Appendix M. Noise and vibration impact assessment

Shoalhaven Hydro Expansion Project - Main Works Environmental Impact Statement

SSI-10033

Origin Energy Eraring Pty Ltd

November 2022

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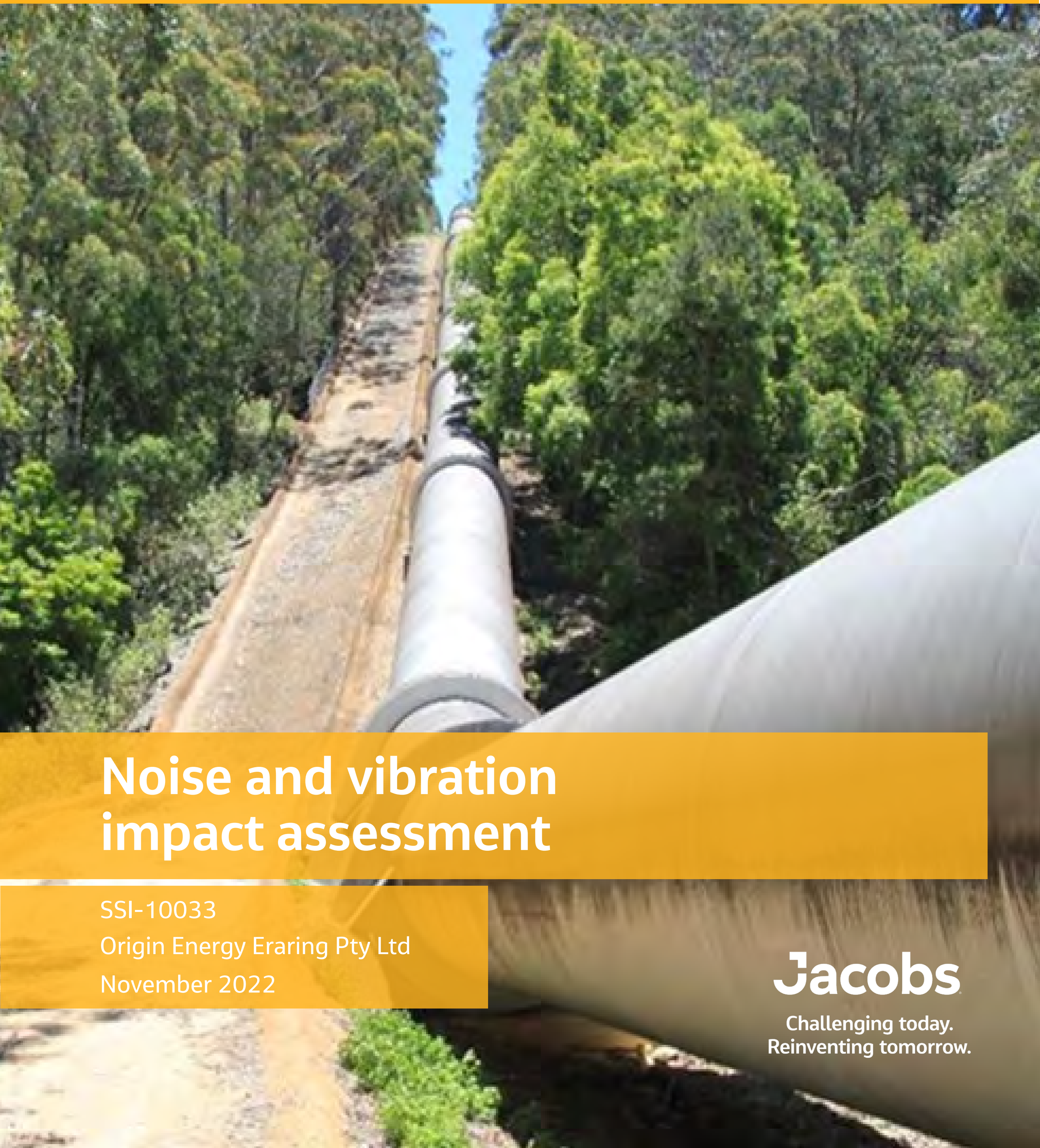
Reinventing tomorrow.

Shoalhaven Hydro Expansion Project - Main Works



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Executive summary

Origin Energy (Eraring) Pty Ltd (Origin) proposes to develop the Shoalhaven Hydro Expansion Project, a Project to construct and operate a new pumped hydro power station on and under the land between the Fitzroy Falls Reservoir and Lake Yarrunga (the Project). The Project would draw on Origin's existing water allocations to pump water up from Lake Yarrunga consuming energy during periods of low demand. Energy would then be generated through the return of water from Fitzroy Falls Reservoir to Lake Yarrunga when demand for energy increases.

This report provides an assessment of the potential noise and vibration impacts of the Project. Key noise and vibration-related issues, characterising key features of the existing environment relevant for the assessment, quantifying the different types of noise and vibration that is expected to be generated and assessing the potential impact of the Project on surrounding sensitive receivers. The assessment was carried out in accordance with the applicable legislation, policies, guidelines and standards. The key issues identified were airborne and ground-borne noise, air blast overpressure and vibration from surface and underground activities during construction (including blasting), operational noise and changes in road traffic noise along affected public routes during construction and operations. These issues were the focus of the assessment.

A review of key features of the existing environment was carried out including the identification of surrounding land uses and sensitive receivers, establishment of local background noise levels and existing traffic conditions along key Project travel and haulage routes. The following conclusions were made in relation to the existing environment:

- Twenty two sensitive receivers were identified within the vicinity of the Project. More populated areas were noted with the closest being Kangaroo Valley set approximately three kilometres (km) away
- Monitoring was completed at eight locations to establish background noise levels at these identified receivers. At all eight locations, background noise levels were low (less than 41 dB(A)), with most below the minimum day (35 dB(A)) and evening/night-time (30 dB(A)) RBLs recommended by the NPI
- Low traffic flows along key Project travel routes, with the nearest receivers also noted as being nearby (i.e. within 20 metres (m)) along these roads.

The key outcomes of the assessment were as follows:

- Construction airborne noise: A small number of receivers were predicted to experience noise levels above applicable noise management levels (NMLs). These exceedances are generally expected to be noticeable or clearly audible although over longer durations, rather than being highly intrusive. Measures to mitigate or otherwise effectively manage these risks were developed
- Operational airborne noise: Noise from operations during neutral and adverse, noise-enhancing meteorological conditions were predicted to be below the Project operational noise limits for all periods of the day (day, evening and night) at all surrounding sensitive receivers. As such, no specific measures were recommended
- Construction ground-borne noise and vibration from tunnelling: Ground-borne noise from the simultaneous construction of the Multipurpose Ventilation Tunnel and Underground Power Station. Access Tunnel using road headers was predicted to exceed the night-time limit of 35 dB(A) at one receiver. Predicted ground vibration levels were also estimated to exceed the criteria for human comfort during the day and night-time periods at two receivers. Recommendations to avoid more sensitive periods around this receiver were made, with additional actions included in-line with guidance presented in the CNVG
- Construction and operational traffic noise: Changes in noise from additional traffic may be noticeable at nearby receivers along key Project travel roads during construction. Measures were recommended to manage these effects
- Vibration from surface construction activities: Building cosmetic damage and human response vibration-related impacts for the using of plant and equipment during surface construction activities was not determined to present a risk at surrounding receivers
- Air blast overpressure and ground vibration from surface blasting during construction: Ground vibration and air blast overpressure are identified as Project risks and require detailed blast planning to comply with

the applicable criteria at all receivers and be protective of existing Water NSW infrastructure. It is recommended that the blast designers establish site-specific propagation parameters including weather conditions and rock and soil vibration transmission properties to ensure that the blast design achieves compliance with the ground vibration and air blast overpressure criteria

- Vibration from underground blasting during construction: Vibration levels from underground blasting activities associated with the underground power station cavern construction at surrounding sensitive receivers were predicted to remain below the adopted criterion of 5 mm/s. Detailed blast planning is recommended for management of underground blasting particularly should it be required as part of tunnelling works.

The noise and vibration impact assessment has been undertaken based on a conceptual model. Actual impacts and necessary mitigation measures would be confirmed as part of detailed design and documented in a construction noise and vibration management plan.

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Tables

Figures

Glossary and terms

Term	Definition
Ambient Noise Level	The prevailing noise level at a location due to all noise sources but excluding the noise from the specific noise source under consideration. Generally measured as a dB(A) noise level.
Acoustic Spectrum	The sound pressure level (or sound power level) as a function of frequency (eg octave band, ⅓ octave or narrow band). Generally used to identify noise sources or items contributing disproportionately to an overall noise level.
Barriers	Generally a wall or an earth mound that obstructs or restricts the passage of sounds waves from a noise source. Barriers usually require a surface density of not less than 15 kg/m^2 and an overall weighted Sound Reduction Index (R_w) of no less than 30 dB when tested in accordance with ISO 10140-2:2021[1] to be considered effective. The barriers are also assumed to be installed without holes or gaps (eg underneath the barrier), to prevent noise transmission.
Background Noise Level	The lower ambient noise level, usually defined as the value of the time varying ambient noise level exceeded for 90% of the measurement time. Usually defined in the dB(A) scale - L_{A90}.
CNVG	Construction Noise and Vibration Guideline
dB	Sound pressure levels are expressed in decibels as a ratio between the measured sound pressure level and the reference pressure. The reference pressure is 20×10^{-6} Pascal (Newtons per square metre (m^2). Some typical noise levels are presented below:

Sound Pressure Level, dB(A)	Example
130	Threshold of pain
120	Jet aircraft take-off at 100 m
110	Power tool at 1 m
100	Nightclub
90	Heavy trucks at 5 m
80	Kerbside of busy street
70	Loud radio (in typical domestic room)
60	Office
50	Domestic fan heater at 1m
40	Living room
30	Theatre
20	Rural environment on still night
10	Sound insulated test chamber
0	Threshold of hearing

[1] ISO 10140-2:2021 Acoustics — Laboratory measurement of sound insulation of building elements — Part 2: Measurement of airborne sound insulation

Term	Definition
dB(A)	The A-weighted sound pressure level in decibels, denoted dB(A) is the unit generally used for the measurement of environmental, transportation or industrial noise. The A-weighting scale approximates the sensitivity of the human ear when it is exposed to normal levels and correlates well with subjective perception over a number of different types of sounds. An increase or decrease in sound level of approximately 10 dB corresponds to a subjective doubling or halving in loudness. A change in environmental noise level of 2 dB is considered to be just noticeable.
dB(C)	The unit used for measuring occupational health and safety maximum industrial noise levels in Australia is the C-weighted sound pressure level in decibels, denoted dB(C). C-weighting has a relatively flat response when compared to an A-weighting network.
dB(Z)	Z-Weighted Decibel or Linear Decibel
DEC	Department of Environment and Conservation
DECC	Department of Environment and Climate Change
DECCW	Department of Environment, Climate Change and Water NSW
DIL	Dynamic Insertion Loss
DPE	Department of Planning and Environment (formerly Department of Planning, Industry and Environment or DPIE)
EPA	NSW Environment Protection Authority
EPL	Environment Protection Licence
Feasible and reasonable	Consideration of best practice taking into account the benefit of proposed measures and their technological and associated operational application in the NSW and Australian context. Feasible relates to engineering considerations and what is practical to build. Reasonable relates to the application of judgement in arriving at a decision, taking into account mitigation benefits and cost of mitigation versus benefits provided, community views and nature and extent of potential improvements.
Frequency	The rate of repetition of a sound wave. The unit of frequency is the Hertz (Hz), defined as one cycle per second.
Feasible and reasonable	Consideration of best practice taking into account the benefit of proposed measures and their technological and associated operational application in the NSW and Australian context. Feasible relates to engineering considerations and what is practical to build. Reasonable relates to the application of judgement in arriving at a decision, taking into account mitigation benefits and cost of mitigation versus benefits provided, community views and nature and extent of potential improvements.
Frequency	The rate of repetition of a sound wave. The unit of frequency is the Hertz (Hz), defined as one cycle per second. Human hearing ranges approximately from 20 Hz to 20,000 Hz. For design purposes, the octave bands between 63 Hz to 8 kHz are generally used. The most commonly used frequency bands are octave bands. For more detailed analysis each octave band may be split into three one-third octave bands or in some cases, narrow frequency bands.
ICNG	Interim Construction Noise Guideline, (DECC, 2009)
ISO	International Organization for Standardization
Jacobs	Jacobs Group (Australia) Pty Limited

Term	Definition
L_1	The L_1 statistical level is sometimes used to represent the maximum level of a sound that varies with time. Mathematically, the L_1 level is the level exceeded for 1% of the measurement period.
$L_{AF1(1\ minute)}$	The A-weighted sound pressure level measured using the 'Fast' response time setting, exceeded for 1% of the time interval, where the time interval is 1 minute.
L_{A10}	The A weighted sound pressure level that is exceeded for 10% of the measurement period. It is often referred to as the average of the maximum values.
L_{A90}	The A weighted sound pressure level that is exceeded for 90% of the measurement period. Usually used to represent the background noise level.
L_{eq}	The equivalent continuous sound level. The 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.
L_{Aeq}	The A weighted equivalent continuous sound level is denoted L_{Aeq}.
L_{Max}, L_{FMax}, L_{Smax} L_{AMax}, L_{AFMax}, L_{ASMax}	The maximum measured linear (un-weighted or Z) sound pressure level. The L_{Max} variations, L_{FMax}, L_{SMax} are the L_{Max} levels using the "Fast" and "Slow" networks respectively. The A-weighted variations, L_{AMax}, L_{AFMax} and L_{ASMax}.are also used in various guidelines and standards
L_W	The Sound Power Level of a source is a measure of the total acoustic power radiated by a source. It is a characteristic of the sound source which is not affected by the environment within which the source is located.
NATA	National Association of Testing Authorities
NC	Noise Control
NCA	Noise Catchment Area
Noise immission	Received noise at a receiver (either internally within a building or external at an outdoor receiver)
NR	Noise Reduction
NSW RMS	New South Wales Roads and Maritime Service
PPV	Peak particle velocity measured in millimetres per second
RBL	The Rating Background Level for each period is the medium value of the ABL values for the period over all of the days measured. There is therefore an RBL value for each period (day, evening and night)
RMS	Root mean squared
SEARs	Secretary's Environmental Assessment Requirements
Sound Level Meter	An instrument consisting of a microphone, amplifier and data analysis package for measuring and quantifying noise.
SPL	Sound Pressure level (dB)
SWL	Sound Power Level (dB)
Suitably qualified acoustic consultant	An acoustic consultant who is a full member of the Australian Acoustical Society (or equivalent)

Term	Definition
t	Tonnes
TL	Transmission Loss, a measure of change in sound pressure level, incidence vs. transmitted
UTM	Universal Transverse Mercator

1. Introduction

1.1 Project overview

Origin Energy (Eraring) Pty Ltd (Origin) proposes to develop the Shoalhaven Hydro Expansion Project, to construct and operate a new pumped hydro power station on and under the land between the Fitzroy Falls Reservoir and Lake Yarrunga (the Project). The Project would draw on Origin's existing water allocations to pump water up from Lake Yarrunga consuming energy during periods of low demand. Energy would then be generated through the return of water from Fitzroy Falls Reservoir to Lake Yarrunga when demand for energy increases.

The Project would involve almost doubling the electricity generation capacity of the existing scheme, providing a nominal additional 235 megawatts (MW) of generation capacity. The operation of the scheme would respond to the needs of the National Energy Market (NEM) and involve up to one pumping and generation cycle per day. Each generation cycle is anticipated to involve up to eight hours of generation and 16 hours of pumping, each of which could be divided into shorter durations to best satisfy the needs of the NEM.

The Project overview is shown in **Figure 1-1**. An indicative Project layout based on the current reference design is provided in **Figure 1-2** and consists of the construction and operation of:

- Upper scheme components (Upper Scheme) including:
  - Connection to existing upper intake control structure at the southern end of the Fitzroy Canal
  - A surface penstock (water transfer pipeline and associated infrastructure) from the existing Fitzroy Canal control structure to the vicinity of the Existing Scheme surge tank
  - A new surge tank adjacent to the Existing Scheme surge tank
  - A further section of surface penstock, adjacent to the Existing Scheme, from the new surge tank to the high pressure shaft
- Underground works (Underground Works) including:
  - Vertical shaft and headrace tunnel connecting to the southern end of Upper Scheme surface penstock to an underground power station
  - An underground power station cavern housing a transformer, reversible motor generator and pump turbine capable of supplying a nominal 235 MW of hydroelectric power
  - Associated access tunnel and multipurpose (egress, ventilation and services) tunnel with an entrance in the vicinity of the existing Kangaroo Valley Power Station
  - A tailrace tunnel, including an underground surge chamber located just downstream of the underground power station, terminating west of the existing Bendeela Power Station on Lake Yarrunga
- Lower scheme surface components (Lower Scheme) including:
  - Lower intake /outlet structure west of the Bendeela Power Station connected to the tailrace tunnel
  - Spoil emplacement facility east of Bendeela Pondage
  - High voltage network connection to existing Kangaroo Valley substation
  - Operational surface infrastructure including administration building, water treatment infrastructure and ventilation building.

The Project would also require ancillary works which may include the carrying out of works to upgrade or construct access roads, spoil disposal sites, utilities infrastructure, construction compounds and construction power and water supply.

Importantly, the Project essentially duplicates the existing scheme and as such does not propose any new water storages or connections between waterbodies that have not already been utilised for the existing scheme. In addition, no transmission line augmentations are required to receive or distribute electricity from the existing Kangaroo Valley Power Station substation.

A full Project description is provided in Chapter 3 of the Environmental Impact Statement (EIS). Key components of the Project of relevance to this report are provided in **Section 5**. This report provides an assessment of the potential noise and vibration impacts of the Project.

Legend

- Project location
- Points of interest
- Indicative Shoalhaven Hydro Expansion Project Footprint
- NPWS Reserve
- State Forest

0 5 10 km

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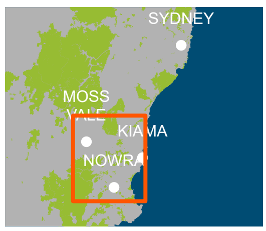
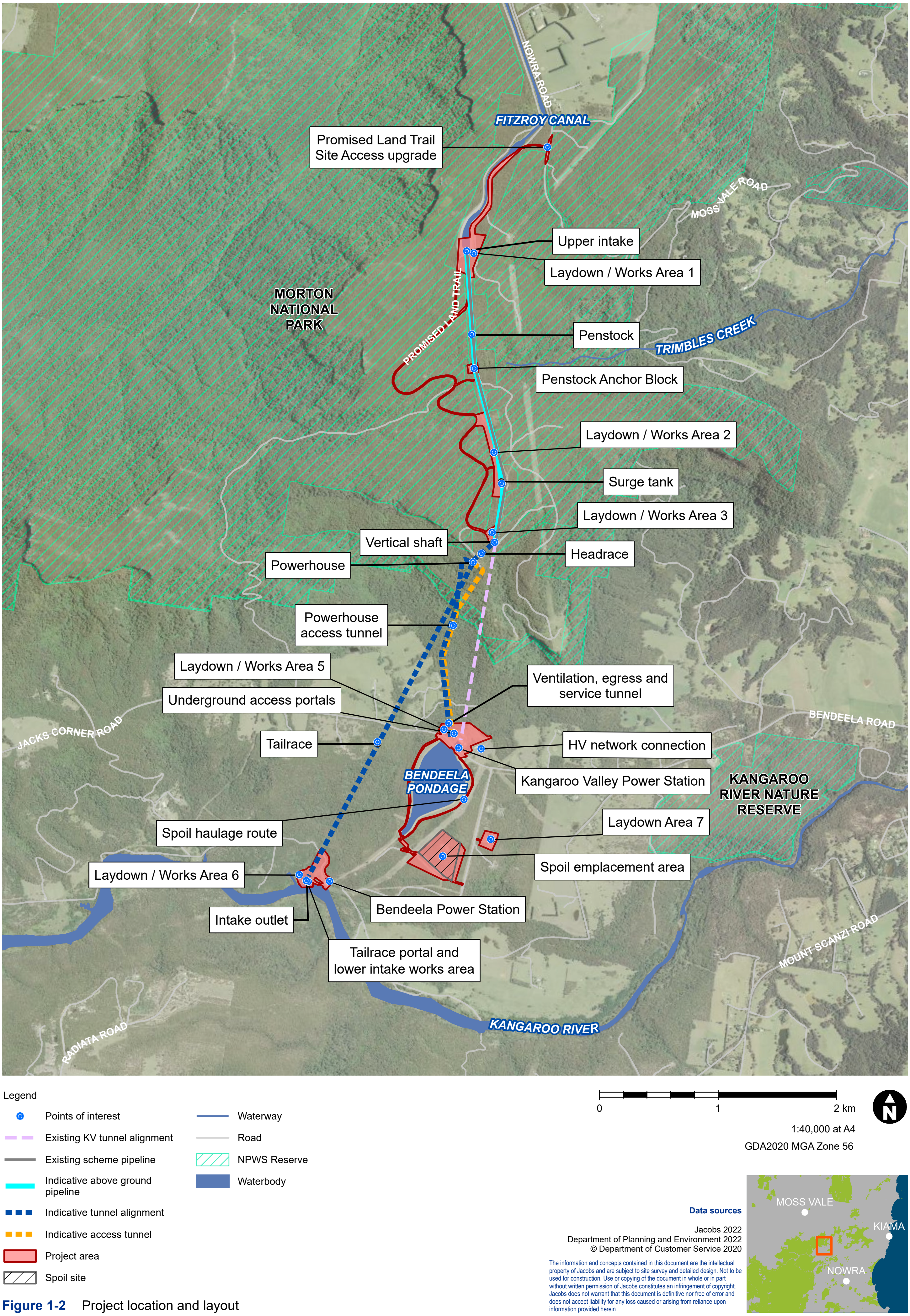
GDA 1994 MGA Zone 56



Data sources

Jacobs 2021
NSW Spatial Services 2021

Figure 1-1 Project overview



Data sources

Jacobs 2022
Department of Planning and Environment 2022
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Figure 1-2 Project location and layout

1.2 Project location

The Shoalhaven Hydro Expansion Project is to be carried out in the Wingecarribee and Shoalhaven Local Government Areas (LGAs). Access to the upper portion of the Project on the plateau, for pipeline, surge tank and vertical shaft construction would be via the Promised Land Trail. The Promised Land Trail is accessed from Moss Vale Road and traverses both WaterNSW land and the Morton National Park and was constructed as part of the original scheme. Access to the lower portion of the Project within Kangaroo Valley would be via Bendeela Road from Moss Vale Road in the vicinity of the townships of Kangaroo Valley and Barrengarry.

1.3 Primary noise and vibration related risks

Impacts can arise when noise and vibration from industry or construction activities result in unacceptable levels at surrounding sensitive receivers. Noise and vibration have the potential to be generated during the construction and operational phases of the Project. The key risks associated with the Project which are the subject of this assessment include:

- Temporary noise impacts during construction, including sleep disturbance and air blast overpressure impacts from blasting
- Ongoing noise impacts during operations, including sleep disturbance.
- Ground-borne noise from underground tunnelling activities
- Vibration impacts associated with surface construction, underground blasting and tunnelling activities
- Changes in roads noise as a result of additional traffic generated during the construction and operational phases of the Project.

1.4 Secretary's Environmental Assessment Requirements

This assessment forms part of the EIS for the Project. The EIS has been prepared under Division 5.2 of the EP&A Act. This assessment has been prepared to address the Secretary's Environmental Assessment Requirements (SEARs) relating to noise and vibration and will assist the Minister for Planning to make a determination on whether or not to approve the Project.

Table 1.1 outlines the SEARs relevant to this assessment along with a reference to where these are addressed. It is noted that there is no specific mention to the assessment of noise during operations in the SEARs. That being said, operational noise has still been assessed as outlined below in **Table 1.1**.

Table 1.1. SEARs relevant to noise

Secretary's requirement	Where addressed in this report
Noise - including an assessment of the construction noise, road noise and vibration impacts of the Project	This report, in particular: - **Section 1.3** (identification of issues) - **Section 6** assessment of noise and vibration impacts during construction and operations, including road noise)

1.5 Structure of this report

The structure and content of this report are outlined in **Table 1.2**.

Table 1.2. Structure and content

Chapter	Description
Chapter 1 Introduction	Outlines key elements of the Project, SEARs and the purpose of this report (this Chapter)
Chapter 2 Policy and planning setting	Provides an outline of the statutory context, including applicable legislation, planning policies and guidance.
Chapter 3 Assessment methodology	Describes key features of the existing environment relevant to the assessment.
Chapter 4 Management levels	Describes the various levels established from the legislation, planning policies and guidance for the assessment of potential impacts
Chapter 5 Assessment methodology	Provides a description of the assessment methodology for this assessment
Chapter 6 Impact assessment	Presents the outcomes of the noise and vibration impact assessment
Chapter 7 Potential cumulative impacts	Presents the qualitative assessment of potential cumulative construction and operational impacts with other projects near the Project
Chapter 8 Mitigation measures	Presents the noise and vibration measures applicable for the Project
Chapter 9 Conclusion	Summarises the findings of this report

2. Legislative and policy context

2.1 Overview

As identified above in **Section 1.3** there are a variety of different noise and vibration-related matters requiring assessment. This section provides an overview of the relevant NSW legislative requirements. It also details the applicable policy and guidance for assessing each particular noise and vibration-related risk associated with the Project.

2.2 NSW legislation

2.2.1 Environmental Planning and Assessment Act 1979

As noted in **Section 1**, the Project is State Significant Infrastructure and subject to the provisions of Part 5 Division 5.2 of the EP&A Act. As State Significant Infrastructure, the Project needs to be approved by the Minister for Planning and the application for approval needs to be supported by an EIS. SEARs have been provided to Origin by the Department of Planning and Environment. The SEAR relevant to noise and vibration and is provided in **Table 1.1**.

2.2.2 Protection of Environmental Operations Act 1997

The *Protection of the Environment Operations Act 1997* (POEO Act) is administered by the Environment Protection Authority (EPA). The POEO Act regulates air and water pollution, noise control and waste management. The Act contains pollution controls and requirements for granting environment protection licences. Schedule 1 of the Act lists activities that require an environment protection licence. The Project is of a kind listed in Schedule 1 of the POEO Act (electricity generation) and would require an environment protection licence under this schedule. In accordance with section 43(d) of the POEO Act, an environment protection licence may also be issued to control the carrying out of a non-scheduled activity for the purpose of regulating water pollution.

Construction activities must comply with the requirements of the POEO Act. Section 139 of the Act relates to the operation of plant and noise pollution and requires that plant be operated in a proper and efficient manner and maintained in an efficient condition.

2.3 Aspect-specific assessment policies, guidelines and standards

There are a range of policies, standards and guidelines that are used to assess the different noise and vibration aspects associated with the Project identified above in **Section 1.3**. Each of these are outlined below. Specific details of how each was used to develop suitable objectives for the assessment is provided in **Section 5**.

2.3.1 Interim Construction Noise Guideline

The ICNG (DECC, 2009) was developed by a number of NSW state agencies along with extensive public consultation. The guideline was developed to apply a range of work practices suited to minimise the impacts of construction noise. The guideline covers the construction, maintenance or renewal activities carried out by a public authority (section 6 of the POEO Act), including public roads, rail and other urban infrastructure. The methodology provided by the guideline which has been applied to this assessment includes:

- Identifying sensitive land uses
- Identifying the hours of works for proposed construction works
- Identifying noise impacts at sensitive land uses
- Selecting and applying the best work practices to minimise noise impacts.

The guideline also sets out the method to determine noise management levels for each sensitive land use types, including residential, commercial, educational, medical and others. Additionally, the ICNG includes guidance for evaluating other effects including ground-borne noise which is also applicable for construction works occurring underground as associated with the Project.

The Draft Construction Noise Guideline (NSW Environment Protection Authority [EPA], 2021) is currently being developed and is in the process of public review and feedback. A review of this document indicates that the derivation of NMLs, or the application and quantitative methodology for this Project has not changed from the ICNG, except for the addition of an out of hours 'highly noise affected' noise level of 65 dB(A). As this updated CNG is yet to be released, this update has not been included in this assessment. Further, the guidance from the ICNG remains applicable for Projects with licence or consent conditions that refer to it.

2.3.2 Noise Policy for Industry

The 'Noise Policy for Industry' (NPI), (EPA, 2017) provides guidance in minimising intrusive sound from operational industrial noise sources. The NPI is non statutory and sets assessment noise levels and thresholds through consistent methods and best practice measures. The NPI also sets out minimum rating background levels (RBLs), especially for rural areas where measured noise levels can be inconsistent (i.e., night-time background noise levels higher than daytime measured levels). These minimum RBLs are based on best practice measures, community consultation and research and have been adopted for this assessment.

2.3.3 Assessing Vibration: a technical guideline

'Assessing Vibration: a technical guideline', (Department of Environment and Conservation [DEC], 2006) is based on guidelines contained in British Standard BS6472–1992 *Evaluation of human exposure to vibration in buildings (1–80 Hz)*. This guideline presents preferred and maximum vibration values for use in assessing human responses to vibration and provides recommendations for measurement and evaluation techniques. The vibration criteria set out in this guideline have been adopted for this assessment, as further detailed in **Section 4**, although this assessment references the latest version of BS6472 which was published in 2008, after publication of *Assessing Vibration: a technical guideline* (2006).

2.3.4 NSW Road Noise Policy

Changes in traffic noise along key public routes due to additional traffic generated during the construction and operation of the Project were assessed against the following guidance from the application notes of the 'NSW Road Noise Policy' (RNP), (Department of Environment, Climate Change and Water NSW [DECCW],2011):

> *'…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 as a result of the development should be limited to 2 dB above that of the noise level without the development. This limit applies wherever the noise level without the development is within 2 dB of, or exceeds, the relevant day or night noise assessment criterion'.*

The RNP also includes guidance for evaluating the potential for sleep disturbance which is referred to in Section 4.3 of the ICNG, as well as in the NPI. This guidance was also considered as part of the assessment.

2.3.5 Technical Basis for Guidelines to Minimise Annoyance Due to Blasting Overpressure and Ground Vibration

Blasting generates ground vibration in the form of waves that are transmitted through the ground including soil and rock, as well as airborne vibration in the form of air blast overpressure waves. The ground vibration and air blast can result in environmental impact in the form of human annoyance and/or structural damage.

The ICNG states that overpressure and vibration from blasting are to be assessed against the levels in the 'Technical Basis for Guidelines to Minimise Annoyance Due to Blasting Overpressure and Ground Vibration' (ANZEC 1990). Guidance from ANZEC 1990 were adopted for the evaluation of overpressure and vibration-related effects from blasting.

2.3.6 Other guidance

Guidance from 'Australian Standard Explosives – Storage and use Part 2: Use of explosives' (AS2187.2-2006) and the German standard, 'DIN 4150-3 Vibrations in buildings – Part 3: Effects on structures' (DIN 4150-3: 2016) were also considered. AS2187.2-2006 provides guidance for avoiding structural/architectural damage from air blast resulting from surface blasting activities, noting that the guideline values from ANZEC 1990 are intended to minimise human annoyance effects. The guidance from DIN 4150-3: 2016 was considered to evaluate potential vibration impacts at atypical sensitive structures such as heritage structures, as well as surrounding buried services.

Additionally, the 'Construction Noise and Vibration Guideline' (CNVG), (NSW Roads and Maritime Services [NSW RMS], 2016) provides useful guidance insofar as indicative safe setback distances to achieve human comfort (DECC, 2006) and cosmetic building damage (BS7385-2:1993) criteria for a range of different plant and equipment commonly used during construction. This guidance was also considered as part of the assessment, as well as the recommendations for mitigating and managing construction noise and vibration included in Appendix B and C of the document.

3. Existing environment

3.1 Overview

This section of the report describes the key features of the existing environment as relevant to the assessment of potential noise and vibration-related impacts from the Project. These include the nature and proximity of surrounding land uses, including sensitive receivers, existing background noise conditions and local meteorology. These features are described in the following subsections.

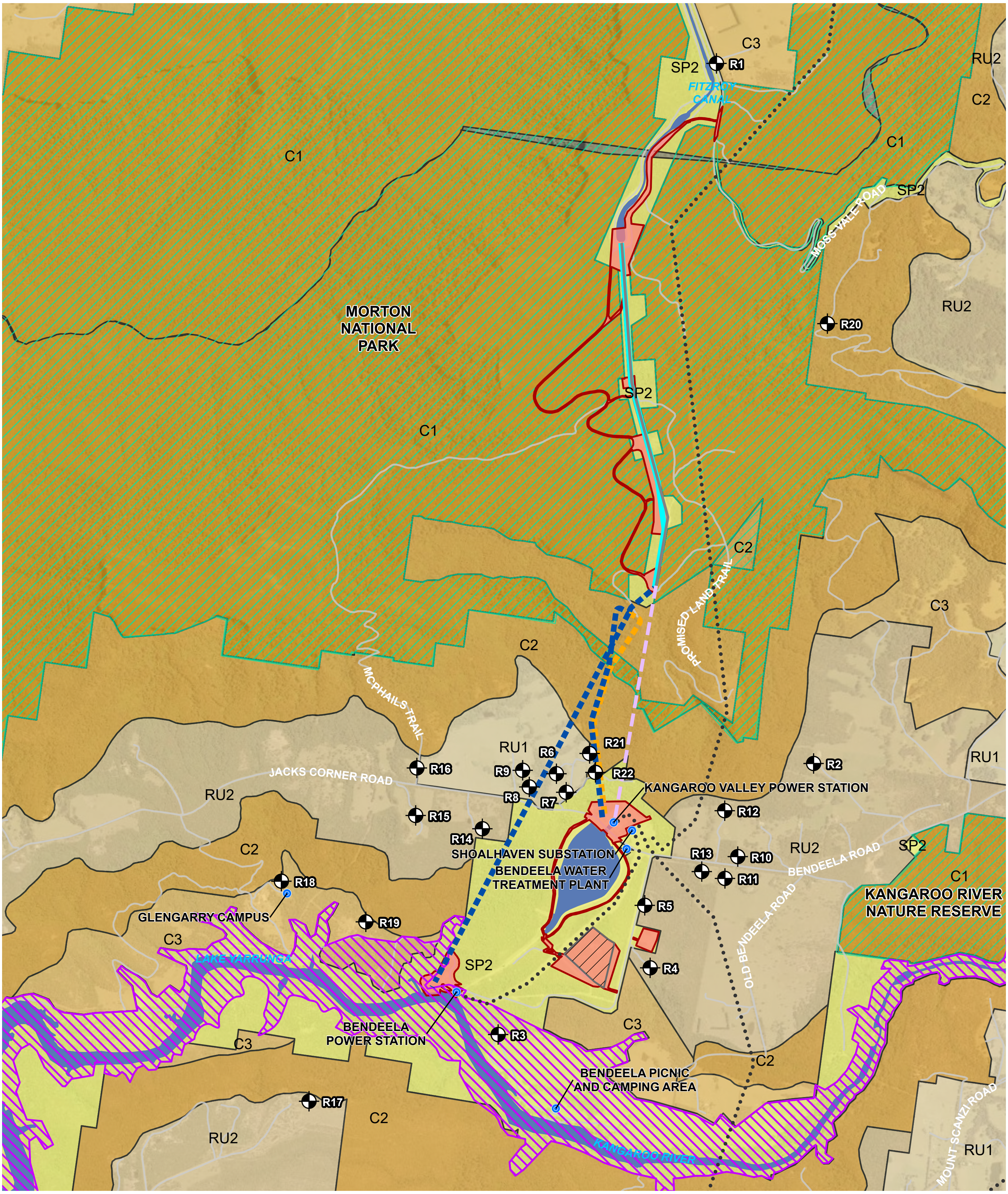
3.2 Surrounding land uses

An understanding of land uses around the Project is important as different uses are more sensitive to noise and vibration. Different land uses can also interact differently, affecting how noise propagates.

The Project Site is located partly within Water NSW Shoalhaven Special Area catchment, The above ground pipeline, surge tank and top of vertical shaft is located within a narrow (80-300m wide) strip of land excised from the Morton National Park associated with the existing scheme.

The zoning according to Shoalhaven City Council of all proposed works is located in Infrastructure Zone (SP2) with zones in the immediate vicinity of the works consisting of National Parks and Nature Reserves (E1), Environmental Conservation (E2), Environmental management (E3), Primary Production (RU1) and Rural Landscape (RU2).

Land uses in relation to the Project are displayed below in **Figure 3-1**.



Legend

- Sensitive receptors
- Existing KV tunnel alignment
- Existing scheme pipeline
- Indicative above ground pipeline
- Indicative tunnel alignment
- Indicative access tunnel
- Project area
- Spoil site
- Shoalhaven special area

Land use

- C1 National Parks and Nature Reserves
- C2 Environmental Conservation
- C3 Environmental Management
- RU1 Primary Production
- RU2 Rural Landscape
- SP2 Water Supply System
- Transmission lines

- Points of interest
- Road
- Waterway
- Waterbody
- NPWS Reserve

0 1 2 km

1:37,500 at A4

GDA2020 MGA Zone 56

N

MOSS VALE

KIAMA

NOWRA

Data sources

Jacobs 2022
Department of Planning and Environment 2022
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Figure 3-1 Surrounding land uses

3.3 Sensitive receivers

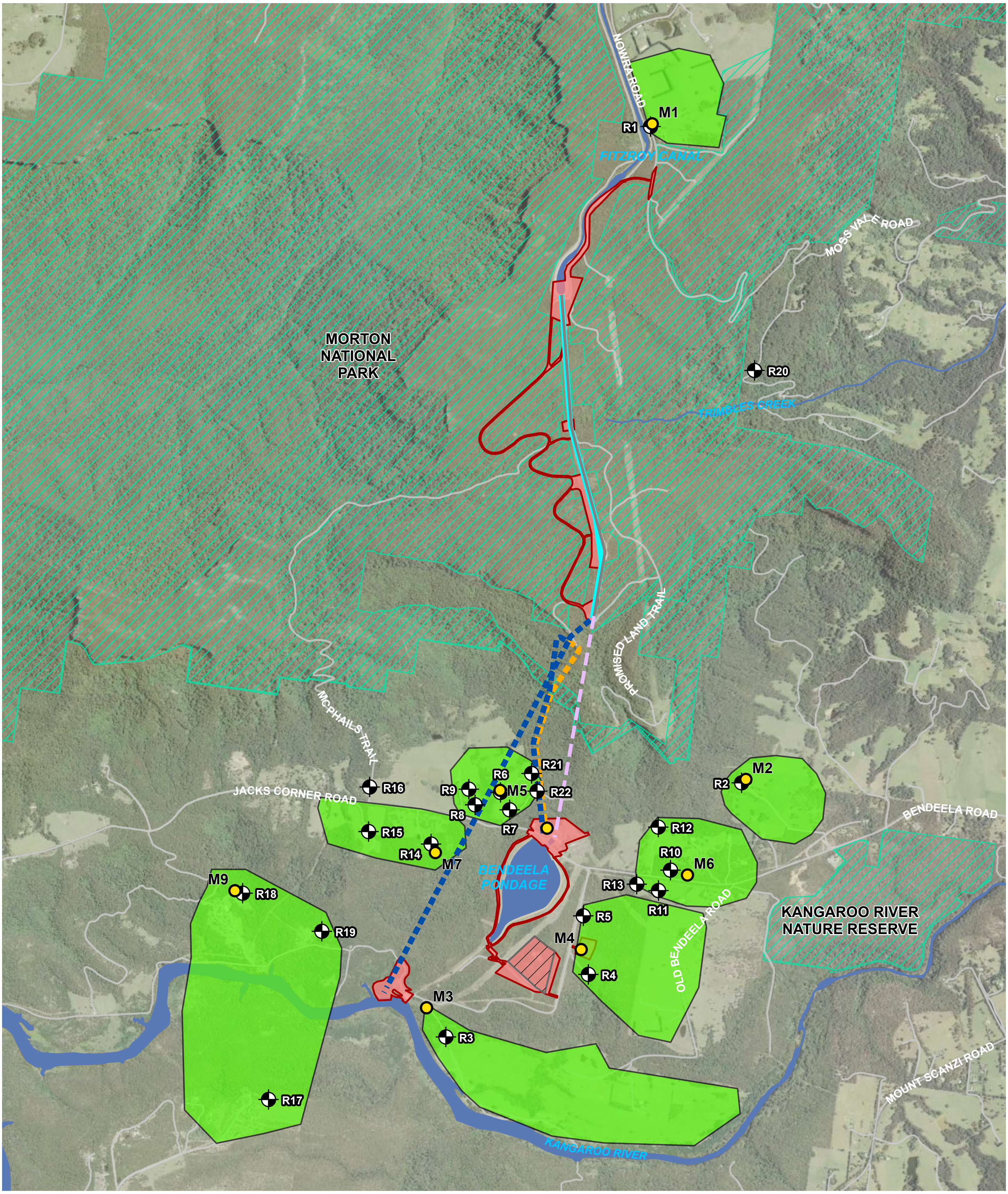
3.3.1 Surrounding the Project

Where noise and vibration is not properly managed and controlled, it can lead to off-site impacts. Aerial imagery was reviewed to identify nearby sensitive receiver locations in relation to the Project disturbance area (refer to **Figure 1-2**). Details for the nearest receivers are listed in **Table 3.1** below, with each location displayed in **Figure 3-2**.

Table 3.1. Nearby sensitive receivers around Project

ID	Address	Type	Approximate distance from Kangaroo Valley Portal	Approximate distance to nearest disturbance	Disturbance
R1	1671 Nowra Road Fitzroy Falls	Residential	5440 m	440 m	Road Upgrades
R2	198 Bendeela Road Kangaroo Valley	Residential	1540 m	1480 m	Kangaroo Portal
R3	407C Bendeela Road (Camp) Kangaroo Valley	Passive recreation	1720 m	500 m	Tail Race Portal
R4	407D Bendeela Road Kangaroo Valley	Residential	1120 m	100 m	J-Storage
R5	407A Bendeela Road Kangaroo Valley	Residential	690 m	160 m	J-Storage
R6	35 Jim Edwardes Place Kangaroo Valley	Residential	470 m	370 m	Kangaroo Portal
R7	13 Jim Edwardes Place Kangaroo Valley	Residential	330 m	240 m	Kangaroo Portal
R8	94 Jacks Corner Road Kangaroo Valley	Residential	580 m	500 m	Kangaroo Portal
R9	110 Jacks Corner Road Kangaroo Valley	Residential	680 m	590 m	Kangaroo Portal
R10	340 Bendeela Road Kangaroo Valley	Residential	990 m	780 m	Haulage (non-road)
R11	353 Bendeela Road Kangaroo Valley	Residential	960 m	610 m	J-Storage
R12	360 Bendeela Road Kangaroo Valley	Residential	860 m	800 m	Kangaroo Portal
R13	369 Bendeela Road Kangaroo Valley	Residential	790 m	520 m	Haulage (non-road)
R14	145 Jacks Corner Road Kangaroo Valley	Residential	880 m	790 m	Kangaroo Portal
R15	199 Jacks Corner Road Kangaroo Valley	Residential	1350 m	1130 m	Tail Race Portal

ID	Address	Type	Approximate distance from Kangaroo Valley Portal	Approximate distance to nearest disturbance	Disturbance
R16	180 Jacks Corner Road Kangaroo Valley	Residential	1390 m	1310 m	Kangaroo Portal
R17	114 Radiata Road (Cottages) Kangaroo Valley	Residential	2920 m	1160 m	Tail Race Portal
R18	369 Jacks Corner Road (Campus) Kangaroo Valley	Educational	2350 m	1270 m	Tail Race Portal
R19	369 Jacks Corner Road (Dorms) Kangaroo Valley	Residential	1860 m	610 m	Tail Race Portal
R20	2999 Moss Vale Road Barrengarry	Residential	3870 m	1630 m	Road Upgrades
R21	40 Jim Edwardes Place (North) Kangaroo Valley	Residential	330 m	390 m	Kangaroo Portal
R22	40 Jim Edwardes Place (South) Kangaroo Valley	Residential	470 m	260 m	Kangaroo Portal



Legend

- Monitoring location
- Sensitive receptors
- Existing KV tunnel alignment
- Existing scheme pipeline
- Indicative above ground pipeline
- Indicative tunnel alignment
- Indicative access tunnel
- Noise catchment area
- Project area
- Spoil site
- NPWS Reserve
- Road
- Waterway
- Waterbody

0 1 2 km

1:40,000 at A4

GDA2020 MGA Zone 56

Data sources

Jacobs 2022
Department of Planning and Environment 2022
© Department of Customer Service 2020

Figure 3-2 Surrounding sensitive receivers, monitoring locations and noise catchment areas

3.3.2 Surface blasting at Tailrace Inlet/Outlet

The Tailrace Inlet/Outlet may be constructed with a surface blast. The approximate distance of the surrounding sensitive receivers identified from this location is summarised below in **Table 3.2**.

Table 3.2. Nearby sensitive receivers, approximate setback from Tailrace Inlet/Outlet blast location

ID	Address	Type	Approximate distance (m) from Tailrace Inlet/Outlet
R1	1671 Nowra Road Fitzroy Falls	Residential	6880 m
R2	198 Bendeela Road Kangaroo Valley	Residential	3140 m
R3	407C Bendeela Road (Camp) Kangaroo Valley	Passive recreation	580 m
R4	407D Bendeela Road Kangaroo Valley	Residential	1550 m
R5	407A Bendeela Road Kangaroo Valley	Residential	1610 m
R6	35 Jim Edwardes Place Kangaroo Valley	Residential	1750 m
R7	13 Jim Edwardes Place Kangaroo Valley	Residential	1670 m
R8	94 Jacks Corner Road Kangaroo Valley	Residential	1570 m
R9	110 Jacks Corner Road Kangaroo Valley	Residential	1660 m
R10	340 Bendeela Road Kangaroo Valley	Residential	2360 m
R11	353 Bendeela Road Kangaroo Valley	Residential	2210 m
R12	360 Bendeela Road Kangaroo Valley	Residential	2420 m
R13	369 Bendeela Road Kangaroo Valley	Residential	2080 m
R14	145 Jacks Corner Road Kangaroo Valley	Residential	1170 m
R15	199 Jacks Corner Road Kangaroo Valley	Residential	1220 m
R16	180 Jacks Corner Road Kangaroo Valley	Residential	1560 m
R17	114 Radiata Road (Cottages) Kangaroo Valley	Residential	1220 m
R18	369 Jacks Corner Road (Campus) Kangaroo Valley	Active recreation	1320 m
R19	369 Jacks Corner Road (Dorms) Kangaroo Valley	Residential	660 m
R20	2999 Moss Vale Road Barrengarry	Residential	5500 m
R21	40 Jim Edwardes Place (North) Kangaroo Valley	Residential	2020 m
R22	40 Jim Edwardes Place (South) Kangaroo Valley	Residential	1940 m

3.3.3 Underground drilling and blasting at the power station cavern

The primary excavation method for construction of the power station cavern is to drill and blast the rock material. This blasting has the potential to result in perceptible ground vibration at nearby receivers. Understanding that the blasting would take place underground, the three-dimensional distance to these receivers, taking into account the distance as well as depth from the activity is of importance. This is referred to as the 'slant distance' and is listed in relation to each nearby receiver below in **Table 3.3**.

Table 3.3. Nearby sensitive receivers, approximate three-dimensional setback from underground blasting at power station cavern

ID	Address	Type	Approximate 3-d slant distance (m) from power station cavern
R1	1671 Nowra Road Fitzroy Falls	Residential	4020 m
R2	198 Bendeela Road Kangaroo Valley	Residential	1720 m
R3	407C Bendeela Road (Camp) Kangaroo Valley	Passive recreation	3160 m
R4	407D Bendeela Road Kangaroo Valley	Residential	2550 m
R5	407A Bendeela Road Kangaroo Valley	Residential	2110 m
R6	35 Jim Edwardes Place Kangaroo Valley	Residential	1280 m
R7	13 Jim Edwardes Place Kangaroo Valley	Residential	1380 m
R8	94 Jacks Corner Road Kangaroo Valley	Residential	1450 m
R9	110 Jacks Corner Road Kangaroo Valley	Residential	1380 m
R10	340 Bendeela Road Kangaroo Valley	Residential	1920 m
R11	353 Bendeela Road Kangaroo Valley	Residential	2030 m
R12	360 Bendeela Road Kangaroo Valley	Residential	1590 m
R13	369 Bendeela Road Kangaroo Valley	Residential	1940 m
R14	145 Jacks Corner Road Kangaroo Valley	Residential	1880 m
R15	199 Jacks Corner Road Kangaroo Valley	Residential	2120 m
R16	180 Jacks Corner Road Kangaroo Valley	Residential	1900 m
R17	114 Radiata Road (Cottages) Kangaroo Valley	Residential	4180 m
R18	369 Jacks Corner Road (Campus) Kangaroo Valley	Active recreation	3140 m
R19	369 Jacks Corner Road (Dorms) Kangaroo Valley	Residential	2910 m
R20	2999 Moss Vale Road Barrengarry	Residential	2530 m
R21	40 Jim Edwardes Place (North) Kangaroo Valley	Residential	1040 m
R22	40 Jim Edwardes Place (South) Kangaroo Valley	Residential	1150 m

3.3.4 Heritage structures and other vibration-sensitive land uses

Whilst all receivers and surrounding structures are sensitive to vibration impacts, heritage and precision (including medical) industries are more typically more susceptible and are subject to more stringent criteria. The Aboriginal Cultural Heritage and Non-Aboriginal Historic Heritage Technical Reports (Jacobs, 2022) prepared for the Project were reviewed to identify the nearest off-site heritage structures in relation to the Project.

There are no listed heritage items, or places of archaeological potential, situated along the tunnel alignments or within proximity of vibration-generating Project works and there are no medical facilities were identified within 15 km of the Project.

3.4 Background noise

3.4.1 Background noise monitoring

To understand and quantify levels of existing background noise around the Project, continuous unattended noise monitoring was completed at eight locations around the Project. Each of these eight locations are displayed above in **Figure 3-1**. The monitoring was carried out between 26 March and 8 April 2019 using Type 1 Ngara noise loggers. The devices were set up as described in the methodology outlined in the 'Australian Standard 1055-2018 Acoustics – Description and measurement of environmental noise'. Details of each monitoring location, including the key information collected are summarised below in **Table 3.4**. The term 'L_{90}' is a statistical descriptor which refers to the noise level exceeded 90 per cent of the time during the monitoring period. It is commonly used to define the background noise level. 'L_{Aeq}' is the equivalent continuous sound level or energy-time average for the period of monitoring.

Table 3.4. Background noise levels

Monitor ID	NCA	Monitoring Location	Monitoring Duration	Measurement	Measured Noise Level – dB(A)		
					Day (7am to 6pm)	Evening (6pm to 10pm)	Night (10pm to 7am)
NM1	NCA 1	1671 Nowra Road Fitzroy Falls	26-Mar to 30-Mar	SPL ($L_{Aeq,t}$)	59	56	52
				RBL (L_{A90})	35 (34) [1]	35 (41) [2]	32
NM2	NCA 2	198 Bendeela Road Kangaroo Valley	26-Mar to 29-Mar	SPL ($L_{Aeq,t}$)	42	41	45
				RBL (L_{A90})	35 (27) [1]	35 (36) [2]	33
NM3	NCA 3	Bendeela Camping Ground, 62 Old Bendeela Road Kangaroo Valley	26-Mar 29-Mar to	SPL ($L_{Aeq,t}$)	48	48	45.3
				RBL (L_{A90})	35 (24) [1]	30	30 (24) [1]
NM4	NCA 4	57 Old Bendeela Road Kangaroo Valley	26-Mar 1-Apr to	SPL ($L_{Aeq,t}$)	49	47	46
				RBL (L_{A90})	35 (26) [1]	34	30 (28) [1]
NM5	NCA 5	35 Jim Edwards Pl adj PS, Jacks Corner Rd	26-Mar 31-Mar to	SPL ($L_{Aeq,t}$)	49	49	48
				RBL (L_{A90})	35 (26) [1]	31	30 (29) [1]
NM6	NCA 6	336 Bendeela Rd - traffic impacts	26-Mar 5-Apr to	SPL ($L_{Aeq,t}$)	49	48	46
				RBL (L_{A90})	35 (26) [1]	31	30 (29) [1]
NM7			26-Mar	SPL ($L_{Aeq,t}$)	44	51	42

Monitor ID	NCA	Monitoring Location	Monitoring Duration	Measurement	Measured Noise Level – dB(A)		
					Day (7am to 6pm)	Evening (6pm to 10pm)	Night (10pm to 7am)
	NCA 7	145 Jacks Corner Road Kangaroo Valley	7-Apr to	RBL (L_{A90})	35 (25) [1]	30 (26) [1]	30 (23) [1]
NM8	NCA 8	114 Radiata Road (Cottages) Kangaroo Valley	26-Mar 8-Apr to	SPL ($L_{Aeq,t}$)	47	46	43
				RBL (L_{A90})	35 (25) [1]	30 (25) [1]	30 (22) [1]

1. Measured RBL is below minimum RBL and minimum RBL is used for the assessment
2. Evening criteria higher than daytime criteria due to wildlife chorus can be adjusted to reflect daytime RBL

Graphical depictions of this data are in **Appendix A**. Although this data was collected in 2019 they are still considered appropriate. The environment around each monitoring location has remained unchanged, with the predominant sources contributing to the measured background levels similarly expected as remaining generally the same. Additionally, most were measured at or below the minimum rating background noise levels (RBLs) from the NPI, so the minimum background noise levels are already mostly being applied.

3.4.2 Noise catchment areas

Noise catchment areas (NCAs) are used to describe locations with similar background noise levels, including the sources that contribute to these conditions. Each NCA is displayed above in **Figure 3-2**. **Table 3.5** lists the background noise levels adopted for each NCA, with each sensitive receiver identified in **Table 3.1** listed, as well as the noise monitor used to characterise conditions across each NCA.

Table 3.5. Noise catchment areas

NCA	Sensitive receivers	Key noise features of the existing noise environment	Characterised by results from the following noise monitor	Adopted background (L_{A90}) noise levels dB(A)		
				Day (7am to 6pm)	Evening (6pm to 10pm)	Night (10pm to 7am)
NCA01	1671 Nowra Road Fitzroy Falls	Flora and fauna with occasional vehicle passbys	NM1	35	35	32
NCA02	198 Bendeela Road Kangaroo Valley 2999 Moss Vale Road Barrengarry		NM2	35	35	33
NCA03	407C Bendeela Road (Camp) Kangaroo Valley		NM3	35	30	30
NCA04	407D Bendeela Road Kangaroo Valley 407A Bendeela Road Kangaroo Valley		NM4	35	34	30
NCA05	35 Jim Edwardes Place Kangaroo Valley 13 Jim Edwardes Place Kangaroo Valley 94 Jacks Corner Road Kangaroo Valley 110 Jacks Corner Road Kangaroo Valley 40 Jim Edwardes Place (North) Kangaroo Valley 40 Jim Edwardes Place (South) Kangaroo Valley		NM5	35	31	30
NCA06	340 Bendeela Road Kangaroo Valley 353 Bendeela Road Kangaroo Valley 360 Bendeela Road Kangaroo Valley 369 Bendeela Road Kangaroo Valley		NM6	35	31	30
NCA07	145 Jacks Corner Road Kangaroo Valley 199 Jacks Corner Road Kangaroo Valley 180 Jacks Corner Road Kangaroo Valley		NM7	35	30	30
NCA08	114 Radiata Road (Cottages) Kangaroo Valley 369 Jacks Corner Road (Campus) Kangaroo Valley		NM8	35	30	30

NCA	Sensitive receivers	Key noise features of the existing noise environment	Characterised by results from the following noise monitor	Adopted background (L_{A90}) noise levels dB(A)		
				Day (7am to 6pm)	Evening (6pm to 10pm)	Night (10pm to 7am)
	369 Jacks Corner Road (Dorms) Kangaroo Valley					

3.5 Meteorology

Certain meteorological conditions can enhance the propagation of noise. These include persistent prevailing winds blowing in the direction from Project sources towards surrounding sensitive receivers and temperature inversions. Fact Sheet D of the NSW Environment Protection Authority's (EPA's) 'Noise Policy for Industry' (NPI) (2017) outlines how potential operational noise impacts from industrial developments need to be considered during adverse meteorological conditions as applicable to the Project location. The policy provides two options for addressing these requirements;

1. the application of default noise-enhancing meteorological conditions, or
2. the review of site-specific meteorological conditions to determine the 'significance' of local wind and temperature inversions.

For this assessment, option 1 has been applied with operational noise from the Project assessed under the default standard and noise-enhancing conditions listed in Table D1 of the NPI (and reproduced below in **Table 3.6**).

Table 3.6. Adopted meteorological conditions (EPA, 2017)

Meteorological conditions	Meteorological parameters
Standard meteorological conditions	Day/evening/night: Stability class A to D with wind speed up to 0.5 meters per second (m/s) at 10 meters above ground level (AGL)
Noise-enhancing meteorological conditions	Day/evening: Stability class A to D with light winds (up to 3 m/s) at 10 meters AGL Night: Stability class A to D with light winds (up to 3 m/s) at 10 meters AGL and/or stability category F with winds up to 2 m/s at 10 meters AGL

3.6 Existing traffic conditions

Assessing the potential for changes in traffic-related noise as a result of additional traffic generated from a Project requires an understanding of existing traffic conditions along key travel routes. As part of the traffic assessment completed the EIS in February 2019 traffic counts were collected at two key roads (Bendeela Road, west of Moss Vale Road and at Moss Vale Road, North of Bendeela Road) to be used during the Project. The daytime (considered as 7am to 10pm for road noise assessments) and night-time (10pm to 7am) light and heavy vehicle volumes developed for existing 2022 conditions (based on 3% annual growth from the measured 2019 volumes) are summarised below in **Table 3.7**.

Table 3.7. Existing day (15-hour) and night (9-hour) traffic conditions (2022)

Road	Direction	Day (7am to 10pm), 15-hour		Night (10pm to 7am), 9-hour	
		Light vehicle	Heavy vehicle	Light vehicle	Heavy vehicle
Moss Vale Road	Southbound	1630	194	90	15
	Northbound	1504	181	135	30
Bendeela Road	Westbound	369	38	19	2

Road	Direction	Day (7am to 10pm), 15-hour		Night (10pm to 7am), 9-hour	
		Light vehicle	Heavy vehicle	Light vehicle	Heavy vehicle
	Eastbound	378	38	13	2

Noting that Bendeela Road is a 'local road' in the context of the NSW RNP, day and night-time 1-hour averaged traffic flows are also of interest. Existing (2022) 1-hour traffic flows along Bendeela Road are listed below in **Table 3.8**.

Table 3.8. Existing 1-hour traffic conditions along

Road	Direction	Day (7am to 10pm), 1-hour		Night (10pm to 7am), 1-hour	
		Light vehicle	Heavy vehicle	Light vehicle	Heavy vehicle
Bendeela Road	Westbound	60	9	15	2
	Eastbound	84	9	8	3

These volumes in **Table 3.7** and **Table 3.8** were considered in reviewing the potential for changes in road traffic noise levels at surrounding receivers as a result of additional traffic generated during the construction and operation of the Project.

It is noted that the data above in **Table 3.7** and **Table 3.8** highlight the limited existing traffic along key roads that would be used during the Project. Their sensitivity to additional traffic and how this would affect resulting noise levels is noted, understanding that the relative changes (even for smaller volumes of Project traffic) would be greater than the same additional traffic being generated along busier roads.

4. Management levels

4.1 Overview

Using the guidance presented in the legislation, policies, guidelines and standards outlined above in **Section 2** and the background noise information presented in **Section 3.4,** management levels were developed for the Project. The management levels determined for the assessment of the various noise and vibration-related aspects of the Project are described below.

