Macquarie University Arts Precinct

Noise & Vibration Impact Assessment for State Significant Development Application

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Revision

REVISION	DATE	COMMENT	APPROVED BY
03	2/02/2018	Following further comments	**Brandon Notaras**
02	21/09/2017	Following comments	**Mathew McGrory**
01	31/05/2017	Initial Issue	**Mathew McGrory**

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Contents

1. Introduction

As part of the DA documentation process, Wood & Grieve Engineers has been engaged by Architectus/BNMH Architects to provide an acoustic assessment for the State Significant Development Application of the proposed Arts Precinct located at Macquarie University.

This report addresses the requirements established by the Department of Planning as part of the State Significant Development Application process.

This report has been prepared with the following references:

1. AS/NZS 2107:2016 "Acoustics – Recommended design sound levels and reverberation times for building interiors"
2. Secretary's Environmental Assessment Requirements (SEARs) issued by the Department of Planning and Environment for the proposed MQU Arts Precinct dated 10th May 2017
3. City of Ryde Development Control Plan (DCP) 2014
4. NSW OEH Industrial Noise Policy (INP)
5. NSW OEH "Assessing Vibration: A Technical Guideline (2006)
6. British Standard BS7385:1993 "Evaluation and Measurement for Vibration in Buildings" – Part 2: "Guide to Damage Levels from Groundborne Vibration"
7. Interim Construction Noise Guideline (NSW Department of Environment and Climate Change)
8. German Standard DIN4150-Part 3 "Structural vibration in buildings – Effects on structures"

This report provides:

- A statement of compliance with the SEAR's and City of Ryde requirements for the proposed MQU Arts Precinct within the vicinity of the nearest potentially affected residential receivers.
- Recommendations for noise mitigation measures for the proposed MQU Arts Precinct in order to meet the relevant criteria if required.

This noise assessment is based on noise data collected by a combination of unattended and attended noise measurements at representative locations around the site over 10 days during April 2017.

2. Background

2.1 Information Sources

The following documentation has been used for the preparation of this report:

- Site drawings presenting the location of the proposed development in relation to the nearest receivers.
- Architectural drawings provided by Architectus/BNMH Architects
- Noise data collected on site through the use of noise loggers and a hand held spectrum analyser.

3. Project Overview

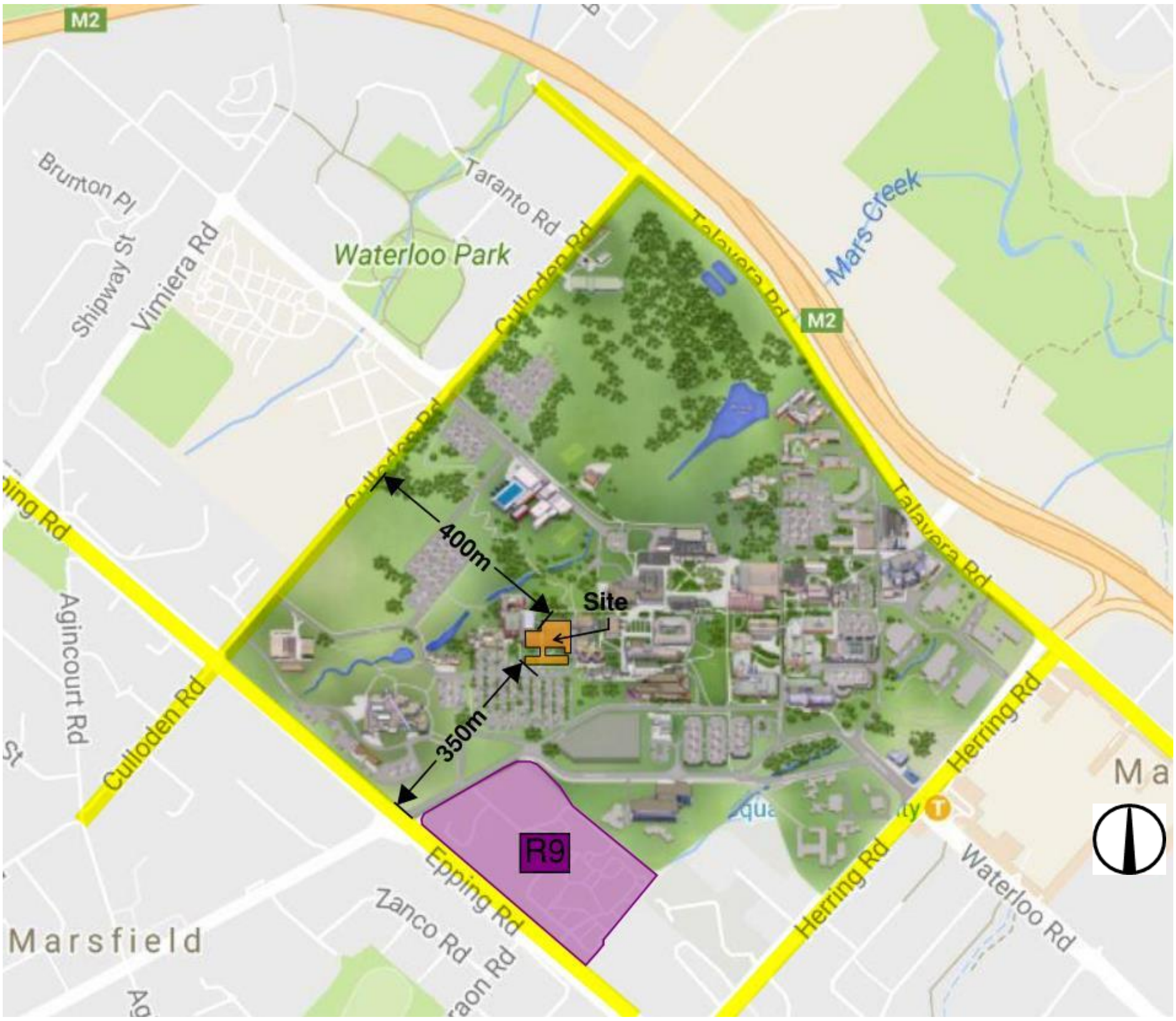
3.1 Site description

The proposed Arts Precinct is located at buildings W6A and W6B of Macquarie University, Macquarie Park, NSW.

Figure 1 shows the proposed development site within the university precinct. The site is approximately 350m in from the nearest major public road, Epping Road located to the South West of the Site.

Figure 1 and Figure 2 presents the locations of the surrounding receivers (R1-R9). The receivers are all educational faculty buildings, noting that the lotus theatre may be of a particularly sensitive nature.

Figure 1: Aerial photo of the area illustrating nearest sensitive receivers and noise measurement locations



Source: nearmap.com

Project Overview

Figure 2: Aerial photo of the area illustrating nearest sensitive receivers and noise measurement locations

4. Noise Survey

4.1 Existing Noise Environment

The local ambient noise level is currently dominated by pedestrians, nature sounds and distant traffic noise sources.

4.2 Instrumentation

The equipment used for the noise survey was the following:

- ARL Environmental Noise Logger ARL EL-316 S/N 16-306-037
- ARL Environmental Noise Logger ARL EL-316 S/N 16-707-006
- ARL Environmental Noise Logger ARL EL-316 S/N 16-302-490
- Hand-held sound spectrum analyzer Casella CEL-63X, S/N 0166013
- Sound Calibrator B&K Type 4231, S/N 2709826

All equipment was calibrated before and after the measurements and no significant drift was found. All equipment carries current traceable calibration certificates that can be provided upon request.

4.3 Attended Noise Survey Results

Attended noise measurements of 15-minute duration were conducted on site to characterise the acoustic environment for noise intrusion into the proposed development. The measurement positions are shown in Figure 2, and a summary of the attended noise measurements taken at site are shown in Table 1.

Table 1: Attended noise measurements

Measurement Location	Measurement Time	$L_{Aeq, 15mins}$ dB(A)	L_{A90} dB(A)	Comments
P1	20/04/17 – 10:41am	48.6	45	Some pedestrian activity, noise from birds, distant noise from traffic
P2	20/04/17 – 11:00am	48.5	42.5	General environmental noise

4.4 Unattended Background Survey Results

The NSW OEH Industrial Noise Policy (INP) defines background noise for the daytime, evening and night time periods as follows:

Day: is defined as 7:00am to 6:00pm, Monday to Saturday and 8:00am to 6:00pm Sundays & Public Holidays.

Evening: is defined as 6:00pm to 10:00pm, Monday to Sunday & Public Holidays.

Night: is defined as 10:00pm to 7:00am, Monday to Saturday and 10:00pm to 8:00am Sundays & Public Holidays.

Noise Survey

Noise monitors were placed in the locations as shown in Figure 2 in order to measure the ambient and background noise that is representative of the site. Noise monitors were positioned in locations on campus where noise from traffic movements on Epping road did not contribute to the ambient and background noise levels. Furthermore, this is a conservative approach to establishing ambient and background noise levels for receivers off-campus (BaptistCare Willandra Retirement Village) that may be in close proximity to Epping Road. The noise monitors were installed from the 10th April to the 19th April 2017. The results of the unattended noise surveys are shown in Table 2 below. Any rain affected data has been excluded from the calculations. Refer to Figure 3, Figure 4 and Figure 5 for the noise data. The measured daily noise data is shown in Appendix 2.

Table 2: Unattended Background Noise Measurements South Site

Location	Equivalent Continuous Noise Level $L_{Aeq,15\ minutes}$ - dB(A)			Background Noise Level RBL - dB(A)		
	Day	Evening	Night	Day	Evening	Night
L1	57	52	48	39	39	32
L2	58	52	56	44	42	39
L3	56	51	48	43	37	35

Figure 3: Unattended Background Noise Monitoring Data – L1

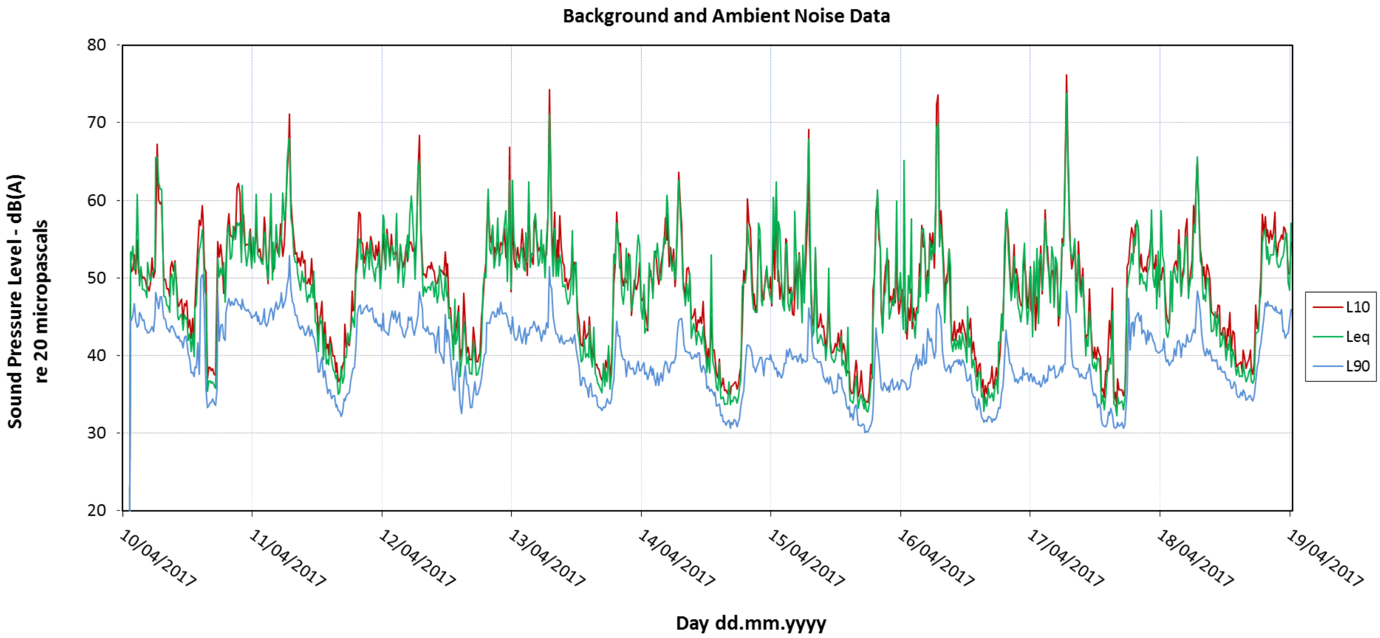


Figure 4: Unattended Background Noise Monitoring Data – L2

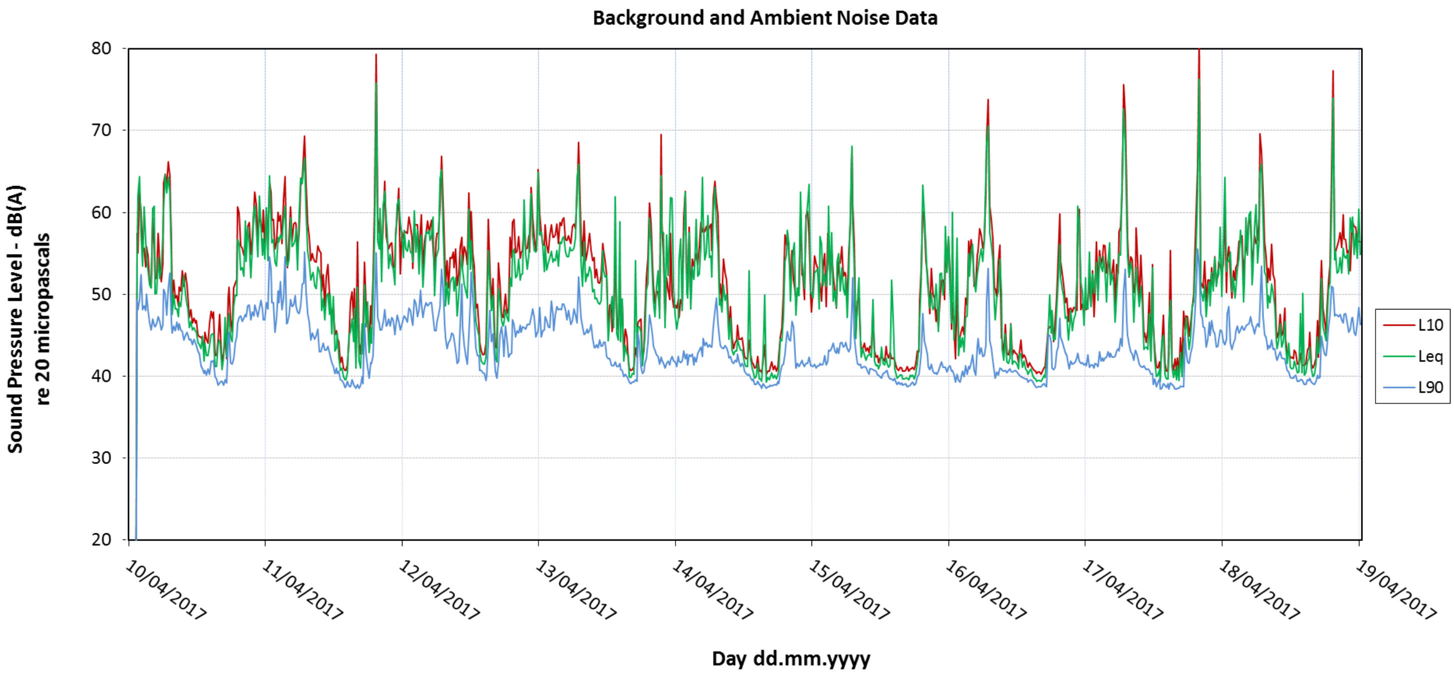
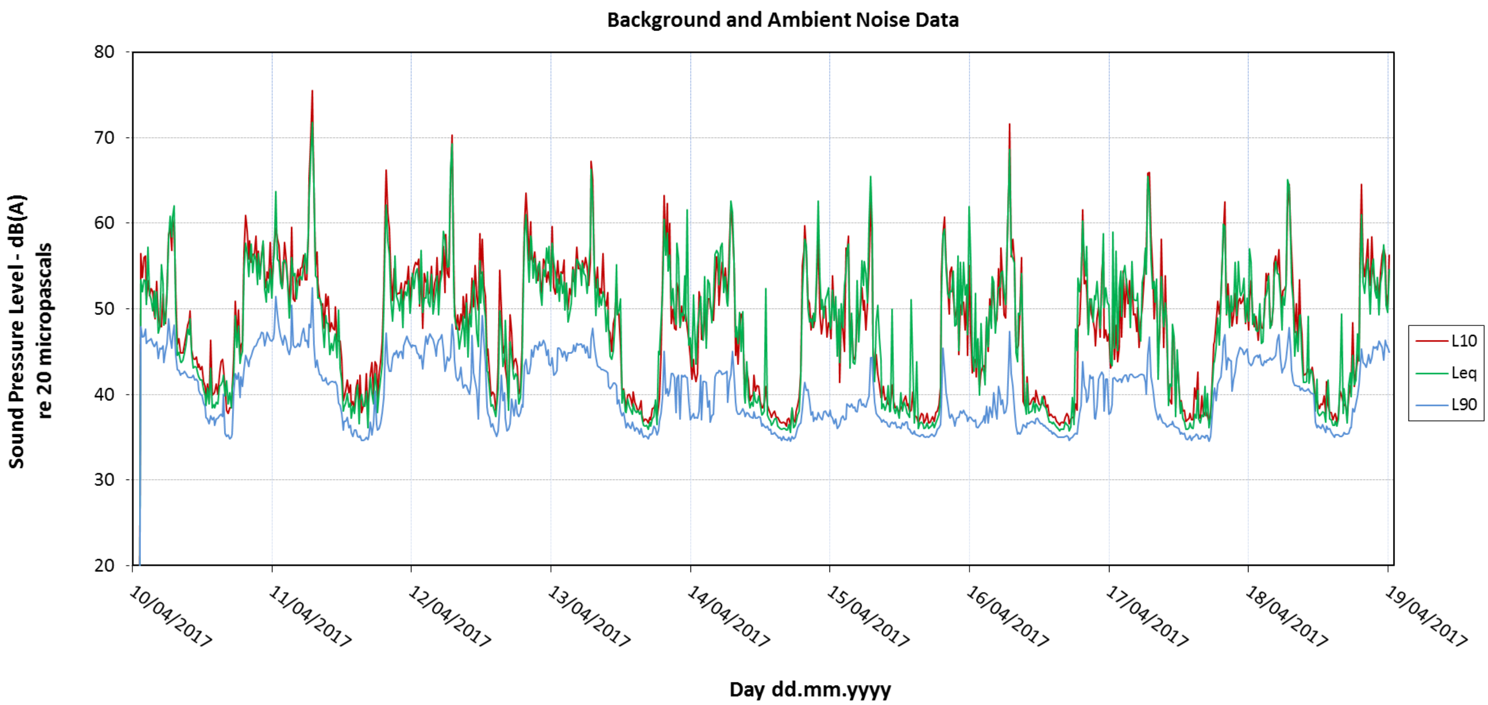


Figure 5: Unattended Background Noise Monitoring Data – L3



5. Noise and Vibration Criteria

5.1 Internal Noise Levels

This section details the criteria used to define the internal noise goals for spaces in the development in regards to external noise intrusion from traffic and other airborne noise factors affecting the development.

5.1.1 Australia Standard (AS) 2107:2016

Australian Standard (AS) 2107:2016 – *'Acoustics- Recommended design sound levels and reverberation times for building interiors'* specifies target noise levels for internal spaces to the development. Refer to Table 3 for the values corresponding to the non-residential spaces that are expected to be within the development.

Table 3: Recommended noise levels according to AS/NZS 2107:2016

Type of Occupancy/Activity	Design sound level ($L_{Aeq,t}$) range
Small Meeting Rooms	40 – 45
Medium Meeting Rooms	40 – 45
Large Meeting Rooms	35 – 40
Seminar Rooms	35 – 40
Staff Meeting Room	35 – 45
Teaching Offices	35 – 40
Library	40 – 45
Offices (multi-person)	40 – 45
Private Offices	35 – 40
Café	40 – 50
Kitchen	40 – 45
IT services	45 – 50
Student Lounges	40 – 45
Help Desk	40 – 45
Student Support	40 – 45
Archaeology Laboratory	35 – 45
Museum/ Exhibitions	40 – 45
Tea Point	40 – 45
Break Away Area	40 – 45
Teaching Room	35 – 40
Function Room	35 – 40
Language Lab	35 – 35
Lounge/ Meeting space	35 – 45

NOTE 1: Reverberation time should be minimized for noise control

5.2 Secretary's Environmental Assessment Requirements (SEAR's)

The Noise and Vibration Criteria for this State Significant Development is based upon the Secretary's Environmental Assessment Requirements (SEARs) issued by the Department of Planning and Environment.

The SEARSs requirements promote the use of the following guidelines and policies:

- NSW Industrial Noise Policy (NSW EPA, 2000)
- Interim Construction Noise Guideline (NSW EPA, 2009)
- Assessing Vibration: A Technical Guideline (NSW EPA, 2006)

In addition to the above, other relevant standards, guidelines and policies have been adopted, these include:

- AAAC Guideline for Child Care Centre Acoustic Assessment
- City of Ryde Development Control Plan 2014
- Australian Standard AS 2107:2016"*Acoustics—Recommended design sound levels and reverberation times for building interiors"*
- DIN 4150-Part 3 "Structural vibration in buildings – Effects on structures"
- BS 7385: Part 2: 1993 Evaluation and Measurement for vibration in Buildings: Guide to damage levels from ground-borne vibration

5.2.1 NSW OEH Industrial Noise Policy

The INP sets out noise criteria to control the noise emission from industrial noise sources. The external noise due to mechanical services from the proposed development is also addressed following the guideline in the NSW OEH's INP.

