to as ‘the project’.

This report establishes noise management levels that will be used to guide the selection of plant during detailed design and it does not assess the impact of them.

The acoustic analysis has been based upon:

- An unattended and attended noise survey undertaken at the site
- Analysis and review of noise survey data
- Fitzpatrick + Partners (for the office tower) and Kann Finch Group (for the substation) preliminary drawings dated 29 August 2011
- Relevant local regulations and Australian Standards

Acoustic design targets have been provided to achieve acceptable criteria for:

- Noise break-out to the community
- Noise break-in to the development and internal noise levels
- Vibration and structureborne noise levels

Noise from the surroundings affecting the development such as general road traffic, plant and services noise from adjacent properties and pedestrian activities will be controlled by the selection of facade glazing and appropriate construction system to meet the recommended internal background noise levels.

The development is immediately surrounded by two hotels (one along Bligh Street and the other along O’Connell Street) and the Lowy Institute which are considered to be sensitive receivers to noise. Therefore it is important to control noise emission from the project so as not to cause an adverse impact on the acoustic amenity of the surrounding area. This can be achieved through appropriate plant selection (including the SF6 transformers) and by providing acoustic treatment on the ventilation systems of the Bligh Street development to meet the criteria outlined in this report.

Environmental noise levels will be controlled to the criteria outlined in this report. As included in the Director-General’s Requirements (DGR) for the project, the criteria considered for this development application are based on the NSW Industrial Noise Policy.

The commercial tower is also being designed to achieve a five star Green Star rating (Office Design v3) from the Green Building Council of Australia (GBCA), targeting two points under the IEQ-12.

1 Introduction

This report identifies acoustic considerations relating to the proposed new development at 33 Bligh Street, Sydney.

The project seeks to redevelop the site by demolishing the existing 33 Bligh Street building and also the 20-22 and 24-26 O'Connell Street buildings and in their place constructing a new development composed of a zone substation and an office tower.

The zone substation consists of eleven levels (some below the ground) including parking, transformers bays, switch rooms, cable joining rooms, amenities, commercial lobby and plant rooms. The entrance to the zone substation will be on O'Connell Street.

The office tower consists of 26 levels including open plan offices and related facilities and plant rooms on level 12, 13, 26 and level 37 (roof plant). A sky garden is also included on level 32.

The site is located in a commercial area, between two roads Bligh and O'Connell Street, within the Sydney Central Business District. Three noise sensitive receivers have been identified along these two streets:

- along Bligh Street, Sofitel Wentworth and Lowy Institute
- along O'Connell Street, Radisson Plaza Hotel

This report addresses the acoustic impact of the project and is based on architectural drawings provided by Fitzpatrick + Partners for the office tower and by Kann Finch Group (both dated 29 August 2011) for the substation and preliminary information on building services.

In this report acoustic design targets are established for:

- Noise impact of the project on the surrounding community
- Noise impact of the surrounding community on the project, including internal noise levels
- Vibration and structureborne noise levels.

The acoustic design targets have been derived from the following regulations and Australian standards:

- *NSW Industrial Noise Policy*, Environmental Protection Authority (INP), January 2000
- *NSW Environmental Criteria for Road Traffic Noise*, (ECRTN), May 1999
- AS/NZS 2107 (2000), *Acoustics- Recommended design sound levels and reverberation times for building interiors*

The acoustic design will be addressed so that the acoustic design targets will be met at the noise sensitive receivers and also the environmental noise requirements will be satisfied.

A glossary of acoustic terminology used in this report is included in Appendix A.

2 Site Description

The site is located between two roads within the Sydney Central Business District, Bligh Street on the east side and O'Connell Street on the west side of the site.

The land usage of the surrounding area is mostly a mixture of commercial and office buildings with the Radisson Plaza Hotel along O'Connell Street on the west side of the site and Sofitel Wentworth along Bligh Street on the north-east side of the site. Also the Lowy Institute is located along Bligh Street, next to the existing 33 Bligh Street building.

On the south side of the site, along Hunter Street both commercial and office buildings are also located.

It is understood that the City East Zone substation building will be located directly over the easement for the proposed Metro Pitt railway corridor and the proposed alignment of Stage 1 CBD Metro project. The Metro Pitt easement establishes a protected underground corridor for the future construction of the proposed Sydney Metro underground railway tunnels.

In order to build the new office and substation towers, the existing 33 Bligh street building together with the 20-22 and 24-26 O'Connell Street buildings will be demolished and the demolition is addressed in the Stage 2A(i) project approval.

A site plan of the substation and office towers site vicinity is provided in Figure 1 below.

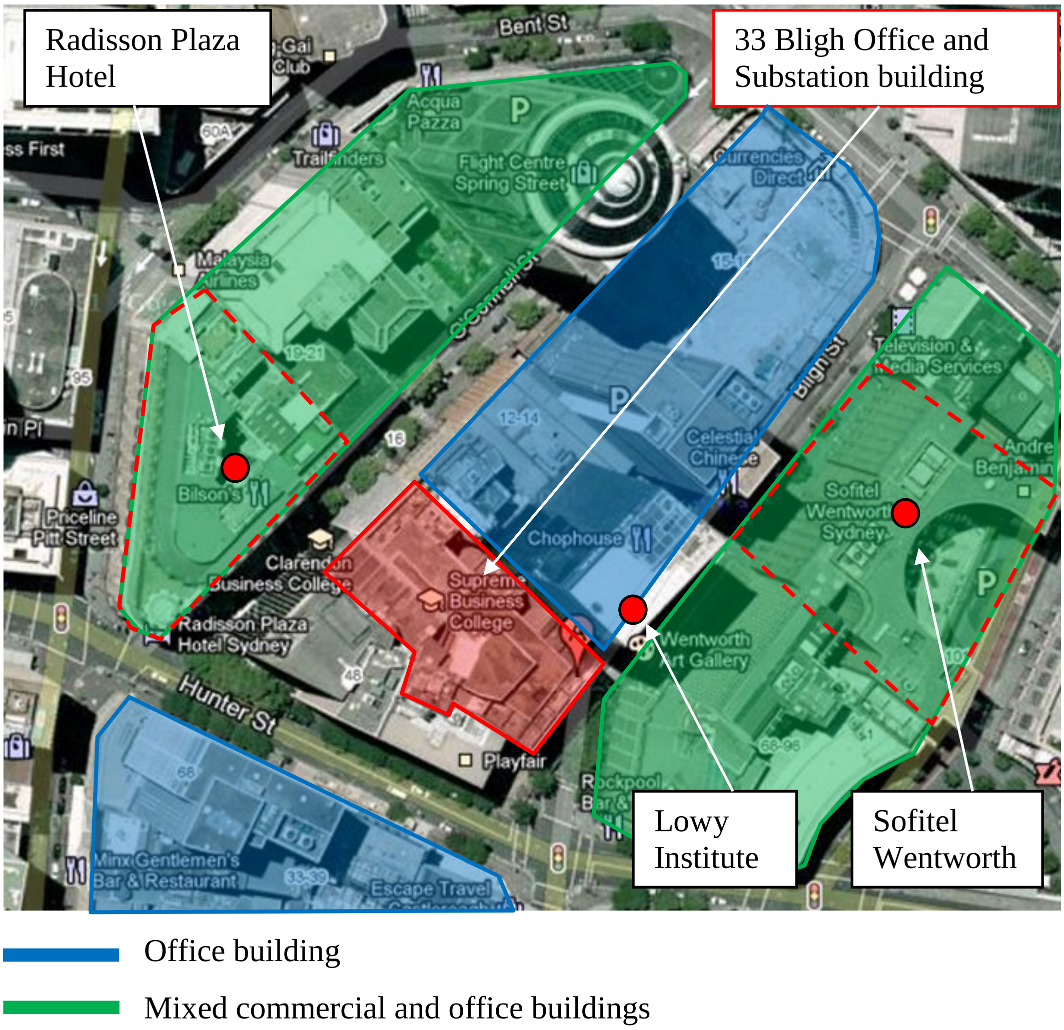

Figure 1: Site plan of the existing 33 Bligh Street development and surrounding area

3 Acoustic Considerations

3.1 Noise and Vibration Impact of the Project on the Environment

Noise impacts on the community from the project when operational are expected to be from the following sources:

- plant and services equipment associated with the new facilities
- SF6 transformers located in the zone substation
- activities from the site (ie vehicle movements on site, unloading activities etc.)
- traffic noise from the site on public roads

Noise and vibration impacts from mechanical and electrical plants are discussed further in Section 8.

It should be noted that the project will include a car park split in two levels (Level 03 and Level 04) including 40 car spaces and 8 service vehicle spaces in total. The existing building utilised 43 car parking spaces in the basement with access from O'Connell Street and contained a loading dock which would have generated very similar traffic movements to the proposed development.

Therefore considering the number of parking spaces provided and the level of loading and service vehicle activity anticipated it can be considered that the additional effect of these vehicles is minimal on the nearest intersections to the site after which vehicles disperse. This is discussed further in the Traffic and Parking study

3.2 External Noise and Vibration Affecting the Development

Environmental noise and vibration sources that may affect the project once operational are:

- traffic noise from Bligh and O'Connell streets through the facade
- vibration and ground-borne noise from the proposed Sydney Metro
- plant and services from the substation to the office tower
- plant and services noise from adjacent properties.

The traffic noise break-in from Bligh and O'Connell Streets can be resolved with adequate facade glazing and building envelope construction. Traffic vibration impact on the project is unlikely to be an issue since road traffic generally produces low vibration levels. It should also be controlled by appropriate design of the building structure by the structural engineer.

As explained in Section 2 above, the City East Zone substation building will be located directly over the easement for the proposed Metro railway corridor. Vibration and structureborne noise generated by the operation of the future railway will propagate into the building above and may be perceptible as:

a) structureborne noise heard by the occupants of the building as a low-frequency ‘rumbling’ noise that is radiated by the vibrating surfaces of the building.

b) tactile low-frequency vibration that is directly perceptible to occupants (‘feelable vibration’)

The vibration and structureborne noise has the potential to adversely impact on the City East Zone Substation building without specific engineering solutions being implemented.

In terms of human impacts, structureborne noise is generally more of an issue than the lower-frequency structural vibration effects. A groundborne noise level criterion for general commercial office space of between 40–45 $dBL_{Amax,slow}$ is usually applied. It may be appropriate to adopt slightly lower limits for more critical spaces such as private offices, meeting rooms and board rooms.

In the absence of any definitive information, it would be appropriate to set an initial vibration limit equivalent to Curve 4 of AS2670.2[1] for both the substation and office tower. This limit is consistent with minimising the risk of adverse comment from occupants due to structural vibration.

There has been some design work undertaken on the proposed Metro railway alignment, beyond initial route studies and protection of the easement. However, it is understood that the Metro is likely to comprise a slab track with rails directly fixed using conventional moderately resilient track fixings to provide a ‘basic’ level of vibration attenuation within the trackform.

Since the railway infrastructure has not been built it is not possible to undertake vibration measurements at the existing site to quantify the actual vibration exposure. However, based on previous studies undertaken within the Sydney CBD, and given the proximity of the building to the proposed railway and the likely lithology, it is expected that groundborne noise from the railway would marginally exceed the limits given above in the commercial tenancies within the lower areas of the building without specific engineering solutions being implemented.

There are no established vibration criteria relating to vibration impacts on large power transformers. Transformers without specific engineering solutions have the potential of generating high levels of vibration due to magnetostriction of the core. However, an assessment of noise and vibration from typical gas transformers shows that:

- vibration generated by the transformers is below the threshold of perception; and
- reverberant noise within transformer bays can be reduced to achieve criteria at the noise sensitive receivers, once breaking out.

Refer to Section 7 for details about the noise and vibration assessment of the existing gas transformer at the City South Substation.

Criteria for internal noise levels have been set in Section 5.1.

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[1] AS 2670.2-1990 Evaluation of human exposure to whole-body vibration - Continuous and shock-induced vibration in buildings (1 to 80 Hz)

3.3 Internal Noise and Vibration Impacts on the Development

Without mitigation measures, occupants of the commercial tower may be affected by noise and vibration generated within the project itself. Potential noise impacts are expected to be from:

- Noise from plant and services equipment associated with the project transmitted via the structure and through the ventilation system
- Structure-borne noise from lifts
- Noise and vibration transmitted from the transformers bays to the levels above

As specified in Section 3.2, transformers generally have the potential of generating high levels of groundborne vibration due to magnetostriction of the core if the mitigation measures are not implemented.

Therefore a more detailed assessment of noise and vibration from the transformers within the substation will be considered further in the detailed design of the development.

4 Noise Survey

4.1 Purpose of the Noise Survey

Noise surveys involving attended and unattended monitoring have been conducted around the site.

The purpose of the noise surveys was to:

- Identify existing ambient noise levels, as a baseline in setting appropriate noise criteria to assess the impact of the development on the surroundings
- Identify sources and levels of noise that are likely to affect the development
- Identify potential noise-sensitive receivers in the vicinity

4.2 Noise Sensitive Receivers

The closest noise sensitive receivers to the building are the Lowy Institute (adjacent to the northern site boundary) and the Sofitel Wentworth Hotel (on the north-east side of the site, about 65 m from the site) along Bligh Street. Along O'Connell Street the closest noise sensitive receivers to the development is the Radisson Plaza Hotel (located on the south-west of the site, on the opposite site of O'Connell Street).

The ambient noise environment is generally characterised by road traffic noise from Bligh Street and O'Connell Street and residual traffic noise from Hunter Street.

Whilst on the top floor of the 25 Bligh Street (Mulpha building) roof plant noise was also noted.

4.3 Methodology

Three noise loggers were installed on site for a week in the following locations:

- In front of the Radisson Plaza Hotel (logger A)
- Between ground and first floor of the existing 33 Bligh Street building (logger B)
- At Level 31 of the Mulpha building at 25 Bligh Street (logger C)

It should be noted that the noise logger data from the Radisson Plaza Hotel has been provided by Wilkinson Murray (WM) who conducted the unattended noise monitoring from 16 February to 23 February 2010. WM also installed a noise logger in front of the Lowy Institute but the data has not been considered as affected by construction noise from the facade remediation works being carried out at 31 Bligh Street (the Lowy Institute) development during the entire week of monitoring for a period between 06:00 and 14:00.

The unattended measurements representative of the Lowy Institute and the Sofitel Wentworth Hotel noise sensitive receivers have therefore been repeated. A noise logger has been installed for a week from 6 September to 13 September 2011 between ground and first floor of the existing 33 Bligh Street building.

A noise logger had also been installed for a week from 19 November 2010 to 26 November 2010 at the balcony of Level 31 of the Mulpha building. This noise logger was installed considering the sources and levels of noise that are likely to affect the new development at different heights of the building. The data will be used to assess the break-in noise to the office tower facade at different levels and will not be assessed under the Industrial Noise Policy.

The logger recorded L_{A1}, L_{A10}, L_{A90}, and L_{Aeq} noise parameters at 15 minute intervals continuously for the measurement period. Weather observations were undertaken during this period and where noise levels were affected the data was not used. The logger was checked for calibration before and after the monitoring period and no deviation had occurred.

The noise levels measured are considered as representative for the current noise environment of the closest noise-sensitive receivers to the substation and commercial development.

To supplement and verify the unattended noise measurements attended measurements were undertaken at the logger locations before and after setting up the loggers and also on surrounding areas of the development. The same L_{A1}, L_{A10}, L_{A90} and L_{Aeq} noise parameters were measured for 15-minute periods. A B&K 2260 sound level meter was used to take the measurements. The sound level meter was checked for calibration before and after the measurements and only an acceptable deviation occurred.

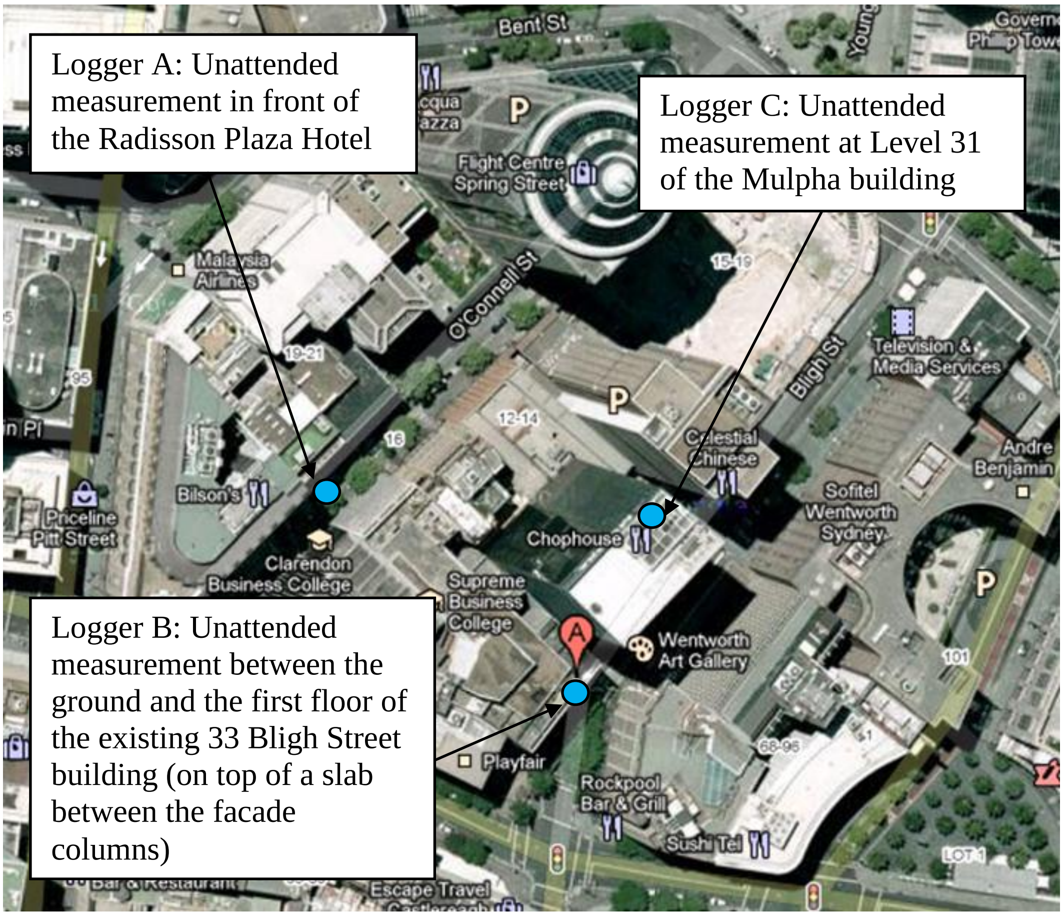


Figure 2: Attended and unattended noise measurement locations

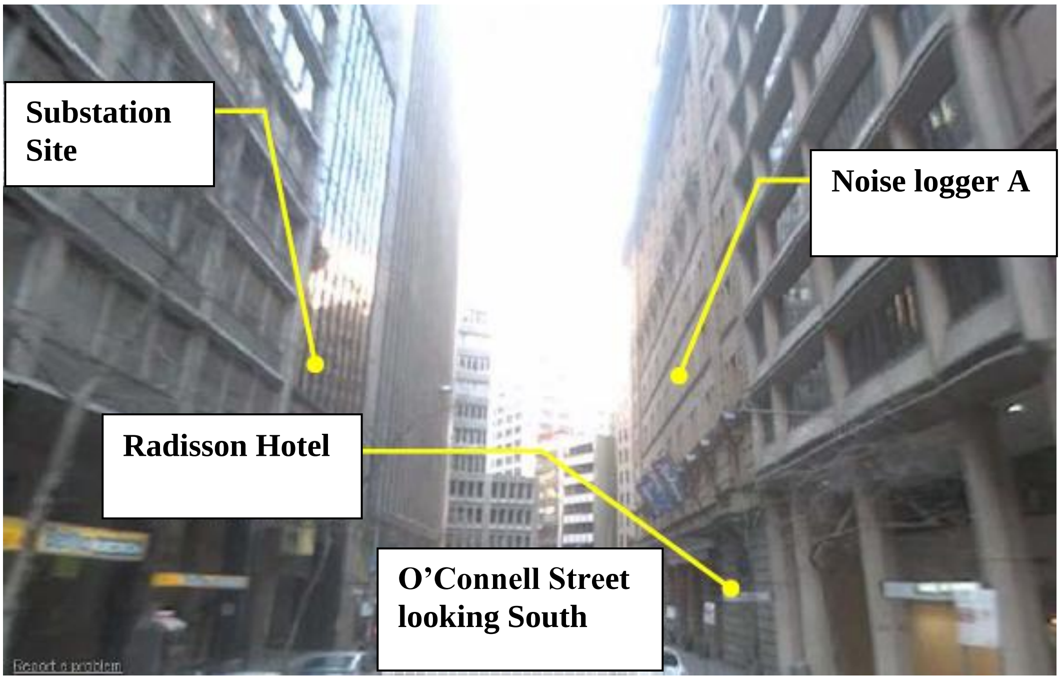


Figure 3: Location of the noise logger A in front of the Radisson Plaza Hotel (monitoring conducted by WM)

Figure 4: Location of the noise logger B in front of the existing 33 Bligh Street building

Figure 5: Location of the noise logger C on Level 31 of the Mulpha building

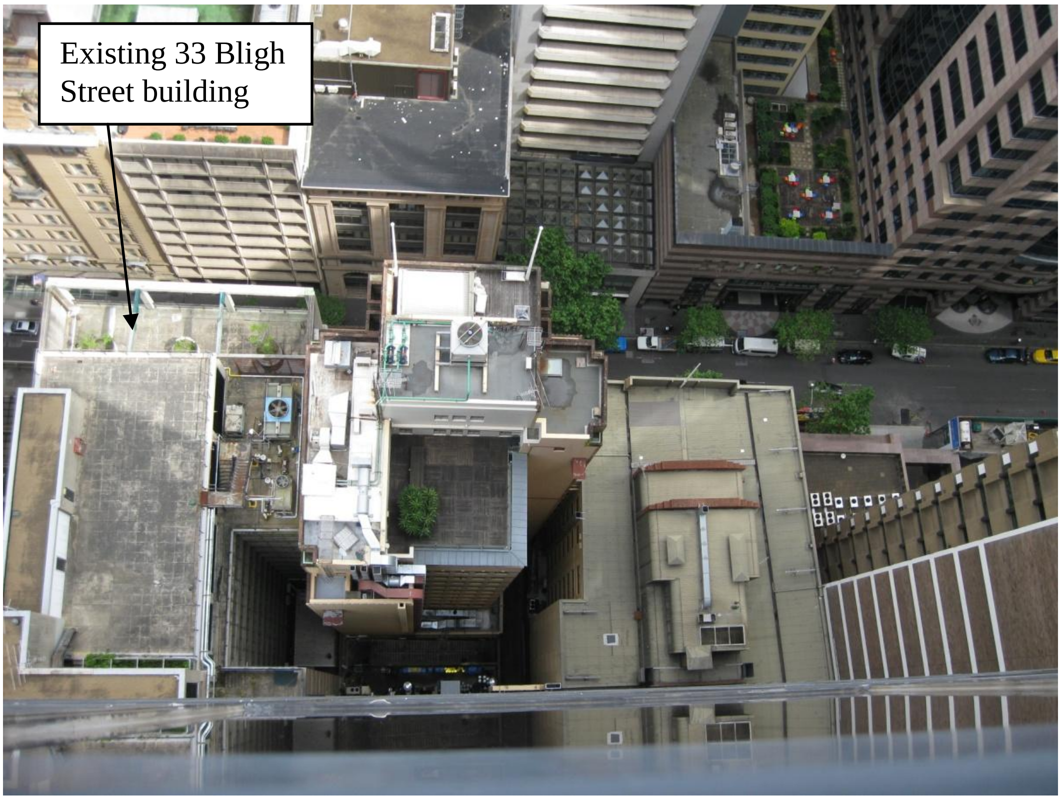


Figure 6: Roof plant viewed from the Mulpha building

4.4 Results

The entire measurement period for the three loggers has been split into weekdays and weekend and the 15-minute measured noise levels averaged throughout the day. These are presented graphically in Figure 7 and Figure 8, for Logger A and in Figure 9 and Figure 10 for Logger B.