4.2 Construction airborne noise

4.2.1 Noise management levels

The ICNG provides guidance for assessing noise from construction activities in NSW. It establishes noise management levels (NMLs) for recommended standard construction hours and for outside of the recommended standard hours. Construction is considered to have the potential to cause a noise impact if the predicted noise exceeds the applicable noise management level. **Table 4.1** lists ICNG guidance for establishing construction NMLs at residential receivers.

Table 4.1. ICNG guidance for establishing construction NML at residential receivers

<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 (SH):
Monday to Friday 7am to 6pm
Saturday 8am to 1pm
No work on Sundays or public holidays</td><td>Noise affected:
Rating Background Level (RBL) + 10 dB(A)</td><td>The noise affected level represents the point above which there may be some community reaction to noise.
Where the predicted or measured $L_{Aeq(15\ min)}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level.
The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.</td></tr>
<tr><td>Highly noise affected:
75 dB(A)</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 relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account: times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences if the community is prepared to accept a longer period of construction in exchange for restrictions on construction times.</td></tr>
<tr><td>Outside recommended standard hours (OOH) - All other times including public holidays</td><td>Noise affected:
RBL + 5 dB(A)</td><td>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 of the ICNG.</td></tr>
</table>

Considering the measured RBLs presented in **Section 3.4** and the guidance above in **Table 4.1** the following NMLs were developed for the identified surrounding residential receivers.

Table 4.2. Construction noise management levels (residential receivers)

NCA	NML $L_{eq\ 15\ min}$ dB(A)			
	Day (during standard hours) 7am – 6pm Weekdays, 8am – 1pm Saturdays RBL->NML	**Outside standard hours, Day** 1pm – 6pm Saturday	**Outside standard hours, Evening** 6pm-10pm Weekdays 6pm – 10pm Saturdays RBL->NML	**Outside standard hours, Night** 10pm-7am Weekdays, 10pm – 8am Saturdays 6pm – 7am Sundays and Public Holidays RBL->NML
NCA 1	35 -> 45	35 > 40	35->40	32->37
NCA 2	35 -> 45	35 > 40	35->40	33->38
NCA 3	35 -> 45	35 > 40	30->35	30->35
NCA 4	35 -> 45	35 > 40	34->39	30->35
NCA 5	35 -> 45	35 > 40	31->36	30->35
NCA 6	35 -> 45	35 > 40	31->36	30->35
NCA 7	35 -> 45	35 > 40	30->35	30->35
NCA 8	35 -> 45	35 > 40	30->35	30->35

The ICNG also provides construction NMLs for non-residential sensitive land uses. These are presented for the relevant types of non-residential receivers around the Project below in **Table 4.3**.

Table 4.3. ICNG NMLs for non-residential receivers

Non-residential receiver type	Noise management level, $L_{Aeq(15min)}$ (applies when properties are being used)
Educational facilities	Internal Noise Level – 45 dB(A)
Passive Recreation	External Noise Level – 60 dB(A)
Active Recreation	External Noise Level – 65 dB(A)

Windows often allow the greatest amount of sound transmission from outside to inside across a building façade. Noting guidance presented in Australian Standard AS2436-2010 'Guide to noise and vibration control on construction, demolition and maintenance sites':

'*Where rooms are ventilated by an opened window a transmission loss of 10 dB(A) would apply*'.

Considering this, an external (free-field) NML of 55 dB(A) was conservatively applied at the identified surrounding educational and medical receivers.

4.2.2 Sleep disturbance

For premises where night construction (and operations) occurs, the potential for noise levels to lead to sleep disturbance should be considered. Section 4.3 of the ICNG discusses the method for assessing and managing sleep disturbance. This guidance references further information in the RNP that discusses criteria for the assessment of sleep disturbance.

From the research on sleep disturbance, it is concluded that:

- Maximum internal noise levels below 50-55 dB(A) are unlikely to awaken people from sleep, and
- One or two noise events per night with maximum internal noise levels of 65-75 dB(A), are not likely to affect health and wellbeing significantly.

The former NSW Roads and Traffic Authority's (NSW RTA's) Practice Note 3 (2008a) outlines an assessment and reporting protocol on maximum noise levels and potential for sleep disturbance.

Based on this guidance, **Table 4.4** presents sleep disturbance screening criterion for residential receivers within the noise catchment areas surrounding the Project. This is based on the 55 dB(A) sleep awakening value above, with 10 dB(A) conservatively applied to account for the noise level externally (noting that the guidance above is for the internal noise level). This 10 dB(A) is based on windows often allowing the greatest amount of sound transmission from outside to inside across a building façade. Noting guidance presented in 'Australian Standard AS2436-2010 Guide to noise and vibration control on construction, demolition and maintenance sites' (AS2436-2010), where bedrooms are ventilated by an opened window a transmission loss of 10 dB(A) applies.

Table 4.4. Sleep disturbance criterion

Noise Catchment Area	L_{AFMax} dB(A) external
NCA 1	65
NCA 2	65
NCA 3	65
NCA 4	65
NCA 5	65
NCA 6	65
NCA 7	65
NCA 8	65

4.2.3 Construction traffic noise impacts

Road traffic noise impacts due to the construction (and operation) of the Project were assessed against the following guidance from the application notes of the EPA's RNP (2011):

> *'…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 as a result of the development should be limited to 2 dB above that of the noise level without the development. This limit applies wherever the noise level without the development is within 2 dB of, or exceeds, the relevant day or night noise assessment criterion'.*

The existing volumes listed above in **Section 3.6** were used as the basis for evaluating whether the additional traffic generated during construction would result in increases more than 2 dB. If this is predicted the RNP, recommends that resulting noise levels are also compared against the relevant noise assessment criteria. These are listed below in **Table 4.5**.

Table 4.5. Road traffic noise assessment criteria

Road	Road category	Day (7am to 10pm) $L_{AEq\ 15\text{-}hour}$ dB(A)	Night (10pm to 7am) $L_{AEq\ 9\text{-}hour}$ dB(A)
Moss Vale Road	Freeway / arterial / sub-arterial road	60	55
Bendeela Road	Local road	55	50

4.3 Construction vibration from sources other than blasting

Construction works can cause ground vibration that can result in damage to structures and can be perceived by occupants. Ground vibration can be caused by surface construction activities and by underground construction works. The environmental impacts from ground vibration caused by surface or underground activities are assessed using methodologies and guidelines that are selected and adopted for the most relevant types of impacts.

4.3.1 Damage to structures

The environmental risks associated with the impacts of ground vibration on structures include the potential for minor cosmetic damage such as cracks in plasterboard or for more severe damage that may compromise a receiver's structural integrity such as cracks in load-bearing masonry walls. The potential for cosmetic or structural damage to structures such as buildings depends on the types of building construction materials used and the size, strength and age of the structures. Various international publications provide guidance for various types of structures including residential dwellings, commercial and industrial buildings, as well as special receivers such as heritage structures, buried pipes and cables. Vibration impacts for other types of structures such as electrical transmission infrastructure and underground tunnels typically need to be assessed against specific vibration guidelines relevant for the individual receiver on a case-by-case basis.

There are currently no legislative requirements or published guidelines in NSW regarding the assessment and management of vibration levels relating to potential structural damage to buildings, structures or services. The assessment approach commonly used in NSW is to adopt the guidelines from British Standards (BS) and German Standards (DIN) for environmental ground vibration assessment.

Criteria for non-heritage receiver structures such as residential, commercial and industrial buildings are given in BS 7385-2:1993 'Evaluation and measurement for vibration in buildings — Part 2: Guide to damage levels from ground-borne vibration', as shown in **Table 4.6**.

Table 4.6. Vibration Criteria for non-heritage structures, from BS 7385-2:1993 Vibration Guide Values for Cosmetic Damage (PPV, mm/s)

Type of Building	Peak component particle velocity (PPV, mm/s) in frequency range of predominant pulse			
	Transient vibration		Continuous vibration	
	4 Hz to 15 Hz	15 Hz and above	4 Hz to 15 Hz	15 Hz and above
Unreinforced or light framed structure. Residential or light commercial type buildings[1]	15 mm/s at 4 Hz, increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz, increasing to 50 mm/s at 40 Hz and above	7.5 mm/s at 4 Hz, increasing to 10 mm/s at 15 Hz	10 mm/s at 15 Hz, increasing to 25 mm/s at 40 Hz and above
Reinforced or framed structures. Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above		25 mm/s at 4 Hz and above	

Note 1: At frequencies below 4 Hz, a maximum displacement of 0.6mm (zero to peak) should not be exceeded.

Section 7 of the CNVG provides guidance for safe working distances to achieve human comfort (Assessing Vibration: a technical guideline, (DEC, 2006) and cosmetic damage (BS7385-2:1993) criteria for a range of different plant and equipment. These have been reproduced for the relevant vibration-generating plant intended to be used during the Project in **Table 4.7**.

Table 4.7. Recommended safe setback distances

Plant	Rating / description	Safe working distance (m)	
		Cosmetic damage (BS7385-2: 1993)	Human response (DEC, 2006)
Vibratory pile driver	Sheet piles	2 to 20 m	20 m
Large hydraulic hammer	(1600 kg – 18t to 34t excavator)	22 m	73 m
Jackhammer	Hand-held	1 m (nominal)	2 m

Source: TfNSW(RMS) (2016)

4.3.2 Human comfort

Ground vibration can result in structural vibration within occupied buildings that is subjectively perceptible and could potentially cause annoyance.

Guidelines for ground/structural vibration within buildings to assess potential impacts related to human comfort are provided in 'Assessing Vibration: A Technical Guideline' (DEC, 2006. The guidance is based on British Standard 6472-1992 'Evaluation of human exposure to vibration in buildings (1-80 Hz)'. The criteria in DEC, 2006 are not mandatory; they are goals that should be sought to be achieved through the application of all feasible and reasonable mitigation measures. DEC,2006 provides criteria for three types of vibration:

- Continuous vibration
- Impulsive vibration (except from blasting)
- Intermittent vibration.

Guideline values for the assessment of the different types of vibration within residential buildings are provided in **Table 4.8**.

Table 4.8. Guidelines for human comfort in residential buildings – vibration (non-blasting)

Type of vibration	Metric	Time period	Preferred values		Maximum values	
			z-axis	x- and y-axis	z-axis	x- and y-axis
Continuous	Acceleration (rms, m/s^2)	Day 7am-10pm	0.010	0.0071	0.020	0.014
		Night 10pm-7am	0.007	0.005	0.014	0.010
Impulsive	Acceleration (rms, m/s^2)	Day 7am-10pm	0.30	0.21	0.60	0.42
		Night 10pm-7am	0.10	0.071	0.20	0.14

Type of vibration	Metric	Time period	Preferred values		Maximum values	
			z-axis	x- and y-axis	z-axis	x- and y-axis
Intermittent	VDV $m/s^{1.75}$	Day 7am-10pm	0.20		0.40	
		Night 10pm-7am	0.13		0.26	

Relevant guidance from the CNVG for human comfort impacts for relevant plant and equipment are also listed above in **Table 4.7**.

4.3.3 Heritage structures

Criteria for atypical sensitive structures such as heritage structures is provided in DIN 4150-3:2016. Criteria are provided for short-term vibration (from vibration sources such as impact pile driving and blasting) as well as for long-term vibration (for sources such as road headers).

The DIN4150-3 criteria for heritage structures for exposure to long-term vibration sources such as from road headers are shown in **Table 4.9**.

Table 4.9. Vibration Criteria, from DIN 4150-3:2016 Guideline values for vibration velocity to be used when evaluating the effects of long-term vibration on structures

Type of Building	Guideline values for vibration velocity (PPV, mm/s)	
	Topmost floor, horizontal direction	Floor slab, vertical direction
Sensitive structures e.g. Heritage buildings	2.5	10[1]
Note 1: Additional guidance is provided in DIN 4150-3:2016, clause 6.1.2		

Noting that the nearest heritage or particularly sensitive structure is more than three km away, the Project is not expected to cause impacts at these locations.

4.3.4 Buried services

It is recommended that criteria for protection of buried services from vibration due to construction sources other than blasting be selected on a case-by-case basis, appropriate to the specific buried services being subjected to the vibration.

4.4 Construction ground-borne noise

Vibration from construction activities can induce vibration within receiver structures, wherein some of the vibration of building elements such as the floors, walls and ceilings can be converted into sound. The sound that is thereby induced by re-radiation of the structural vibration into the air within the receiving building is called structure-borne noise. This type of noise within receiver buildings subjectively sounds characteristically different from typical construction noise and hence is perceived and assessed separately from other types of construction noise impacts.

Ground-borne/structure-borne noise is normally only significant for construction works occurring underground such as tunnelling and is typically never considered for aboveground construction works. This is because the sound pressure levels of ground-borne noise that are induced inside receiver buildings from aboveground sources of vibration are typically overwhelmed and insignificant compared to the airborne noise levels generated by aboveground construction activities.

Assessment values for ground-borne noise are provided in the ICNG (DECC, 2009), shown in **Table 4.10**. The ground-borne noise levels are provided as guidance for when management actions should be implemented. These levels recognise the temporary nature of construction, are provided for residential receivers only, and for evening and night-time periods only, as the objectives are to protect the amenity and sleep of people when they are at home. The noise levels are not required to incorporate any adjustments or penalties due to subjective characteristics (such as tonality, impulsiveness, low-frequency content, etc.).

Table 4.10. Ground-borne noise assessment levels

Receiver type	Time Period	Ground-borne noise level $L_{Aeq(15\ minutes)}$
Residential only	Evening (6pm to 10 pm)	40 dB(A)
(Internal; within the most affected habitable room)	Night (10 pm to 7 am)	35 dB(A)

4.5 Construction blasting, air blast overpressure and ground vibration

Blasting generates ground vibration in the form of waves that are transmitted through the ground including soil and rock, as well as airborne vibration in the form of air blast overpressure waves. The ground vibration and air blast can result in environmental impact in the form of human annoyance and/or structural damage.

4.5.1 Overview

The ICNG states that overpressure and vibration from blasting are to be assessed against the levels in the 'Technical Basis for Guidelines to Minimise Annoyance Due to Blasting Overpressure and Ground Vibration', (ANZEC 1990).

The ANZEC guidelines for air blast overpressure and ground vibration are:

- The recommended maximum level for air blast overpressure is 115 dB (Linear Peak), for 95% of blasts, however the level should not exceed 120 dB (Linear Peak) at any time
- The recommended maximum level for ground vibration is 5 mm/sec (peak particle velocity).

The criteria given in the ANZEC guidelines are based upon the principle of minimising human annoyance for receivers that are exposed to regular blasts, such as would be occurring from continuous operation of quarries and mines. However, in cases where blasting is used for construction purposes and there will be a very small number of blasts it would be more appropriate to select criteria on the basis of avoidance of structural damage.

4.5.2 Surface blasting

The construction program for the Project includes only limited surface blasts, at the location of construction of the Tailrace Outlet/Inlet and potentially at the surge tank, high pressure shaft top and access and multi-purpose tunnel portals.

As the construction program only includes limited blasting for construction purposes, it is considered more appropriate that the criteria for ground vibration and air blast be adopted on the basis of protection of structures and prevention of damage to receiver buildings.

4.5.2.1 Air blast overpressure

AS2187.2-2006 states:

> *"From Australian and overseas research, damage (even of a cosmetic nature) has not been found to occur at air blast levels below 133 dBL. The probability of damage increases as the air blast levels increase above this level. Windows are the building element currently regarded as the most sensitive to air blast, and damage to windows is considered as improbable below 140 dBL.*

A limit of 133 dBL is recommended as a safe level that will prevent structural/architectural damage from air blast".

Based on this, the criterion adopted for the assessment of impacts from air blast overpressure resulting from surface blasting is 133 dBL.

4.5.3 Vibration

4.5.3.1 Non-heritage structures

Australian Standard AS2187.2-2006 provides appropriate criteria for the protection of structures from physical damage due to ground vibration and/or air blast from blasting. The criteria for ground vibration in AS2187.2-2006 are reproduced from British Standard BS7385-2:1993 Evaluation and measurement for vibration in buildings — Part 2: Guide to damage levels from ground-borne vibration, shown in **Table 4.7**. The criteria shown in shown in **Table 4.11** provide vibration guide values for the prevention of cosmetic damage to receiver buildings from sources of transient vibration such as blasting.

Table 4.11. Vibration Criteria for non-heritage structures, from AS 2187.2-2006 Table J4.4.2.1 (PPV, mm/s)

Type of Building	Transient vibration in frequency range of predominant pulse (PPV, mm/s)	
	4 Hz to 15 Hz	15 Hz and above
Unreinforced or light framed structure. Residential or light commercial type buildings	15 mm/s at 4 Hz, increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz, increasing to 50 mm/s at 40 Hz and above
Reinforced or framed structures. Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	

4.5.3.2 Heritage structures

The DIN 4150-3:2016 criteria for heritage buildings for short-term vibration such as blasting are shown in **Table 4.12**.

Table 4.12. Vibration Criteria, from DIN 4150-3:2016 Guideline values for vibration velocity to be used when evaluating the effects of short-term vibration on structures

Type of Building	Guideline values for velocity, mm/s				
	Vibration at the foundation at a frequency of			Horizontal plane of highest floor	Floor slabs, vertical direction
	1 Hz to 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz		
Sensitive structures eg. Heritage buildings	3 mm/s	3 to 8 mm/s	8 to 10 mm/s	8 mm/s	20[1]
Note 1: This value may need to be lowered for individual buildings on a case-by-case basis					

The criteria shown in **Table 4.12** would be applicable for both surface blasting and underground blasting.

4.5.3.3 Buried services

Criteria for buried services for short-term vibration (from vibration sources such as impact pile driving and blasting) are provided in DIN 4150-3:2016, shown in **Table 4.13**.

Table 4.13. DIN 4150-3:2016 - Guideline values for vibration velocity to be used when evaluating the effects of short-term vibration on buried pipework

Pipe material	Guideline values for vibration measured on the pipe (PPV, mm/s)
Steel, welded	100
Vitrified clay, concrete, reinforced concrete, prestressed concrete, metal (with or without flange)	80
Masonry, plastics	50

4.5.4 Underground blasting

The construction of the underground power station involves excavation of a cavern, for which the primary excavation technique is proposed to be drill & blast. For these blasting activities, air blast overpressure is not relevant as the blasts will be underground. However, the ground vibration impacts will be semi-regular throughout the duration of the cavern excavation works, therefore the vibration criteria will need to be adopted accordingly.

Due to the semi-regular nature of the underground blasting during excavation of the cavern, it would be appropriate for the applicable vibration criteria to be based on human comfort, rather than structural damage. The ICNG/ANZEC guidelines would recommend a criteria of peak particle velocity 5mm/s for all blasts. However, the guidance in Australian Standard AS2187.2-2006 would recommend a vibration criterion of 10 mm/s for all blasts if the construction period is less than 12 months. Consequently, if the construction period of the cavern is less than 12 months, the vibration criteria for the underground drill & blasting is PPV 10 mm/s. If the drill & blast construction period is more than 12 months, the recommended vibration criteria for the underground drill & blasting is PPV 5 mm/s.

The criteria listed above for heritage structures and buried services also apply for underground blasting activities.

4.6 Operation Noise

4.6.1 Overview

Operational noise objectives for the Project were determined in accordance with the NSW EPA's NPI which seeks to regulate noise impact from 'industrial activity' pertaining to noise from fixed industry and mechanical plant rather than from road, rail or construction sources. To achieve this, the NPI applies two separate noise criteria:

- Limiting the intrusiveness of the Project's noise against the prevailing background noise
- Achieving suitable acoustic amenity for the surrounding land uses from industry.

The more stringent of these is used to define the operational noise limit for a Project. The following sub-sections detail how operational noise objectives were determined for the Project, as well as objectives for other operational noise-related matters, including noise from additional traffic generated during operations.

4.6.2 Intrusive Noise Levels

A noise source will be deemed to be non-intrusive if the monitored $L_{Aeq\ (period)}$ noise level of the development does not exceed the RBL by more than 5 dB(A). **Table 4.14** presents the noise intrusiveness criteria for the noise catchment areas, based on their RBLs (see **Table 3.4**). Intrusiveness noise levels are not used directly as regulatory criterion. They are used in combination with the amenity noise level to assess the potential impact of noise, assess reasonable and feasible mitigation options and subsequently determine achievable noise requirements.

Table 4.14. NPI intrusiveness noise levels

Receiver Group	Time of Day	L_{90} (RBL) dB(A)	Allowance	Noise intrusiveness level dB(A)
NCA 1	Day (7 am to 6 pm)	35 (34)	+5 dB(A)	40
	Evening (6 pm to 10 pm)	35 (41)		40
	Night (10 pm to 7 am)	32		37
NCA 2	Day (7 am to 6 pm)	35 (27)		40
	Evening (6 pm to 10 pm)	35 (36)		40
	Night (10 pm to 7 am)	33		38
NCA 3	Day (7 am to 6 pm)	35 (24)		40
	Evening (6 pm to 10 pm)	30		35
	Night (10 pm to 7 am)	30 (24)		35
NCA 4	Day (7 am to 6 pm)	35 (26)		40
	Evening (6 pm to 10 pm)	34		39
	Night (10 pm to 7 am)	30 (28)		35
NCA 5	Day (7 am to 6 pm)	35 (26)		40
	Evening (6 pm to 10 pm)	31		36
	Night (10 pm to 7 am)	30		35
NCA 6	Day (7 am to 6 pm)	35 (26)		40
	Evening (6 pm to 10 pm)	31		36
	Night (10 pm to 7 am)	30 (29)		35
NCA 7	Day (7 am to 6 pm)	35 (25)		40
	Evening (6 pm to 10 pm)	30 (26)		35
	Night (10 pm to 7 am)	30 (23)		35
NCA 8	Day (7 am to 6 pm)	35 (25)		40
	Evening (6 pm to 10 pm)	30 (25		35
	Night (10 pm to 7 am)	30 (22)		35

4.6.3 Amenity Noise Levels

As per the NPI (2017), the recommended amenity noise levels represent the objective for total industrial noise at a receiver location, whereas the Project amenity noise level represents the objective for noise from a single industrial development at a receiver location. Project amenity noise levels ensure that industrial noise levels remain within the recommended amenity noise levels for an area.

Amenity noise levels are not used directly as regulatory criteria. They are used in combination with the Project intrusiveness noise level to assess the potential impact of noise, assess reasonable and feasible mitigation options, and subsequently determine achievable noise requirements.

Amenity noise levels for residential receivers are defined based on three amenity noise areas: 'urban', 'suburban' and 'rural'. **Table 4.15** presents the selected noise amenity area for each NCA and the justification for the classification of each NCA. The table also displays the recommended amenity noise levels tied to the amenity noise areas, and the resulting Project amenity noise level (recommended amenity noise level minus 5 dB, plus 3 dB to convert from a period level to a 15-minute noise level).

Table 4.15. NPI amenity noise criteria, residential receivers

NCA	Noise Amenity Area	Reasoning (In reference to Table 2.3 of the Noise Policy for Industry)	Time of Day*	Recommended L_{Aeq} Noise Level dB(A)	Project amenity $L_{eq\ 15\text{-minute}}$ Noise Level dB(A)
NCA 1	Rural Residential	Categorized as C3, Environmental management is not identified in Table 2.3 of the NPI. Background landscape matches Rural Residential	Day	50	48
			Evening	45	43
			Night	40	38
NCA 2	Rural Residential	Categorized as RU2 rural landscape	Day	50	48
			Evening	45	43
			Night	40	38
NCA 3	Rural Residential	Categorised as C Environmental Conservation, C3 Environmental Management and Infrastructure SP2 not identified in Table 2.3 of the NPI. Background landscape matches Rural Residential	Day	50	48
			Evening	45	43
			Night	40	38
NCA 4	Rural Residential	Categorized as RU2 rural landscape	Day	50	48
			Evening	45	42
			Night	40	38
NCA 5	Rural Residential	Categorized as RU1 primary production landscape	Day	50	48
			Evening	45	43
			Night	40	38
NCA 6	Rural Residential	Categorized as RU2 rural landscape	Day	50	48
			Evening	45	43
			Night	40	38
NCA 7	Rural Residential	RU2 Rural Landscape	Day	50	48
			Evening	45	43
			Night	40	38
NCA 8	Rural Residential	Categorized as C2 Environmental Conservation, C3, Environmental management, SP2 Infrastructure and RU2 Rural Landscape	Day	50	48
			Evening	45	43
			Night	40	38

*Where Day: is 7 am to 6 pm, Evening: 6 pm to 10 pm, Night:10 pm to 7 am

The NPI also provides amenity noise levels for non-residential receivers. **Table 4.16** presents these levels for non-residential land usage.

Table 4.16. NPI amenity noise criteria, non-residential receivers

Receiver type	Time of Day	Recommended L_{Aeq} Noise Level dB(A)	Project amenity $L_{eq\ 15\text{-minute}}$ Noise Level dB(A)
Commercial	When in use	65	63
Industrial	When in use	70	68
Educational / Childcare	Noisiest 1-hour period when in use	35 (internal), 45 (external)	33 (internal), 43 (external)
Hospital / Medical	Noisiest 1-hour period	35 (internal), 50 (external)	33 (internal), 48 (external)
Place of Worship	When in use	40 (internal), 50 (external)	38 (internal), 48 (external)
Passive Recreation	When in use	50	48
Active Recreation	When in use	55	53

4.6.4 Project operational noise levels

The NPI recommends that the more stringent values between intrusiveness and amenity noise level criteria be applied for an operational noise assessment. Considering the intrusive and amenity criteria outlined in **Table 4.14** and **Table 4.15**, **Table 4.17** presents the Project operational noise levels adopted for the purpose of assessing the potential for operational noise impacts at surrounding residential receivers from the Project:

Table 4.17. Project operational noise criteria

Receiver type	Time of day	Noise intrusiveness level dB(A)	Project amenity $L_{eq\ 15\text{-minute}}$ Noise Level dB(A)	Recommended L_{Aeq} Noise Level dB(A)
NCA 1	Day (7 am to 6 pm)	40	48	40
	Evening (6 pm to 10 pm)	40	43	40
	Night (10 pm to 7 am)	37	38	37
NCA 2	Day (7 am to 6 pm)	40	48	40
	Evening (6 pm to 10 pm)	40	43	40
	Night (10 pm to 7 am)	38	38	38
NCA 3	Day (7 am to 6 pm)	40	48	40
	Evening (6 pm to 10 pm)	35	43	35
	Night (10 pm to 7 am)	35	38	35
NCA 4	Day (7 am to 6 pm)	40	48	40
	Evening (6 pm to 10 pm)	39	42	39
	Night (10 pm to 7 am)	35	38	35
NCA 5	Day (7 am to 6 pm)	40	48	40

Receiver type	Time of day	Noise intrusiveness level dB(A)	Project amenity $L_{eq\ 15\text{-}minute}$ Noise Level dB(A)	Recommended L_{Aeq} Noise Level dB(A)
	Evening (6 pm to 10 pm)	36	43	36
	Night (10 pm to 7 am)	35	38	35
NCA 6	Day (7 am to 6 pm)	40	48	40
	Evening (6 pm to 10 pm)	36	43	36
	Night (10 pm to 7 am)	35	38	35
NCA 7	Day (7 am to 6 pm)	40	48	40
	Evening (6 pm to 10 pm)	35	43	35
	Night (10 pm to 7 am)	35	38	35
NCA 8	Day (7 am to 6 pm)	40	48	40
	Evening (6 pm to 10 pm)	35	43	35
	Night (10 pm to 7 am)	35	38	35

4.6.5 Sleep Disturbance

The NPI (2017) also derives its guidance for the sleep disturbance screening criteria from the RNP (NSW EPA, 2011). As such, the criteria adopted for the construction phase (refer to **Table 4.4**) is also applicable for operations.

4.6.6 Operational traffic noise impacts

Similar to construction, the guidance for assessing noise generated from additional traffic during operations from EPA's RNP (2011) was applied as detailed above in **Section 4.2.3**.

5. Assessment methodology

5.1 Overview

This section outlines the methods used to assess the various noise and vibration-related matters associated with the Project.

5.2 Construction and operational airborne noise

Potential noise impacts during construction and operations were assessed quantitatively. Project details were initially reviewed to determine likely types of plant and equipment, where they would be used and when. Details for both phases as applied in the assessment are detailed below.

5.2.1 Construction staging and plant/equipment

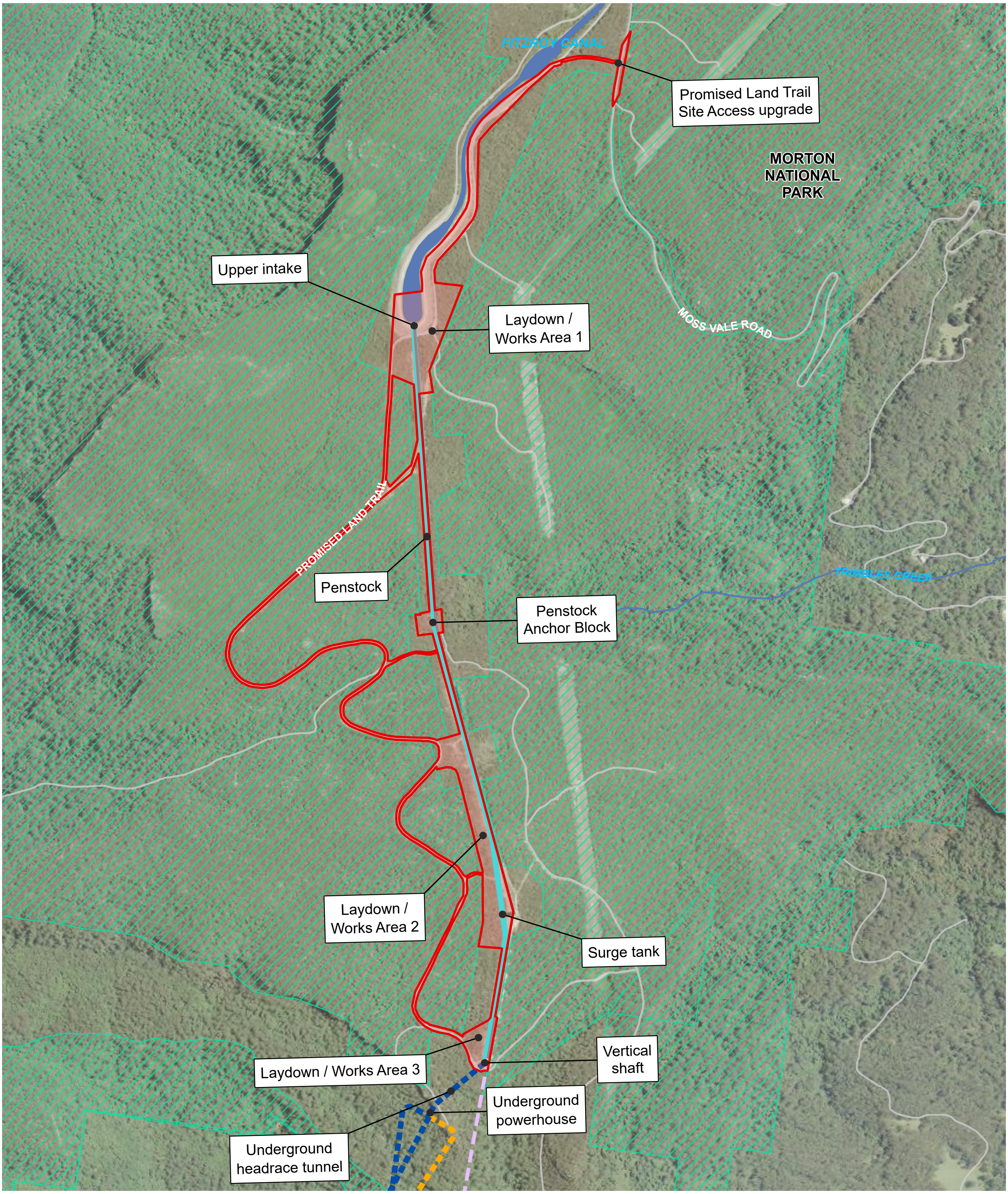
Construction takes place in two distinct schemes 'Upper Scheme' and 'Lower Scheme' that for acoustic purposes is assessed according to 'construction phase' and 'tunnelling phase'.

Further details of the Upper Scheme and Lower Scheme relevant to the assessment are discussed in the following sub-sections.

5.2.1.1 Upper Scheme

The Upper Scheme refers to works carried out above Kangaroo Valley portal revolving around site access improvements, upper laydown works, pipeline installation and shaft boring. Although an identified 21 phases are scattered an estimated construction program of over 54 months, for acoustic purposes they are modelled as single worst-case event over standard operating hours.

The layout of the Upper Scheme is displayed below in **Figure 5-1**.



Legend

- Existing KV tunnel alignment
- Existing scheme pipeline
- Indicative above ground pipeline
- Indicative tunnel alignment
- Indicative access tunnel Project
- Project area
- Road
- Waterway
- Waterbody
- NPWS Reserve

0 0.5 1 km

1:17,500 at A4

GDA2020 MGA Zone 56

Data sources

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Figure 5-1 Indicative location of Upper Scheme works

Date: 9/29/2022 Path: \\ausyd0vs01\GISProj\NSW_IS392600_ShoalhavenEIS\Apps\IS392600_Acoustic.aprx
Created by : NT | QA by : CC

The indicative program of works for construction of the Upper Scheme by month is displayed in **Figure 5-2**.

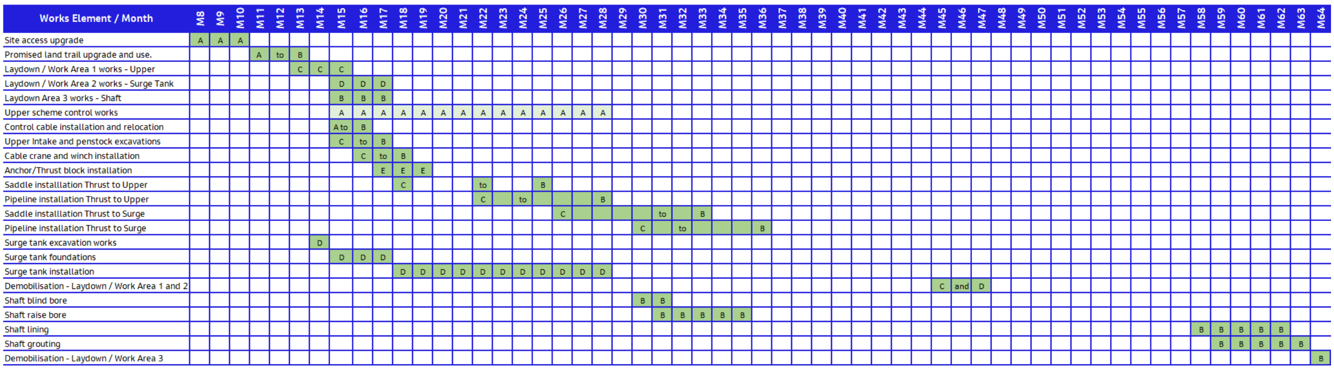


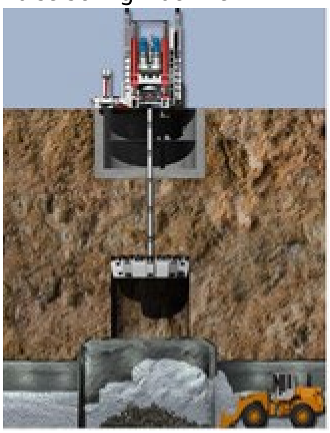
Figure 5-2. Indicative construction schedule for Upper Scheme works

Each of the Upper Scheme work locations and elements displayed above in **Figure 5-1** and listed in **Figure 5-2** are described in further detail below in **Table 5.1**.

Table 5.1. Summary of construction works in the Upper Scheme

Ref. Location	Descriptor	Summary of the works	Indicative methods, plant and equipment
A	Site access upgrade	Intersection upgrade to access the Promised Land Trail from Moss Vale Road. Likely to consist of localised widening to provide turn in and acceleration lanes. This work will be complete in advance of any major construction works in the Upper Schemes. No likely overlap with other Upper Scheme works.	▪ Standard intersection upgrade equipment. ▪ Pneumatic jackhammers (not modelled) ▪ Small excavator (40T) ▪ Loader ▪ Grader ▪ Roller (12T) ▪ Road Paver ▪ Concreting equipment.
A to B	Promised Land Trail upgrade and use	Grading along full extent of Promised Land Trail to re-establish original width. From Moss Vale Road (A) through to the headrace shaft (B).Periodic re-grading, water truck dust suppression and maintenance will be performed throughout the construction phase.	▪ Grader ▪ Vibrating roller ▪ Roller single smooth drum ▪ Small excavator (40T) ▪ Regular use by small vehicles. ▪ Periodic delivery along the route of heavy components on trucks, including pipelayer crane, generators, pipe cans (6-9m x 3.1m), cable crane towers and components, Dongas and site office facilities, fuel tanks, precast saddles etc ▪ Water tank truck.
C	Upper Laydown / Works Area 1 civil preparation and mobilisation	Some levelling and clearing to prepare hardstands for offices, plant and equipment and laydown of equipment (Laydown Area 1). Further clearing and hardstand formation may occur along a short stretch of the Promised Land Trail toward Moss Vale Road for laydown of pipe cans. This area will likely be sufficient for "just in time" construction of the penstock	▪ Grader x 2 ▪ Vibrating roller ▪ Roller single smooth drum ▪ Small excavator ▪ Dump truck tipper.

Ref. Location	Descriptor	Summary of the works	Indicative methods, plant and equipment
		with other offsite laydown used for staging. Mobilisation of site offices, cribbing facilities, containers for storage of tools and equipment and amenities.	
C	Upper intake / Area 1 Laydown / Works operations	Various construction works including: ▪ Mobilisation of cable crane and winch system along the route ▪ Construction and fit out of upper intake control structures ▪ Connection of surface penstock to existing anchor ▪ Truck unloading and crane to deliver equipment from laydown into penstock alignment ▪ Likely hub for diesel generators for welding machines, utility power and power for cable crane and winch operations ▪ Crane loading and laydown area operation ▪ Concrete batching works.	▪ Track type tractor ▪ Concrete batching plant ▪ Concrete Mixer 500 l type ▪ Crane – All terrain 80t ▪ Crane rough terrain 30t  ▪ Crane 60t rough terrain ▪ Diesel Generators ▪ Diesel welding machine ▪ Concrete pump on truck ▪ Forklifts ▪ Dump truck tipper ▪ Truck Crane 5t ▪ Semi trailer flatbed.
E	Anchor/Thrust block installation	Establishment of anchor block at penstock low point involving deeper excavations and more extensive concreting works.	▪ Small excavator ▪ Crane – All terrain 80t.
A to B	Saddle and Pipeline Installation	Minor excavation and installation of pre-cast concrete penstock saddle supports (98 off). Installation of steel pipeline segments using cable crane or winch / pulley arrangement. Welding of stiffener rings on to penstock segments. Welding pipeline segments 300 – 350 pipe can movements. Total 3750 metric ton of steel.	▪ Small excavator ▪ Welding equipment ▪ Cable crane or winch system usage  ▪ Crane – All terrain 80t.
D	Laydown Area 2	Main construction compound and laydown area including office and crib facilities and amenities. Tool containers and laydown area for pipe and surge tank steel. Active work	▪ Generators ▪ Cranes ▪ excavators ▪ trucks unloading and loading ▪ Loaders.

Ref. Location	Descriptor	Summary of the works	Indicative methods, plant and equipment
		site for full duration of the works. Including construction of the surge tank, construction of the penstock from the surge tank to the thrust block and to the shaft.	
D	Surge tank foundations	Excavating, piling and form-working and pouring concrete tank foundations.	▪ Excavator ▪ Piling rig ▪ Concrete trucks.
D	Surge tank construction	Lifting and welding metal plates into place.	▪ Crane rough terrain 30t ▪ Crane – All terrain 80t ▪ EWP / knuckle boom ▪ Welding equipment.
B	Laydown Area 3 works - Shaft	This area will be used to predominantly service the construction of a vertical or incline shaft most likely through raise bore methods. This area will also be used to service the saddle and pipeline installation between the surge tank and the shaft.	▪ Excavator ▪ Concrete truck ▪ Crane rough terrain 30t ▪ Generator.
B	Pilot hole blind bore	Boring the pilot hole to connect the drive shaft of the raise boring machine with the cutting head.	▪ Boring rig ▪ Loader ▪ Dump truck ▪ Slurry pumps for spoil ▪ Diesel generator.
B	Shaft raise bore	Raise boring the shaft.	▪ Raise boring machine 
B	Shaft Reaming (if required)	Expanding the diameter of the shaft working from top down and installing support into the sides of the hole as it progresses.	▪ Gantry crane

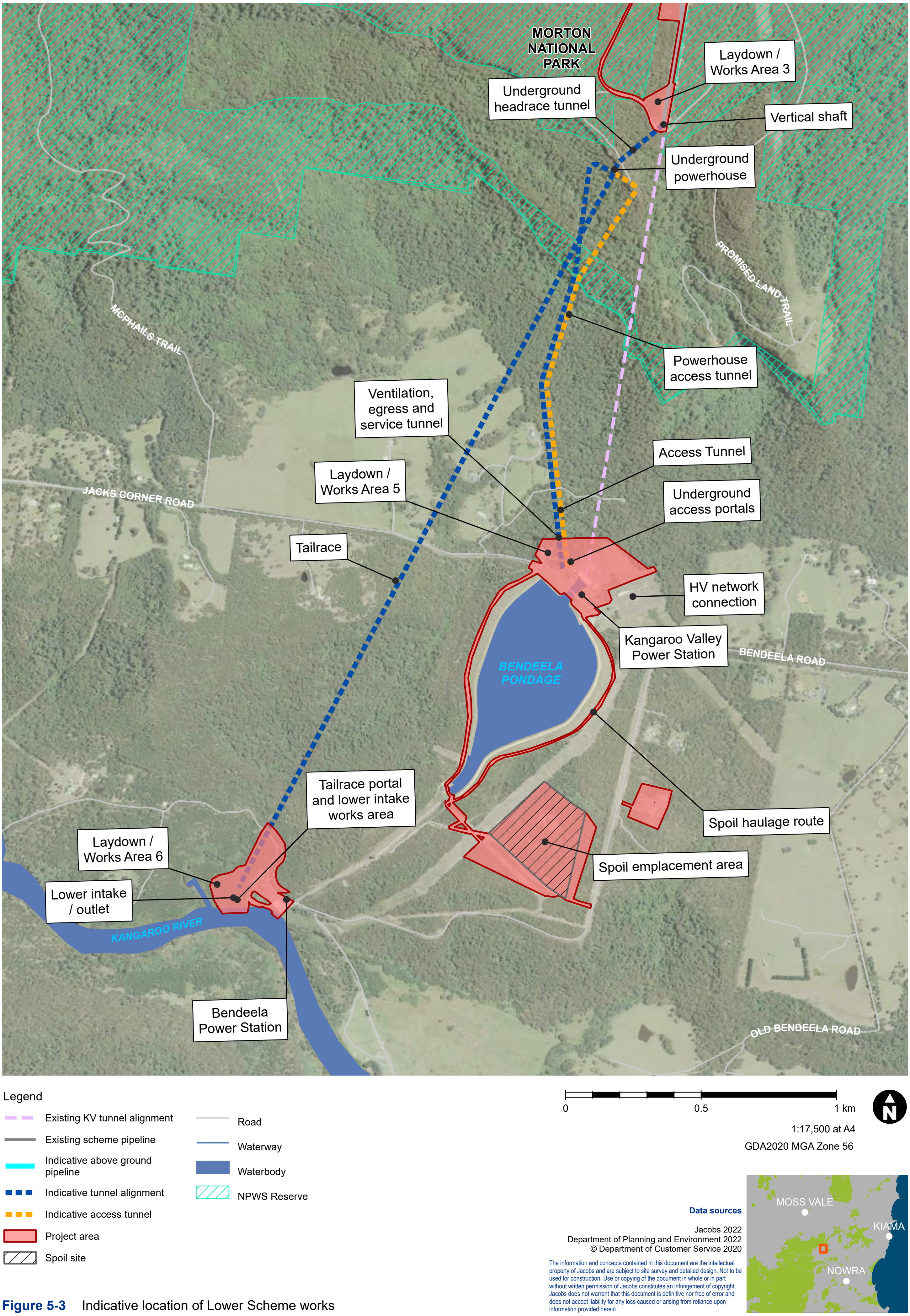
Ref. Location	Descriptor	Summary of the works	Indicative methods, plant and equipment
			 ▪ Reaming equipment  ▪ Rock bolting equipment.
B	Shaft lining	Lowering steel sections of pipe into the vertical shaft.	▪ Trucks to deliver pipe sections ▪ Gantry crane to lower sections into shaft ▪ Welding equipment.
B	Shaft concreting	Filling the void between the steel pipe and the excavated shaft with concrete.	▪ Concrete truck and pumps ▪ Hose ▪ Concrete vibrators.

Noise from each phase of the Upper Scheme listed in **Table 5.1** was considered as part of the assessment. Estimated noise emissions for each phase is described below in **Section 5.2.3**.

5.2.1.2 Lower Scheme

The Lower Scheme refers to works carried out at Kangaroo Valley portal, tail race portal, Laydown Area 7 and spoil emplacement area and traffic between portals and storage/spoil sites. The construction of the Lower Scheme is broken into 'construction phase' and 'tunnelling phase'. The construction phase considers standard daytime construction and for acoustic purposes models all construction and preparatory activities as single worst-case event. The 'tunnelling phase' is considered as separate item as this work is carried out 24-hours a day, 7 days a week and includes activities relating to tunnelling activities including surface works essential to support underground works.

Figure 5-3 shows the indicative layout of the Lower Scheme.



Data sources

Jacobs 2022
Department of Planning and Environment 2022
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Figure 5-3 Indicative location of Lower Scheme works

The program for construction of the Lower Scheme by month is displayed in **Figure 5-4**.

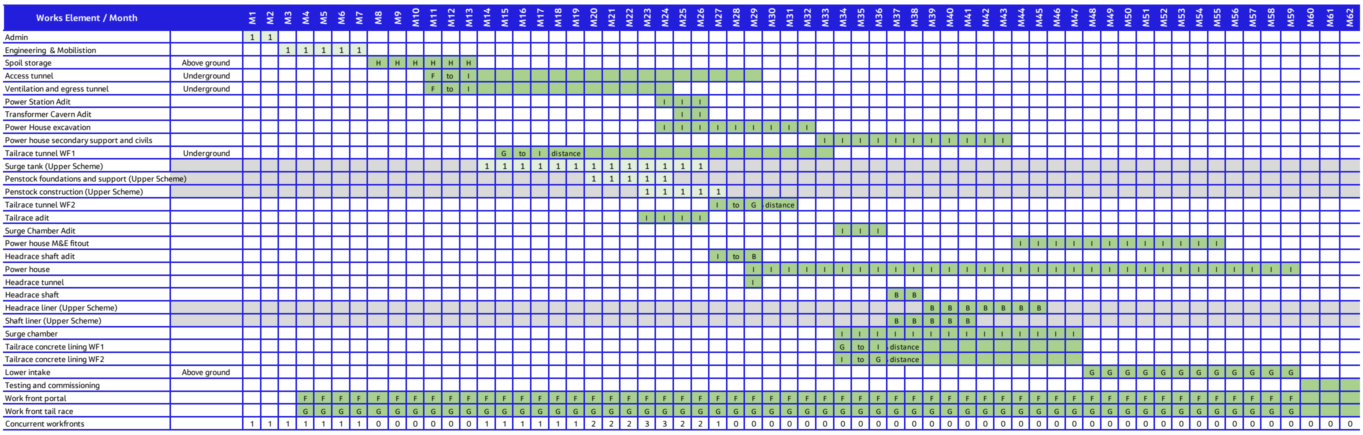

Figure 5-4. Indicative construction schedule for Lower Scheme works

Each Lower Scheme work location and elements shown in **Figure 5-3** and listed in **Figure 5-4** are detailed below in **Table 5.2**.

Table 5.2. Summary of construction works in the Lower Scheme

Ref. Location	Descriptor	Summary	Indicative methods, plant and equipment
F	Tunnel Portal Entry adjacent to Kangaroo Valley Power Station (Laydown / Works Area 5)	▪ Initial cut and cover plus initial tunnelling ▪ Ongoing construction services including water treatment plant and ventilation ▪ Construction compound.	▪ Excavators ▪ Loaders ▪ 20t dump truck ▪ Road header  ▪ 100t mobile crane ▪ Rock bolting equipment ▪ Shotcreting equipment  ▪ Diesel Generator ▪ Water treatment plant ▪ Ventilation fans Batching plant.
F	HV connection from tunnel	Construction of works necessary to connect HV cable from Tunnel portal to TransGrid switchyard.	▪ Small Excavator.

Ref. Location	Descriptor	Summary	Indicative methods, plant and equipment
	portal to switchyard		
F	Surface Facility Construction	Construction of the surface facilities for servicing the underground power station including fire water tanks, smoke exhaust system building, water treatment plant, fire pumps, ventilation system and carparking.	▪ Excavator ▪ Grader ▪ Paver ▪ Generator ▪ Air compressor ▪ 50t Crane ▪ Lighting poles ▪ Forklifts.
H	Spoil haulage	Potential 24/7 haulage of tunnel spoil to spoil disposal location from both access portal and tailrace portal.	▪ Approximately 62 x 20t trucks per day.
H	Clear and Prepare spoil site	Vegetation clearing, earthworks and embankment building, liner construction and placement, overflow containment sumps.	▪ Standard earthworks equipment ▪ Bulldozer ▪ Grader ▪ Loader ▪ Excavator.
H	Spoil disposal location	Receipt and placement of spoil. Crushing of excavated material for reuse in concrete mixing.	▪ Loaders ▪ 20t dump trucks ▪ crushing plant.
J	Clear and prepare construction laydown area	Clearing, scrubbing and flattening laydown area.	▪ Bulldozer ▪ Grader ▪ Loader ▪ Excavator.
J	Construction Laydown Area 7	Unloading, storage and re-loading of equipment and construction material ready for installation.	▪ Flatbed trucks ▪ Forklifts ▪ 50t crane.
G	Tail race portal works (Laydown / Works Area 6)	Cut and cover plus initial tunneling ; Ongoing tunnelling services including ventilation and water management.	▪ Excavator ▪ Dewatering system ▪ Ventilation equipment ▪ 50t rough terrain crane.
G	Lower Intake construction (Laydown / Works Area 6)	Excavation, construction of concrete intake structure, connection to tailrace tunnel, backfilling and blasting of rock plug for water filling once complete.	▪ Standard construction works for lower intake construction. ▪ Dewatering system ▪ Explosives Crane.
F to I	Underground tunnelling works	Tunnelling of the access tunnel and multipurpose egress, ventilation and services tunnel and construction adits with mucking through the main portal near KV station. Rock bolting and shotcreting.	▪ Road header ▪ 20t trucks ▪ Boom drill for rock bolting  ▪ Loader ▪ Shotcreting equipment

Ref. Location	Descriptor	Summary	Indicative methods, plant and equipment
			▪ Lighting rigs.
G to I	Underground tunnelling of the Tailrace	Tunnelling, with mucking via trucks through the tailrace portal, rock bolting and shotcreting.	▪ Road header ▪ 20t trucks ▪ Rock bolting equipment ▪ Shotcreting equipment.
G to I	Tailrace Tunnel lining	Concrete lining. 	▪ Concrete truck ▪ Rail and formwork system ▪ Concrete Injection equipment ▪ Concrete vibrators.
I	Powerhouse Cavern Excavation and Structural Work	Underground excavation and installing supports for the cavern. Mucking through the MAT and EGV tunnel. Erecting structural components including underground power station columns, beams, stairways, platforms, equipment foundations and floors.	▪ Excavator ▪ Loader ▪ 20t truck ▪ Concreting equipment ▪ Concrete truck ▪ Formwork ▪ Concrete vibrators ▪ Overhead and mobile cranes.
I	Power Station M&E Installation	Installing the equipment within the underground station.	▪ Flatbed trucks ▪ Overhead and mobile cranes ▪ Forklifts ▪ Welding equipment ▪ Rattle guns.

Noise from each phase of the Lower Scheme listed in **Table 5.2** was similarly considered in the assessment. Estimated noise emissions for each phase is also described below in **Section 5.2.3**.

5.2.1.3 Other construction assessment stages

As well as the Upper Scheme and Lower Scheme, noise impacts were also evaluated for two other stages of construction:

- Underground works. This stage considers longer-term noise that may arise from spoil and equipment management activities at the Kangaroo portal and tail race portal locations.
- Short term bulk delivery events. Owing to the size of plant, equipment and materials needed for the Project, these deliveries are generally expected to be classified as being overs size and or over mass (OSOM) and are expected to require deliveries to be completed during night-time, to comply with road rules.

5.2.2 Construction hours

Construction of the Upper Scheme and Lower Scheme are assessed as occurring during standard hours and from 1pm to 6pm Saturdays (i.e. outside standard hours, daytime). The underground spoil, materials and equipment management are required to take place on a continuous, 24-hour basis (i.e. during and outside standard construction hours). Finally, the OSOM deliver events may be undertaken at any time, although are most likely to occur outside standard hours, at night to minimise traffic disruptions.

5.2.3 Construction noise emissions

Sound power levels (SWLs) were estimated for each construction stage, including each associated sub-phase of the Project. Sound power levels were determined by developing an inventory of noise producing equipment and the estimated numbers of equipment based on the works taking place. Individual plant and equipment SWLs were estimated from guidance presented in national and international standards and guidelines, as well as from a Jacobs measurement database. **Table 5.3** lists the emissions inventory developed for the assessment of airborne noise from the Project during construction.

Table 5.3. Airborne noise emissions inventory, construction

Stage	Phase	Activity	Plant and equipment	SWL (indiv)	SWL (overall)
Upper Scheme	A. Site Access upgrade	Road Upgrades	Grader	106	119
			40T Exc.	107	
			12T Roller incl. penalty (+5dB due to ICNG)	117	
			Asphalt paver	112	
			Concrete pump on truck (87m3/h)	108	
	B. Trail Upgrade	Road Upgrades	Grader	106	119
			40T Exc.	107	
			12T Roller incl penalty (+5dB due to ICNG)	117	
			Truck Dump	114	
			Water Truck	109	
	C. Surge	Construction	Grader	106	120
			Excavator	115	
			Roller incl penalty (+5dB due to ICNG)	115	
			Truck Dump	114	
			Water Truck	109	
	C. Laydown	Construction	Track type Tractor 240HP CatD7E	110	120
			Concrete batching plant	115	
			Concrete mixer 500 l type	107	
			Crane - All terrain 80t	105	
			Crane - Rough terrain 30t	98	
			Crane - 60t rough terrain	105	
			Diesel Generator	107	

Stage	Phase	Activity	Plant and equipment	SWL (indiv)	SWL (overall)
			Diesel welding machine 400	102	
			Concrete pump on truck (87m3/h)	111	
			Forklift 1	99	
			Forklift 2	99	
			Truck Dump	114	
			Truck Crane 5t	105	
			Semi-Trailer Flatbed	111	
			Crane - Unloading	98	
	E. Penstock	Construction	Small Excavator	105	108
			Crane - All terrain 80t	105	
	A-B. Saddle	Preparation	Small excavator	105	118
			Diesel welding machine 400	107	
			Cable crane or winch system	117	
			Crane - All terrain 80t	105	
	D. Laydown Area	Construction	Diesel Generator	107	120
			Crane - All terrain 80t	105	
			Excavator	115	
			Truck Dump	114	
			Truck Dump	114	
			Loaders	111	
	D. Surge Foundation	Foundation	Excavator	107	113
			Piling incl. penalty (+5dB due to ICNG)	103	
			Concrete pump on truck (87m3/h)	111	
	D. Surge Construction	Construction	Crane - Rough terrain 30t	98	107
			Crane - All terrain 80t	105	
			EWP	97	
			Diesel welding machine 400	102	
	B. Blind Bore	Construction	Raise bore machine / could also be blind bore	114	120

Stage	Phase	Activity	Plant and equipment	SWL (indiv)	SWL (overall)
			Generator blind bore	107	
			Crane - All terrain 80t	105	
			Grouting	114	
			Concrete batching plant	115	
			Concrete pump on truck (87m3/h)	111	
			Pipe delivery	111	
Lower Scheme	F. Kangaroo Valley Portal	Construction	Excavator1	115	123
			Excavator2	115	
			Concrete pump on truck (87m3/h)	111	
			Drott	110	
			Road Header	114	
			Pump	110	
			Batching Plant	115	
			100t mobile crane	99	
			Rock anchor drill incl. penalty (+5dB due to ICNG)	113	
			Air Compressor	105	
			Small Water Treatment Plant	107	
			Grader	106	
			Road Paver	112	
			Forklift 1	99	
			Forklift 2	99	
	G. Tail Portal	Construction	Excavator – site prep	115	122
			Excavator – site prep	115	
			Concrete pump on truck (87m3/h)	114	
			Drott – site prep	110	
			Road Header	114	
			Pump	110	
			Batching Plant	115	

Stage	Phase	Activity	Plant and equipment	SWL (indiv)	SWL (overall)
			Crane - All terrain 80t	105	
			Air Compressor	105	
			Small Water Treatment Plant	107	
	J. Storage	Preparation	Grader	106	116
			40T Exc.	107	
			Loader	113	
			Drott	110	
Tunnelling Work	H. Spoil site	Preparation	Track type Tractor 240HP CatD7E	110	116
			Excavator	115	
	J. Transport	Typical arrival & unloading	Semi-Trailer Flatbed	111	112
			Crane unloading	105	
	F. Kangaroo Valley Portal	24/7	Concrete pump on truck (87m3/h)	111	118
			Pump	11	
			Batching Plant	115	
			Fan Inlet Silenced	97	
			Fan Casing/Duct breakout	97	
			Air Compressor	105	
			Small Water Treatment Plant	107	
	G. Tailrace Portal	24/7	Loader	113	122
			Pump	110	
			Batching Plant	115	
			Fan Inlet Silenced	101	
			Fan Inlet Case breakout	119	
			Air Compressor	105	
			Small Water Treatment Plant	107	
	H. Spoil management	Delivery, placement and management of spoil	Truck Haulage - Kangaroo	114	122
			Truck Haulage - Tail	114	
			Truck Haulage - D-Upper Scheme - down mountain	114	

Stage	Phase	Activity	Plant and equipment	SWL (indiv)	SWL (overall)
			Truck Haulage - D-Upper Scheme - to H	114	
			Dumping - Kangaroo portal	107	
			Dumping - Tail portal	107	
			Dumping - D-Upper Scheme	107	
			Track type Tractor 240HP CatD7E	110	
			Excavator	115	
			Crusher	112	
Short Term Night Deliveries	Short Term Night Deliveries	OSOM arrival & unloading	Semi-Trailer Flatbed	111	112
			Crane unloading where applicable	105	

Section 4.5 of the ICNG identifies construction activities and types of plant and equipment that can generate noise perceived as being particularly annoying for nearby residents. This penalty was applied for the relevant plant and equipment, as listed above.

5.2.3.1 Scenario Overview

The construction occurs over an extensive period of time with multiple overlapping and non-overlapping phases. Actual construction typically deviates somewhat and a conservative approach of modelling all activities based broadly divided into “Upper Scheme” and “Lower Scheme” is taken. Additional context is provided by considering peak tunnelling activities with spoil haulage considered in daytime and 24-7 haulage scenario. It is noted that some infrastructure components delivered to site are of a size requiring night-time transportation.

A visualisation of all scenario noise sources and resulting noise impact predictions is illustrated in **Appendix C.**

5.2.3.2 Construction Upper Scheme - Daytime Only

Construction upper scheme refers to all construction activities north of Kangaroo Valley Portal. The phases associated with the works is outlined in the “upper scheme” portion of **Table 5.3** in **Section 5.2.3**. The activities included road works, construction, and preparation work.