The calculation is based on the results of the ambient and background noise unattended monitoring, addressing two components:

- Controlling intrusive noise into nearby residences (Intrusiveness Criteria)
- Maintaining noise level amenity for particular land uses (Amenity Criteria)

Once both criteria are established, the most stringent for each considered assessment period (day, evening, night) is adopted as the project-specific noise level (PSNL).

Intrusiveness Criteria

The NSW OEH INP states the following:

> *"The intrusiveness of an industrial noise source may generally be considered acceptable if the equivalent continuous (energy-average) A-weighted level of noise from the source (represented by the Laeq descriptor), measured over a 15-minute period, does not exceed the background noise level measured in the absence of the source by more than 5 dB(A)."*

The intrusiveness criterion can be summarised as L_{Aeq}, 15 minute ≤ RBL background noise level plus 5 dB(A).

Table 4: OEH INP intrusiveness criteria – R9

Period	Noise Descriptor – dB(A)	Noise Criteria – dB(A)
Daytime 7am – 6pm	$L_{Aeq,15min}$ ≤ RBL + 5	44
Evening 6pm – 10pm	$L_{Aeq,15min}$ ≤ RBL + 5	44
Night 10pm – 7am	$L_{Aeq,15min}$ ≤ RBL + 5	37

Noise and Vibration Criteria

Amenity Criteria

The NSW INP states the following:

> *"To limit continuing increases in noise levels, the maximum ambient noise level within an area from industrial noise sources should not normally exceed the acceptable noise levels specified in Table 2.1 of the INP. Meeting the acceptable noise levels in table 2.1 will protect against noise impacts such as speech interference, community annoyance and to some extent sleep disturbance. These levels represent best practice for assessing industrial noise sources, based on research and a review of assessment practices used overseas and within Australia."*

The applicable parts of Table 2.1: Recommended L_{Aeq} Noise Levels from Industrial Noise Sources - dB(A) which are relevant to the project are reproduced below:

Table 5: Amenity criteria for external noise levels

Type of Receiver	Indicative Noise Amenity Area	Time of Day	Recommended L_{Aeq} Noise Level, dB(A)		Adjusted Acceptable L_{Aeq} Levels
			Acceptable	Maximum	
Commercial	All	When in use	65	70	65
School Classroom – internal**	All	Noisiest 1 hour period	35	40	35
Residence	Suburban	Day	55	60	55
		Evening	45	50	45
		Night	40	45	40

*Urban area as defined in EPA INP 2. 2.1.6.
**In the case where existing schools are affected by noise from existing industrial noise sources, the acceptable LAeq noise level may be increased to 40 dB LAeq(1hr).

'Modifying Factor' Adjustments

The NSW INP also states:

> *"Where a noise source contains certain characteristics, such as tonality, impulsiveness, intermittency, irregularity or dominant low-frequency content, there is evidence to suggest that it can cause greater annoyance than other noise at the same noise level."*

In order to take into account, the potential annoying character of the noise an adjustment of 5 dB(A) for each annoying character aspect and cumulative of up to a total of 10 dB(A), is to be added to the measured value to penalise the noise for its potentially greater annoyance aspect. Table 4.1 of Chapter 4 of the NSW DECCW INP (see Table 6 below) provides procedures for determining whether an adjustment should be applied for greater annoyance aspect.

Table 6: Table 4.1 NSW DECCW INP – Modifying factor corrections

Factor	Assessment / Measurement	When to Apply	Correction[1]	Comments
Tonal Noise	One-third octave or narrow band analysis	Level of one-third octave band exceeds the level of the adjacent bands on both sides by: - 5 dB or more if the centre frequency of the band containing the tone is above 400 Hz - 8 dB or more if the centre frequency band containing the tone is 160 to 400 Hz inclusive - 15 dB or more if the centre frequency of the band containing the tone is below 160 Hz	5 dB[2]	Narrow-band frequency analysis may be required to precisely detect occurrence.
Low Frequency Noise	Measurement of C-weighted and A-weighted level	Measure / assesses C- and A- weighted levels over same time period. Correction to be applied if the difference between the two levels is 15 dB or more	5 dB[2]	C-weighting is designed to be more responsive to low-frequency noise, especially at higher overall levels
Impulsive Noise	A-weighted fast response and impulsive response	If difference in A-weighted maximum noise levels between fast response and impulse response is greater than 2 dB	Apply difference in measured levels as the correction, up to a maximum of 5dB.	Characterised by a short rise time of 35 milliseconds (ms) and decay time of 1.5 s.
Intermittent Noise	Subjectively assessed	Level varies by more than 5 dB	5dB	Adjustment to be applied for night-time only.
Duration	Single-event noise duration may range from 1.5 min to 2.5 h	On event in any 24-hour period	0 to – 20 dB(A)	The acceptable noise level may be increased by an adjustment depending on duration of noise.
Maximum Adjustment	Refer to individual modifying factors	Where two or more modifying factors are indicated	Maximum correction of 10dB(A)[2] (excluding duration correction)	

Notes:

1. Corrections to be added to the measured or predicted levels.
2. Where a source emits tonal and low-frequency noise, only one 5 dB correction should be applied if the tone is in the low-frequency range.

Noise and Vibration Criteria

5.2.2 AAAC Guideline for Child Care Centre Acoustic Assessment

In the absence of any specific acoustic requirements in the City of Ryde DCP regarding the acoustic amenity of Child Care Centres, the Association of Australian Acoustical Consultants (AAAC) Guideline for Child Care Centre Acoustic Assessment has been adopted. The AAAC guideline is in accordance with the NSW OEH Industrial Noise Policy.

The guideline provides noise criteria with the purpose of protecting children from excessive which may be experienced due to the Child Care Centre's close proximity to roads, industrial premises and aircraft or rail operations. Child Care Centres typically operate from 7am to 6pm, Monday to Friday for up to 52 weeks per year.

While conducting an external noise impact assessment on children within a Child Care Centre, the AAAC Guideline for Child Care Centre Acoustic Assessment states:

> *"The noise level $L_{Aeq,1\ hour}$ from road, rail traffic or industry at any location within the outdoor play or activity area during the hours when the Centre is operating shall not exceed 55 dB(A).*
>
> *The noise level $L_{Aeq,1\ hour}$ from road, rail traffic or industry at any location within the indoor play or sleeping areas of the Centre during the hours when the centre is operating shall not exceed 40 dB(A)."*

Table 7 summarises the noise criteria for any external noise emissions from the proposed redevelopment impacting upon a surrounding Child Care Centre.

Table 7: AAAC Noise Criteria for External Emissions

Area Type	Noise Criteria – $L_{Aeq,1\ hour}$ dB(A)
Outdoor Play or Activity Areas	55
Indoor Play or Sleeping Areas	40

5.2.3 Project-specific noise levels (PSNL)

The following criteria is applicable for the external noise emissions from the development, as detailed below in Table 8. These project specific noise levels are in accordance with the requirements of the NSW INP.

Table 8: Project specific noise levels

Receiver	Period	Descriptor	PSNL dB(A)
R1	Noisiest 1-hour period when in use	$L_{Aeq, period, external}$	45
R2	Noisiest 1-hour period when in use	$L_{Aeq, period, external}$	45
R3	Noisiest 1-hour period when in use	$L_{Aeq, period, external}$	45
R4	Noisiest 1-hour period when in use	$L_{Aeq, period, external}$	45
R5	Noisiest 1-hour period when in use	$L_{Aeq, period, external}$	45
R6	Noisiest 1-hour period when in use	$L_{Aeq, period, external}$	45
R7	7:00am to 6:00pm	$L_{Aeq,1 hour, external}$	55
R8	Noisiest 1-hour period when in use	$L_{Aeq, period, external}$	45
R9	7:00am – 6:00pm (Day)	$L_{Aeq,15min}$	44
	6:00pm – 10:00pm (Evening)	$L_{Aeq,15min}$	44
	10:00pm – 7:00am (Night)	$L_{Aeq,15min}$	37

Where necessary, noise mitigation measures will be incorporated in the design to ensure that noise levels comply with the recommended noise emission criteria noted above.

5.3 Traffic Noise Generation Criteria

The L_{Aeq} noise level or the "equivalent continuous noise level" correlates best with the human perception of annoyance associated with traffic noise.

Road traffic noise impact is assessed in accordance with the newly introduced NSW Road Noise Policy (Office of Environment and Heritage July 2011) which supersedes the *NSW Environmental Criteria for Road Traffic Noise* (ECRTN, Department of Environment Climate Change and Water 1999). The criterion (Table 3 – Road Traffic Noise Assessment Criteria for Residential Land Uses) divides land use developments into different categories and lists the respective criteria for each case. The category that is relevant to the proposed use of the site is shown below:

Table 9: NSW Road Noise Policy – traffic noise assessment criteria

Road Category	Type of project/land use	Assessment Criteria – dB(A)	
		Day (7am – 10pm)	Night (10pm – 7am)
Local roads	Existing Residences affected by additional traffic on existing local roads generated by land use developments	$L_{Aeq,1\,hour}$ 55 (external)	$L_{Aeq,1\,hour}$ 48 (external)

In the event that the traffic noise at the site is already in excess of the criteria noted above, the NSW RNP states that the primary objective is to reduce the existing level through feasible and reasonable measures to meet the criteria above. If this is not achievable, Section 3.4.1 Process for applying the criteria – Step 4 states that for existing residences affected by additional traffic on existing roads generated by land use developments, any increase in the total traffic noise should be limited to 2 dB above that of the corresponding 'no build option'.

5.4 Construction Noise Criteria

The noise criteria for construction sites are established in accordance with the Interim Construction Noise Guideline (ICNG July 2009) by the Office of Environment and Heritage (OEH). This document is referred to as OEH's standard policy for assessing construction noise on new projects.

The noise criteria associated with construction and its related activities are shown below in Table 10. For further construction criteria and assessment refer to the construction noise and vibration management plan prepared by WGE (ref AC-RE-CNVMP_Early Works_002).

Table 10: Construction noise criteria at residences (ICNG 2009)

Time of Day	Management Level $L_{Aeq,15min}$ *	How to Apply
Recommended Standard Hours:	Noise Affected RBL + 10dB	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 meet the noise affected level. • The proponent should also inform all potentially impacted residences of the nature of works to be carried out, the expected noise levels and duration as well as contact details.
	Highly Noise Affected 75 dB(A)	The highly noise affected level represents the point above which there may be strong community reaction to noise. • Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur in, taking into account: 1. Times identified by the community when they are less sensitive to noise (such as before and after school, for works near schools, or mid-morning or mid-afternoon for works near residences) 2. If the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.
Outside Recommended Standard Hours	Noise Affected RBL + 5dB	• A strong justification would typically be required for works outside the recommended standard hours. • The proponent should apply all feasible and reasonable work practices to meet the noise affected level. • Where all feasible and reasonable practices have been applied and noise is more than 5 dB(A) above the noise affected level, the proponent should negotiate with the community. • For guidance on negotiating agreements see section 7.2.2.

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

5.5 Construction Vibration Criteria

The Office of Environment and Heritage (OEH) developed a document, "Assessing vibration: A technical Guideline" in February 2006 to assist in preventing people from exposure to excessive vibration levels within buildings. The guideline does not however address vibration induced damage to structures or structure-borne noise effects. Vibration and its associated effects are usually classified as continuous, impulsive or intermittent.

5.5.1 Human Comfort – Continuous and Impulsive Vibration Criteria

Structural vibration in buildings can be detected by occupants and can affect them in many ways including reducing their quality of life and also their working efficiency. Complaint levels from occupants of buildings subject to vibration depend upon their use of the building and the time of the day.

Maximum allowable magnitudes of building vibration with respect to human response are shown in Table 11. It should be noted that the human comfort for vibration are more stringent than the building damage criteria.

Table 11: Weighted RMS values for continuous and impulsive vibration acceleration (m/s2) 1-80Hz

Location	Assessment period[1]	Preferred values		Maximum values	
		z-axis	x- and y-axis	z-axis	x- and y-axis
Continuous vibration					
Residences	Daytime	0.010	0.0071	0.020	0.014
	Night time	0.007	0.005	0.014	0.010
Offices, schools, educational institutions and place of worship	Day or night time	0.020	0.014	0.040	0.028
Impulsive vibration					
Residences	Daytime	0.30	0.21	0.60	0.42
	Night time	0.10	0.071	0.20	0.14
Offices, schools, educational institutions and place of worship	Day or night time	0.64	0.46	1.28	0.92

Human Comfort – Intermittent Vibration Criteria

Disturbance caused by vibration will depend on its duration and its magnitude. This methodology of assessing intermittent vibration levels involves the calculation of a parameter called the Vibration Dose Value (VDV) which is used to evaluate the cumulative effects of intermittent vibration. Various studies support the fact that VDV assessment methods are far more accurate in assessing the level of disturbance than methods which is only based on the vibration magnitude.

Table 12: Acceptable Vibration Dose Values for Intermittent Vibration (m/s1.75)

Location	Daytime (7:00am to 10:00pm)		Night-time (10:00pm to 7:00am)	
	Preferred value	Maximum value	Preferred value	Maximum value
Residences	0.20	0.40	0.13	0.26
Offices, schools, educational institutions and place of worship	0.40	0.80	0.40	0.80

5.5.2 Structural Damage – Vibration Criteria

Ground vibration criteria are defined in terms of levels of vibration emission from infrastructures or from the construction activities which will avoid the risk of damaging surrounding buildings or structures. It should be noted that human comfort criteria are normally expressed in terms of acceleration whereas structural damage criteria are normally expressed in terms of velocity.
Most commonly specified structural vibration levels are defined to minimize the risk of cosmetic surface cracks and are set below the levels that have the potential to cause damage to the main structure. Structural damage criteria are presented in German Standard DIN4150-Part 3 "Structural vibration in buildings – Effects on structures" and British Standard BS7385-Part 2: 1993 "Evaluation and Measurement for Vibration in Buildings". Table 13 indicates the vibration limits presented in DIN4150-Part 3 to ensure structural damage doesn't occur.

Table 13: Guideline value of vibration velocity, vi, for evaluating the effects of short-term vibration

Line	Type of Structure	Vibration velocity, vi, in mm/s			
		Foundation			Plane of floor of uppermost full storey
		At a frequency of			
		Less than 10Hz	10 to 50Hz	50 to 100*Hz	All Frequencies
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 to 40	40 to 50	40
2	Dwellings and buildings of similar design and/or use	5	5 to 15	15 to 20	15
3	Structures that, because of their particular sensitivity to vibration, do not correspond to those listed in lines 1 and 2 and are of great intrinsic value (e.g. buildings that are under a preservation order)	3	3 to 8	8 to 10	8
*For frequencies above 100Hz, at least the values specified in this column shall be applied					

Table 14 presents guide values for building vibration, based on the lowest vibration levels above which cosmetic damage has been demonstrated as per BS7385-Part 2:1993.

Table 14: Transient vibration guide values for cosmetic damage

Type of Building	Peak Particle Velocity in frequency range of predominant pulse (PPV)	
Residential or light commercial type buildings	4 Hz to 15 Hz	15 Hz and above
	15mm/s at 4Hz increasing to 20mm/s at 15Hz	20mm/s at 15Hz increasing to 50mm/s at 40Hz and above

5.5.3 Vibration Objectives

Table 15 indicates the vibration criteria for the nearest educational facilities to the development.

Table 15: Construction vibration criteria summary

Location	Period	Human Comfort Vibration Objectives			Building damage Objectives – Velocity (mm/s)
		Continuous mm/s^2 (RMS)		Intermittent $m/s^{1.75}$ (VDV)	
		z-axis	x- and y-axis		
Schools	Any time	20 - 40	14 - 28	0.40 – 0.80	20

6. Noise Impact Assessment

6.1 External Glazing

The general limiting factor of the performance of a building façade in terms of noise attenuation is the glazing. With regards to the proposed MQU Arts Precinct, there are no dominant sources of external noise which place a high acoustic demand on the facades of the development.

The ratings presented are based on the worst case scenario of external noise obtained from the attended noise measurement, noise data from the unattended logger. The glazing thicknesses corresponding to the Rw ratings are presented below in Table 16, and should be considered with a 6.38mm glass as the minimum for the development. Greater glazing thicknesses may be required for structural loading, wind loading, thermal requirements etc.

Table 16: Recommended acoustic performance of glazing system

Facade	Spaces	Fixed Single Glazed System	Required Acoustic Rating of Glazing Assembly, Rw[1]
All	All	6.38mm	32
The required acoustic rating of glazing assembly, refers to the acoustic performance of the glazing once installed on site (including the frame)			

During the detailed design stage of the project the acoustic performance of the glazing facade should be reviewed as the combined noise from external sources and mechanical services could result in the internal noise level exceeding the design sound level ($L_{Aeq,T}$ dBA).

[1] See Appendix 1 for Rw definition

6.2 Mechanical Noise Emissions

The following noise sources are associated with the site operation, and details about expected noise levels from these sources are given in the ensuing sub-sections. Noise sources from general operations at the site typically include mechanical services noise from air handling units, cooling towers and chillers required to service the internal spaces. These noise sources have been used to predict the worst case scenario noise impact of the proposed use of the site to the surrounding receivers. The main mechanical sources associated with the development will include isolated plant rooms across the levels ground – 7 on the east and west side of buildings WWB & WWC and the rooftops of buildings 25WWB and 25WWC. Mechanical plant items include:

- Cooling towers located on the building 25WWC rooftop plant room
- Air handling units within enclosed plantrooms on the east and west sides of buildings 25WWB & 25WWC
- Exhaust fans connected to air handling units within the same enclosed plant rooms
- Chillers located on the building 25WWB rooftop plant room

A comprehensive quantitative assessment of operational noise impacts on the surrounding noise sensitive receivers has been conducted, with a safety margin for the maximum sound power levels nominated to meet the established noise criteria in Section 5.2.3. The units have been calculated from each of the plantrooms to the most affected external receivers (R3 & R9). In regards to educational buildings, the internal noise level must not exceed 35dB(A). With the windows open to achieve adequate ventilation to the spaces, it is typical to assume 10dB attenuation through the window. Therefore, the assessment has considered a maximum of 45dB(A) at the external point of the most affected windows for R3. The assessment was also considered at the window within the façade of the BaptistCare Willandra Retirement Village (R9).

Refer to Table 17 for the proposed maximum sound power levels within the mechanical plantrooms associated with the proposed development. Note that in order to meet these sound power levels, acoustic mitigation measures such as attenuators, acoustic louvres and internal acoustic lining may be required.

Table 17: Sound Power Levels for mechanical plant rooms

Item	Sound Power Level SWL re 10^{-12} W dB							
	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	Overall dB(A)
Typical East/West AHU Plantroom (WWB & WWC)	69	73	77	74	72	71	69	78
25WWC Rooftop Plant	105	106	101	94	90	86	79	98
25WWB Rooftop Plant	85	89	88	89	86	88	91	95

6.2.1 Mitigation Measures

An acoustic louvre 200mm is recommended for all plant room openings from Ground level to Level 8. The insertion loss values for the proposed acoustic louvres are presented below in Table 18.

Table 18: Acoustic louvre insertion loss

Item	Insertion Loss – dB					
	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
Acran Series 200 Acoustic Louvre	8	7	11	21	24	16

In addition to this, acoustic louvres are required on the 25WWB rooftop surrounding the plant in the locations shown below in Figure 6.

The cooling tower plant on the roof of 25WWC is anticipated to require a solid acoustic barrier to the bridge link as per the extent shown in Figure 7. The height of the barriers and louvres is required to be designed at a height where appropriate screening/shielding is provided. The barrier shall be free of any gaps and constructed from a solid material with a surface density no less than 17kg/m^2.