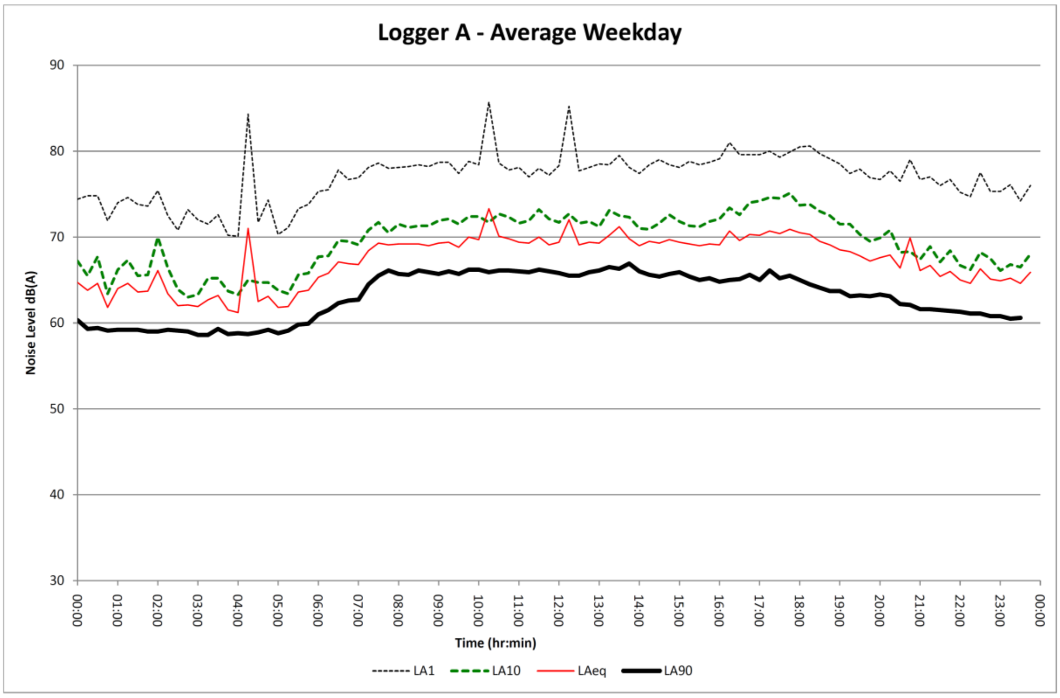


Figure 7: Average Weekday for the location of logger A (in front of Radisson Plaza Hotel), dB re 20µPa

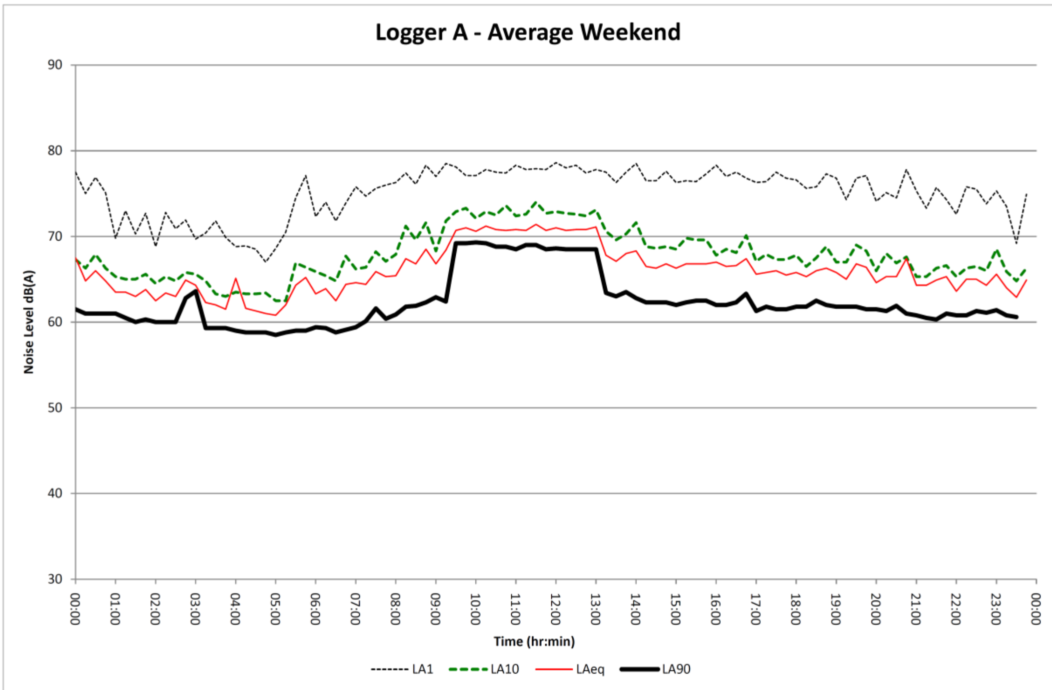


Figure 8: Average Weekend for the location of logger A (in front of Radisson Plaza Hotel), dB re 20µPa

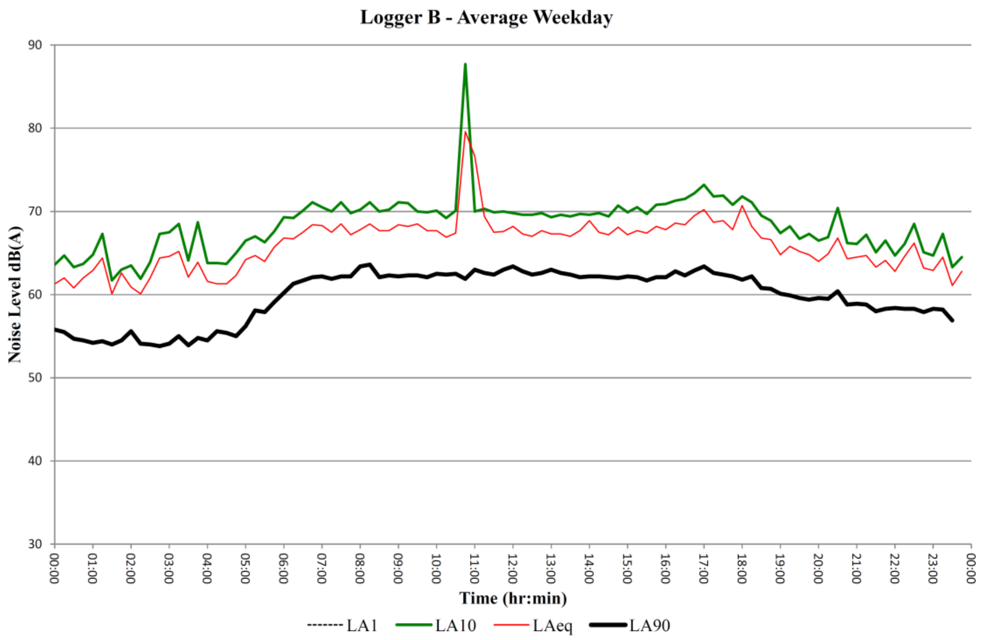


Figure 9: Average Weekday for the location of logger B (in front of the existing Bligh Street building), dB re 20µPa

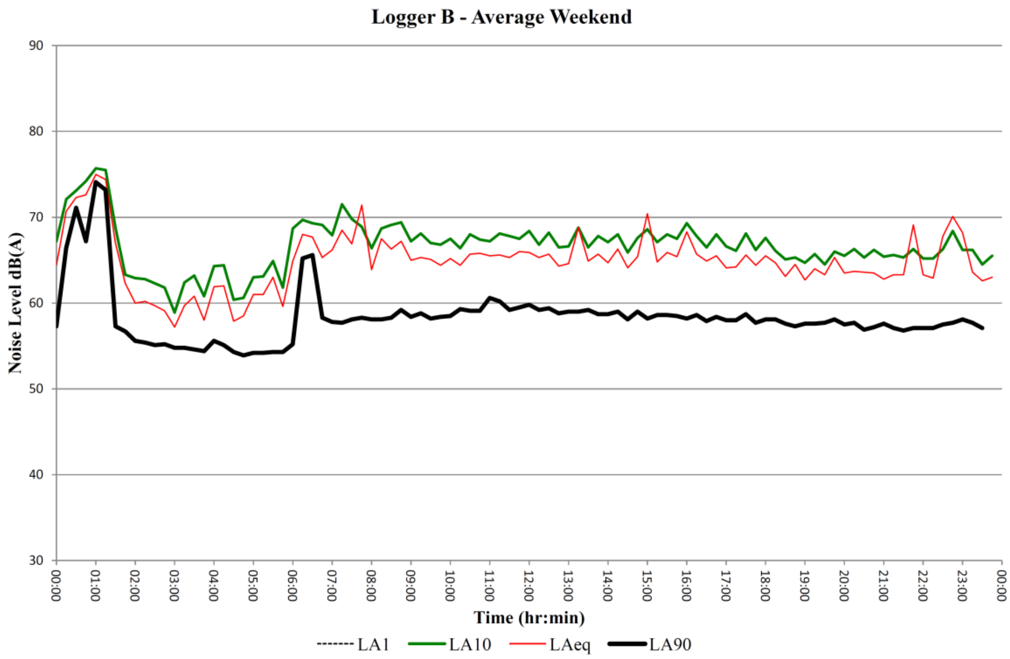


Figure 10: Average Weekend for the location of logger B (in front of the existing Bligh Street building), dB re 20µPa

Table 1 and Table 2 below show the average of weekday and weekend-day hourly L_{Aeq} for the daytime, evening-time and night-time, for Logger A and Logger B.

	Daytime (0700 – 1800)	Evening-time (1800 – 2200)	Night-time (2200 – 0700)
Average hourly Weekdays $L_{Aeq(1h)}$ dB	69	68	64
Average hourly Weekend-days $L_{Aeq(1h)}$ dB	68	66	64

Table 1: Average of the hourly Weekdays and Weekend-days, for the Logger A

	Daytime (0700 – 1800)	Evening-time (1800 – 2200)	Night-time (2200 – 0700)
Average hourly Weekdays $L_{Aeq(1h)}$ dB	70	66	64
Average hourly Weekend-days $L_{Aeq(1h)}$ dB	66	64	67

Table 2: Average of the hourly Weekdays and Weekend-days, for the Logger B

The Rating Background Level (RBL) is presented in Table 3 for the logger locations. The RBL is presented for the day, evening and night time periods, as defined in the NSW Industrial Noise Policy.

The Rating Background Level was calculated using the 'tenth percentile' method given in Appendix B of the INP. The average industrial L_{Aeq} noise level (which is the noise level from all industrial noise sources, not necessarily the measured ambient L_{Aeq} noise level) was represented by the measured L_{A90} noise level.

Time Period	**Rating Background Level RBL L_{A90}**	
	Logger A	**Logger B**
Day (0700hrs – 1800hrs)	65	61
Evening (1800hrs – 2200hrs)	61	57
Night time (2200hrs – 0700hrs)	59	54

Table 3: Rating Background Levels based on the noise survey results from logger located in front of the Radisson Plaza Hotel (16 February to 23 February 2010) and at the ground floor of the existing 33 Bligh Street building (30 September 2011 to 7 October 2011) dB re 20μPa.

4.5 Attended Noise Measurements

Table 4 below gives details of the measured noise levels and activities during the attended measurement periods.

Location	Date	Period of time	Noise Level, dB				Comments
			L_{A1}	L_{A10}	L_{Aeq}	L_{A90}	
Lowy Institute	01/09/11	12:19 – 12:34	75	70	68	64	Light traffic along Bligh Street and distant road traffic from Hunter Street.
	06/09/11	09:31 – 09:46	75	70	68	64	(Location moved in front of the existing 33 Bligh Street for temporary works on the pavement) Distant construction noise; light traffic on Bligh Street and distant road traffic noise from Hunter Street
Sofitel Wentworth	01/09/11	12:39 – 12:54	73	68	66	63	Distant road traffic noise from Bent Street and light road traffic from Bligh Street. Cars leaving and arriving at the Sofitel Hotel car park.
	06/09/11	09:50 – 10:05	77	68	68	63	Cars leaving and arriving at the Sofitel Hotel car park; cars parking along Bligh Street
Radisson Plaza Hotel	01/09/11	13:10 – 13:25	74	70	67	64	Road traffic noise from O’Connell Street and distant road traffic noise from Hunter Street. Car parking and leaving from

Location	Date	Period of	Noise Level, dB				Comments
							O'Connell Street
	06/09/11	10:10 – 10:25	74	69	66	62	Audible road traffic noise from Hunter Street; cars idling at O'Connell traffic light.

Table 4: Results of the attended noise measurements

5 Acoustic Design Criteria

This section provides relevant acoustic criteria for the project.

5.1 Internal Noise Criteria

AS 2107 provides guidance for design background noise levels for various types of occupancy. The limits apply to steady-state or quasi steady-state sounds such as noise from air conditioning systems, and are given as overall dB(A) limits for many types of room.

Target noise limits for steady-state noise generated by building services and noise break-in from external sources have been determined by a combination of guidance from AS 2107 and experience from similar projects.

In addition to the overall dB(A) limits, will design to a rating curve such as the Noise Rating (NR) curves. This will assist in achieving a balanced background noise spectrum, avoiding annoying characteristics such as low-frequency “rumble” or high-frequency “hiss”, while still achieving the overall AS 2107 dB(A) noise levels.

For a typical building services spectrum, the NR rating of the spectrum is approximately 5 units below the dB(A) rating – e.g. an overall level of 45 dB(A) typically would be rated at approximately NR 40.

At this stage, these limits generally correspond to the maximum limits given in AS 2107, rather than the satisfactory limits (which are ~5 dB lower). The maximum limits have been chosen since they promote a higher level of speech privacy and have proved to be acceptable based on extensive experience.

Table 5 outlines noise level targets for the various spaces to be achieved by all services running normally and together plus quasi-steady external noise break-in.

5.1.1 Green Star IEQ-12

In order to achieve Green Star (Office Design v3) compliance for the Interior Environment Quality category, up to two points are awarded where 95% of the project’s net lettable area (NLA) does not exceed the ‘satisfactory’ ambient internal noise levels in accordance with AS/NZS 2107:2000, as follows:

- Building Services Design: One point is awarded where, within the entire base building general office space, noise from the building services does not exceed 40 dBL_{Aeq}
- Overall Building: One point is awarded where within the base building office space, the sound level does not exceed 40 dBL_{Aeq} (assuming open plan offices)

Type of occupancy	Recommended design sound level (From Table 1, AS2107)
Car Parking	NR 60 / ~ 65 dB(A)
Transformer Bays	NR 75 / ~ 80 dB(A)
Radiator Space	NR 75 / ~ 80 dB(A)
Control Room	NR 55 / ~ 60 dB(A)
Switch Room	N/A
Substation Amenities	NR 55 / ~ 60 dB(A)
Cable Joining	NR 70 / ~ 75 dB(A)
Commercial Lobby	NR 45 / ~ 50 dB(A)
Open plan offices	NR 40 / ~ 45 dB(A)
Plant Room	N/A
Toilets	NR 50 / ~ 55 dB(A)
Sky lobby / reception	NR 40 / ~ 45 dB(A)
Sky Garden	NR 45 / ~ 50 dB(A)

Note: The recommended design sound levels given in this table are used ‘traditionally’ for sealed, air-conditioned buildings, and apply only to “quasi steady-state” noise – typically building services noise.

Table 5: Design Internal Sound Levels, dB re 20μPa

The project will use the ‘maximum’ levels for design in order to provide a degree of noise masking and speech privacy in internal areas.

5.2 Reverberation Times

AS 2107 also provides recommended mid-frequency design reverberation times for building interiors. The recommended reverberation times represent appropriate room acoustic conditions for different building areas.

Type of occupancy	Recommended reverberation times (From Table 1, AS2107)
Car Parking	N/A
Transformer Bays	(*)
Radiator Space	N/A
Control Room	0.4 – 0.7
Switch Room	N/A
Substation Amenities	(*)
Cable Joining	N/A
Commercial Lobby	0.5 – 1.0
Open plan offices	0.4 - 0.6
Plant Room	N/A
Toilets	N/A
Sky lobby / reception	(*)
Sky Garden	(*)

(*) Reverberation time should be minimized as far as practicable for noise control

Table 6: Design Reverberation Time targets

5.3 Environmental Noise

5.3.1 Industrial Noise Policy Criteria

The New South Wales environmental noise policy relating to industrial noise is the *New South Wales Environment Protection Authority Industrial Noise Policy* (INP) dated January 2000, which covers noise emission from operation of a facility and from plant and equipment on the proposed facility.

Noise from traffic movements on a site (i.e. not on public roads) is assessed as being operational noise under the INP.

The objective of the INP is to protect sensitive receivers such as residences from noise generated by commercial, industrial or trade premises. Noise limits are set based on land use in the area and existing background noise levels. Compliance is achieved if the adjusted L_{Aeq} noise level at any sensitive receivers affected by noise from the facility is below the noise limit. The adjusted L_{Aeq} is determined by applying corrections for such noise characteristics as duration, intermittency, tonality, and impulsiveness.

The assessment of noise emission under INP is based on the calculation of a noise limit at a receiver position, taking into account the land-use in the surrounding area and the existing background noise level.

The INP separates the day into three different time periods – day, evening and night. These time periods are detailed in Table 7.

Period	Day of Week	Time period
Day	Monday-Saturday	7:00 am-6:00 pm
	Sunday, Public Holidays	8:00 am-6:00 pm
Evening	Monday-Sunday	6:00 pm -10:00 pm
Night	Monday-Saturday	10:00 pm -7:00 am
	Sunday, Public Holidays	10:00 pm -8:00 am

Table 7 : Standard INP Time Periods

The INP states that background noise levels should be determined over the "days and times of operation of the project". When setting criteria, only the measured data from the hours of operation of the project should be included.

The INP provides guidance on acceptable noise levels from the introduction of new industrial noise sources to an area. The assessment procedure for industrial noise sources has two components:

- Controlling intrusive noise impacts in the short term for residences.
- Protecting noise level amenity for particular land uses such as residences and commercial offices etc.

Both of these components result in noise criteria that should not be exceeded in order to avoid any adverse noise impacts on the affected areas. Both criteria should be taken into account when assessing the noise impact of industrial source(s) associated with the project, and where the intrusiveness and the amenity criterion differ, the most stringent of the noise criteria should be adopted as the project-specific noise criterion.

It should be noted that the intrusiveness criterion only applies at residential receivers and the amenity criterion applies at both residential and commercial receivers.

5.3.1.1 Intrusiveness Criterion

A 15-minute sampling period is typically used when measuring the level of intrusive noise. This is taken to be a reasonable estimate of the period over which annoyance may occur. The intrusiveness criterion is summarised as follows:

$L_{Aeq\ (15\ min)} \leq L_{A90\ (15\ min)}$ Background Level + 5 dB

Because of the variable nature of background noise levels, the INP specifies single number background noise levels for use in setting the intrusiveness noise criterion. The Assessment Background Level (ABL) for each time period of a day is the level exceeded by 90 % of the $L_{A90,15min}$ measurements. The Rating Background Level (RBL) for a particular time period is the median of the ABL values for that time period for each day of the measurement period.

Industrial noise from the subject project should be controlled to not exceed the Rating Background Level (RBL) + 5 dB at the boundary of any noise sensitive receiver.

Two noise loggers have been left for a week as described in Section 4.3 of this report, to inform on the typical background noise level at the closest noise sensitive receivers.

It should be noted that along O'Connell Street the closest noise sensitive receiver is the Radisson Plaza Hotel, which includes sleeping rooms. Therefore the receiver has been considered comparable with a residential receiver and the intrusiveness criteria assessed.

Along Bligh Street the closest noise sensitive receiver is the Lowy Institute, considered to be a commercial receiver. However the Sofitel Wentworth Hotel is only 65m from the site and the ambient noise can be considered the same. Therefore the intrusiveness criteria have been calculated only for the Sofitel Wentworth Hotel (using the noise logger data installed at 33 Bligh Street project) as considered comparable to a residential receiver. The intrusiveness criteria have not been calculated for the Lowy Institute noise sensitive receiver as the intrusiveness criterion only applies at residential receivers.

The intrusiveness criteria for the Radisson Plaza Hotel receiver located along O'Connell Street are summarised in Table 8:

Time Period	**Rating Background Level RBL L_{A90}**	**Intrusiveness Criterion RBL + 5dB(A)**
Day (0700hrs – 1800hrs)	65	70
Evening (1800hrs – 2200hrs)	61	66
Night time (2200hrs – 0700hrs)	59	64

Table 8: Intrusiveness Criteria for the Radisson Plaza Hotel receiver, along O'Connell Street

The intrusiveness criteria for the Sofitel Wentworth Hotel receiver located along Bligh Street are summarised in Table 9:

Time Period	**Rating Background Level RBL L_{A90}**	**Intrusiveness Criterion RBL + 5dB(A)**
Day (0700hrs – 1800hrs)	61	66
Evening (1800hrs – 2200hrs)	57	62
Night time (2200hrs – 0700hrs)	54	59

Table 9: Intrusiveness Criteria for the Sofitel Wentworth Hotel receiver, along Bligh Street

5.3.1.2 Amenity Criteria

Criteria for the protection of amenity are given for various types of receiver and different times of the day. The amenity criterion is set so that the noise levels from the industrial noise source do not increase the total industrial noise levels at the receiver above the acceptable noise level (ANL) for that receiver.

The amenity criterion applies to the L_{Aeq} noise level from all industrial noise sources over the time period T, (i.e. $L_{Aeq,T}$) which is the time period over which the criterion applies – e.g. for the Day time period, T is 11 hours, and the amenity criterion is a $L_{Aeq,11hr}$ noise level.