5.2.3.3 Construction Upper Scheme Daytime Only with peak tunnelling & day spoil management in the Lower Scheme

Construction upper scheme refers to all construction activities north of Kangaroo Valley Portal. The phases associated with the works is outlined in the “upper scheme” and “tunnelling work” portion of **Table 5.3** in **Section 5.2.3**. The activities included road works, construction, preparation and construction work. The tunnelling activity includes, some spoil site preparation, transportation and tunnelling related activities

5.2.3.4 Construction Lower Scheme - Daytime Only

Construction Lower Scheme refers to all construction activities around and south of Kangaroo Valley Portal. The phases associated with the works is outlined in the “Lower Scheme” portion of **Table 5.3** in **Section 5.2.3**.

5.2.3.5 Construction Lower Scheme Daytime Only – peak tunnelling & day spoil management

Construction Lower Scheme refers to all construction activities around and south of Kangaroo Valley Portal. The phases associated with the works is outlined in the “Lower Scheme” and “tunnelling work” portion of **Table 5.3** in **Section 5.2.3**.

5.2.3.6 Tunnelling – 24/7 Peak including haulage

Tunnelling 24/7 peak, refers to highest haulage activities during tunnel only following initial construction. Activities include surface activities of the tunnelling portal (Kangaroo Valley, Tail Race), spoilage transport, spoil management and equipment storage. The phases associated with the works is outlined in the “tunnelling work” portion of **Table 5.3** in **Section 5.2.3**.

5.2.3.7 Tunnelling – 24/7 Peak, Daytime-haulage only

Tunnelling 24/7 peak Daytime-haulage, refers to highest haulage activities (daytime only) during tunnel only following initial construction. Activities include surface activities of the tunnel portals (Kangaroo Valley, Tail Race), and equipment storage. Spoilage transport and spoil management at spoil storage site is managed in daytime only. The phases associated with the works is outlined in the “Tunnelling Work” portion of **Table 5.3** in **Section 5.2.3**.

5.2.3.8 Deliveries – Night Time

Deliveries night time refers to short term transport requirements of large and bulky equipment (i.e. steel liners / other OSOM deliveries). Activities revolve around crane and truck movements on site. The phases associated with the works is outlined in the “Short Term Night Deliveries” portion of **Table 5.3** in **Section 5.2.3**.

5.3 Operational details

The operating plant associated with the Project consists of turbines, transformers, ventilation facilities, a water treatment plant and other support infrastructure. The bulk of these would be located deep underground and are not expected to cause any noise-related issues.

Surface infrastructure that would generate noise during operations include the water treatment plant and ventilation facilities for the underground installations. The estimated sound power levels and unit numbers applied in the assessment are detailed below in **Table 5.4**. The noise levels of the units assume the units will be operating at their peak load (i.e., at their highest noise producing capability).

Table 5.4. Airborne noise emissions inventory, operations

Noise Source	Number of Units	Sound Power Level (dB(A))
Water Treatment Plant	1	93
Tunnel Ventilation	1 duty, 1 standby	100

Annoying’ noise characteristics associated with the operation of industrial facilities are addressed in Fact Sheet C of the NPI. Where an ‘annoying’ noise characteristic is identified, a correction is to be applied account for these effects. Neither of the sources listed above in **Table 5.4** are expected to exhibit noise with ‘annoying’ characteristics. As such, no penalties were applied to the noise levels applied as part of the operational noise assessment.

Noise resulting from the two operational sources above is expected to be generally constant. Some variability may occur during start-up and shutdown, during maintenance and extraordinary circumstances. Considering this, the assessment of sleep disturbance impacts considered L_{AFmax} levels as being 3 dB(A) higher than L_{AEq} predictions.

5.3.1 Operational hours

The assessment has considered that the water treatment plant and tunnel ventilation facilities would operate continuously 24-hours a day and 7-days per week. As such, results were evaluated against the Project operational noise levels established for all periods (i.e. day, evening and night) as outlined above in **Section 4.6.4**.

5.4 Model setup

Noise levels at surrounding sensitive receivers during construction and operations were predicted using a site noise model. Key details of the model which was developed using the Cadna acoustic software package are listed in **Table 5.5** below.

Table 5.5. Model settings, construction and operational noise

Model Setting	Value	Detail
Topography	Derived from 10m and 1m interval data set	Derived from published and Lidar data.
Buildings	Reflection loss 1dB	Footprints for receiver and other buildings in the area surrounding works was determined from aerial photography. Heights and floor numbers were ascertained from Google Street view, or otherwise, assuming a building height of 3 meters per floor plus 2m for the roof.
Receivers	1.5m height (varying location for construction and operations)	Construction receivers placed approx. 30m from the façade of identified residential dwelling at 1.5m height, in-line with the ICNG. Operational receivers were placed at the potentially affected receiver buildings.
Ground absorption	0.75	A 'rural' ground absorption factor of 0.75 was applied across the whole model area.
	0.5	A 'urban' ground absorption factor of 0.5 was applied to Major Urban Area.
	0.3	Facility where applicable.
	0.0	Waterbodies and roads.
Order of reflections	3	Reflection effects account for 3 orders of reflection.
Noise Sources	Table	Sources were arranged and sound power levels were set as outlined in Section 5.2.1, Section 5.2.3 (construction) and Section 5.3 (operations).
Foliage	Not included	Foliage especially densely forested areas can play a role in noise attenuation. The site is predominantly rural developments and Foliage has not been included in the noise calculation.
Prediction Method	CONCAWE	Engineering method to calculate the attenuation of sound during propagation outdoors. The method accounts for noise enhancing propagation considering temperature inversion. Standard (construction) and noise-enhancing meteorological conditions (operations) as outlined above in **Table 3.6** were applied.

5.5 Evaluation of predictions

Noise levels at surrounding sensitive receivers during construction and operations were predicted using a site noise model described above. These predictions were evaluated by comparing the results with the noise management levels (construction) and Project operational noise levels (operations), as well as sleep disturbance objectives established in Section 4 above. The outcomes of this comparison were used to determine mitigation and management required which is discussed below in **Section 8**.

5.6 Ground-borne noise

Ground-borne noise within receiver structures is dependent on the magnitude of the vibration levels that enter the structure via the building's footings, and the transmission, attenuation, and amplification of the vibration as it travels through the structure, and the conversion of the vibration energy into sound as it is re-radiated into the rooms within the buildings. All of these factors are highly variable between different structures, different types of soil/rock that the building is founded upon, and different types of vibration sources. The prediction methodologies that are typically used for estimating ground-borne noise are therefore necessarily general in nature, and conservative.

Empirical techniques to predict ground-borne noise from some types of underground construction activities are published in several industry-standard technical references. However, most published technical references typically do not provide estimation techniques for predicting ground-borne noise from underground construction activities using road headers, which would be the primary sources of underground vibration to be used in construction of the Project. British Standard 5228-2:2009+A1:2014 'Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration' states:

> *'The mechanisms which give rise to the propagation of vibration through media such as soil are complex. The magnitude of vibration is determined by the characteristics of the vibration source, the properties of the excavated ground, and the ground between the vibration source and receiver. Multi-layered soils and/or the presence of deep piled building foundations can further complicate and modify magnitudes and estimates. As such, it is inappropriate to provide definitive generic guidance on the likely magnitudes of groundborne noise and vibration that might be expected as a result of a particular construction technique. Estimation of the likely noise and vibration effects from sub-surface construction activities based solely on consideration of previous case studies should therefore be undertaken with caution. Calculating groundborne noise and vibration is highly specialized, and expert advice should be sought if a high degree of confidence in the predicted levels is required'.*
>
> *Source: BS 5228-2:2009+A1:2014 - Code of practice for noise and vibration control on construction and open sites – Part 2: Vibration*

Based on the recommendations in BS 5228-2:2009+A1:2014, it is considered that indicative ground-borne noise levels from the underground road headers -should be estimated using empirical methods based upon similar projects undertaken in the Greater Sydney region.

Empirical methods that have been used to predict ground-borne noise from underground construction activities, including in the Greater Sydney area using road headers are described in several technical publications including:

- 'Brisbane North-South Bypass Tunnel – Tunnelling Noise & Vibration – Information for Tender', Wilkinson Murray Report No 05181-T Version A, September 2005
- Karantonis, P. et al (2018) 'Ground-borne Noise & Vibration Results from recent Tunnelling & Construction Projects in Sydney', Proc. Acoustics 2018, Adelaide, South Australia, 6-9 November
- 'Australian Acoustical Society Technical Meeting - Tunnelling Noise and Vibration Management', Wilkinson Murray, December 2003.

On the basis of similarity in geology and construction equipment, an empirical prediction method to predict ground-borne noise levels from underground road headers is provided in Wilkinson Murray Report No 05181-T (ver A), 2005:

Ground-borne noise level $L_{Aeq} = 84 - 30.3 \cdot \log_{10}(R)$

Where:

R = 3-dimensional (slant) distance between the underground road header and the receiver building (m).

Using this equation and the indicative 3-dimernsional slant distances to the surrounding sensitive receivers, ground-borne noise from road header tunnelling activities were predicted. The results were evaluated by comparing the predictions against the limits from the ICNG above in **Table 4.10**.

5.7 Construction and operational traffic noise impacts

Noise associated with addition traffic movements generated during construction and operations were predicted using Transport for New South Wales' Construction Noise Estimator (CNE) tool. Anticipated additional traffic associated with the Project and existing traffic (outlined in **Section 3.6**) were applied in the CNE to predict resulting day and night-time noise levels at the nearest sensitive receivers along main transport routes. Details of the estimated additional traffic associated with the Project during construction and operations is included below in **Section 6.4**.

Results with and without the additional traffic generated by the Project were reviewed to determine if increases more than 2 dB(A) were predicted. Where applicable, levels were compared against the relevant road noise assessment criteria listed in **Table 4.5** to determine if specific management actions would be required.

5.8 Vibration from activities other than blasting

5.8.1 Tunnelling using road headers

Vibration impacts from tunnel construction are highly variable depending on the type of road header cutting head and the type of rock/soil being excavated. In practice, vibration levels from underground construction using road headers can only be estimated based on empirical data gathered from similar projects.

Several published technical reports and research papers have presented empirical data based on measurements of ground vibration from similar tunnelling projects, including within in the Greater Sydney area. These include:

- 'East West Link – Eastern Section Tunnel Vibration & Regenerated Noise Assessment', Heilig & Partners Pty. Ltd. Report No HP 1303-2, September 2013
- Karantonis, P. et al (2018) 'Ground-borne Noise & Vibration Results from recent Tunnelling & Construction Projects in Sydney', Proc. Acoustics 2018, Adelaide, South Australia, 6-9 November
- 'Brisbane North-South Bypass Tunnel – Tunnelling Noise & Vibration – Information for Tender', Wilkinson Murray Report No 05181-T Version A, September 2005.

These publications have provided sufficiently detailed information to allow prediction of the risk of vibration impacts from the underground tunnel construction works using road headers.

According to the Wilkinson Murray Report No 05181-T ver. A (2005), ground vibration from road headers can be inferred from the predicted ground-borne noise level. According to Melbourne Metro Rail Authority (MMRA) 'Technical Note 042' (19 August 2016), the vibration from road headers is dominant between 25 Hz and 80 Hz. Assuming all of the received ground-borne noise energy is concentrated at a single frequency between 25 Hz and 80 Hz, the ground vibration can be conservatively estimated. An approximate relationship between ground-borne noise and ground vibration was derived by Kurtzweil (1979):

$$L_p = 20 \cdot \log_{10}(V_{rms}) + 93$$

Where:

L_p = Calculated octave or ⅓ octave band sound pressure level inside the receiving room (dB re: 20 mPa)

V_{rms} = The rms vibration velocity in octave or ⅓ octave band (mm/s)

Source: Kurzweil, L.G. 1979, *Ground borne noise and vibration from underground rail systems*, Journal of Sound and Vibration, Vol 66(3), pp 363-370

The peak vibration velocity (PPV) can then be estimated from V_{rms} by assuming sinusoidal vibration with the approximate relationship: PPV = $V_{rms} \cdot \sqrt{2}$.

For the assessment of vibration levels against the criteria for structural damage, due to the shape of the A-weighting curve between 25 Hz and 80 Hz, the conservative approach would be to assume that all of the sound and vibration energy is concentrated at a frequency of 25 Hz.

For the assessment of vibration against the criteria for human annoyance, the conservative approach would also be to assume that all of the sound and vibration energy is concentrated at a frequency of 25 Hz, due to the shape of the A-weighting curve between 25 Hz and 80 Hz and the conversion of vibration *rms* velocity into vibration *rms* acceleration.

The prediction methodology has considered the likelihood of ground vibration from more than one road header constructing more than one tunnel at the same time, being received at receivers simultaneously, as shown in the extract from the construction plan in **Figure 5-5**.

As shown in **Figure 5-5**, ground vibration and ground-borne noise are likely to be received at receivers from the road headers constructing the Ventilation and Egress Tunnel and the Access Tunnel in close proximity to each other at the same time. Similarly, it is possible that ground-borne noise and vibration may be received at the nearest receivers from the simultaneous construction of the two work fronts of the Tailrace tunnel. However, due to the locations of the receivers and the rate of progression of each tunnel's construction, the ground vibration and ground-borne noise from construction of the Tailrace Tunnel and the other tunnels will not be received simultaneously, so the ground-borne noise and vibration impacts from construction of the Tailrace Tunnel can be assessed independently of the other tunnels.

Using this information and the method outlined above, vibration from underground tunnelling activities involving road headers was predicted at surrounding receivers. Results were evaluated by comparing predictions against the building damage and human comfort criteria from BS 7385-2:1993 and DEC, 2006 outlined above in **Section 4.3.1** and **Section 4.3.2** respectively.

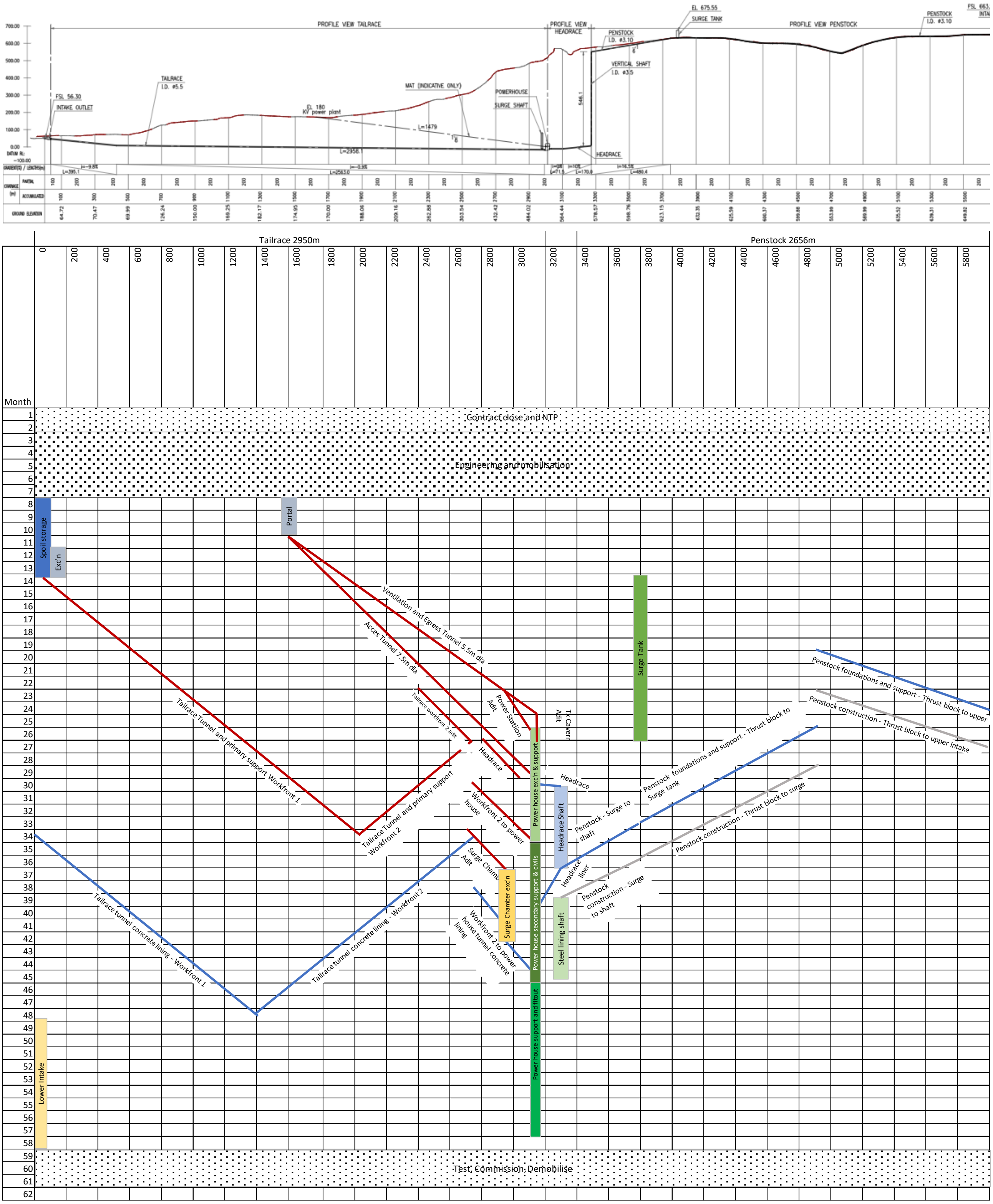

Figure 5-5. Indicative construction program showing relevant tunnelling locations and timelines

Source: Origin Energy (2022)

5.8.2 Other surface plant and equipment

Of the plant and equipment expected to be used during surface construction activities, the following have the potential to generate vibration impacts:

- Vibratory pile driver
- Large hydraulic hammer (1600 kg – 18 t to 34 t excavator)
- Jackhammer.

Potential vibration impacts associated with the use of these plant and equipment during construction were evaluated using the safe setback distance guidance from the CNVG to meet building damage and human comfort criteria from BS 7385-2:1993 and DEC, 2006 criteria. These setbacks were compared with the distances to surrounding receivers to determine the potential for impacts.

5.9 Blasting

Ground vibration and air blast overpressure are predicted using the methods presented in Australian Standard 2187.2-2006. These prediction methods can be used to design blasts so that ground vibration and air blast overpressure levels will comply with the applicable criteria.

5.9.1 Air blast overpressure

Air blast levels can be estimated for an unconfined surface blast using the method provided in AS2187.2-2006, Appendix J7 'Estimation of Ground Vibration and Air blast Levels'. This equation has been reproduced below:

$$P = K_a \left(\frac{R}{Q^{1/3}}\right)^a$$

Where:

P = pressure in kilopascals
Q = explosive charge mass, in kilograms
R = distance from charge, in m
K_a = site constant
a = site exponent

For confined blasthole charges, $a \approx -1.45$ and K_a is commonly in the range 10 to 100.

Under noise-enhancing meteorological conditions such as wind gradient and/or temperature inversion, air blast levels can be increased by up to 20 dB.

It is usually advisable to determine the site-specific parameters K_a and a to enable the blast designers to select configuration parameters such as charge sizes so that blasting will comply with the air blast overpressure targets.

Based on the need and ability to carefully design blasts and uncertainty around locations and charge size, no predictions of air blast overpressure are provided. Should surface blasting be required, detailed blast planning would be undertaken in accordance with a blast management strategy as described and committed to in Chapter 3 of the EIS to achieve criteria established above in **Section 4**.

5.9.2 Ground vibration from surface blasting

Appendix J7 'Estimation of Ground Vibration and Air blast Levels' from AS2187.2-2006 also provides guidance for predicting ground vibration from surface blasting. The equation below outlines the prediction method.

$$V = K_g \left(\frac{R}{Q^{1/2}}\right)^{-B}$$

Where:

V = ground vibration as vector peak particle velocity (PPV), in millimetres per second (mm/s)
R = distance in m
Q = maximum instantaneous charge (MIC) (effective charge mass per delay), in kilograms
K_g, B = constants related to site and rock properties

When blasting is to be carried out to a free face in average field conditions, the average (mean) PPV can be estimated with K_g = 1140 and B = -1.6. In practice, due to variations in ground conditions and other factors, the resulting ground vibration levels can vary from two-fifths to four times the mean PPV values estimated using these values. It is usually advisable to determine the site-specific values of K_g and B on site prior to conducting blasting.

This guidance will be used as part of detailed blast design planning to predict ground vibration levels (as PPV) at surrounding sensitive receivers to achieve compliance with the criteria from BS 7385-2:1993 listed in **Table 4.6**. Should surface blasting be required detailed blast planning would be undertaken in accordance with a blast management strategy as described and committed to in Chapter 3 of the EIS.

5.9.3 Ground vibration from underground blasting

Ground vibration levels from underground blasting is dependent on the size of the explosive charge, the 3-dimensional (slant or slope) distance through the soil/rock between the blast and the receiver, and the vibration transmission properties of the soil/rock.

An indicative estimate of vibration levels from underground blasting is provided in the 'ICI Explosives Blasting Guide – Technical Services', ICI Explosives, October 1995. The prediction is given by:

$$V(\text{mm/s}) = 608 \times \left(\frac{Q^{0.5}}{R}\right)^{1.6}$$

Where:

Q = charge size (kilograms)
R = slant distance (m)

It is usually advisable to determine the site-specific vibration transmission properties of the soil/rock to enable the blast designers to select configuration parameters such as charge sizes so that blasting will comply with the vibration targets.

It is noted that the vibration criteria and the vibration prediction method are both independent of the frequency spectrum content of the ground vibration blast waves.

Using the approach above, ground vibration levels from underground blasting associated with cavern construction were predicted. Results were evaluated by comparing the predictions with the 5 mm/s PPV value from the ANZEC guidelines as outlined above in **Section 4.5.4**. Should drill and blast be required as part of tunnel methodology, detailed blast planning would be undertaken in accordance with a blast management strategy as described and committed to in Chapter 3 of the EIS.

6. Impact assessment

Predicted results for each of the different noise and vibration-related aspects of the assessment using the methods outlined above in **Section 5** are detailed below.

6.1 Construction airborne noise

6.1.1 Upper Scheme

Results for the assessment of noise from construction of the Upper Scheme are detailed below. These results represent the worst-case noise impacts with all associated phases conservatively assumed as taking place at the same time. Levels in **Table 6.1** were compared against the NMLs developed for standard hours, as well as the NMLs for daytime out of hours noting that activities may also be completed from 1pm to 6pm on Saturday. Bold italics are used to identify exceedances of Standard Construction Hours NMLs while bold depicts exceedances of Outside standard hours daytime NMLs.

Table 6.1. Predicted noise levels, Upper Scheme construction activities

Receiver ID	Noise level $L_{Aeq\ 15\text{-}minute}$ dB(A)			
	Construction	Construction w. Peak Daytime only Haulage	NML Standard hours	NML Outside standard hours, day
R1	***46.5***	***46.5***	45	40
R2	<20	<20	45	40
R3	<20	43.6	60	60
R4	<20	***49.2***	45	40
R5	<20	***57.9***	45	40
R6	<20	**41.9**	45	40
R7	<20	***47.1***	45	40
R8	<20	**43.4**	45	40
R9	<20	**41.6**	45	40
R10	<20	37.7	45	40
R11	<20	39.7	45	40
R12	<20	37.2	45	40
R13	<20	**42.4**	45	40
R14	<20	**43.6**	45	40
R15	<20	34.9	45	40
R16	<20	33.6	45	40
R17	<20	31.9	45	40
R18	<20	22.0	55	55
R19	<20	30.7	45	40

Receiver ID	Noise level $L_{Aeq\ 15\text{-minute}}$ dB(A)			
	Construction	Construction w. Peak Daytime only Haulage	NML Standard hours	NML Outside standard hours, day
R20	<20	<20	45	40
R21	<20	**40.9**	45	40
R22	<20	**44.3**	45	40

As **Table 6.1** shows, noise levels from construction of the Upper Scheme were generally predicted to remain below the NMLs established for standard hours and outside standard hours, day-time periods. The only exception was at R1 (approximately 1.5 dB(A)). With the inclusion of peak daytime haulage activities, exceedances ranging from 1.5 dB(A) to 13 dB(A) were predicted at receivers R1, R4, R5 and R7. All levels were predicted to remain below the revised 'Highly noise-affected level' of 65 dB(A) in the Draft CNG.

It is noted that some Upper Scheme works may be required outside standard construction hours including shaft excavation, support and lining activities and concrete pours for anchor blocks and surge tank foundation. Based on noise modelling undertaken, once the intersection upgrade is complete and in the absence of haulage, Upper Scheme construction is predicted to be inaudible at receivers and out of hours works as such acceptable subject to management in accordance with the requirements of an Environmental Protection Licence (EPL).

No sleep disturbance impacts are expected, noting that no night-time works were considered for this assessment scenario.

Results are also presented as contours in **Appendix C.**

6.1.2 Lower Scheme

Table 6.2 displays the predicted results for the assessment of noise from construction of the Lower Scheme. These are the worst-case noise impacts with all associated phases conservatively assumed as taking place simultaneously. Levels in **Table 6.2** were compared against the NMLs developed for standard hours, as well as the NMLs for daytime out of hours noting that activities may also be completed from 1pm to 6pm on Saturday. Bold italics are used to identify exceedances of Standard Construction Hours NMLs while bold depicts exceedances of Outside standard hours daytime NMLs.

Table 6.2. Predicted noise levels, Lower Scheme surface construction activities

Receiver ID	Noise level $L_{Aeq\ 15\text{-minute}}$ dB(A)			
	Predicted SPL	Construction w. Peak Daytime only Haulage	NML Standard hours	NML Outside standard hours, day
R1	<20	<20	45	40
R2	<20	<20	45	40
R3	42.1	**45.9**	60	60
R4	***53.8***	***55.3***	45	40
R5	***50.2***	***58.7***	45	40
R6	***45.2***	***46.9***	45	40
R7	***53.8***	***54.6***	45	40

Receiver ID	Noise level $L_{Aeq\ 15\text{-}minute}$ dB(A)			
R8	***47.7***	***49.0***	45	40
R9	***45.2***	***46.8***	45	40
R10	37.1	40.5	45	40
R11	39.7	42.7	45	40
R12	35.0	39.1	45	40
R13	39.9	44.4	45	40
R14	43.0	***46.2***	45	40
R15	35.3	38.0	45	40
R16	32.4	35.8	45	40
R17	35.6	37.0	45	40
R18	27.1	28.2	55	55
R19	36.9	37.8	45	40
R20	<20	<20	45	40
R21	44.3	***46.0***	45	40
R22	***47.6***	***49.3***	45	40

As displayed, noise levels from construction of the Lower Scheme were generally predicted to remain below the NMLs established for standard hours and outside standard hours, day-time periods. Exceedances of the NMLs for standard hours and outside standard hours, daytime were predicted at R4, R5, R6, R7, R8, R9 and R22. All exceedances were approximately 9 dB(A) or less above the standard hours NML and 14 dB(A) or less above the NML for outside standard hours, daytime. Exceedances of the outside standard hours, daytime NML were also predicted at R14 and R21, although noise levels at both locations was predicted to comply with the standard hours NML. Measures to mitigate and effectively manage these potential impacts are presented below in **Section 8**. With the inclusion of peak spoil haulage, exceedances of standard hours NMLs are also predicted at R14 and R21 while exceedances of outside standard hours daytime NMLs were also predicted at R10, R11 and 13.

Predicted exceedances at R4 and R5 are associated with activities at works Area 7 and spoil emplacement facility. The remaining predicted exceedances are associated with activities at the access and multipurpose tunnel surface works. These predictions are based on most intensive use of these area comprising spoil emplacement towards completion and open cut and cover activities at the portal site and without mitigation measures applied. Detailed design and actual construction methods would be used to refine impact predictions and reasonable and feasible mitigation measures.

All levels were predicted to remain below the revised 'Highly noise-affected level' of 65 dB(A) in the Draft CNG.

The Lower Scheme surface construction works are also to be completed during standard hours and outside standard hours, day-time periods only. As such, no sleep disturbance impacts are expected.

Results are also presented as contours below in **Appendix C**.

6.1.3 Tunnelling works

Predicted noise levels from the underground works are listed below in **Table 6.3** for peak spoil movement periods. As outlined in **Section 5.2.3**, noise emissions differ between standard and outside standard hours, with noisier plant and equipment only in-use during standard hours. Bold text is used to identify exceedances applicable NMLs for the relevant period.

Table 6.3. Predicted peak noise levels, underground works with Haulage condition (24-7 or Day-time)

Receiver ID	Noise level $L_{Aeq\ 15\text{-minute}}$ dB(A)				NMLs			
	24/7 Haulage		Day only haulage		Standard	Outside Std Hours		
	Std	Out-Std	Std	Out-Std	Hours	Day	Eve	Night
R1 (NCA 01)	<20	<20	<20	<20	45	40	40	37
R2 (NCA 02)	<20	<20	<20	<20	45	40	40	38
R3 (NCA 03)	42.5	40.1	45.2	34.3	60	60	60	60
R4 (NCA 04)	**46.0**	**40.9**	**50.6**	30.3	45	40	39	35
R5 (NCA 04)	**47.6**	**44.4**	**58.2**	**35.7**	45	40	39	35
R6 (NCA 05)	39.9	**37.1**	**42.5**	**36.2**	45	40	36	35
R7 (NCA 05)	**45.3**	**41.8**	**47.6**	**41.2**	45	40	36	35
R8 (NCA 05)	43.2	**40.1**	**45.1**	**39.6**	45	40	36	35
R9 (NCA 05)	40.8	**38.4**	**42.8**	**37.8**	45	40	36	35
R10 (NCA 06)	37.9	34.9	40.1	27.8	45	40	36	35
R11 (NCA 06)	38.2	**36.1**	41.3	28.6	45	40	36	35
R12 (NCA 06)	38.2	**36.5**	40.2	26.1	45	40	36	35
R13 (NCA 06)	39.4	**37.2**	43.6	29.2	45	40	36	35
R14 (NCA 07)	42.4	**40.2**	**45.7**	**39.2**	45	40	35	35
R15 (NCA 07)	35.3	33.7	37.6	32.1	45	40	35	35
R16 (NCA 07)	34.1	32.7	36.0	28.9	45	40	35	35
R17 (NCA 08)	39.3	**38.7**	39.8	**37.9**	45	40	35	35
R18 (NCA 08)	26.1	24.2	27.3	23.7	55	55	55	55
R19 (NCA 08)	35.7	33.8	36.8	33.7	45	40	35	35
R20 (NCA 02)	<20	<20	<20	<20	45	40	40	38
R21 (NCA 05)	41.4	**39.1**	**43.5**	**37.3**	45	40	36	35
R22 (NCA 05)	43.6	**41.4**	**46.4**	**40.5**	45	40	36	35

As identified in **Table 6.3**, for tunnelling works with spoil haulage spread over 24/7 avoiding localised stockpiling, exceedances of standard construction hours NMLs were predicted at receivers R4, R5 and R7.

Exceedances were predicted to be below standard daytime NMLs at all other receivers. Exceedances of the standard hours NML were all less than 3 dB(A). With 24/7 haulage, tunnelling works were predicted to exceed out of hours NMLs at R4, R5, R6, R7, R8, R9, R11, R12, R13, R14, R17, R21 and R22. Exceedances of night NML was predicted at 9.4 dB(A) at R5, under 7 dB(A) at R7, R8 and R14 and under 5 dB(A) at other receivers.

For tunnelling works with spoil haulage limited to standard construction hours, necessitating higher haulage rates and loading at portal sites, additional exceedances of standard construction hours NMLs were predicted at R8, R14 and R22 that were not predicted under 24/7 haulage scenario. The predicted exceedance of standard construction hours NMLs increases to 13.2 dB(A) at R5 and 5.6 dB(A) at R4 with all other exceedances limited to under 3 dB(A). Without 24/7 haulage, exceedances of night NMLs were predicted to reduce with exceedances no longer predicted at R4, R11, R12 and R13. Where exceedances remain they would be reduced.

Predicted exceedances at R4 and R5 are related to night-time spoil haulage and spoil unloading. Other predicted exceedances are related to essential night-time tunnelling support activities at the portals with limited mitigation. Detailed design and actual construction methods would be used to refine impact predictions and reasonable and feasible mitigation measures.

All levels were predicted to remain below the revised 'Highly noise-affected level' of 65 dB(A) in the Draft CNG.

The potential for sleep disturbance impacts associated with these activities were also assessed. Predicted maximum noise levels (L_{AFMax} dB(A)) at the surrounding receivers are listed below in **Table 6.4**.

Table 6.4. Predicted maximum noise levels and potential for sleep disturbance, night-time tunnelling with 24/7 haulage

Receiver ID	Maximum noise level L_{AFMax} dB(A)	
	Predicted peak level	Objective
R1	<20	65
R2	<20	65
R3	57.0	N/A, non-residential
R4	55.7	65
R5	58.3	65
R6	44.7	65
R7	54.2	65
R8	47.4	65
R9	44.5	65
R10	41.8	65
R11	43.8	65
R12	41.8	65
R13	47.7	65
R14	41.5	65

Receiver ID	Maximum noise level L_{AFMax} dB(A)	
	Predicted peak level	Objective
R15	34.2	65
R16	31.5	65
R17	36.0	65
R18	24.2	N/A, non-residential
R19	32.3	65
R20	<20	65
R21	43.3	65
R22	44.2	65

Table 6.4 shows how maximum noise levels were predicted to be below the 65 dB(A) objective value at all surrounding receivers during the Lower Scheme peak nigh time works. As such, it was concluded that sleep disturbance impacts would be unlikely. Still, measures to address the exceedances of the NMLs discussed above were developed and are included in **Section 8**.

Results for the underground works are presented as contours below in **Appendix C**.

6.1.4 Short term bulk delivery events

The predicted results for noise arising from short term bulk delivery events are listed in **Table 6.5**. These were also assessed against NMLs for standard and outside standard construction hours, noting that they are likely to be required to be completed outside standard hours so that peak traffic periods are avoided.

Table 6.5. Predicted noise levels, short term bulk delivery events

Receiver ID	Noise level $L_{Aeq\ 15\text{-minute}}$ dB(A)				
	Predicted SPL	NML Standard hours	NML Outside standard hours, day	NML Outside standard hours, evening	NML Outside standard hours, night
R1 (NCA 01)	40.2	45	40	40	37
R2 (NCA 02)	<20	45	40	40	38
R3 (NCA 03)	<20	60	60	60	60
R4 (NCA 04)	**45.0**	45	40	39	35
R5 (NCA 04)	**47.1**	45	40	39	35
R6 (NCA 05)	<20	45	40	36	35
R7 (NCA 05)	<20	45	40	36	35
R8 (NCA 05)	<20	45	40	36	35
R9 (NCA 05)	<20	45	40	36	35

Receiver ID	Noise level $L_{Aeq\ 15\text{-minute}}$ dB(A)				
	Predicted SPL	NML Standard hours	NML Outside standard hours, day	NML Outside standard hours, evening	NML Outside standard hours, night
R10 (NCA 06)	31.0	45	40	36	35
R11 (NCA 06)	33.3	45	40	36	35
R12 (NCA 06)	28.8	45	40	36	35
R13 (NCA 06)	34.6	45	40	36	35
R14 (NCA 07)	<20	45	40	35	35
R15 (NCA 07)	<20	45	40	35	35
R16 (NCA 07)	<20	45	40	35	35
R17 (NCA 08)	<20	45	40	35	35
R18 (NCA 08)	<20	65	65	65	65
R19 (NCA 08)	<20	45	40	35	35
R20 (NCA 02)	<20	45	40	40	38
R21 (NCA 05)	<20	45	40	36	35
R22 (NCA 05)	<20	45	40	36	35

As **Table 6.5** displays, noise levels from the short-term bulk delivery events were generally predicted to remain below the NMLs established for all periods. However, NMLs for all periods were predicted to be exceeded at R5. Exceedance of the out of hours NMLs were also predicted at R1 and R4. The highest predicted exceedance of the night-time NML was approximately 12 dB(A) at R5. All levels were predicted to remain below the revised 'Highly noise-affected level' of 65 dB(A) in the Draft CNG.

Understanding that oversized deliveries will be completed during night-time periods, the potential for sleep disturbance impacts were also assessed. Predicted maximum noise levels (L_{AFMax} dB(A)) at the surrounding receivers are listed below in **Table 6.6**.

Table 6.6. Predicted maximum noise levels and potential for sleep disturbance, Short term bulk delivery events

Receiver ID	Maximum noise level L_{AFMax} dB(A)	
	Predicted level	Objective
R1	40.1	65
R2	<20	65
R3	<20	N/A, non-residential
R4	49.6	65
R5	67.8	65
R6	22.7	65

Receiver ID	Maximum noise level L_{AFMax} dB(A)	
	Predicted level	Objective
R7	25.1	65
R8	22.6	65
R9	21.8	65
R10	41.4	65
R11	44.3	65
R12	41.6	65
R13	47.5	65
R14	23.0	65
R15	20.6	65
R16	<20	65
R17	<20	65
R18	<20	N/A, non-residential
R19	<20	65
R20	<20	65
R21	25.8	65
R22	26.6	65

As listed, the only location where levels exceeding the 65 dB(A) sleep disturbance objective value from the RNP was R5. As outlined in **Section 4.2.2**, the predicted level (67.8 dB(A)) is below the 75-85 dB(A) external level that could affect health and wellbeing.

Measures to address predicted exceedances associated with short term bulk delivery events are recommended below in **Section 8**.

Results are also presented as contours below in **Appendix C**.

6.2 Operation airborne noise

Results for the assessment of noise from operations are summarised in **Table 6.7**. Predicted levels under neutral and adverse, noise-enhancing meteorological conditions were compared against the Project operational noise limits developed for all periods of the day, noting that noise from these sources is expected to be generated continuously, 24-hour each day and 7 days per week.

Table 6.7. Predicted noise levels, operations

Receiver ID	Noise level $L_{Aeq\ 15\text{-}minute}$ dB(A)				
	Predicted SPL		Project operational noise level		
	Neutral conditions	Adverse conditions	Day	Evening	Night
R1 (NCA 01)	<20	<20	40	40	37
R2 (NCA 02)	<20	<20	40	40	38
R3 (NCA 03)	<20	<20	48	48	48
R4 (NCA 04)	<20	<20	40	39	35
R5 (NCA 04)	21.0	21.9	40	39	35
R6 (NCA 05)	30.2	31.2	40	36	35
R7 (NCA 05)	34.0	35.0	40	36	35
R8 (NCA 05)	31.1	32.2	40	36	35
R9 (NCA 05)	31.5	32.5	40	36	35
R10 (NCA 06)	<20	<20	40	36	35
R11 (NCA 06)	<20	<20	40	36	35
R12 (NCA 06)	<20	<20	40	36	35
R13 (NCA 06)	<20	<20	40	36	35
R14 (NCA 07)	27.0	27.8	40	35	35
R15 (NCA 07)	<20	<20	40	35	35
R16 (NCA 07)	24.4	25.1	40	35	35
R17 (NCA 08)	<20	<20	40	35	35
R18 (NCA 08)	<20	<20	53	53	53
R19 (NCA 08)	<20	<20	40	35	35
R20 (NCA 02)	<20	<20	40	40	38
R21 (NCA 05)	29.2	30.3	40	36	35
R22 (NCA 05)	29.1	30.1	40	36	35

As **Table 6.7** shows, noise from operations during neutral and adverse, noise-enhancing meteorological conditions were predicted to be below the Project operational noise limits for all periods of the day (day, evening and night).

The potential for sleep disturbance impacts were also assessed. Predicted maximum noise levels (L_{AFMax} dB(A)) at the surrounding receivers are listed below in **Table 6.8**.

Table 6.8. Predicted maximum noise levels and potential for sleep disturbance, operations

Receiver ID	Maximum noise level L_{AFMax} dB(A)		
	Predicted level		Objective
	Neutral conditions	Adverse conditions	
R1	<20	<20	65
R2	<20	<20	65
R3	<20	<20	N/A, non-residential
R4	<20	<20	65
R5	21.0	22.0	65
R6	30.0	31.0	65
R7	33.0	34.0	65
R8	31.0	32.0	65
R9	31.0	32.0	65
R10	<20	<20	65
R11	<20	<20	65
R12	<20	<20	65
R13	<20	<20	65
R14	27.0	28.0	65
R15	<20	20.0	65
R16	25.0	25.0	65
R17	<20	<20	65
R18	<20	<20	N/A, non-residential
R19	<20	<20	65
R20	<20	<20	65
R21	28.0	29.0	65
R22	29.0	30.0	65

Table 6.8 shows how maximum noise levels were predicted to be below the 65 dB(A) objective value at all surrounding receivers during operations. As such, it was concluded that sleep disturbance impacts would be unlikely.

Based on the outcomes above, it was determined that there would be no unacceptable noise impacts during operations. As such, no specific measures were recommended below in **Section 8**.

Results are also presented as contours below in **Appendix C**.

6.3 Ground-borne noise

Based on the three-dimensional slant distances between the receivers and the nearest point of the Tailrace Tunnel to each receiver, the predicted maximum ground-borne noise levels from construction of the tunnel using road headers are shown in **Table 6.9**. The predictions are based on road headers operating at the closest points of both of the Tailrace Tunnel construction work fronts simultaneously. Predictions are only shown at receivers where the ground-borne noise levels are above 10 dB(A), which is marginally above the threshold of hearing.

Table 6.9. Predicted ground-borne noise levels from tunnelling using road headers, LAeq dB(A)

Receiver ID	Receiver	Ground-borne noise level L_{Aeq} dB(A)	
		Tailrace tunnel (both work fronts simultaneously)	Multipurpose Ventilation Tunnel and Powerhouse Access Tunnel (simultaneously)
R6	35 Jim Edwardes Place Kangaroo Valley	16	13
R7	13 Jim Edwardes Place Kangaroo Valley	13	13
R8	94 Jacks Corner Road Kangaroo Valley	15	<10
R9	110 Jacks Corner Road Kangaroo Valley	12	<10
R21	40 Jim Edwardes Place (North) Kangaroo Valley	12	32
R22	40 Jim Edwardes Place (South) Kangaroo Valley	<10	38

As shown in **Table 6.9**, the predicted ground-borne noise levels from the combined construction of both work fronts of the Tailrace Tunnel are substantially lower than the criteria of 40 dB(A) during the day and 35 dB(A) during the night (refer **Table 4.10**).

Also as shown in **Table 6.9**, the predicted ground-borne noise levels from the simultaneous construction of the multipurpose tunnel and access tunnel comply with the criterion of 40 dB(A) for the daytime period at all receivers. However, the predictions indicate that the ground-borne noise levels may potentially exceed the night-time criterion of 35 dB(A) at one receiver: R22 (40 Jim Edwardes Place (South), Kangaroo Valley). At this location the predicted ground-borne noise level of 38 dB(A) would exceed the night-time period criterion by 3 dB(A). The predicted ground-borne noise levels comply with the night-time period criterion at all other receivers.

Measures to address this potential risk at R22 are included below in **Section 8**.

6.4 Construction and operational traffic noise

As outlined in **Section 5.7**, changes in road noise associated with addition traffic movements generated during construction and operations were predicted using the CNE. This assessment considered the existing traffic flows detailed above in **Section 3.6** and the peak additional traffic anticipated during construction and operations.

Based on these inputs, the following outcomes were determined:

Table 6.10. Predicted changes in road traffic noise, Moss Vale Road

Project Phase	Road	Change in noise level dB(A)		Predicted noise level	
		Day	Night	Day $L_{AEQ\ 15\text{-}hour}$ dB(A)	Night $L_{AEQ\ 9\text{-}hour}$ dB(A)
Construction	Moss Vale Road	+2.4	+0.8	66.7	58.8

Project Phase	Road	Change in noise level dB(A)		Predicted noise level	
		Day	Night	Day $L_{AEQ\ 15\text{-}hour}$ dB(A)	Night $L_{AEQ\ 9\text{-}hour}$ dB(A)
Operation		<0.1	+0.3	64.7	58.6

Table 6.11. Predicted changes in road traffic noise, Bendeela Road

Project Phase	Road	Change in noise level dB(A)		Predicted noise level	
		Day	Night	Day L_{AEQ} dB(A)	Night L_{AEQ} dB(A)
Construction	Bendeela Road	+3.7	+5.3	65.2	61.9
Operation		+0.3	+1.2	61.7	57.8

As **Table 6.10** and **Table 6.11** display, the following outcomes were determined for the worst-case additional traffic generated during the Project:

- Increases in daytime traffic noise levels of more than 2 dB(A) at the nearest receiver along Moss Vale Road during construction. Levels at this location were also predicted to exceed the $L_{AEq\ 15\text{-}hour}$ 60 dB(A) criterion from the RNP. This was predicted for receivers within approximately 45 meters of the road. Increases in night-time noise levels along Moss Vale Road during construction were predicted to be less than 2 dB(A)
- Increases in daytime and night-time traffic noise levels from additional traffic generated during operations were both less than 2 dB(A)
- Day and night-time increases along Bendeela Road greater than 2 dB(A) during construction with the applicable criteria from the RNP. Exceedances of the RNP criteria were predicted at receivers within approximately 70 meters of Bendeela Road. Increases during operations were predicted to be less than 2 dB(A).

These results indicate that changes in noise from additional traffic may be noticeable at nearby receivers during construction. Measures to address these risks are included below in **Section 8**.

6.5 Vibration from construction activities other than blasting

6.5.1 Tunnelling using road headers

6.5.1.1 Damage to structures

Based on the predicted ground-borne noise levels shown in **Table 6.9**, and the methodology described in **Section 5.8.1**, the predicted ground vibration levels from construction of the tunnels using road headers are shown in **Table 6.12**. Since all receivers are residential buildings or are less sensitive, the relevant vibration criteria from **Table 4.6** is PPV 7.5mm/s at 4 Hz, increasing to 10 mm/s at 15 Hz, increasing to 25 mm/s at 40Hz and above. As stated in **Section 5.8.1**, the vibration from road headers is dominant between 25 and 80 Hz.

Table 6.12. Predicted ground vibration levels from tunnel construction using road headers (PPV mm/s)

Receiver ID	Address	Tailrace tunnel (Workfront 1) + simultaneous Tailrace tunnel (Workfront 2)	Multipurpose Vent Tunnel + Powerhouse Access Tunnel
R1	1671 Nowra Road Fitzroy Falls	< 0.01	< 0.01
R2	198 Bendeela Road Kangaroo Valley	< 0.01	< 0.01
R3	407C Bendeela Road (Camp) Kangaroo Valley	< 0.01	< 0.01

Receiver ID	Address	Tailrace tunnel (Workfront 1) + simultaneous Tailrace tunnel (Workfront 2)	Multipurpose Vent Tunnel + Powerhouse Access Tunnel
R4	407D Bendeela Road Kangaroo Valley	< 0.01	< 0.01
R5	407A Bendeela Road Kangaroo Valley	< 0.01	< 0.01
R6	35 Jim Edwardes Place Kangaroo Valley	0.03	0.02
R7	13 Jim Edwardes Place Kangaroo Valley	0.02	0.03
R8	94 Jacks Corner Road Kangaroo Valley	0.03	< 0.01
R9	110 Jacks Corner Road Kangaroo Valley	0.02	< 0.01
R10	340 Bendeela Road Kangaroo Valley	< 0.01	< 0.01
R11	353 Bendeela Road Kangaroo Valley	< 0.01	< 0.01
R12	360 Bendeela Road Kangaroo Valley	< 0.01	< 0.01
R13	369 Bendeela Road Kangaroo Valley	< 0.01	< 0.01
R14	145 Jacks Corner Road Kangaroo Valley	0.02	< 0.01
R15	199 Jacks Corner Road Kangaroo Valley	< 0.01	< 0.01
R16	180 Jacks Corner Road Kangaroo Valley	< 0.01	< 0.01
R17	114 Radiata Road (Cottages) Kangaroo Valley	< 0.01	< 0.01
R18	369 Jacks Corner Road (Campus) Kangaroo Valley	< 0.01	< 0.01
R19	369 Jacks Corner Road (Dorms) Kangaroo Valley	< 0.01	< 0.01
R20	2999 Moss Vale Road Barrengarry	< 0.01	< 0.01
R21	40 Jim Edwardes Place (North) Kangaroo Valley	0.02	0.21
R22	40 Jim Edwardes Place (South) Kangaroo Valley	0.02	0.43

As shown in **Table 6.12**, the predicted ground vibration levels from tunnel construction using road headers are expected to comply with the criteria for cosmetic/minor building damage shown in **Table 4.6** at all receivers.

6.5.1.2 Human comfort

Based on the predicted ground-borne noise levels shown in **Table 6.9**, and the methodology described in **Section 5.8.1**, the predicted ground vibration levels from construction of the tunnels using road headers are shown in **Table 6.13**. Since the type of vibration from road headers is 'continuous' and tunnel construction may occur during the day and/or night-time periods, the applicable criteria are:

- Daytime period:
  - z-axis: 0.010 m/s^2
  - x- and y-axes: 0.0071 m/s^2

- Night-time period:
  - z-axis: 0.007 m/s^2
  - x- and y-axes: 0.005 m/s^2.

Table 6.13. Predicted Ground Vibration Levels from Tunnel Construction Using Road headers (rms acceleration m/s2)

Receiver ID	Receiver address	Tailrace tunnel (Workfront 1) + simultaneous Tailrace tunnel (Workfront 2)	Multipurpose Vent Tunnel + Powerhouse Access Tunnel
R1	1671 Nowra Road Fitzroy Falls	0.000	0.000
R2	198 Bendeela Road Kangaroo Valley	0.000	0.000
R3	407C Bendeela Road (Camp) Kangaroo Valley	0.001	0.000
R4	407D Bendeela Road Kangaroo Valley	0.000	0.000
R5	407A Bendeela Road Kangaroo Valley	0.000	0.001
R6	35 Jim Edwardes Place Kangaroo Valley	0.004	0.003
R7	13 Jim Edwardes Place Kangaroo Valley	0.003	0.003
R8	94 Jacks Corner Road Kangaroo Valley	0.003	0.001
R9	110 Jacks Corner Road Kangaroo Valley	0.002	0.001
R10	340 Bendeela Road Kangaroo Valley	0.000	0.000
R11	353 Bendeela Road Kangaroo Valley	0.000	0.000
R12	360 Bendeela Road Kangaroo Valley	0.000	0.000
R13	369 Bendeela Road Kangaroo Valley	0.000	0.001
R14	145 Jacks Corner Road Kangaroo Valley	0.002	0.000
R15	199 Jacks Corner Road Kangaroo Valley	0.001	0.000
R16	180 Jacks Corner Road Kangaroo Valley	0.000	0.000
R17	114 Radiata Road (Cottages) Kangaroo Valley	0.000	0.000
R18	369 Jacks Corner Road (Campus) Kangaroo Valley	0.000	0.000
R19	369 Jacks Corner Road (Dorms) Kangaroo Valley	0.001	0.000
R20	2999 Moss Vale Road Barrengarry	0.000	0.000
R21	40 Jim Edwardes Place (North) Kangaroo Valley	0.002	0.023
R22	40 Jim Edwardes Place (South) Kangaroo Valley	0.002	0.048

As shown in **Table 6.13**, the predicted ground vibration levels from tunnel construction using road headers are estimated to potentially exceed the criteria for human comfort during the day and night-time periods at two (2): receivers:

- R21: 40 Jim Edwardes Place (North) Kangaroo Valley
- R22: 40 Jim Edwardes Place (South) Kangaroo Valley.

It should be noted that the predicted exceedances have been estimated based on the short term, worst-case ground vibration and ground-borne noise levels, occurring at the point of closest approach of the tunnel alignment to the receiver location. Vibration levels and ground-borne noise levels would be less than the worst-case predicted values when the tunnel construction work front is further away from the receivers, however this distance has not been estimated. Mitigation measures to address this risk are included below in **Section 8**.

6.5.2 Other surface plant and equipment

The potential for vibration-related impacts for the using of vibration-generating plant and equipment during surface construction activities was assessed. As shown below in **Table 6.14**, the nearest offsite sensitive receivers (R7 and R21) more than 200 m beyond the highest building cosmetic damage and human response safe setback distances

Table 6.14. Review of vibration risks from surface vibration-generating construction activities

Plant	Rating / description	Safe working distance (m)		Minimum distance to sensitive receiver (m)
		Cosmetic damage (BS7385-2: 1993)	Human response (DEC, 2006)	
Vibratory pile driver	Sheet piles	2 to 20	20	330
Large hydraulic hammer	(1600 kg – 18t to 34t excavator)	22	73	
Jackhammer	Hand-held	1	2	

Based on this, it was determined that vibration from vibration-generating plant and equipment during surface construction activities would not present a risk to offsite receivers during construction of the Project. Impacts to existing onsite infrastructure would be managed in accordance with mitigation measures provided in **Section 8**.

6.6 Blasting

6.6.1 Air blast overpressure and ground vibration from surface blasting

The surface blasting proposed for construction of the Tailrace Inlet/Outlet may is likely to be required and has the potential to result in ground vibration and/or air blast overpressure to be received at receivers. The need for surface blasting at other locations has not been confirmed at the time of writing.

Noting the presence of existing WNSW onsite infrastructure, detailed blast design will be required to not only achieve compliance with offsite criterion but to be protective existing infrastructure. A commitment to this effect is provided in **Section 8** and within the EIS Project description and on this basis impacts to offsite and onsite infrastructure would be avoided.

6.6.2 Ground vibration from underground blasting

The primary excavation method for construction of the Powerhouse cavern is to drill & blast the rock material. This type of construction methodology can potentially generate ground vibration that may be perceptible by occupants of receiver buildings and may also potentially result in some damage to structures including heritage structures and receiver buildings. Ground vibration from underground blasting is a very short-term, momentary impact and is not typically assessed for ground-borne noise. Furthermore, underground blasting does not result in air blast overpressure which is therefore not required to be assessed.

Based on the approximate three-dimensional slant distances between the underground Powerhouse cavern construction location and the nearest receivers, the calculated maximum instantaneous charge size for underground blasts in the cavern that complies with the criterion of 5 mm/s is approximately 2,700 kg of standard explosive (ANFO). The predicted vibration levels at the receivers with 2,700 kg of ANFO per blast are shown in **Table 6.15**.

Table 6.15. Estimated vibration at receivers for 2,700 kg blast in the Powerhouse Cavern

Receiver ID	Receiver address	Approx. 3D (slant) distance (m)	Vibration velocity (PPV, mm/s)
R1	1671 Nowra Road Fitzroy Falls	4015.3	0.6
R2	198 Bendeela Road Kangaroo Valley	1715.5	2.3
R3	407C Bendeela Road (Camp) Kangaroo Valley	3163.9	0.8
R4	407D Bendeela Road Kangaroo Valley	2554.9	1.2
R5	407A Bendeela Road Kangaroo Valley	2109.0	1.6
R6	35 Jim Edwardes Place Kangaroo Valley	1284.3	3.6
R7	13 Jim Edwardes Place Kangaroo Valley	1380.3	3.2
R8	94 Jacks Corner Road Kangaroo Valley	1454.5	2.9
R9	110 Jacks Corner Road Kangaroo Valley	1379.7	3.2
R10	340 Bendeela Road Kangaroo Valley	1924.0	1.9
R11	353 Bendeela Road Kangaroo Valley	2033.4	1.7
R12	360 Bendeela Road Kangaroo Valley	1590.1	2.6
R13	369 Bendeela Road Kangaroo Valley	1936.5	1.9
R14	145 Jacks Corner Road Kangaroo Valley	1884.4	1.9
R15	199 Jacks Corner Road Kangaroo Valley	2119.5	1.6
R16	180 Jacks Corner Road Kangaroo Valley	1898.2	1.9
R17	114 Radiata Road (Cottages) Kangaroo Valley	4178.8	0.5
R18	369 Jacks Corner Road (Campus) Kangaroo Valley	3144.2	0.9
R19	369 Jacks Corner Road (Dorms) Kangaroo Valley	2908.7	1.0
R20	2999 Moss Vale Road Barrengarry	2525.9	1.2
R21	40 Jim Edwardes Place (North) Kangaroo Valley	1041.6	5.0
R22	40 Jim Edwardes Place (South) Kangaroo Valley	1153.0	4.3

As shown in **Table 6.15**, with a maximum instantaneous charge size of approximately 2,700 kg, the predicted vibration level at the nearest receiver (40 Jim Edwardes Place (South) Kangaroo Valley) is 5.0 mm/s, which complies with the adopted criteria of 5 mm/s. Measures to address this aspect are provided below in **Section 8**.

Should drill and blast be required as part of tunnel methodology, detailed blast planning would be undertaken in accordance with a blast management strategy as described and committed to in Chapter 3 of the EIS. Based on the need and ability to carefully design blasts in accordance with a blast management strategy as described and committed to in Chapter 3 of the EIS, disturbance from underground blasting can be undertaken to avoid significant impacts.

7. Cumulative impacts

Cumulative impacts have the potential to occur when impacts from a Project interact or overlap with impacts from other projects and can potentially result in a larger overall effect (positive or negative) on the environment, businesses or local communities. Cumulative impacts may occur during construction stages when projects are constructed concurrently or consecutively. Projects constructed consecutively (or sequentially) can result in construction activities occurring over an extended period of time with little or no break in construction activities, potentially causing increased impacts and fatigue for local communities.

The extent to which another development or activity could interact with the construction of the Project would depend on its scale, location and/or timing of construction. Generally, cumulative impacts would be expected to occur where multiple long-duration construction activities are undertaken close to, and over a similar timescale to, construction activities for the Project, or where consecutive construction occurs in the same area.

The overall effect of cumulative benefits or impacts could be positive or negative, depending on the nature of the projects and the nearby communities and environment.

7.1 Legislative and policy context

The Cumulative Impact Assessment Guidelines for State Significant Projects (DPIE, 2021) has been used to inform this assessment [https://www.planning.nsw.gov.au/-/media/Files/DPE/Guidelines/Policy-and-legislation/SSPT-Guidelines/GD1259-RAF-Assessing-Cumulative-Impacts-Guide-final.pdf]. The guidelines indicates the following future projects should be considered in the cumulative impact assessment:

- Changes to existing projects (expansions, modifications, closure)
- Approved projects (approved but construction has not commenced)
- Projects under assessment (application of the Project has been exhibited and is currently under assessment)
- Related development (development that is required for the Project but subject to separate development).

7.2 Assessment methodology

The assessment methodology for the cumulative impact assessment of the Project involved the identification of projects (which have publicly available information) that could be considered for cumulative impacts, and assessment of these projects against screening criteria.

Four criteria were applied to identify whether a project should be assessed for cumulative impacts, as shown in **Table 7.1**. Several triggers were developed for each screening criteria to objectively determine whether a project could potentially cause a cumulative impact with the Project.

Table 7.1. Screening criteria for cumulative impact assessment

Screening criteria	Description
Location	▪ Direct overlap – Construction footprints of a project intersect with this Project ▪ In the area – Construction footprints are adjacent or in close proximity to this Project.
Timeframe	▪ Concurrent construction program with the Project ▪ Consecutive construction program with the program.
Status	▪ Changes to existing projects (expansions, modifications, closure) ▪ Approved projects (approved but construction has not commenced) ▪ Projects under assessment (application of the project has been exhibited and is currently under assessment)

Screening criteria	Description
	▪ Related development (development that is required for the project but subject to separate development).
Scale	▪ A project was considered relevant where it is a large-scale major development or infrastructure project that could cause cumulative impacts with the Project.

7.3 Assessment of cumulative impacts

Table 7.2 lists the identified projects and provides an assessment of potential for cumulative noise and vibration-related impacts.