Figure 6: 25WWB rooftop plant acoustic barriers and louvres

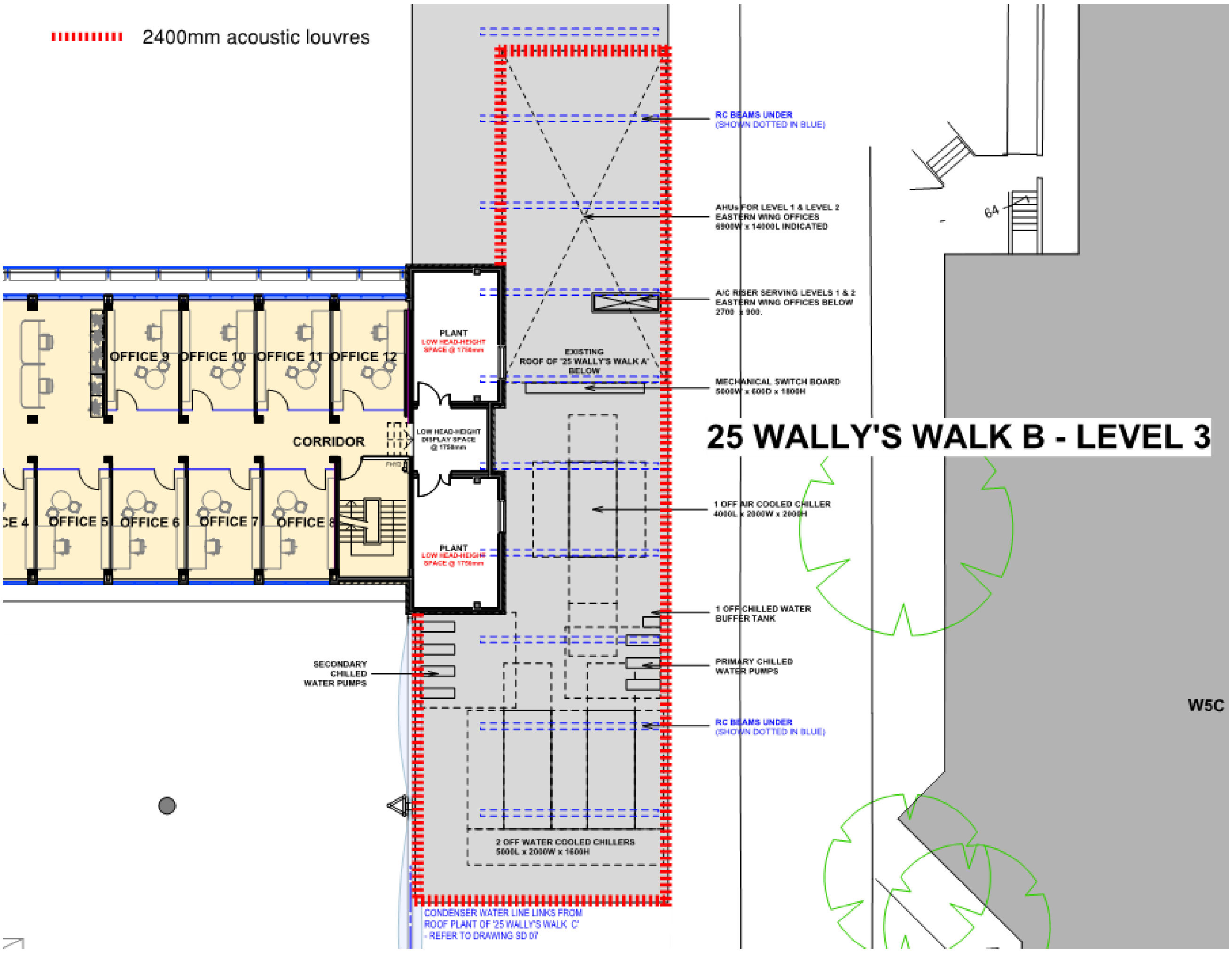
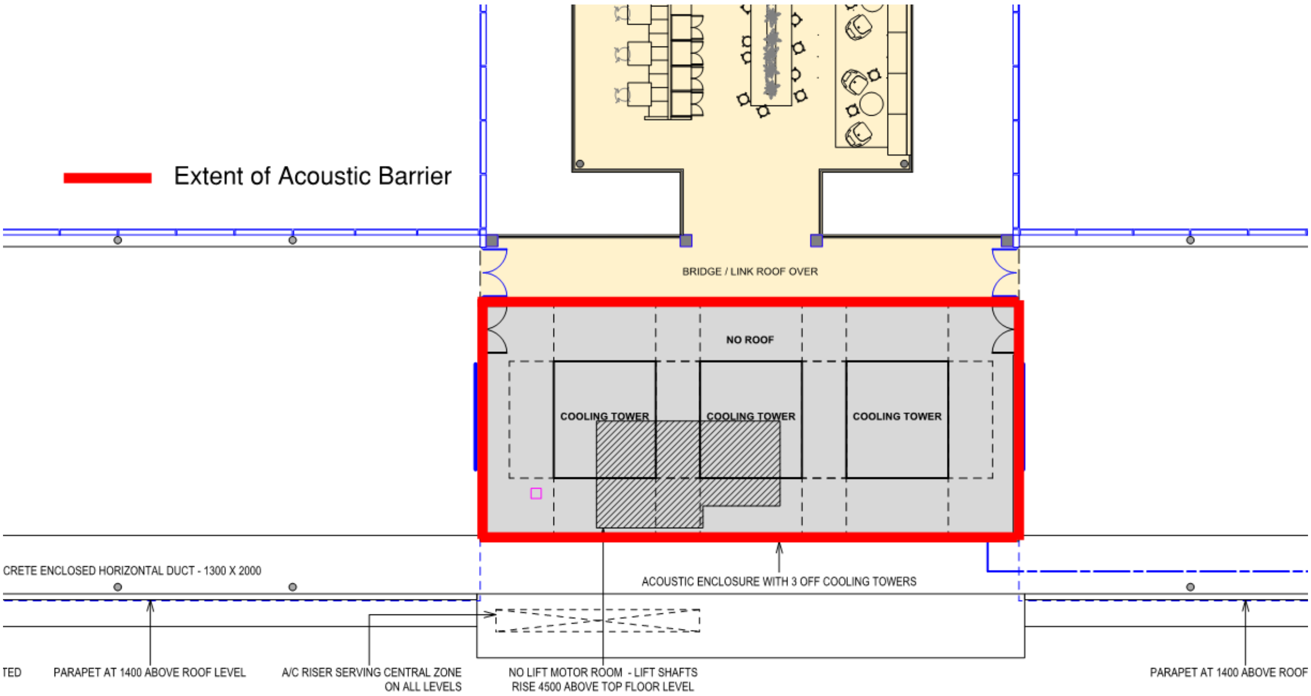


Figure 7: 25WWC rooftop plant acoustic barriers and louvres



6.2.2 General Mitigation Measures

In addition to the above, further mitigation measures for the mechanical plant should be considered during the Design Development stage so as to comply with the outlined criteria at the nearest sensitive receivers. These amelioration measures could include but not limited to the following:

- Positioning mechanical plant away from nearby receivers
- Acoustic attenuators fitted to duct work
- Screening around mechanical plant
- Acoustic insulation within duct work

6.3 Construction Noise Assessment

The noise associated with construction activities at the boundary of the nearest sensitive receivers has been assessed within the Construction Noise and Vibration Management Plans (Ref. AC-RE-CNVMP_Early Works_002 dated 9th May 2017 & AC-RE-CNVMP_REF_001 dated 31st May 2017).

The Construction Noise and Vibration Management Plans present the result of the predicted noise and vibration levels at the boundary of the potentially most affected receivers. The predictive noise and vibration models will be based on a construction program and type of equipment being used for the construction.

The construction noise and vibration against which these predicted noise and vibration levels will be assessed have been established and presented within the Section 5.5 and 5.6 of this report.

According to AS 2436 – 2010 *"Guide to noise and vibration control on construction, demolition and maintenance sites"* the following techniques could be applied to minimize the spread of noise and vibrations to the potential receivers.

If a process that generates significant noise levels cannot be avoided, the amount of noise reaching the receiver should be minimized. Two ways of achieving this are to either increase the distance between the noise source and the receiver or to introduce noise reduction measures such as screens.

Screening
On sites where distance is limited, the screening of noise may be beneficial and this should be taken into account during the planning stages.

If structures such as stores, site offices and other temporary buildings are situated between the noisiest part of the site and the nearest dwellings, some of the noise emission from the site can be reduced. If these buildings are occupied, sound insulation measures may be necessary to protect workers inside the buildings.

Storage of building materials or the placement of shipping containers between the noise source and any noise-sensitive area may also provide useful screening and the same is true of partially completed or demolished buildings. A noisy, stationary plant can be placed in a basement, the shell of which has been completed, provided reverberant noise can be controlled. Where compressors or generators are used in closed areas, it is necessary to ensure that the exhaust gases are discharged directly to the outside air and that there is good cross-ventilation to prevent the build-up of poisonous carbon monoxide fumes and to allow an adequate air supply to maintain efficiency when operating the equipment.

Where such noise barriers are not practical, a worthwhile reduction in noise can be obtained by siting the plant behind and as close as possible to mounds of earth, which may effectively screen any noise-sensitive areas from the plant. These can often be designed into the construction schedule or site arrangement for future landscaping.

Water pumps, fans and other plant equipment that operate on a 24-hour basis may not be an irritating source of noise during the day but may be problematic at night. They should therefore be effectively screened by either situating them behind a noise barrier or by being positioned in a trench or a hollow in the ground provided this does not generate reverberant noise. In such cases, however, adequate ventilation should also be ensured. Long, temporary earth embankments can provide quite an effective noise screen for mobile equipment moving, for example, on a haulage road. When the earthworks are complete, the earth mounds should be removed if possible with smaller, quieter excavators. A noise barrier may be a more reliable method of noise control than the imposition of restrictions on throttle settings.

In many cases it is not be practical to screen earthmoving operations effectively, but it may be possible to partially shield a construction plant or to build-in at the early stages protective features required to screen traffic noise.

Where earth noise barriers are not practical due to lack of space, consideration should be given to the possibility of constructing temporary screens from wood or any of the materials suggested in Appendix D.

The usefulness of a noise barrier will depend upon its length, its height, its position relative to the source and to the receiver, and the material from which it is made. A barrier designed to reduce noise from a moving source should extend beyond the last property to be protected to a distance of not less than ten times the shortest measurement from the property to the barrier. A barrier designed to reduce noise from a stationary source should, where possible, extend to a distance beyond the direct line between the noise source and the receiver to a distance equal to ten times the effective barrier height, which is the height above the direct line between source and receiver.

If the works are predominately within nominally closed structures, careful consideration should be given to reducing noise breakout at any openings.

Crane (diesel operated)
An appropriate silencer on the muffler and acoustic screen around the engine bay are recommended to attenuate the noise from it.

Reversing and warning alarms
Community complaints often involve the intrusive noise of alarms commonly used to provide a safe system of work for vehicles operating on a site. Beeper reversing alarm noise is generally tonal and may cause annoyance at significant distances from the work site.

There are alternative warning alarms capable of providing a safe system of work that are equal to or better than the traditional 'beeper', while also reducing environmental noise impacts. The following alternatives should be considered for use on construction sites as appropriate:

(a) Broadband audible alarms incorporating a wide range of sound frequencies (as opposed to the tonal-frequency 'beep') are less intrusive when heard in the neighbourhood.
(b) Variable-level alarms reduce the emitted noise levels by detecting the background noise level and adjusting the alarm level accordingly.
(c) Non-audible warning systems (e.g. flashing lights, reversing cameras) may also be employed, providing safety considerations, are not compromised.
(d) Proximity alarms that use sensors to determine the distance from objects, such as people or structures, and generate an audible alarm in cabin for the driver.
(e) Spotters or observers.

The above methods should be combined, where appropriate.

6.4 Construction Vibration

The vibration associated with construction is dependent on a number of variables including the types of machinery, the proximity to the nearby receivers as well as the ground type.

A preliminary Construction Noise and Vibration Management Plan has been conducted as part of the development (Ref. AC-RE-CNVMP_Early Works_002 dated 9th May 2017 & AC-RE-CNVMP_REF_001 dated 31st May 2017. The CNVMP outlines mitigation measures and monitoring strategies in order to meet the relevant construction vibration criteria.

Further to the above, generic safe working distances for vibration impacts associated with various types of machinery at given distances are presented within the transport for NSW 'Construction Noise Strategy' document. This document presents the safe construction working limits for Cosmetic Damage to adjacent structures (in accordance with BS 7385) and Human Comfort (OH&E).

Table 19: Working Distances for Vibration Intensive Plant

Plant Item	Rating/Description	Safe Working Distance	
		Cosmetic Damage (BS 7385)	Human Response (OH&E Vibration Guideline)
Vibratory Roller	<50 kN (Typically 1-2 tonnes)	5m	15m to 20m
	<100 kN (Typically 2-4 tonnes)	6m	20m
	<200 kN (Typically 4-6 tonnes)	12m	40m
	<300 kN (Typically 7-13 tonnes)	15m	100m
	>300 kN (Typically 13-18 tonnes)	20m	100m
	>300 kN (> 18 tonnes)	25m	100m
Small Hydraulic Hammer	(300kg – 5 to 12t excavator)	2m	7m
Medium Hydraulic Hammer	(900kg – 12 to 18t excavator)	7m	23m
Large Hydraulic Hammer	(1600kg – 18 to 34t excavator)	22m	73m
Vibratory Pile Driver	Sheet Piles	2m to 20m	20m
Pile Boring	≤800mm	2m	N/A
Jackhammer	Hand held	1m	Avoid contact with structure

Based on the information presented above in Table 19 and the proximity from the proposed site to the nearby receivers, it is expected that the human comfort vibration levels may be exceeded during construction. Vibration measures have been provided in the subsequent section as to prevent such exceedances.

6.5 Vibration Amelioration Measures

Amelioration measures are recommended to be utilised during construction in order to minimise the transmitted vibration around the site. These measures include the following:

- Monitor vibration levels using attended/un-attended methods during construction so as to manage potential excessive vibration
- Manage construction program so as to minimise heavy machinery operating concurrently to each other
- Prepare dilapidation reports on adjacent structures and monitor the effects
- As far as practical, locate heavy machinery away from nearby sensitive receivers

7. Conclusion

An acoustic assessment for the proposed works at the Macquarie University Arts Precinct has been conducted. This document forms part of the documentation package to be submitted to relevant authorities as part of the SSD Application process

This report has provided criteria, in-principle treatment and design requirements which aim to achieve the statutory criteria discussed in Section 5. In terms of noise criteria, we have provided the following:

- Recommendations for internal noise levels within the proposed development in accordance with AS 2107:2016, provided in Section 5.1;
- Noise criteria for emissions from the development to residential receivers in accordance with SEAR's, AAAC Guidelines and the NSW INP, provided in Section 5.2;
- Construction noise criteria provided in Section 5.4 in accordance with the ICNG;
- Construction vibration criteria provided in Section 5.5.

Glazing for the buildings has been designed to achieve internal noise levels in accordance with the internal noise levels goals. The glazing is presented in Section 6.1.

Acoustic screening has been nominated for the rooftop plant on the eastern side of 25WWA and the norther side of the rooftop plant on 25WWC.

Even though no assessment can be considered as being thorough enough to preclude all potential environmental impacts, having given regard to the above listed conclusions, it is the finding of this assessment that the development application should not be refused on the grounds of excessive noise generation.

The information presented in this report shall be reviewed if any modifications to the features of the development specified in this report occur, including and not restricted to selection of air-conditioning units, layout of equipment, modifications to the building and introduction of any additional noise sources.

Appendix 1 - Glossary of Acoustic Terms

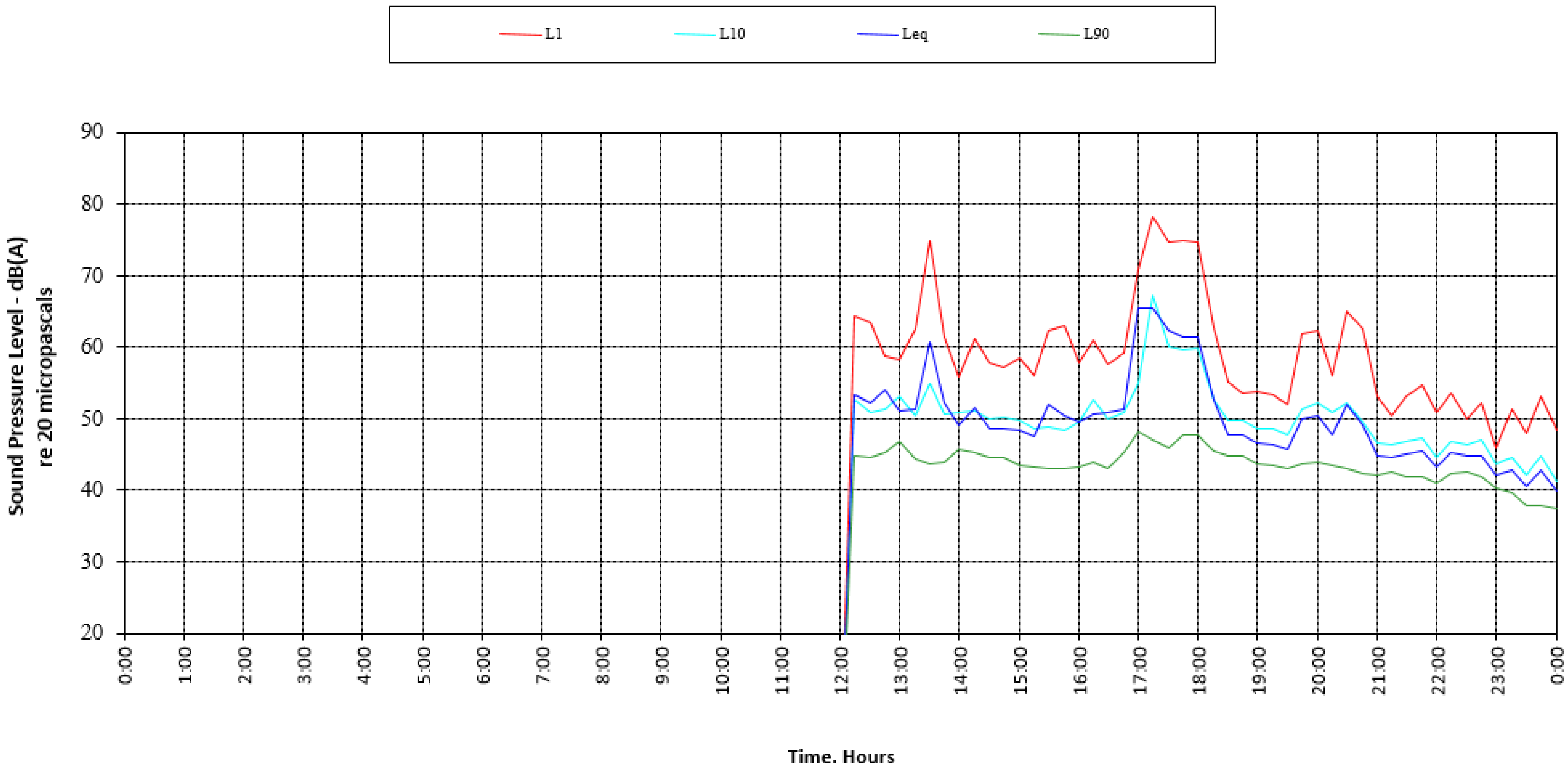
NOISE	
Acceptable Noise Level:	The acceptable LAeq noise level from industrial sources, recommended by the EPA (Table 2.1, INP). Note that this noise level refers to all industrial sources at the receiver location, and not only noise due to a specific project under consideration.
Adverse Weather:	Weather conditions that affect noise (wind and temperature inversions) that occur at a particular site for a significant period of time. The previous conditions are for wind occurring more than 30% of the time in any assessment period in any season and/or for temperature inversions occurring more than 30% of the nights in winter).
Acoustic Barrier:	Solid walls or partitions, solid fences, earth mounds, earth berms, buildings, etc. used to reduce noise.
Ambient Noise:	The all-encompassing noise associated within a given environment at a given time, usually composed of sound from all sources near and far.
Assessment Period:	The period in a day over which assessments are made.
Assessment Location	The position at which noise measurements are undertaken or estimated.
Background Noise:	Background noise is the term used to describe the underlying level of noise present in the ambient noise, measured in the absence of the noise under investigation, when extraneous noise is removed. It is described as the average of the minimum noise levels measured on a sound level meter and is measured statistically as the A-weighted noise level exceeded for ninety percent of a sample period. This is represented as the L90 noise level.
Decibel [dB]:	The units of sound pressure level.
dB(A):	A-weighted decibels. Noise measured using the A filter.
Extraneous Noise:	Noise resulting from activities that are not typical of the area. Atypical activities include construction, and traffic generated by holidays period and by special events such as concert or sporting events. Normal daily traffic is not considered to be extraneous.
Free Field:	An environment in which there are no acoustic reflective surfaces. Free field noise measurements are carried out outdoors at least 3.5m from any acoustic reflecting structures other than the ground
Frequency:	Frequency is synonymous to pitch. Frequency or pitch can be measured on a scale in units of Hertz (Hz).
Impulsive Noise:	Noise having a high peak of short duration or a sequence of such peaks. A sequence of impulses in rapid succession is termed repetitive impulsive noise.

Appendix 1 - Glossary of Acoustic Terms

Intermittent Noise:	Level that drops to the background noise level several times during the period of observation.
LAmax	The maximum A-weighted sound pressure level measured over a period.
LAmin	The minimum A-weighted sound pressure level measured over a period.
LA1	The A-weighted sound pressure level that is exceeded for 1% of the time for which the sound is measured.
LA10	The A-weighted sound pressure level that is exceeded for 10% of the time for which the sound is measured.
LA90	The A-weighted level of noise exceeded for 90% of the time. The bottom 10% of the sample is the L90 noise level expressed in units of dB(A).
LAeq	The A-weighted "equivalent noise level" is the summation of noise events and integrated over a selected period of time.
LAeqT	The constant A-weighted sound which has the same energy as the fluctuating sound of the traffic, averaged over time T.
Reflection:	Sound wave changed in direction of propagation due to a solid object met on its path.
R-w:	The Sound Insulation Rating R-w is a measure of the noise reduction performance of the partition.
SEL:	Sound Exposure Level is the constant sound level which, if maintained for a period of 1 second would have the same acoustic energy as the measured noise event. SEL noise measurements are useful as they can be converted to obtain Leq sound levels over any period of time and can be used for predicting noise at various locations.
Sound Absorption:	The ability of a material to absorb sound energy through its conversion into thermal energy.
Sound Level Meter:	An instrument consisting of a microphone, amplifier and indicating device, having a declared performance and designed to measure sound pressure levels.
Sound Pressure Level:	The level of noise, usually expressed in decibels, as measured by a standard sound level meter with a microphone.
Sound Power Level:	Ten times the logarithm to the base 10 of the ratio of the sound power of the source to the reference sound power.
Tonal noise:	Containing a prominent frequency and characterised by a definite pitch.