The amenity criterion is set based on how close the existing average industrial noise levels ($L_{Aeq,average}$) are to the ANL, using adjustment factors given in Table 2.2 of the INP.

In cases where the existing $L_{Aeq,average}$ noise levels exceed the ANL by more than 2 dB(A), and the existing noise levels are unlikely to decrease in future, then the amenity criterion is set to be 10 dB(A) lower than the existing noise levels at the receiver. This is to prevent a creeping background noise environment.

Note that the L_{Aeq} industrial noise level is not necessarily the measured L_{Aeq} noise level from a noise logger or attended measurements; in cases where the existing industrial noise sources are steady-state the measured L_{A90} noise level may be a better representation of the existing industrial noise levels.

A summary of the amenity criteria is presented in Table 10.

Noise Sensitive Receiver	Time period	Existing L_{Aeq}, dB(A)	ANL* L_{Aeq}, dB(A)	Modification to acceptable noise limit**	Amenity Criterion Existing $L_{Aeq,T}$ + modification of ANL (L_{eq}, dB(A))
Radisson Plaza Hotel	Day	69	60	ANL–10 dB	59
	Evening	68	50	L_{Aeq}-10 dB	58
	Night	64	45	L_{Aeq}-10 dB	54
Sofitel Wentworth Hotel	Day	69	60	L_{Aeq}-10 dB	59
	Evening	65	50	L_{Aeq}-10 dB	55
	Night	65	45	L_{Aeq}-10 dB	55
Lowy Institute	Day	69	65	L_{Aeq}-10 dB	59
	Evening	65	N/A	N/A	N/A
	Night	65	N/A	N/A	N/A

* Acceptable Noise Level, according to Table 2.1 (NSW Industrial Noise Policy, 2000)

** According to Table 2.2 (NSW Industrial Noise Policy, 2000)

Table 10: Deviation of amenity criteria for the receivers located on the Northern and Southern side of the site

5.3.2 Industrial Noise Policy Limiting Criteria

The most stringent of the intrusiveness and the amenity criteria is the limiting criterion according to the INP, and sets the project specific noise level to be met by the project. Table 11 compares the intrusiveness and the amenity criteria at the Noise Sensitive Receivers and identifies the limiting criterion for each time period for each area.

Noise Sensitive Receiver	Time period	Intrusiveness Criterion	Amenity Criterion	Limiting Criterion
Radisson Plaza Hotel	Day	70	59	59
	Evening	66	58	58
	Night	64	54	54
Sofitel Wentworth Hotel	Day	66	59	59
	Evening	62	55	55
	Night	59	55	55
Lowy Institute	Day	N/A	59	59
	Evening	N/A	N/A	N/A
	Night	N/A	N/A	N/A

Table 11: Industrial Noise Policy Limiting Criteria for the noise sensitive receivers along Bligh and O'Connell Streets of the site.

5.1 Criteria for Traffic Noise on Public Roads

Noise criteria for traffic movements on public roads resulting from the substation and commercial tower at 33 Bligh Street were developed from the Environmental Criteria for Road Traffic Noise (ECRTN).

In accordance with the INP, road traffic noise from vehicles while on site is characterised as industrial noise, and therefore vehicle movements on site are subject to the noise criteria discussed in Section 5.3.2.

Road traffic noise from vehicles from the project operating on public roads is subject to the ECRTN noise criteria. The ECRTN provides several categories for type of project and appropriate noise planning targets are given for each type of project.

The ECRTN noise criteria are planning goals for new project and as such are not legislative requirements that must be met by new projects. Rather, these criteria should be used as design goals for the project. The ECRTN recognises that "the criteria are applied as targets, but recognise that there will be situations where planning strategies are not feasible".

A traffic impact assessment for the project has been carried out. The traffic impact of the project has been considered on the basis of the number of parking spaces provided and the level of loading and service vehicle activity anticipated. As a result of the assessment it can be considered that the additional affect of these vehicles is minimal on the nearest intersections to the site after which vehicles disperse.

Also the existing building utilised 43 car parking spaces in the basement with access from O'Connell Street and contained a loading dock which would have generated very similar traffic movements to the project.

Therefore it could be concluded that there will be no additional impact as a result of this project compared to traffic conditions when the building was previously fully tenanted.

6 Vibration Criteria

Vibration levels caused by activities on the site (including plant) should not exceed the levels specified in the DECCW Assessing Vibration guideline at any place of different occupancy at and around the site. The Assessing Vibration guideline provides operational vibration criteria for maintaining human comfort within different space uses.

For intermittent sources (e.g. trains, heavy vehicles, intermittent construction), the Assessing Vibration guideline uses the Vibration Dose Value (VDV) metric to assess human comfort effects of vibration. VDV takes into account both the magnitude of vibration events and the number of instances of the vibration event.

Intermittent events that occur less than 3 times in an assessment period (either day, 7am to 10pm, or night, 10pm to 7am) are counted as "impulsive" sources for the purposes of the Assessing Vibration guideline.

The vibration limits recommended for maintaining human comfort in residences and offices are shown in Table 12 below.

Location	**Maximum z-axis weighted rms vibration acceleration (m/s^2)**		**Vibration Dose Value ($m/s^{1.75}$)**
	Continuous	**Impulsive**	**Intermittent**
Office and retail areas	0.020	0.64	0.40

Table 12: Vibration limits in AS 2670.2 for Offices and Retail areas

In addition to the above, the risk of vibration-induced damage should be evaluated taking into account the magnitude, the frequency and duration of recorded vibration together with consideration of the type of building which is exposed.

This is considered in the British Standard BS 7385-2:1993 – *Evaluation and measurement for vibration in buildings – Part2: Guide to damage levels from groundborne vibration.*

The vibration levels suggested are judged to give a minimal risk of vibration-induced damage. Limits for transient vibration, above which cosmetic damage could occur are given numerically in Table 13 and Figure 11. In the lower frequency region where strains associated with a given vibration velocity magnitude are higher, the guide values for the building types corresponding to line 2 are reduced. Below a frequency of 4 Hz, where a high displacement is associated with a relatively low peak component particle velocity value a maximum displacement of 0.6 mm should be used.

Line (see Figure 11)	Type of building	Peak component particle velocity in frequency range of predominant pulse	
		4Hz to 15Hz	15Hz and above
1	Reinforced or framed structures Industrial and heavy commercial buildings	50mm/s at 4Hz and above	
2	Unreinforced or light framed structures Residential or light commercial type buildings	15mm/s at 4Hz increasing to 20mm/s at 15Hz	20mm/s at 15Hz increasing to 50mm/s at 40Hz and above
NOTE 1 – Values referred to are at the base of the building NOTE 2 – for line 2, at frequencies below 4Hz, a maximum displacement of 0.6mm should not be exceeded.			

Table 13: Transient vibration guide values for cosmetic damage

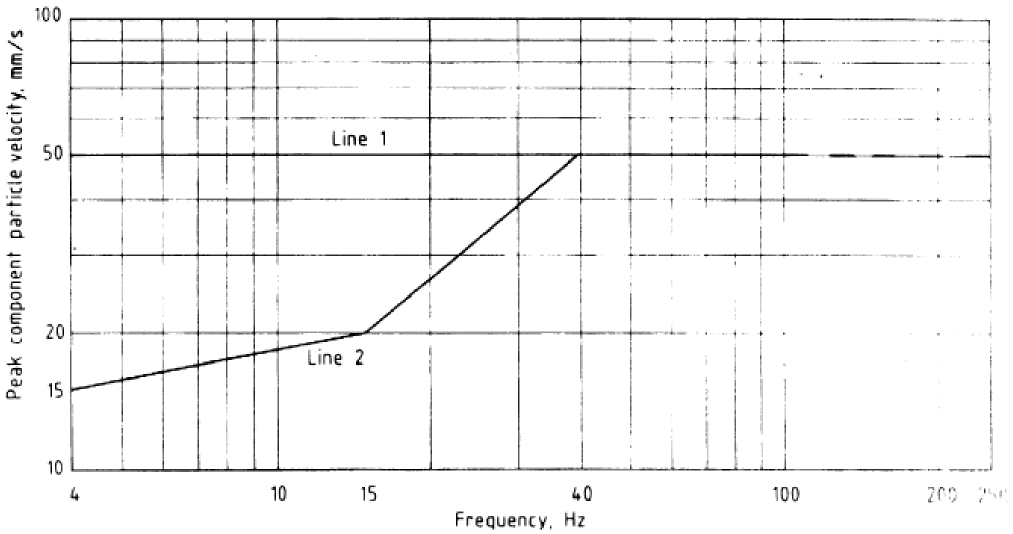


Figure 11: Transient vibration guide values for cosmetic damage

Minor damage is possible at vibration magnitudes which are greater than twice those given in Table 13, and major damage to a building structure may occur at values greater than four times the tabulated values.

7 Noise and Vibration from SF6 Transformers

Noise and vibration measurements were carried out at the City South Substation, in Cunningham Street, Sydney.

The measurements were undertaken in order to establish indicative noise and vibration levels from the gas transformer included in the City South Substation, as at the time of writing the acoustic performance data of the gas transformer to be installed in the new project was not available.

7.1 Assessment of Transformer Noise

A noise level at 1m from the gas transformer in the City South Substation was measured on 12 December 2010. This level has been used to undertake a preliminary assessment of the reverberant noise in the transformer bays breaking out through the transformer roadway to the nearest noise sensitive receivers. In order to carry out the calculations, the level has been normalised to the overall Mitsubishi transformer noise data provided by Ausgrid.

It should be noted that this exercise has been done to inform if, using the measured noise level at the City South Substation, transformer noise within the new project will meet the criteria at the noise sensitive receivers.

-The sound power level from the gas transformer normalised to the Mitsubishi t:ransformer overall noise level used in the calculation is as follows:

	Octave Band Centre Frequency							
	63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
Gas transformer sound power level (dB)	80	85	84	79	74	67	59	48

Table 14: Gas transformer sound power level used for noise level predictions

7.1.1 To O'Connell Street

A hollow concrete block called Boral Acousticell has been used in the transformer bays back wall, together with an absorptive ceiling, to reduce the reverberant noise level inside the transformer bays.

The hollow concrete block has already been used previously on other Ausgrid substations and has proved to be a suitable solution for Transformer Substation enclosures.

Boral Acousticell absorption characteristics are suitable to control reverberance within the above spaces as it offers significant sound absorbing properties.

It can be confirmed that using the Boral Acousticell on the rear wall of each transformer bay and absorptive ceilings in the transformer bays, the limiting noise criteria for the day, evening and night time will be met at the noise sensitive receivers along O'Connell Street.

7.1.2 To Bligh Street

It can be confirmed that using the Boral Acousticell on the rear wall of each transformer bay and absorptive ceilings in the transformer bays, the limiting noise criteria for the day, evening and night time will be met at the Sofitel Wentworth Hotel and for the daytime at the Lowy Institute.

7.2 Assessment of Transformer Vibration

A preliminary assessment of the vibration from the gas transformers has been carried out.

It should be noted that in the City South Substation the gas transformer and the oil transformer no. 3 are mounted on vibration isolation pads whilst the oil transformers no. 2 and no. 4 are not.

It is also noted that the transformers in both the existing City South and the proposed City East Zone substations are located on a suspended concrete floor.

Following the preliminary assessment undertaken, it can be confirmed that the vibration levels measured were below the threshold of perception.

A more detailed vibration assessment is required when data from the particular gas transformer being installed in the new substation is available. In the meantime further measurements are required to be carried out at the City South substation at a later stage of the design in order to confirm the above vibration levels.

8 Noise and Vibration Impacts from Mechanical and Electrical Plant

The Table below shows the type and location of the plant and related louvres that will be included in the West and East facades of the project.

8.1 Bligh Street Elevation Plants and Louvres

Plant Type	Plant Location	Working hours
• **Substation**		
Transformer Corridor Natural Ventilation	Level 7	Transformers working 24/7
2 x general exhaust 1 x garbage exhaust 1 x toilet exhaust	Level 7	During office hours

Plant Type	Plant Location	Working hours
Transformer Corridor Natural Ventilation	Level 8	Transformers working 24/7, at different % loads depending on energy demand
Stair Press Intake	Level 8	In the event of a fire
• **Office Tower**		
AHU Plant	Level 12	During office hours
AHU Plant	Level 26	During office hours
3 x Cooling Towers	Level 37	Working 24/7
Chillers	Level 37	During office hours

Table 15: Bligh Street (East) Elevation Plants and Louvres

8.2 O'Connell Street Elevation Plants and Louvres

Plant Type	Plant Location	Working hours
• **Substation**		
Intake for ground lobby vent	Level 5	During office hours
Transformer Corridor Natural Ventilation	Level 5 to Level 7	Transformers working 24/7, at different % loads depending on energy demand
Stair Press Intake	Level 7	In the event of a fire
Carpark Exhaust discharge	Level 9	During office hours
Stair Press Intake	Level 12	In the event of a fire
• **Office Tower**		
AHU Plant	Level 12	During office hours
AHU Plant	Level 26	During office hours
3 x Cooling Towers	Level 37	Working 24/7

Plant Type	Plant Location	Working hours
Chillers	Level 37	During office hours

Table 16: O'Connell Street (West) Elevation Plants and Louvres

It is understood that the Chillers on the rooftop will be fully enclosed and the three cooling towers will have louvred barriers around them and open roof.

At this stage the selection of the mechanical plant has not been finalised. In the detailed design stage of the project, plant noise will be controlled to meet the criteria at the noise sensitive receivers listed in Table 11. Typical noise mitigation strategies include selection of low noise plant, the use of plant enclosures, acoustic louvers on air intake/exhaust paths and acoustic attenuators.

Also in order to achieve the vibration criteria in Table 12 it is recommended that the plants included in the development to be installed on vibration isolation systems.

9 Conclusion

This report presents acoustic input to the Stage 2A(ii) Project Application submission for the new City East Zone Substation and integrated commercial develpment building at 33 Bligh Street, Sydney.

This report establishes noise management levels that will be used to guide the selection of plants during detailed design and it does not assess the impact of them.

Acoustic design targets have been provided to achieve acceptable criteria for:

- Noise break-out to the community
- Noise break-in to the development and internal noise levels
- Vibration and structureborne noise levels

An attended and unattended noise survey has been undertaken. The purpose of the noise surveys was to:

- Identify existing ambient noise levels, as a baseline in setting appropriate noise criteria to assess the impact of the development on the surroundings
- Identify sources and levels of noise that are likely to affect the development
- Identify potential noise-sensitive receivers in the vicinity

In order to assess the noise emission from operation of a facility and from plant and equipment on the proposed facility, the NSW Industrial Noise Policy (INP) has been used to establish the noise limits at the noise sensitive receivers.

The type and location of the plant and related louvers that will be included in the West and East facades of the project have been proposed. Details of acoustic requirements for mechanical services plant noise and vibration will be coordinated during the detailed design phase. During this design stage noise from mechanical plants will be controlled by selection of equipment and the design and implementation of noise control measures to meet the criteria at the noise sensitive receivers and the design internal ambient noise levels within the new project.

A traffic impact assessment for the project has been carried out. The traffic impact of the project has been considered on the basis of the number of parking spaces provided and the level of loading and service vehicle activity anticipated. As a result of the assessment it can be considered that the additional affect of these vehicles is minimal on the nearest intersections to the site after which vehicles disperse.

A comparison between the existing development and the new one has been carried out in terms of traffic movements that they can generate. It has been noted that the number of car parking spaces are more and less the same in the existing building and in the new project. Also the loading dock in the new development will generate similar traffic movements as in the existing development.

Therefore it could be concluded that there will be no additional impact as a result of this project compared to traffic conditions when the building was previously fully tenanted.

At the time of writing the specific noise and vibration data for the gas transformer that will be installed in the new substation is not available.

Therefore indicative noise and vibration measurements have been carried out at the City South Substation where one gas transformer is installed.

An assessment of the possible noise breaking-out from the substation and reaching the noise sensitive receivers has been undertaken. From this assessment it can be confirmed that the INP criteria at the noise sensitive receivers can be achieved by controlling the reverberant levels inside the transformer bays.

Following the preliminary vibration assessment undertaken, it can be confirmed that the vibration levels measured at the City South Substation were below the threshold of perception. However a more detailed vibration assessment is required when data from the gas transformer being installed in the new substation is available.

Appendix A

Acoustic Glossary

A1 Glossary of Acoustic Terminology

ASSESSMENT BACKGROUND LEVEL (ABL)

A single-number figure used to characterise the background noise levels from a single day of a noise survey. ABL is derived from the measured noise levels for the day, evening or night time period of a single day of background measurements. The ABL is calculated to be the tenth percentile of the background LA90 noise levels – i.e. the measured background noise is above the ABL 90% of the time.

'A'-WEIGHTED SOUND LEVEL dB(A)

The unit generally used for measuring environmental, traffic or industrial noise is the A-weighted sound pressure level in decibels, denoted dB(A). An A-weighting network can be built into a sound level measuring instrument such that sound levels in dB(A) can be read directly from a meter. The weighting is based on the frequency response of the human ear and has been found to correlate well with human subjective reactions to various sounds. An increase or decrease of approximately 10 dB corresponds to a subjective doubling or halving of the loudness of a noise. A change of 2 to 3 dB is subjectively barely perceptible.

DECIBEL

The ratio of sound pressures which we can hear is a ratio of 106:1 (one million : one). For convenience, therefore, a logarithmic measurement scale is used. The resulting parameter is called the 'sound level' (L) and the associated measurement unit is the decibel (dB). As the decibel is a logarithmic ratio, the laws of logarithmic addition and subtraction apply.

Some typical noise levels are given below:

Noise Level dB(A)	Example
130	Threshold of pain
120	Jet aircraft take-off at 100 m
110	Chain saw at 1 m
100	Inside disco
90	Heavy trucks at 5 m
80	Kerbside of busy street
70	Loud radio (in typical domestic room)
60	Office or restaurant
50	Domestic fan heater at 1m

40	Living room
30	Theatre
20	Remote countryside on still night
10	Sound insulated test chamber
0	Threshold of hearing

EQUIVALENT CONTINUOUS SOUND LEVEL (LAeq)

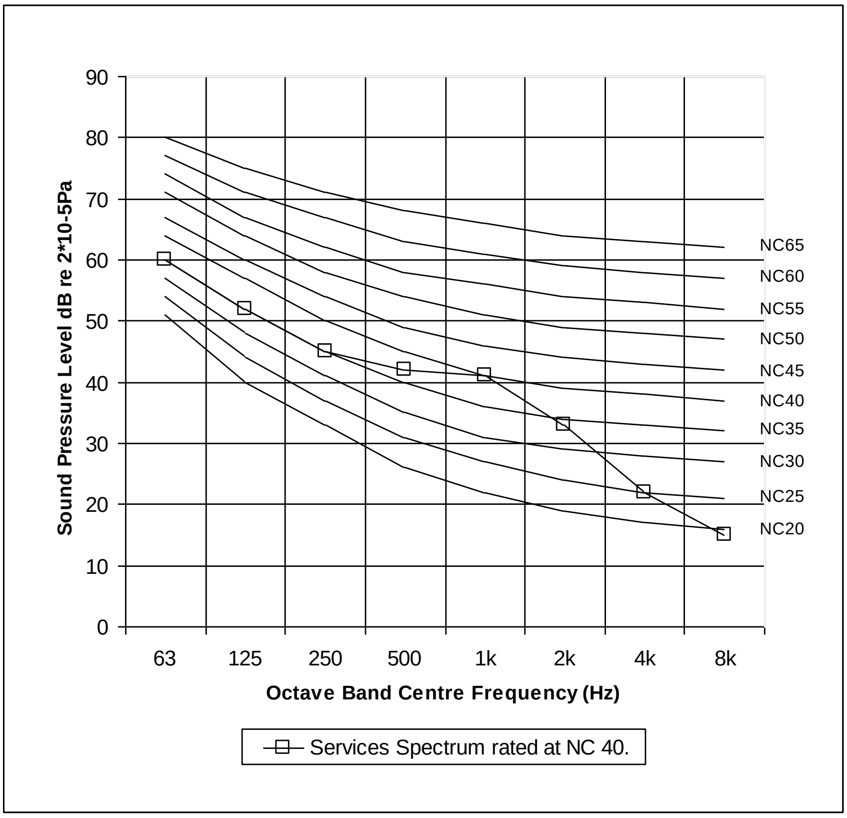
Another index for assessment for overall noise exposure is the equivalent continuous sound level, Leq. This is a notional steady level, which would, over a given period of time, deliver the same sound energy as the actual time-varying sound over the same period. Hence fluctuating levels can be described in terms of a single figure level.

FREQUENCY

The rate of repetition of a sound wave. The subjective equivalent in music is pitch. The unit of frequency is the Hertz (Hz), which is identical to cycles per second. A thousand hertz is often denoted kilohertz (kHz), eg 2 kHz = 2000 Hz. Human hearing ranges from approximately 20 Hz to 20 kHz. The most commonly used frequency bands are octave bands, in which the mid frequency of each band is twice that of the band below it. For design purposes, the octave bands between 63 Hz to 8 kHz are generally used. For more detailed analysis, each octave band may be split into three one-third octave bands or, in some cases, narrow frequency bands.

NOISE RATING (NR) CURVES

Noise rating (NR) curves are a set of internationally-agreed octave band sound pressure level curves, based on the concept of equal loudness. The curves are commonly used to define building services noise limits. The NR value of a noise is obtained by plotting the octave band spectrum on the set of standard curves. The highest value curve which is reached by the spectrum is the NR value. Shown below is a plant noise spectrum that is equivalent to NR 40.



RATING BACKGROUND LEVEL (RBL)

A single-number figure used to characterise the background noise levels from a complete noise survey. The RBL for a day, evening or night time period for the overall survey is calculated from the individual Assessment Background Levels (ABL) for each day of the measurement period, and is numerically equal to the median (middle value) of the ABL values for the days in the noise survey.

REVERBERATION TIME (RT_{60})

The time, in seconds, taken for a sound within a space to decay by 60 dB after the sound source has stopped is denoted at the reverberation time. The RT is an important indicator of the subjective acoustic within an auditorium. A large RT subjectively corresponds to an acoustically ‘live’ or ‘boomy’ space, while a small RT subjectively corresponds to an acoustically ‘dead’ or ‘flat’ space.

SOUND POWER AND SOUND PRESSURE

The sound power level (L_w) of a source is a measure of the total acoustic power radiated by a source. The sound pressure level (L_p) varies as a function of distance from a source. However, the sound power level is an intrinsic characteristic of a source (analogous to its mass), which is not affected by the environment within which the source is located.

STATISTICAL NOISE LEVELS

For levels of noise that vary widely with time, for example road traffic noise, it is necessary to employ an index that allows for this variation. ‘A’-weighted statistical noise levels are denoted L_{A10}, dBL_{A90} etc. The reference time period (T) is normally included, eg. dBL_{A10}, 5min or dBL_{A90}, 8hr.