Table 7.2. Cumulative impact assessment

Project	Brief project description	Assessment
Shoalhaven Hospital Redevelopment SSD-35999468	Proposed construction of a new hospital building and ancillary works, including demolition of existing structures within the footprint of the new building, located about 17 km southeast of the Project area.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.
Nowra Biogas Project SSD-26264096	Construction and operation a large-scale renewable energy biogas power plant to process up to 170,000 tonnes (t) per year of food waste, cow manure and yeast processing waste using anaerobic digestion to produce electricity and would be located about 17 km southeast of the Project area.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.
Shoalhaven Starches Mod 22 – Beverage Grade Ethanol Plant Stage 3 MP06_0228-Mod-22	Proposed expansion to the Beverage Grade Ethanol Plant including proposed increased production capacity to 450 ML of Ethanol, new distillery columns and associated plant infrastructure. The expansion will lead to double the current flour being transported to site, up to 8,600 t per week, located about 17 km southeast.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.
Shoalhaven Starches Modification 25 Rail Line Extension & Addition to Product Dryers	Extension of existing rail line by 1280 m including a 850 m train reverse loop and 180 m rail maintenance spur; and the addition of a roof baghouse to Product Dryer 3 & 4.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.
Rowany Medieval Festival DA 21/0797.01	An annual week-long festival located at Camp Wombaroo, about 33 km north west of the Project area. The festival is the largest event for the Society for Creative Anachronism, and typically would attract more than 1,000 attendees.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.
Wildfest	Community event within the township of Berrima, including a 10-day ‘feast’ event annually located about 24 km northwest of the Project area.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.

Project	Brief project description	Assessment
Dendrobium Mine Extension SSI-33143123	Proposed extension of mining within Area 5 and extension of the life of Dendrobium Mine until 2041 Area 5 is located in the Wingecarribee LGA, about 40 km north of the Project area. The mine extension would involve extraction of coal from the Bulli Seam un the proposed Area 5, with an increase in workforce anticipated during construction and operation.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.
Moss Vale Plastics Recycling Facility SSD-9409987	Proposed facility to sort and recycle plastic waste in Moss Vale. The facility would be located about 17 km northwest of the Project area.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.
New Shellharbour Hospital and Integrated Services	Proposed construction and operation of the New Shellharbour Hospital and Integrated Services project, to meet the demand for healthcare services for the growing Illawarra population, located about 33 km northeast of the Project area. Work would begin before March 2023.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.
Berrima Cement Works Solid Waste Derived Fuels & Delivery Variation Project DA 401-11-2002-I	Proposed modification to increase waste consumption in the kiln, expanding storage and handling facilities, and increase truck deliveries and hours at the existing Berrima Cement Works, located about 22 km northwest of the Project area.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.
Sutton Forest Sand Quarry	Proposed sand quarry which seeks to extract up to 1 million t of friable sandstone per year for up to 30 years.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.
Moss Vale Road Urban Release Area Maculata Park Taylors Landing	Establishment of the URA includes rezoning of land and other works such as water and wastewater infrastructure. Planning is underway to deliver a future residential area in the Nowra-Bomaderry area – Moss Vale Road North Urban Release Area and is currently under exhibition. The Project is located about 13 km southeast of the Project area and would be expecting about 3,400 additional dwellings when complete.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.
Shoalhaven Community and Recreational Precinct – Artie Smith Oval Development	Upgrade of the oval, located about 15 km southeast of the Project area.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.

Project	Brief project description	Assessment
Shoalhaven Community and Recreational Precinct – Shoalhaven Indoor Sports Centre (SISC) Extension	Extension of the sports centre including the refurbishment of the Bomaderry Basketball Stadium, located about 15 km southeast of the Project area.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.
Shoalhaven Community and Recreational Precinct – Northern Section – Bomaderry Sporting Complex	Redevelopment of the area to the north of Cambewarra Road Bomaderry Sporting Complex, and provide new facilities including a new Community Hub, new pools, development of an athletics track and two senior rugby league fields with associated change rooms and amenities. The Project is located about 15 km southeast of the Project area.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.
Moss Vale Sewage Treatment Plant Upgrade	Proposed upgrade to provide treatment capacity to meet current and future population needs within the catchment, located about 18 km northwest of the Project area. Design would be completed in 2022 with tendering and construction to follow.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.
Moss Vale Bypass	The 3-stage project would assist motorists travelling through Moss Vale by providing an alternative to Argyle Street. The Bypass includes an additional crossing of the Main Southern railway and critically, one which is not subject to flooding or height restrictions. The bypass would be located about 17 km northwest of the Project area.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.
Ritters Creek, Meryla Road, Meryla - Bridge Replacement	Replacement of the single span timber bridge on Meryla Road with a new crossing, widening and other works such as bank stabilisation, located about 7 km west of the Project area.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.
Fitzroy Falls RFS	A new Rural Fire Service Shed will be built at Fitzroy Falls at the corner of Myra Vale Road and Nowra Road. The shed will replace the RFS Shed currently situated at Avoca. The detailed design has been completed and the Development Application is currently being reviewed. Located 2 km north of the Project area.	Potential noise and vibration impacts associated with this project are expected to be negligible such that cumulative impacts would not be expected.
Bowral and District Hospital Redevelopment Stage 2	Proposed redevelopment of the Bowral & District Hospital to expand clinical services, located about 21 km northwest of the Project area.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.

Project	Brief project description	Assessment
Bay and Basin Leisure Centre Redevelopment	Redevelop the existing Bay and Basin Leisure Centre and Vincentia Oval to enhance the current facilities, including upgrading and extending the existing centre, sporting precinct. The redevelopment would add new pool, gym extension, sportsground precinct upgrades, carparks, and is located about 40 km southeast of the Project area.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.
East Nowra Sub Arterial Road ENSA	Proposed to connect Greenwell Point Road (in the vicinity of Old Southern Road) to the Princes Highway, at North Street and Junction Street. ENSA will provide a much needed alternative connection to the highway from the East Nowra, Worrigee and coastal village areas. The road would be located about 18 km southeast of the Project area.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.
Shoalhaven Resource Recovery Facility (RRF) West Nowra Resource Recovery Park Stage 2 SSD-9887	Proposal for constructing and operating a resource recovery facility with pre-treatment for mixed municipal waste of up to 130,000 t per year, located about 16 km southeast of the Project area.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.
Nowra Bridge Project – Princes Highway Upgrade	The project will provide a new four lane bridge over the Shoalhaven River, upgraded intersections and additional lanes on the Princes Highway.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.
Jervis Bay Road and Princes Highway intersection upgrade at Falls Creek	The project will provide a grade separated interchange, or flyover, with roundabouts on either side.	As determined above in **Section 6**, highest risk of noise and vibration impacts from the Project is at receivers located in close proximity to the Project. Owing to the distance from the Project, cumulative impacts are not expected.

As **Table 7.2** lists, there were no surrounding projects identified where there was the potential for cumulative noise and vibration impacts along with the Project. Still, measures have been included below in **Section 8** to ensure that no cumulative impacts arise.

8. Mitigation measures

The following sections list recommendations for the mitigation and effective management of the noise and vibration risks for the Project determined in **Section 6** and **Section 7**.

8.1 Construction airborne noise

As identified in **Section 6** there is the potential that noise and vibration levels during construction may exceed assessment criteria at some surrounding sensitive receivers. Standard and additional measures to be implemented during construction are detailed in **Table 8.1**. Although this is not a transport project, Appendix C of the CNVG (RMS, 2016) provides guidance for managing noise during construction that considers the period (i.e. during or outside standard hours) and extent of exceedance of NMLs. The guidance provides a transparent and repeatable basis for the application of these measures. As such, the guidance has been considered in the development of the additional measures in **Table 8.1**.

Subject to confirmed noise and vibration impacts associated with detailed design and construction planning, the measures listed in **Table 8.1** and should be included in the Construction Noise and Vibration Management Plan (CNVMP) developed and implemented for the Project. This guidance includes recommendations that would meet the requirements of the Draft CNG (EPA).

Table 8.1. Project-specific recommendations, construction noise

ID	Aspect	Control	Timing
NV01	Management of construction noise and vibration	A construction noise and vibration management plan will be prepared in consultation with WaterNSW. The construction noise and vibration management plan will include measures, processes and responsibilities to manage noise and vibration and minimise the potential for impacts during construction. The construction noise and vibration management plan will: ▪ Identify nearby sensitive receivers ▪ Include a description of the construction activities, equipment and working hours ▪ Identify relevant noise and vibration performance criteria for the Project and licence and approval requirements ▪ Assess actual construction methods adopted to validate predictions and identify reasonable and feasible controls to mitigate impacts ▪ Outline standard and additional mitigation measures to be adopted ▪ Outline requirements for the development and implementation of an Out-of-hours Work Protocol. ▪ Describe community consultation and complaints handling procedures in accordance with the community communication strategy to be developed for the Project.	Pre-construction
NV02	General construction noise and vibration measures	To the extent reasonable and feasible, the following measures will be adopted: ▪ Limit surface works to standard hours of construction ▪ Select low-noise plant and equipment and ensure equipment mufflers operate in a proper and efficient manner ▪ Use quieter and less vibration emitting construction methods ▪ Only have necessary equipment on-site and turn off when not in use ▪ Concentrate noisy activities at one location and move to another as quickly as possible ▪ Vehicle movements, including deliveries outside standard hours will be minimised and avoided where possible ▪ Ensure all plant and equipment is well maintained and where possible, fitted with silencing devices ▪ Use only the necessary size and powered equipment for tasks	Construction

ID	Aspect	Control	Timing
		▪ Implement training to induct staff on Project noise and vibration sensitivities ▪ Consider the application of less intrusive alternatives to reverse beepers such as 'squawker' or 'broadband' alarms ▪ Consider the installation of temporary construction noise barriers for concentrated, noise-intensive activities ▪ Where practicable, install enclosures around noisy mobile and stationary equipment as necessary ▪ Avoid simultaneous operation of two or more noisy plant close to receivers ▪ The offset distance between noisy plant and sensitive receivers will be maximised ▪ Plan traffic flow, parking and loading/unloading areas to minimise reversing movements ▪ Delivery and loading / unloading of materials will occur as far as possible from sensitive receivers ▪ Select site access points and roads as far as possible from sensitive receivers ▪ Limit speed limits along internal haulage routes to reduce associated noise emissions ▪ To the extent possible, design internal haulage routes so that the need for reversing and hard braking is minimised ▪ Consider the use of quieter spoil transport technologies (e.g., conveyors) rather than trucks as appropriate ▪ Implement consultation, respite, notification, verification and additional requirements as appropriate, as listed in Section 5 of the Draft CNG (EPA). ▪ Complete routine monitoring to evaluate construction noise levels and evaluate whether the mitigation measures in place are adequate or require revision.	
NV03	Out of hours works	All out of hours works will be undertaken in accordance with an out of hours works protocol that includes the following: ▪ Justification of requirement to undertake the works out of hours ▪ Further consideration of noise impacts ▪ Identification of reasonable and feasible mitigation measures as necessary to achieve NML or otherwise mitigate impacts. Communication protocols for impacted receptors.	Construction
NV04	Notification	Where exceedances of noise mitigation measures are predicted, affected residents will be notified of works and potential disruptions. The notification will detail work activities, time periods over which the works will occur, impacts and mitigation measures. Notifications will be given a minimum of five days prior to works commencing.	Construction
NV05	Verification and adaptive management	Attended noise measurements will be undertaken to verify the noise levels predicted in this noise assessment are accurate and whether mitigation measures are appropriate. Attended noise measurements will also be undertaken to address any noise complaints raised as a result of the proposed works.	Construction
NV06	Ground-borne noise and vibration	Detailed design and construction planning will consider final tunnel alignment and construction methodology and develop necessary mitigation measures to address any remaining predicted exceedances. Where likely to be perceptible, affected receivers will be consulted on impacts to be expected and how they are to be avoided or otherwise effectively managed.	Pre-construction

ID	Aspect	Control	Timing
NV07	Blasting	Blasting will be subject to stringent processes in accordance with the legislative and Project requirements. The Interim Construction Noise Guideline recommends blasting on the surface occur between Monday to Friday (9am to 5pm) and Saturday (9am to 1pm) with no blasting on Sundays or public holidays unless otherwise agreed by the NSW Environment Protection Authority. Blasting on the surface will be planned during hours that will cause the least disruption and disturbance to the nearest receivers. Notification protocols prior to blasting for the nearest sensitive receivers will be established. Blasting underground may occur 24/7 where there is no material impact to sensitive receivers. Should the contractor undertake blasting to construct the Project, a Blast Management Strategy will be prepared to address: ▪ Details of blasting to be performed ▪ Identification of all potentially affected sensitive sites including heritage buildings and utilities ▪ Establishment of appropriate criteria for blast overpressure and ground vibration ▪ Details of the transportation, storage and handling arrangements for explosive materials ▪ Determination of potential noise and vibration and risk impacts and appropriate best management practices, including: – A trial blast strategy – Additional pre- and post-dilapidation surveys – Community consultation and information program – Reasonable and feasible mitigation. ▪ The necessary blast trials to establish conformance with the criteria. The Blast Management Strategy will be prepared in consultation with Water NSW and endorsed by a suitably qualified and experienced person.	Prior to undertaking blasting
NV08	Changes in traffic noise during construction	The following controls would be considered in the traffic management plan for the Project: ▪ Schedule Project construction transport to avoid sensitive periods and locations to the extent reasonable and feasible ▪ Ensure drivers operate in a manner that avoids unnecessary impacts (e.g. from air braking) ▪ Ensure that vehicles are adequately silenced before allowing them access to site and consider selection of quieter vehicle types to the extent reasonable and feasible. Review and update measures as necessary through construction.	Construction
NV09	Operational noise impacts	Operational noise sources for the Project will be reviewed as part of detailed design to ensure that the resulting noise levels and outcomes do not exceed predictions or are otherwise managed to achieve Project noise trigger levels during all relevant meteorological conditions.	Detailed design and operation

With the implementation of these controls and management actions, it is expected that impacts would be able to be controlled or otherwise effectively managed. The level of reduction provided by each action would depend on how they are specifically applied, although 'Australian Standard; Guide to noise and vibration control on construction, demolition and maintenance sites', (AS 2436-2010) provides indicative guidance around the extent of noise reductions achievable with different physical controls. Thise has been reproduced below in **Table 8.2.**

Table 8.2. Indicative effectiveness of different physical controls (Source: AS 2436-2010)

Control type	Nominal noise reduction achievable dB(A)
Screening (i.e., barriers, noise mounds, screens)	Normally 5 to 10 dB(A) up to a maximum of 15 dB(A)
Enclosures	Normally 15 to 25 dB(A) up to a maximum of 15 dB(A)
Silencing	Normally 5 to 10 dB(A) up to a maximum of 20 dB(A)

9. Conclusion

This report has provided an assessment of the noise and vibration impacts of the Shoalhaven Hydro Expansion Project. In summary, the noise and vibration impact assessment involved identifying the key noise and vibration-related issues, characterising key features of the existing environment relevant for the assessment, quantifying the different types of noise and vibration that is expected to be generated and assessing the potential impact of the Project on surrounding sensitive receivers. The assessment was carried out in accordance with the applicable legislation, policies, guidelines and standards. The key issues identified were airborne and ground-borne noise, air blast overpressure and vibration from surface and underground activities during construction (including blasting), operational noise and changes in road traffic noise along affected public routes during construction and operations. These issues were the focus of the assessment.

A review of key features of the existing environment was carried out including the identification of surrounding land uses and sensitive receivers, establishment of local background noise levels and existing traffic conditions along key Project travel and haulage routes. The following conclusions were made in relation to the existing environment:

- 22 sensitive receivers were identified within approximately five km of the Project
- Monitoring was completed at eight locations to establish background noise levels at these identified receivers. At all eight locations, background noise levels were low (less than 41 dB(A)), with most below the minimum day (35 dB(A)) and evening/night-time (30 dB(A)) RBLs recommended by the NPI
- Low traffic flows along key Project travel routes, with the nearest receivers also noted as being nearby (i.e. within 20 m) along these roads.

The key outcomes of the assessment were as follows:

- Construction airborne noise: A small number of receivers were predicted to experience noise levels above applicable NMLs. These exceedances are generally expected to be noticeable or clearly audible although over longer durations, rather than being highly intrusive. Measures to mitigate or otherwise effectively manage these risks were developed
- Operational airborne noise: Noise from operations during neutral and adverse, noise-enhancing meteorological conditions were predicted to be below the Project operational noise limits for all periods of the day (day, evening and night) at all surrounding sensitive receivers. As such, no specific measures were recommended
- Construction ground-borne noise and vibration from tunnelling: Ground-borne noise from the simultaneous construction of the Multipurpose Ventilation Tunnel and Powerhouse Access Tunnel using road headers was predicted to exceed the night-time limit of 35 dB(A) at receiver R22. Predicted ground vibration levels were also estimated to exceed the criteria for human comfort during the day and night-time periods at receivers R21 and R22. Recommendations to avoid more sensitive periods around this receiver were made, with additional actions included in-line with guidance presented in the CNVG
- Construction and operational traffic noise: Changes in noise from additional traffic may be noticeable at nearby receivers along key Project travel roads during construction. Measures were recommended to manage these effects
- Vibration from surface construction activities: Building cosmetic damage and human response vibration-related impacts for the using of plant and equipment during surface construction activities was not determined to present a risk at surrounding receivers
- Air blast overpressure and ground vibration from surface blasting during construction: Ground vibration and air blast overpressure are identified as Project risks and require detailed blast planning to comply with the applicable criteria at all receivers and be protective of existing Water NSW infrastructure. It is recommended that the blast designers establish site-specific propagation parameters including weather conditions and rock and soil vibration transmission properties to ensure that the blast design achieves compliance with the ground vibration and air blast overpressure criteria
- Vibration from underground blasting during construction: Vibration levels from underground blasting activities associated with the underground power station cavern construction at surrounding sensitive receivers were predicted to remain below the adopted criterion of 5 mm/s. Detailed blast planning is

recommended for management of underground blasting particularly should it be required as part of tunnelling works.

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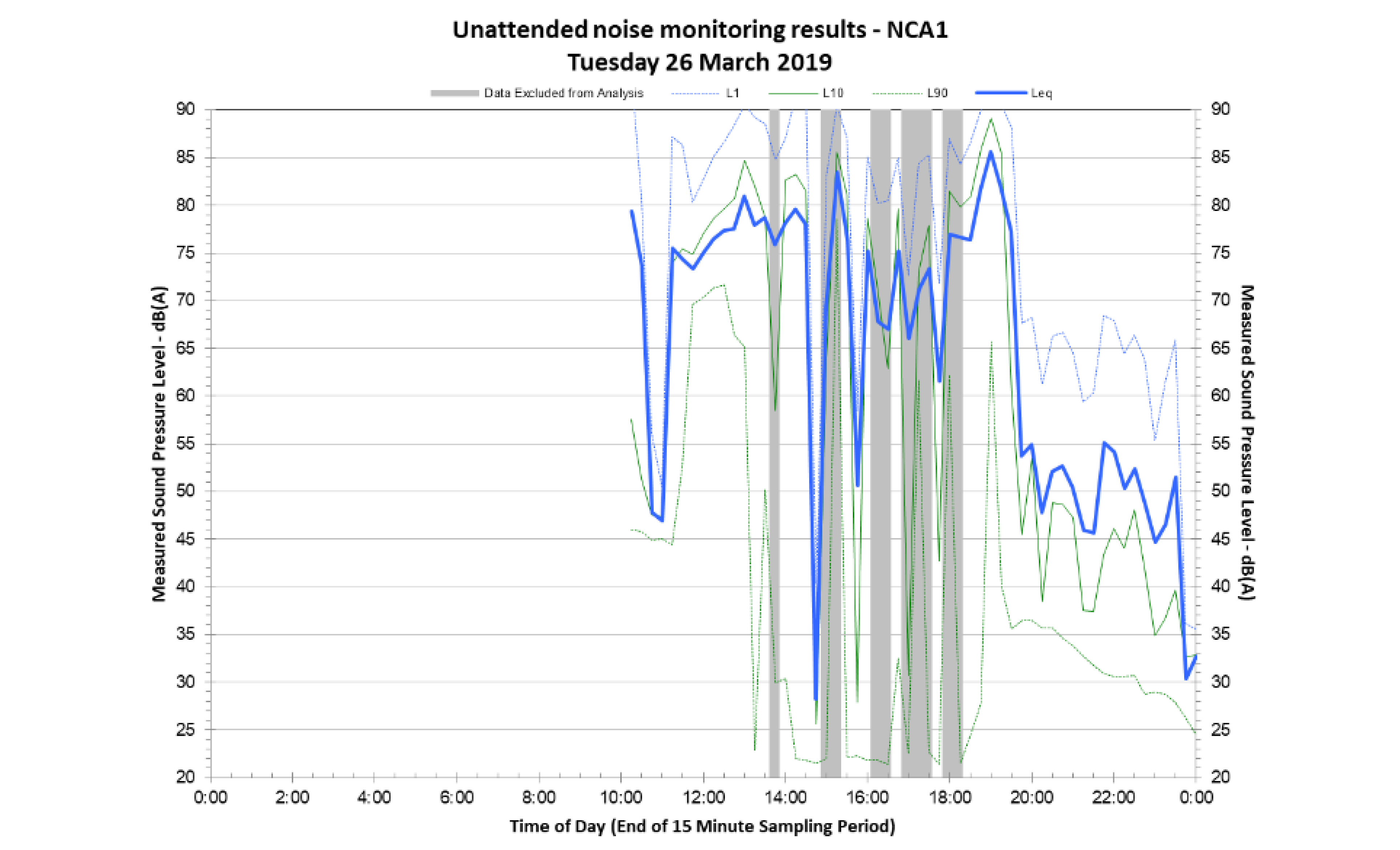
Appendix A. Background noise monitoring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Leq
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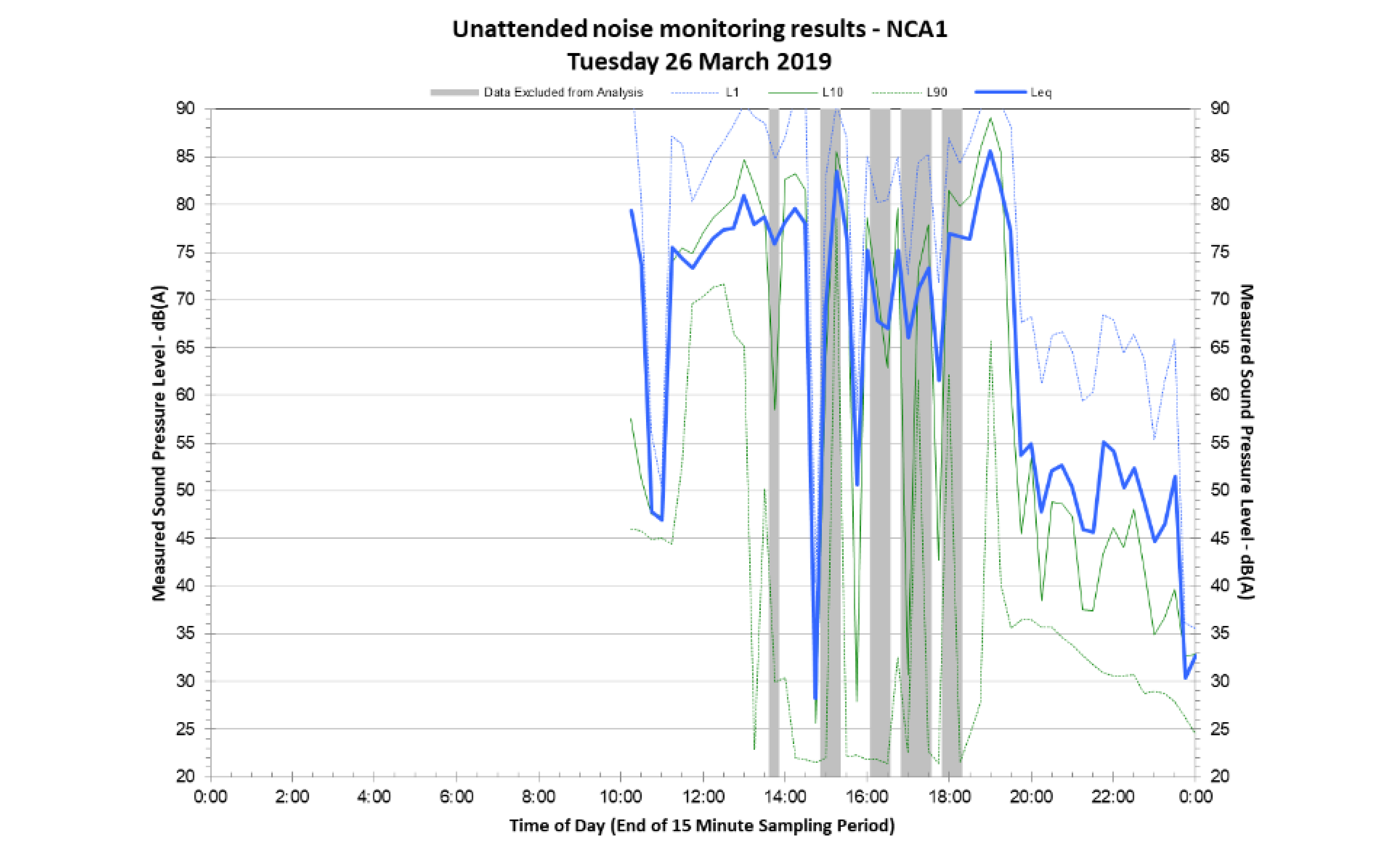
Time of Day (End of 15 Minute Sampling Period)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Data Excluded from Analysis
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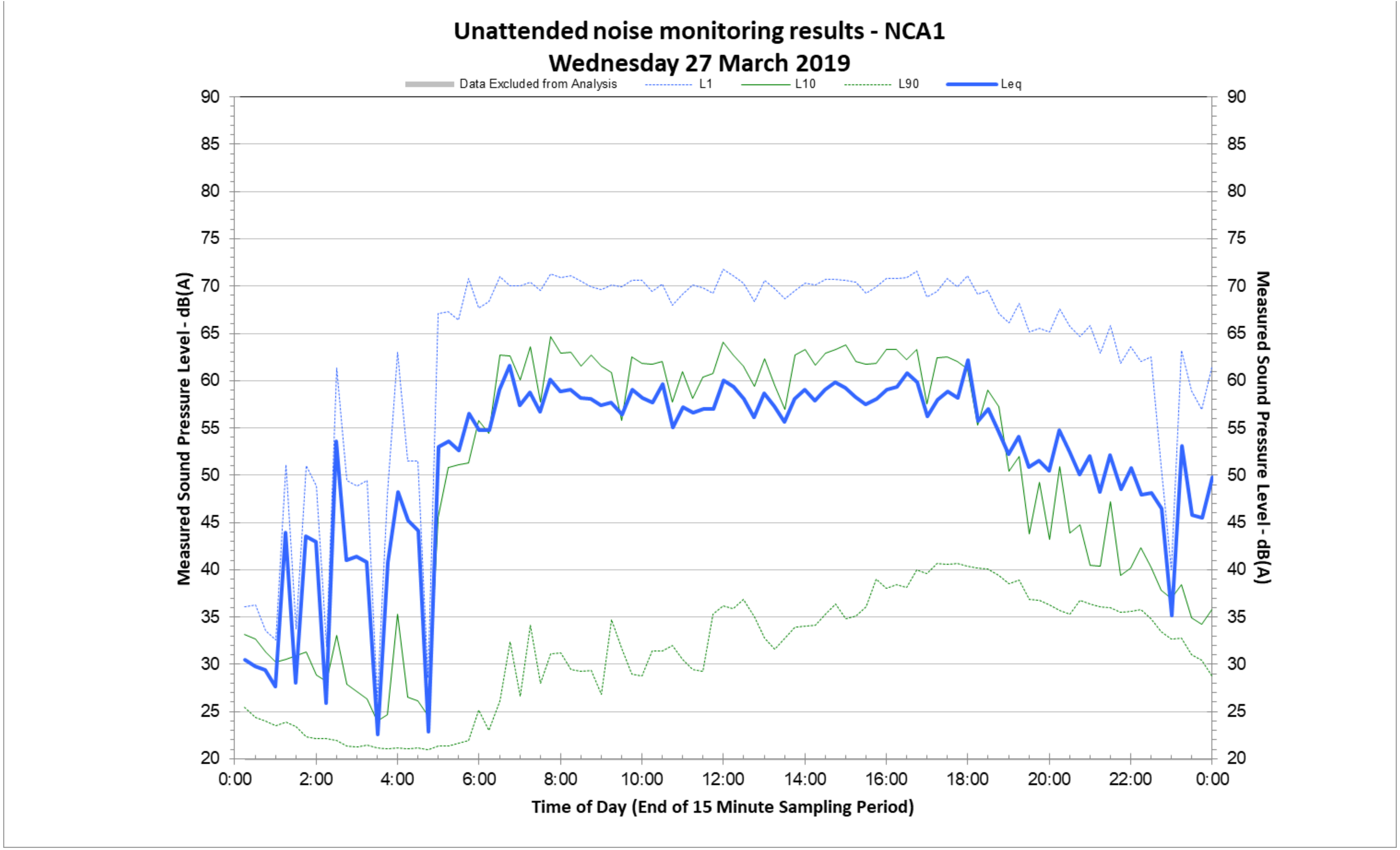

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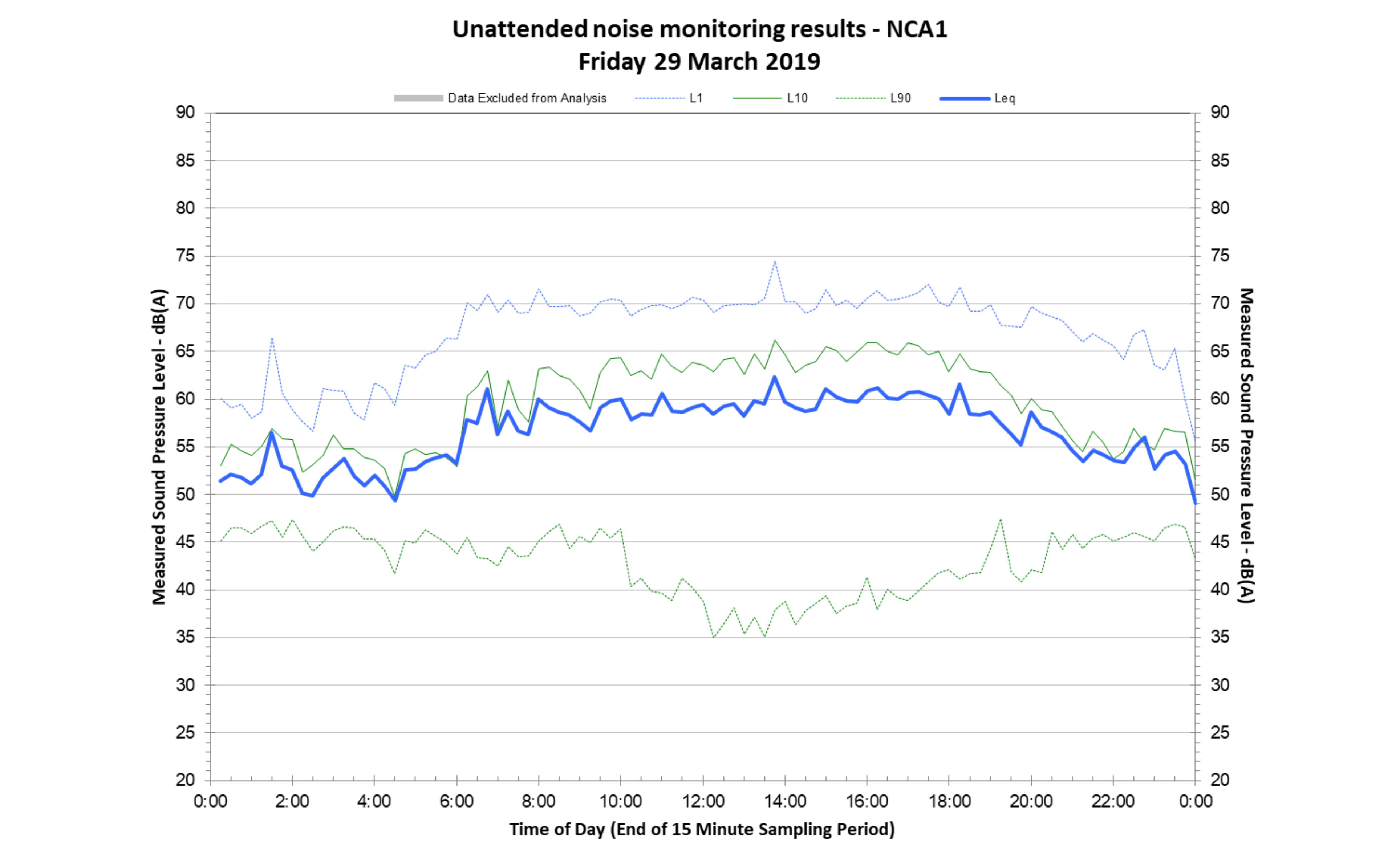
Time of Day (End of 15 Minute Sampling Period)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Time of Day (End of 15 Minute Sampling Period)
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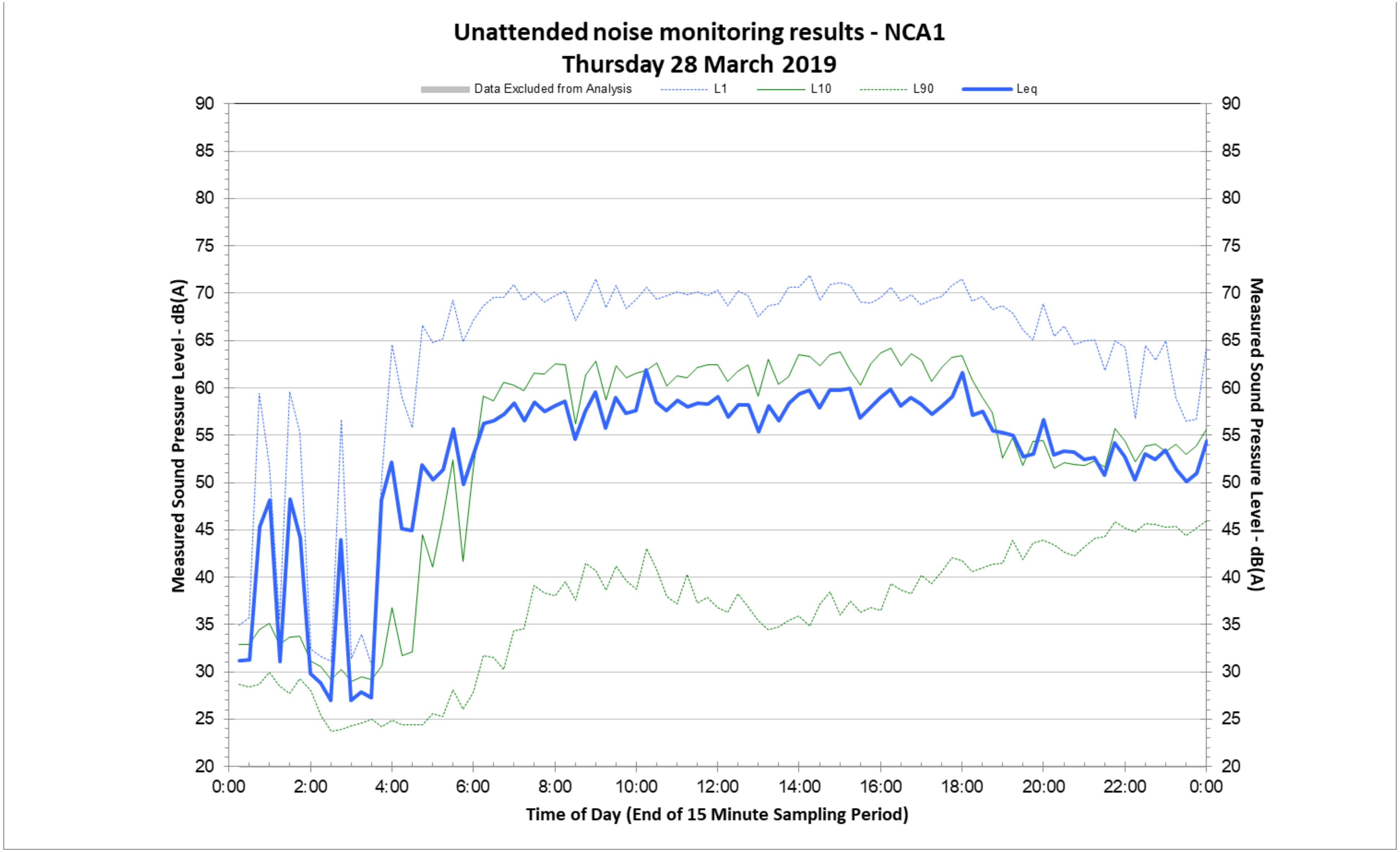
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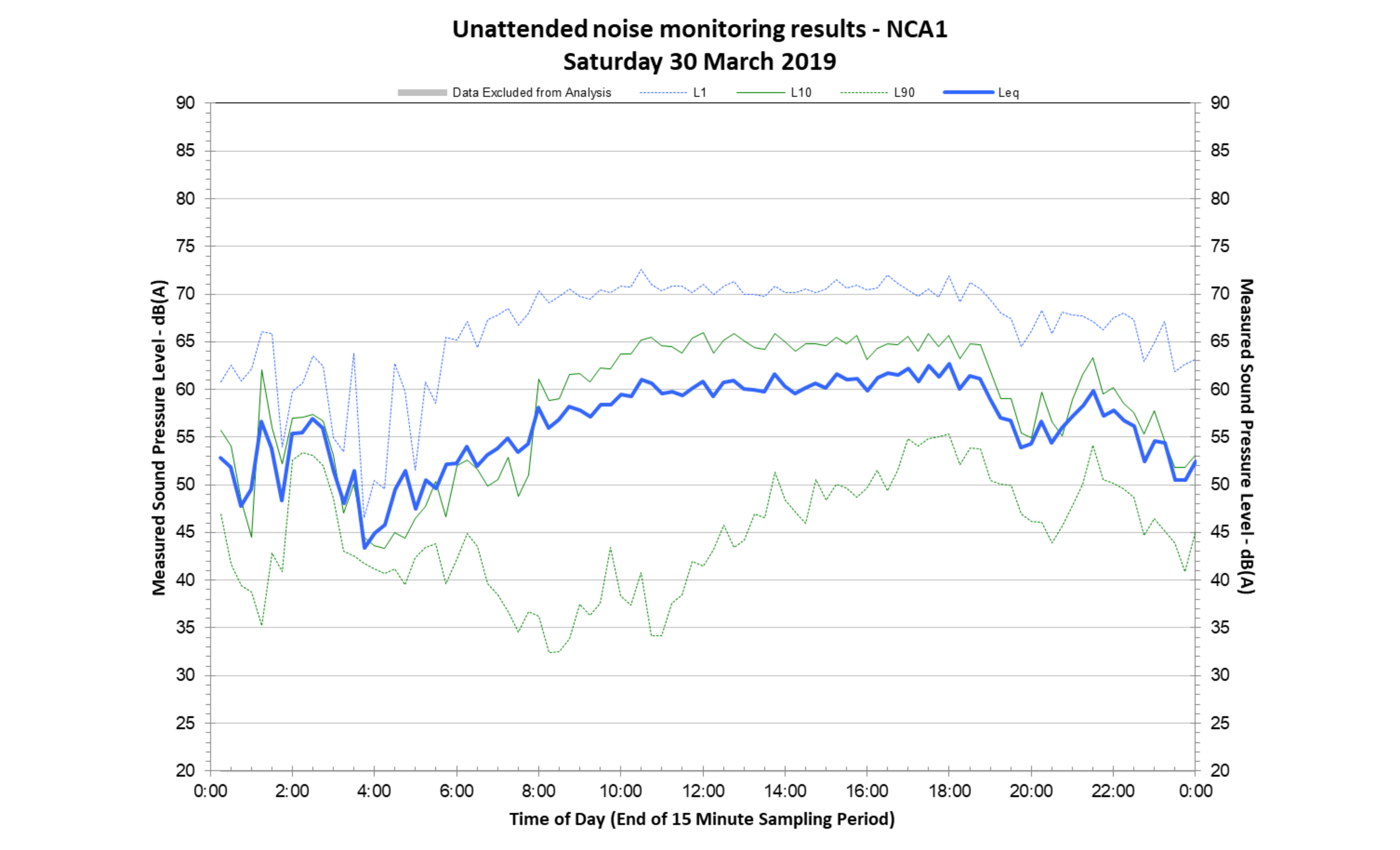
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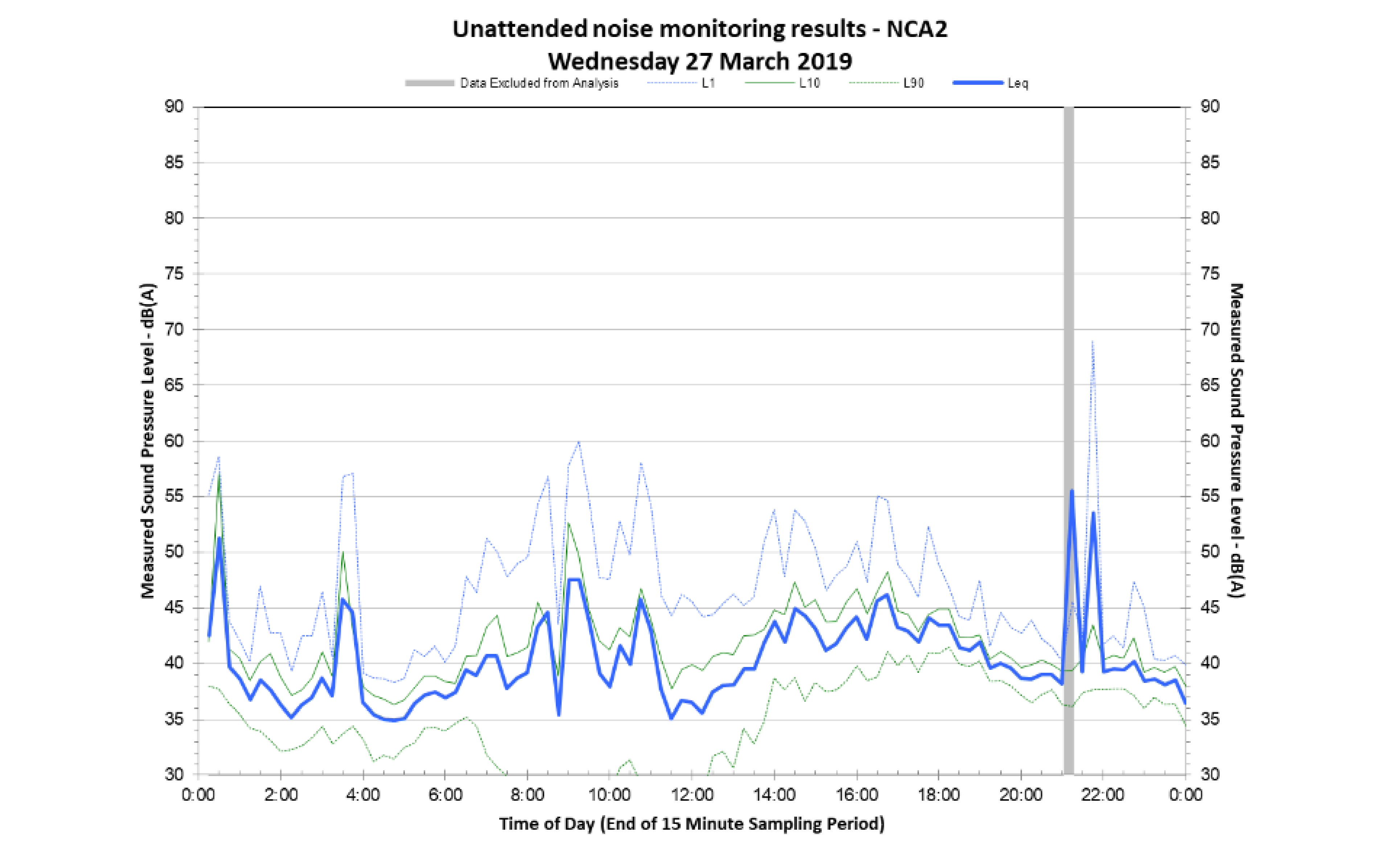
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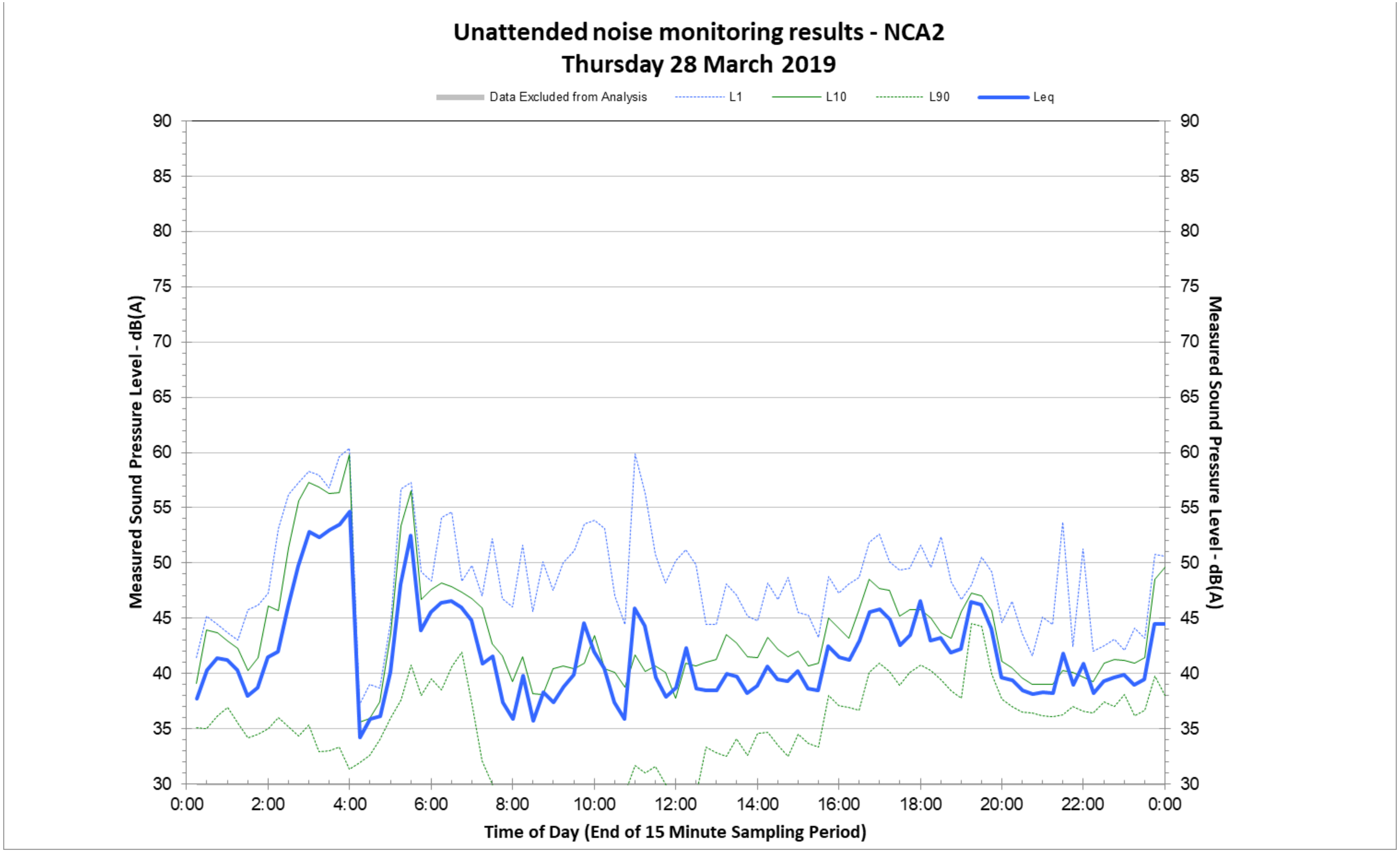