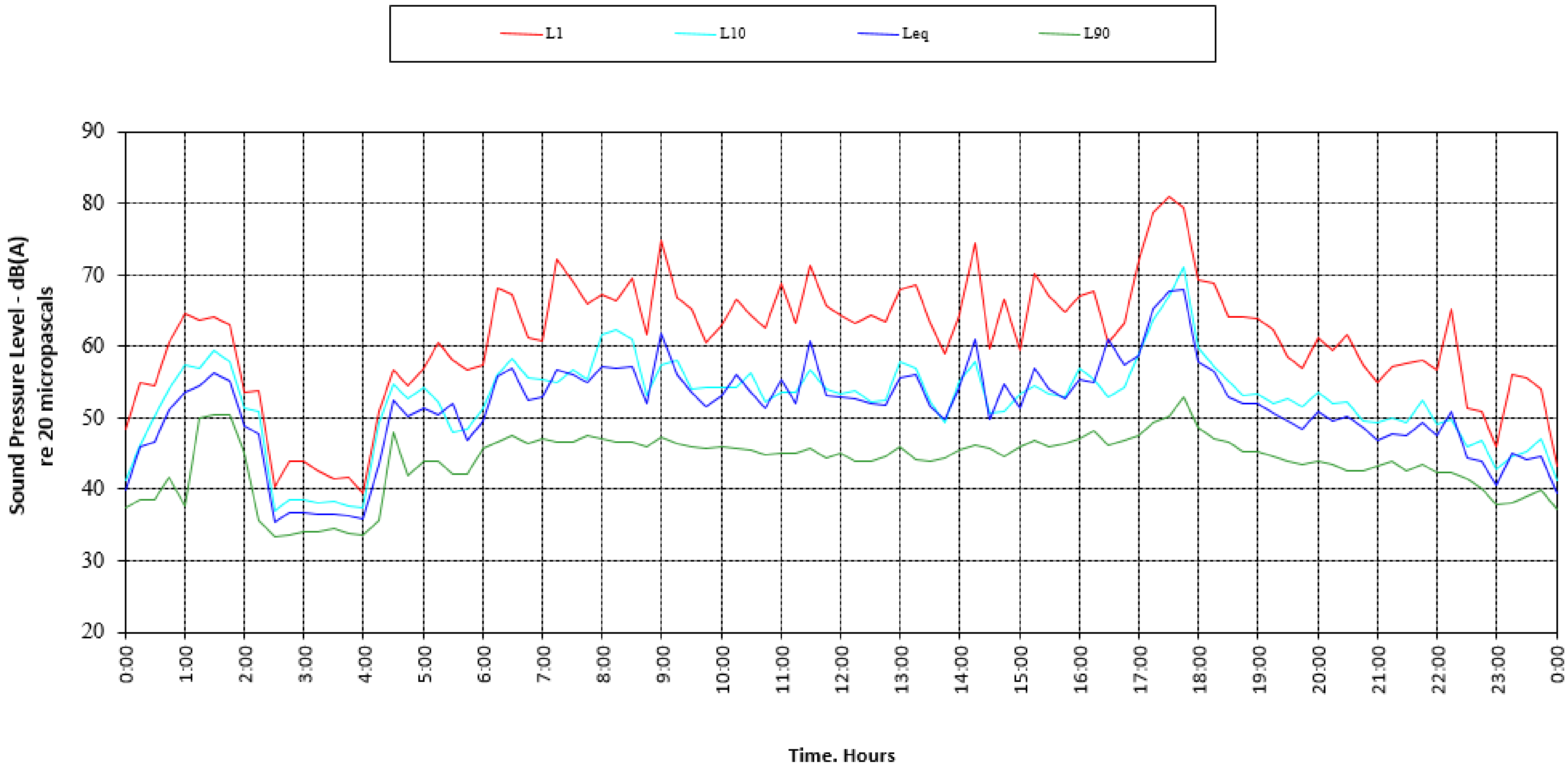
Appendix 2 – Noise Monitoring Data

Figure 8: Noise data 10/04/2017 – L1



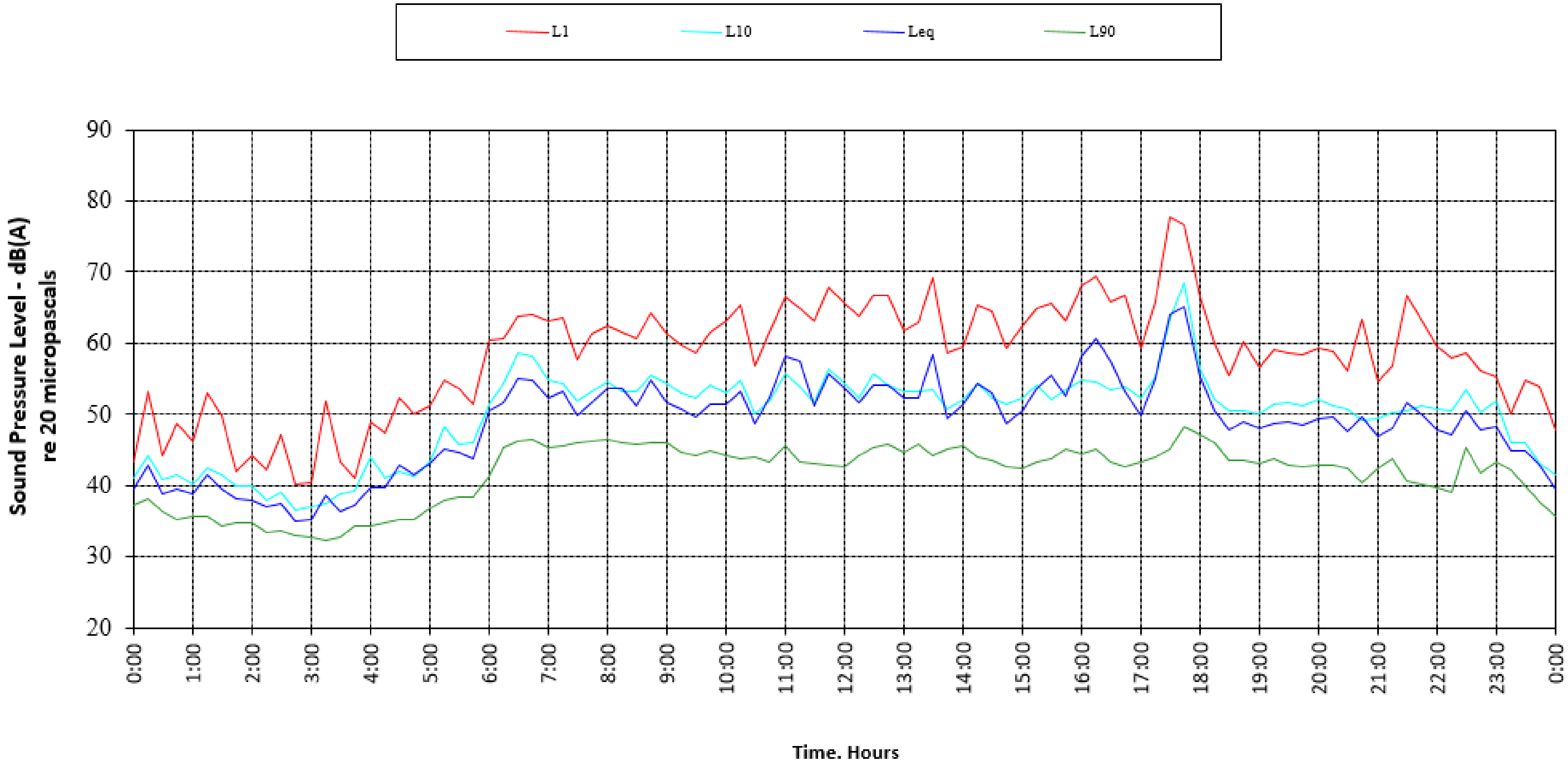
Appendix 2 – Noise Monitoring Data

Figure 9: Noise data 11/04/2017 – L1



Appendix 2 – Noise Monitoring Data

Figure 10: Noise data 12/04/2017 – L1



Appendix 2 – Noise Monitoring Data

Figure 11: Noise data 13/04/2017 – L1

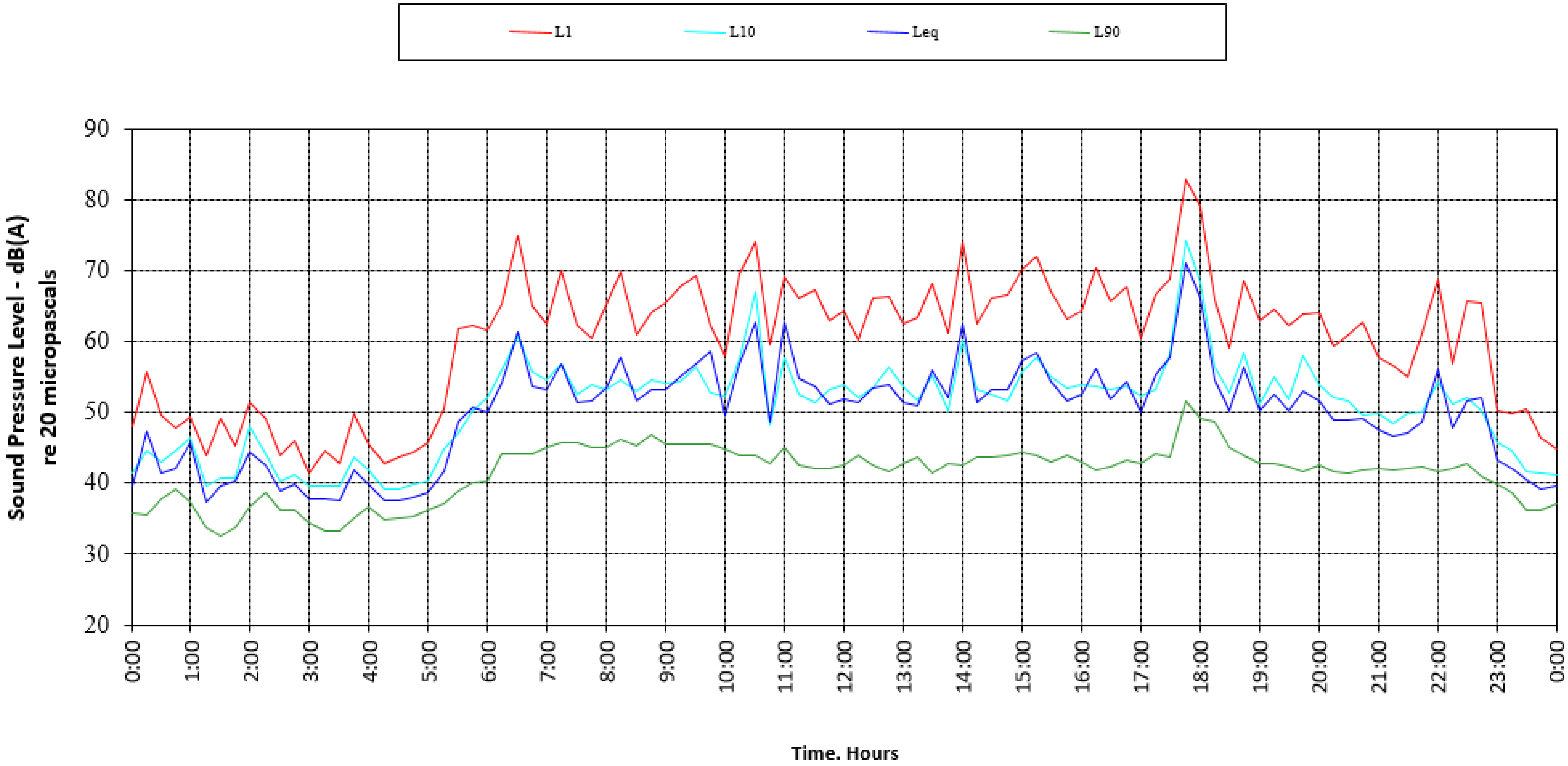
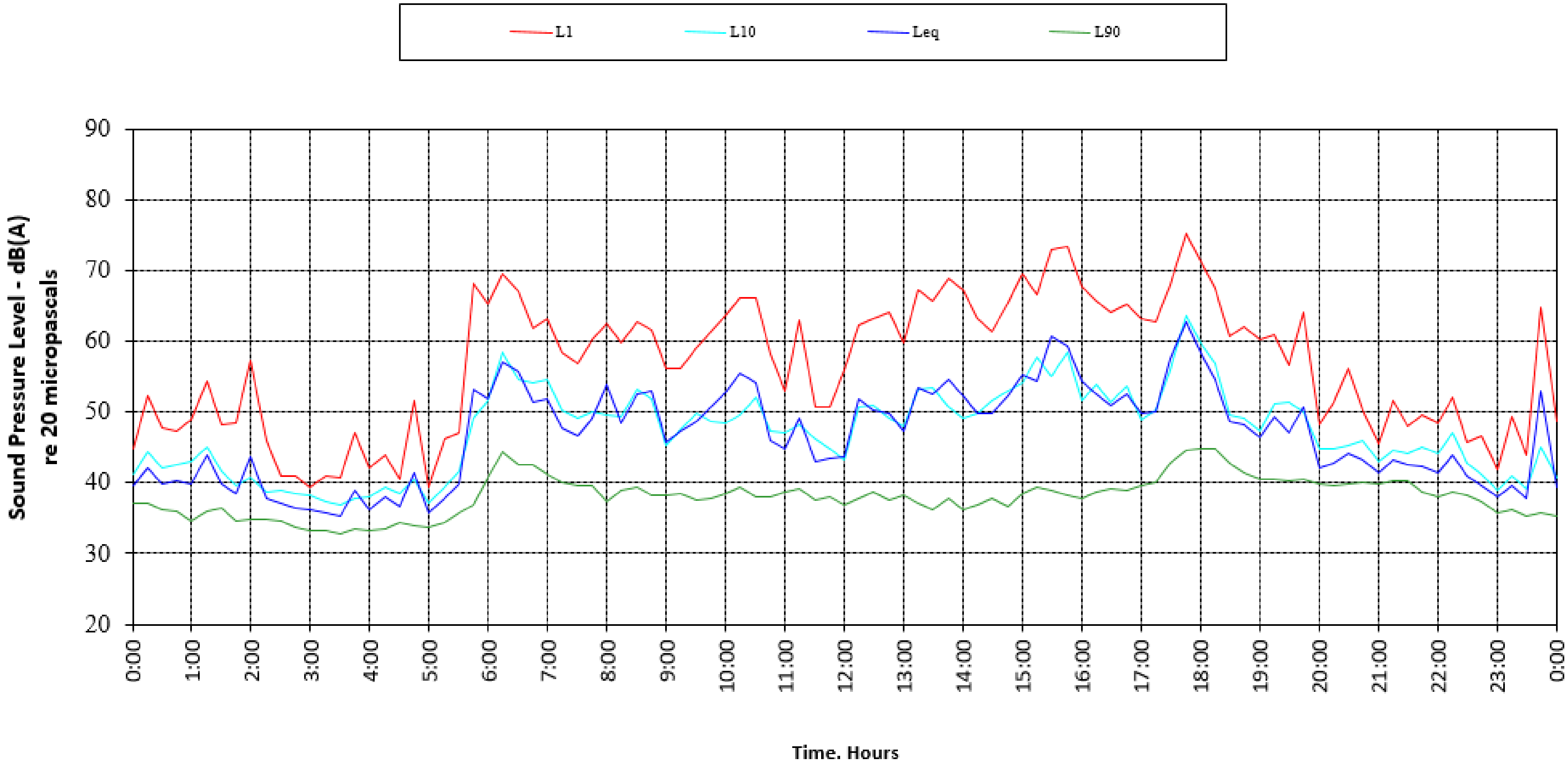
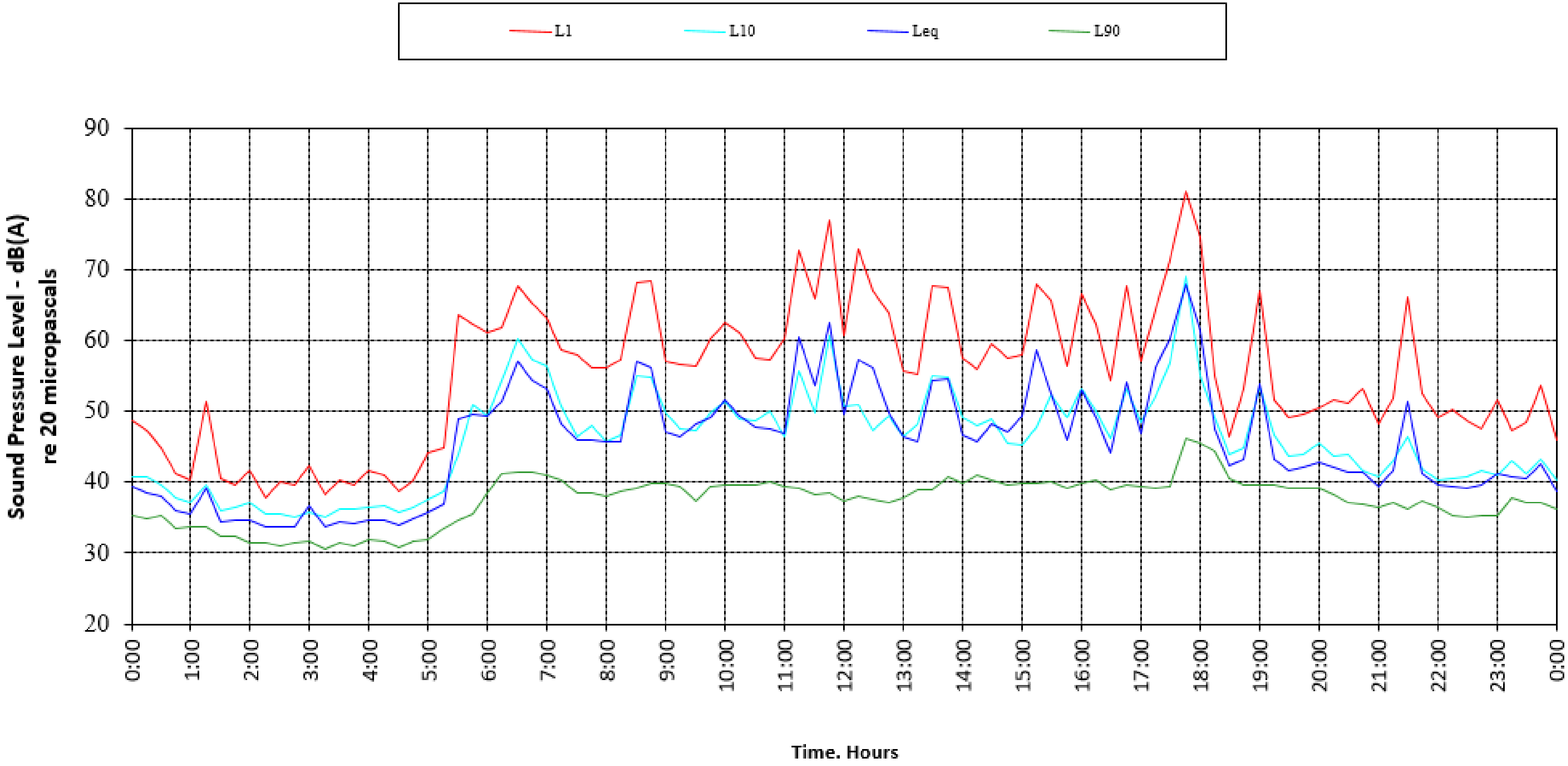