L_{A90} (T)

Refers to the sound pressure level measured in dB(A), exceeded for 90% of the time interval (T) –i.e. measured noise levels were greater than this value for 90% of the time interval. This is also often referred to the background noise level.

L_{A10} (T)

Refers to the sound pressure level measured in dB(A), exceeded for 10% of the time interval (T). This is often referred to as the average maximum noise level and is frequently used to describe traffic noise.

L_{A1} (T)

Refers to the sound pressure level measured in dB(A), exceeded for 1% of the time interval (T). This is often used to represent the maximum noise level from a period of measurement.

VIBRATION

Vibration may be expressed in terms of displacement, velocity and acceleration. Velocity and acceleration are most commonly used when assessing structureborne noise or human comfort issues respectively. Vibration amplitude may be quantified as a peak value, or as a root mean squared (rms) value.

Vibration amplitude can be expressed as an engineering unit value e.g. $1mms^{-1}$ or as a ratio on a logarithmic scale in decibels:

Vibration velocity level, L_V (dB) = 20 log (V/V_{ref}),

(where the preferred reference level, V_{ref}, for vibration velocity = 10^{-9} m/s).

The decibel approach has advantages for manipulation and comparison of data.

SYDNEY CITYGRID PROJECT
CITY EAST ZONE SUBSTATION STAGE 2A(II)
CONSTRUCTION NOISE AND VIBRATION IMPACT ASSESSMENT

A C O U S T I C S   A N D   A I R

REPORT NO. 09300-2II
VERSION A

WILKINSON MURRAY

SYDNEY CITYGRID PROJECT
CITY EAST ZONE SUBSTATION STAGE 2A(II)
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VERSION A

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PREPARED FOR

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1 INTRODUCTION

Wilkinson Murray Pty Limited has been engaged by GHD Pty Ltd to conduct a construction noise and vibration assessment in relation to Stage 2A of the Sydney CityGrid Project cable project.

Stage 2A includes construction and operation of the City East Zone Substation at 33 Bligh Street, Sydney. For expediency, Ausgrid has elected to separate Stage 2A into the following sub stages:

- Stage 2A(i) – demolition of the existing building on the site.
- Stage 2A(ii) of the City East Zone Substation follows on from Stage 2A(i) and now involves the following tasks:
  - ❖ Bulk excavation for the substation basement (previously part of Stage 2A(i));
  - ❖ Excavation and construction of a shaft and a 150 m section of tunnel beneath Bligh Street to the intersection of Bent Street and Bligh Street where it will interface with the City East Cable Tunnel Project. The City East Cable Tunnel is known as Stage 2D of the Sydney CityGrid Project and is subject to a separate Environmental Assessment (previously part of Stage 2A(i));
  - ❖ Construction and operation of the City East Zone Substation and commercial tower.

This report describes the assessment and management of construction noise and vibration associated with Stage 2A(ii) only. Assessment relating to Stage 2A(i) was the subject of a separate approval application. This report relies in part on site investigations conducted for Stage 2A(i).

2 PROJECT DESCRIPTION

Stage 2A(ii) involves the following main construction stages:

- Bulk excavation for the substation basement.
- Excavating and constructing a shaft and a 150 m section of tunnel beneath Bligh Street to the intersection of Bent Street and Bligh Street where it will interface with the City East Cable Tunnel Project. The City East Cable Tunnel is known as Stage 2D of the Sydney CityGrid Project and was approved on 18 July 2011.
- Constructing and operating the City East Zone Substation and integrated commercial tower.
- Construction of Stage 2A(ii) would commence immediately following completion of Stage 2A(i).

The design for the substation and commercial tower was selected following a design review process in accordance with MCoA 3.2 of the Concept Approval. This included an invited competitive design alternatives process that was based on the principles outlined in the Sydney Local Environmental Plan (2005). The submission by Fitzpatrick and Partners was selected as the preferred option as it provided a unique landmark building that would add value and quality to the mix of buildings in the CBD, whilst meeting the specific requirements relating to the proposed use of the site.

The substation would be located in the basement and podium levels and would extend to a height of about 52.58 m above O'Connell Street and 45.68 m above Bligh Street. The commercial component would be a tower above the substation that would have a height of about 161.73 m and would achieve 5 Star Greenstar and 5 Star NABERS ratings. The tower would be composed of three cubic volumes separated by horizontal offsets. It would have a floor space area of 28,050 m^2 with floor plates on the 20 commercial floors ranging between 1,342 m^2 and 1,474 m^2.

A stub tunnel is required beneath Bligh Street to connect to the City East Zone Substation with the City East Cable Tunnel which would pass beneath Bent Street. The stub tunnel would be approximately 150 m long with cross sectional dimensions of approximately 4 m wide by 4 m high.

The stub tunnel would commence from a shaft extending from the basement of the City East Zone Substation at a depth of about RL - 20.2 and decline to about RL–29.3 beneath the intersection of Bent Street and Bligh Street.

Midway along Bligh Street, the stub tunnel would pass beneath the Metro Pitt corridor that has been reserved for future expansion of the rail network by RailCorp. In this location the stub tunnel would be at a depth of about RL – 23, which is at least 5.5 m below the Metro Pitt tunnels (RL - 17.76 and RL - 18.16). RailCorp has confirmed that this separation distance is adequate and would not compromise the future viability of expansion of the rail network within the Metro Pitt corridor.

Further investigations would be undertaken during development of the detailed design to ensure that the stub tunnel is designed and constructed to minimise the risk of ground settlement and potential settlement induced damage to existing buildings and other above ground and underground infrastructure

2.1.1 Hoardings

Hoardings or other protective structures would be installed along several site boundaries to provide a safe working environment for construction workers, as well as those in the surrounding area. All hoardings would be erected in accordance with the City of Sydney Guidelines for Temporary Protective Structures. The overhead hoardings would be designed to accommodate loads from scaffolding that may be required during demolition of the building.

2.1.2 Bulk excavation

Following completion of demolition, bulk excavation would likely commence at the O'Connell Street frontage and would work in an easterly direction. Underpinning and shoring works would commence on the perimeter of the site during the initial stages of the bulk excavation. These works entail a number of different techniques including but not limited to, underpinning, rock anchors and temporary shoring. These works would occur concurrently with the bulk earth removal works.

Bulk excavation would use a range of equipment including rock saws, rock hammers and excavators.

Approximately 34,866m^3 of material would be excavated during this process.

2.1.3 Stub tunnel excavation

A stub tunnel is required below Bligh Street to connect the City East Zone Substation to the proposed City East Cable Tunnel (CECT). The stub tunnel would be approximately 150 metres long with cross sectional dimensions of 4m wide by 4m high. It would be constructed using a road header, Mitsui 200 or similar equipment. These works would not involve any surface excavation beyond the boundary of 33 Bligh Street.

Approximately 5,664m^3 of material would be excavated and removed via a shaft within the site at 33 Bligh Street.

2.1.4 Construction of Substation and Office Tower

Once the excavation works are complete, the tower cranes would be established and construction of the basement would commence. The cranes would be used to handle materials to install the structure, services, facade, roofs.

The crane locations would be determined by the contractor during construction planning.

Constructing the substation and commercial tower would require various items of machinery including cranes, scaffolding, concrete pumps, concrete vibrators, concrete delivery trucks, builders lift, builders hoist, air compressor, jack hammers and concrete saws.

2.1.5 Fitout and commissioning

Once the structure is complete, the internal components of the substation, stub tunnel and commercial tower would be installed and commissioned.

2.1.6 Timing and duration of construction

Construction hours

Construction would generally be carried out during the following hours:

- Monday to Friday 7 am to 7 pm;
- Saturdays 7 am to 5 pm; and
- No work on Sundays or Public Holidays.

Noise intensive activities such as rock breaking would be undertaken during the following hours:

- Monday to Saturday 7 am to 12 pm;
- Monday to Friday 2 pm to 5 pm; and
- At no time on Sundays or public holidays.

The below ground elements of the stub tunnel would be constructed 24 hours per day, however surface works, such as loading spoil into trucks, would be limited to the standard construction hours.

Ancillary activities that may occur outside the standard construction hours include, but may not be limited to, oversize truck movements and deliveries of certain plant and equipment on an occasional basis. Works may also be undertaken outside these hours in the event of a direction from police or other relevant authority for safety reasons, or emergency work to avoid the loss of lives, property and/or to prevent environmental harm.

Duration of construction

Table 2-1 outlines the estimated construction duration. The overall duration of construction is estimated to be 41 months and some tasks listed in Table 2-1 would be undertaken concurrently.

Table 2-1 Estimate duration of construction

Task	Duration*
Bulk excavation	8 months
Stub tunnel and shaft excavation	8 months
Constructing the City East Zone Substation	20 months
Constructing the commercial tower	18 months
Fitout and commission the substation	12 months
Fitout the tower	13 months
Overall construction duration	41 months

- \- to provide a conservative estimate of vehicle movements associated with waste and spoil disposal, these durations are based on works being limited to five days per week.

2.1.7 Traffic

The construction of Stage 2A of the Sydney CityGrid Project cable project would generate traffic movements. The majority of the heavy vehicle movements would be from spoil haulage.

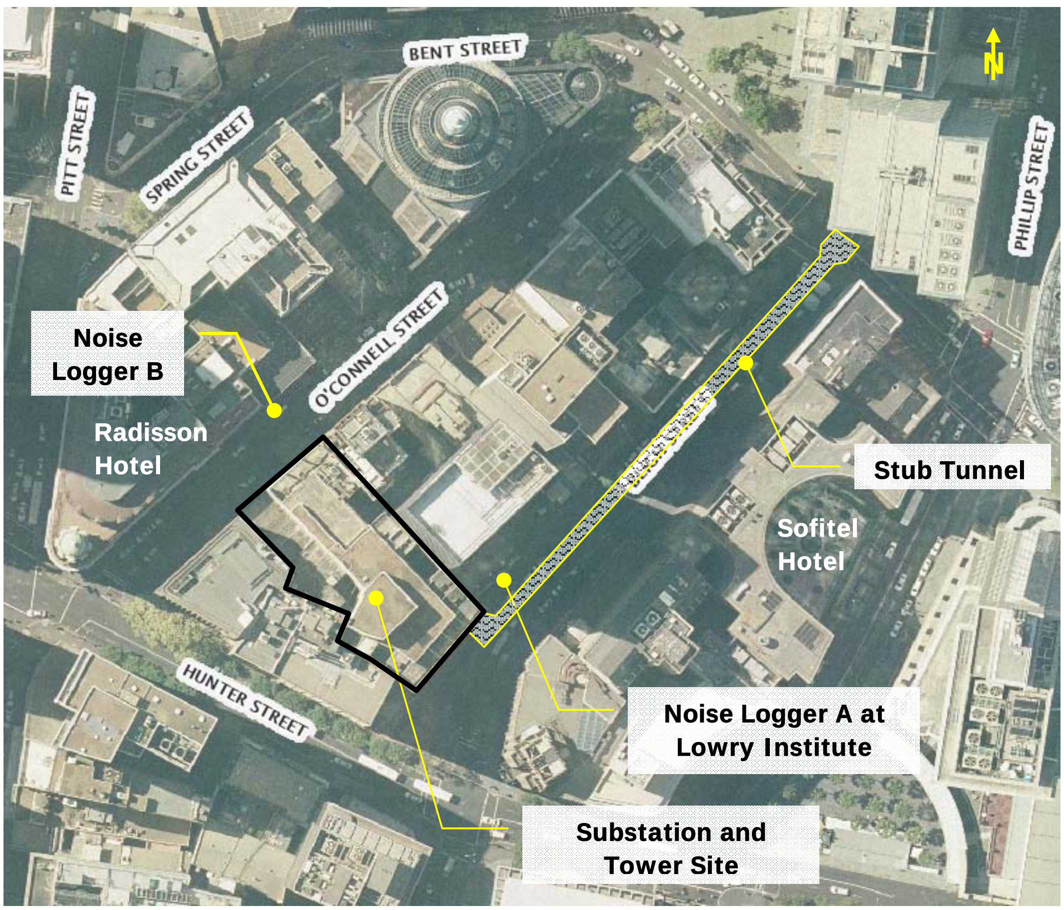
3 AMBIENT NOISE LEVELS AND SURROUNDING RECEIVERS

Long-term ambient noise levels were monitored at two locations surrounding the site (conducted for the Stage 2A(i) application), selected to cover the range of environments in the potentially-affected areas. The locations are presented in Table 3-1. The logger locations are shown in Figure 3-2 and Figure 3-3.

Table 3-1 Long-Term Noise Monitoring Locations

Noise Monitoring Site	Address	Relevant Noises noted on Site Visits
A	Bligh Street Sydney	Local Traffic and general city noise
B	O'Connell Street	Local Traffic and general city noise

Figure 3-1 Noise Monitoring Locations



Surrounding potentially affected receivers areas are presented in Table 3-2.

Table 3-2 Surrounding Receiver Areas

Description	Location
Radisson Hotel – O'Connell Street	Immediately to the West of the Substation Site at a distance of 20m.
Sofitel Wentworth Hotel – Backing on to Bligh Street	To the North East of the Substation Site at a distance of 65m.
Commercial Properties	Immediately to the North and South of the Substation Site.
Heritage Building – Lowy Institute	Immediately to the North of the Substation Site.

Figure 3-1, Figure 3-2 and Figure 3-3 present the logging locations and the surrounding areas.

Figure 3-2 Noise Logger Site A - 31 Bligh Street

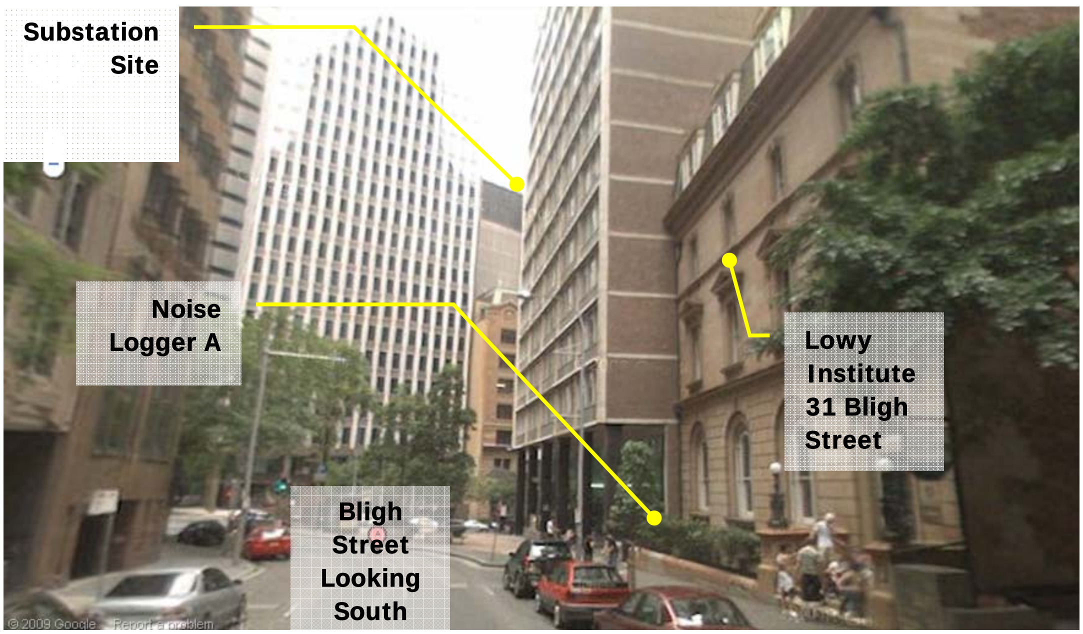
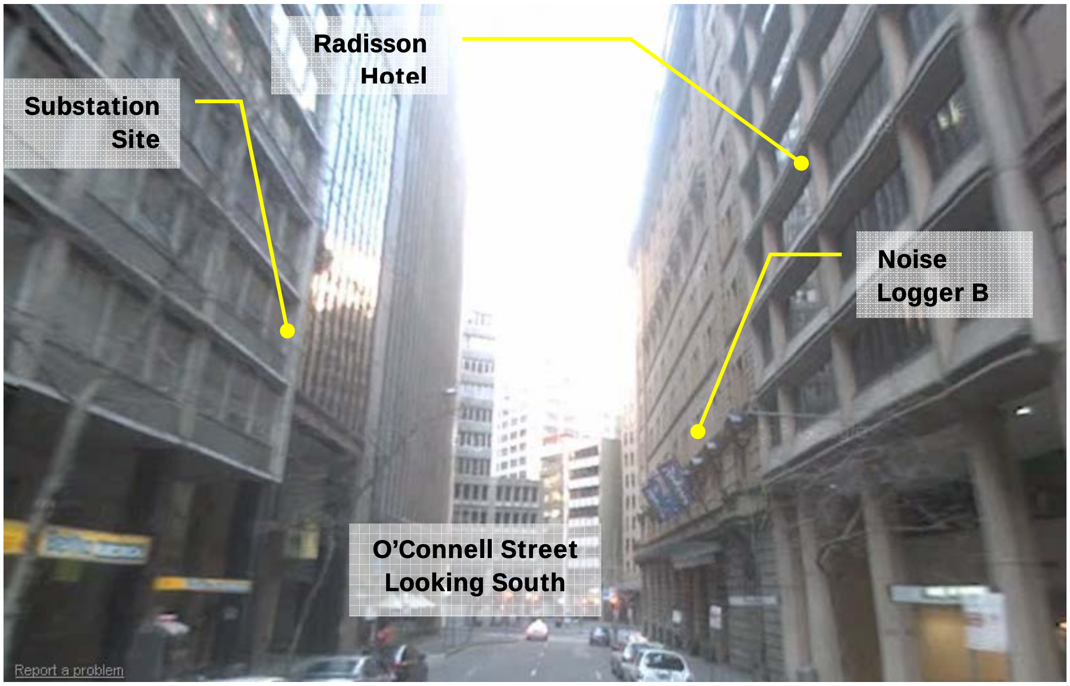


Figure 3-3 Noise Logger at Site B – Radisson Hotel – O'Connell Street



Noise monitoring was conducted between Monday, 15 February and Tuesday, 23 February 2010. The noise monitoring equipment used for these measurements consisted of ARL Type EL-215 environmental noise loggers set to A-weighted, fast response, continuously monitoring over 15-minute sampling periods. This equipment is capable of remotely monitoring and storing noise level descriptors for later detailed analysis. The equipment calibration was checked before and after the survey and no significant drift was noted.

The logger determines L_{A1}, L_{A10}, L_{A90} and L_{Aeq} levels of the ambient noise. L_{A1}, L_{A10} and L_{A90} are the levels exceeded for 1%, 10% and 90% of the sample time respectively (see Appendix A for definitions). The L_{A1} is indicative of maximum noise levels due to individual noise events such as the occasional pass-by of a heavy vehicle. The L_{A90} level is normally taken as the background noise level during the relevant period.

Detailed results for each monitoring location are shown in graphical form in Appendix B. The graphs show measured values of L_{Aeq}, L_{A90}, L_{A10} and L_{A1} for each 15-minute monitoring period.

Table 3-3 summarises the noise results, for daytime, evening, night time periods as defined in CNG. Additionally, noise monitoring results for Saturday (7.00am-5.00pm) has been included as Ausgrid propose to operate outside of CNG hours during that time. The summary values are:

- L_{Aeq} (period) – the equivalent continuous L_{Aeq} noise level measured over the assessment period; and
- RBL – Rating Background Level is a measure of typical background noise levels which are used in determining noise criteria.

Table 3-3 Summary of Measured Noise Levels

Noise Logging Site	RBL (dBA)				$L_{Aeq,period}$ (dBA)			
	Daytime 7am-6pm	Evening 6-10pm	Night Time 10pm-7am	Saturday 7am-5pm	Daytime 7am-6pm	Evening 6-10pm	Night Time 10pm-7am	Saturday 7am-5pm
A	58	59	56	58	63	64	66	63
B	65	61	59	65	70	67	65	70

Weather conditions were suitable for noise measurements during the monitoring period.

The noise logger at Site A was deployed at the Lowy Institute. Consultation with the Lowy Institute indicated that the building façade was being restored and that work hours were 6.00am to 2.00pm weekdays. This is consistent with noise logging results and observations at the time of deployment.

As construction was occurring between 6.00am – 2.00pm at the Lowy Institute, data for this period was excluded from measurements for the purpose of calculating background noise levels.

The noise logger at Site B was deployed in O'Connell Street and was not affected by noise from sources such as fans that emit constant noises. There was no plant or construction noise that affected logger results in this location.

In summary, background levels determined at both locations were free of the influence of extraneous noise sources such as plant or construction activities.

4 PERFORMANCE CRITERIA

The following sections detail the applicable site specific construction noise and vibration criteria based on the guidelines from OEH, being;

- *Interim Construction Noise Guideline*, and;
- *Assessing Vibration: A Technical Guideline*.

4.1 Construction Noise Criteria

The NSW OEH released the "*Interim Construction Noise Guideline*" *(CNG)* in July 2009 the guideline provides noise goals that assist in assessing the impact of construction noise.

For residences, the basic daytime construction noise goal is that the noise should not exceed the L_{A90} background noise by more than 10dBA. This is for standard hours: Monday to Friday 7.00am to 6.00pm, and Saturday 8.00am to 1.00pm. Outside the standard hours, the criterion would be background + 5dBA. A more complete description of the guidelines is in Table 4-1.

Table 4-1 Construction Noise Goals at Residences using Quantitative Assessment

<table>
<tr><th>Time of Day</th><th>Management Level $L_{Aeq,(15min)}$ *</th><th>How to Apply</th></tr>
<tr><td rowspan="2">Recommended Standard Hours:
Monday to Friday
7am to 6pm
Saturday
8am to 1pm
No work on Sundays or Public Holidays</td><td>Noise affected
RBL + 10dBA</td><td>• The noise affected level represents the point above which there may be some community reaction to noise.
• Where the predicted or measured $L_{Aeq,(15min)}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to minimise noise.
• 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.</td></tr>
<tr><td>Highly noise affected
75dBA</td><td>• 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 proponent should consider very carefully if there is any other feasible and reasonable way to reduce noise to below this level.
• If no quieter work method is feasible and reasonable, and the works proceed, the proponent should communicate with the impacted residents by clearly explaining the duration and noise level of the works, and by describing any respite periods that will be provided.</td></tr>
</table>

Time of Day	Management Level $L_{Aeq,(15min)}$ *	How to Apply
Outside recommended standard hours	Noise affected RBL + 5 dB	A strong justification would typically be required for works outside the recommended standard hours. • The proponent should apply all feasible and reasonable work practices to meet the noise affected level. • Where all feasible and reasonable practices have been applied and noise is more than 5dB(A) above the noise affected level, the proponent should negotiate with the community. • For guidance on negotiating agreements see section 7.2.2.