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Time of Day (End of 15 Minute Sampling Period)
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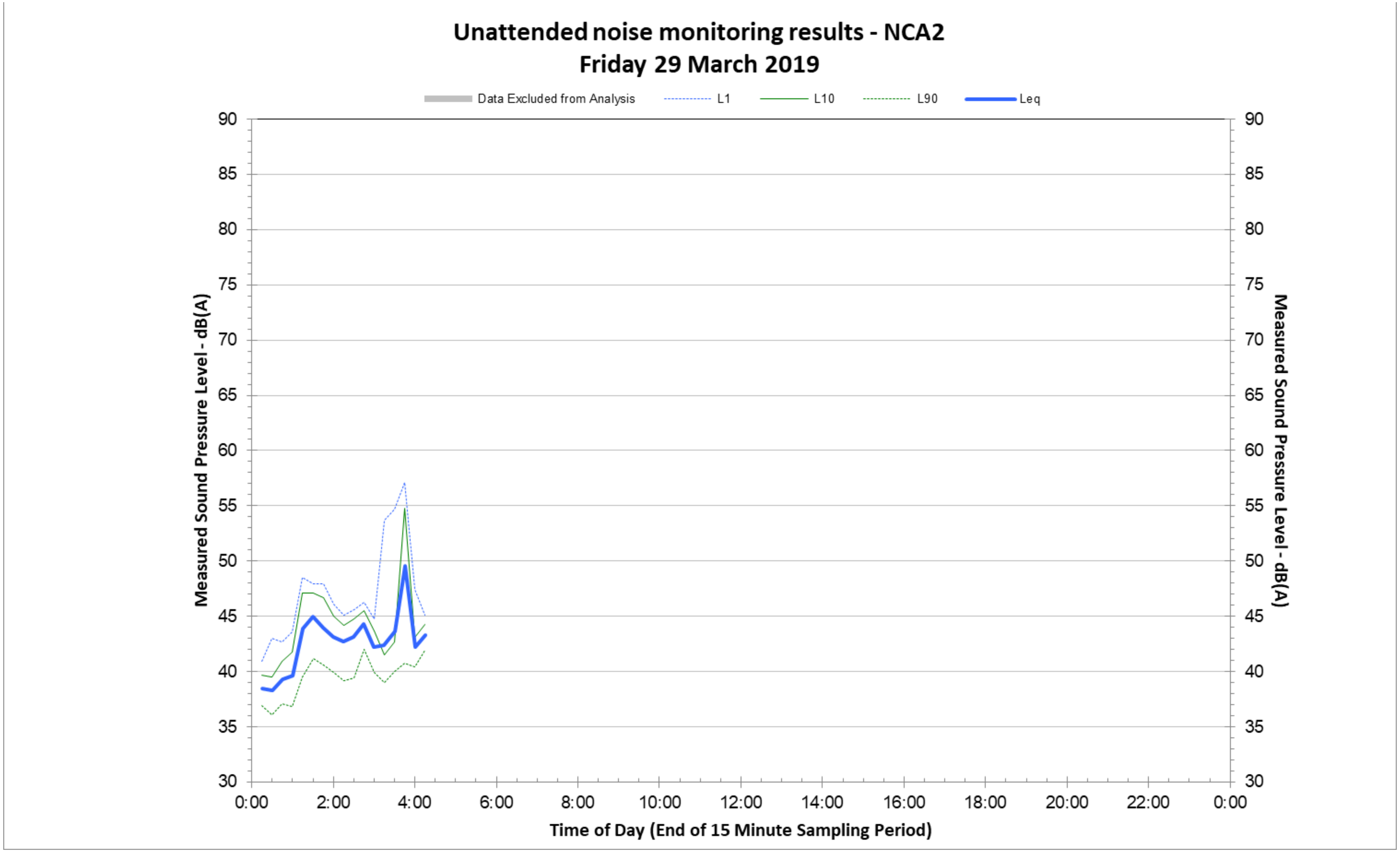
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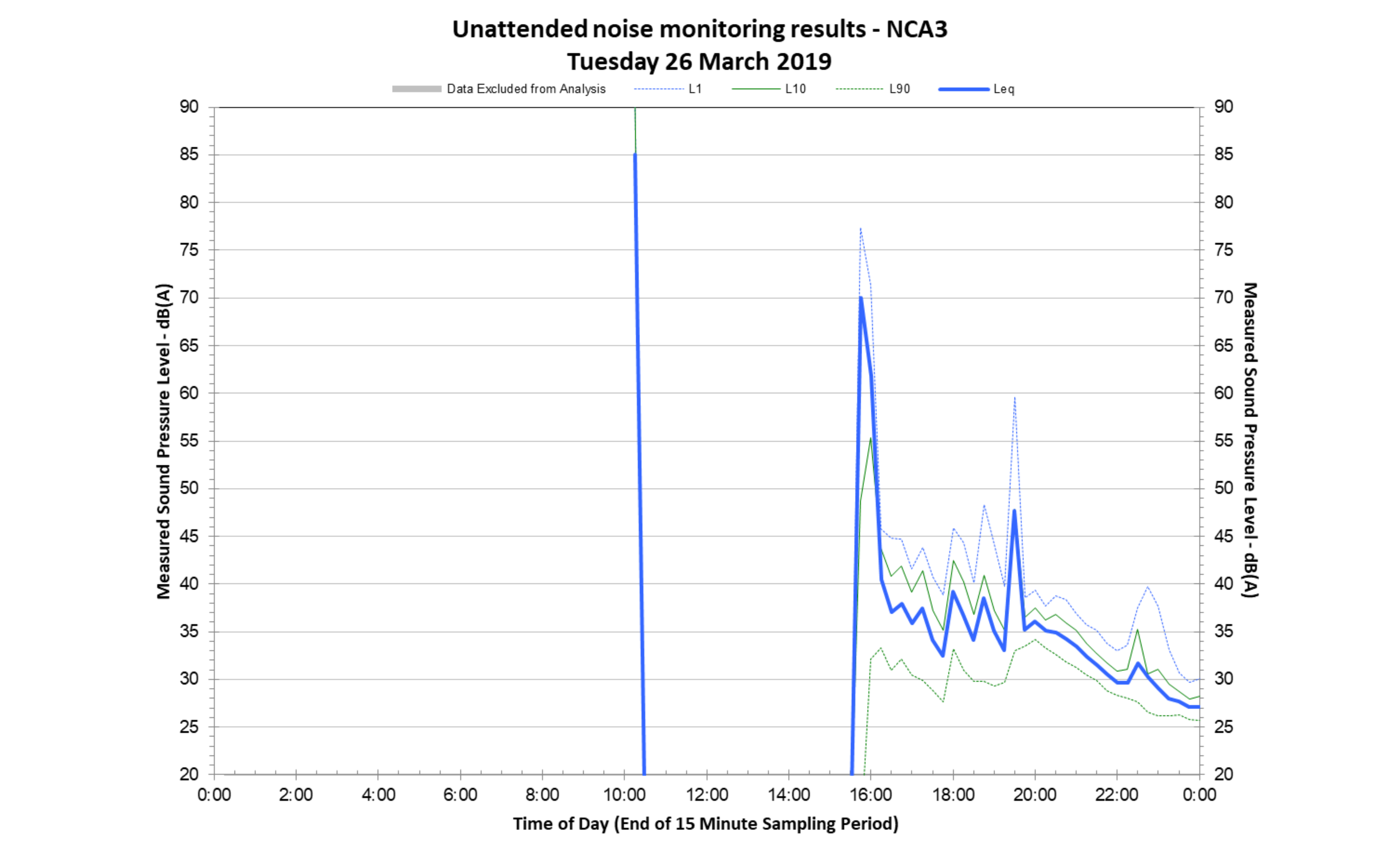
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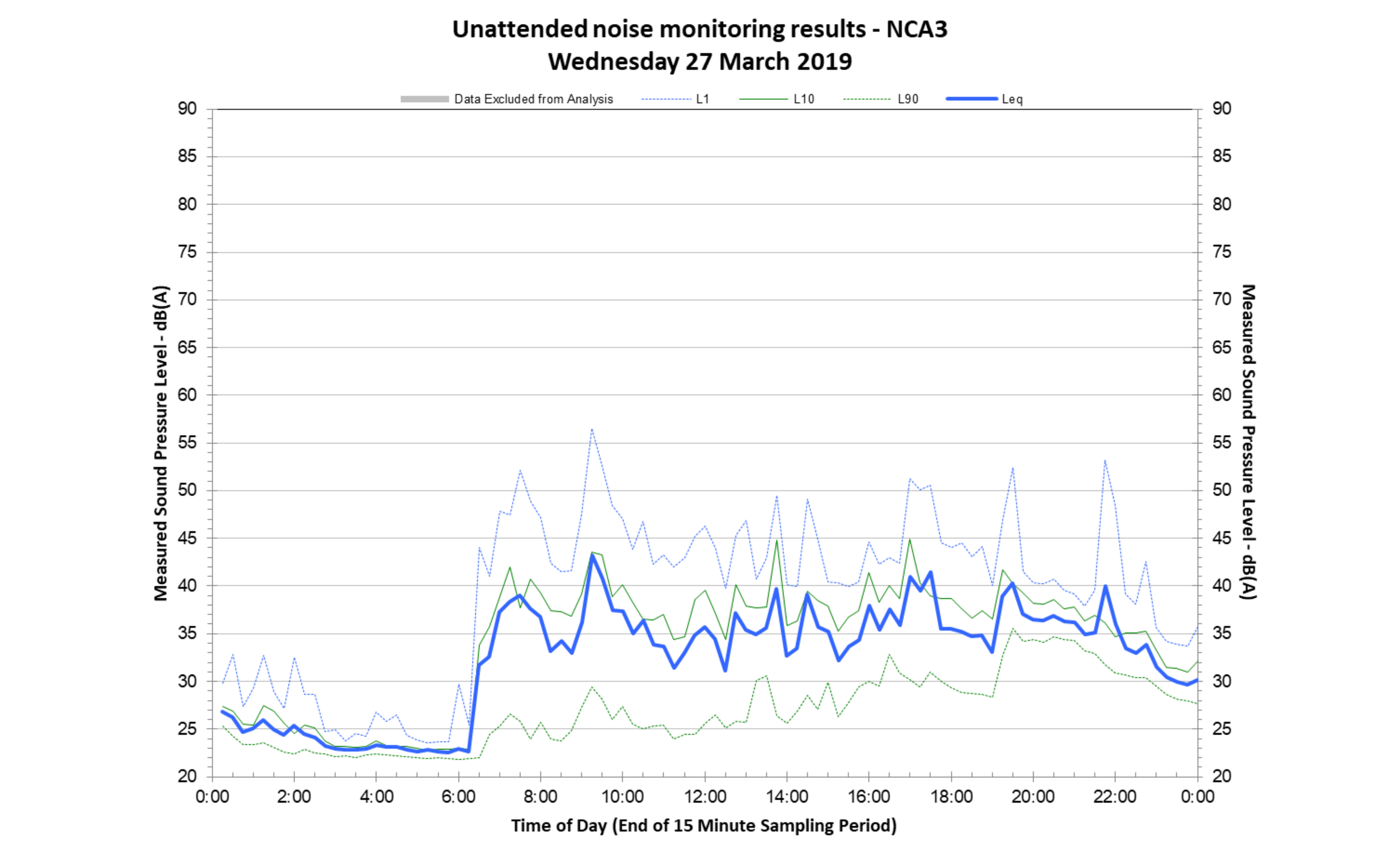
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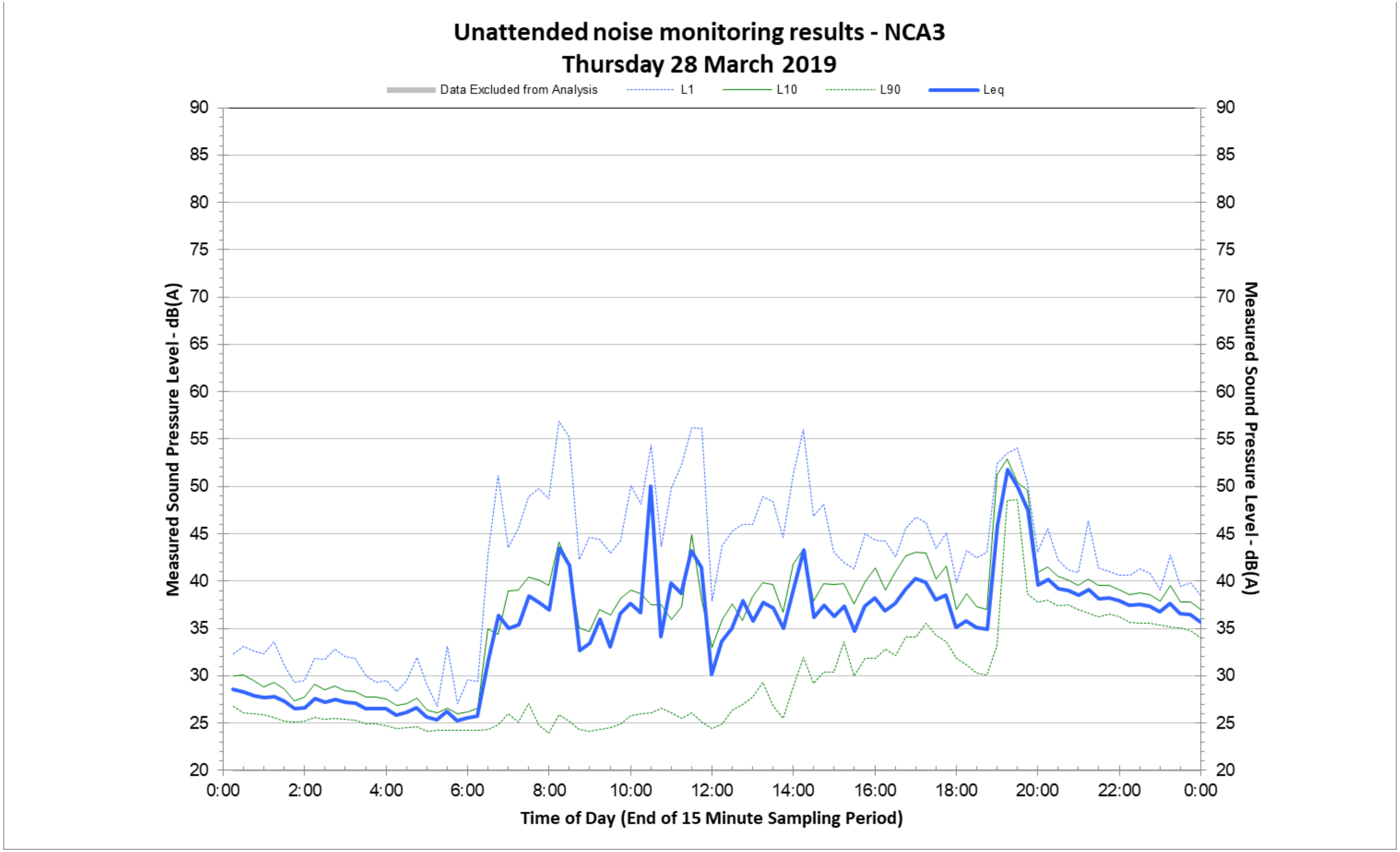
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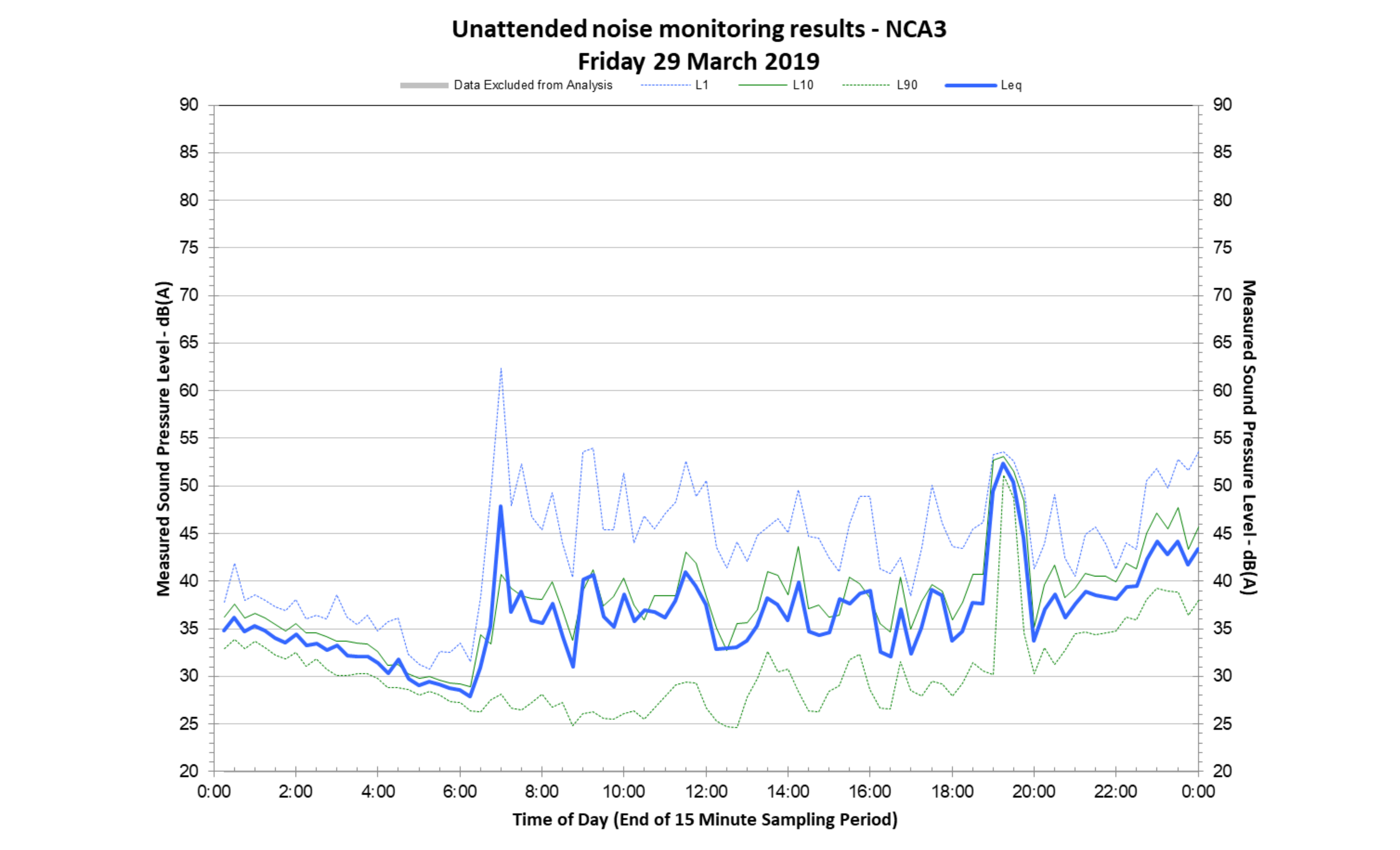
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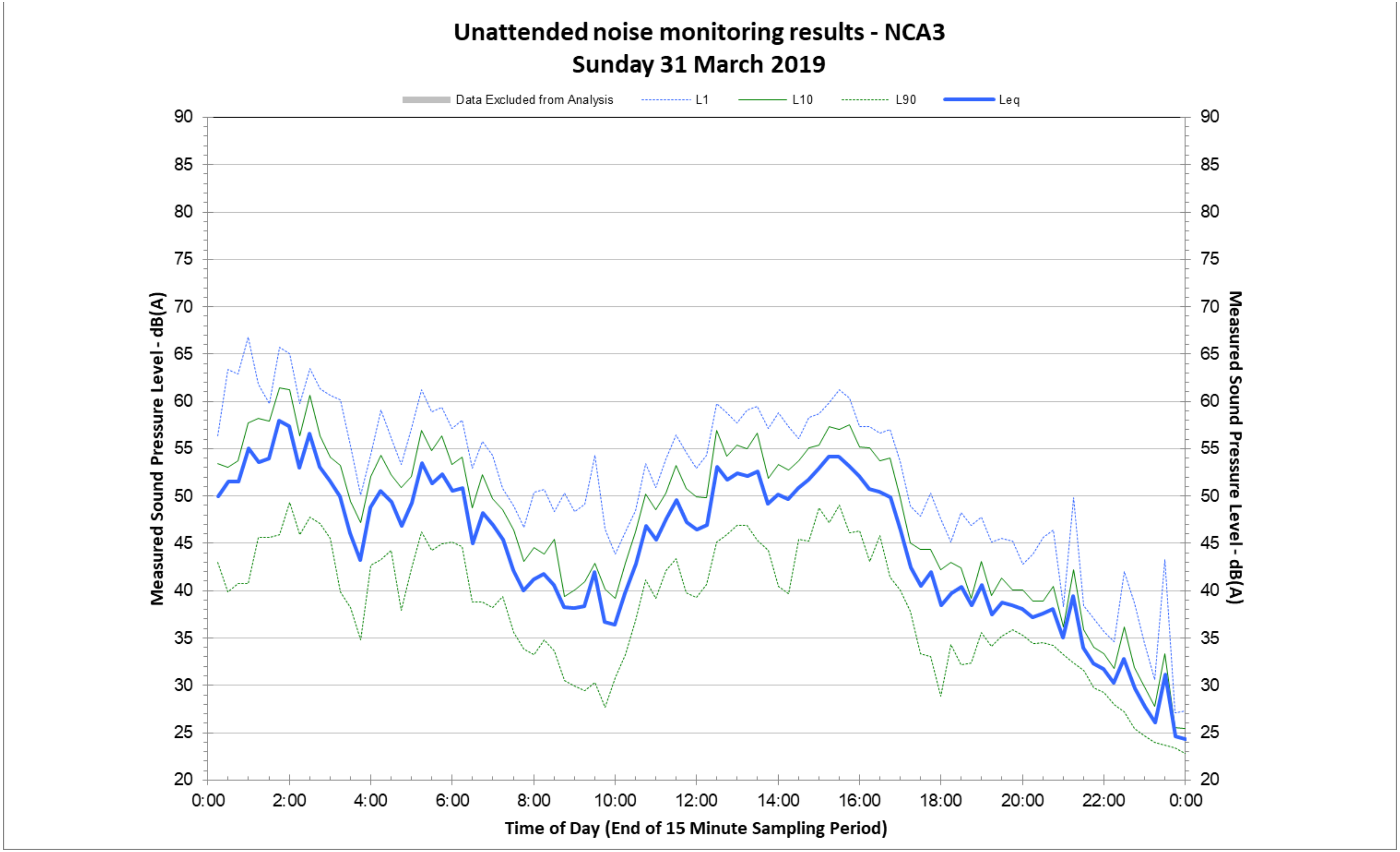
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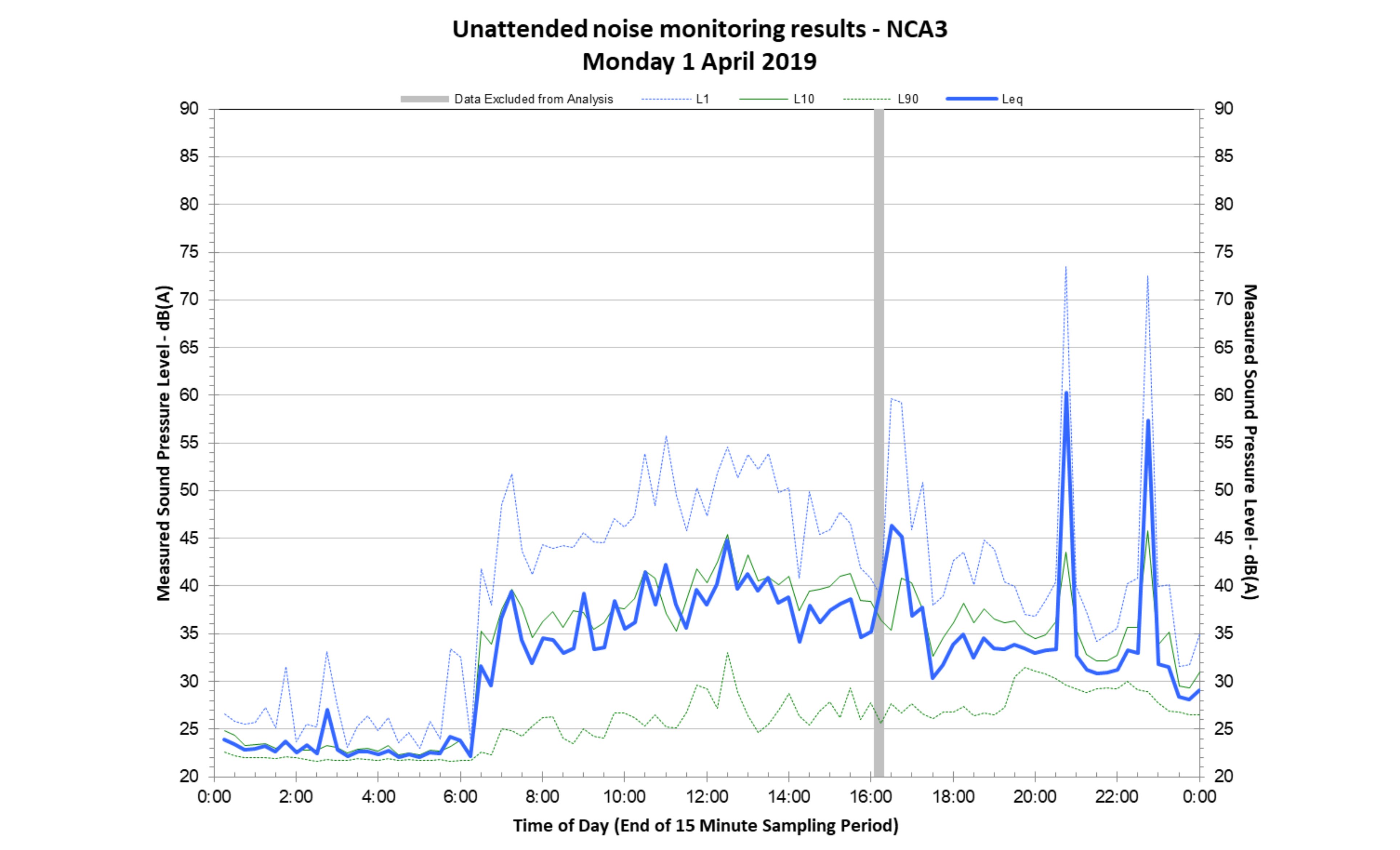
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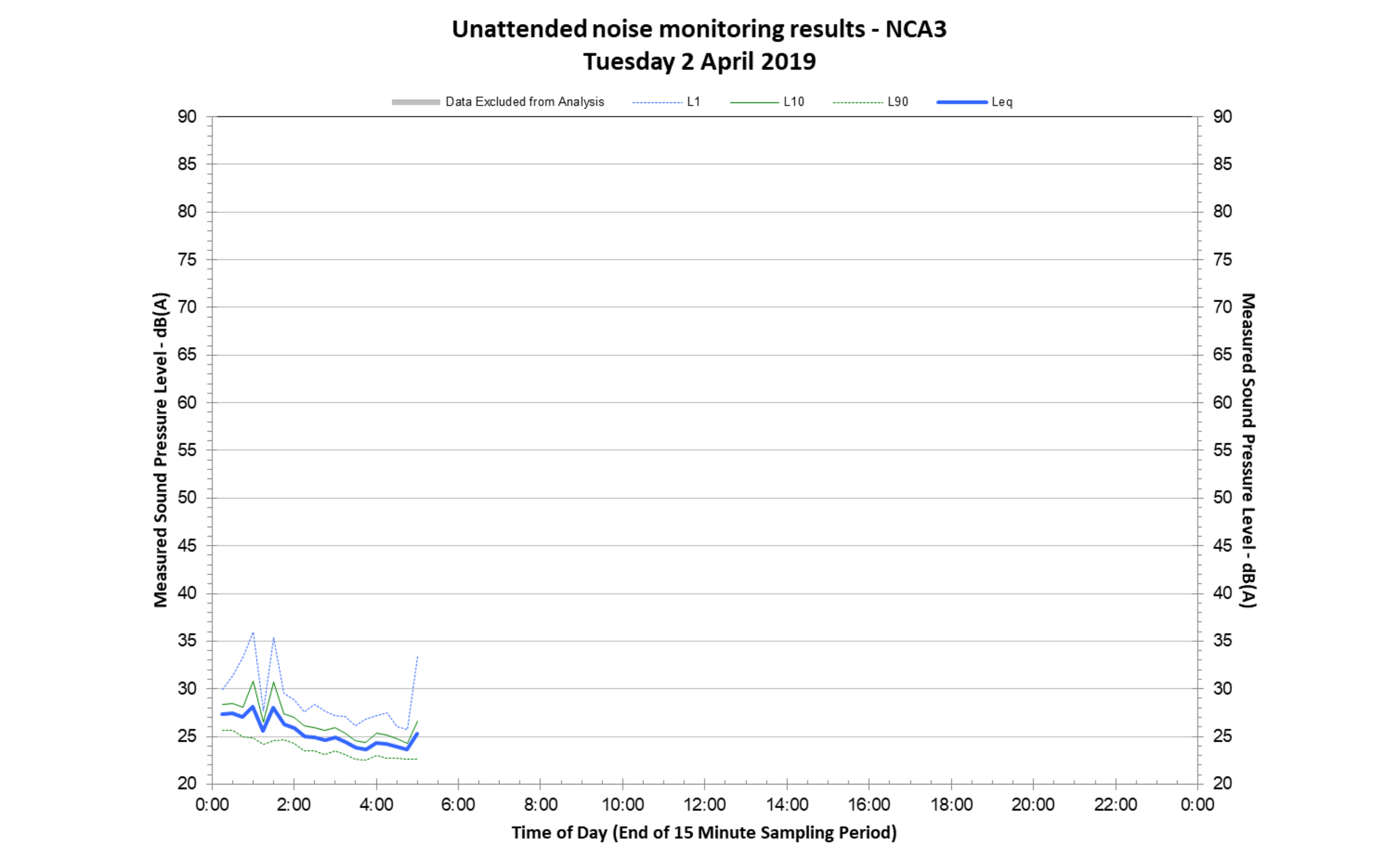

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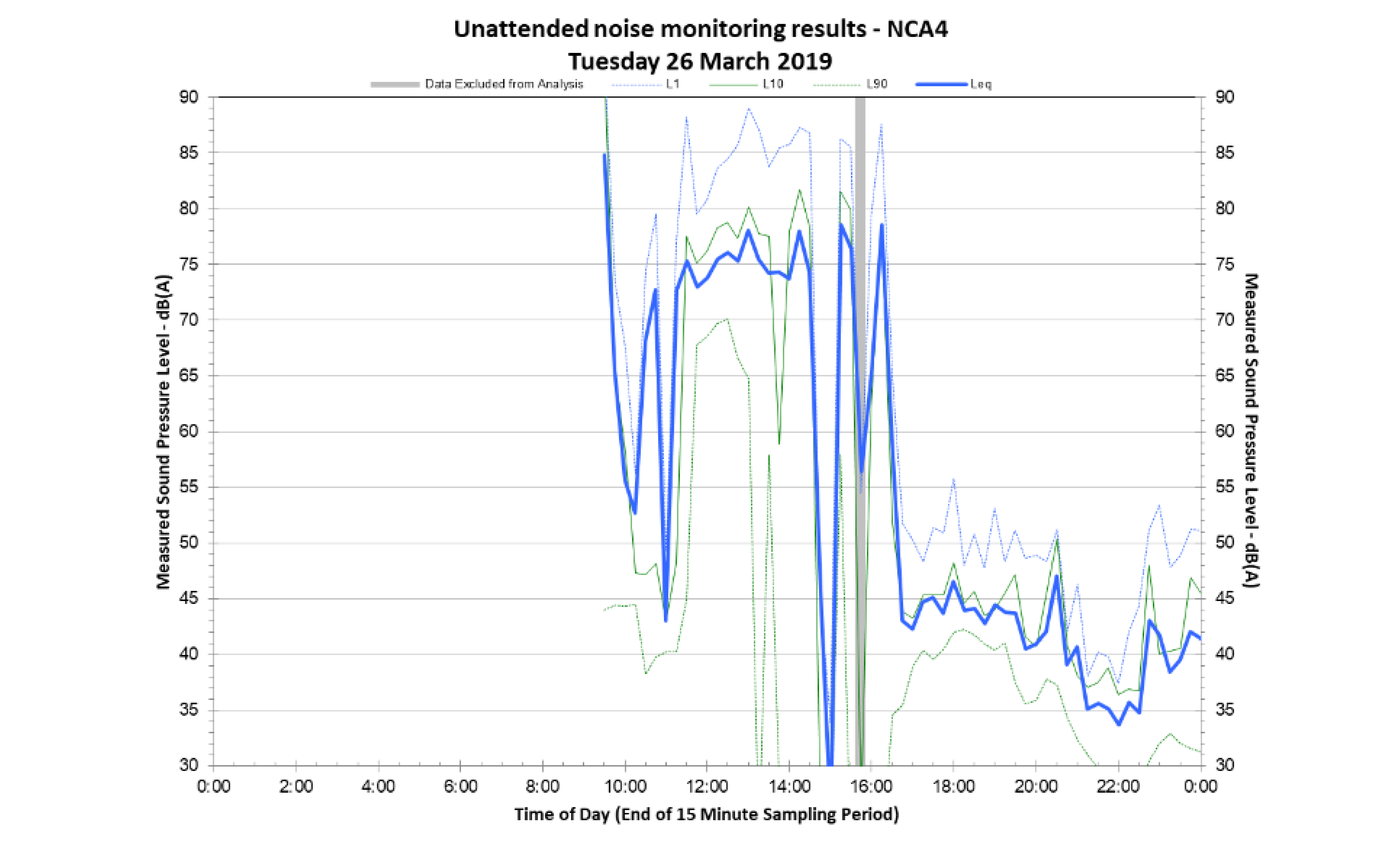
Unattended noise monitoring results - NCA4
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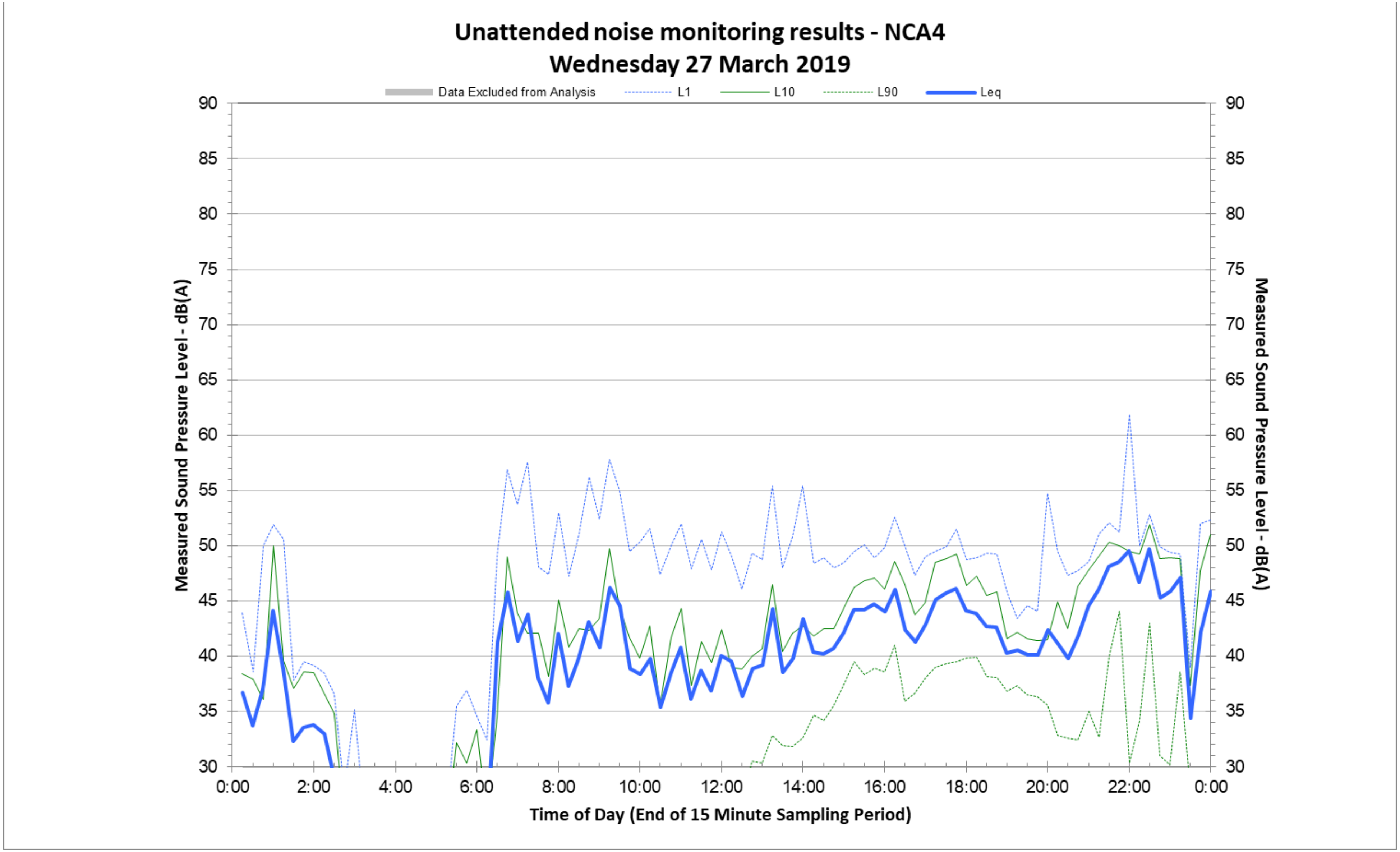
Time of Day (End of 15 Minute Sampling Period)


Unattended noise monitoring results - NCA4
Wednesday 27 March 2019
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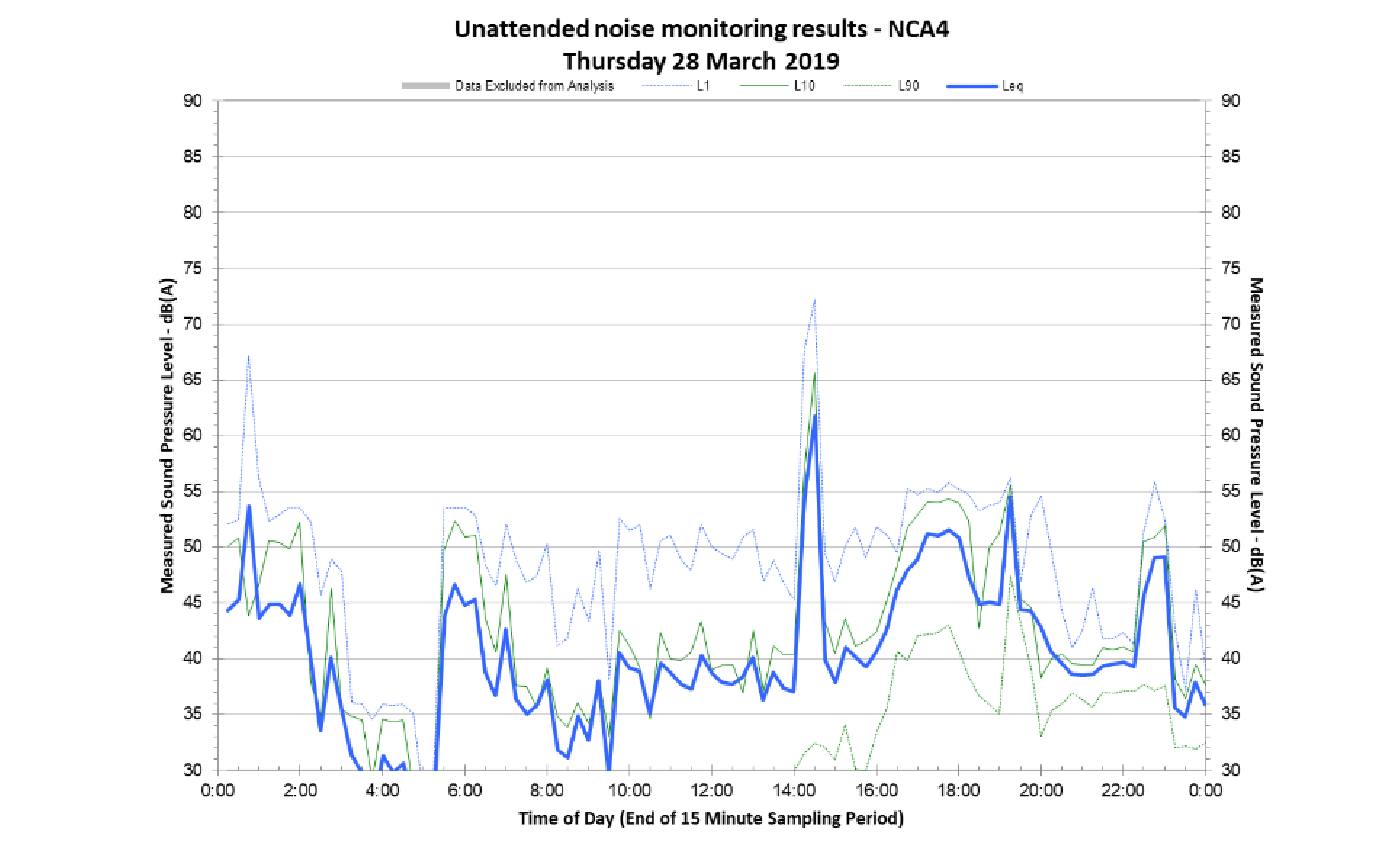
Time of Day (End of 15 Minute Sampling Period)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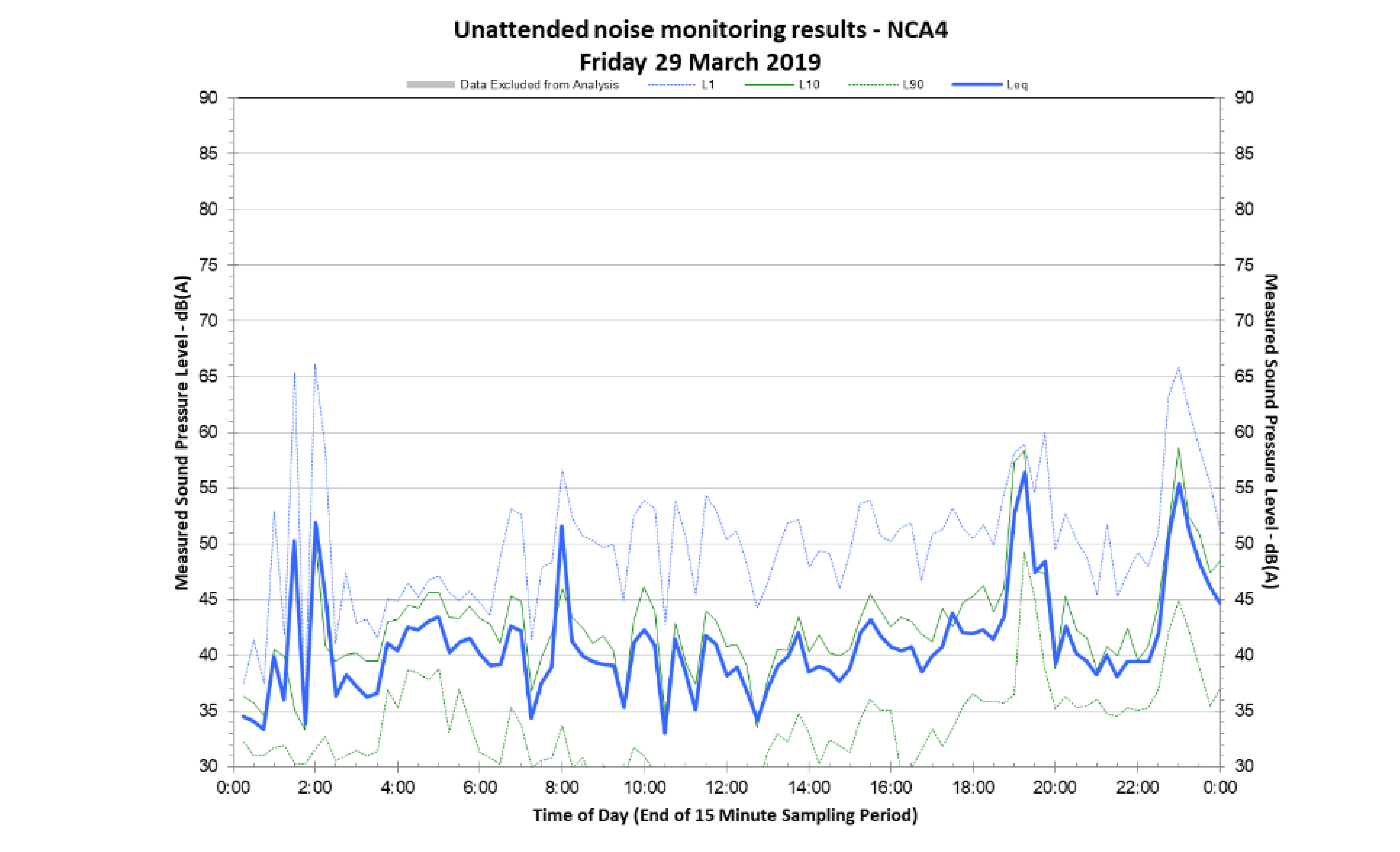
Time of Day (End of 15 Minute Sampling Period)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Measured Sound Pressure Level - dB(A)
Time of Day (End of 15 Minute Sampling Period)
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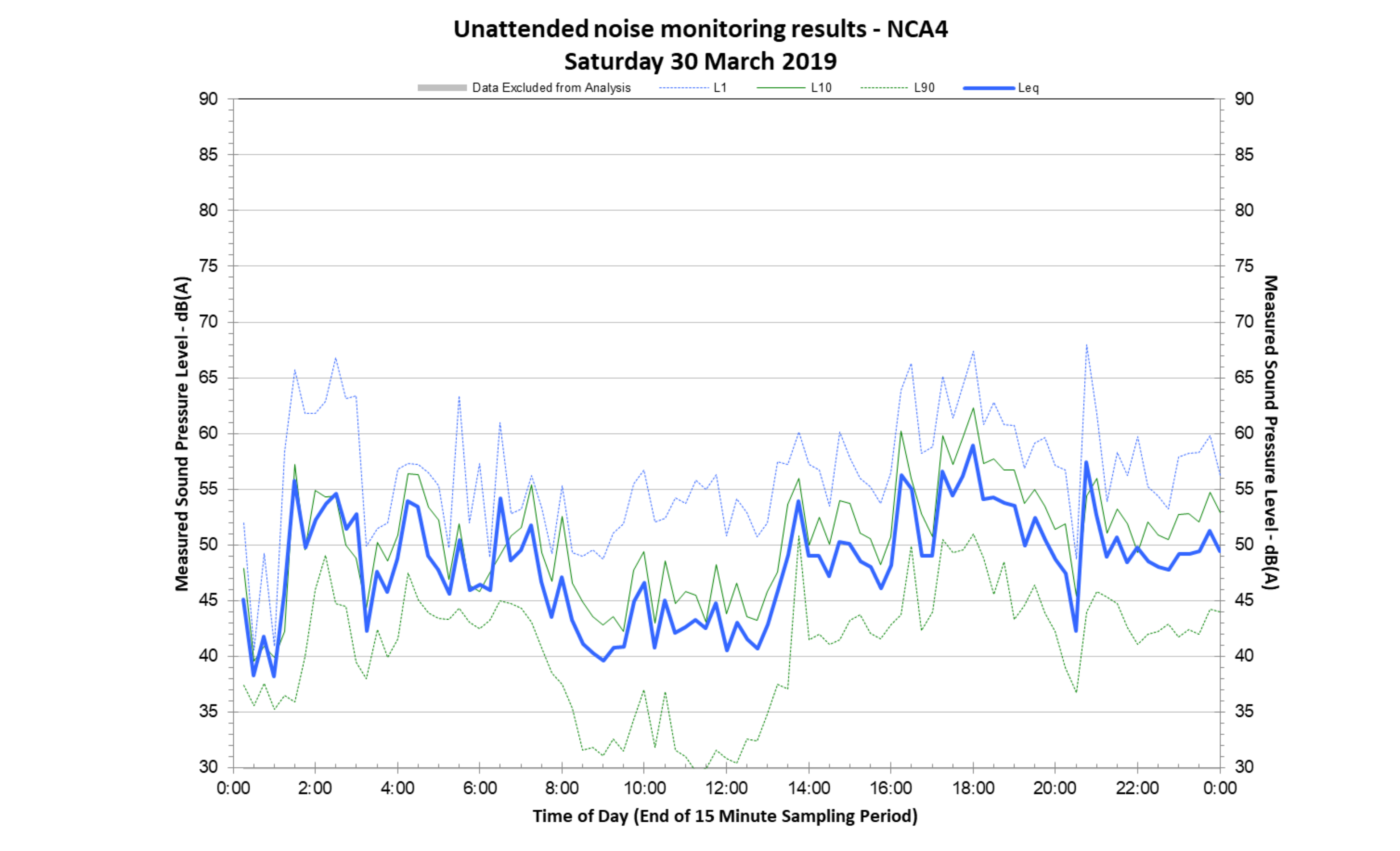
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Measured Sound Pressure Level - dB(A)
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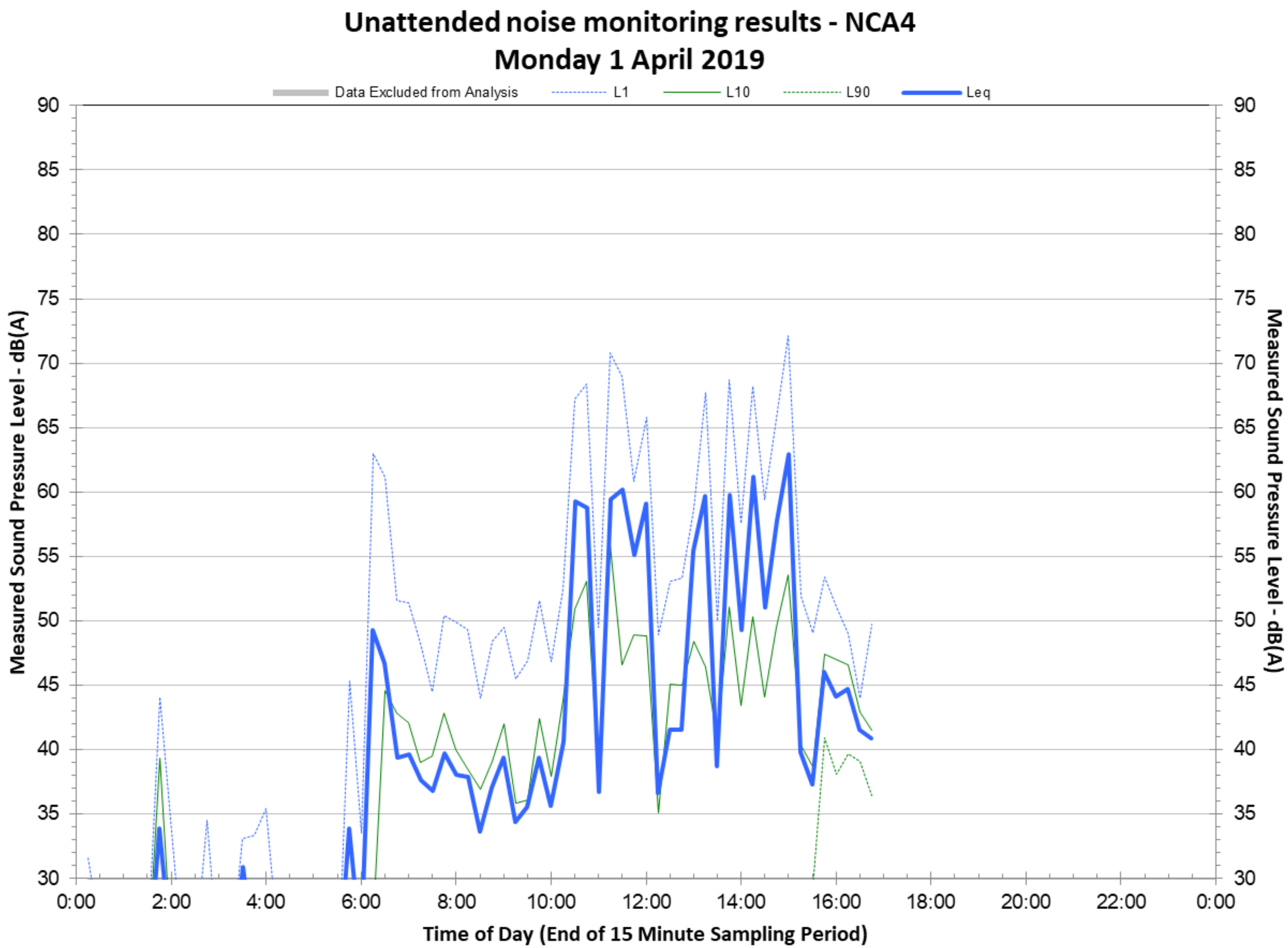
Time of Day (End of 15 Minute Sampling Period)


Unattended noise monitoring results - NCA4
Monday 1 April 2019
Data Excluded from Analysis
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Measured Sound Pressure Level - dB(A)
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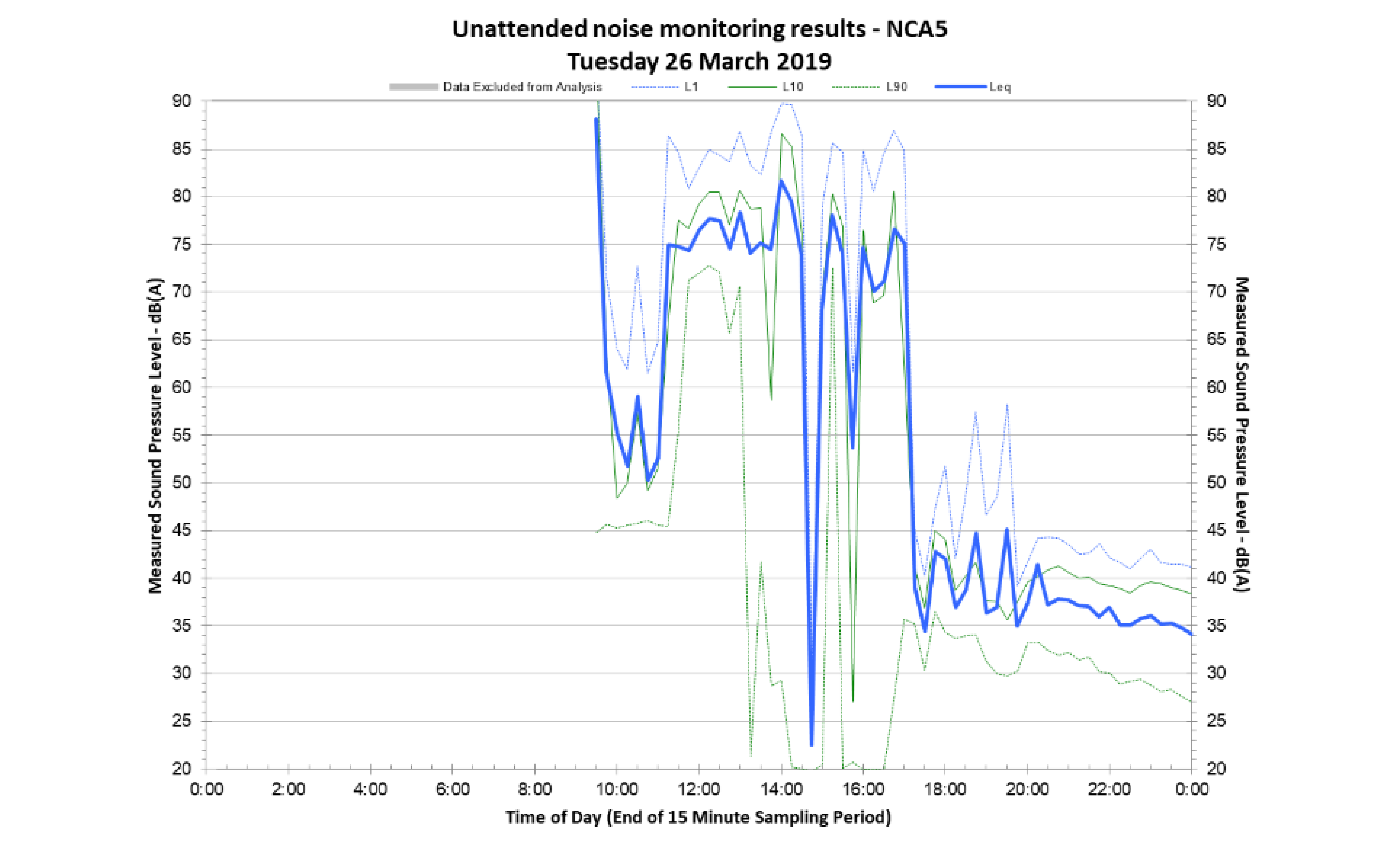
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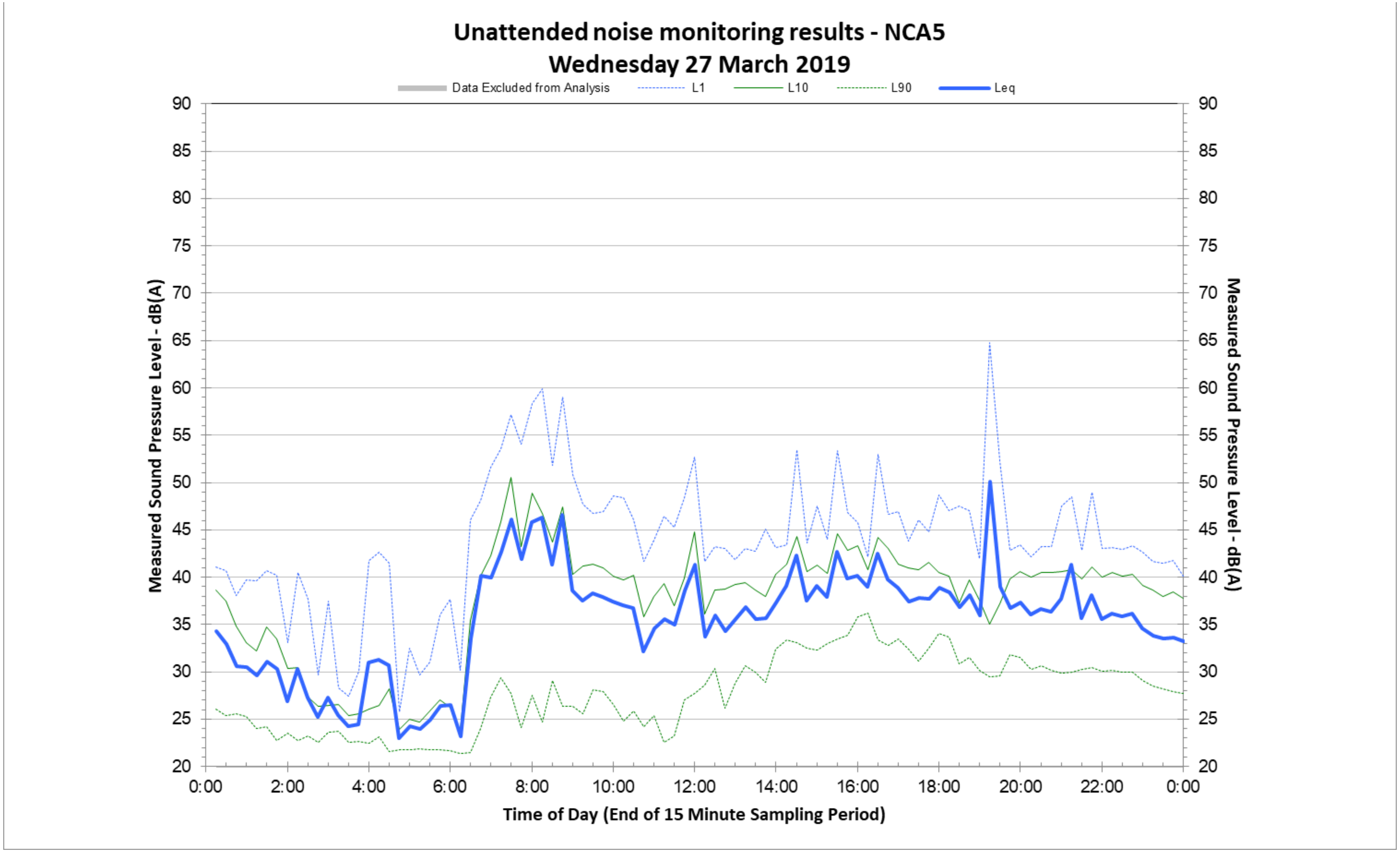
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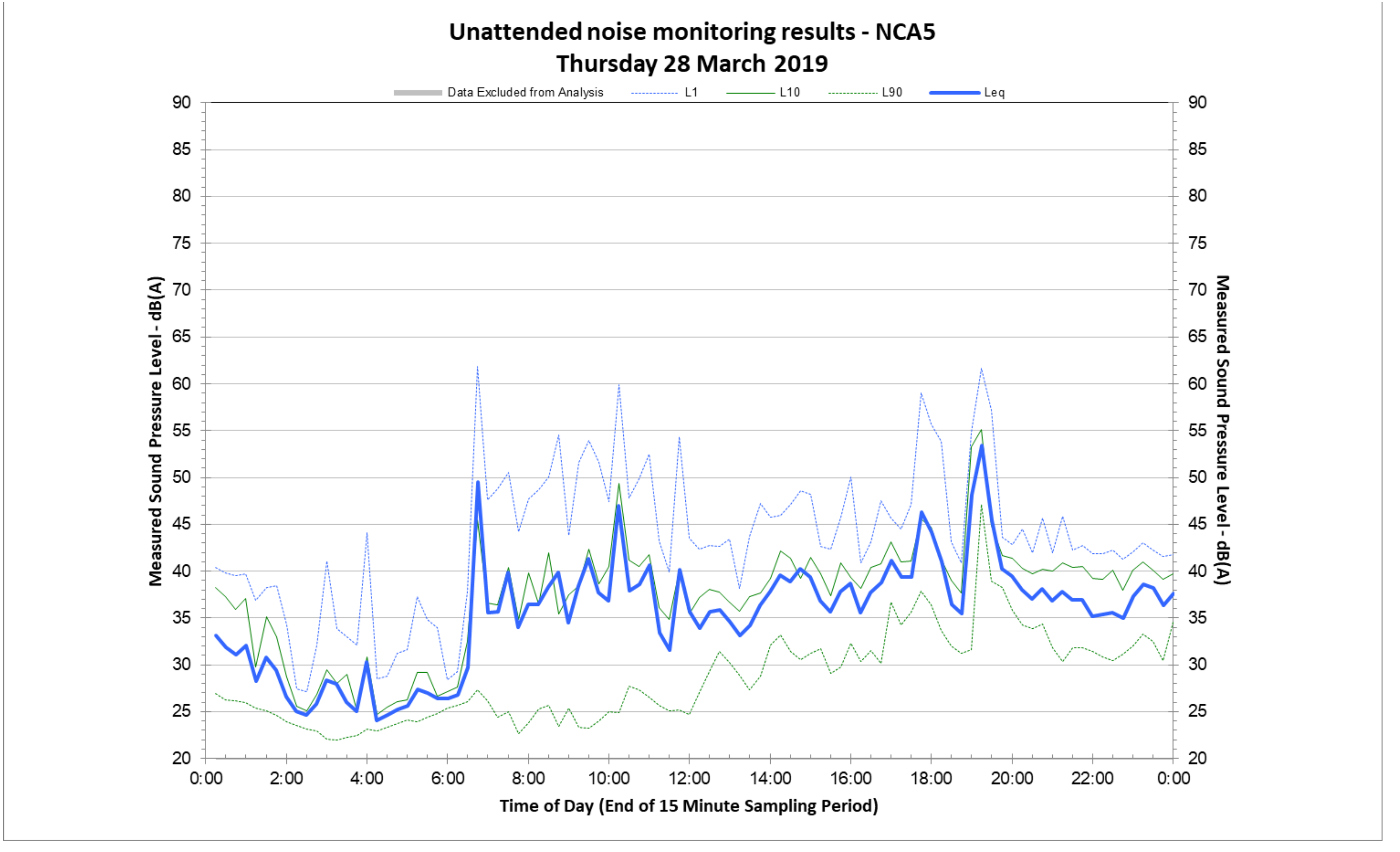

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L10
L90
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Measured Sound Pressure Level - dB(A)
Time of Day (End of 15 Minute Sampling Period)
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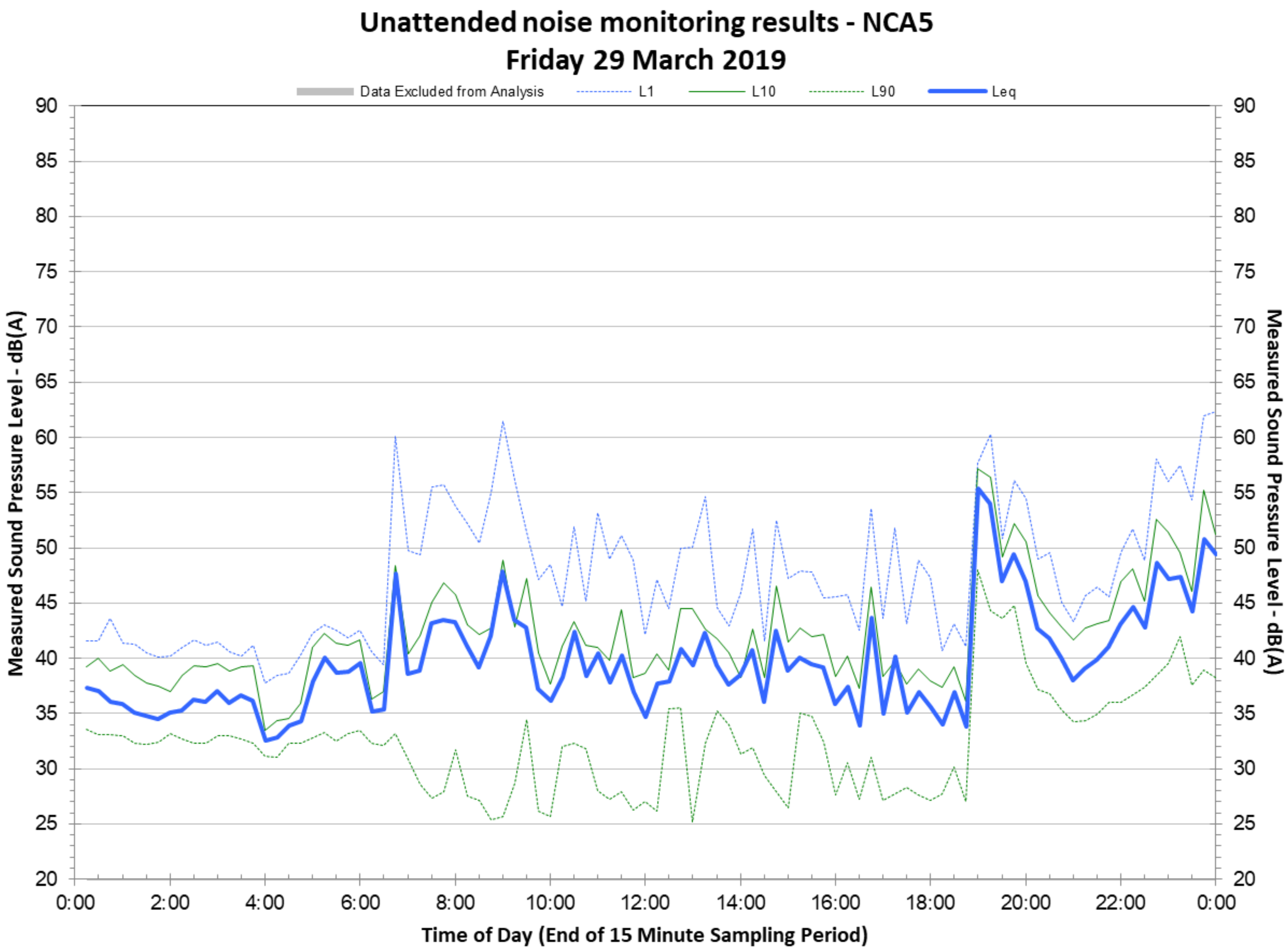
Unattended noise monitoring results - NCA5
Friday 29 March 2019
Data Excluded from Analysis
L1
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Leq
Measured Sound Pressure Level - dB(A)
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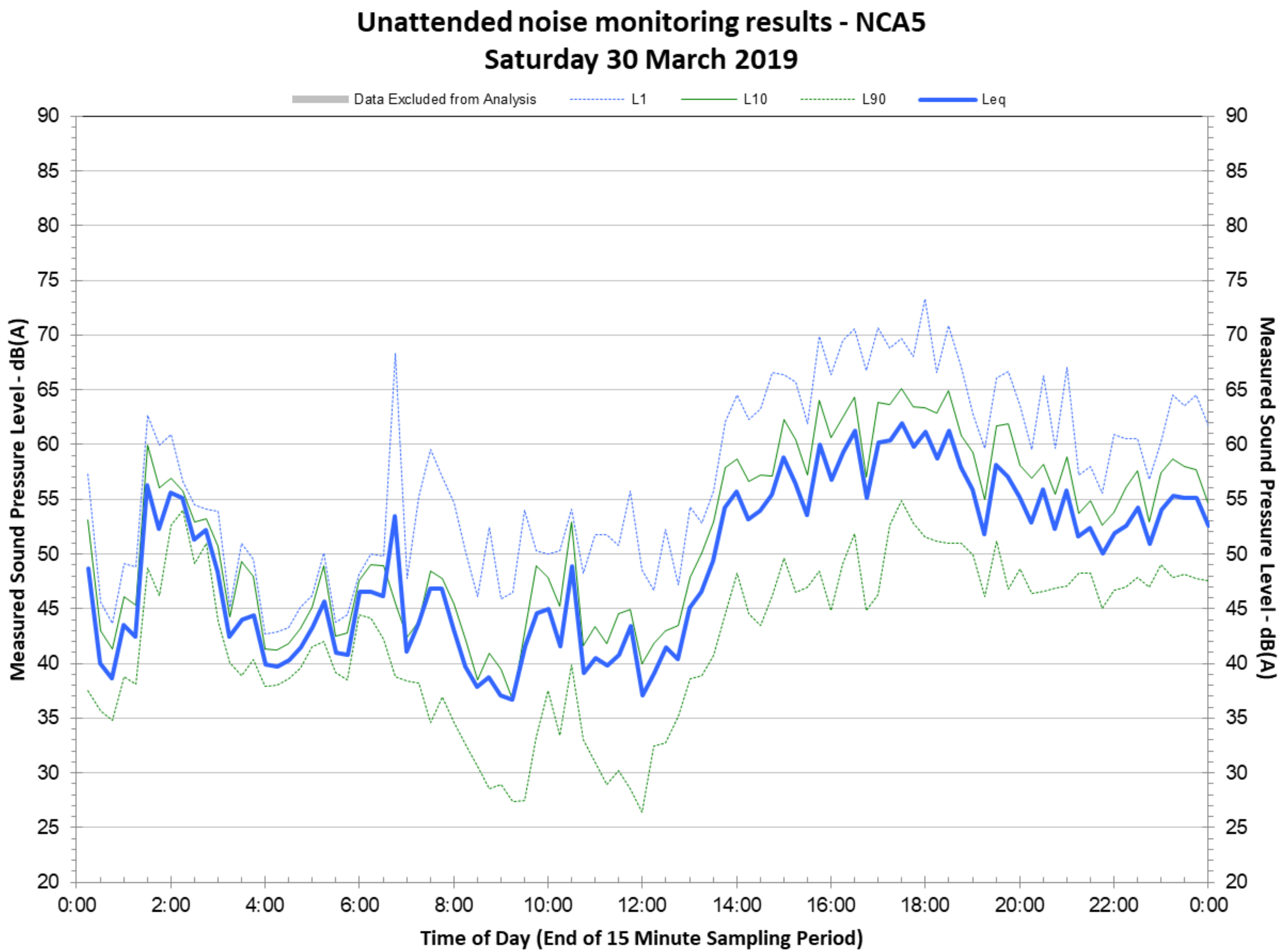
Time of Day (End of 15 Minute Sampling Period)