Figure 12: Noise data 14/04/2017 – L1



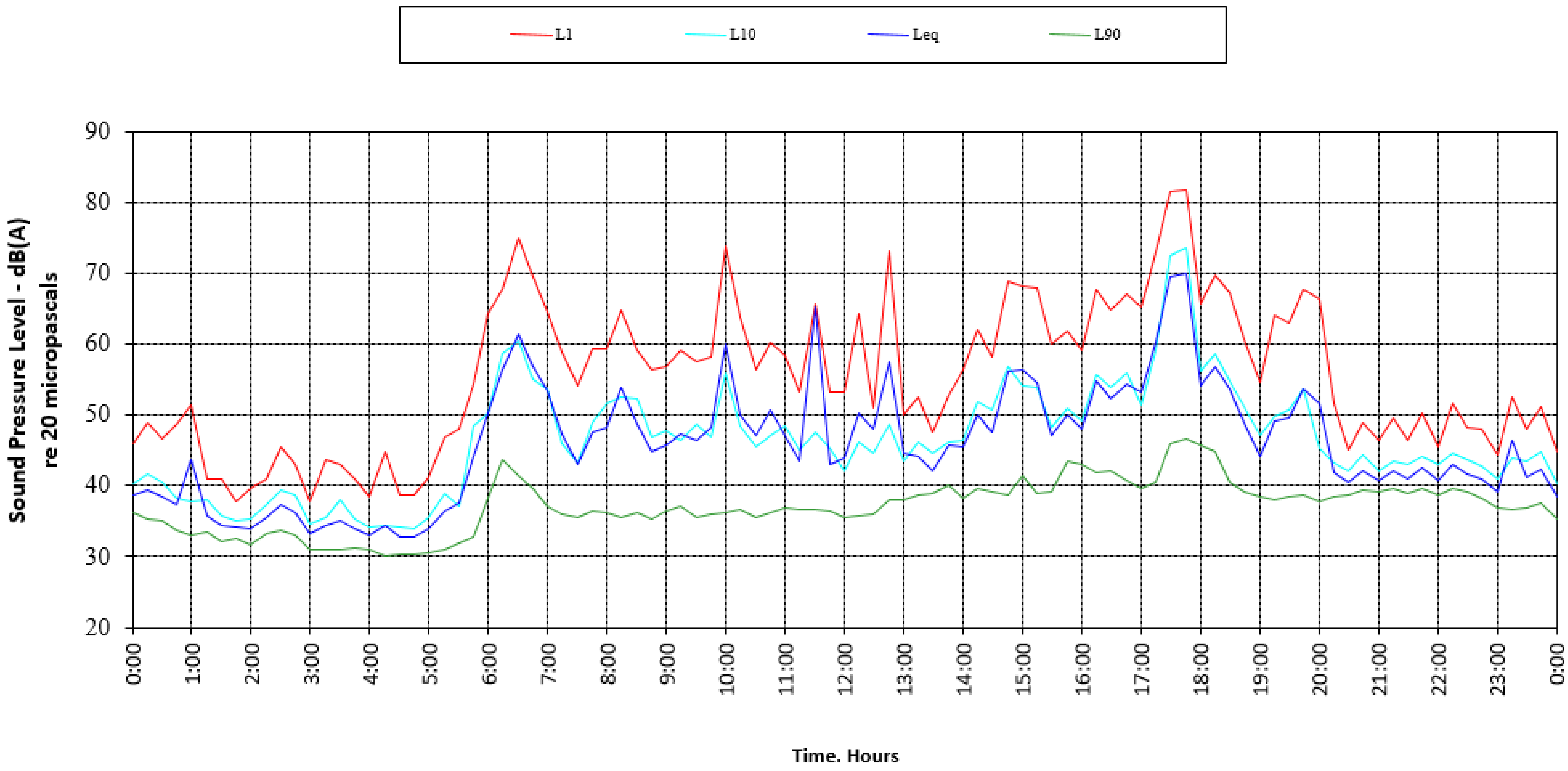
Appendix 2 – Noise Monitoring Data

Figure 13: Noise data 15/04/2017 – L1



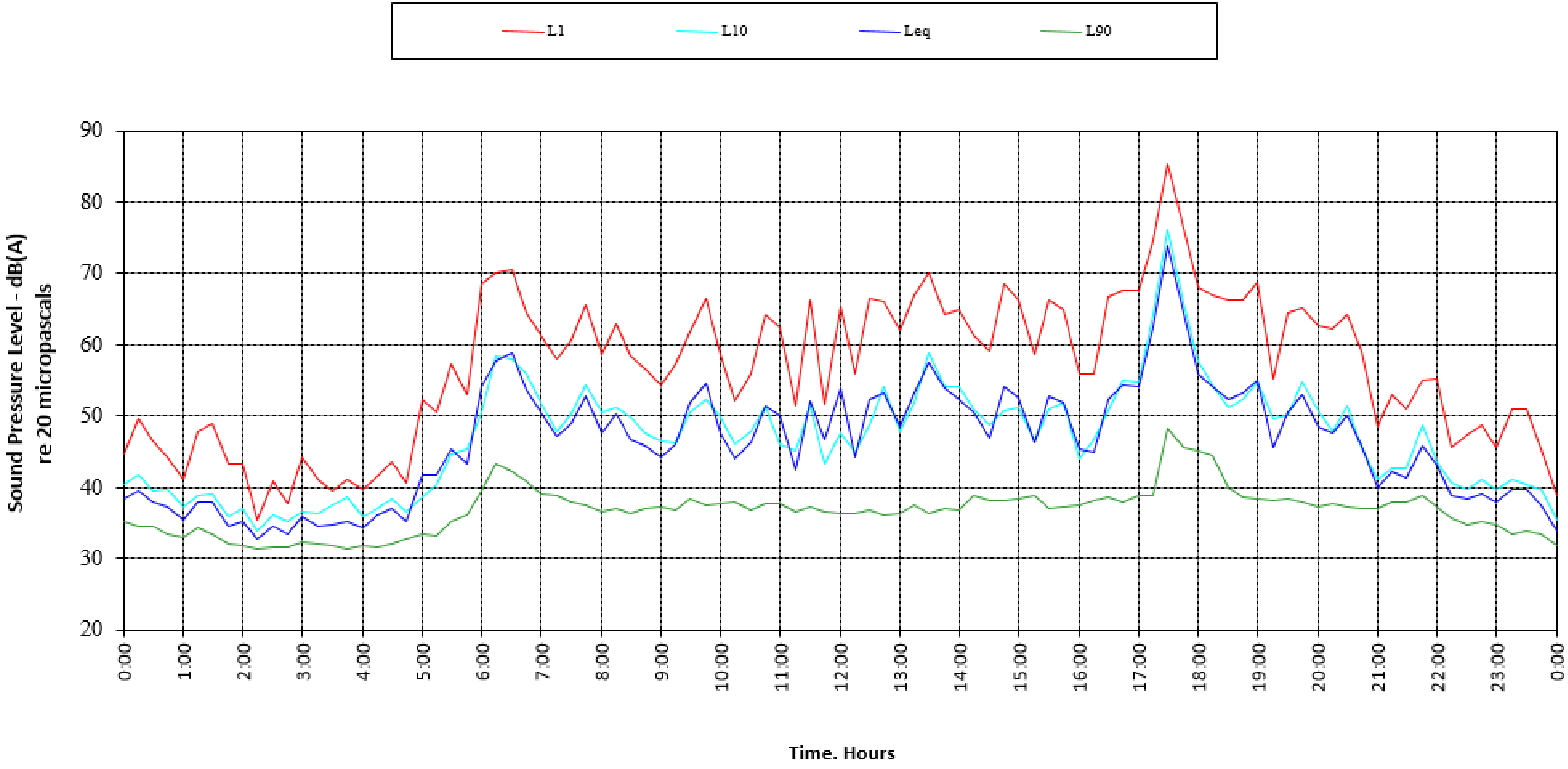
Appendix 2 – Noise Monitoring Data

Figure 14: Noise data 16/04/2017 – L1



Appendix 2 – Noise Monitoring Data

Figure 15: Noise data 17/04/2017 – L1



Appendix 2 – Noise Monitoring Data

Figure 16: Noise data 18/04/2017 – L1

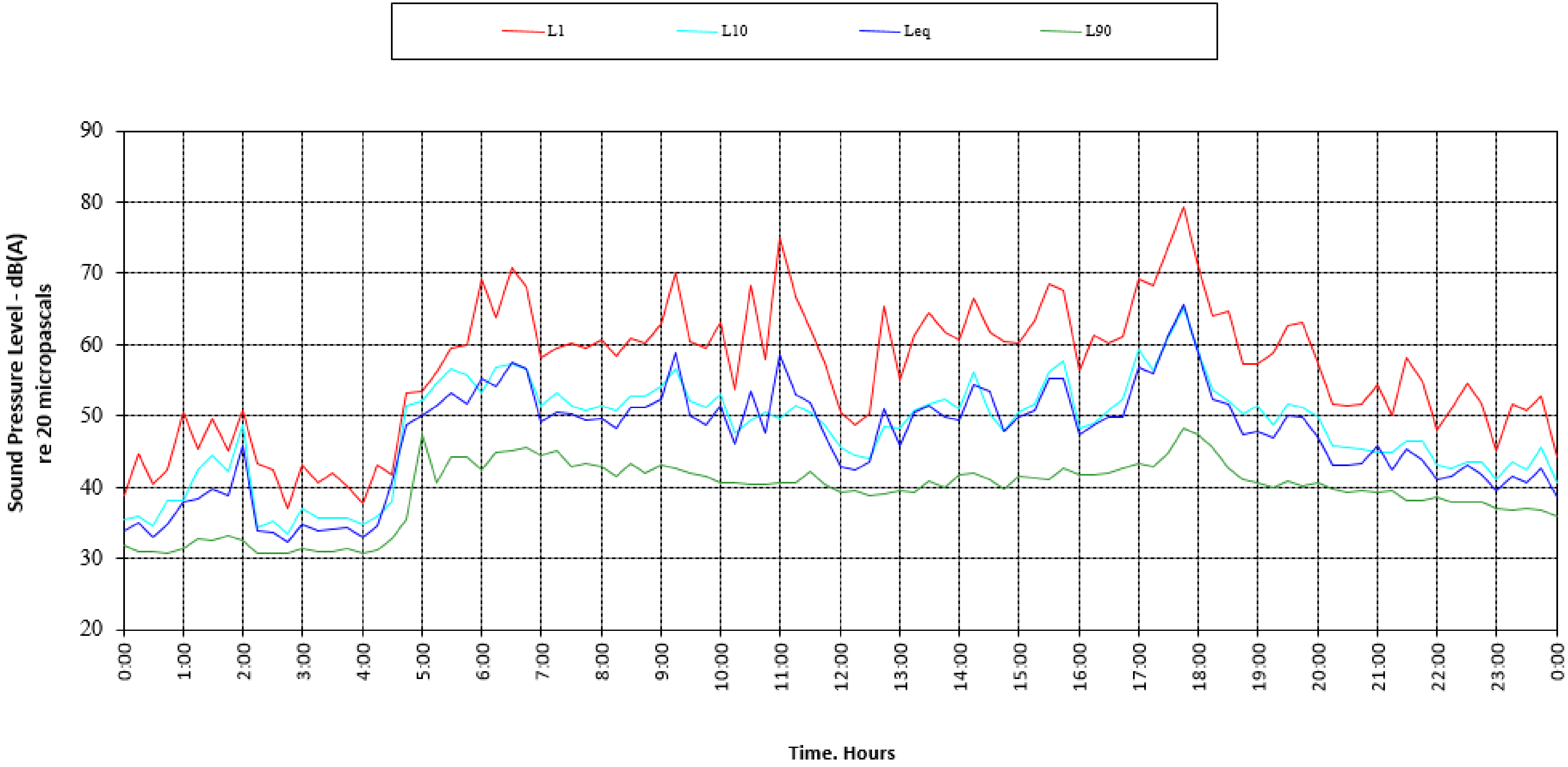
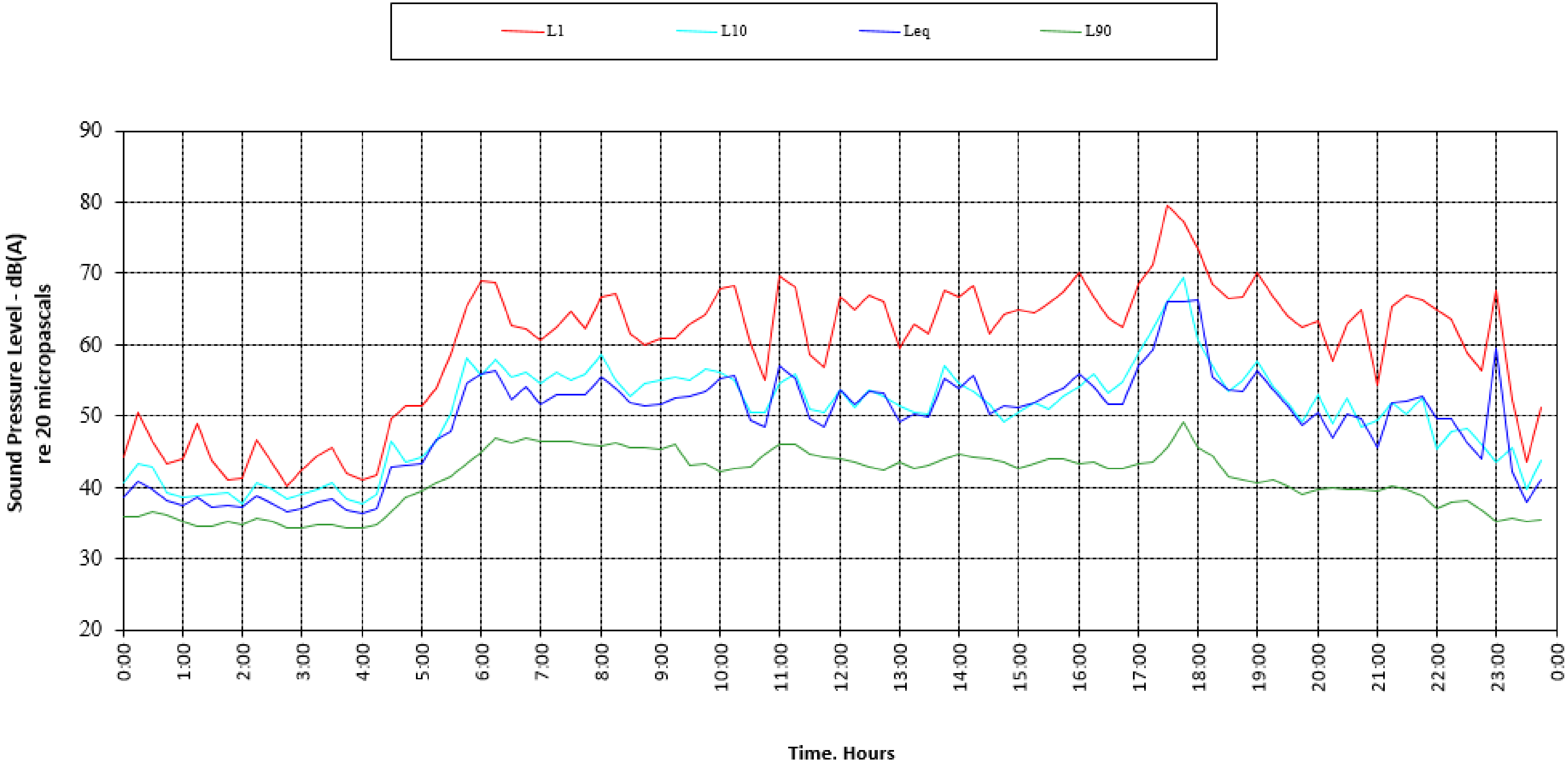
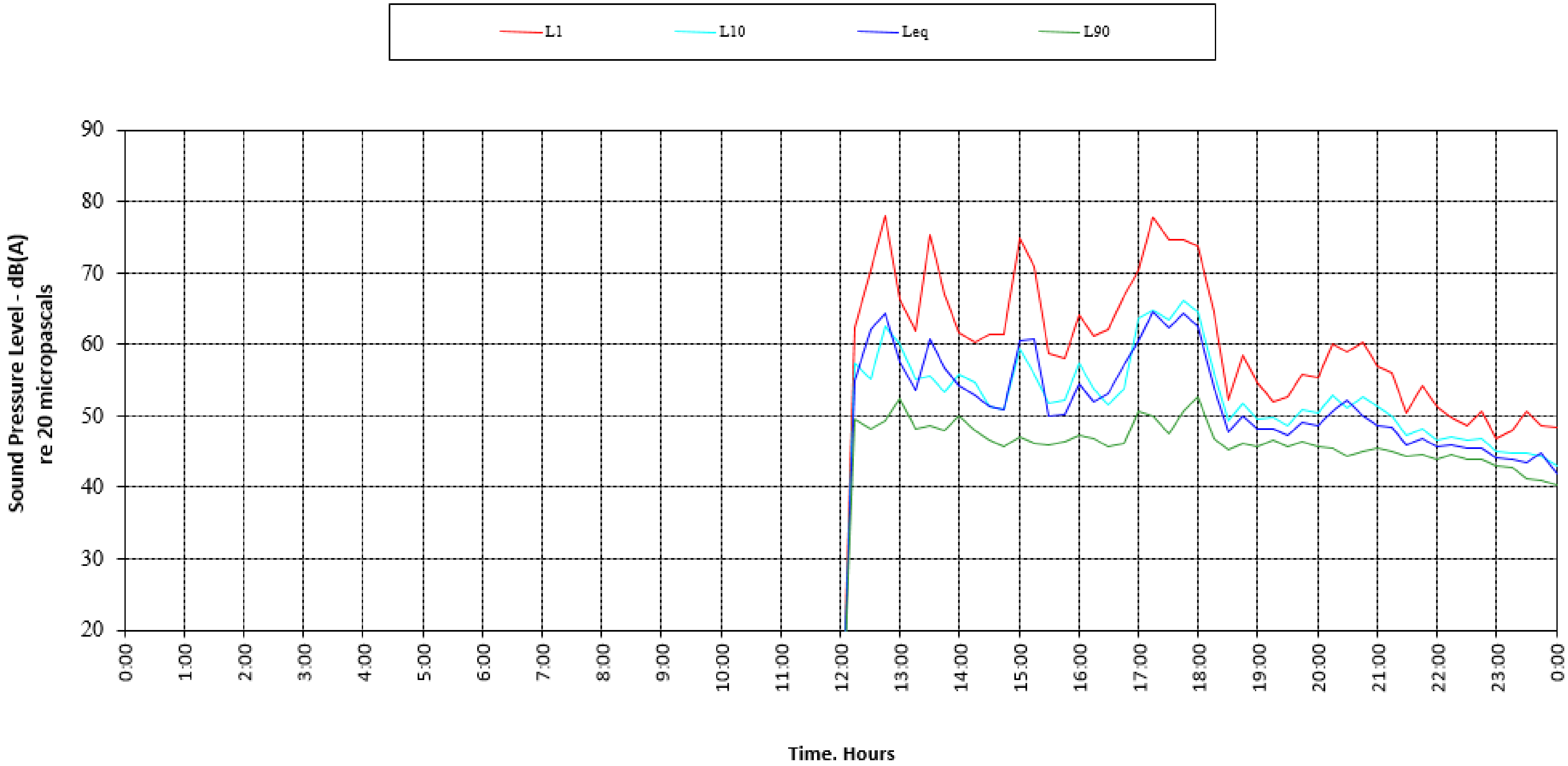