In addition the following construction noise management levels $L_{Aeq\ (15\ min)}$ are recommended for other receivers and areas as follows.

- Active recreation areas (such as parks) external $L_{Aeq\ (15\ min)}$ 65dBA;
- Industrial premises: external $L_{Aeq\ (15\ min)}$ 75dBA; and
- Offices, retail outlets external $L_{Aeq\ (15\ min)}$ 70dBA.

Based on the above, Table 4-2 presents the applicable noise management levels for construction activities.

Table 4-2 Site Specific Construction Noise Management Levels

Location	Construction Noise Management Level, L_{Aeq} - dBA				Maximum Construction Noise Level, L_{Aeq} - dBA
	Day	Evening	Night	Saturday (extended)	
Bligh Street	68	64	61	63	75
O'Connell Street	75	66	64	70	75
Commercial Properties	70				75

4.2 Construction Vibration Criteria

Criteria for assessment of the effects of vibration on human comfort are set out in British Standard 6472-1992. Methods and criteria in that Standard are used to set "preferred" and "maximum" vibration levels in the document "*Assessing Vibration: A Technical Guideline*" (2006) produced by the NSW OEH.

Acceptable values of human exposure to continuous vibration, such as that associated with underground drilling, are dependent on the time of day and the activity taking place in the occupied space (eg; workshop, office, residence or a vibration-critical area). Guidance on preferred values for continuous vibration is set out in Table 4-3.

Table 4-3 Criteria for Exposure to Continuous and Impulsive Vibration

Place	Time	Peak velocity (mm/s)	
		Preferred	**Maximum**
Critical working areas (e.g. hospital operating theatres precision laboratories)	Day or night time	0.14	0.28
Residences	Daytime	0.28	0.56
	Night time	0.20	0.40
Offices	Day or night time	0.56	1.1
Workshops	Day or night time	1.1	2.2

In the case of intermittent vibration, which is caused by plant such as rockbreakers, the criteria are expressed as a Vibration Dose Value (VDV) which is presented in Table 4-4.

Table 4-4 Acceptable Vibration Dose Values for Intermittent Vibration ($m/s^{1.75}$)

Location	Daytime		Night Time	
	Preferred Value	**Maximum Value**	**Preferred Value**	**Maximum Value**
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

Calculation of VDV requires knowledge of the number of events in the relevant time period.

4.3 Building Damage

In terms of the most recent relevant vibration damage objectives, Australian Standard AS 2187: Part 2-2006 “Explosives - Storage and Use - Part 2: 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” as they “are applicable to Australian conditions” BS7385.

The British 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.

The recommended limits (guide values) from BS7385 for transient vibration to ensure minimal risk of cosmetic damage to residential and industrial buildings are presented numerically in Table 4-5.

Table 4-5 Transient Vibration Guide Values - Minimal Risk of Cosmetic Damage

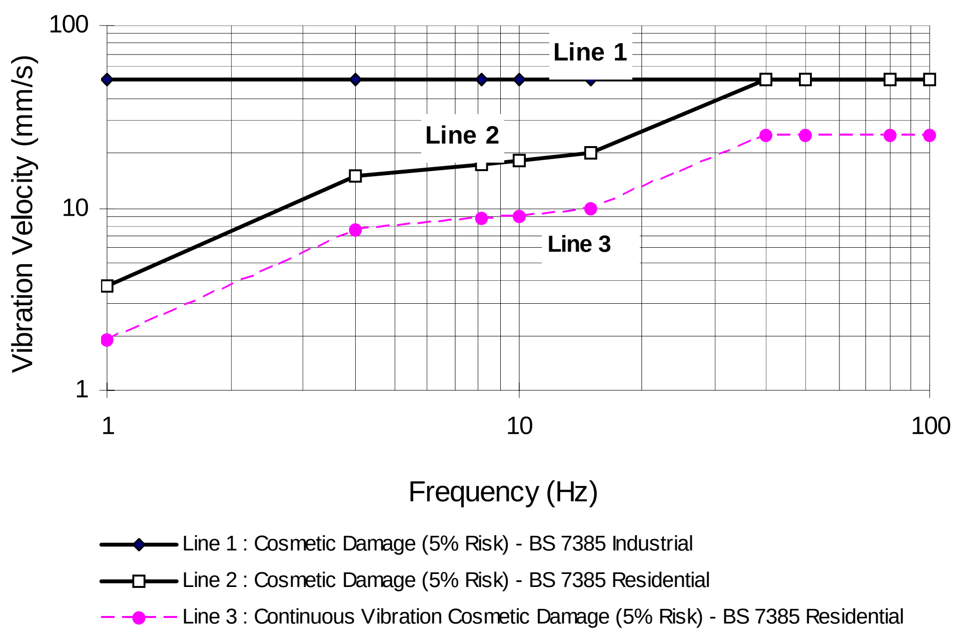
Type of building	Peak component particle velocity in frequency range of predominant pulse	
	4 Hz to 15 Hz	15 Hz and above
Reinforced or framed structures Industrial and heavy commercial buildings	50mm/s at 4 Hz and above	N/A
Unreinforced or light framed structures Residential or light commercial type buildings	15mm/s at 4 Hz increasing to 20mm/s at 15 Hz	20mm/s at 15 Hz increasing to 50mm/s at 40 Hz and above

The standard states that the guide values in Table 4-5 relate predominantly to transient vibration which does not give rise to resonant responses in structures, and to low-rise buildings.

Note that rockbreaking/hammering and sheet piling activities 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%.

The British Standard goes on to state that "*Some data suggests that the probability of damage tends towards zero at 12.5 mm/s peak component particle velocity*". In addition, a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive.

Figure 4.1 Graph of Transient Vibration Guide Values for Cosmetic Damage



In addition to the British Standard, for the case of nearby heritage buildings at 16-18 O'Connell Street and 31 Bligh Street, guidance for structural damage is derived from the German Standard DIN 4150 -3 "Structural Vibration Part 3 – Effects of Vibration on Structures. The following Table details these recommendations for heritage buildings.

Table 4-6 DIN 4150 recommend PPV vibration level for Heritage Buildings

Guideline Values for Velocity – mm/s		
1-10 Hz	*10 to 15 Hz*	*40 to 50 Hz*
3	3 to 8	8-10

Based on the foregoing information, the recommended site vibration control criteria are presented in **Table 4-7.**

Table 4-7 Recommended Site Vibration Control Criteria (ie Operator Warning and Halt Levels)

Structures	Site Control Criteria*		Minimal Risk of Cosmetic Damage Criteria
	Operator Warning Level	Operator Halt Level	
Commercial Building	20mm/s	25mm/s	25mm/s (4 Hz and above)
Residential Building	8mm/s	10mm/s	7.5mm/s to 10mm/s (4Hz to 15Hz) 10mm/s to 25mm/s (15Hz to 40Hz)
Heritage Buildings	2.4mm/s	3mm/s	1.5mm/s to 4mm/s (10 Hz to 15Hz) 4mm/s to 5mm/s (15Hz to 40Hz)

*Note: Based on rockbreaking generating frequencies greater than 10 Hz.

It is noted that the British Standard notes that a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive. Therefore, the surrounding heritage buildings should be inspected by a structural engineer for soundness. If these buildings are found to be structurally sound there may be scope for increasing vibration criteria to that of residential buildings.

An exceedance of the "Operator Halt Level" would require the Site Superintendent to implement alternative techniques.

Exceedances of the "Operator Halt Level" are only permissible when the vibration criteria in **Table 4.7** are achieved (based on the frequency content of the vibration signal) or new vibration criteria are approved by the Site Superintendent.

4.4 Ground-borne Noise

Ground-borne noise refers to noise produced by vibration of floor slabs and other building elements, which radiates noise into the interior of a building. The *Interim NSW Construction Noise Guideline* addresses ground-borne noise as follows;

Ground-borne noise is noise generated by vibration transmitted through the ground into a structure. Ground-borne noise caused, for example by underground works such as tunnelling, can be more noticeable than airborne noise. The following ground-borne noise levels for residences indicate when management actions should be implemented. These levels recognise the temporary nature of construction and are only applicable when ground-borne noise levels are higher than airborne noise levels. The ground-borne noise levels are for evening and night time periods only, as the objectives are to protect the amenity and sleep of people when they are at home.

- Evening (6.00pm to 10.00pm) Internal: $L_{Aeq\ (15\ min)}$ 40dBA
- Night time (10.00pm to 7.00am) Internal: $L_{Aeq\ (15\ min)}$ 35dBA

The internal noise levels are to be assessed at the centre of the most-affected habitable room. For a limited number of discrete, ongoing ground-borne noise events, such as drilling or rock-hammering, $L_{A\ (max)}$ *using a slow response on the sound level meter may be better than* $L_{Aeq\ (15\ min)}$ *in describing the noise impacts.*

4.5 Traffic Noise Criteria

Criteria for assessment of road traffic noise are set out in the NSW Government's *NSW Road Noise Policy (RNP)*. Table 4-8 sets out the assessment criteria for residences to be applied to particular types of project, road category and land use.

In summary the noise level goals at the residential receivers, for this project, based on the *RNP* are:

- $L_{Aeq,15hr}$ day 60 dBA.
- $L_{Aeq,9hr}$ night 55 dBA;

Table 4-8 Traffic noise criteria extracted from the NSW *RNP*

Road category	Type of project/land use	Assessment criteria – dB(A)	
		Day (7 a.m.–10 p.m.)	Night (10 p.m.–7 a.m.)
Freeway/ arterial/ sub-arterial roads	1. Existing residences affected by noise from **new** freeway/arterial/sub-arterial road corridors	$L_{Aeq, (15 hour)}$ 55 (external)	$L_{Aeq, (9 hour)}$ 50 (external)
	2. Existing residences affected by noise from **redevelopment** of existing freeway/arterial/sub-arterial roads 3. Existing residences affected by **additional traffic** on existing freeways/arterial/sub-arterial roads generated by land use developments	$L_{Aeq, (15 hour)}$ 60 (external)	$L_{Aeq, (9 hour)}$ 55 (external)
Local roads	4. Existing residences affected by noise from **new** local road corridors 5. Existing residences affected by noise from **redevelopment** of existing local roads 6. Existing residences affected by **additional traffic** on existing local roads generated by land use developments	$L_{Aeq, (1 hour)}$ 55 (external)	$L_{Aeq, (1 hour)}$ 50 (external)

In addition where the above criteria are already exceeded as a result of existing traffic the policy notes:

For existing residences and other sensitive land uses affected by additional traffic on existing roads generated by land use developments, any increase in the total traffic noise level should be limited to 2 dB above that of the corresponding 'no build option'.

Accordingly all residences potentially affected by traffic noise will be assessed with respect to the above criteria.

5 NOISE SOURCE LEVELS

5.1 Construction and Demolition of the Building

Noise sources that are likely to be associated with the site demolition, excavation and construction of the project are identified in the following sections.

In order to assess the potential noise and vibration impacts during construction, a number of indicative scenarios and typical equipment has been developed. These are summarised in Table 5-1.

Table 5-1 Indicative Construction Scenarios

Scenario	Description	Works
A	Excavation	This scenario includes rockbreaking and spoil removal 1 x Front End Loader, 2 x Dump Truck , 2 x Rock Breakers 1 x Excavator 1 x Mobile Crane
B	Building Construction	This scenario includes concreting and lifting. 2 concrete pumps, 2 forklifts, 4 compressors, 1 cranes, a boom truck and lift are assumed to operate in 15minutes. Also concrete trucks and normal delivery trucks assumed to be 12 movements in 15minutes.
C	Facade	In the event that the construction of the façade occurs in isolation. Forklift and power tools assumed. 2 cranes and a hoist are assumed.
D	Scenarios B + C	Represents periods where both Scenarios B and C occur concurrently.

Typical of the plant likely to be used during excavation and construction are identified in Table 5-2. These SWLs have recently been measured at other similar construction sites. The table gives both Sound Power Level (SWL) and Sound Pressure Levels (SPL) at 7m for the equipment. Sound Power Levels (SWL) is independent of measurement position. (Refer to Appendix A for further explanations.)

Table 5-2 Typical L_{Aeq} Construction Plant Sound Levels - dBA

Plant	Sound Power Level	Sound Pressure Level at 7m
Excavator	107	82
Dump Trucks	112	87
Rock Breaker	122	97
Concrete Pump	112	87
Saws	116	91
Saw Cutter	115	90
Small Excavators	90	65
Concrete Trucks	109	84
Small Generators	95	71
Front End - Low Loader	112	87
Compressor	100	75
Bobcat	103	78
Jackhammer	105	80
Angle Grinder	109	84
Site Cranes	104	79
Concrete Saw	113	88
Compressor	100	75
Bobcat	103	78
Hand Tools	90	65
Jackhammer	105	80

Predicted noise levels at receivers are based on 15-minute periods. This equipment has been distributed across the site for the noise predictions.

5.2 Tunnelling Construction

Noise from a roadheader is not acoustically significant as any noise associated with this equipment is contained by the tunnel walls. It is the ancillary equipment, including the exhaust fan and dust collector, which generate noise associated with this construction activity.

Typical sound levels of the construction plant likely to be used during the project tunnel construction are identified in Table 5-3. These levels have recently been measured at other similar construction sites.

Table 5-3 Typical Tunnelling Equipment Plant Sound Levels (SWL)

Plant	Sound Power Level	Sound Pressure Level at 7m
Excavator with Header	112	87
Bogie (Dump) Truck	112	87
Crane	110	85
Power Tools	115	90
Concrete Trucks	109	84
Small Generators	95	70
Exhaust Fan* and Dust Collector	105	80

Note: *Assumes a silencer on the fan.

6 CONSTRUCTION NOISE ASSESSMENT

6.1 Construction Noise

Assessment of likely noise at surrounding commercial and residential receivers has been assessed for excavation and tower construction.

Table 6-1 presents predicted, excavation and general construction noise levels at residential receivers and commercial premises. Daytime, evening, night time and Saturday construction noise management criteria are also presented in Table 6-1 to gauge compliance when compared to the predicted noise levels. The predicted noise levels are based on equipment noise levels, distance attenuation and shielding from existing building and structures etc, where applicable. The CADNA-A noise prediction program was used to conduct the noise predictions using ISO 9613 noise prediction algorithm.

Figure 6-1 illustrates the noise propagation from the site for the worst case excavation scenario.

Figure 6-1 Predicted Construction Noise from Excavation

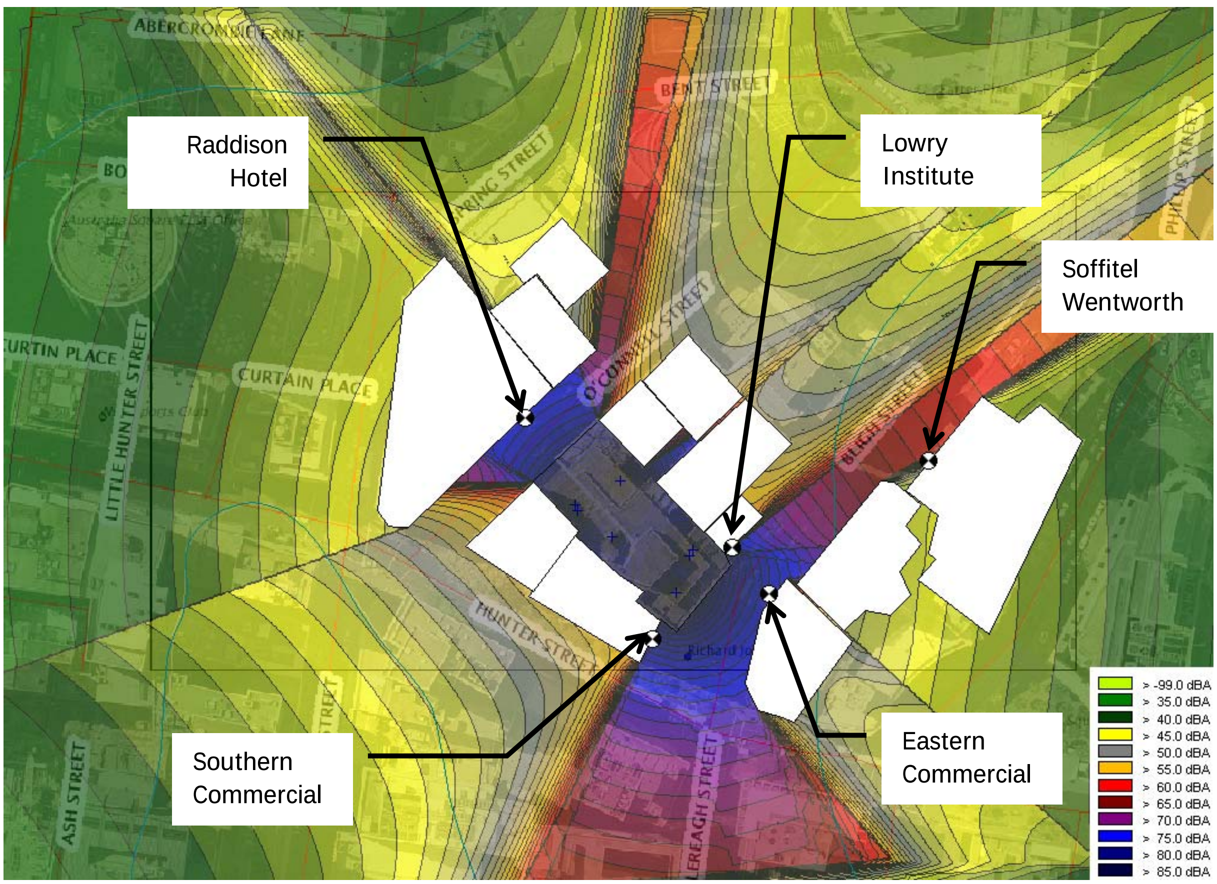


Table 6-1 Predicted Noise Levels at Receivers

Location	Predicted	Day			Evening			Night			Saturday (Extended)		
	Noise dBA	Criteria dBA	Exceedance dBA	Compliance	Criteria dBA	Exceedance dBA	Compliance	Criteria dBA	Exceedance dBA	Compliance	Criteria dBA	Exceedance dBA	Compliance
A – Excavation[1]													
Sofitel Wentworth	55 / 43	68	-	Yes	64	-	Yes	61	-	n/a	63	-	Yes
Radisson Hotel	76 / 74	75	1	**Marginal**	66	8	**No**	64	-	n/a	70	6	**No**
Lowy Institutes	77 / 67	70	7	**No**	70	-	Yes	70	-	n/a	70	7	**No**
Southern Commercial	80 / 73	70	10	**No**	70	3	**No**	70	-	n/a	70	10	**No**
Commercial across Bligh St	78 / 75	70	8	**No**	70	5	**No**	70	-	n/a	70	8	**No**
B – Building Construction													
Sofitel Wentworth	46	68	-	Yes	64	-	Yes	61	-	n/a	63	-	Yes
Radisson Hotel	67	75	-	Yes	66	1	**Marginal**	64	-	n/a	70	-	Yes
Lowy Institutes	65	70	-	Yes	70	-	Yes	70	-	n/a	70	-	Yes
Southern Commercial	66	70	-	Yes	70	-	Yes	70	-	n/a	70	-	Yes
Commercial across Bligh St	65	70	-	Yes	70	-	Yes	70	-	n/a	70	-	Yes
C - Facade													
Sofitel Wentworth	53	68	-	Yes	64	-	Yes	61	-	n/a	63	-	Yes
Radisson Hotel	64	75	-	Yes	66	-	Yes	64	-	n/a	70	-	Yes
Lowy Institutes	60	70	-	Yes	70	-	Yes	70	-	n/a	70	-	Yes
Southern Commercial	59	70	-	Yes	70	-	Yes	70	-	n/a	70	-	Yes
Commercial across Bligh St	62	70	-	Yes	70	-	Yes	70	-	n/a	70	-	Yes
D –Construction and Facade													
Sofitel Wentworth	54	68	-	Yes	64	-	Yes	61	-	n/a	63	-	Yes
Radisson Hotel	67	75	-	Yes	66	1	**Marginal**	64	-	n/a	70	-	Yes
Lowy Institutes	66	70	-	Yes	70	-	Yes	70	-	n/a	70	-	Yes

Location	Predicted	Day			Evening			Night			Saturday (Extended)		
	Noise dBA	Criteria dBA	Exceedance dBA	Compliance	Criteria dBA	Exceedance dBA	Compliance	Criteria dBA	Exceedance dBA	Compliance	Criteria dBA	Exceedance dBA	Compliance
Southern Commercial	66	70	-	Yes	70	-	Yes	70	-	n/a	70	-	Yes
Commercial across Bligh St	66	70	-	Yes	70	-	Yes	70	-	n/a	70	-	Yes

Note 1: Evening construction (6 pm to 7 pm) noise levels for excavation exclude noise from rockbreakers as these are classified as noise intensive activities.

Note 2: The only excavation that would occur at night would be related to tunnelling which is assessed in Section 6.2. Noise from tunnelling would be limited to operation of fans for the ventilation system and other plant and equipment, such as cranes, trucks, etc would not be used at night time.

Exceedance of noise criteria of up to 10 dBA is predicted when excavation occurs and rockbreakers are used. These items of plants are significantly louder than other site equipment and compliance with criteria can be expected when the large rockbreakers are not operating.

Noise control measures that can be adopted to reduce noise levels at surrounding receivers are:

- Use rocksaws and rippers where feasible.
- Install a noise barrier between the site and the street frontages; (the site will be surrounded by hoardings erected in accordance with the City of Sydney Guidelines. These will also act as noise barriers)
- Use smaller rockbreakers.

It is likely that a combination of the above measures will be required to ensure the acoustic amenity of nearby properties is protected during this stage of the project.

For general construction works the predicted noise levels comply with the evening and extended Saturday construction noise criterion. Therefore the extended operating hours proposed by Ausgrid are appropriate for and general construction works.

As a noise control it is proposed that any noise intensive activities such as rock breaking would only be undertaken during the following limited construction hours:

- Monday to Saturday 7.00am to 12.00pm;
- Monday to Friday 2.00pm to 5.00pm; and
- At no time on Sundays or Public Holidays.

6.2 Tunnelling Noise

Assessment of likely construction airborne noise at surrounding residential receivers has been assessed for tunnelling along Bligh Street based on the typical sound power levels presented in Section 5.2. The noise will emanate from the substation site to surrounding hotels.

Table 6-2 presents maximum predicted construction noise levels at nearby residences during tunnelling at night. The modelling is based on noise from exhaust fans and dust collectors as these are the main noise sources that would, at the surface, operate at night. Other plant and equipment associated with tunnelling, such as cranes and trucks, would not operate at night.