Unattended noise monitoring results - NCA5
Saturday 30 March 2019
Data Excluded from Analysis
L1
L10
L90
Leq
Measured Sound Pressure Level - dB(A)
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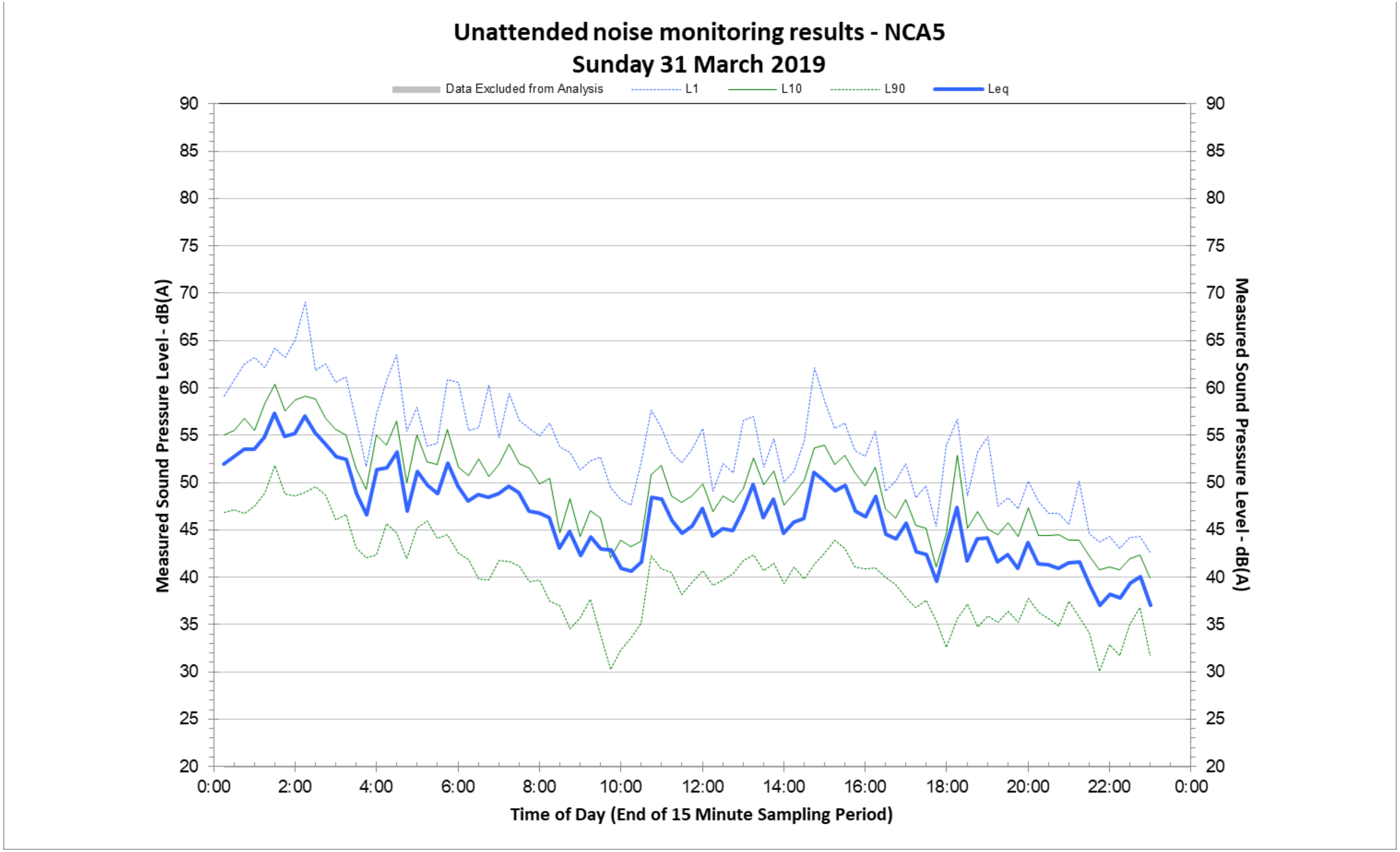
Time of Day (End of 15 Minute Sampling Period)



Unattended noise monitoring results - NCA5
Sunday 31 March 2019
Data Excluded from Analysis
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Leq
Measured Sound Pressure Level - dB(A)
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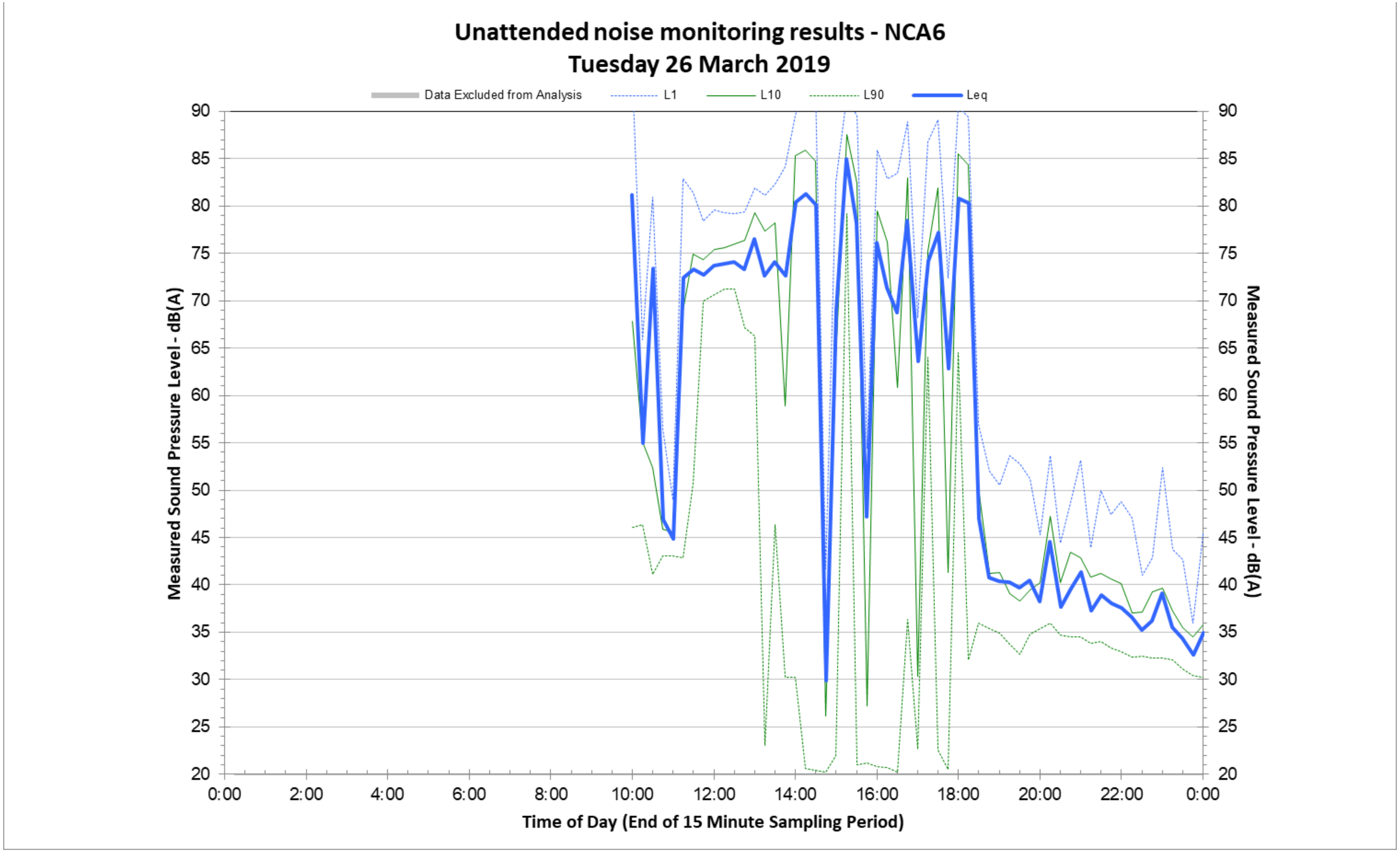
Time of Day (End of 15 Minute Sampling Period)


Unattended noise monitoring results - NCA6
Tuesday 26 March 2019
Data Excluded from Analysis
L1
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Leq
Measured Sound Pressure Level - dB(A)
Time of Day (End of 15 Minute Sampling Period)
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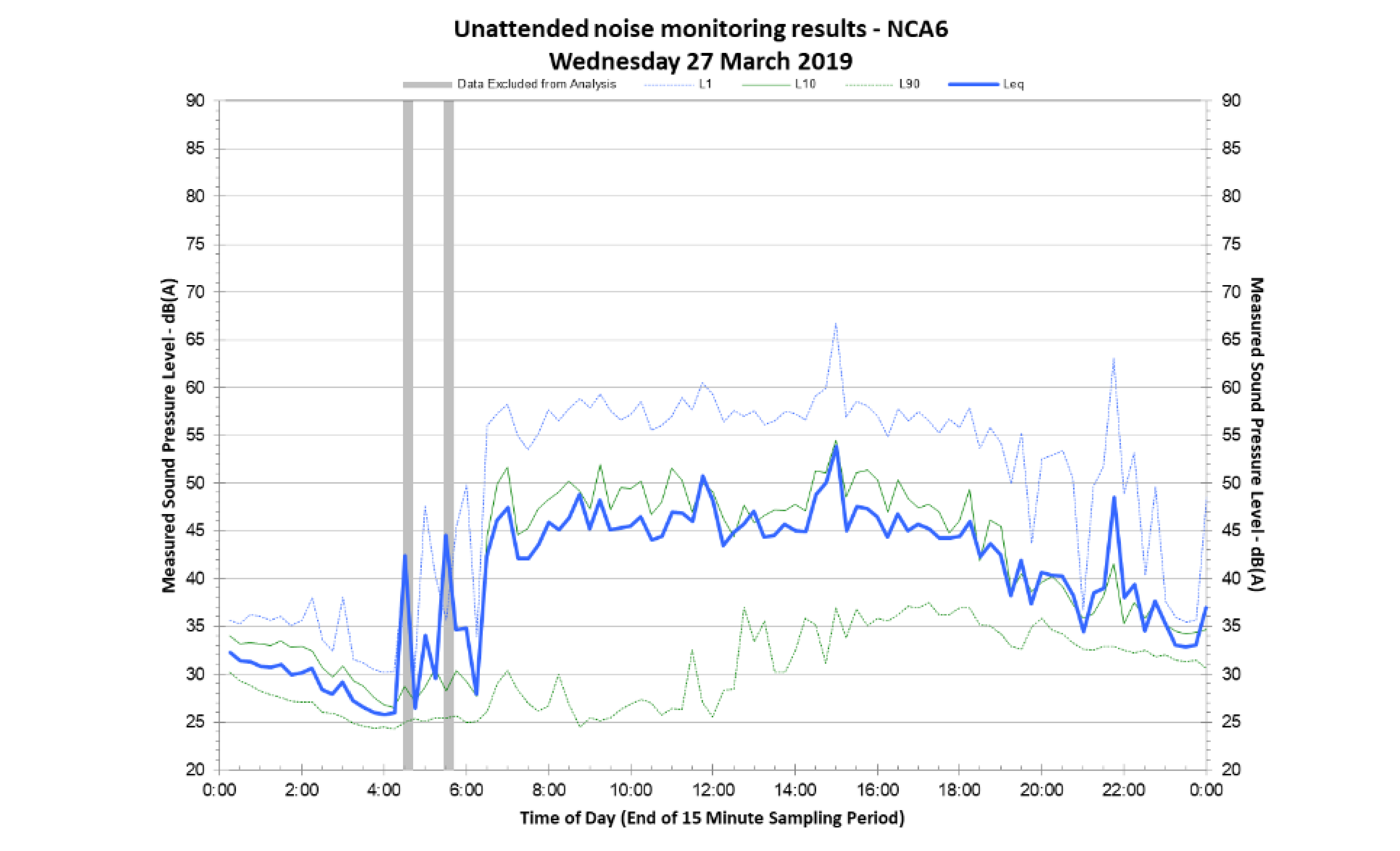
Unattended noise monitoring results - NCA6
Wednesday 27 March 2019
Data Excluded from Analysis
L1
L10
L90
Leq
Measured Sound Pressure Level - dB(A)
Measured Sound Pressure Level - dB(A)
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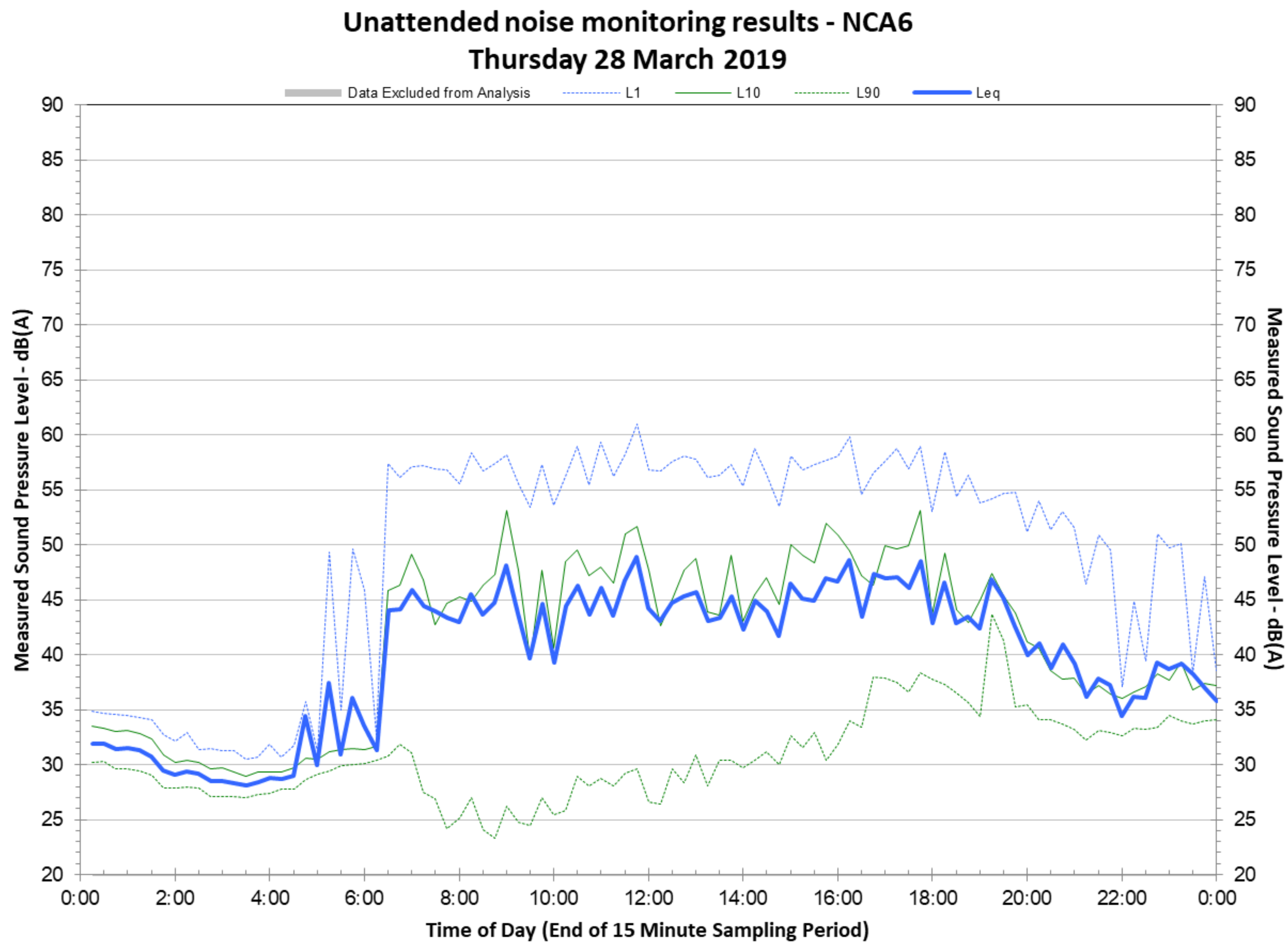
Time of Day (End of 15 Minute Sampling Period)



Unattended noise monitoring results - NCA6
Thursday 28 March 2019
Data Excluded from Analysis
L1
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Leq
Measured Sound Pressure Level - dB(A)
Time of Day (End of 15 Minute Sampling Period)
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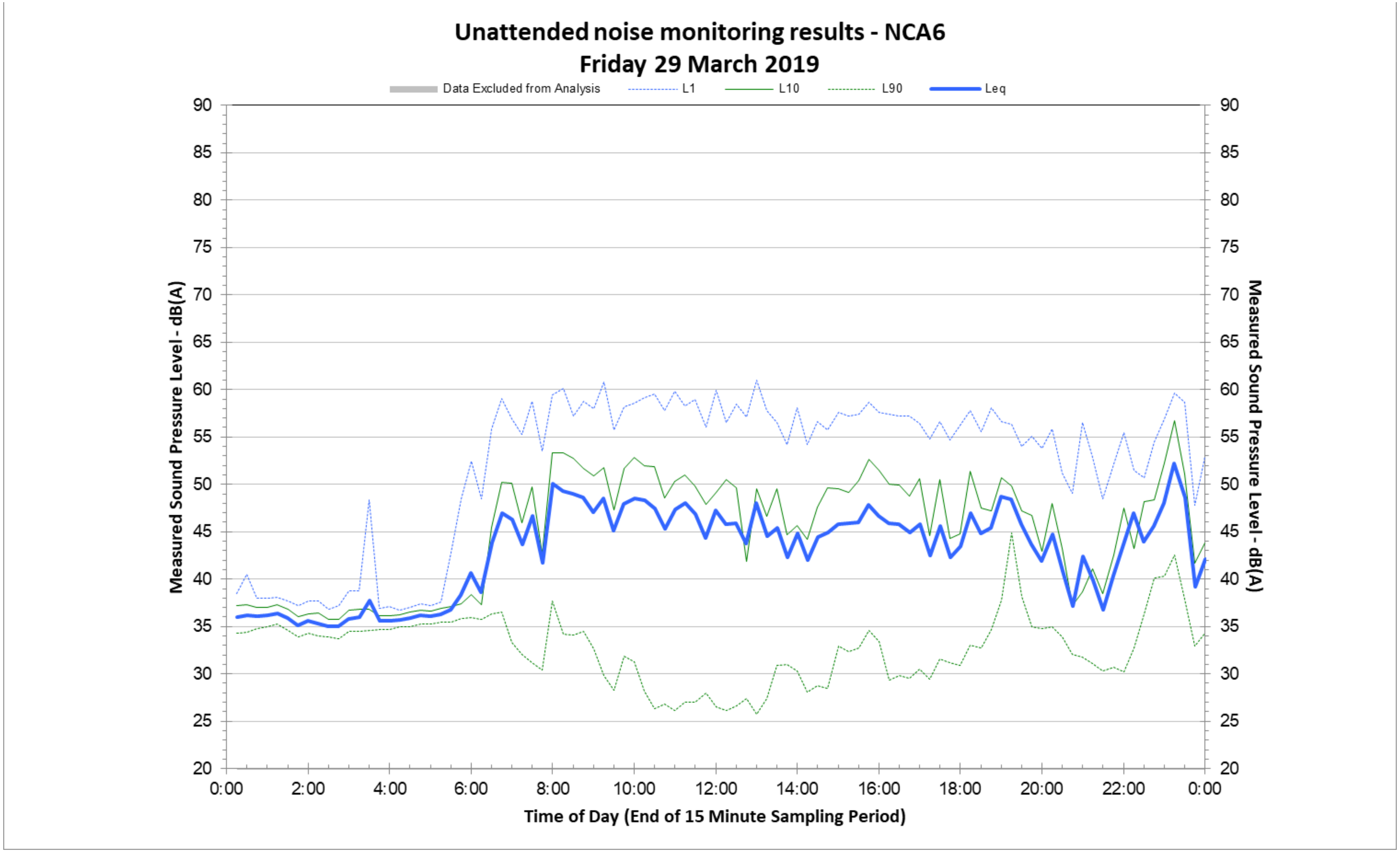
Unattended noise monitoring results - NCA6
Friday 29 March 2019
Data Excluded from Analysis
L1
L10
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Leq
Measured Sound Pressure Level - dB(A)
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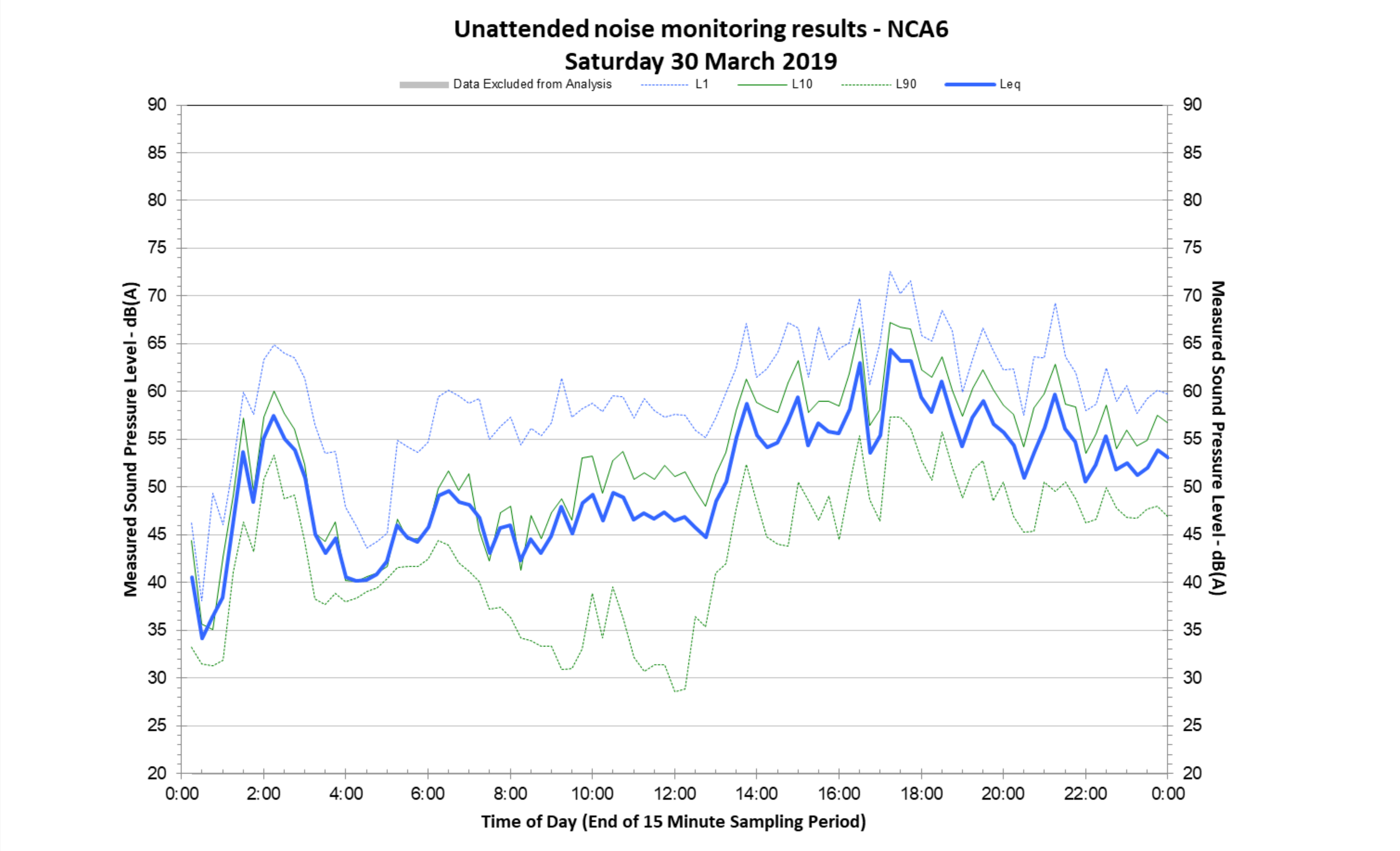
Time of Day (End of 15 Minute Sampling Period)


Unattended noise monitoring results - NCA6
Saturday 30 March 2019
Data Excluded from Analysis
L1
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Leq
Measured Sound Pressure Level - dB(A)
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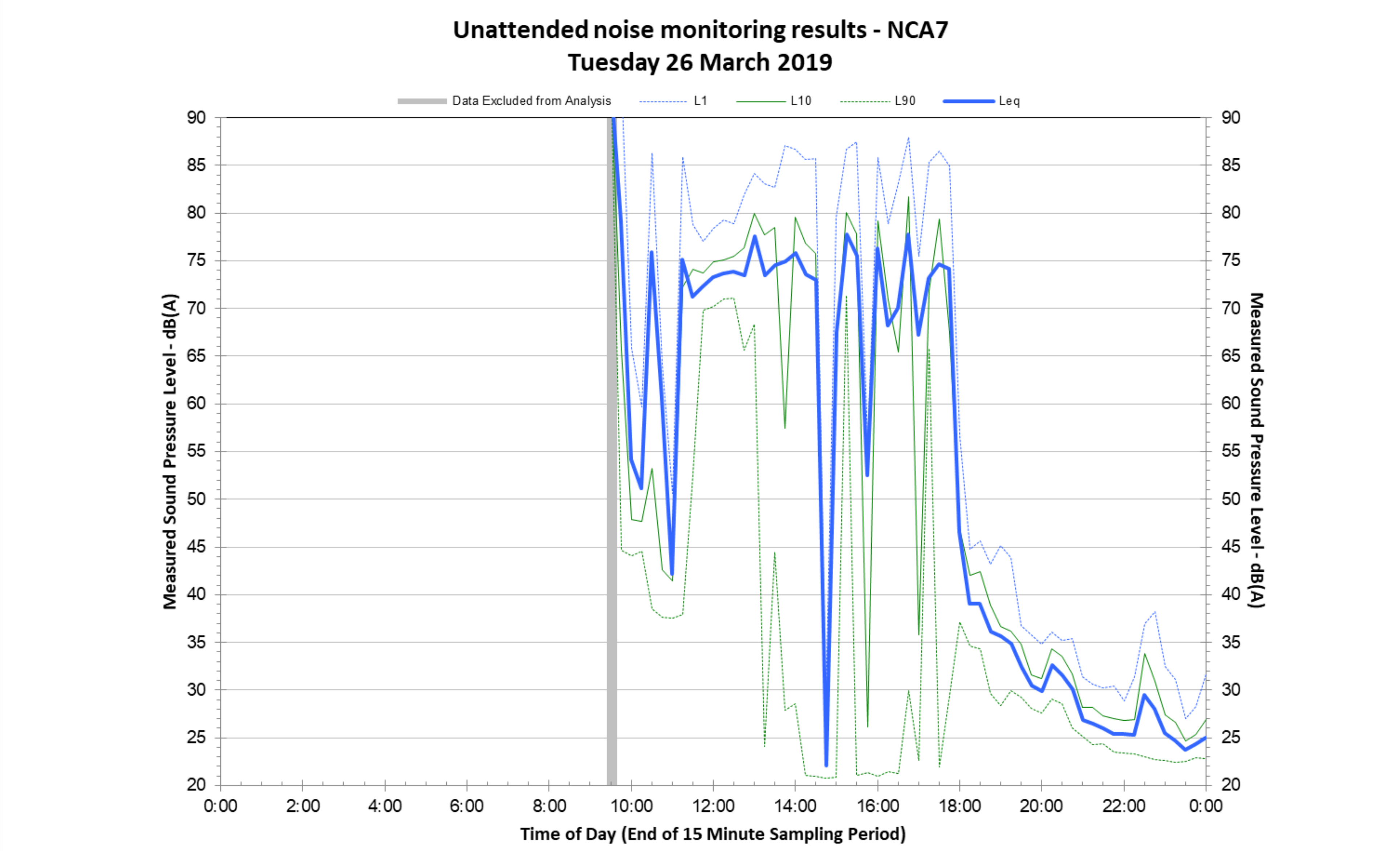
Time of Day (End of 15 Minute Sampling Period)


Unattended noise monitoring results - NCA7
Tuesday 26 March 2019
Data Excluded from Analysis
L1
L10
L90
Leq
Measured Sound Pressure Level - dB(A)
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85
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75
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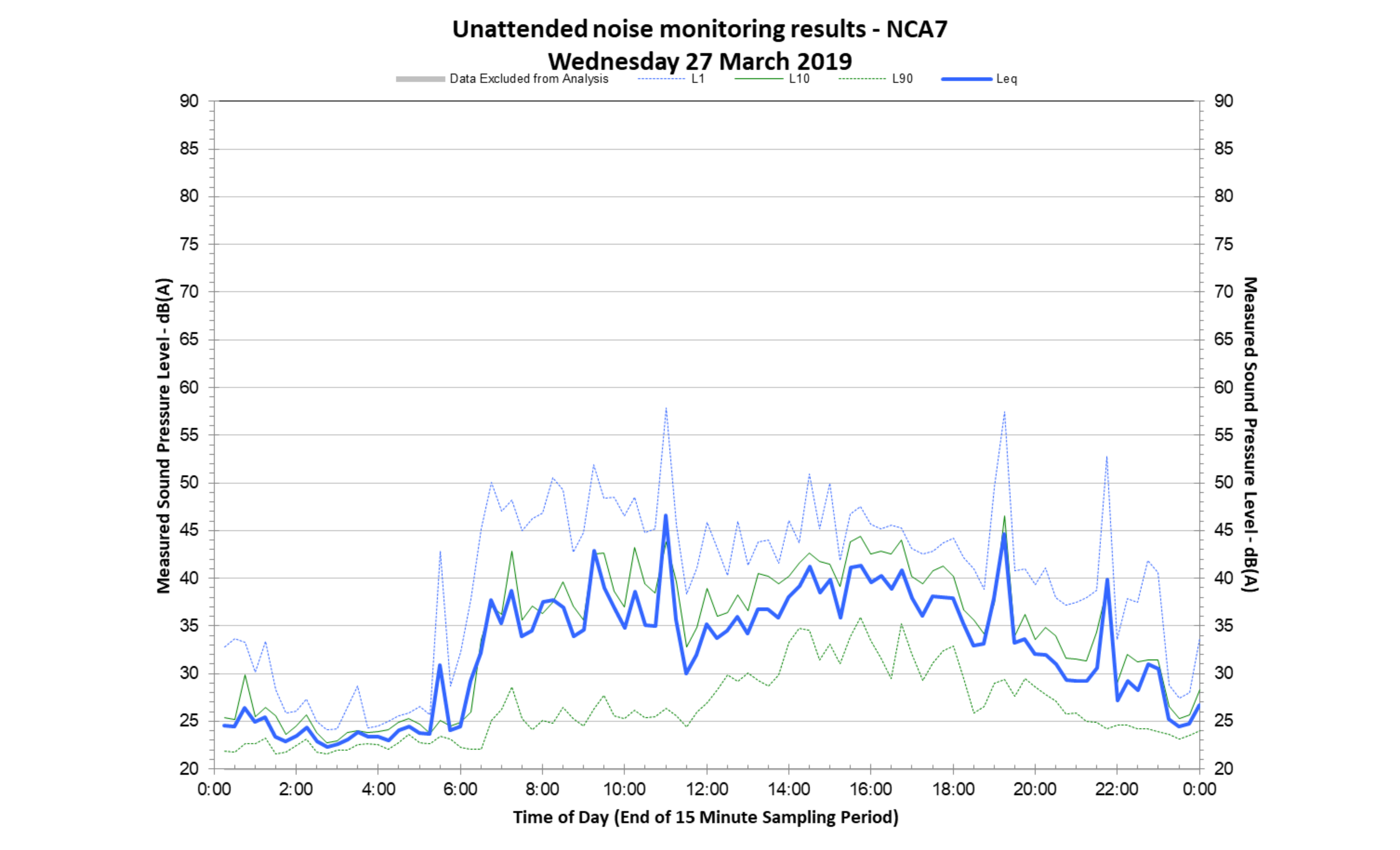
Time of Day (End of 15 Minute Sampling Period)


Unattended noise monitoring results - NCA7
Wednesday 27 March 2019
Data Excluded from Analysis
L1
L10
L90
Leq
Measured Sound Pressure Level - dB(A)
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85
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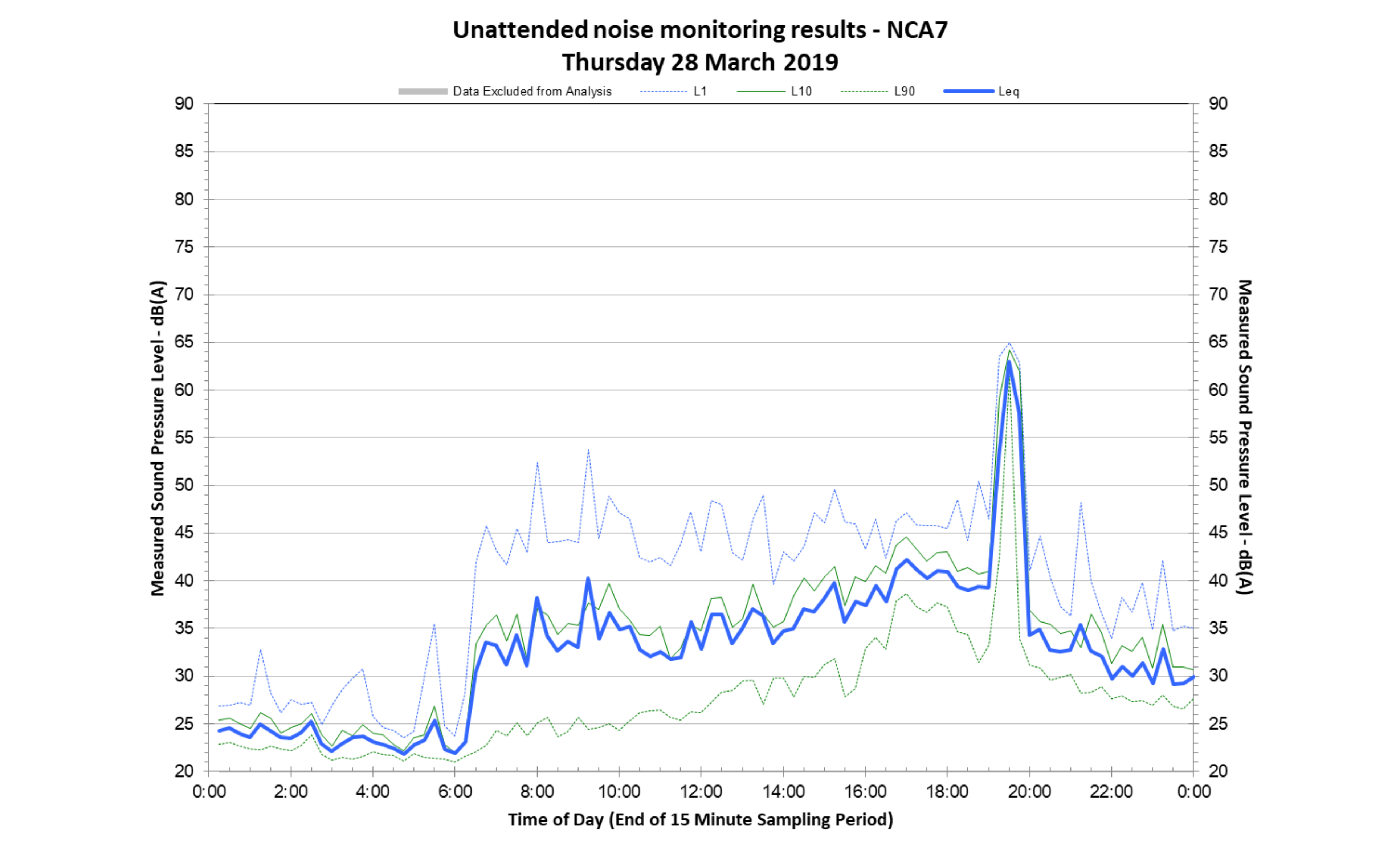
Time of Day (End of 15 Minute Sampling Period)


Unattended noise monitoring results - NCA7
Thursday 28 March 2019
Data Excluded from Analysis
L1
L10
L90
Leq
Measured Sound Pressure Level - dB(A)
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85
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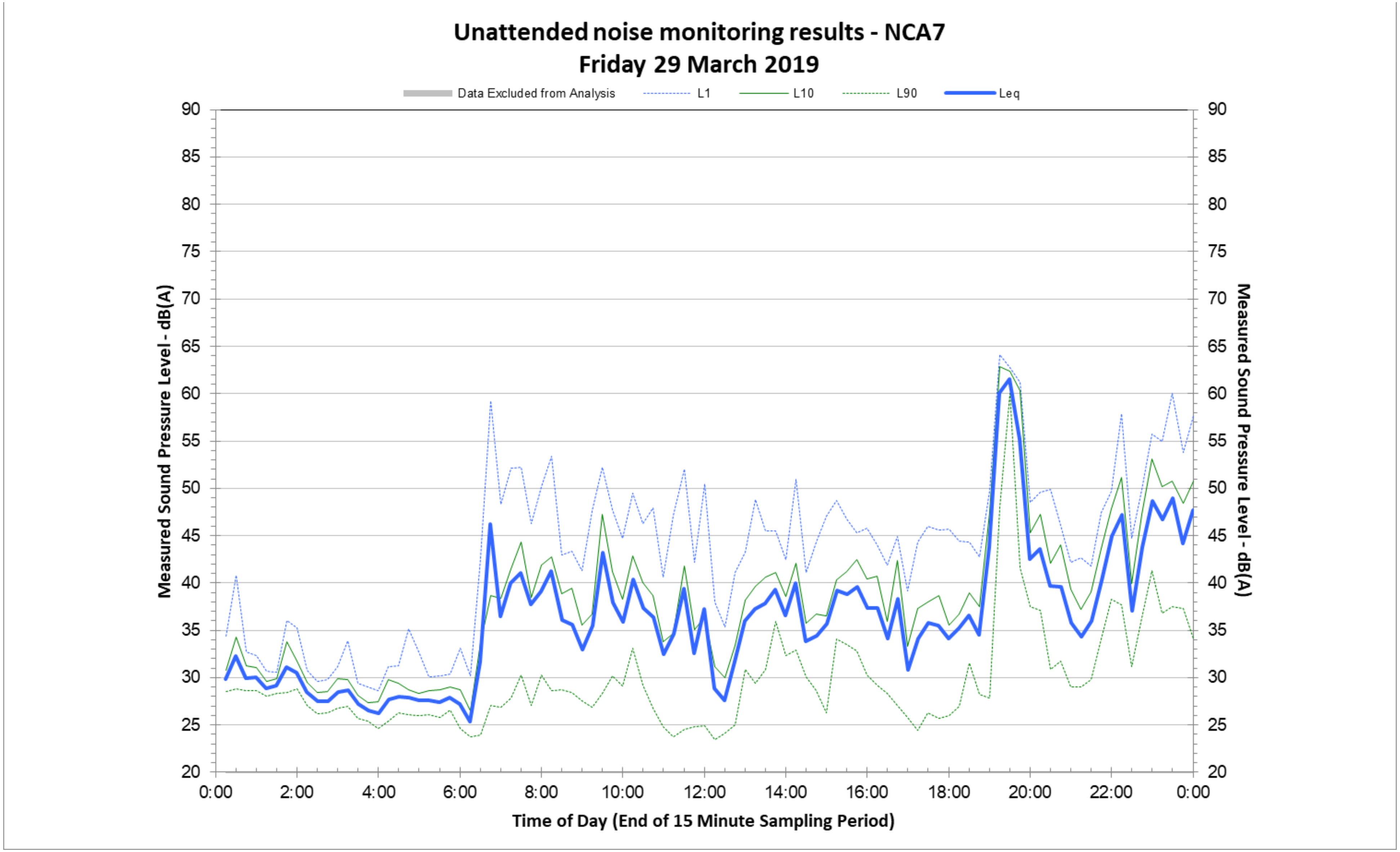
Time of Day (End of 15 Minute Sampling Period)


Unattended noise monitoring results - NCA7
Friday 29 March 2019
Data Excluded from Analysis
L1
L10
L90
Leq
Measured Sound Pressure Level - dB(A)
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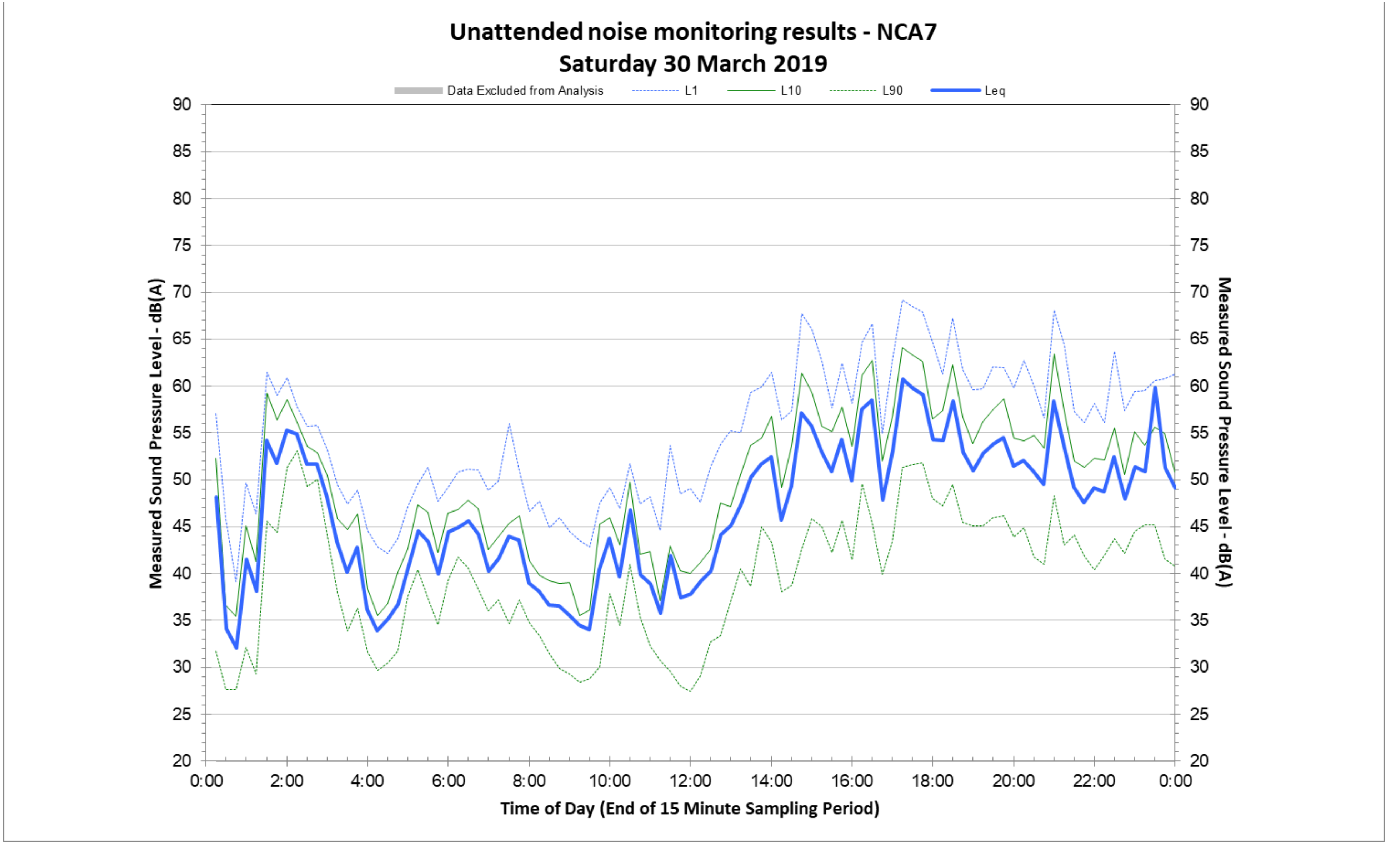
Time of Day (End of 15 Minute Sampling Period)


Unattended noise monitoring results - NCA7
Saturday 30 March 2019
Data Excluded from Analysis
L1
L10
L90
Leq
Measured Sound Pressure Level - dB(A)
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85
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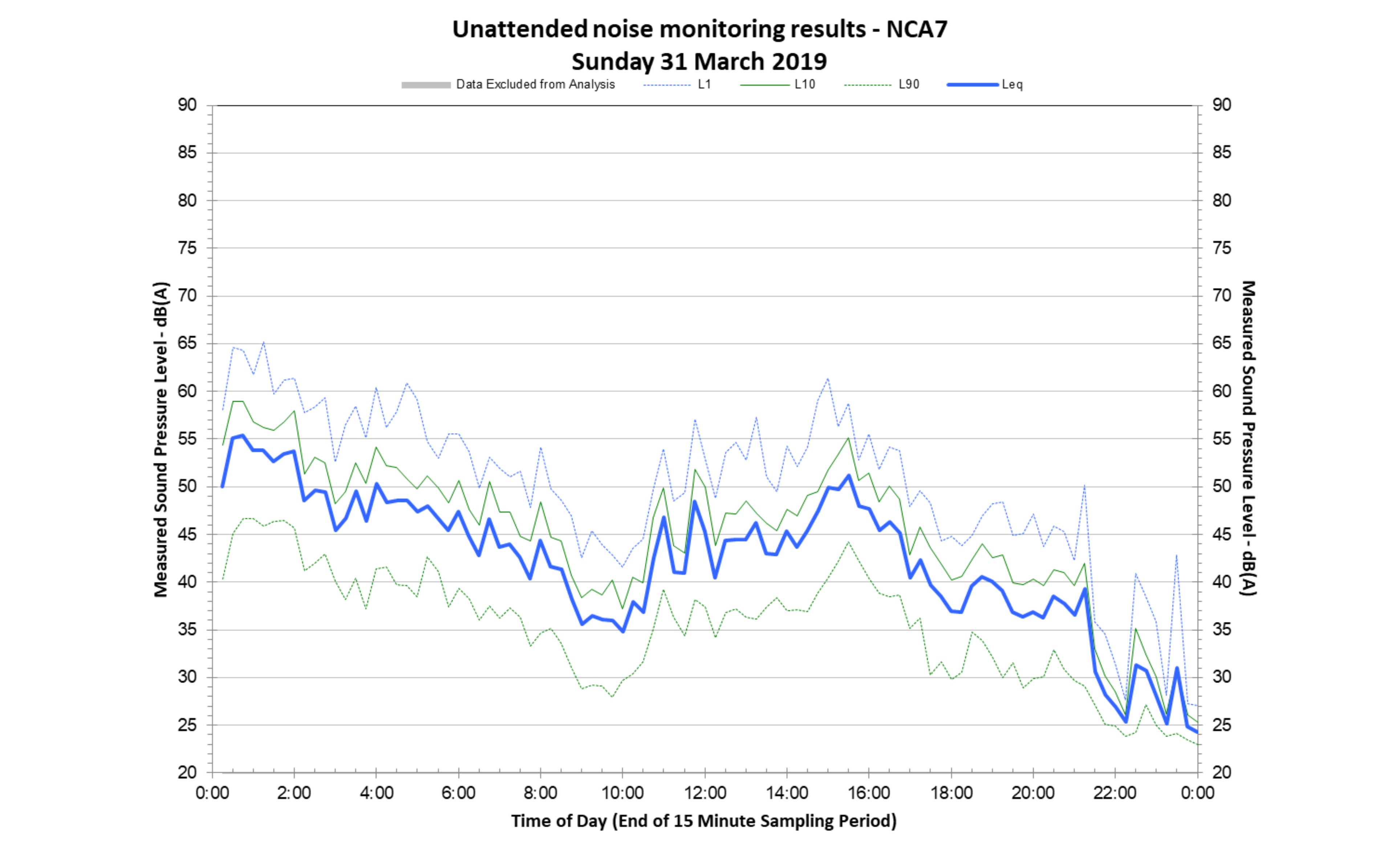
Time of Day (End of 15 Minute Sampling Period)


Unattended noise monitoring results - NCA7
Sunday 31 March 2019
Data Excluded from Analysis
L1
L10
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Leq
Measured Sound Pressure Level - dB(A)
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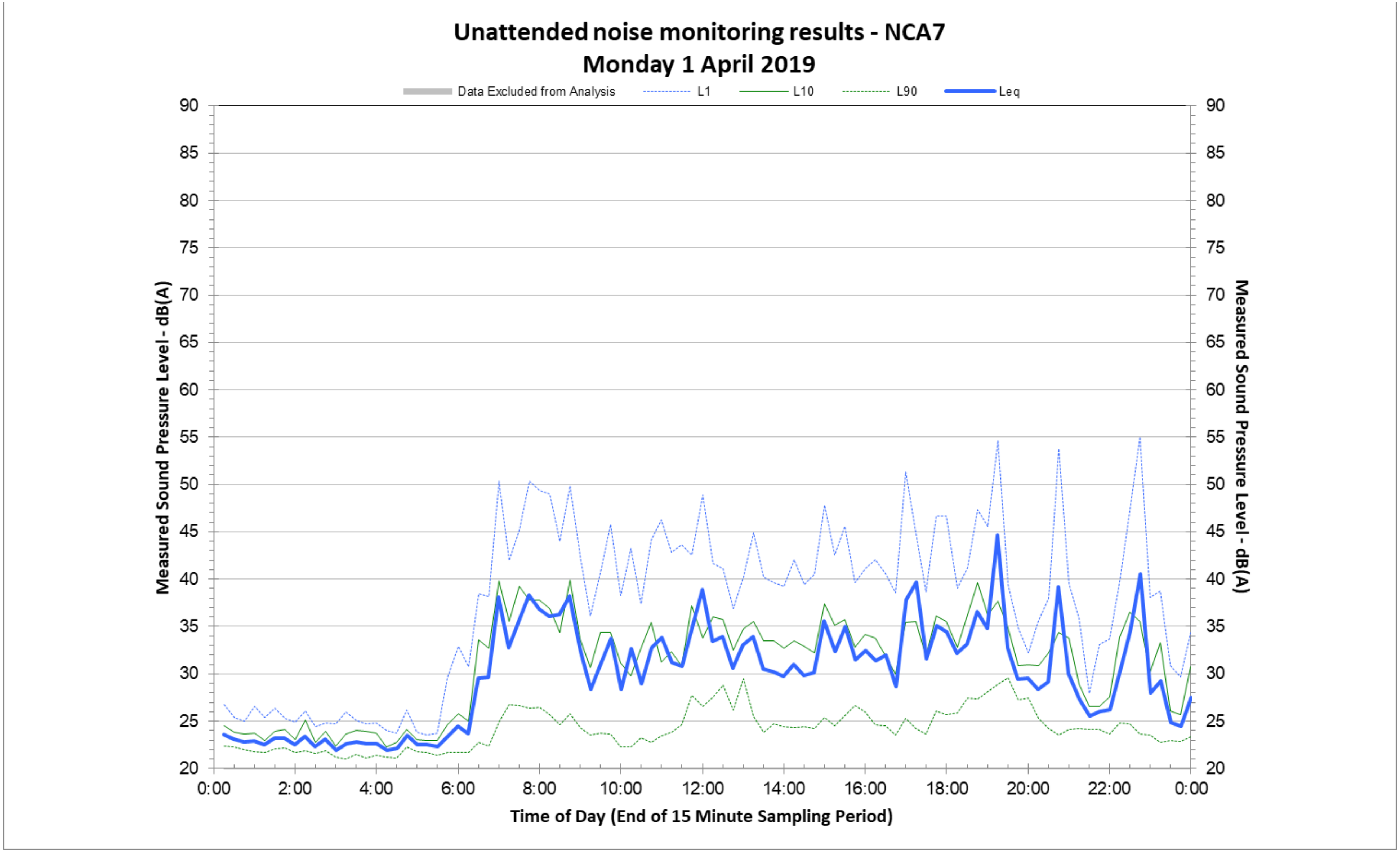
Time of Day (End of 15 Minute Sampling Period)


Unattended noise monitoring results - NCA7
Monday 1 April 2019
Data Excluded from Analysis
L1
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L90
Leq
Measured Sound Pressure Level - dB(A)
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85
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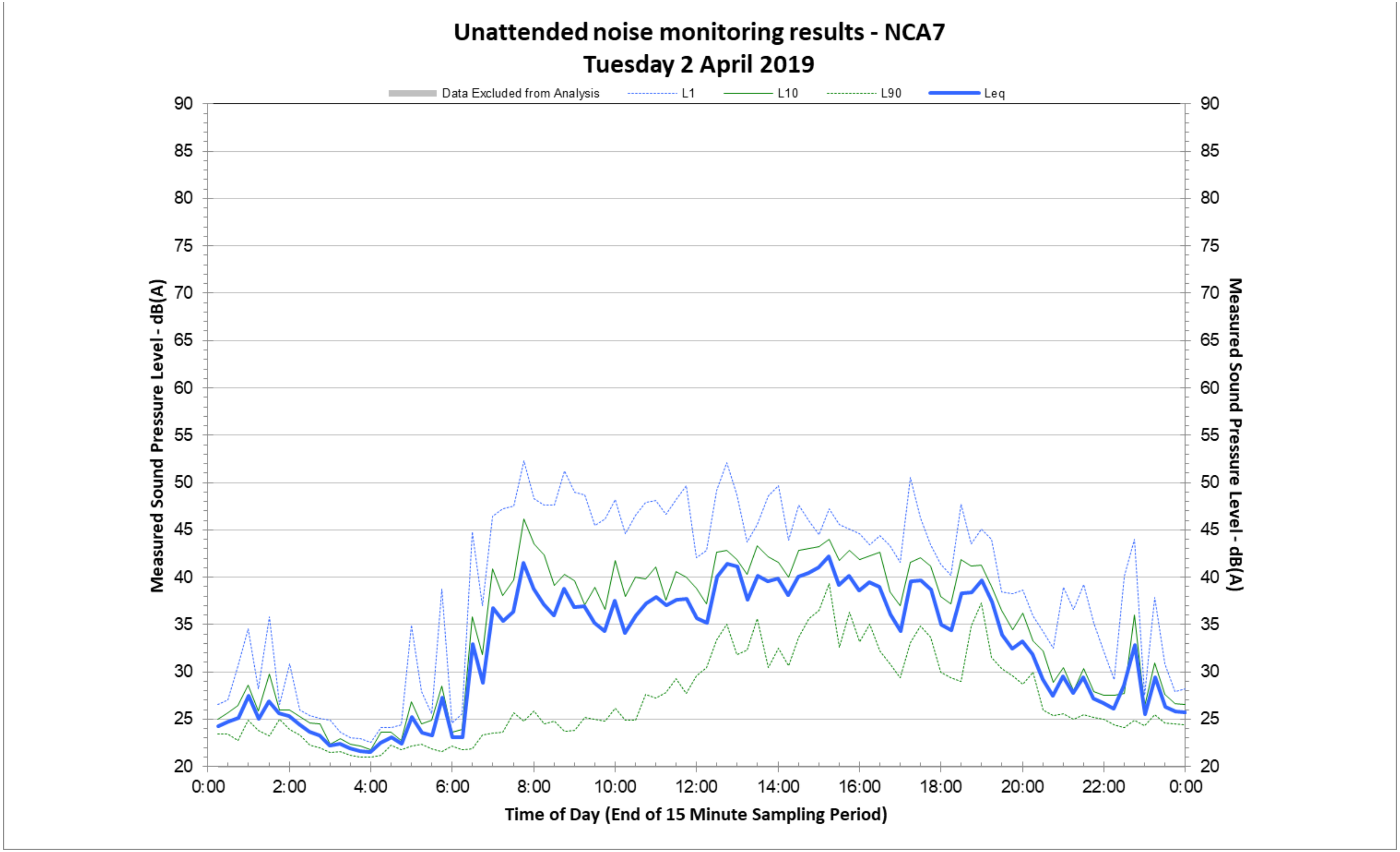
Time of Day (End of 15 Minute Sampling Period)


Unattended noise monitoring results - NCA7
Tuesday 2 April 2019
Data Excluded from Analysis
L1
L10
L90
Leq
Measured Sound Pressure Level - dB(A)
90
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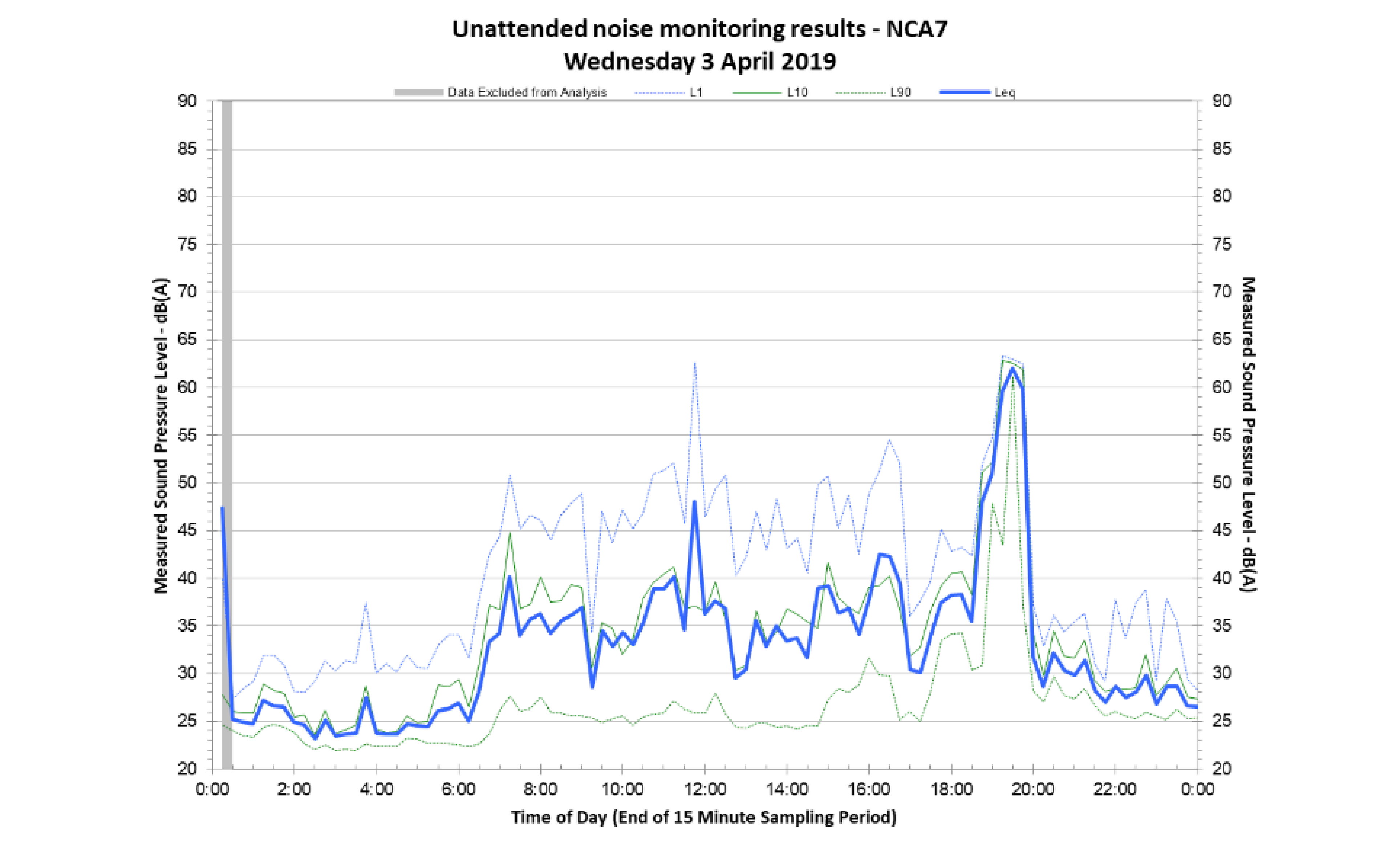
Time of Day (End of 15 Minute Sampling Period)