Figure 17: Noise data 19/04/2017 – L1



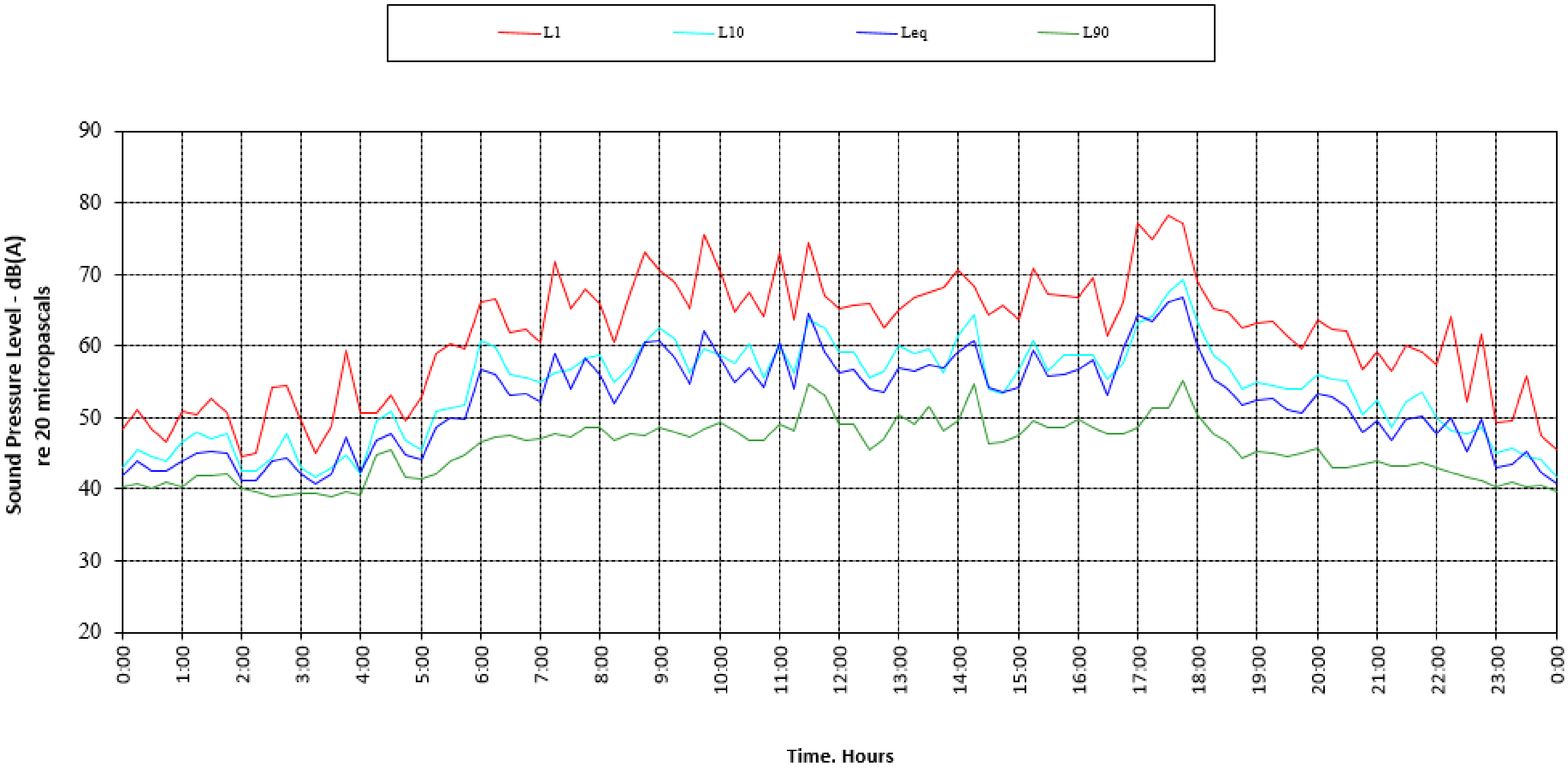
Appendix 2 – Noise Monitoring Data

Figure 18: Noise data 10/04/2017 – L2



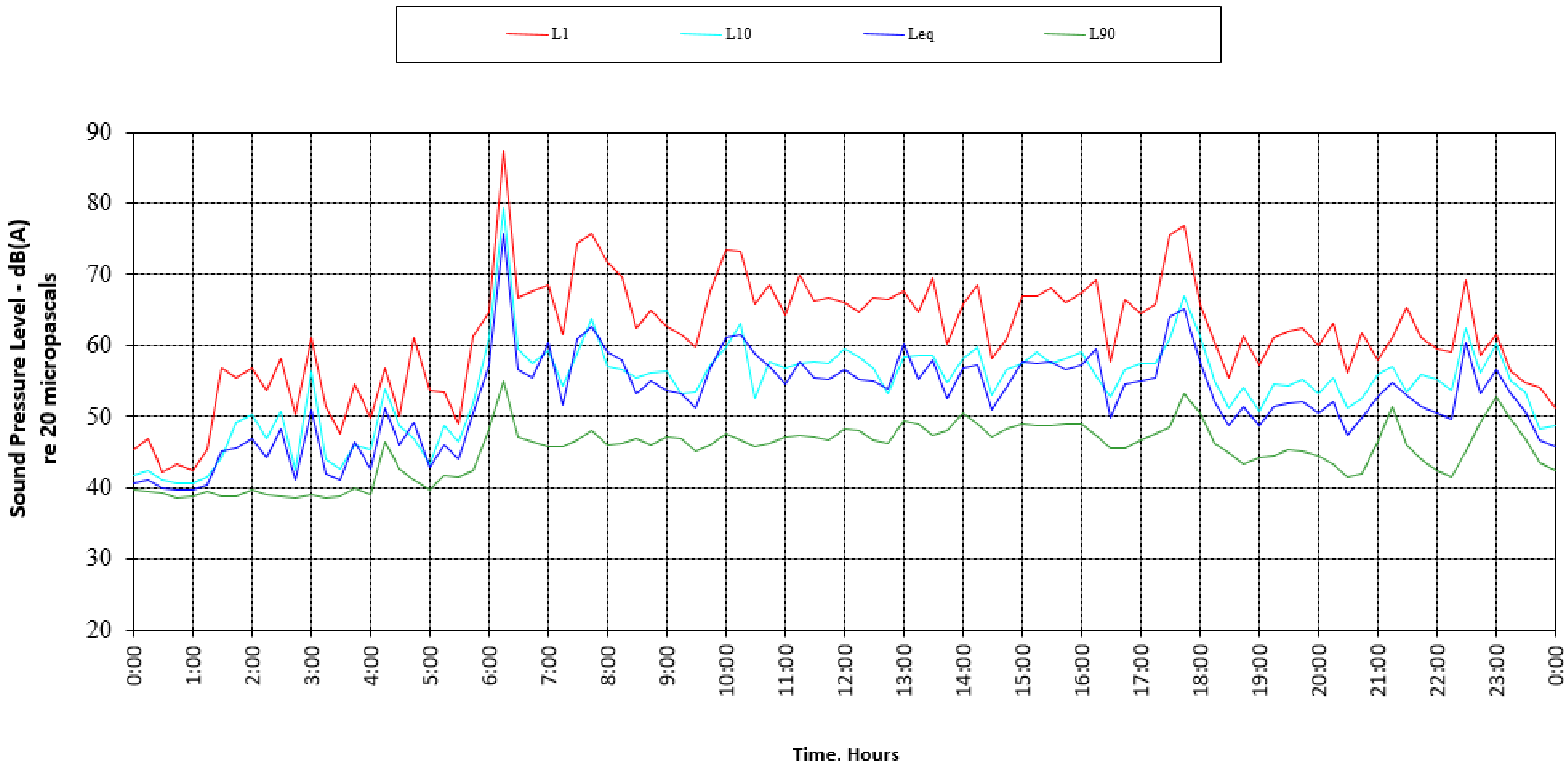
Appendix 2 – Noise Monitoring Data

Figure 19: Noise data 11/04/2017 – L2



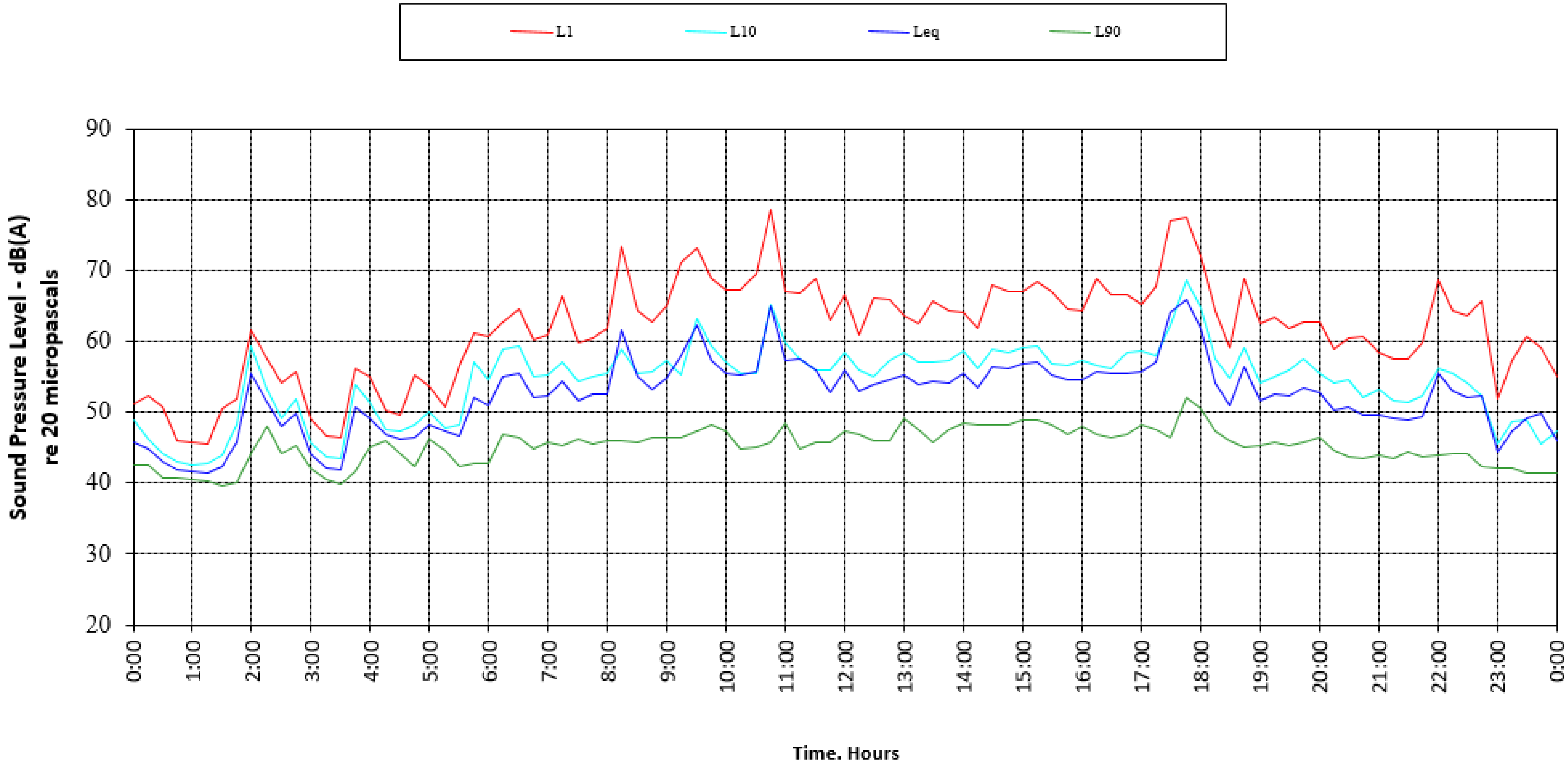
Appendix 2 – Noise Monitoring Data

Figure 20: Noise data 12/04/2017 – L2



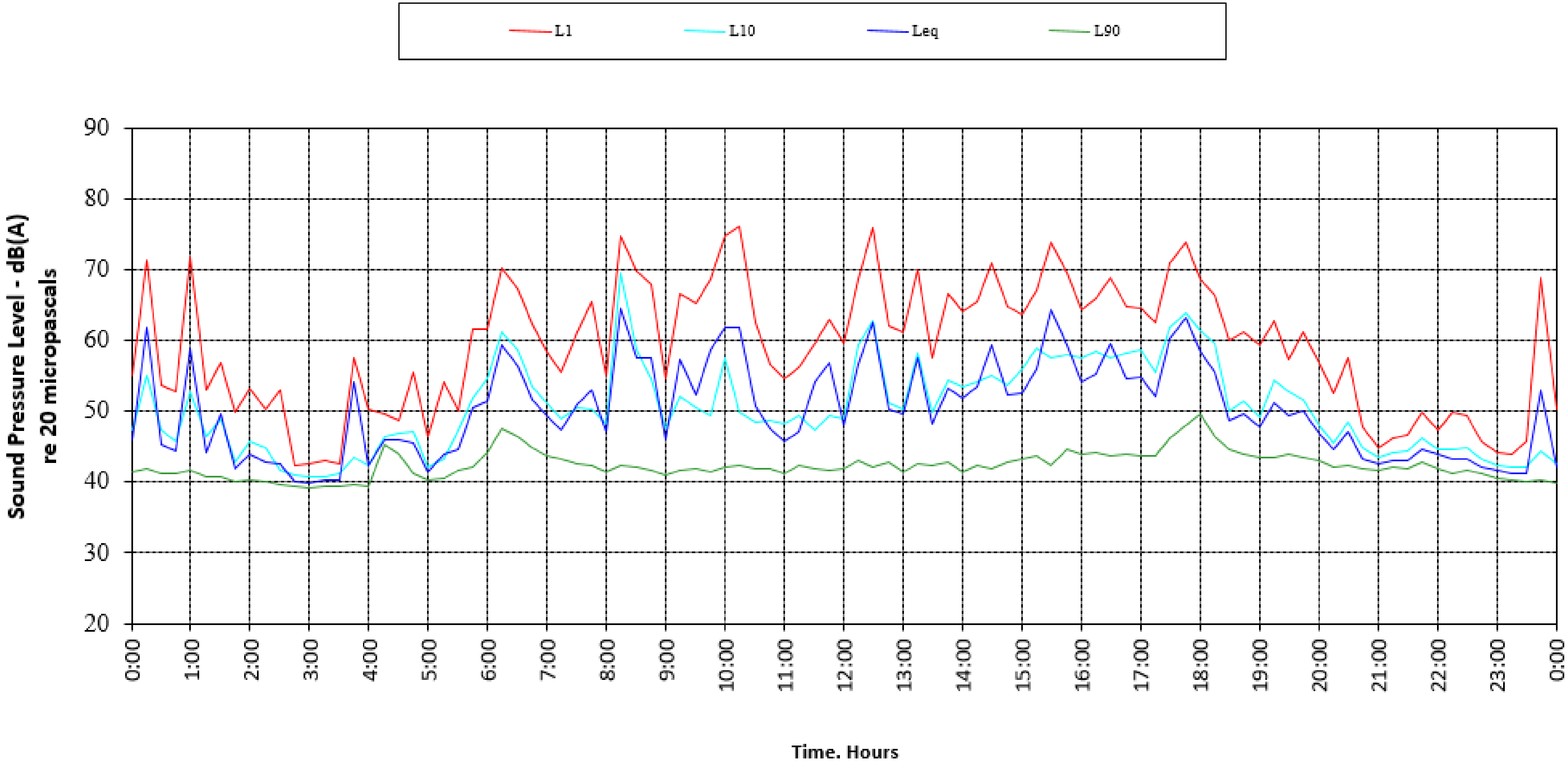
Appendix 2 – Noise Monitoring Data

Figure 21: Noise data 13/04/2017 – L2



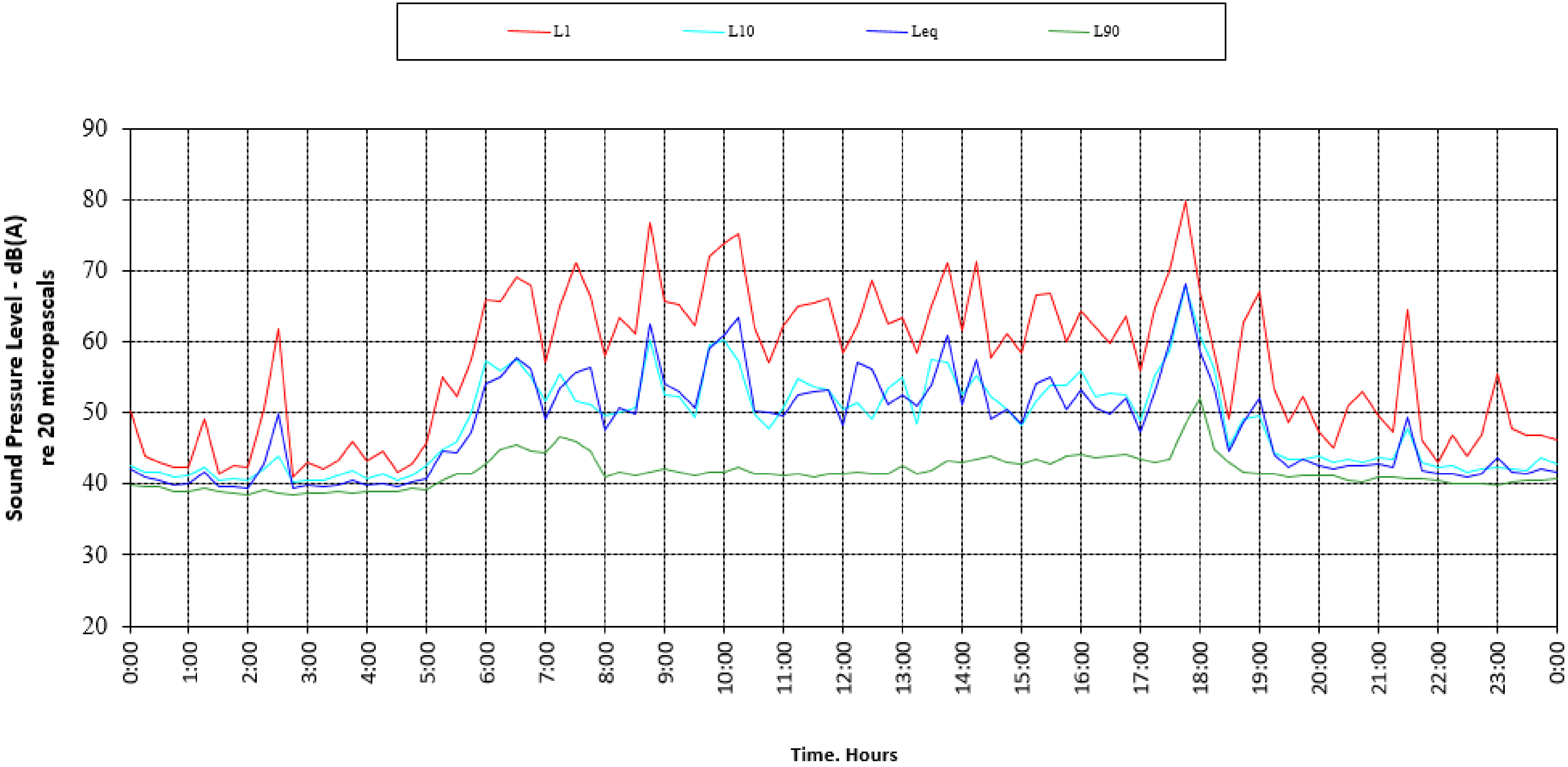