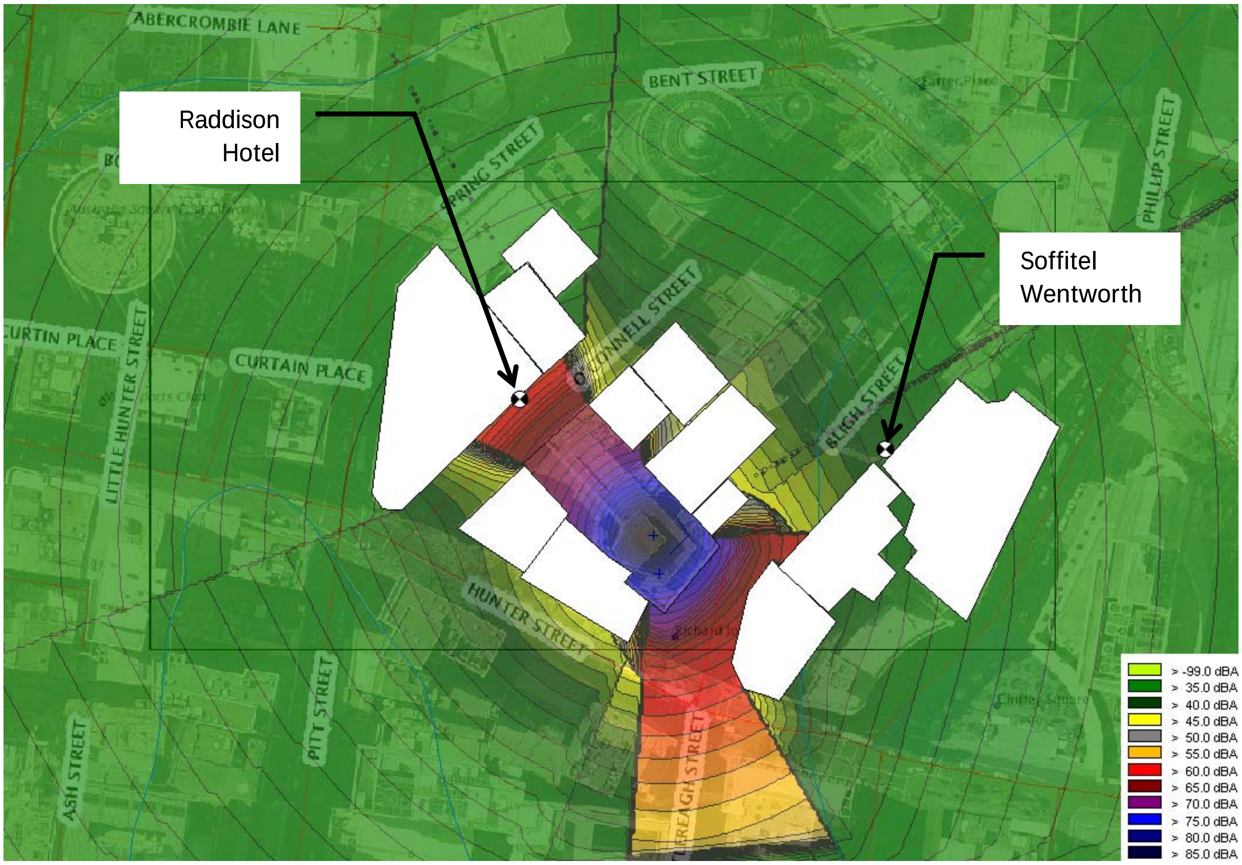
Table 6-2 Predicted Noise Levels at Residences from Tunnelling Works

Location	Predicted Noise Level dBA	Night Criteria dBA	Exceedance dBA	Compliance
Sofitel Wentworth	44	61	-	Yes
Radisson Hotel	64	64	0	Yes

The modelling indicated that acceptable noise levels will occur at the surrounding hotels. In addition, it is noted that these hotels have fixed windows and therefore internal noise levels will be further attenuated by this feature.

Figure 6-2 illustrates the noise propagation from the site.

Figure 6-2   Noise from Tunnelling



7 CONSTRUCTION VIBRATION ASSESSMENT

Construction and excavation activities have the potential to generate significant levels of vibration. Rockbreakers (Figure 7-1) involved in site excavation and road headers (Figure 7-2) conducting tunnelling activities may generate the highest vibration levels compared to other activities. The following sections detail the assessment of these sources.

7.1 Excavation Vibration

Whilst tunnelling equipment (used underground) can generate relatively high airborne noise levels within the tunnels, noise transmission to locations outside the tunnels will be satisfactorily attenuated by the intervening soil or rock.

Operation of roadheaders and rockbreakers also generates ground vibration that has the potential to transmit to nearby buildings as audible (regenerated) noise. Regenerated roadheader noise usually has a low frequency "rumbling" character, whereas rockbreaker noise can be described as having repetitive impulsive character. Regenerated noise is of potentially greater significance than the accompanying tactile vibration, as it is normally perceptible at a greater distance from the source.

It should be noted that for tunnelling operations, regenerated noise is usually transitory in nature, increasing in level as the tunnelling works approach a particular building, reaching a maximum when the works are immediately nearby, and then decreasing in level as tunnelling moves on. The rise and fall of the noise level is controlled by the rate of tunnel advance, which typically ranges from 5m to 10m per day, depending on ground conditions and excavation methods.

Figure 7-1 Hydraulic Rock Breakers

The impulsive vibration from large rockbreakers can cause audible regenerated noise in buildings out to distances of 50 m to 100 m from an excavation site, depending on ground conditions, type of structure and on ambient noise conditions. Levels in the order of 45dBA to 50 dBA have been measured in the basement of properties 70m from a large rockbreaker operating to remove the lower bench in a tunnel.

Table 7-1 sets out the typical ground vibration levels at various distances from rock breakers operating in hard sandstone.

Table 7-1 Rockbreaker PPV Vibration Levels (mm/s) versus Distance

Operation	PPV Vibration Level (mm/s) at given Distance					
	5 m	**10 m**	**20 m**	**30 m**	**40 m**	**50 m**
Heavy Rock Hammer (eg 1500kg)	4.5	1.3	0.4	0.2	0.15	0.02
Medium Rock Hammer (eg 600kg)	0.2	0.06	0.02	0.01	-	-

Excavation is likely to be conducted using rocksaws and rockbreakers whereby the perimeter of site may be sawn with rocksaws and the remainder of the site then excavated by rockbreakers.

Vibration from rockbreaker operations has the potential to generate perceptible vibration at surrounding properties. Previous measurements indicate that PPV vibration levels from heavy (1500kg) and medium sized (600kg) rock breakers will be in the order 4.5mm/s and 0.2mm/s at a distance of 5m from the boundary.

At these levels of vibration, the preferred vibration dose (VDV) of 0.4mm/s$^{1.75}$ is predicted to exceed for heavy rockbreakers after less than 2 hours whilst lighter rock hammers could operate all day without exceeding the VDV. A large size rock breaker could not operate the entire day without exceeding the nominated human comfort criteria.

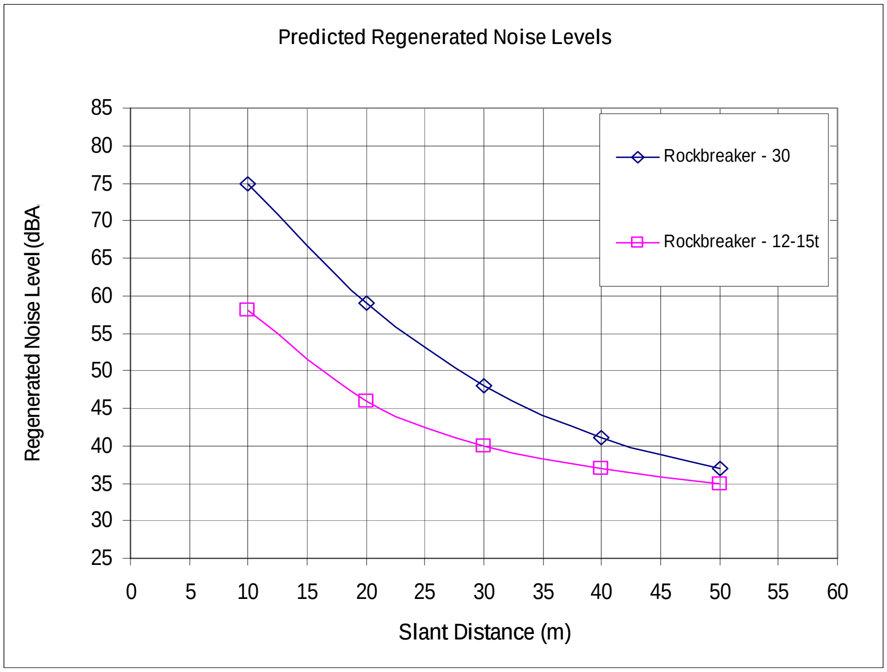
Structural damage vibration criteria in commercial and residential buildings are much higher than human comfort criteria; therefore, compliance with the latter ensures that damage requirements would be satisfied.

In the case of nearby heritage buildings, structural damage vibration may be exceeded by heavy rockbreakers operating in the vicinity of these buildings. Therefore, it is recommended that vibration monitoring be conducted at nearby sensitive receivers to determine vibration levels in heritage structures with respect to established vibration criteria.

7.1.1 Regenerated Noise from Rockbreakers.

The following Figure 7-3 illustrates noise levels from rockbreakers with respect to distance.

Figure 7-3 Regenerated Noise Levels from Rockbreakers



Predicted internal noise levels in surrounding properties are presented in Table 7-2. A range of levels is presented based on the rockbreaker being located around the worksite.

Table 7-2 Predicted Regenerated Noise from Rockbreakers at Bligh Street Site - dBA

Receiver	Heavy Rockbreaker	Medium Rockbreaker	Internal Noise Critera
Adjacent Commercial	45 – 80	40 - 65	45*
Sofitel	30 - 50	30 - 45	40

* Based on AS2107:2000 recommended internal noise levels.

A review of the predicted noise level indicates that there is potential for significant regenerated noise levels at both commercial and residential receivers. The uses of alternative excavation techniques are recommended. Where feasible, the following is recommended:

- Use rock saws and rippers
- Use smaller rockbeakers
- Provide respite to receivers particularly during shoulder periods of the day.

7.1.2 Regenerated Noise from Roadheaders

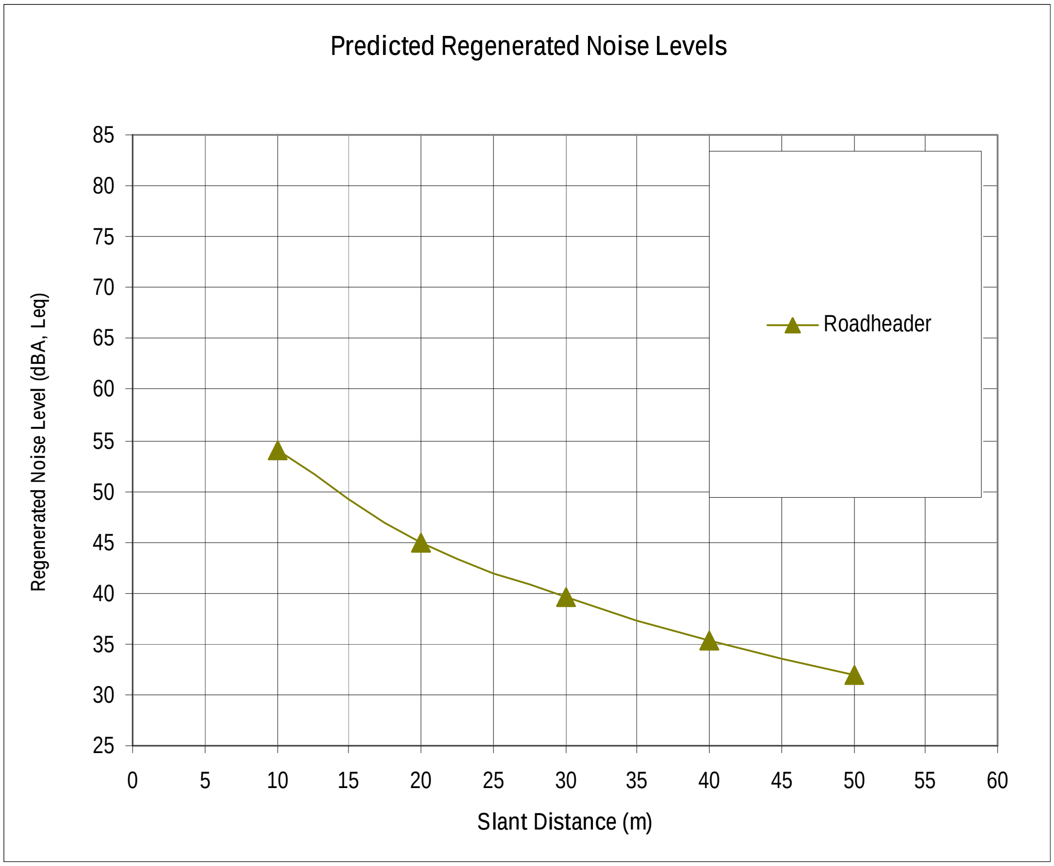
Roadheaders remove rock using a controlled “grinding” action that provides close control over the excavated profile of the tunnel roof and upper walls.

This type of machine can safely perform detailed excavations quite close to sensitive structures such as historic buildings, and generates relatively low levels of vibration (and regenerated noise). Experience has shown that they can be used on a 24 hour basis in tunnels near residences with minimal disturbance to the occupants.

Figure 7-2 Roadheader Tunnelling Operations

Wilkinson Murray has measured ground-borne noise levels from a roadheader. The results of the measurements are shown in Figure 7-4. These results were used to predict noise in basements of buildings near the part of the tunnel excavated by roadheader.

Figure 7-4 Predicted Regenerated Noise from Roadheader



Slant distances from the tunnel to buildings in Bligh Street have been provided by Ausgrid. A review of this information indicates the minimum distance from the head of the tunnel to the basements of commercial properties and the Sofitel Wentworth Hotel is in the order of 30m.

At distances of 30m a regenerated noise level of 39dBA can be expected. This level complies with the daytime regenerated noise criterion. In the case of noise levels in the Sofitel Wentworth, it is noted that the basements of the building are 15m below ground levels which represents 4 levels. Allowing for an attenuation of 2dBA per level, the noise levels at ground floor of the hotel are predicted to be in the order of 31dBA. This level is well below the night regenerated noise criterion of 35dBA.

It should be noted the vibration levels associated with ground-borne noise are well below human comfort or structural damage criteria. No adverse impact with respect to perceptible vibration or structural damage at any residences is predicted.

8 CONSTRUCTION NOISE AND VIBRATION MANAGEMENT MEASURES

8.1 Construction Noise and Vibration Mitigation Measures

Without mitigation, noise levels from some construction activities have been predicted to exceed the noise management levels nominated in the guidelines at some surrounding receivers. Therefore, noise control measures have been recommended to ensure that noise is reduced where feasible.

A range of possible approaches to reducing the impact of construction noise is described below. It is proposed that these strategies be applied to areas of potential exceedance identified in the preceding section.

- *Plant Noise Audit* – Noise emission levels of all critical items of mobile plant and equipment should be checked for compliance with noise limits appropriate to those items prior to the equipment going into regular service. To this end, testing should be established with the contractor.

- *Operator Instruction* – Operators should be trained in order to raise their awareness of potential noise problems and to increase their use of techniques to minimise noise emission.

- *Equipment Selection* - All fixed plant at the work sites should be appropriately selected, and where necessary, fitted with silencers, acoustical enclosures and other noise attenuation measures in order to ensure that the total noise emission from each work site complies with OEH guidelines.

- *Site Noise Planning* - Where practical, the layout and positioning of noise-producing plant and activities on each work site should be optimised to minimise noise emission levels.

- Use rocksaws and rippers where feasible.

- Install a noise barrier between the site and the street frontages with minimum 17mm thick structural plywood; (the site would be surrounded by hoardings erected in accordance with the City of Sydney Guidelines.)

- Use smaller rockbreakers where practible.

- Noise intensive activities such as rock breaking would be undertaken during the following hours: Monday to Saturday 7.00am to 12.00pm and Monday to Friday 2.00pm to 5.00pm providing a respite period between 12.00pm and 2.00pm.

- Install vibration monitors in adjacent commercial buildings, in particular the Lowy Building. The vibration monitoring system should be installed and configured to record the peak vibration levels as well as to trigger a visual and audible alarm when predetermined vibration levels are exceeded. These thresholds would correspond to an “Operator Warning Level” and an “Operator Halt Level”, where the warning level is 80% of the halt level.

  An exceedance of the “Operator Warning Level” would not require activities to cease, but rather alerts the Site Superintendent to proceed with caution at a reduced force or load.

8.2 Community Liaison & General Approaches to Mitigation

An effective community relations programme should be put in place to keep the community that has been identified as being potentially affected appraised of progress of the works, and to forewarn potentially affected groups (eg by letterbox drop, meetings with surrounding tenants, etc) of any anticipated changes in noise and vibration emissions prior to critical stages of the works, and to explain complaint procedures and response mechanisms. This programme will be included in Ausgrid's Community Information Plan that has been specifically developed for the Sydney CityGrid Project.

Close liaison should be maintained between the stakeholders surrounding the work site and the parties associated with the construction works to provide effective feedback in regard to perceived emissions. In this manner, equipment selections and work activities can be coordinated where necessary to minimise disturbance to neighbouring communities, and to ensure prompt response to complaints, should they occur.

8.3 Noise and Vibration Management Plan

A Noise and Vibration Management Plan should be included in the Construction Environmental Management Plan for the project. The plan should be prepared during the project planning process, including components relating to noise and vibration. This plan should detail the mitigation, monitoring and community liaison measures. The plan will be updated to incorporate any additional measures that emerge as the project design evolves and work methodologies become better defined.

Areas that should be addressed in plan include:

- Noise and vibration monitoring.
- Response to complaints.
- Responsibilities.
- Monitoring of noise emissions from plant items.
- Reporting and record keeping.
- Non compliance and corrective action.
- Community consultation and complaint handling.

9 CONSTRUCTION TRAFFIC

The construction of Stage 2A of the Sydney CityGrid Project cable project would generate additional construction traffic movements. Majority of the heavy vehicle movements would be from spoil haulage. Transport of equipment to the site would occur during the initial stage involving site preparation works and intermittently in between stages. Approximately 1-2 deliveries per day are estimated. The number of vehicles per day attributed to the spoil removal are summarised in Table 9-1.

Table 9-1 Heavy vehicle movements attributed to spoil removal

Construction Activity/Source	Expected spoil generation (Bulked volume)	Duration (days) [1]	Truck Trips per day [2]	Maximum Truck Movements per hour [3]
Bulk excavation of basement	72,066 m^3 (158,544 t)	150	192	20
Stub tunnel and shaft excavation	4,866 m^3 (10,706 t)	150	13	2

Notes: 1 At 5 days per week.
2 Number of truck trips per day estimated on the basis of 5m^3 per single unit dump truck and each trip generating one inbound movement and one outbound movement.
3 Maximum truck trips per hour is based on a 10-hr work day or maximum throughput of one truck movement every 5 minutes.

A Traffic Management Plan would be prepared as part of the Construction Environmental Management Plan to manage materials delivery and spoil disposal. Potential spoil disposal sites have been identified and the final disposal site will be selected by the contractor. Haulage routes to and from the site and the major road network would generally utilise designated heavy vehicles routes where possible. The proposed routes for the site are:

Departure Routes:

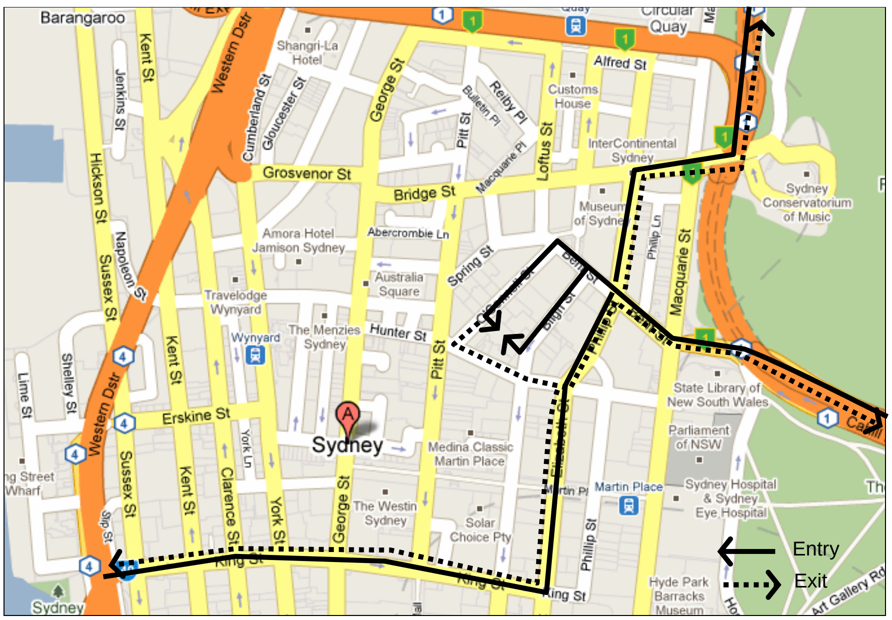
- To the South: Hunter Street – Macquarie Street – Eastern Distributor – Southern Cross Drive;
- To the East: Hunter Street – Macquarie Street – Eastern Distributor – Moore Park Road/Anzac Parade;
- To/from the West: Hunter Street – Macquarie Street - Eastern Distributor – Southern Cross Drive – M5 East Motorway;
- To the Inner West: Hunter Street - Phillip Street – Elizabeth Street – Market Street – Western Distributor – Anzac Bridge – Victoria Road/City West Link;
- To the North: Hunter Street – Macquarie Street – Conservatorium Road – Cahill Expressway.

Arrival Routes:

- From the South: Southern Cross Drive – Eastern Distributor – Bent Street;
- From the East: Anzac Parade / Moore Park Road – Eastern Distributor – Bent Street;
- From the West: M5 East Motorway – Southern Cross Drive – Easter Distributor – Bent Street;
- From the Inner West: Victoria Road / City West Link – Anzac Bridge – Western Distributor – King Street – Elizabeth Street – Phillip Street – Bent Street; and
- From the north: Cahill Expressway – Conservatorium Road – Bridge Street – Phillip Street – Bent Street.

Figure 9-1 presents the haulage routes to and from the site and the major road network.

Figure 9-1 Proposed Heavy Vehicle Routes



For the purpose of this assessment, the following distribution is assumed:

- 60% - South, East and West via the Eastern Distributor
- 20% - North via the Cahill Expressway; and
- 20% - Inner West via Western Distribution.

The average daily traffic through the various road sections in the northern CBD range from 7,000 vehicles per day (Castlereagh Street) up to 30,000 vehicles per day (Macquarie Street) and with the Eastern Distributor/South Dowling Street around 60,000 vehicles per day. The peak hour volumes are estimated to range from 500-1,500 vehicles per hour for the local roads and up to 7,000 vehicles per hour for Eastern Distributor/South Dowling Street.