Unattended noise monitoring results - NCA7
Wednesday 3 April 2019
Data Excluded from Analysis
L1
L10
L90
Leq
Measured Sound Pressure Level - dB(A)
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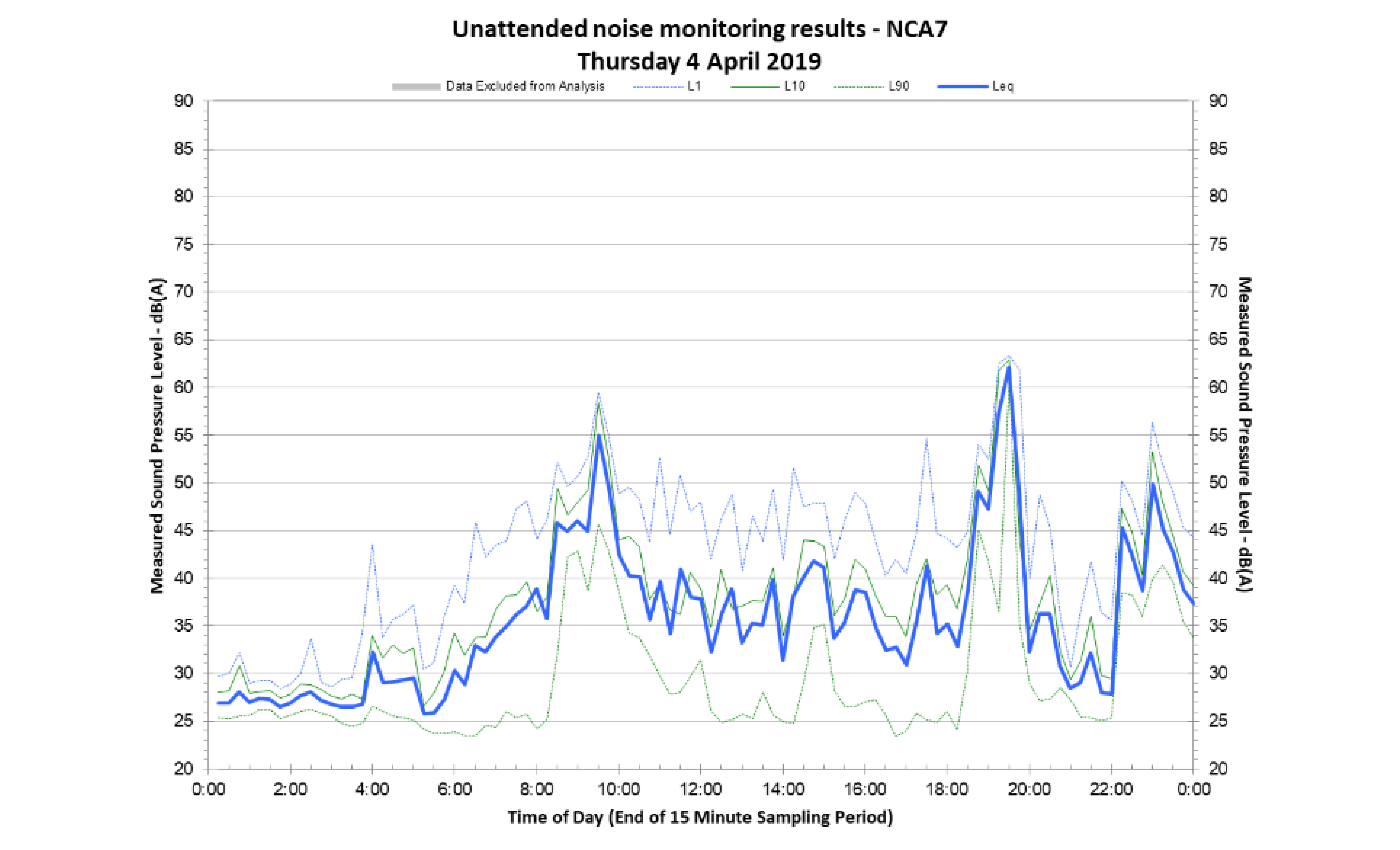
Time of Day (End of 15 Minute Sampling Period)


Unattended noise monitoring results - NCA7
Thursday 4 April 2019
Data Excluded from Analysis
L1
L10
L90
Leq
Measured Sound Pressure Level - dB(A)
Measured Sound Pressure Level - dB(A)
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85
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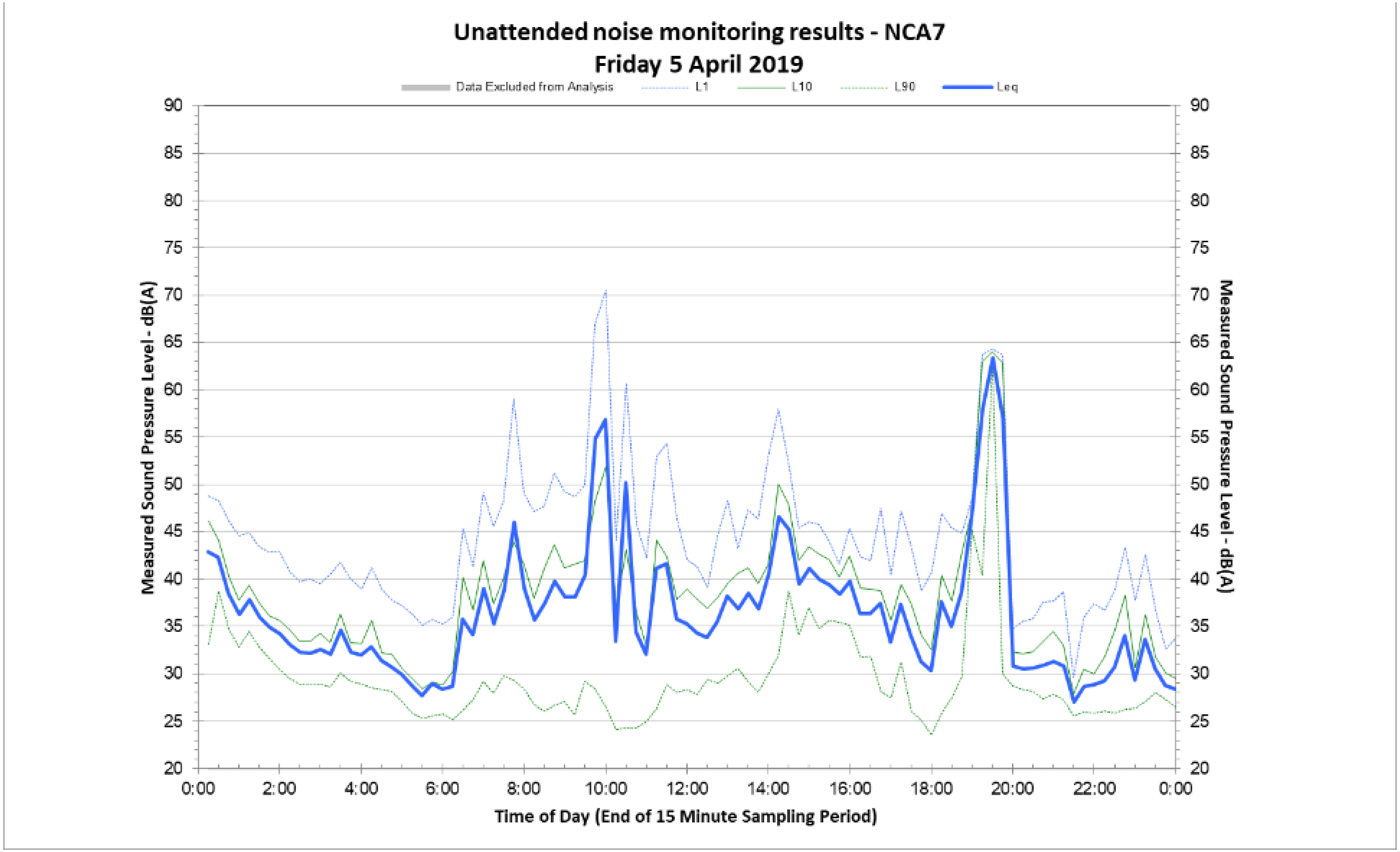
Time of Day (End of 15 Minute Sampling Period)


Unattended noise monitoring results - NCA7
Friday 5 April 2019
Data Excluded from Analysis
L1
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Leq
Measured Sound Pressure Level - dB(A)
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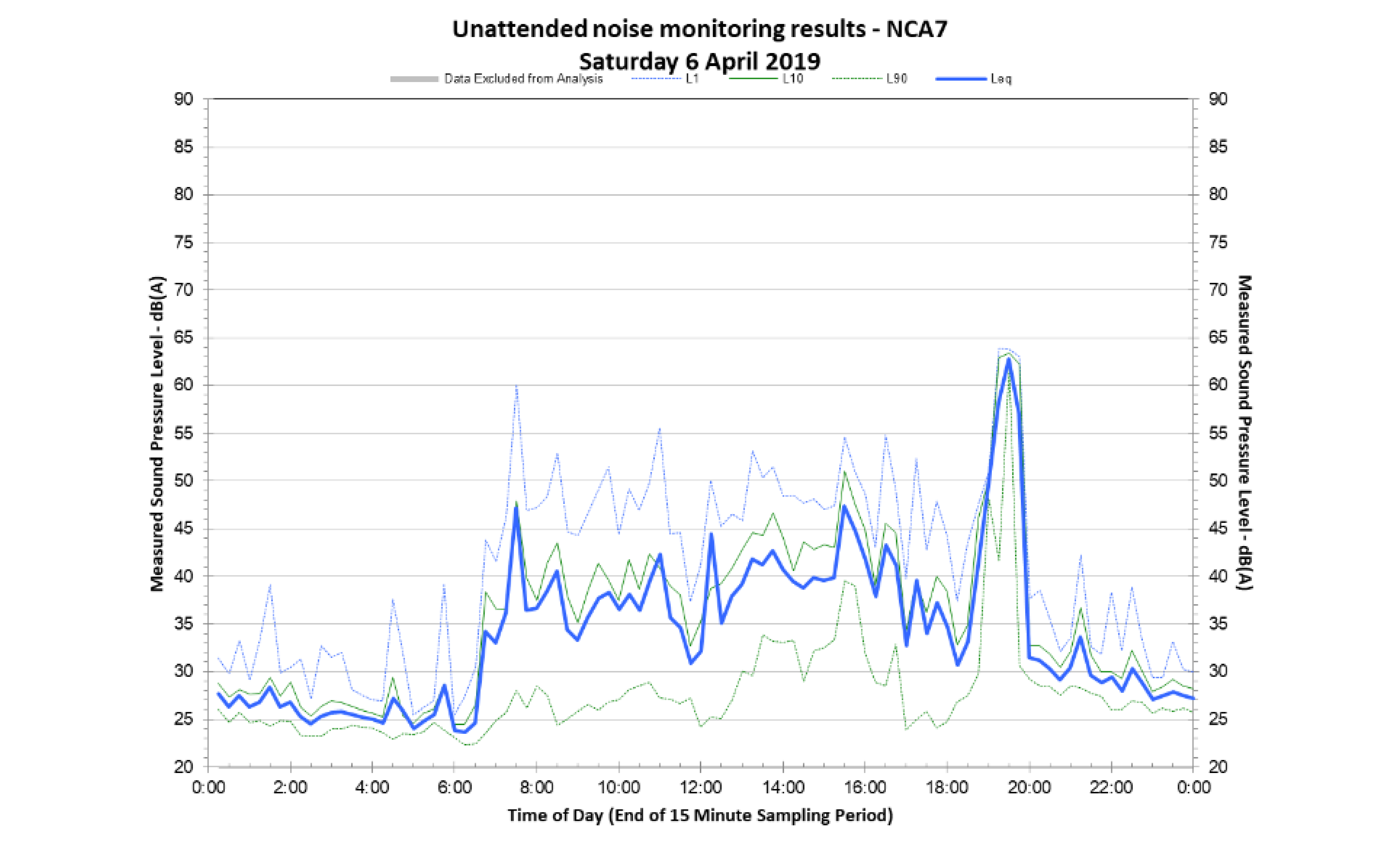
Time of Day (End of 15 Minute Sampling Period)


Unattended noise monitoring results - NCA7
Saturday 6 April 2019
Data Excluded from Analysis
L1
L10
L90
Leq
Measured Sound Pressure Level - dB(A)
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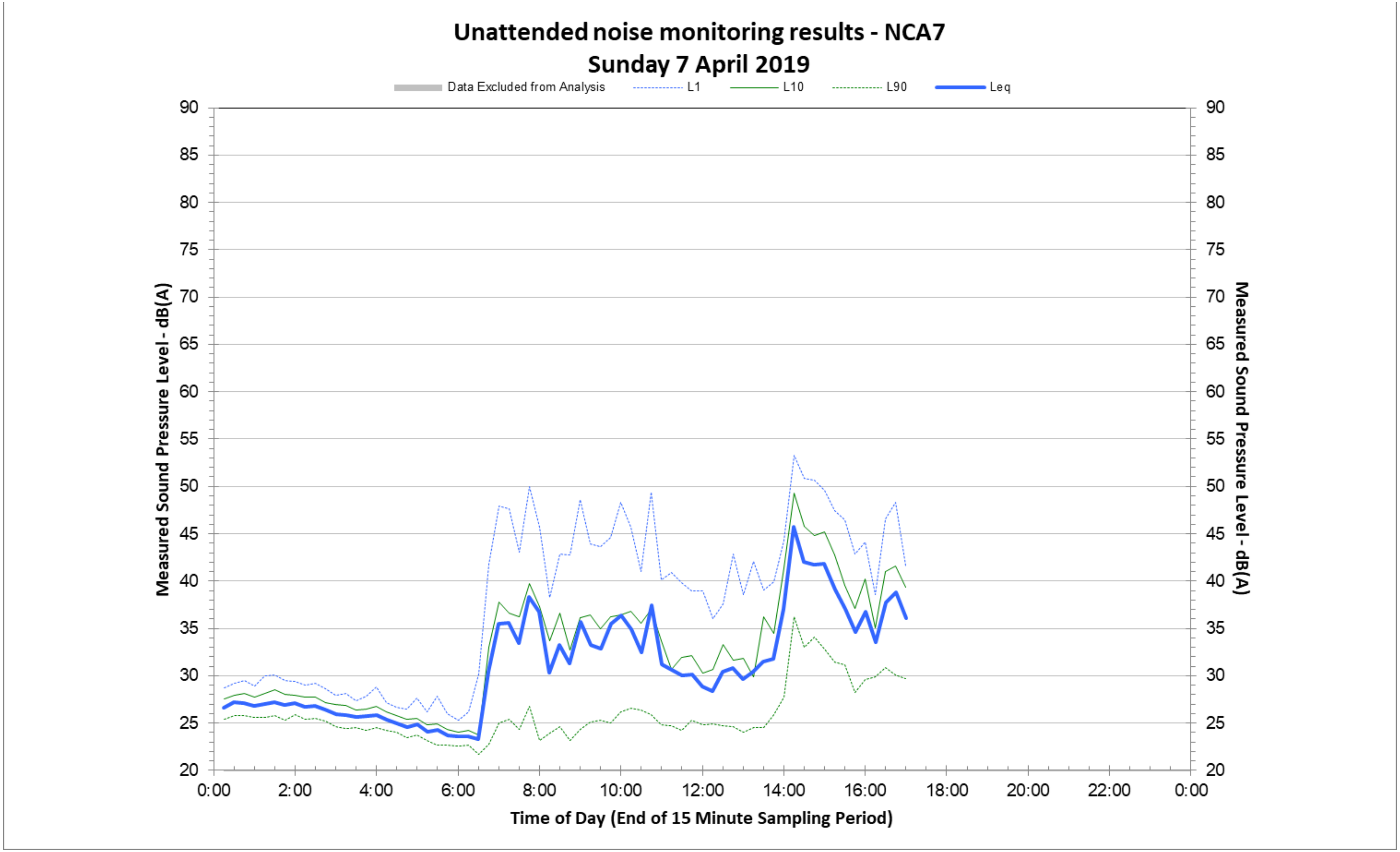
Time of Day (End of 15 Minute Sampling Period)


Unattended noise monitoring results - NCA7
Sunday 7 April 2019
Data Excluded from Analysis
L1
L10
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Leq
Measured Sound Pressure Level - dB(A)
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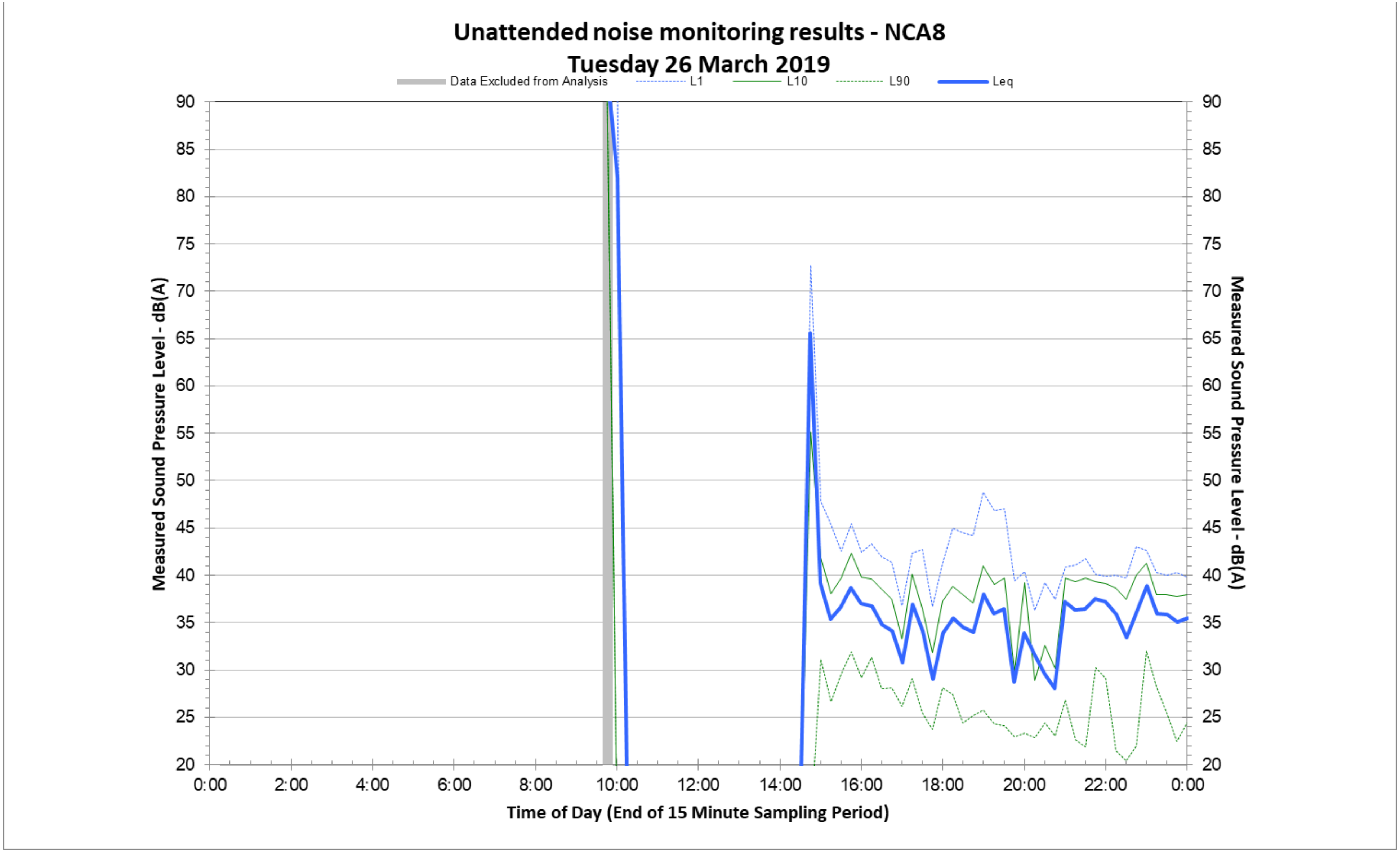
Time of Day (End of 15 Minute Sampling Period)


Unattended noise monitoring results - NCA8
Tuesday 26 March 2019
Data Excluded from Analysis
L1
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Measured Sound Pressure Level - dB(A)
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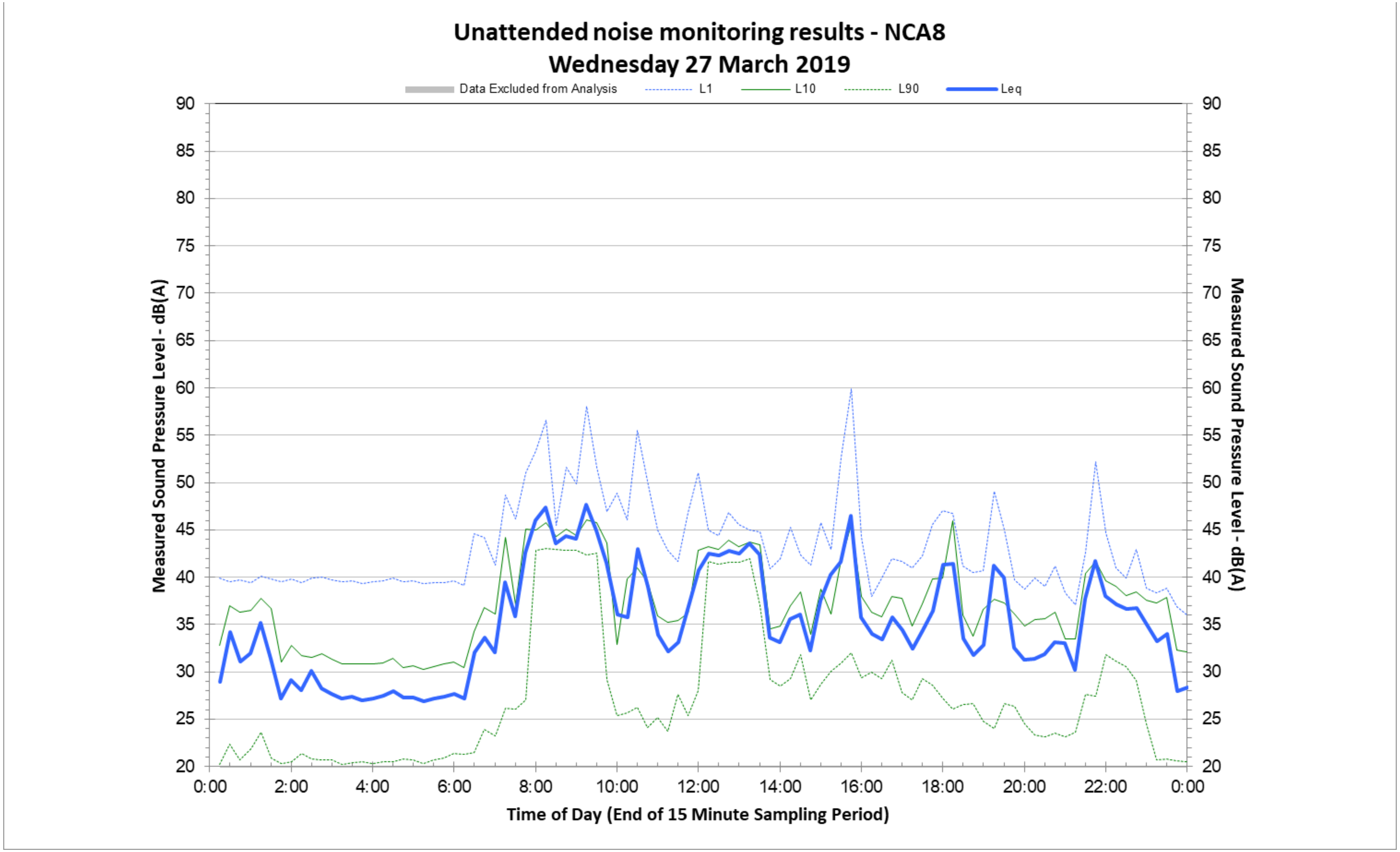
Time of Day (End of 15 Minute Sampling Period)


Unattended noise monitoring results - NCA8
Wednesday 27 March 2019
Data Excluded from Analysis
L1
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Leq
Measured Sound Pressure Level - dB(A)
Time of Day (End of 15 Minute Sampling Period)
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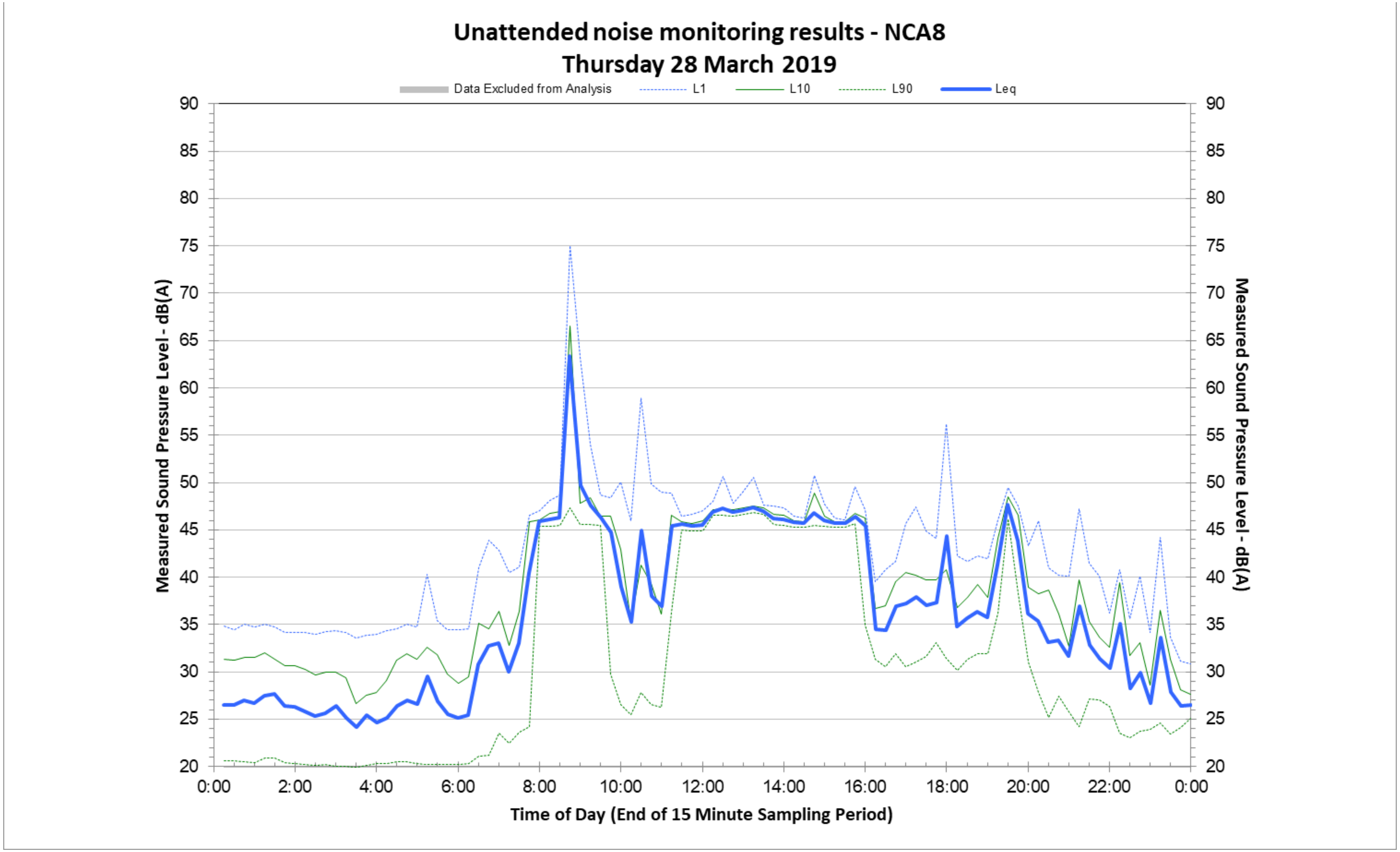
Unattended noise monitoring results - NCA8
Thursday 28 March 2019
Data Excluded from Analysis
L1
L10
L90
Leq
Measured Sound Pressure Level - dB(A)
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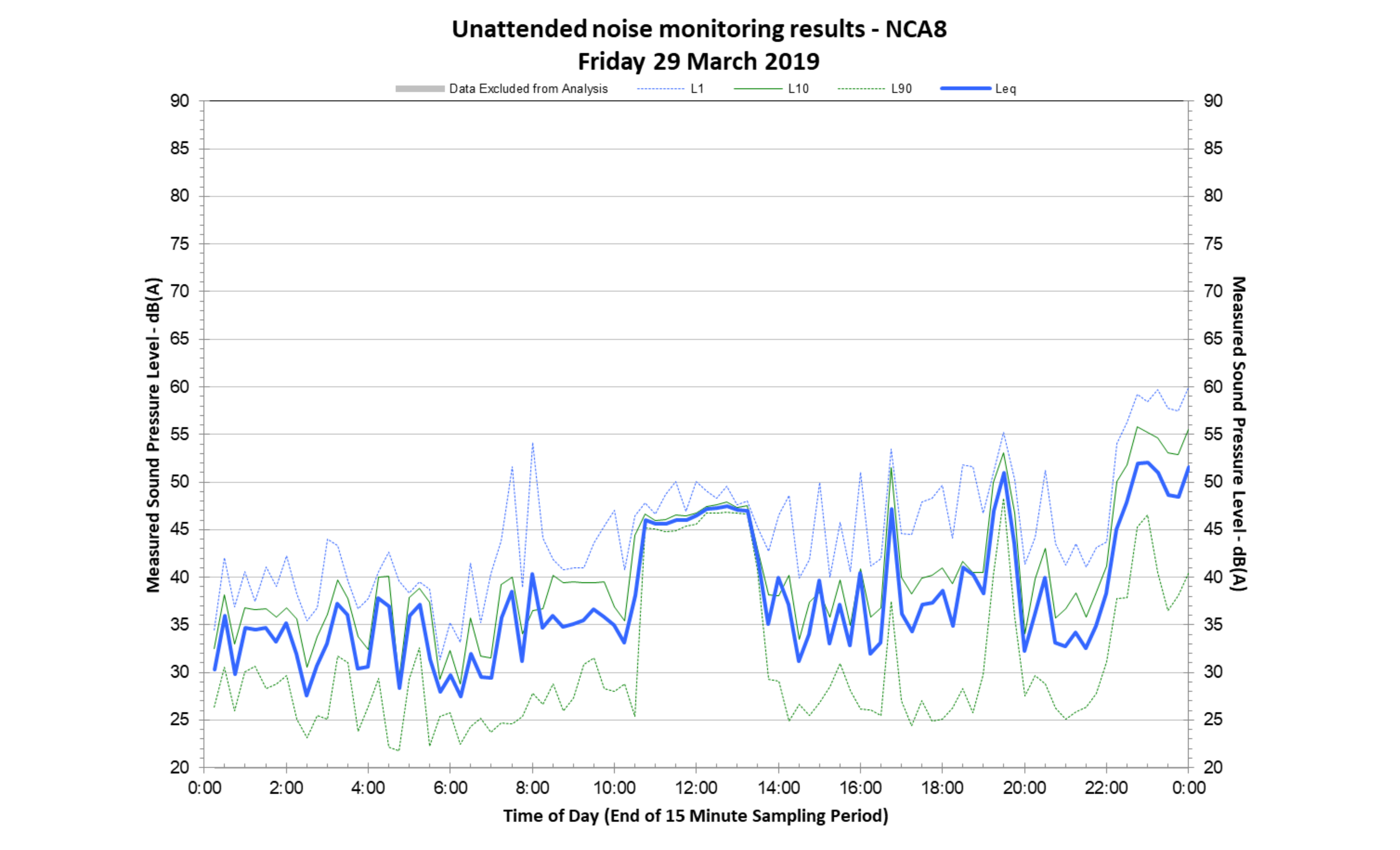
Time of Day (End of 15 Minute Sampling Period)



Unattended noise monitoring results - NCA8
Friday 29 March 2019
Data Excluded from Analysis
L1
L10
L90
Leq
Measured Sound Pressure Level - dB(A)
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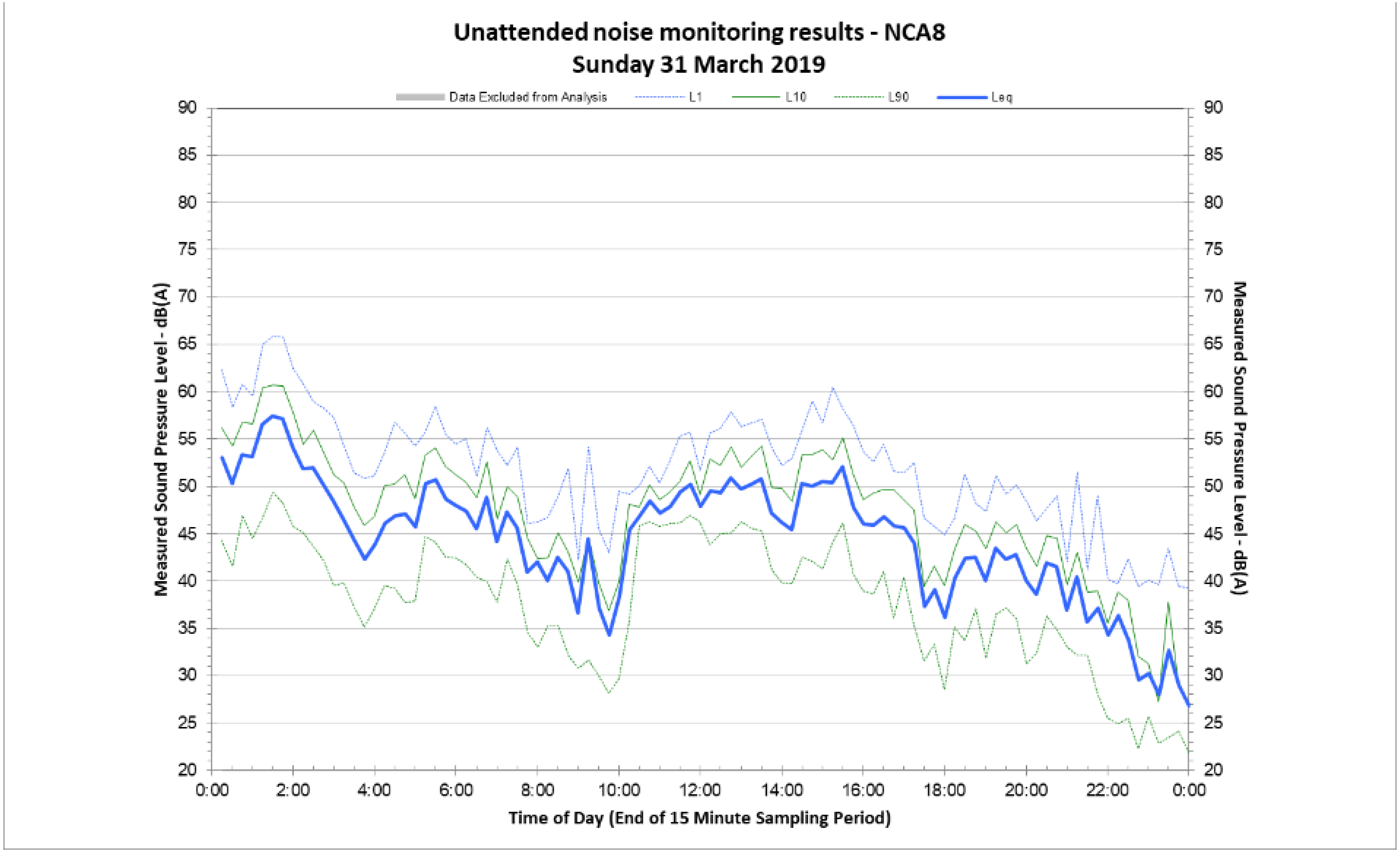
Time of Day (End of 15 Minute Sampling Period)


Unattended noise monitoring results - NCA8
Sunday 31 March 2019
Data Excluded from Analysis
L1
L10
L90
Leq
Measured Sound Pressure Level - dB(A)
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Time of Day (End of 15 Minute Sampling Period)

Appendix B. Sound power levels and Scenario Overview

Table B 1 – Sound Power Levels Octave Band

Overall	Phase	Works	Activity	Standard	ORST	Plant	Individual SWL
Upper Scheme	A	Site Access upgrade	Road Upgrades	x	+	Grader	106
				x	+	40T Exc.	107
				x	+	12T Roller incl. penalty (+5dB due to ICNG)	117
				x	+	Asphalt paver	112
				x	+	Concrete pump on truck (87m3/h)	108
	B	Trail Upgrade	Road Upgrades	x	+	Grader	106
				x	+	40T Exc.	107
				x	+	12T Roller incl penalty (+5dB due to ICNG)	117
				x	+	Truck Dump	114
				x	+	Water Truck	109
	C	Surge	Construction	x	+	Grader	106
				x	+	Excavator	115
				x	+	Roller incl penalty (+5dB due to ICNG)	115
				x	+	Truck Dump	114
				x	+	Watertruck	109
	C	Laydown	Construction	x	+	Track type Tractor 240HP CatD7E	110
				x	+	Concrete batching plant	115
				x	+	Concrete mixer 500 l type	107
				x	+	Crane - All terrain 80t	105
				x	+	Crane - Rough terrain 30t	98
				x	+	Crane - 60t rough terrain	105
				x	+	Diesel Generator	107
				x	+	Diesel welding machine 400	102
				x	+	Concrete pump on truck (87m3/h)	111
				x	+	Forklift 1	99
				x	+	Forklift 2	99
				x	+	Truck Dump	114
				x	+	Truck Crane 5t	105
				x	+	Semi-Trailer Flatbed	111
				x	+	Crane - Unloading	98
	E	Penstock	Construction	x	+	Small Excavator	105
				x	+	Crane - All terrain 80t	105
	A-B	Saddle	Preparation	x	+	Small excavator	105
				x	+	Diesel welding machine 400	107
				x	+	Cable crane or winch system	117
				x	+	Crane - All terrain 80t	105
	D	Laydown Area	Construction	x	+	Diesel Generator	107

Overall	Phase	Works	Activity	Standard	ORST	Plant	Individual SWL
				x	+	Crane - All terrain 80t	105
				x	+	Excavator	115
				x	+	Truck Dump	114
				x	+	Truck Dump	114
				x	+	Loaders	111
	D	Surge Foundation	Foundation	x	+	Excavator	107
				x	+	Piling incl. penalty (+5dB due to ICNG)	103
				x	+	Concrete pump on truck (87m3/h)	111
	D	Surge Construction	Construction	x	+	Crane - Rough terrain 30t	98
				x	+	Crane - All terrain 80t	105
				x	+	EWP	97
				x	+	Diesel welding machine 400	102
	B	Blind Bore	Construction	x	+	Raise bore machine / could also be blind bore	114
				x	+	Generator bllind bore	107
				x	+	Crane - All terrain 80t	105
				x	+	Grouting	114
				x	+	Concrete batching plant	115
				x	+	Concrete pump on truck (87m3/h)	111
				x	+	Pipe delivery	111
Lower Scheme	F	Kangaroo Valley Portal	Construction	x	-	Excavator1	115
				x	-	Excavator2	115
				x	-	Concrete pump on truck (87m3/h)	111
				x	-	Drott	110
				x	-	Road Header	114
				x	-	Pump	110
				x	-	Batching Plant	115
				x	-	100t mobile crane	99
				x	-	Rock anchor drill incl. penalty (+5dB due to ICNG)	113
				x	-	Air Compressor	105
				x	-	Small Water Treatment Plant	107
				x	-	Grader	106
				x	-	Road Paver	112
				x	-	Forklift 1	99
				x	-	Forklift 2	99
	G	Tail Portal	Construction	x	-	Excavator - siteprep	115
				x	-	Excavator - siteprep	115
				x	-	Concrete pump on truck (87m3/h)	114
				x	-	Drott - siteprep	110
				x	-	Road Header	114
				x	-	Pump	110

Overall	Phase	Works	Activity	Standard	ORST	Plant	Individual SWL
				x	-	Batching Plant	115
				x	-	Crane - All terrain 80t	105
				x	-	Air Compressor	105
				x	-	Small Water Treatment Plant	107
	J	Storage	preparation	x	-	Grader	106
				x	-	40T Exc.	107
				x	-	Loader	113
				x	-	Drott	110
Tunneling Work	H	Spoil site	preparation	x	-	Track type Tractor 240HP CatD7E	110
				x	-	Excavator	115
	J	Transport	Typical arrival & unloading	x	+	Semi-Trailer Flatbed	111
				x	-	Crane unloading	105
	F	Kangaroo Valley Portal	247	x	+	Concrete pump on truck (87m3/h)	111
				x	+	Pump	110
				x	+	Batching Plant	115
				x	+	Fan Inlet Silenced	97
				x	+	Fan Casing/Duct breakout	97
				x	+	Air Compressor	105
				x	+	Small Water Treatment Plant	107
	G	Tail Portal	247	x	+	Loader	113
				x	+	Pump	110
				x	-	Batching Plant	115
				x	+	Fan Inlet Silenced	101
				x	+	Fan Inlet Case breakout	119
				x	+	Air Compressor	105
				x	+	Small Water Treatment Plant	107
	H	Spoilage - deliverabls	247	x	+	Truck Haulage - Kangaroo	114
				x	+	Truck Haulage - Tail	114
				x	+	Truck Haulage - Upper Scheme - down mountain	114
				x	+	Truck Haulage - D-Upper Scheme - to H	114
				x	+	Dumping - Kangaroo portal	107
				x	+	Dumping - Tail portal	107
				x	+	Dumping - D-Upper Scheme	107
				x	+	Track type Tractor 240HP CatD7E	110
				x	+	Excavator	115
				x	-	Crusher	112
Short Term Night Deliveries	-	Short Term Night time deliveries	Steel Liner arrival & unloading	x	+	Semi-Trailer Flatbed	111
				x	+	Crane unloading where applicable	105

Appendix C. Airborne noise contours

Upper Scheme Construction

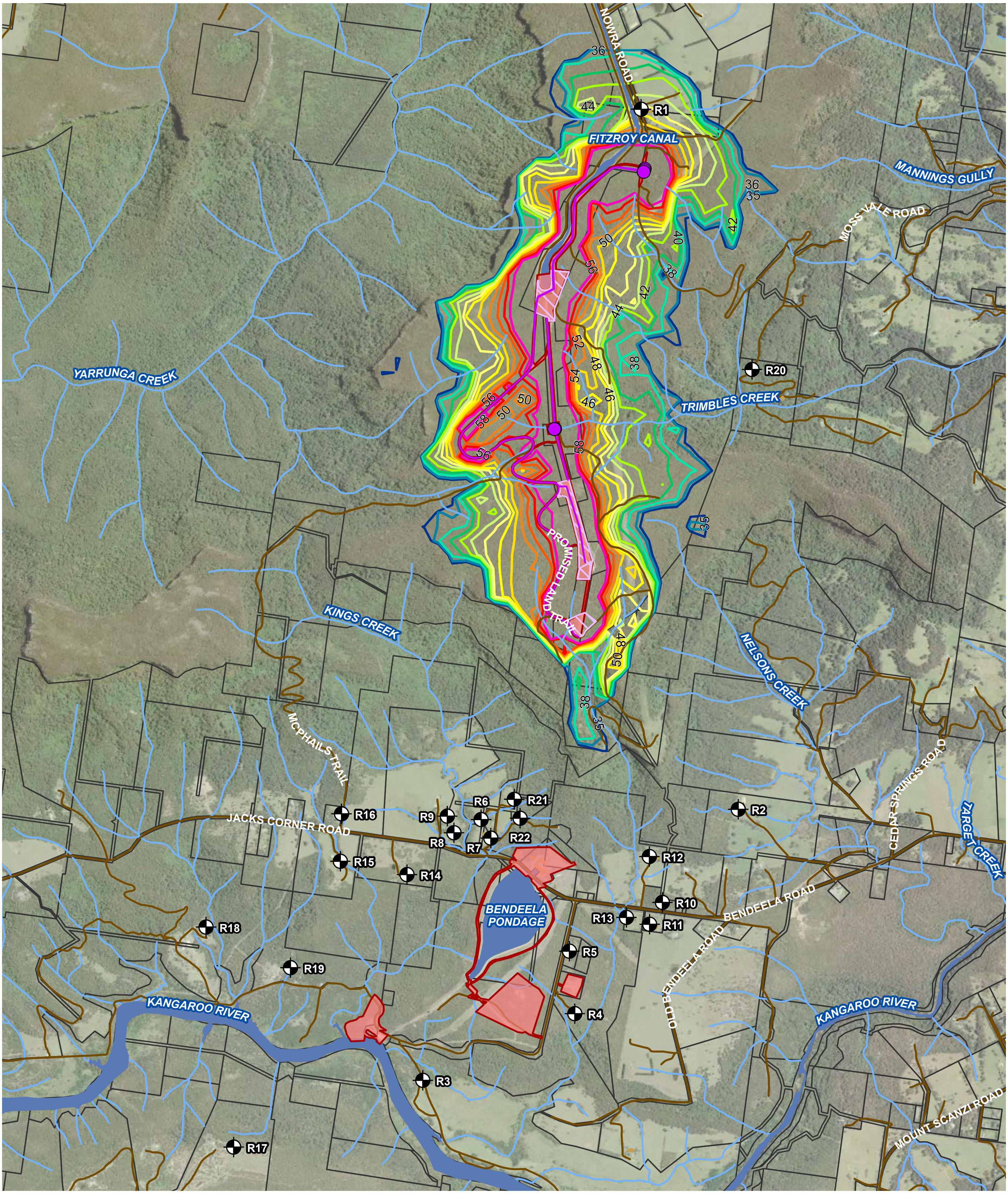
The *"Upper Scheme Construction"* scenario revolves around indicative construction activities in the Upper Scheme occurring concurrently. This is unlikely to occur in practice and it is expected that the values represent a reasonable worst case scenario.

The activities modelled are outlined in the **Table C 1** below and resulting noise contours are illustrated in **Figure C-1**.

Table C 1 – Daytime - Upper Scheme Equipment Sound Power Level

Source	LWA
Up_ A_Site Access_12T Roller incl. penalty	117
Up_ A_Site Access_40T Exc	107
Up_ A_Site Access_Concrete pump on truck	108
Up_ A_Site Access_Grader	106
Up_ A_Site Access_Road Paver	112
UP_ AB_P1_Promise_Trail_12T Roller incl penalty	117
UP_ AB_P1_Promise_Trail_40T Exc	107
Up_ AB_P1_Promise_Trail_Grader	106
UP_ AB_P1_Promise_Trail_Heavy Truck deliveries (scale)	114
UP_ AB_P1_Promise_Trail_Roller Single Smooth Drum incl penalty	117
UP_ AB_P1_Promise_Trail_Water Tank Truck	109
UP_ A-B_Saddle_pipeline_Cable crane or winch system	117
UP_ A-B_Saddle_pipeline_Crane - All terrain 80t	105
UP_ A-B_Saddle_pipeline_Small excavator	104
UP_ A-B_Saddle_pipeline_Welding equipment	107
UP_ B_Laydowon A3 - shaft_Piple delivery - shaft lining	111
UP_ B_Shaft Blind Bore _Crane - 80tone to lower pipe down the shaft	105
UP_ B_Shaft Blind Bore _Generator bllind bore	107
UP_ B_Shaft Blind Bore _Raise bore machine / could also be blind bore	114
UP_ B_Shaft lining bore_Batching plant	115
UP_ B_Shaft lining bore_Concrete pump on truck	111
UP_ B_Shaft lining bore_Grouting	114
UP_ C_UpperIntake_Concrete batching plant	115
UP_ C_UpperIntake_Concrete mixer 500 l type	107
UP_ C_UpperIntake_Concrete pump on truck	111
UP_ C_UpperIntake_Crane - 60t rough terrain	105
UP_ C_UpperIntake_Crane - All terrain 80t	105
UP_ C_UpperIntake_Crane - Rough terrain 30t	98
UP_ C_UpperIntake_Diesel Generator	107
UP_ C_UpperIntake_Diesel welding machine 400	102

Source	LWA
UP_ C_UpperIntake_Dump truck tipper	114
UP_ C_UpperIntake_Forklift 1	99
UP_ C_UpperIntake_Forklift 2	114
UP_ C_UpperIntake_Semi-Trailer Flatbed - Day	111
UP_ C_UpperIntake_Track type Tractor 240HP CatD7E	110
UP_ C_UpperIntake_Truck Crane 5t	105
UP_ C_UpperLaydown-surge tank_Dump truck tipper	114
UP_ C_UpperLaydown-surge tank_Grader 140HP_1	106
UP_ C_UpperLaydown-surge tank_Grader 140HP_2	106
UP_ C_UpperLaydown-surge tank_Large Excavator	115
UP_ C_UpperLaydown-surge tank_Roller incl penalty	115
UP_ C_UpperLaydown-surge tank_Vibrating roller_Dynapac CA512 incl. penalty	115
UP_ D_Laydown_Crane	105
UP_ D_Laydown_Excavator	115
UP_ D_Laydown_Generator	107
UP_ D_Laydown_Loader1 31T	111
UP_ D_Laydown_Loader2 31T	111
UP_ D_Laydown_Truck Deliveries	114
UP_ D_Surge_construction_Crane - All terrain 80t	105
UP_ D_Surge_construction_Crane - Rough terrain 30t	98
UP_ D_Surge_construction_Diesel welding machine 400	102
UP_ D_Surge_construction_EWP	97
UP_ D_Surge_foundation_40T Excavator	107
UP_ D_Surge_foundation_Concrete pump on truck	111
UP_ D_Surge_foundation_Piling incl. penalty	103
UP_ E_Penstock_Crane - All terrain 80t	105
UP_ E_Penstock_Small Excavator	104



Legend

- Sensitive receptors
- Point source
- Line source
- Area source
- Project area
- Construction building
- Road
- Waterway Waterbody
- Cadastre

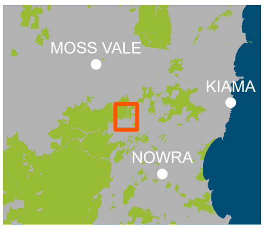
Decibel

35, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58

0 1 2 km

1:37,500 at A4

GDA2020 MGA Zone 56



Data sources

Jacobs 2022
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Figure C-1 Upper Scheme construction - Day

Construction – Upper Scheme Construction with Lower Scheme Peak Tunnelling and Daytime Spoil management

The *"Upper Scheme"* construction with "*peak tunnelling*" and *"daytime spoil management"* revolves around all construction activities occurring concurrently in the Upper Scheme (as per C 1) and peak tunnelling and spoil haulage truck movements in the Lower Scheme occurring concurrently.

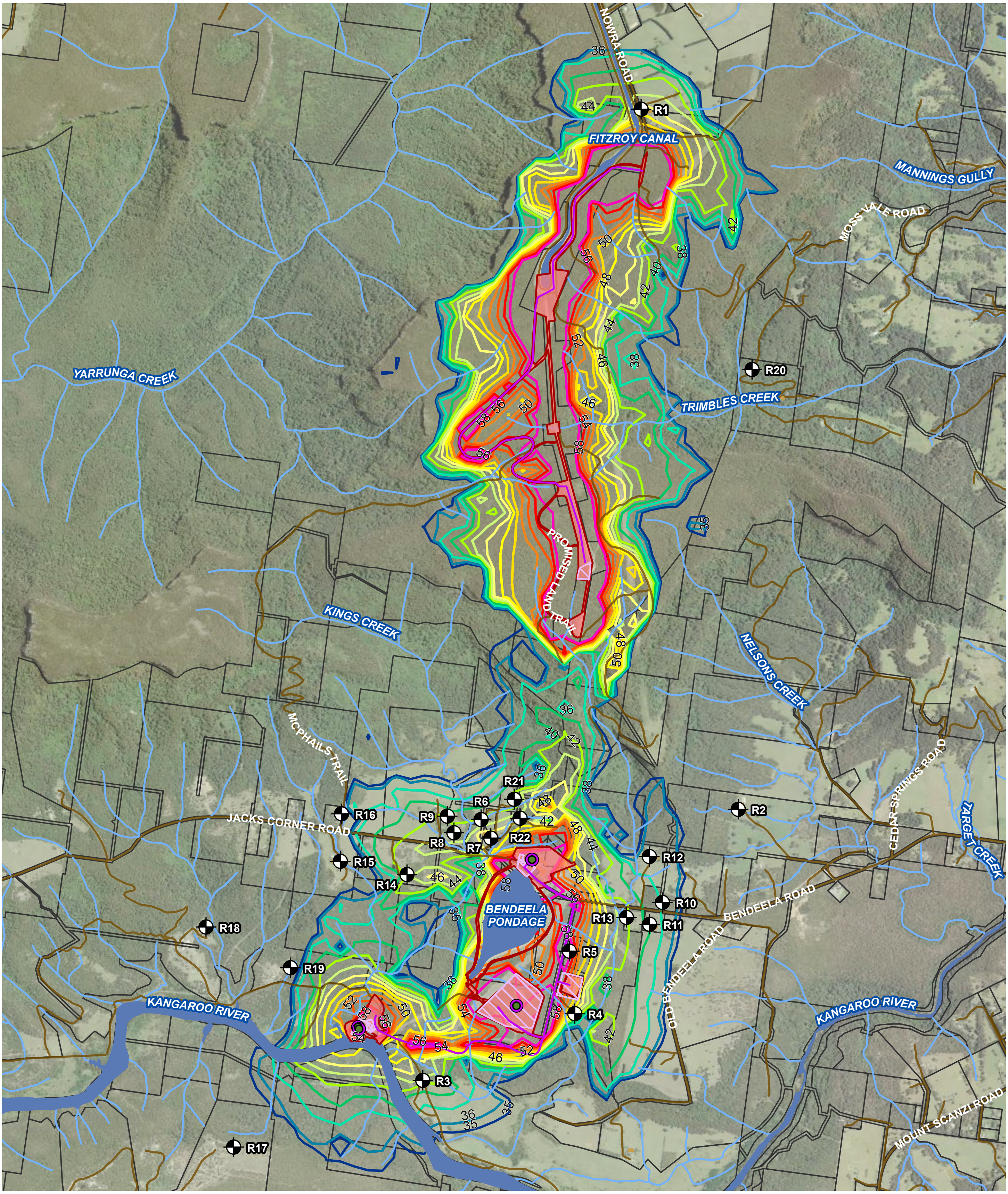
The activities modelled are outlined in the **Table C 2** below and resulting noise contours are illustrated in **Figure C-2**.

Table C 2 – Daytime - Upper Scheme Construction with Peak Tunnelling and Daytime Spoil - LWA

Source	LWA
M16 / M29_ H_H-site_Crusher	117
M16 / M29_ H_H-site_Day Drott	110
M16 / M29_ H_H-site_Day Excavator	115
M29_ H_Kportal_Day H-deposit	107
M29_ H_Kportal_Day Kang-deposit	107
M29_ H_Kportal_Day Loader1	113
M29_ H_Kportal_Day Loader2	113
M29_ H_Kportal_Day-Transport - Truck	114
M29_ H_Tportal_Day H-deposit	107
M29_ H_TPortal_Day Loader1	113
M29_ H_Tportal_Day Tail-deposit	107
M29_ H_Tportal_Day-Transport - Truck	114
Up_ A_Site Access_12T Roller incl. penalty	117
Up_ A_Site Access_40T Exc.	107
Up_ A_Site Access_Concrete pump on truck	108
Up_ A_Site Access_Grader	106
Up_ A_Site Access_Road Paver	112
UP_ AB_P1_Promise_Trail_12T Roller incl penalty	117
UP_ AB_P1_Promise_Trail_40T Exc	107
Up_ AB_P1_Promise_Trail_Grader	106
UP_ AB_P1_Promise_Trail_Heavy Truck deliveries (scale)	114
UP_ AB_P1_Promise_Trail_Roller Single Smooth Drum incl penalty	117
UP_ AB_P1_Promise_Trail_Water Tank Truck	109
UP_ A-B_Saddle_pipeline_Cable crane or winch system	117
UP_ A-B_Saddle_pipeline_Crane - All terrain 80t	105
UP_ A-B_Saddle_pipeline_Small excavator	104
UP_ A-B_Saddle_pipeline_Welding equipment	107
UP_ B_Laydowon A3 - shaft_Piple delivery - shaft lining	111
UP_ B_Shaft Blind Bore _Crane - 80tone to lower pipe down the shaft	105

Source	LWA
UP_ B_Shaft Blind Bore _Generator bllind bore	107
UP_ B_Shaft Blind Bore _Raise bore machine / could also be blind bore	114
UP_ B_Shaft lining bore_Batching plant	115
UP_ B_Shaft lining bore_Concrete pump on truck	111
UP_ B_Shaft lining bore_Grouting	114
UP_ C_UpperIntake_Concrete batching plant	115
UP_ C_UpperIntake_Concrete mixer 500 l type	107
UP_ C_UpperIntake_Concrete pump on truck	111
UP_ C_UpperIntake_Crane - 60t rough terrain	105
UP_ C_UpperIntake_Crane - All terrain 80t	105
UP_ C_UpperIntake_Crane - Rough terrain 30t	98
UP_ C_UpperIntake_Diesel Generator	107
UP_ C_UpperIntake_Diesel welding machine 400	102
UP_ C_UpperIntake_Dump truck tipper	114
UP_ C_UpperIntake_Forklift 1	99
UP_ C_UpperIntake_Forklift 2	114
UP_ C_UpperIntake_Semi-Trailer Flatbed - Day	111
UP_ C_UpperIntake_Track type Tractor 240HP CatD7E	110
UP_ C_UpperIntake_Truck Crane 5t	105
UP_ C_UpperLaydown-surge tank_Dump truck tipper	114
UP_ C_UpperLaydown-surge tank_Grader 140HP_1	106
UP_ C_UpperLaydown-surge tank_Grader 140HP_2	106
UP_ C_UpperLaydown-surge tank_Large Excavator	115
UP_ C_UpperLaydown-surge tank_Roller incl penalty	115
UP_ C_UpperLaydown-surge tank_Vibrating roller_Dynapac CA512 incl. penalty	115
UP_ D_Laydown_Crane	105
UP_ D_Laydown_Excavator	115
UP_ D_Laydown_Generator	107
UP_ D_Laydown_Loader1 31T	111
UP_ D_Laydown_Loader2 31T	111
UP_ D_Laydown_Truck Deliveries	114
UP_ D_Surge_construction_Crane - All terrain 80t	105
UP_ D_Surge_construction_Crane - Rough terrain 30t	98
UP_ D_Surge_construction_Diesel welding machine 400	102
UP_ D_Surge_construction_EWP	97
UP_ D_Surge_foundation_40T Excavator	107

Source	LWA
UP_ D_Surge_foundation_Concrete pump on truck	111
UP_ D_Surge_foundation_Piling incl. penalty	103
UP_ E_Penstock_Crane - All terrain 80t	105
UP_ E_Penstock_Small Excavator	104



Legend

- Sensitive receptors
- Point source
- Line source
- Area source
- Construction building
- Project area
- Road
- Waterway Waterbody
- Cadastre

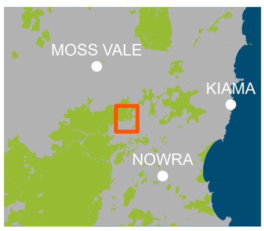
Decibel

- 35
- 36
- 38
- 40
- 42
- 44
- 46
- 48
- 50
- 52
- 54
- 56
- 58

0 1 2 km

1:37,500 at A4

GDA2020 MGA Zone 56



Data sources

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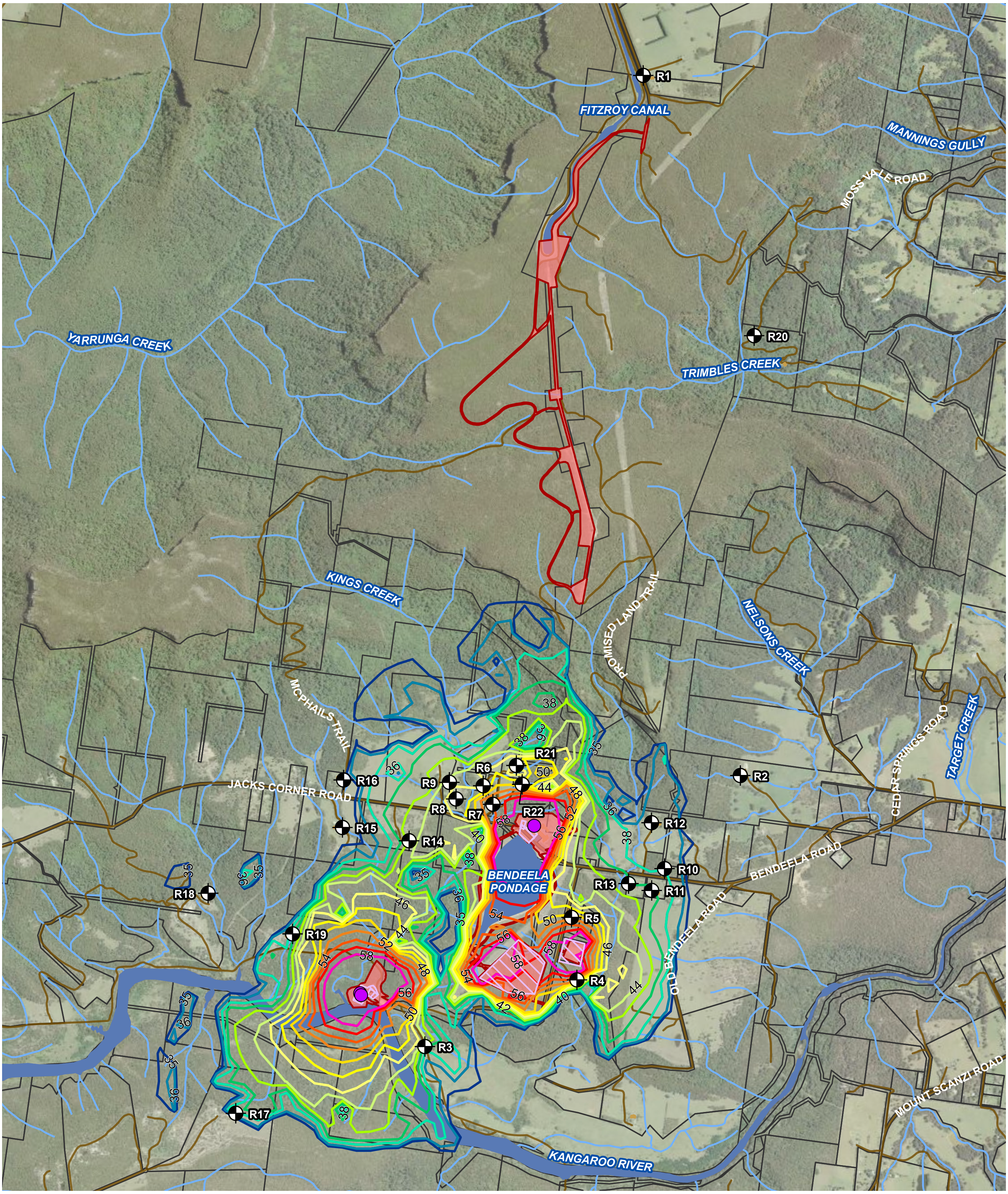
Figure C-2 Upper Scheme construction - with peak tunnelling and daytime spoil management - Day

Lower Scheme Construction

The *"Lower Scheme Construction"* scenario revolves around indicative activities south of Kangaroo Valley Portal in the area occurring concurrently and represents peak surface activities associated with tunnel portal, spoil emplacing area and works areas establishment. The activities modelled are outlined in the **Table C 3** below and resulting noise contours are illustrated in **Figure C-3**.