Appendix 2 – Noise Monitoring Data

Figure 22: Noise data 14/04/2017 – L2



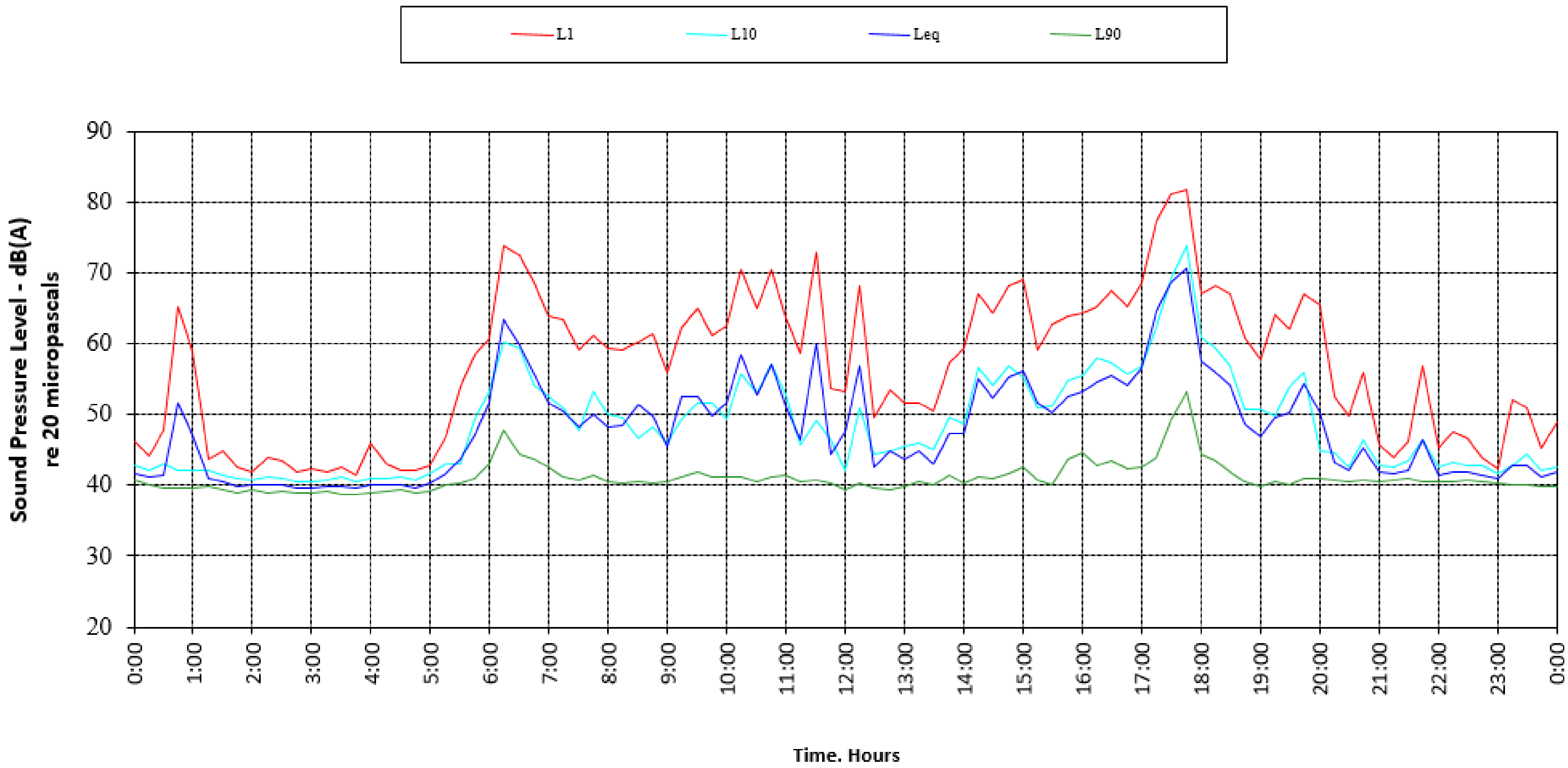
Appendix 2 – Noise Monitoring Data

Figure 23: Noise data 15/04/2017 – L2



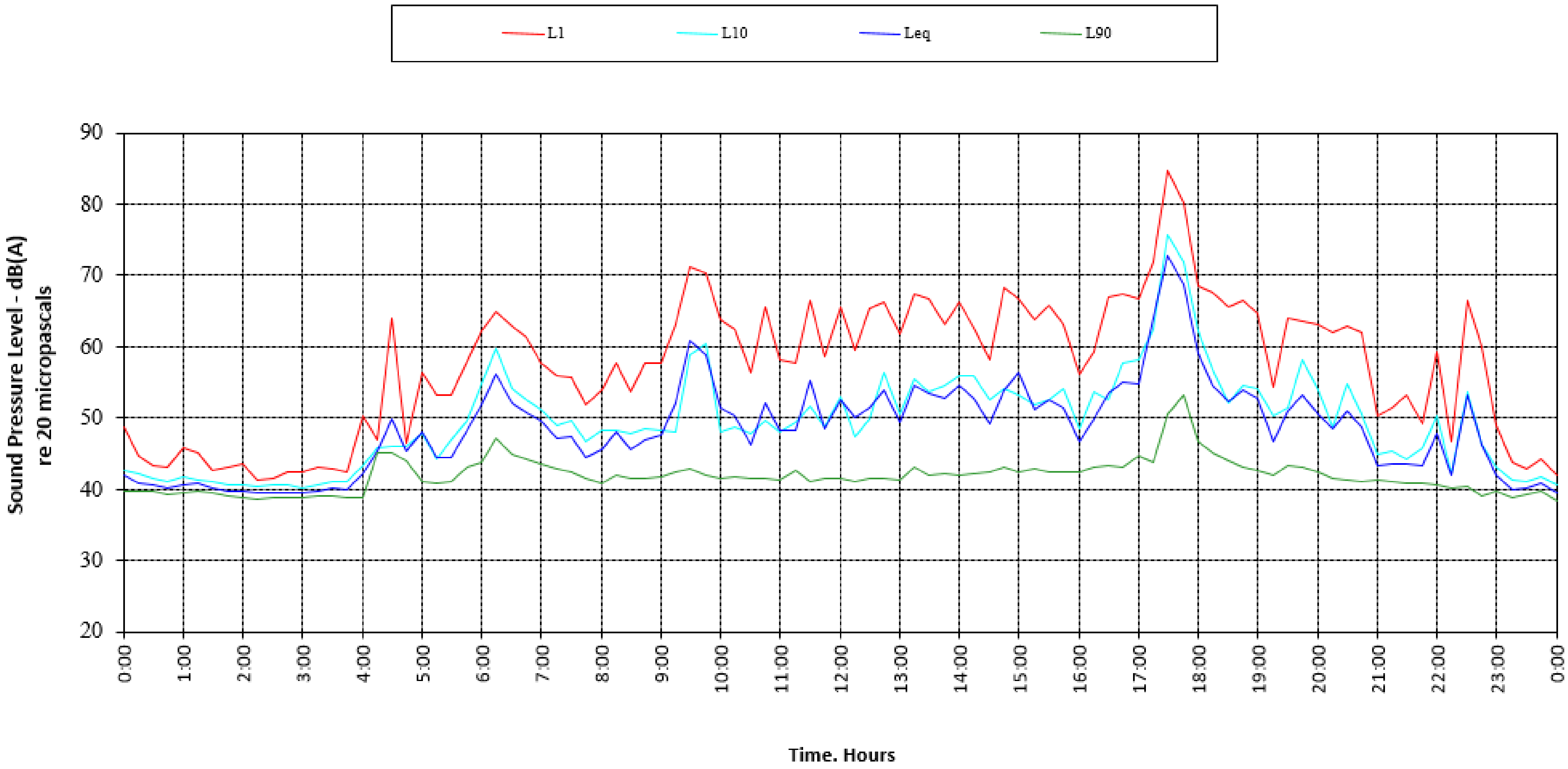
Appendix 2 – Noise Monitoring Data

Figure 24: Noise data 16/04/2017 – L2



Appendix 2 – Noise Monitoring Data

Figure 25: Noise data 17/04/2017 – L2



Appendix 2 – Noise Monitoring Data

Figure 26: Noise data 18/04/2017 – L2

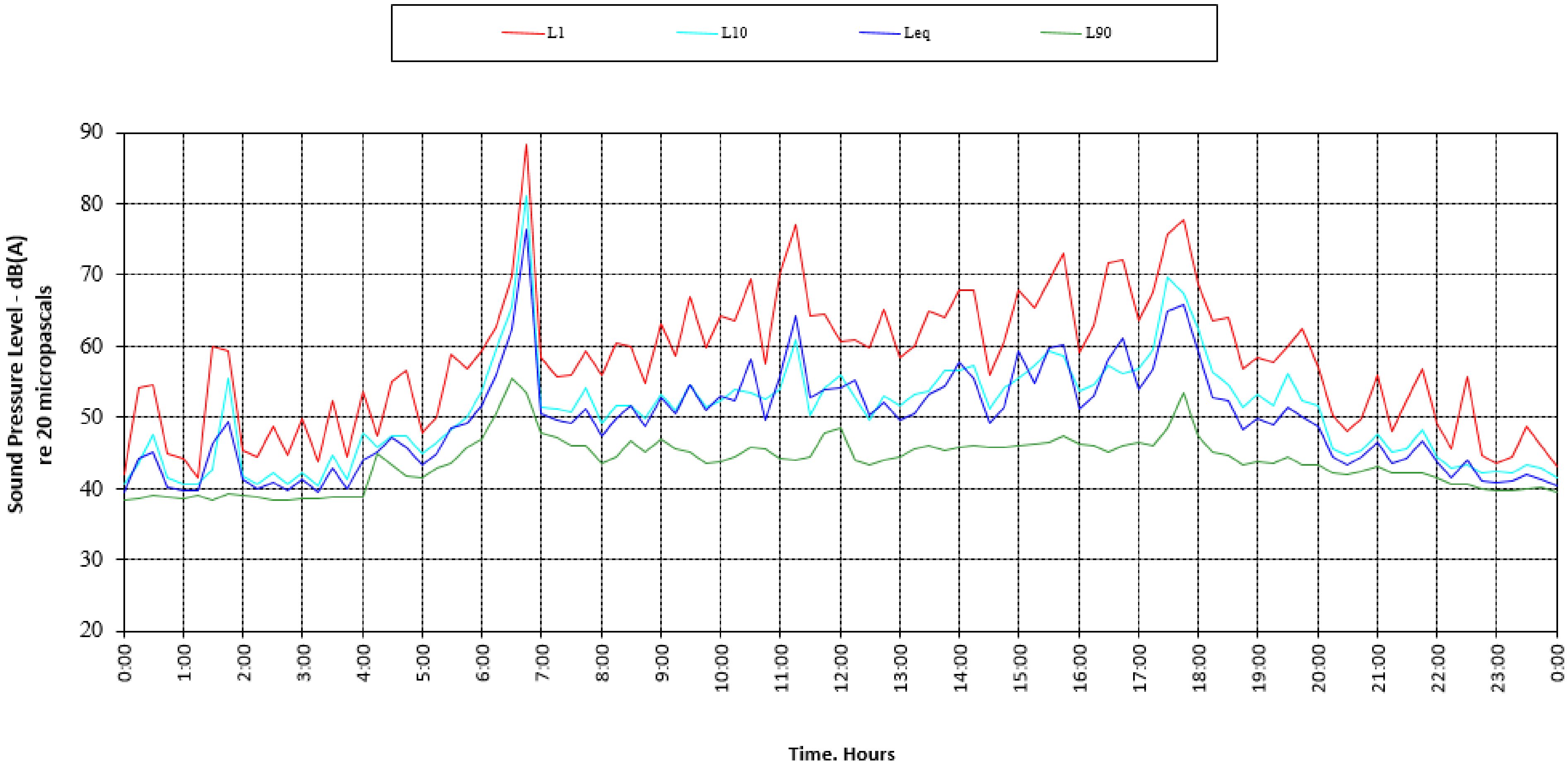
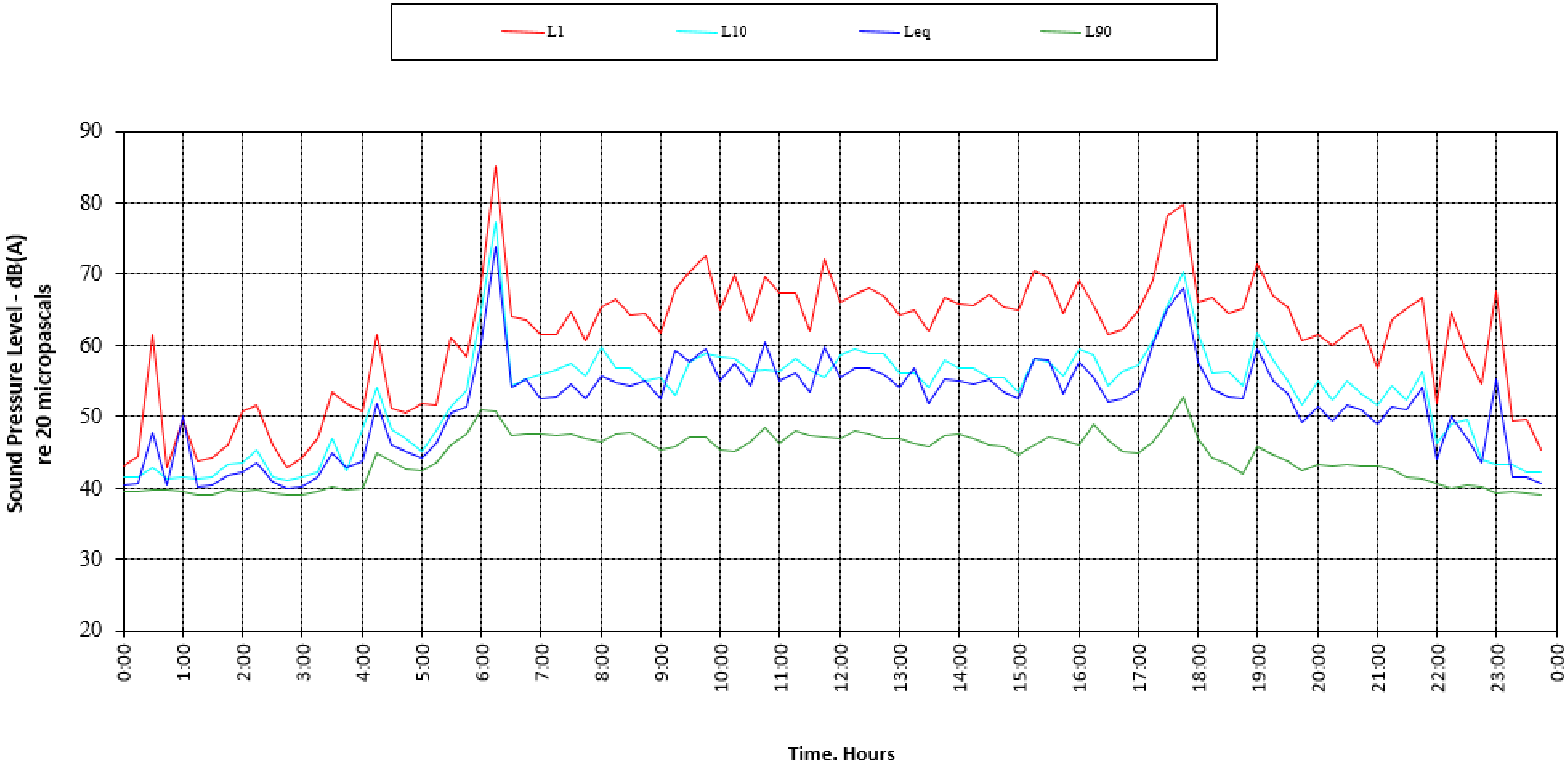
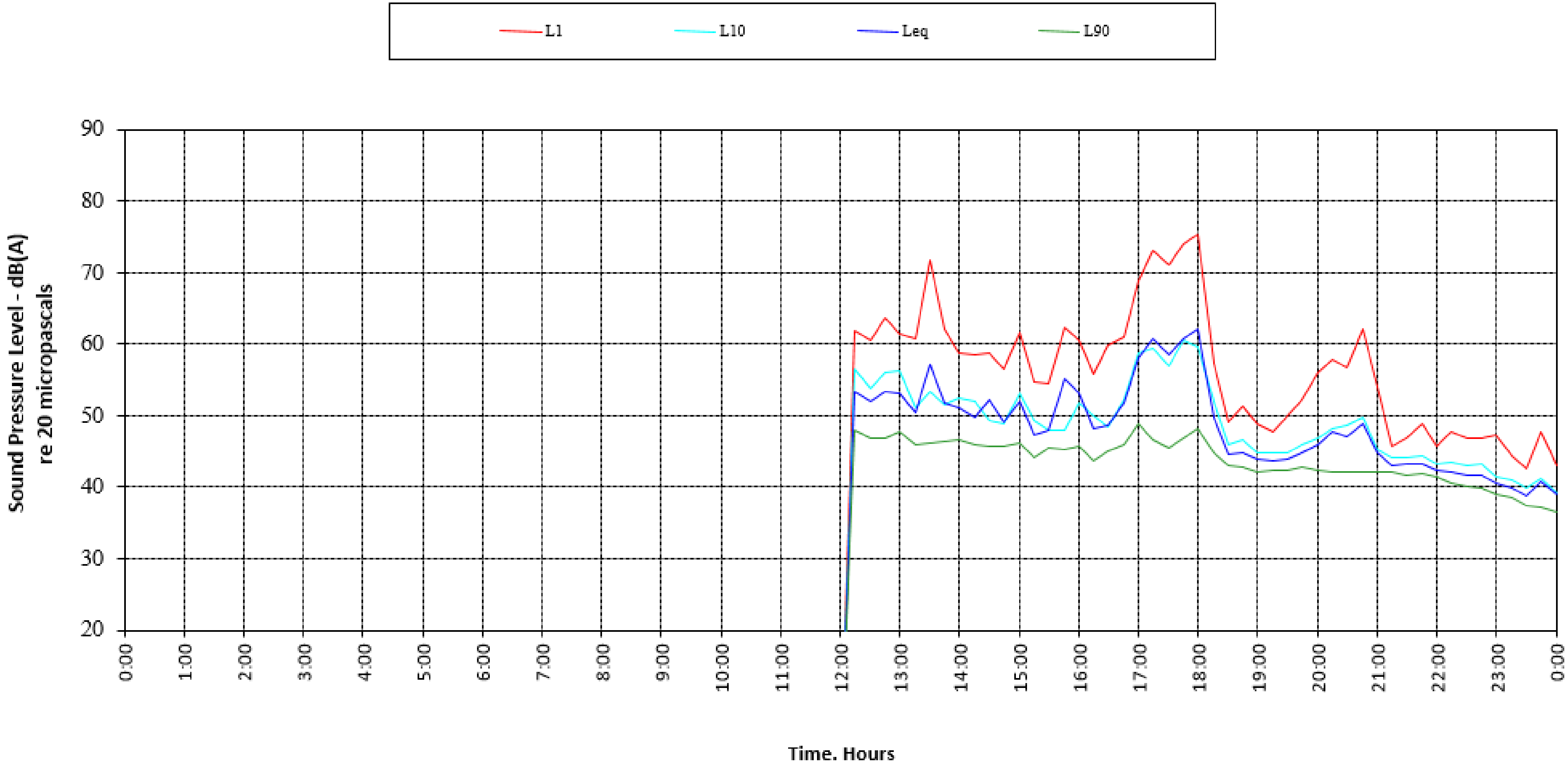