In the case of Eastern Distributor, Southern Cross Drive, Anzac Parade, Moore Park Road, M5 East Motorway, Western Distributor, Victoria Road and City West Link the roads can be classified as an arterial Road. In the case of Macquarie Street, Hunter Street, Elizabeth Street, Market Street the roads can be classified as a collector road. Bent Street; Phillip Street, King Street and Bridge Street are classified as local roads.

Analysing the traffic data and the estimated vehicle movements during the construction phase as supplied by GHD the 2dB limit applies. Calculations indicate there will be minor increases in road noise during the peak construction activities of less than 0.4dB.

10 SUMMARY OF RECOMMENDATIONS

Based on our investigations of the project the following findings have been determined.

10.1 Noise Criteria

Noise criteria for construction have been established based on OEH procedures. These criteria should be adopted as objectives to work towards in minimising any noise impact at surrounding residences.

The following Table 10-1 presents applicable noise criteria at residential receivers in the vicinity of works that are part of Stage 2A(ii).

Table 10-1 Site Specific Construction Noise Management Levels – dBA

Location	Construction Noise Management level, L_{Aeq} - dBA				Maximum Construction Noise Level, L_{Aeq} - dBA
	Day	Evening	Night	Saturday (Extended)	
Bligh Street	68	64	61	63	75
O'Connell Street	75	66	64	70	75
Commercial Properties	70				75

10.2 Vibration Criteria

Vibration criteria are presented in Table 10-2 as follows:

Table 10-2 Preferred and Maximum Weighted rms Values for Continuous and Impulsive Vibration Acceleration (m/s^2)1-80 Hz

Location	Assessment Period[1]	Preferred Values		Maximum Values	
		z-axis	x- and y-axes	z-axis	x- and y-axes
Critical areas	Day or night time	0.0050	0.0036	0.010	0.0072
Residences	Daytime	0.010	0.0071	0.020	0.014
	Night-time	0.007	0.005	0.014	0.010

A regenerated noise goal of 40dBA between 6.00pm – 10.00pm and 35dBA between 10.00pm – 7.00am at commercial and residential receivers respectively is recommended for noise associated with tunnelling operations. It is recommended this goal be incorporated in the project Environmental Management Plan to ensure that any issues associated with this noise can be effectively managed.

10.3 Construction Noise and Vibration

It has been determined that noise from construction activities during the day period may potentially exceed established noise goals. Therefore, the planning and management of construction activities must take into account the sensitivities of surrounding residents so as to minimise the impact of construction activities at these receivers.

Table 10-3 summarises the findings of the construction noise and vibration assessment.

Table 10-3 Summary of Construction Noise and Vibration Findings

Activity	Findings	Comments / Recommendation
Excavation	Exceedances of up to 10dBA are predicted whilst equipment, principally heavy rock breakers, is adjacent to commercial properties. Vibration associated with a large rockbreaker may be above acceptable Human Comfort Criteria at adjacent commercial receivers. Regenrated noise from Heavy rockbreakers is likely to be excessive in adjacent commercial and residential receivers.	• Noise impact is greatest at adjacent commercial properties. • Best practice noise management of plant should be adopted. That is equipment in good condition should be used on site. • The use of rock saws should be used in preference to rock breakers. • Where practicable, heavy rock breakers should not be used. • Vibration Monitoring should be conducted at Heritage buildings during excavation.
Tower and Fitout	Compliance with noise objectives is indicated	• Best practice noise management of plant should be adopted. That is equipment in good condition should be used on site.
Tunnelling using a Road header	Works would comply with the night time noise criteria. Ventilation plant will require silencers. A barrier on both site boundaries is recommended the barrier should be in the order of 3m in height. Ground-borne noise from roadheader operation is predicted to comply with criteria for regenerated noise	• Barriers / hoarding are required at site boundaries. • Silencers on Ventilation Plant

The control of construction noise and vibration should form a part of the Construction Environmental Management Plan that would detail reasonable and feasible management measures and community consultation that would be employed.

11 CONCLUSION

This assessment of Stage 2A(ii) of the proposed new City East Zone Substation Project has established site specific noise and vibration criteria appropriate for the excavation and tunnelling activities.

Noise and vibration associated with tunnelling construction activities under Bligh Street is likely to comply with established noise goals at residences.

Daytime excavation noise is predicted to occasionally exceed noise management goals at adjacent commercial properties for excavation activities. The exceedance is primarily due to the use of rock breakers. Accordingly, management of this issue to limit noise to established goals and minimise exceedance events will require implementation of all reasonable and feasible mitigation measures to minimise acoustic impact at receivers.

A review of the predicted regenerated noise level associated with heavy rockbreakers indicates that there is potential for significant regenerated noise levels at both commercial and residential receivers. The uses of alternative excavation techniques are recommended.

During tower and fitout construction works, the predicted noise levels comply with the evening and extended Saturday construction noise objectives. Therefore, the extended operating hours proposed by Ausgrid are appropriate for excavation general construction works.

Vibration associated with excavation activities is predicted to exceed established human comfort criteria unless mitigation measures are implemented. Therefore, it is recommended that vibration testing be conducted at an early stage during excavation to determine the magnitude of vibration levels. Should levels above the established vibration goals be indicated, mitigation measures should be implemented. If exceedances are unavoidable on specific occasions then residents should be kept informed of the nature and duration of any identified noise or vibration impact.

Version	Status	Date	Prepared by	Checked by
A	Draft	13 October 2011	Brian Clarke	John Wasserman

APPENDIX A

GLOSSARY OF TERMS

GLOSSARY

Most environments are affected by environmental noise which continuously varies, largely as a result of road traffic. To describe the overall noise environment, a number of noise descriptors have been developed and these involve statistical and other analysis of the varying noise over sampling periods, typically taken as 15 minutes. These descriptors, which are demonstrated in the graph overleaf, are here defined.

Maximum Noise Level (L_{Amax}) – The maximum noise level over a sample period is the maximum level, measured on fast response, during the sample period.

L_{A1} – The L_{A1} level is the noise level which is exceeded for 1% of the sample period. During the sample period, the noise level is below the L_{A1} level for 99% of the time.

L_{A10} – The L_{A10} level is the noise level which is exceeded for 10% of the sample period. During the sample period, the noise level is below the L_{A10} level for 90% of the time. The L_{A10} is a common noise descriptor for environmental noise and road traffic noise.

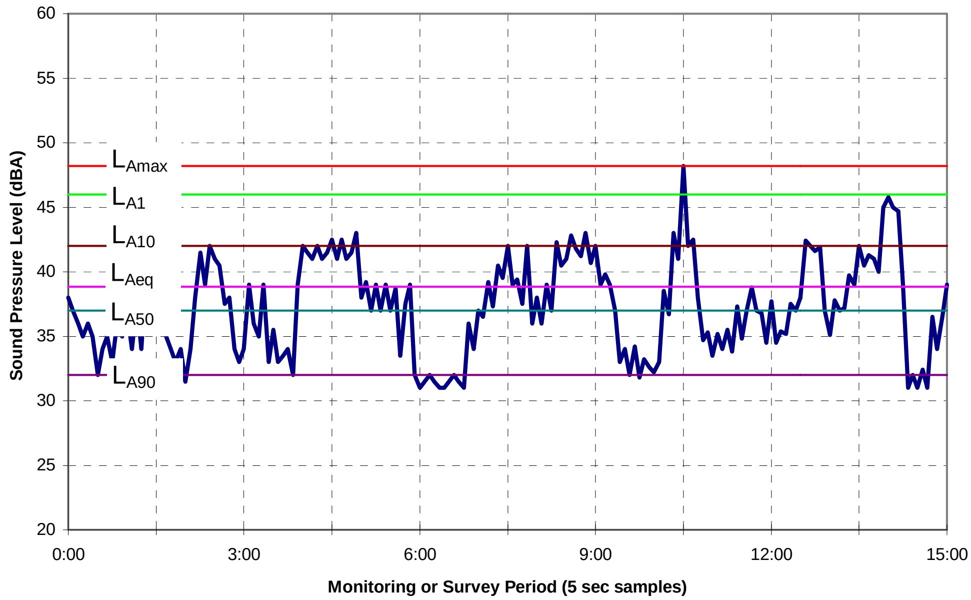
L_{Aeq} – The equivalent continuous sound level (L_{Aeq}) is the energy average of the varying noise over the sample period and is equivalent to the level of a constant noise which contains the same energy as the varying noise environment. This measure is also a common measure of environmental noise and road traffic noise.

L_{A50} – The L_{A50} level is the noise level which is exceeded for 50% of the sample period. During the sample period, the noise level is below the L_{A50} level for 50% of the time.

L_{A90} – The L_{A90} level is the noise level which is exceeded for 90% of the sample period. During the sample period, the noise level is below the L_{A90} level for 10% of the time. This measure is commonly referred to as the background noise level.

ABL – The Assessment Background Level is the single figure background level representing each assessment period (daytime, evening and night time) for each day. It is determined by calculating the 10^{th} percentile (lowest 10^{th} percent) background level (L_{A90}) for each period.

RBL – The Rating Background Level for each period is the median value of the ABL values for the period over all of the days measured. There is therefore an RBL value for each period **–** daytime, evening and night time.



Sound pressure level (SPL) or sound level L_p is a logarithmic measure of the effective sound pressure of a sound relative to a reference value. It is measured in decibels (dB) above a standard reference level.

$$L_p = 10 \log_{10}\left(\frac{{p_{\mathrm{rms}}}^2}{{p_{\mathrm{ref}}}^2}\right)$$

where p_{ref} (20 µPa)is the reference sound pressure and p_{rms} is the rms sound pressure being measured.

Sound power level is a logarithmic measure of the sound power in comparison to a specified reference level. While sound pressure level is given in decibels SPL, or dB SPL, sound power is given in dB SWL. The dimensionless term "SWL" can be thought of as "sound watts level," the acoustic output power measured relative to a very low base level of watts given as 10^{-12} watts.