Table C 3 – Daytime - Lower Scheme Equipment Sound Power Level

Source	LWA
Low_ F_Portal_Kang_const_100t mobile crane	99
Low_ F_Portal_Kang_const_Air Compressor	105
Low_ F_Portal_Kang_const_Batching Plant	115
Low_ F_Portal_Kang_const_Concrete pump on truck (87m3/h)	111
Low_ F_Portal_Kang_const_Drott	110
Low_ F_Portal_Kang_const_Excavator1	115
Low_ F_Portal_Kang_const_Excavator2	115
Low_ F_Portal_Kang_const_Forklift 1	99
Low_ F_Portal_Kang_const_Forklift 2	99
Low_ F_Portal_Kang_const_Grader	106
Low_ F_Portal_Kang_const_Pump	110
Low_ F_Portal_Kang_const_Road Header	114
Low_ F_Portal_Kang_const_Road Paver	112
Low_ F_Portal_Kang_const_Rock anchor drill incl. penalty	113
Low_ F_Portal_Kang_const_Small Water Treatment Plant	107
Low_ G_Tail race Portal_Air compressor	105
Low_ G_Tail race Portal_All terrain 50T	105
Low_ G_Tail race Portal_Batching plant	115
Low_ G_Tail race Portal_Conrete Pump	114
Low_ G_Tail race Portal_Drott	110
Low_ G_Tail race Portal_Excavator 1	115
Low_ G_Tail race Portal_Excavator 2	115
Low_ G_Tail race Portal_Pump	110
Low_ G_Tail race Portal_Road Headder	114
Low_ G_Tail race Portal_WTP	107
Low_ J_Clear and Prep_40T Exc.	107
Low_ J_Clear and Prep_Drott	110
Low_ J_Clear and Prep_Grader	106
Low_ J_Clear and Prep_Loader	113
M16 / M29_ H_H-site_Day Drott	110
M16 / M29_ H_H-site_Day Excavator	115



Legend

- Sensitive receptors
- Point source
- Area source
- Construction building
- Project area
- Road
- Waterway Waterbody
- Cadastre

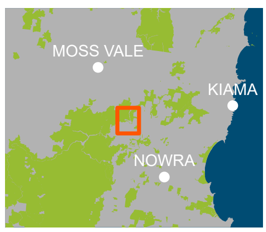
Decibel

- 35
- 36
- 38
- 40
- 42
- 44
- 46
- 48
- 50
- 52
- 54
- 56
- 58

0 1 2 km

1:37,500 at A4

GDA2020 MGA Zone 56



Data sources

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Figure C-3 Lower Scheme construction - Day

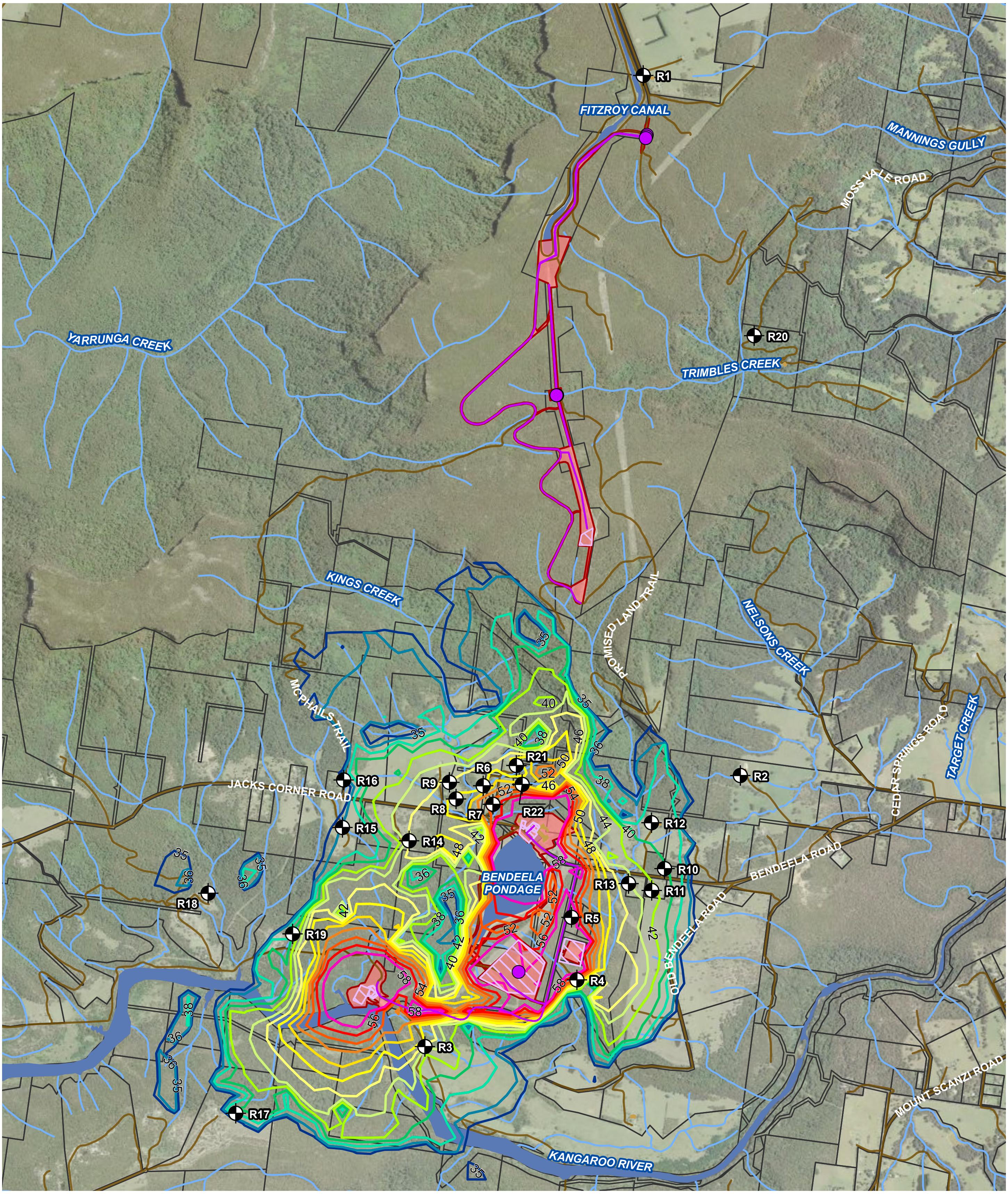
Lower Scheme Construction with Peak Tunnelling and Daytime Spoil management

The *"Lower Scheme Construction"* with *"peak tunnelling"* and *"daytime spoil management"* revolves around activities south of Kangaroo Valley Portal and Peak tunnelling truck movements in the area occurring concurrently. The activities modelled are outlined in the **Table C4** below and resulting noise contours are illustrated in **Figure C-4**.

Table C 4 – Daytime - Lower Scheme Construction with Peak Tunnelling and Daytime Spoil - LWA

Source	LWA
Low_ F_Portal_Kang_const_100t mobile crane	99
Low_ F_Portal_Kang_const_Air Compressor	105
Low_ F_Portal_Kang_const_Batching Plant	115
Low_ F_Portal_Kang_const_Concrete pump on truck (87m3/h)	111
Low_ F_Portal_Kang_const_Drott	110
Low_ F_Portal_Kang_const_Excavator1	115
Low_ F_Portal_Kang_const_Excavator2	115
Low_ F_Portal_Kang_const_Forklift 1	99
Low_ F_Portal_Kang_const_Forklift 2	99
Low_ F_Portal_Kang_const_Grader	106
Low_ F_Portal_Kang_const_Pump	110
Low_ F_Portal_Kang_const_Road Header	114
Low_ F_Portal_Kang_const_Road Paver	112
Low_ F_Portal_Kang_const_Rock anchor drill incl. penalty	113
Low_ F_Portal_Kang_const_Small Water Treatment Plant	107
Low_ G_Tail race Portal_Air compressor	105
Low_ G_Tail race Portal_All terrain 50T	105
Low_ G_Tail race Portal_Batching plant	115
Low_ G_Tail race Portal_Conrete Pump	114
Low_ G_Tail race Portal_Drott	110
Low_ G_Tail race Portal_Excavator 1	115
Low_ G_Tail race Portal_Excavator 2	115
Low_ G_Tail race Portal_Pump	110
Low_ G_Tail race Portal_Road Headder	114
Low_ G_Tail race Portal_WTP	107
Low_ J_Clear and Prep_40T Exc.	107
Low_ J_Clear and Prep_Drott	110
Low_ J_Clear and Prep_Grader	106
Low_ J_Clear and Prep_Loader	113
Low_ J_Transport_Crane	105
Low_ J_Transport_Semi-Trailer Flatbed to KV	111
M16 / M29_ H_H-site_Crusher	112
M16 / M29_ H_H-site_Day Drott	110
M16 / M29_ H_H-site_Day Excavator	115

Source	LWA
M29_ H_Kportal_Day H-deposit	107
M29_ H_Kportal_Day Kang-deposit	107
M29_ H_Kportal_Day Loader1	113
M29_ H_Kportal_Day Loader2	113
M29_ H_Kportal_Day-Transport - Truck	114
M29_ H_Tportal_Day H-deposit	107
M29_ H_TPortal_Day Loader1	113
M29_ H_Tportal_Day Tail-deposit	107
M29_ H_Tportal_Day-Transport - Truck	114



Legend

- Sensitive receptors
- Point source
- Line source
- Area source
- Construction building
- Project area
- Road
- Waterway
- Waterbody
- Cadastre

Decibel

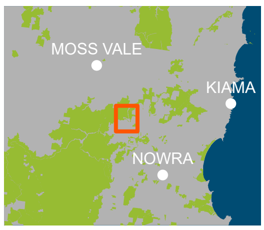
- 35
- 36
- 38
- 40
- 42
- 44
- 46
- 48
- 50
- 52
- 54
- 56
- 58

0 1 2 km

1:37,500 at A4

GDA2020 MGA Zone 56

N



Data sources

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Figure C-4 Lower Scheme construction - with peak tunnelling and daytime spoil management - Day

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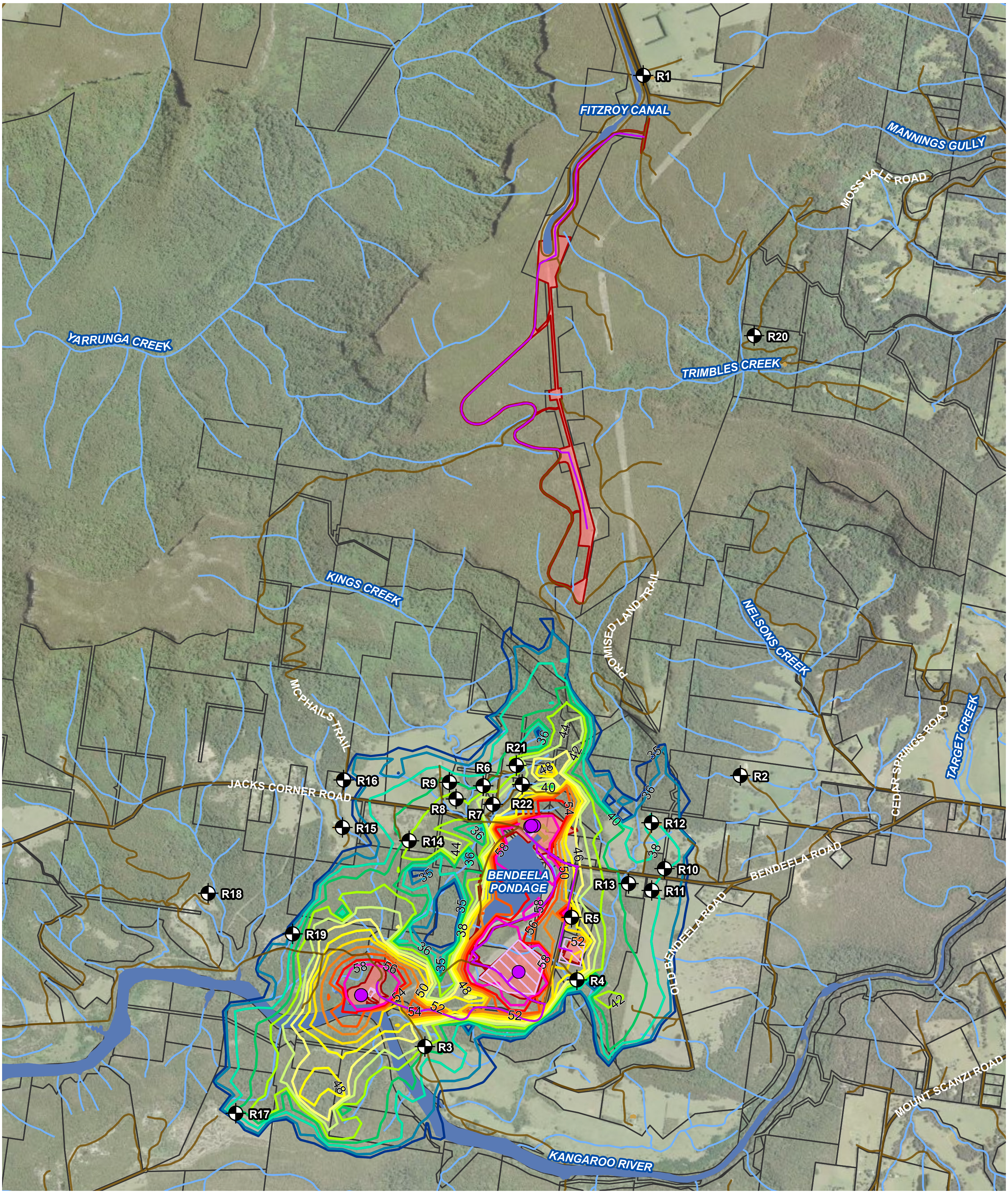
Tunnelling Activity

The *"Tunnelling Activity"* revolves around daytime, evening and night time tunnelling and essential surface tunnelling support activities including 24 / 7 spoil haulage. This encompasses selected truck movements, spoil deposit activities and portal activities. The activities modelled are outlined in the **Table C5** (Day), **Table C6** (Evening) and **Table C7** (night) below and resulting noise contours are illustrated in **Figure C-5, Figure C-6** and **Figure C-7.**

Table C 5 Peak tunnelling Sound Power levels - Day

Source	LWA
Low_ F_Portal_Kang_247_Air compressor	105
Low_ F_Portal_Kang_247_Batching Plant	115
Low_ F_Portal_Kang_247_Conrete Pump	111
Low_ F_Portal_Kang_247_Fan Breakout	97
Low_ F_Portal_Kang_247_Fan Inlet	97
Low_ F_Portal_Kang_247_Pump	110
Low_ F_Portal_Kang_247_Small Water Treatment Plant	107
Low_ F_Portal_Kang_Day_Loader1	113
Low_ F_Portal_Kang_Day_Loader2	113
Low_ G_Tail race Portal 24-7_Air compressor	105
Low_ G_Tail race Portal 24-7_Fan Inlet Case breakout	119
Low_ G_Tail race Portal 24-7_Fan Inlet Silenced	101
Low_ G_Tail race Portal 24-7_Pump	110
Low_ G_Tail race Portal 24-7_WTP	107
Low_ G_Tail race Portal Day_Batching Plant	115
Low_ G_Tail race Portal Day_Loader	113
Low_ J_Transport_Crane	105
Low_ J_Transport_Semi-Trailer Flatbed to KV	111
M16 / M29_ H_H-site_Day Crushing	112
M16 / M29_ H_H-site_Day Drott	110
M16 / M29_ H_H-site_Day Excavator	115
M29_ H_Kportal_247 H-deposit	107
M29_ H_Kportal_247-Transport truck	114
M29_ H_Tportal_247H- deposit	107
M29_ H_tportal_247Transport truck	114



Legend

- Sensitive receptors
- Point source
- Line source
- Area source
- Construction building
- Project area
- Road
- Waterway Waterbody
- Cadastre

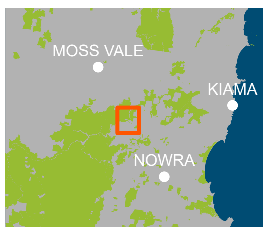
Decibel

- 35
- 36
- 38
- 40
- 42
- 44
- 46
- 48
- 50
- 52
- 54
- 56
- 58

0 1 2 km

1:37,500 at A4

GDA2020 MGA Zone 56



Data sources

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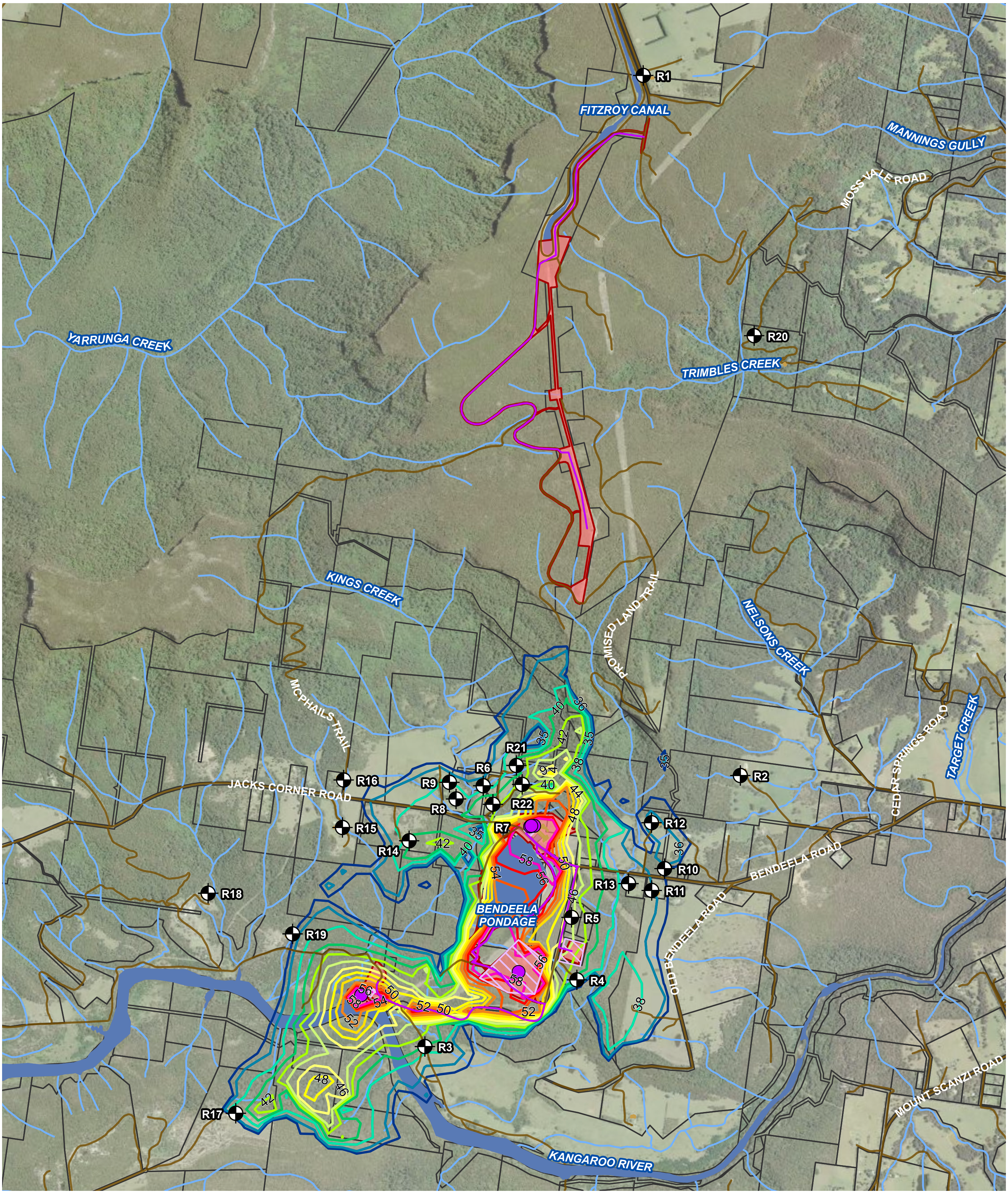
Figure C-5 Peak tunneling - 24-7 spoil management - Day

Table C 6 – Peak tunnelling – Evening

Source	LWA
Low_ F_Portal_Kang_247_Air compressor	105
Low_ F_Portal_Kang_247_Batching Plant	115
Low_ F_Portal_Kang_247_Conrete Pump	111
Low_ F_Portal_Kang_247_Fan Breakout	97
Low_ F_Portal_Kang_247_Fan Inlet	97
Low_ F_Portal_Kang_247_Pump	110
Low_ F_Portal_Kang_247_Small Water Treatment Plant	107
Low_ G_Tail race Portal 24-7_Air compressor	105
Low_ G_Tail race Portal 24-7_Fan Inlet Case breakout	119
Low_ G_Tail race Portal 24-7_Fan Inlet Silenced	101
Low_ G_Tail race Portal 24-7_Pump	110
Low_ G_Tail race Portal 24-7_WTP	107
M29_ H_Kportal_247 H-deposit	107
M29_ H_Kportal_247Transport - Truck	114
M29_ H_Tportal_247 H-deposit	107
M29_ H_Tportal_247Transport - Truck	114



Legend

- Sensitive receptors
- Point source
- Line source
- Area source
- Construction building
- Disturbance area
- Road
- Waterway
- Waterbody
- Cadastre

Decibel

- 35
- 36
- 38
- 40
- 42
- 44
- 46
- 48
- 50
- 52
- 54
- 56
- 58

0 1 2 km

1:37,500 at A4

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Data sources

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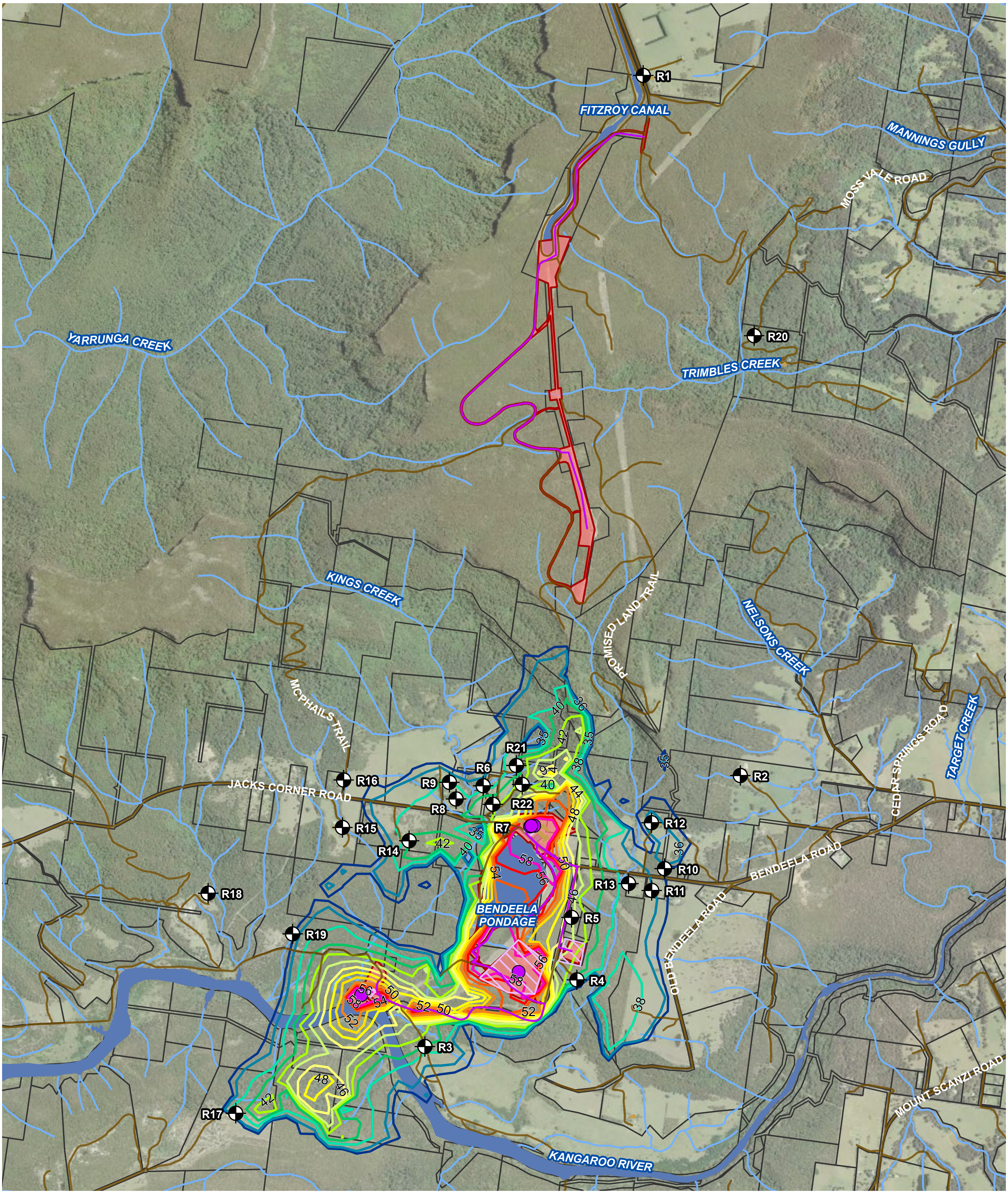
Figure C-6 Peak tunneling - 24-7 spoil management - Evening

Table C 7 – Peak tunnelling – Night

Source	LWA
Low_ F_Portal_Kang_247_Air compressor	105
Low_ F_Portal_Kang_247_Batching Plant	115
Low_ F_Portal_Kang_247_Conrete Pump	111
Low_ F_Portal_Kang_247_Fan Breakout	97
Low_ F_Portal_Kang_247_Fan Inlet	97
Low_ F_Portal_Kang_247_Pump	110
Low_ F_Portal_Kang_247_Small Water Treatment Plant	107
Low_ G_Tail race Portal 24-7_Air compressor	105
Low_ G_Tail race Portal 24-7_Fan Inlet Case breakout	119
Low_ G_Tail race Portal 24-7_Fan Inlet Silenced	101
Low_ G_Tail race Portal 24-7_Pump	110
Low_ G_Tail race Portal 24-7_WTP	107
M29_ H_Kportal_247 H-deposit	107
M29_ H_Kportal_247Transport - Truck	114
M29_ H_Tportal_247 H-deposit	107
M29_ H_Tportal_247Transport - Truck	114



Legend

- Sensitive receptors
- Point source
- Line source
- Area source
- Construction building
- Project area
- Road
- Waterway Waterbody
- Cadastre

Decibel

35, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58

0 1 2 km

1:37,500 at A4

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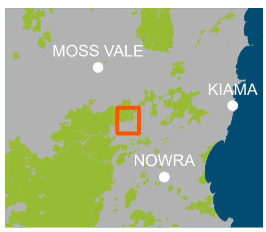

Data sources

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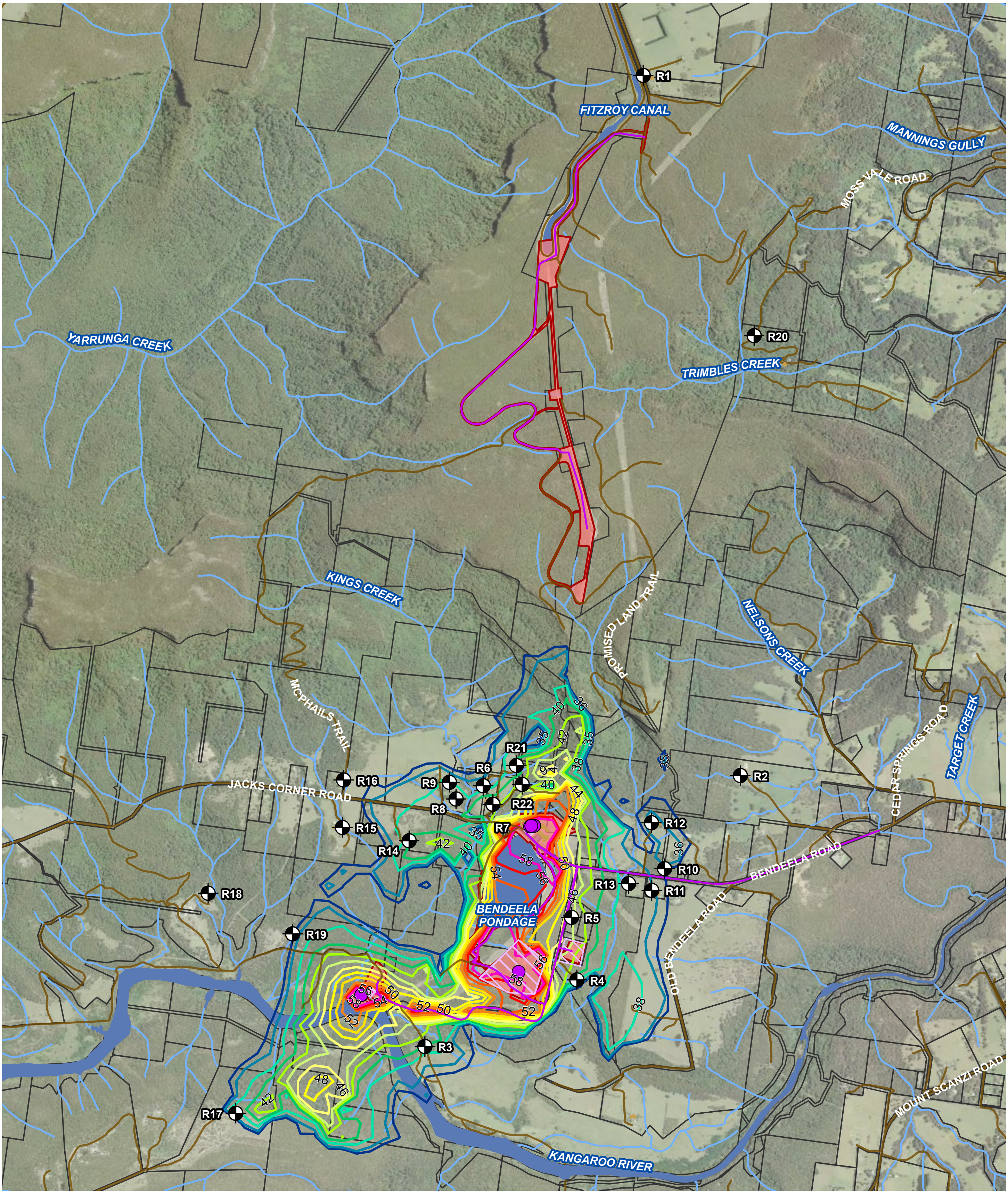
Figure C-7 Peak tunneling - 24-7 spoil management - Night

Peak Tunnelling Activity with Daytime Spoil Management

The *"Tunnelling Activity"* with "*Daytime Spoil Management*" revolves around daytime, evening and night time tunnelling with spoil management carried out in the day only. This encompasses selected truck movements (day only), spoil deposit (day only) activities, and portal activities (24-7). The activities modelled are outlined in the **Table C8** (Day), **Table C9** (Evening) and **Table C10** (night) below and resulting noise contours are illustrated in **Figure C-8, Figure C-9** and **Figure C-10.**

Table C 8 Peak tunnelling Sound Power levels with Daytime spoil management - Day

Source	LWA
Low_ F_Portal_Kang_247_Air compressor	105
Low_ F_Portal_Kang_247_Batching Plant	115
Low_ F_Portal_Kang_247_Conrete Pump	111
Low_ F_Portal_Kang_247_Fan Breakout	97
Low_ F_Portal_Kang_247_Fan Inlet	97
Low_ F_Portal_Kang_247_Pump	110
Low_ F_Portal_Kang_247_Small Water Treatment Plant	107
Low_ F_Portal_Kang_Day_Loader1	113
Low_ F_Portal_Kang_Day_Loader2	113
Low_ G_Tail race Portal 24-7_Air compressor	105
Low_ G_Tail race Portal 24-7_Fan Inlet Case breakout	119
Low_ G_Tail race Portal 24-7_Fan Inlet Silenced	101
Low_ G_Tail race Portal 24-7_Pump	110
Low_ G_Tail race Portal 24-7_WTP	107
Low_ G_Tail race Portal Day_Batching Plant	115
Low_ G_Tail race Portal Day_Loader	113
Low_ J_Transport_Crane	105
Low_ J_Transport_Semi-Trailer Flatbed to KV	111
M16 / M29_ H_H-site_Crusher	112
M16 / M29_ H_H-site_Day Drott	110
M16 / M29_ H_H-site_Day Excavator	115
M29_ H_Kportal_Day H-deposit	107
M29_ H_Kportal_Day Kang-deposit	107
M29_ H_Kportal_Day Loader1	113
M29_ H_Kportal_Day Loader2	113
M29_ H_Kportal_Day-Transport - Truck	114
M29_ H_Tportal_Day H-deposit	107
M29_ H_TPortal_Day Loader1	113
M29_ H_Tportal_Day Tail-deposit	107
M29_ H_Tportal_Day-Transport - Truck	114



Legend

Sensitive receptors	Cadastre
Point source	**Decibel**
Line source	35
Area source	36
Project area	38
Construction building	40
Road	42
Waterway	44
Waterbody	46
	48
	50
	52
	54
	56
	58

0 1 2 km

1:37,500 at A4

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Data sources

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MOSS VALE
KIAMA
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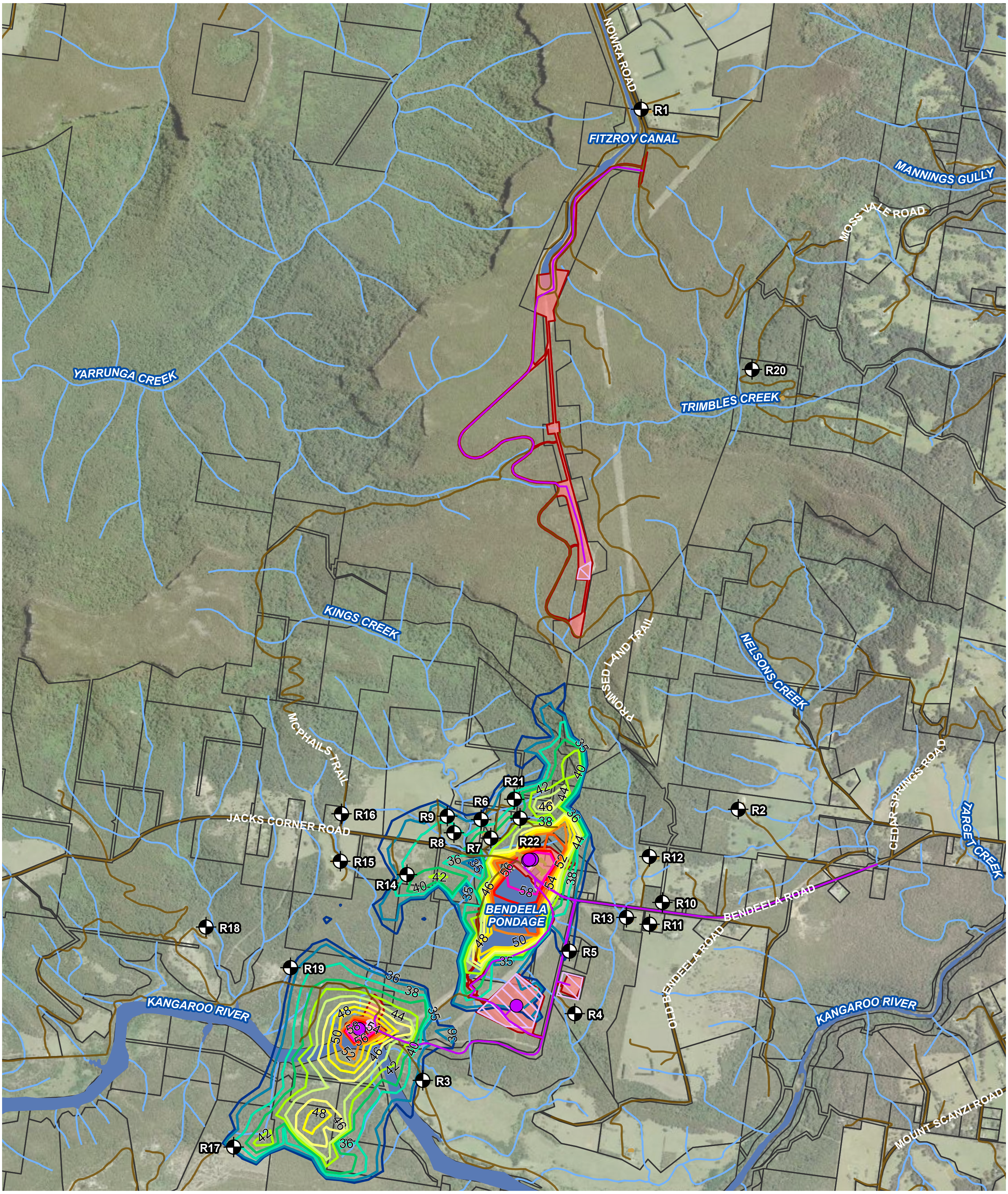
Figure C-8 Peak tunneling - day only spoil management - Day

Table C 9 – Peak tunnelling with daytime spoil management – Evening

Source	LWA
Low_ F_Portal_Kang_247_Air compressor	105
Low_ F_Portal_Kang_247_Batching Plant	115
Low_ F_Portal_Kang_247_Conrete Pump	111
Low_ F_Portal_Kang_247_Fan Breakout	97
Low_ F_Portal_Kang_247_Fan Inlet	97
Low_ F_Portal_Kang_247_Pump	110
Low_ F_Portal_Kang_247_Small Water Treatment Plant	107
Low_ G_Tail race Portal 24-7_Air compressor	105
Low_ G_Tail race Portal 24-7_Fan Inlet Case breakout	119
Low_ G_Tail race Portal 24-7_Fan Inlet Silenced	101
Low_ G_Tail race Portal 24-7_Pump	110
Low_ G_Tail race Portal 24-7_WTP	107
M29_ H_Kportal_Day Kang-deposit	107
M29_ H_Tportal_Day Tail-deposit	107



Legend

Sensitive receptors
Point source
Line source
Area source
Project area
Construction building
Road
Waterway
Waterbody

Cadastre

Decibel

35
36
38
40
42
44
46
48
50
52
54
56
58

0 1 2 km

1:37,500 at A4

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Data sources

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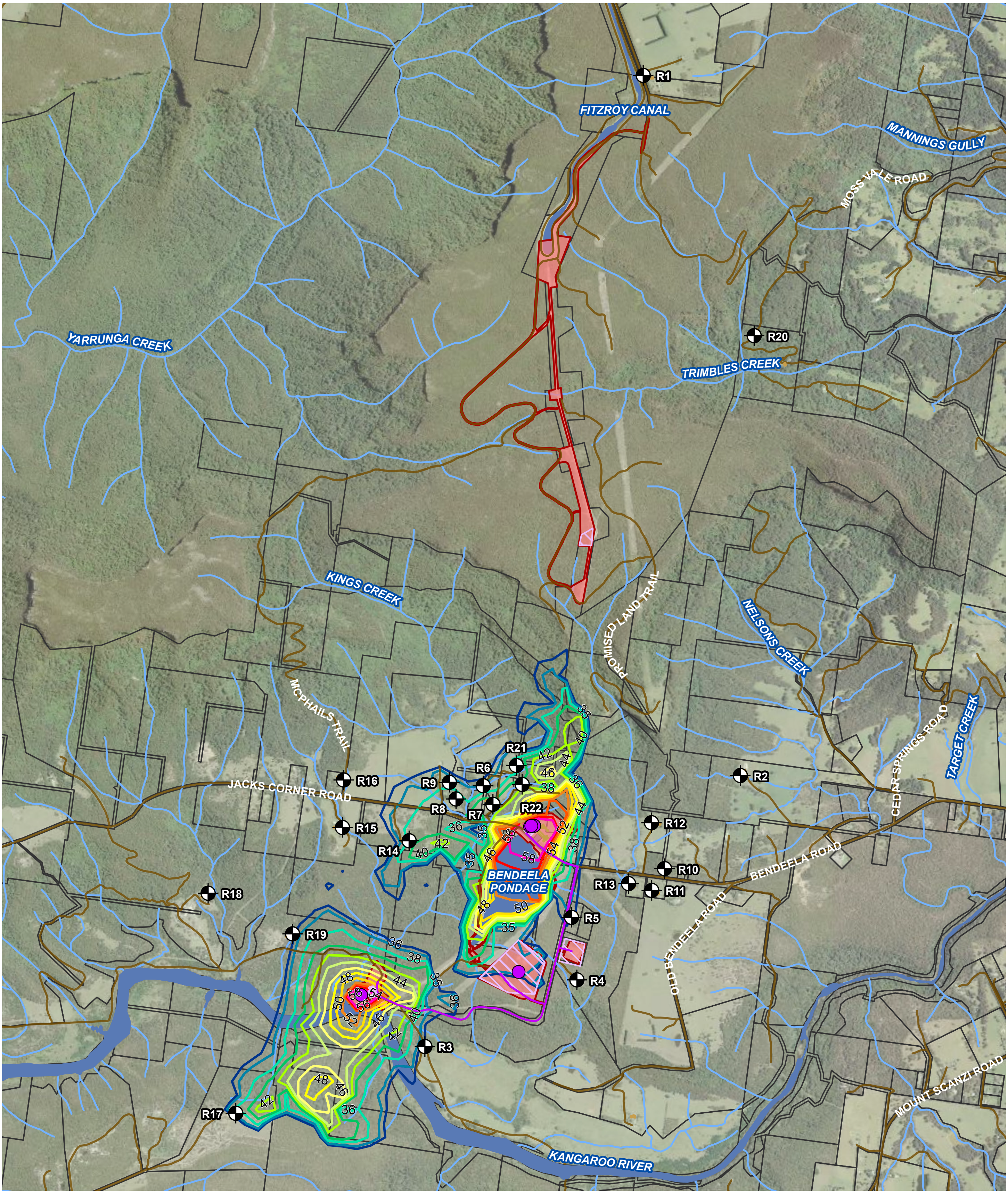
Figure C-9 Peak tunneling - day only spoil management - Evening

Table C 10 – Peak tunnelling – Night

Source	LWA
Low_ F_Portal_Kang_247_Air compressor	105
Low_ F_Portal_Kang_247_Batching Plant	115
Low_ F_Portal_Kang_247_Conrete Pump	111
Low_ F_Portal_Kang_247_Fan Breakout	97
Low_ F_Portal_Kang_247_Fan Inlet	97
Low_ F_Portal_Kang_247_Pump	110
Low_ F_Portal_Kang_247_Small Water Treatment Plant	107
Low_ G_Tail race Portal 24-7_Air compressor	105
Low_ G_Tail race Portal 24-7_Fan Inlet Case breakout	119
Low_ G_Tail race Portal 24-7_Fan Inlet Silenced	101
Low_ G_Tail race Portal 24-7_Pump	110
Low_ G_Tail race Portal 24-7_WTP	107
M29_ H_Kportal_Day Kang-deposit	107
M29_ H_Tportal_Day Tail-deposit	107



Legend

Sensitive receptors	Cadastre
Point source	**Decibel**
Line source	35
Area source Project	36
Project area	38
Construction building	40
Road	42
Waterway	44
Waterbody	46
	48
	50
	52
	54
	56
	58

0 1 2 km

1:37,500 at A4

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Data sources

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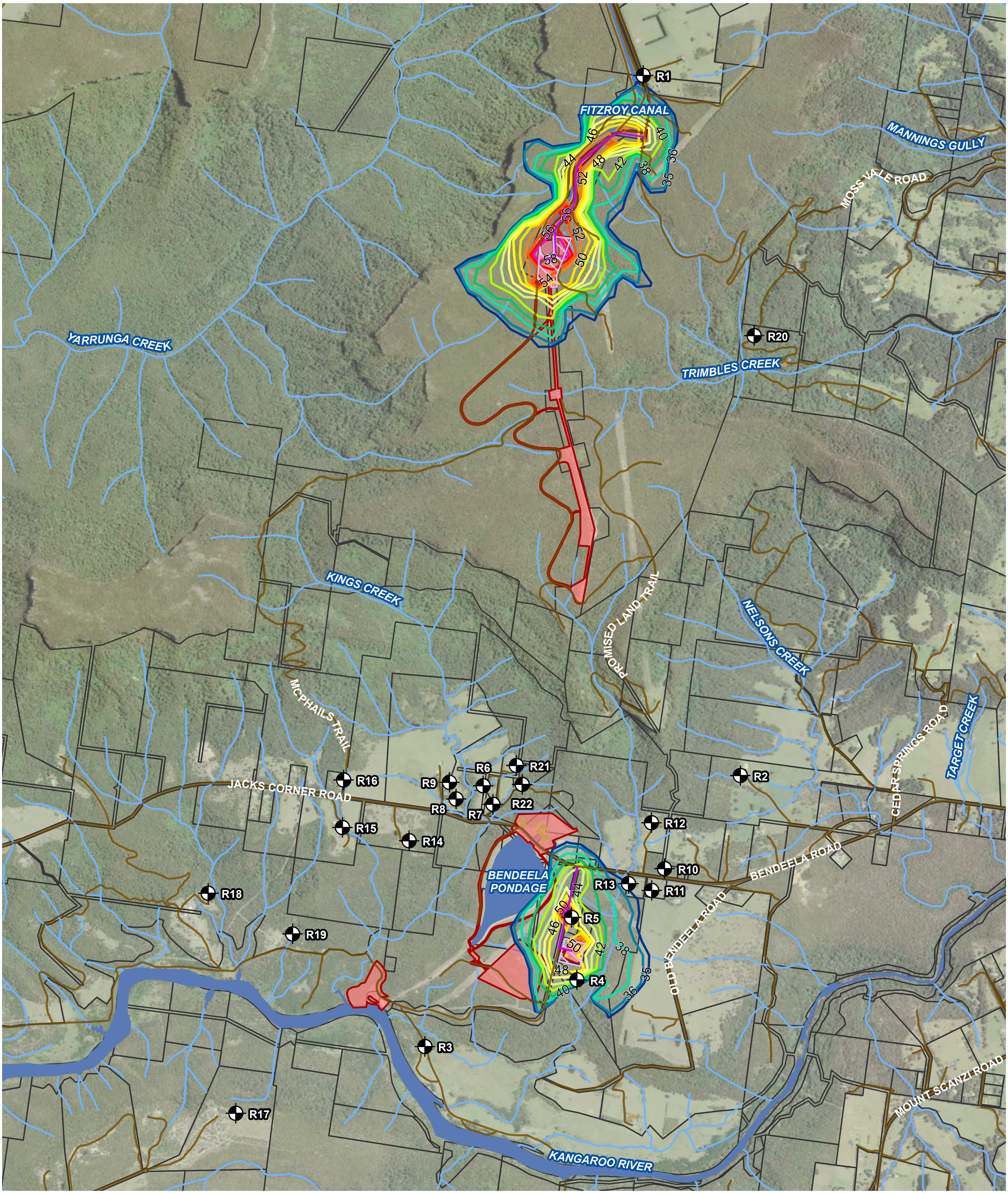
Figure C-10 Peak tunneling - day only spoil management - Night

Construction – Short Term night Deliveries

The *"short term night deliveries"* consider noise levels due to deliveries and management of extra large equipment occurring at night. The activities modelled are outlined in the **Table C11** below and resulting noise contours are illustrated in **Figure C-11**.

Table C 11 – Night time – Large equipment night time transportation

Source	LWA
Low_ J_Transport_Crane H-site - Night	105
Low_ J_Transport_Semi-Trailer Flatbed H-site - Night	111
UP_ C_UpperIntake_Crane1 - Night	105
UP_ C_UpperIntake_Crane2 - Night	105
UP_ C_UpperIntake_Semi-Trailer Flatbed - Night	111



Legend

Sensitive receptors	
Line source	
Area source	
Project area	
Construction building	
Road	
Waterway	
Waterbody	
Cadastre	

Decibel

35, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58

0 1 2 km

1:37,500 at A4

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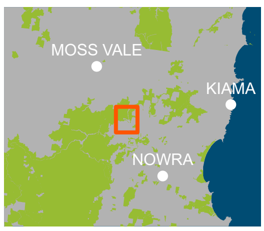

Data sources

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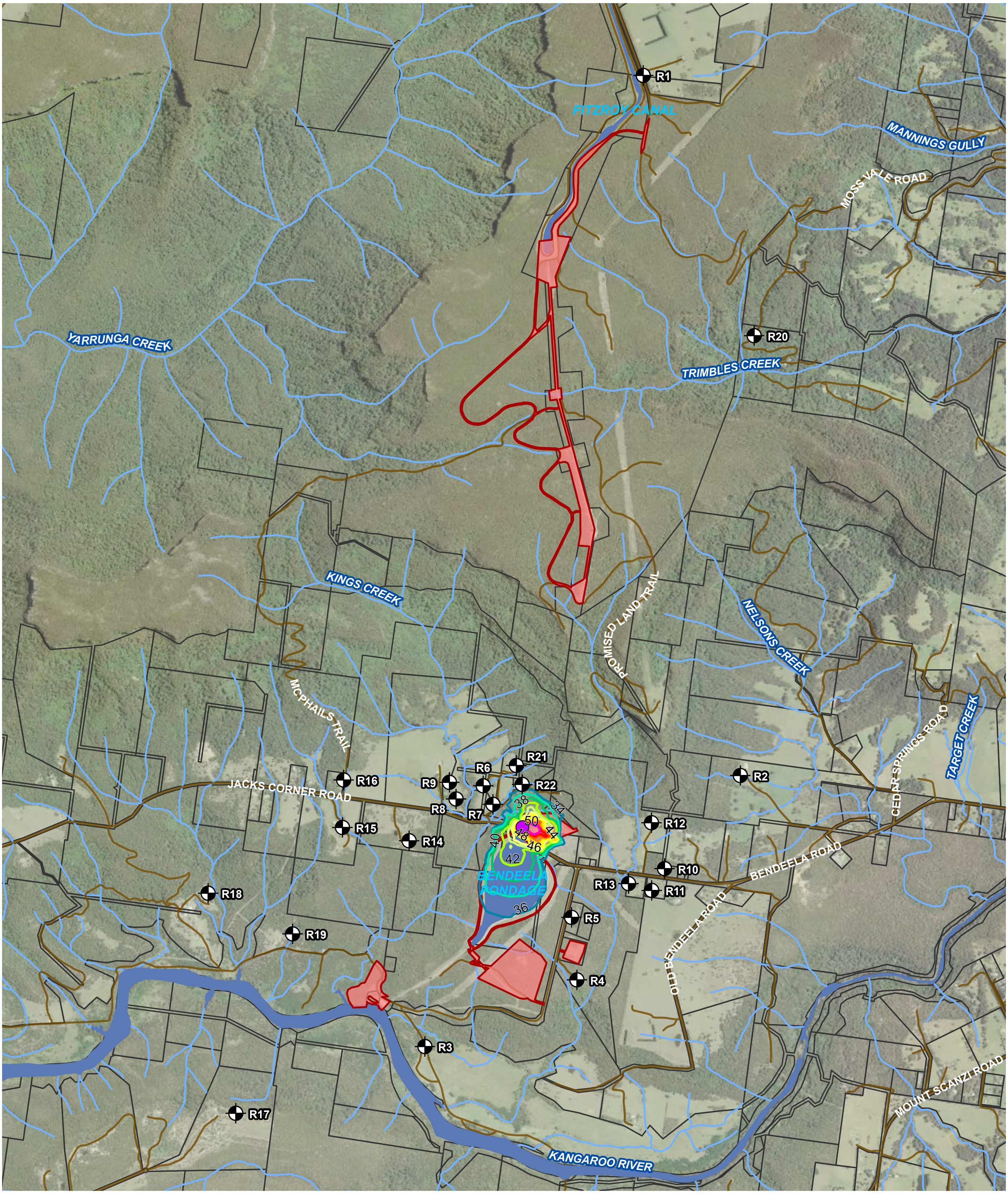
Figure C-11 OSOM deliveries - Night

Operational

The operational contours “standard” and “enhanced refer to the equipment as outlined in the Table below. The equipment operates on a continuous and steady operating point with the images reflecting day, evening and night time periods. The activities modelled are outlined in the **Table C 12** below and resulting noise contours are illustrated in **Figure C-12**.

Table C 12 – Operational noise levels – Day Evening and Night

Source	LWA
Transformer	93
Fan discharge	97
Fan breakout	97



Legend

- Sensitive receptors
- Point source
- Vertical area source
- Project area
- Road
- Waterway
- Waterbody
- Cadastre

Decibel

36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58

0 1 2 km

1:37,500 at A4

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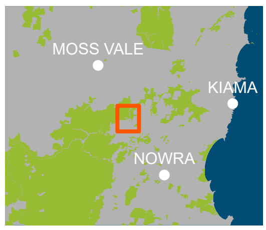

Data sources

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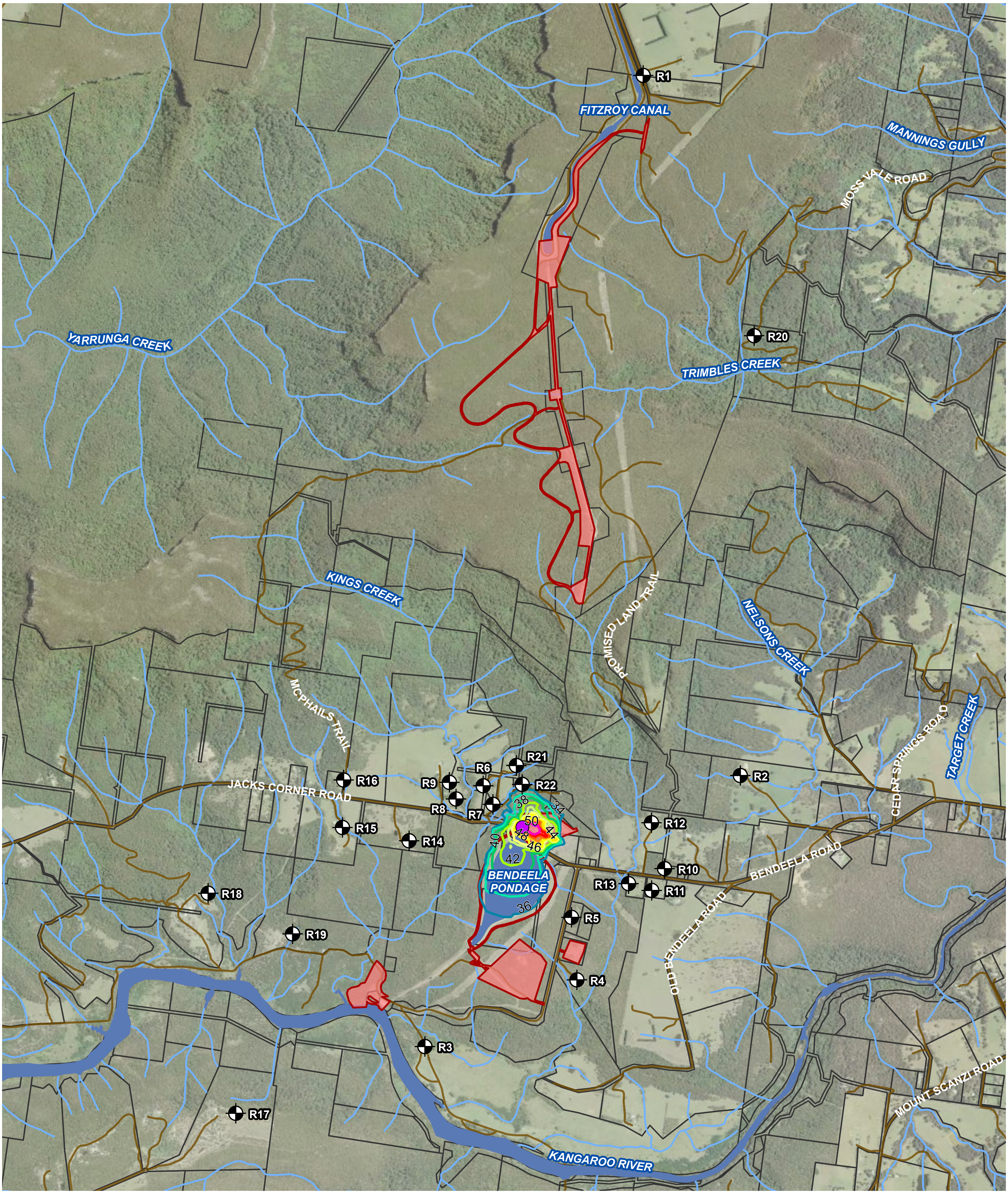
Figure C-12 Operational enhanced conditions Day, Evening & Night - dBA



Legend

- Sensitive receptors
- Point source
- Vertical area source
- Project area
- Road
- Waterway
- Waterbody
- Cadastre

Decibel: 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58

Data sources

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Figure C-13 Operational standard conditions Day, Evening & Night - dBA