Figure 27: Noise data 19/04/2017 – L2



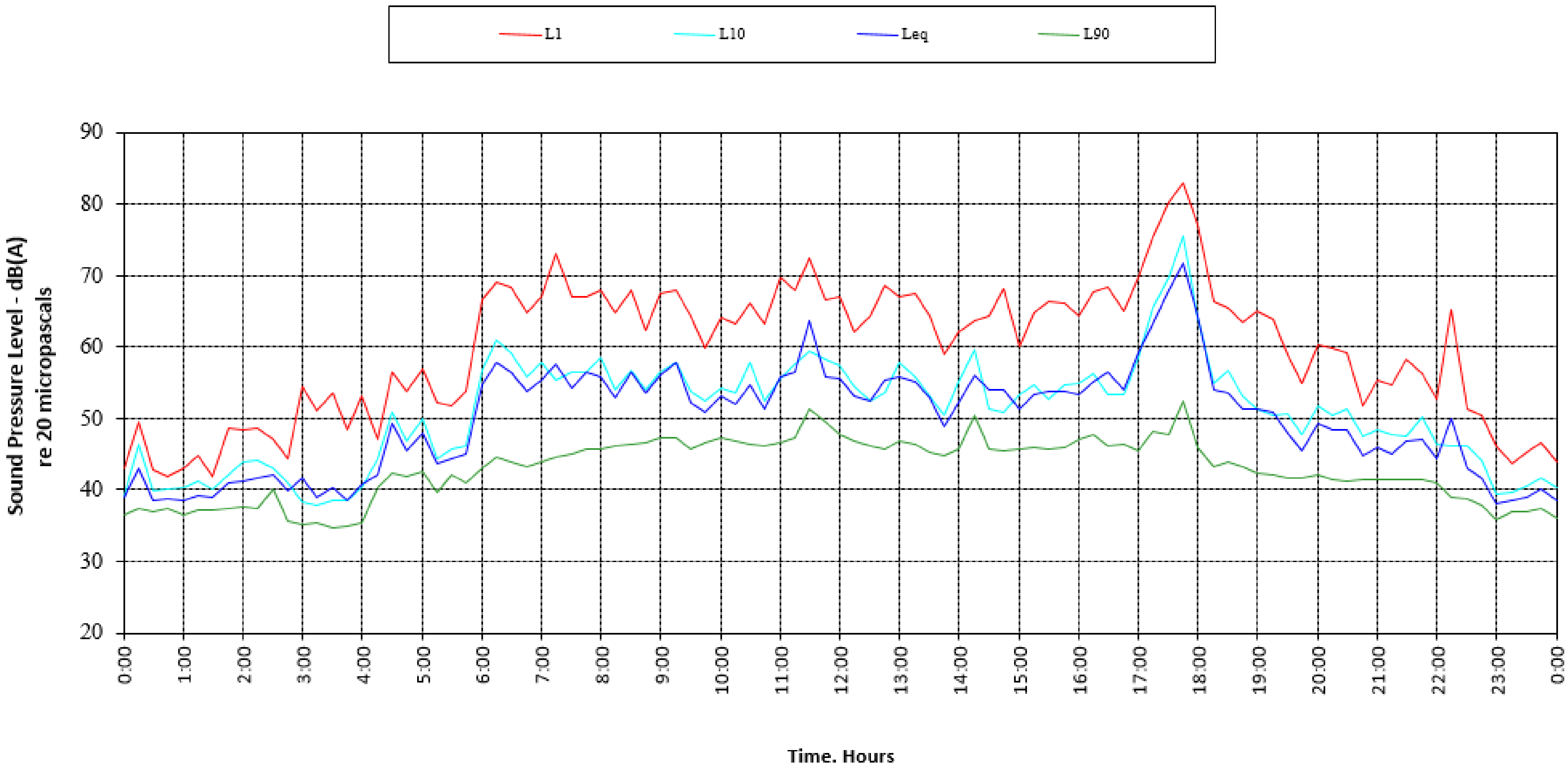
Appendix 2 – Noise Monitoring Data

Figure 28: Noise data 10/04/2017 – L3



Appendix 2 – Noise Monitoring Data

Figure 29: Noise data 11/04/2017 – L3



Appendix 2 – Noise Monitoring Data

Figure 30: Noise data 12/04/2017 – L3

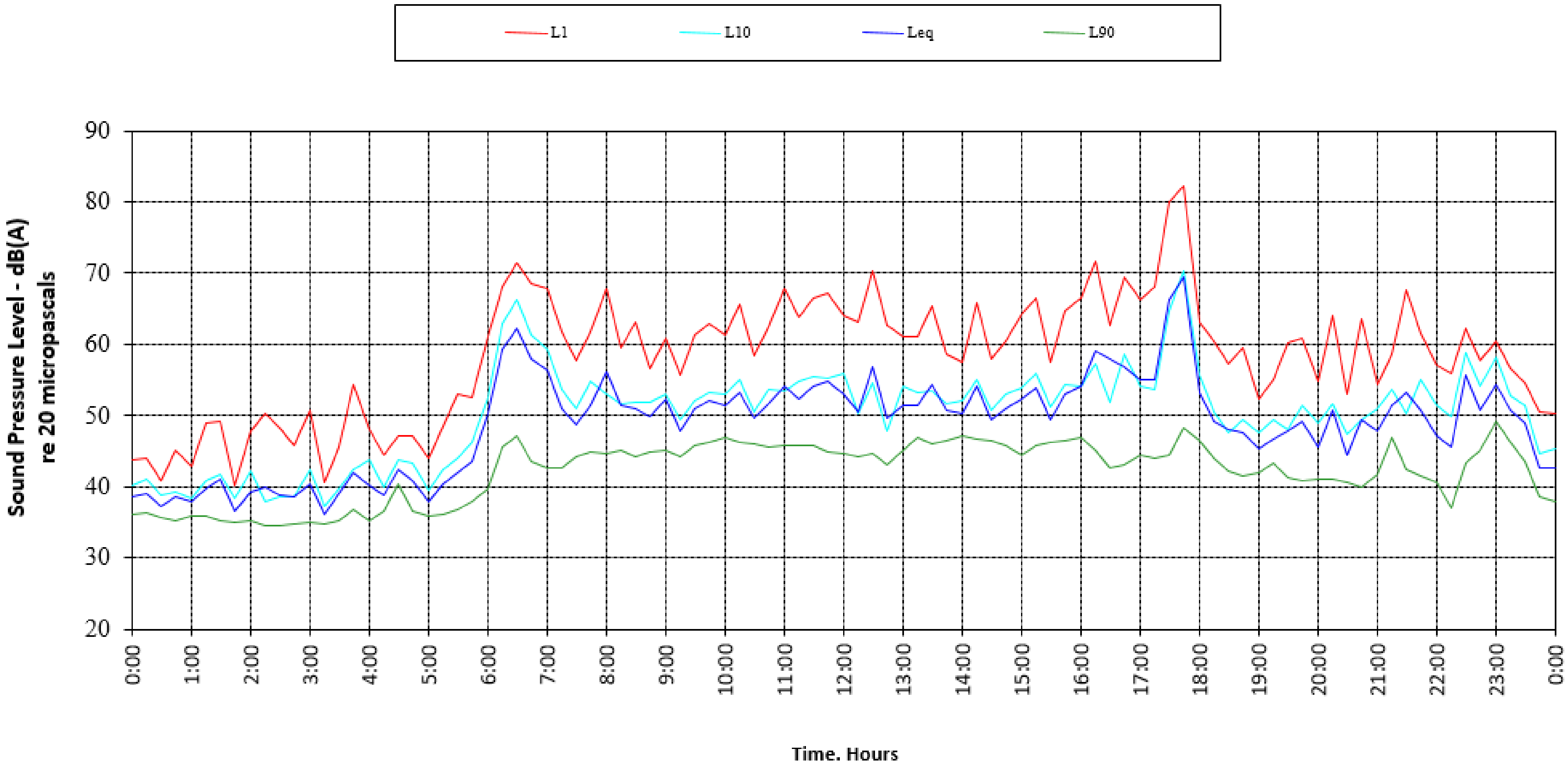


Figure 31: Noise data 13/04/2017 – L3

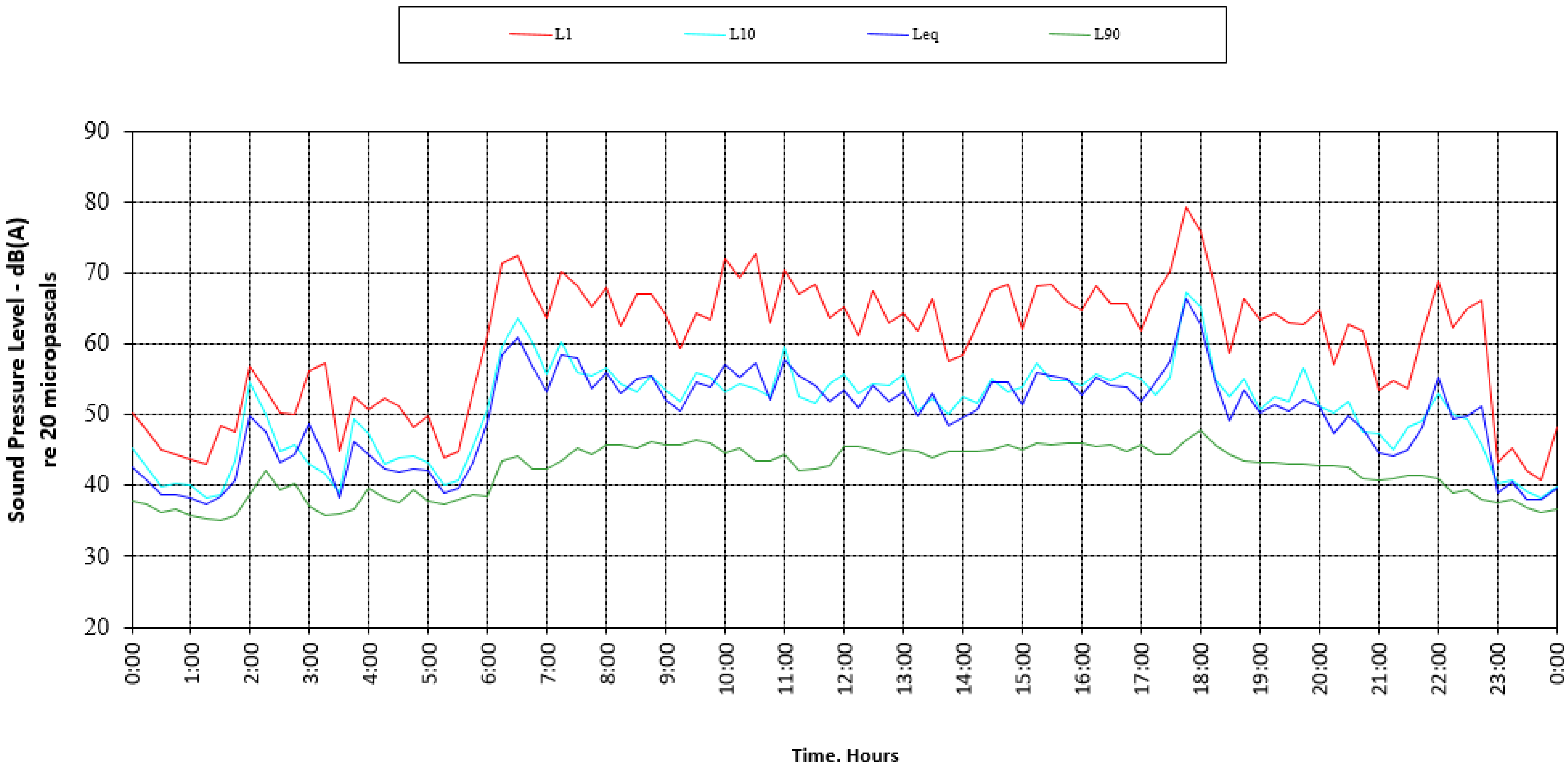


Figure 32: Noise data 14/04/2017 – L3

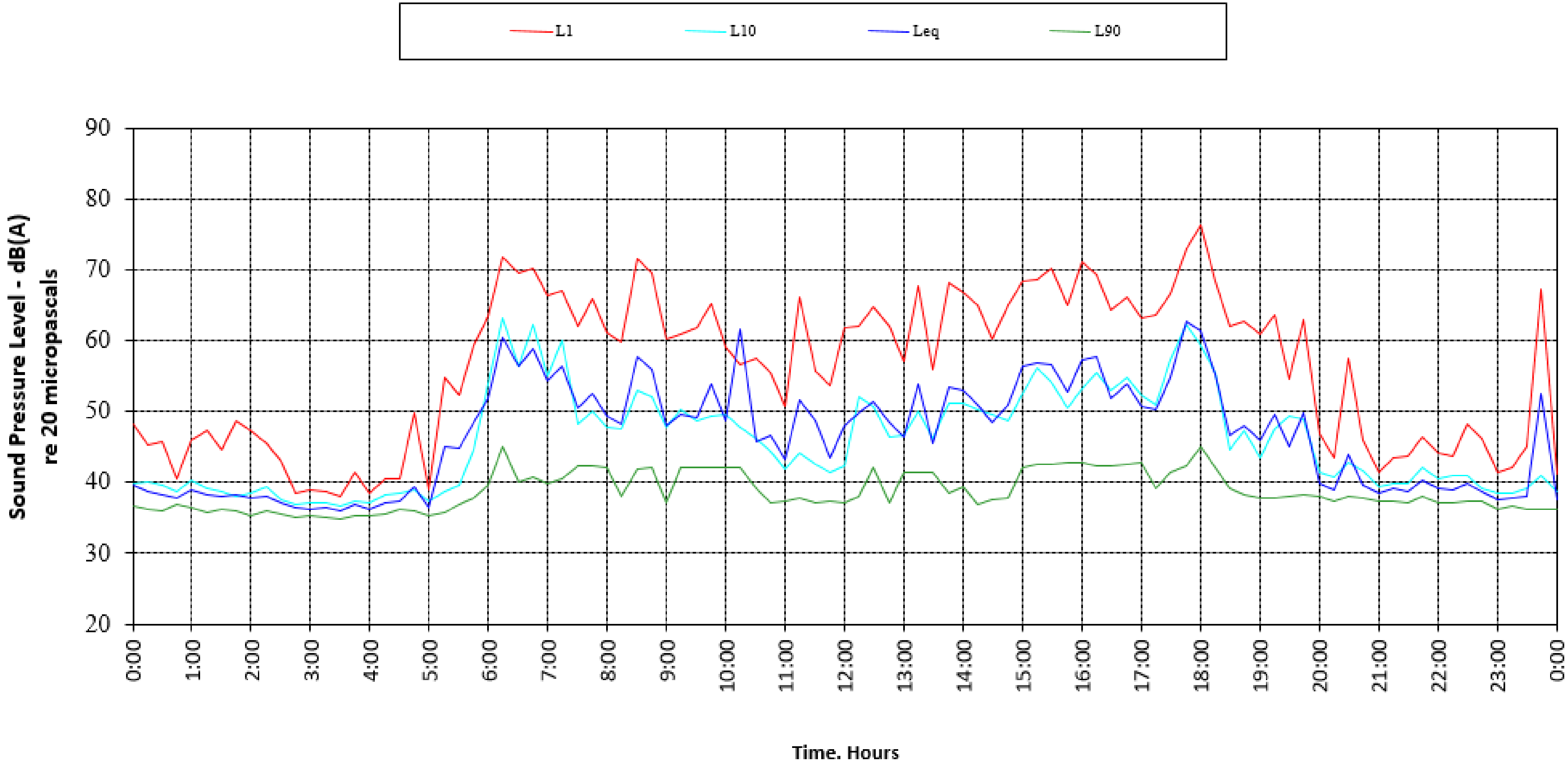
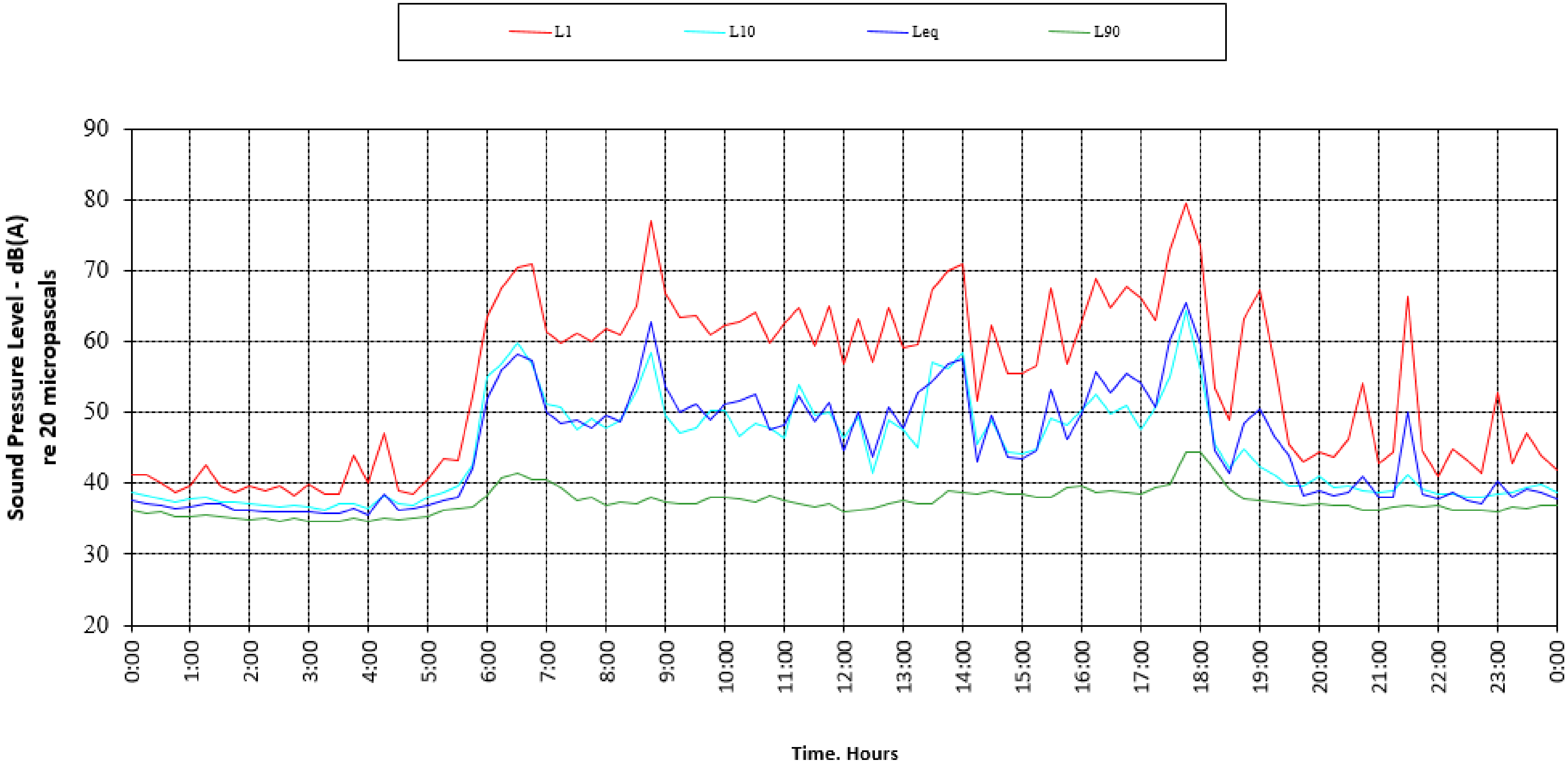
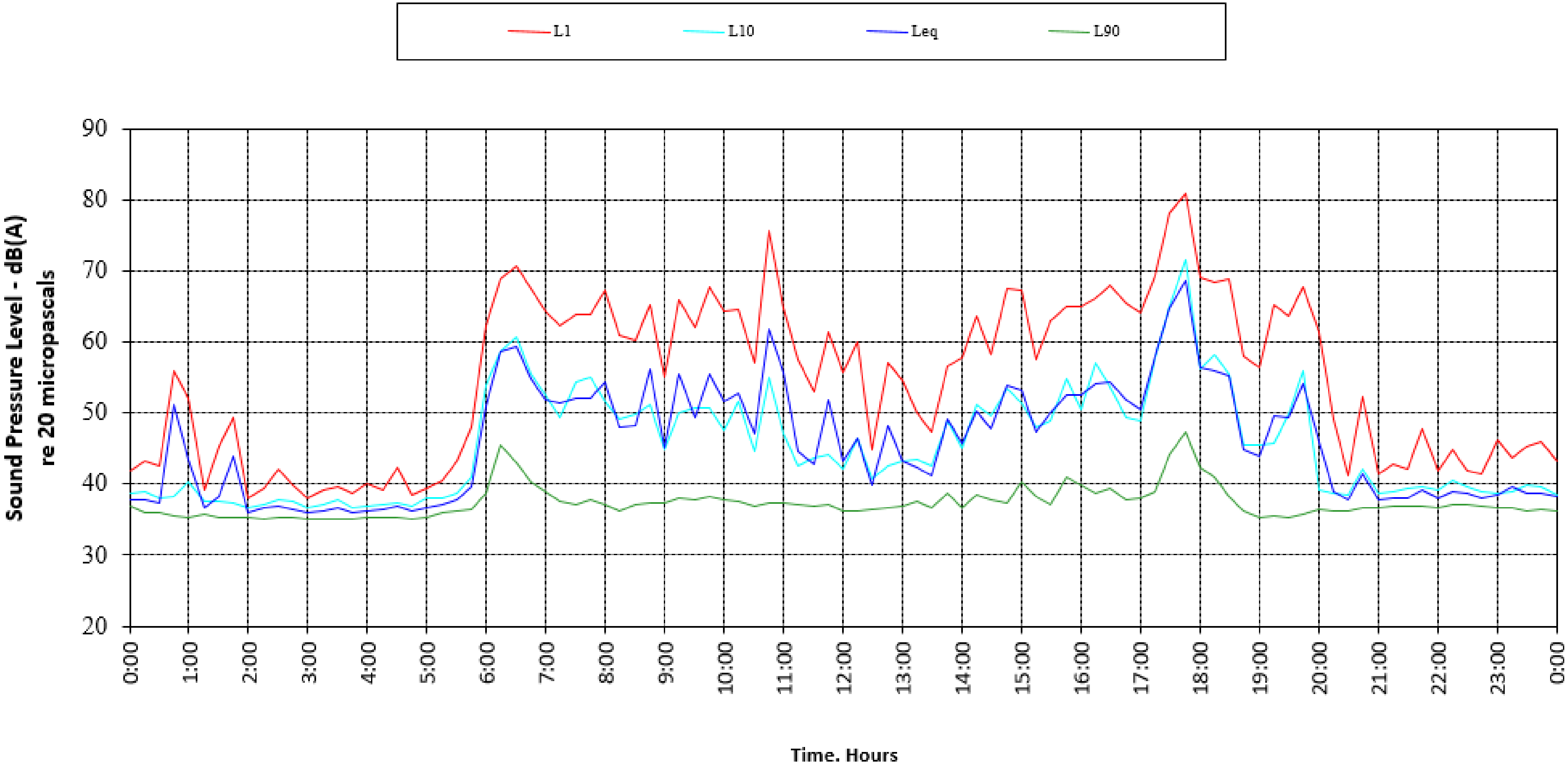


Figure 33: Noise data 15/04/2017 – L3



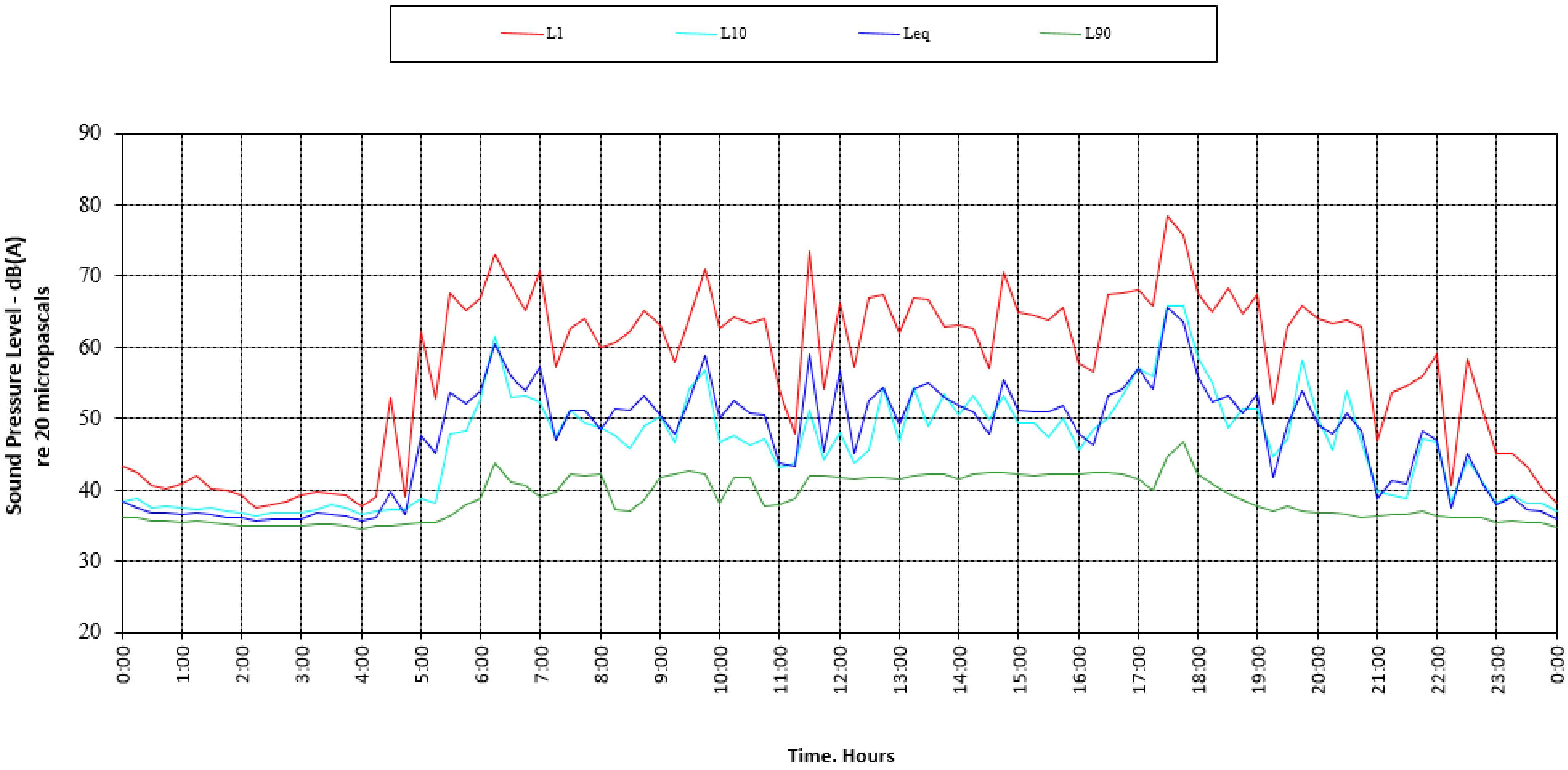
Appendix 2 – Noise Monitoring Data

Figure 34: Noise data 16/04/2017 – L3



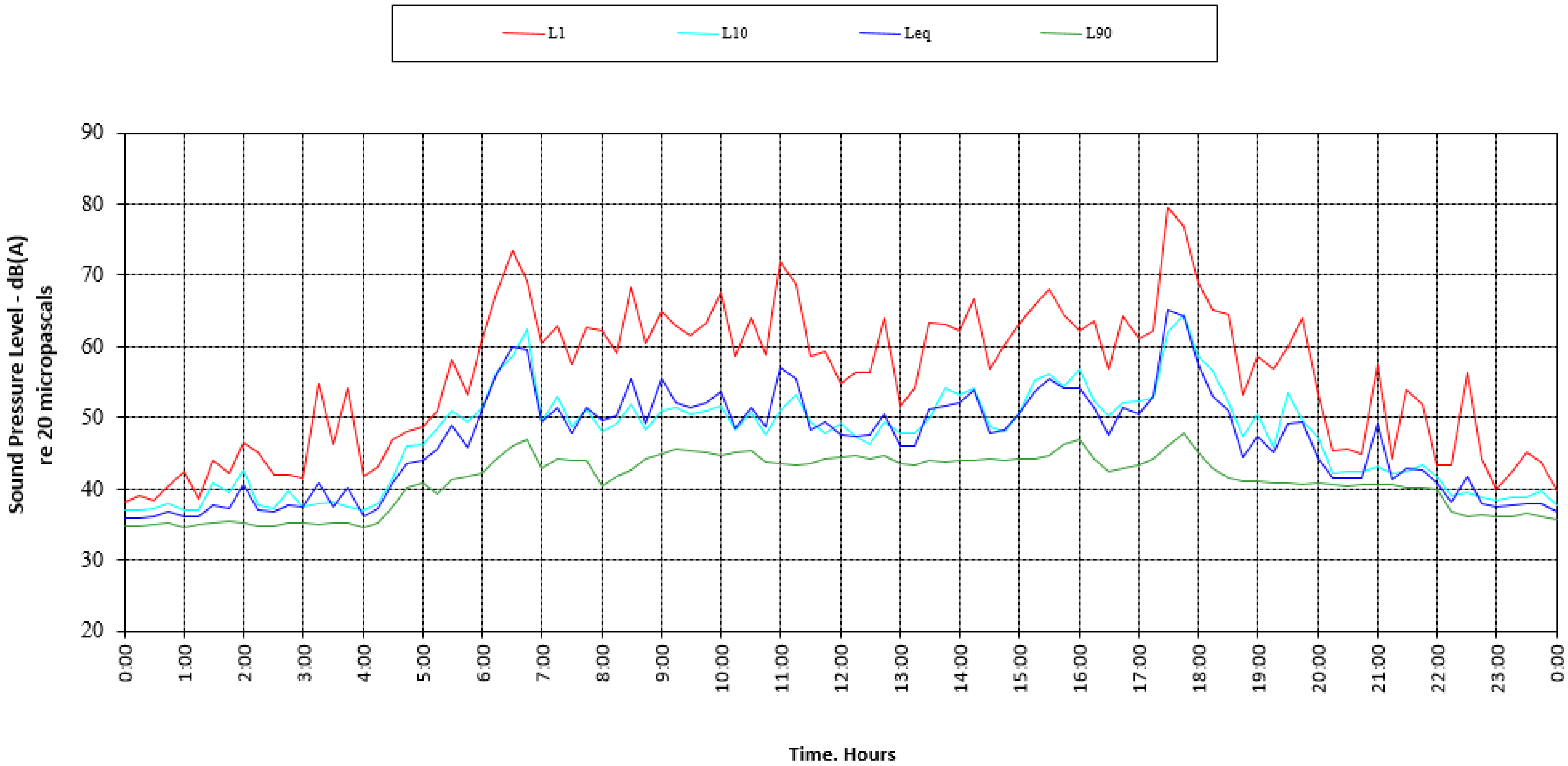
Appendix 2 – Noise Monitoring Data

Figure 35: Noise data 17/04/2017 – L3



Appendix 2 – Noise Monitoring Data

Figure 36: Noise data 18/04/2017 – L3



Appendix 2 – Noise Monitoring Data

Figure 37: Noise data 19/04/2017 – L3