$$L_{\mathrm{W}} = 10\ \log_{10}\left(\frac{W}{W_0}\right)\ \mathrm{dB}$$

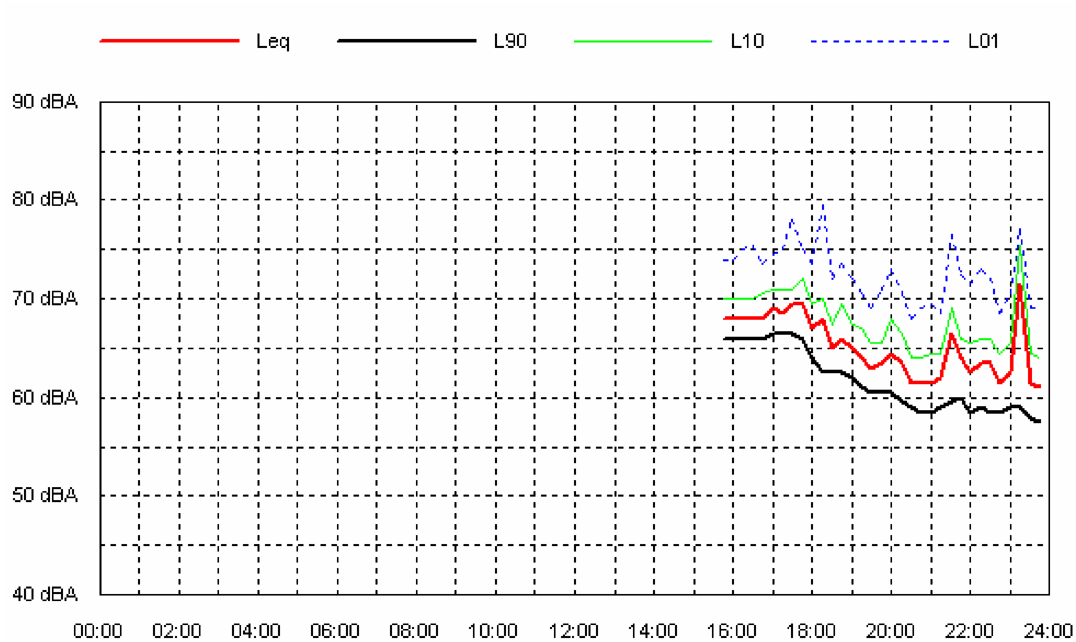
APPENDIX B

NOISE MEASUREMENT RESULTS

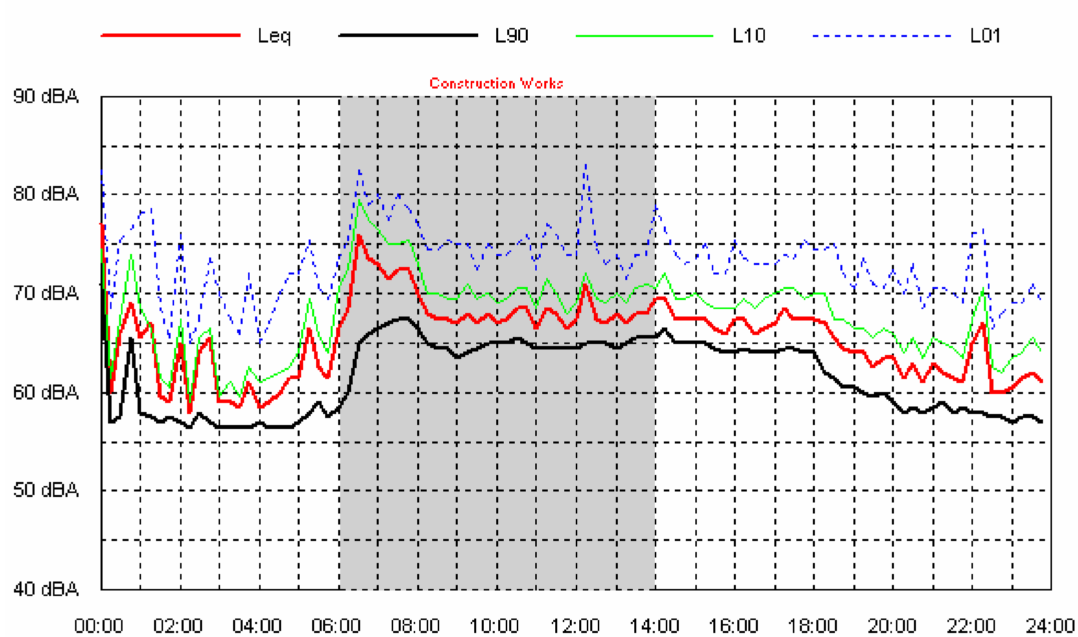
Location: Bligh Street

Data shaded: Construction Works

Mon 15 Feb 10



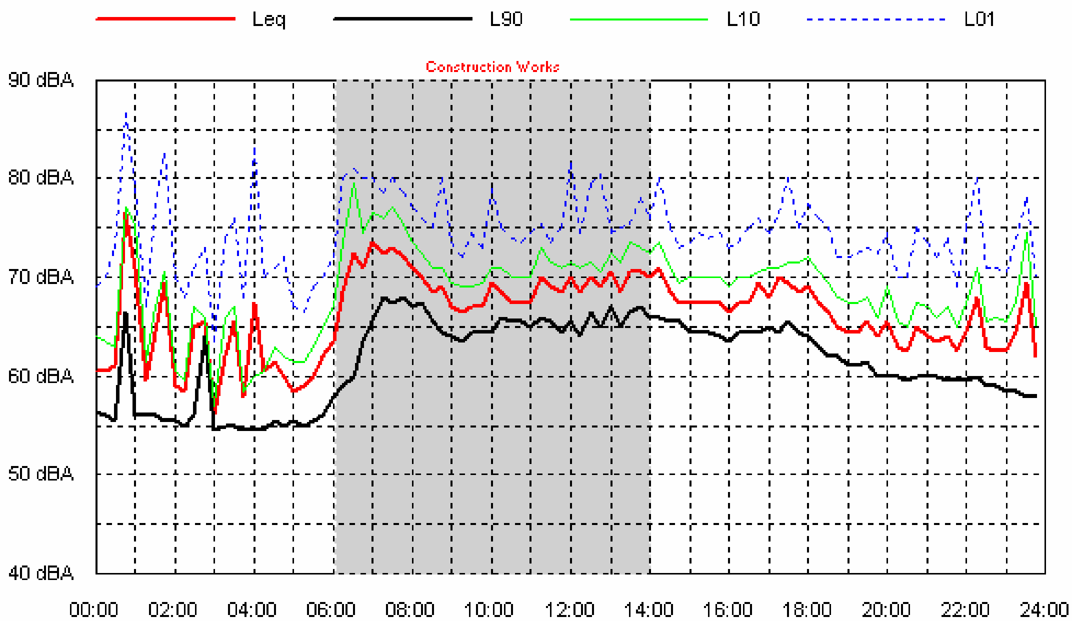
Tue 16 Feb 10



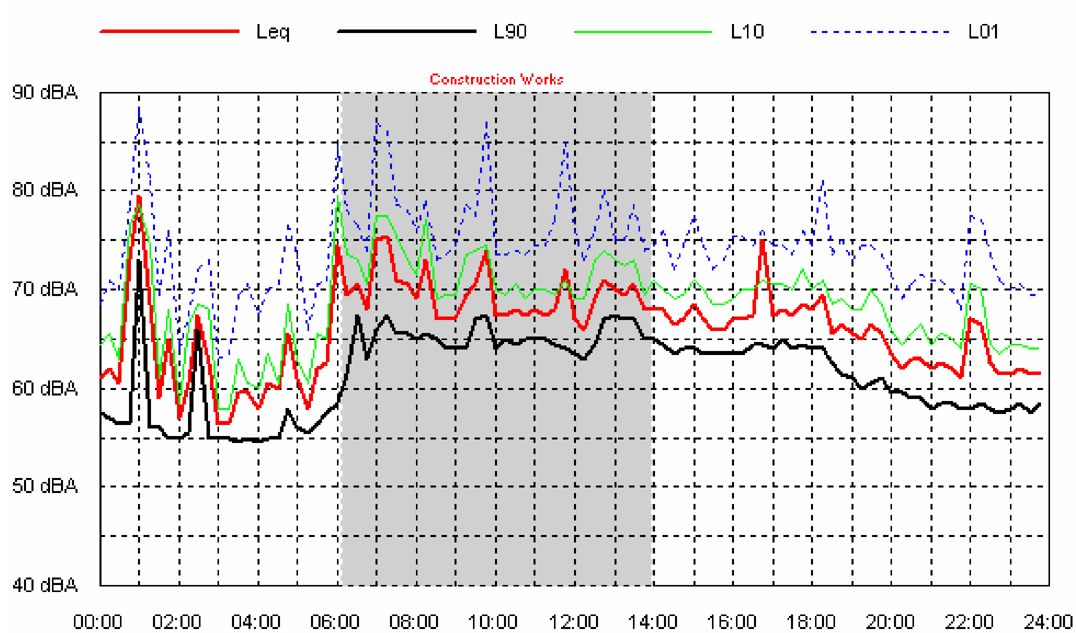
Location: Bligh Street

Data shaded: Construction Works

Wed 17 Feb 10



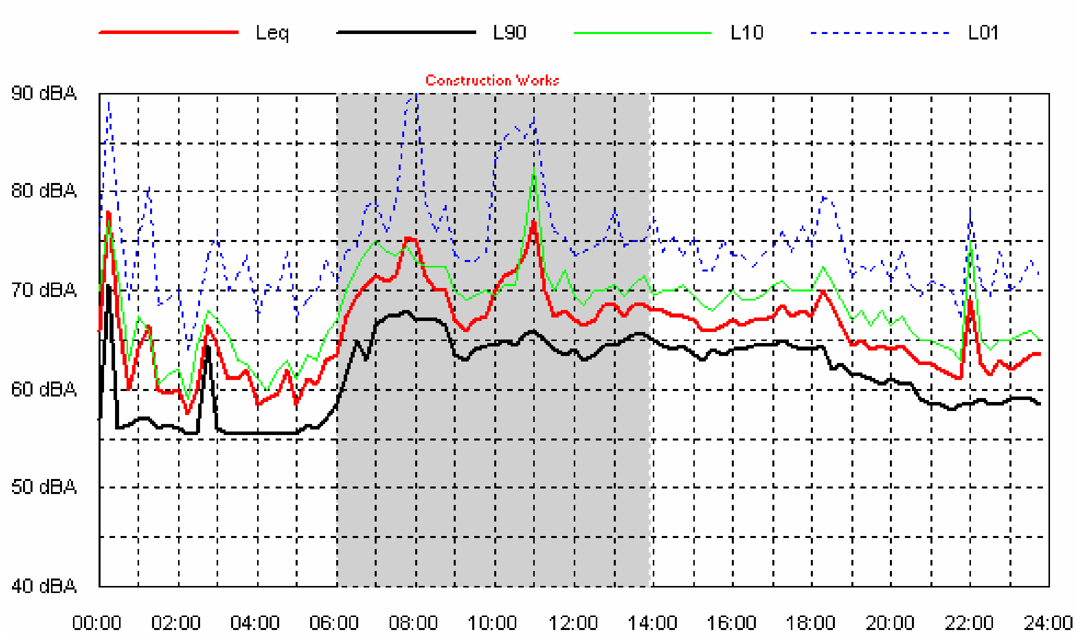
Thu 18 Feb 10



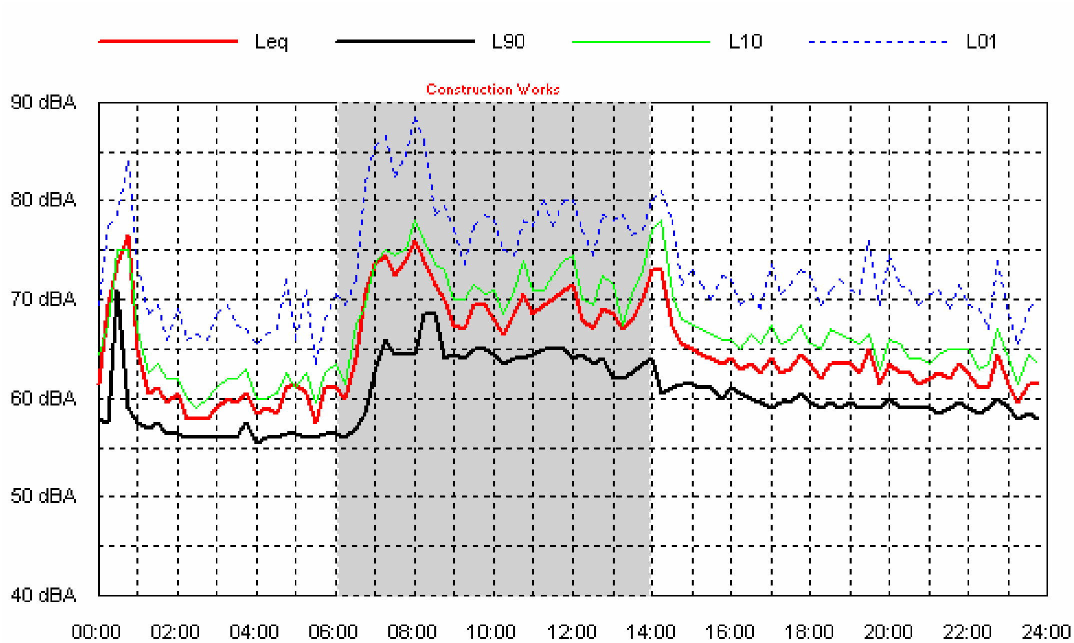
Location: Bligh Street

Data shaded: Construction Works

Fri 19 Feb 10



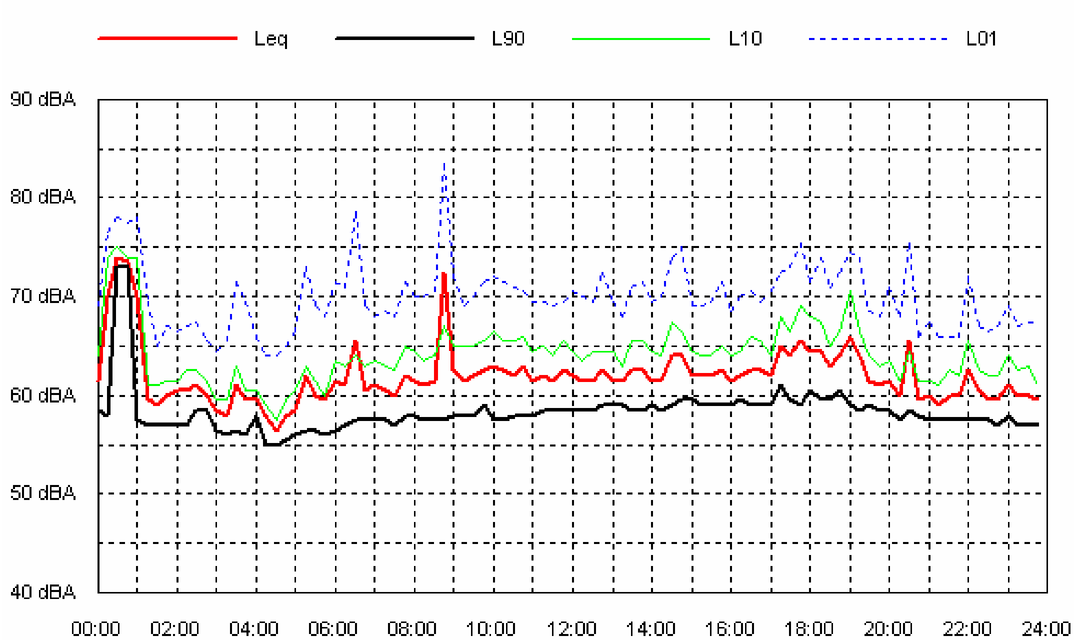
Sat 20 Feb 10



Location: Bligh Street

Data shaded: Construction Works

Sun 21 Feb 10



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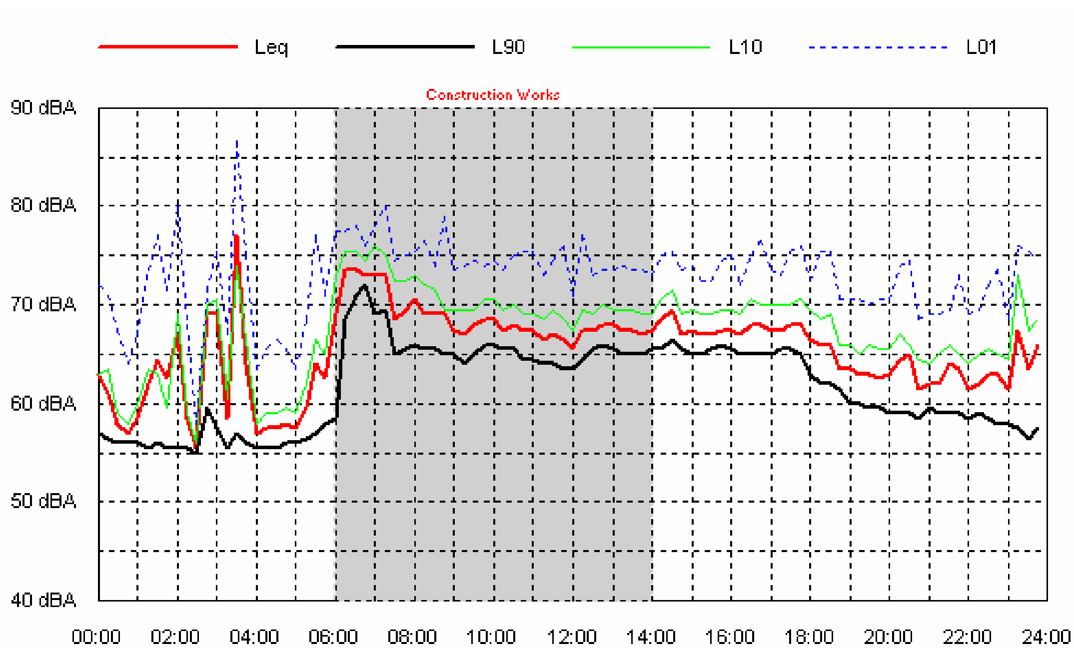
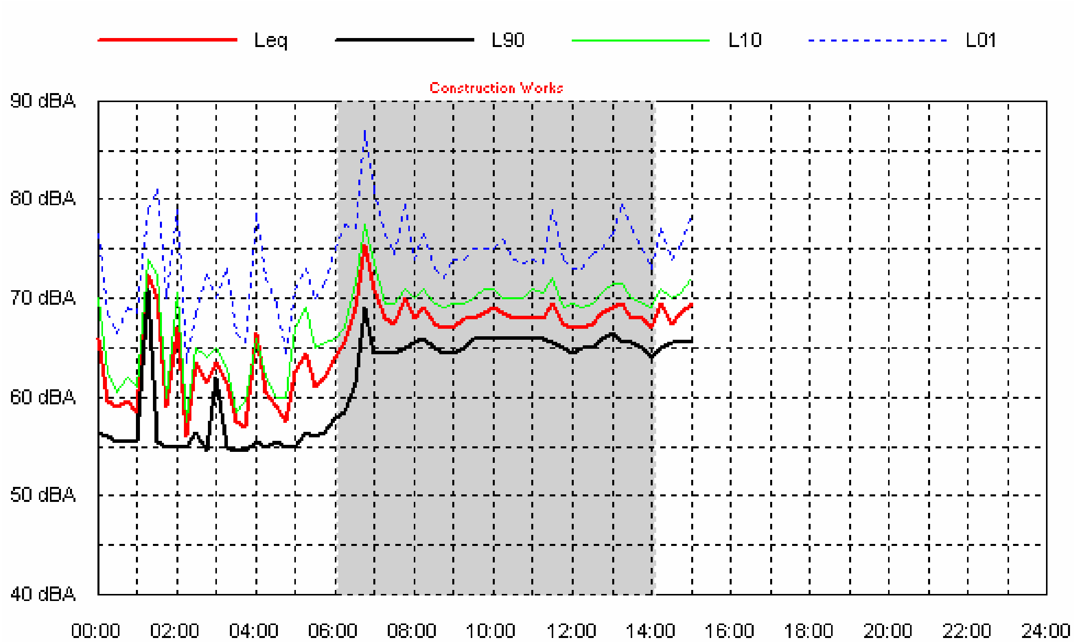


Location: Bligh Street

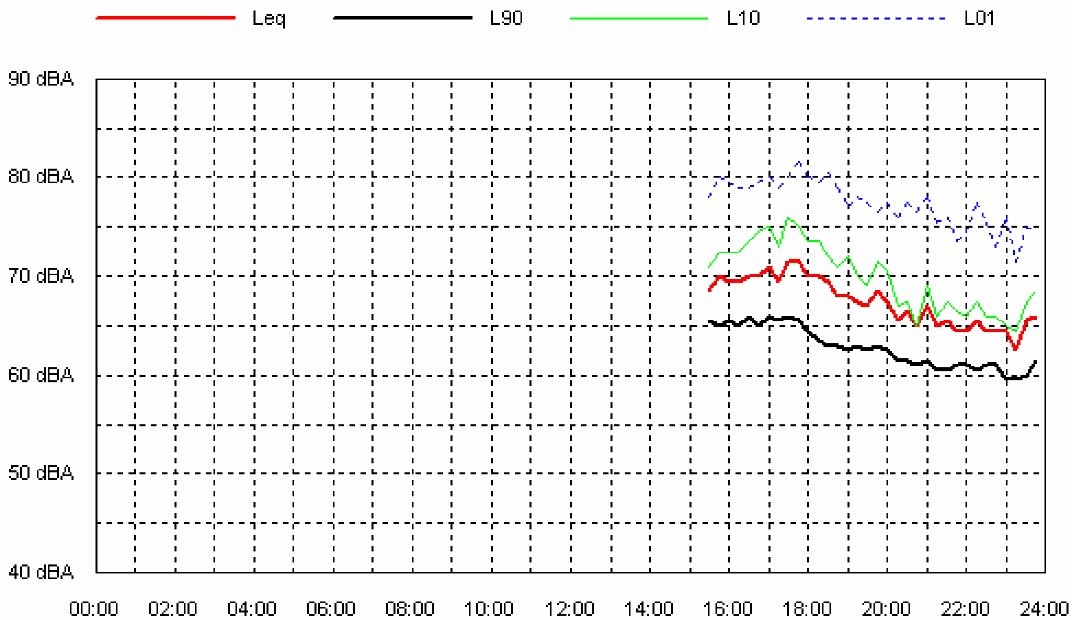
Data shaded: Construction Works

Tue 23 Feb 10



Location: O Connell Street

Tues 16 Feb 09



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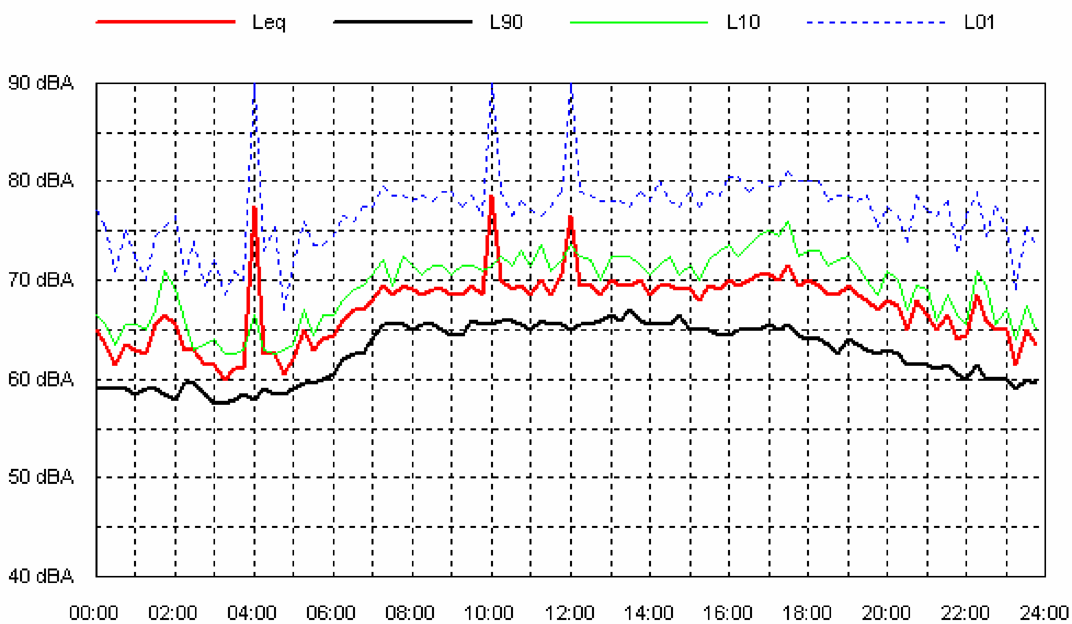

Location: O Connell Street

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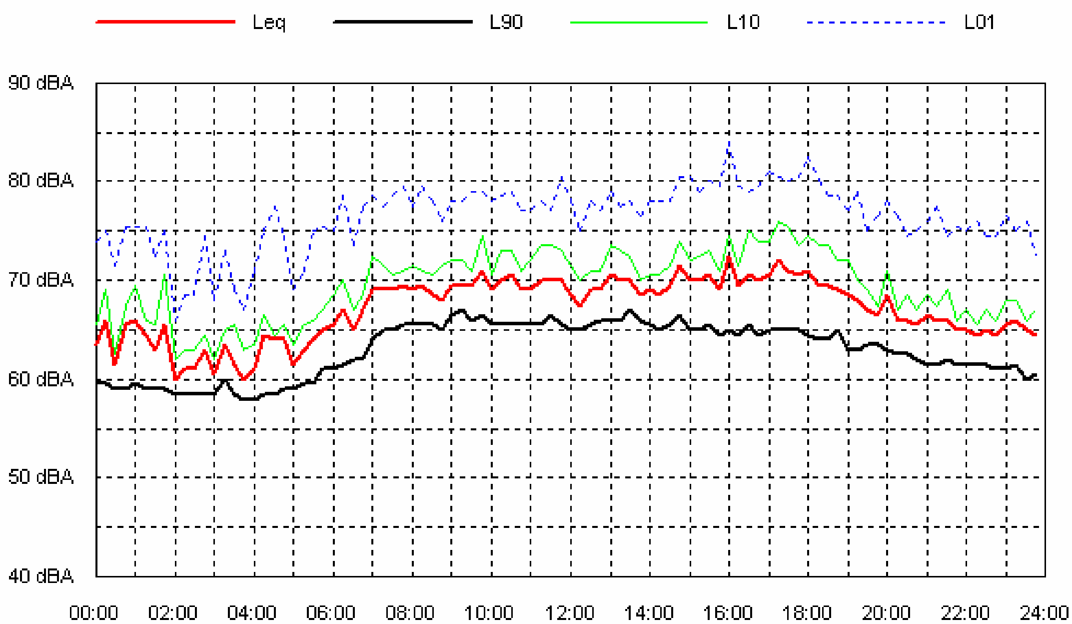

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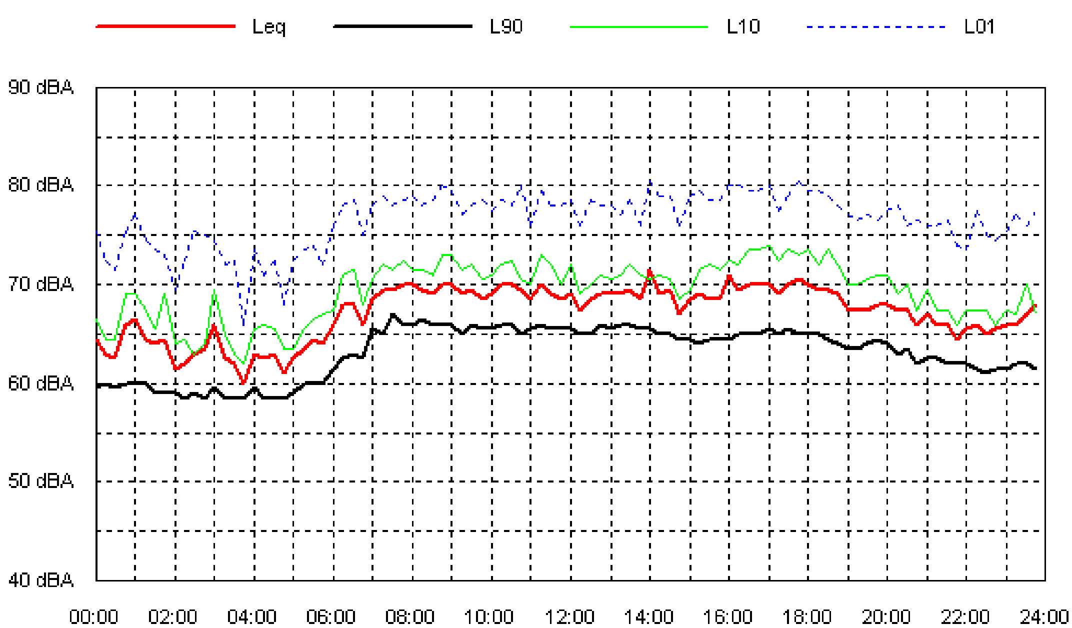

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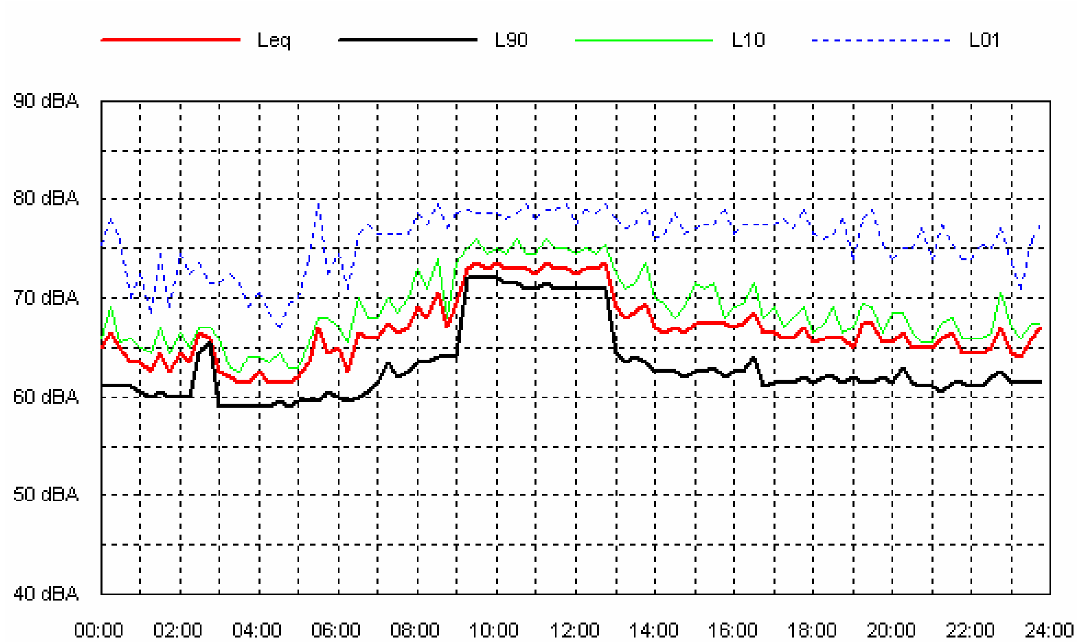

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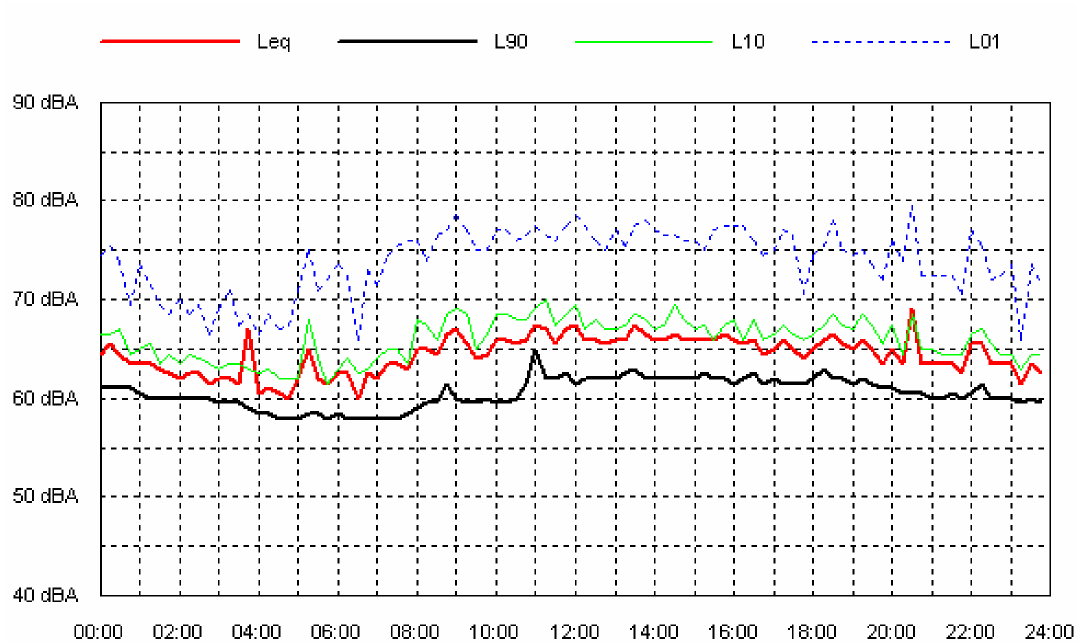
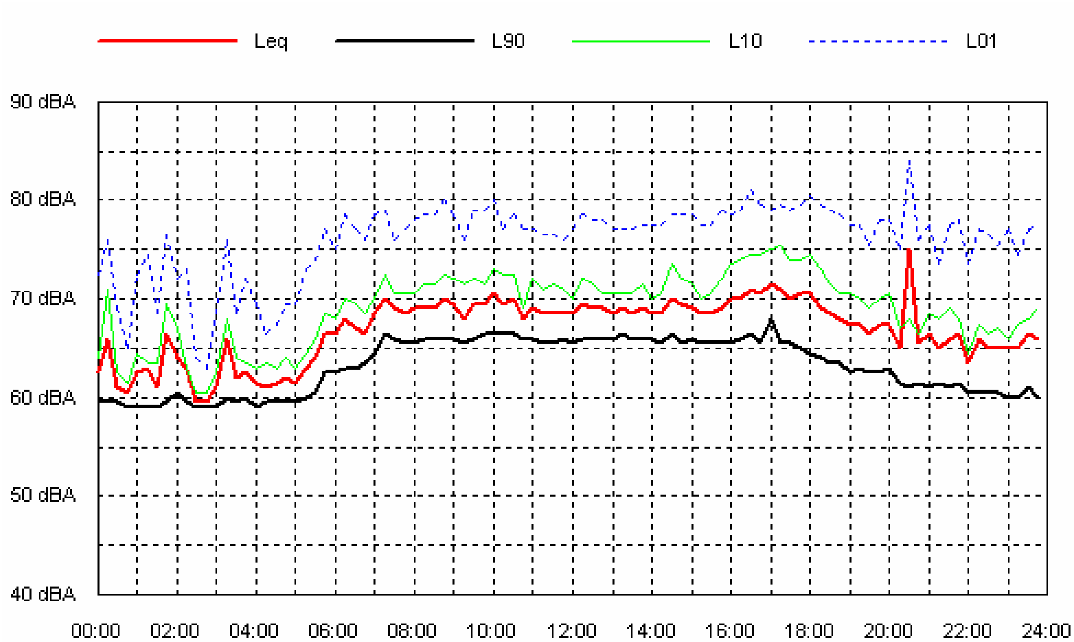


Location: O Connell Street

Mon 22 Feb 09



Tues 23 Feb 09