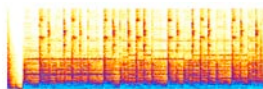


TARONGA ZOO AFRICAN SAVANNAH AND CONGO EXHIBITS

ACOUSTIC REPORT FOR STATE SIGNIFICANT DEVELOPMENT APPLICATION

Issued

12 May 2017

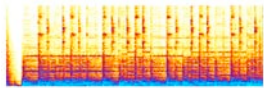


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1 Introduction

Acoustic Studio has been commissioned to provide acoustic engineering services for the proposed construction and operation of the new African Savannah and Congo Exhibits at Taronga Zoo, Mosman.

The Taronga Zoo African Savannah and Congo Exhibit Project has been categorised as a “State Significant Development”. This acoustic assessment report has been prepared in support of the EIS for the proposed project.

An operational and construction acoustic assessment has been carried out for the proposal, and is detailed in this report along with the findings and recommendations. It has been prepared as part of the State Significant Development Application to be submitted to NSW Department of Planning and Environment for the proposed redevelopment of the African Savannah and Congo Exhibit.

The objectives of this assessment are to:

- Identify noise sensitive receivers that will potentially be affected by the construction and operation of the proposed African Savannah and Congo Exhibit.
- Determine existing ambient and background noise levels at the nearest noise sensitive receivers that surround the site.
- Establish the appropriate noise assessment criteria in accordance with the relevant standards and guidelines.
- Carry out an assessment to determine whether the relevant criteria can be achieved based on proposed operations and likely construction methods. Where applicable, provide recommendations for any necessary acoustic control measures that will need to be incorporated into the development or use in order to ensure compliance with the assessment criteria.

2 Project Description

2.1 Project overview

Taronga Zoo Conservation Society is proposing to construct and operate a redeveloped African Savannah and Congo Exhibit in the grounds of Taronga Zoo.

The African Savannah and Congo Exhibit will cater for zoo patrons and will operate during normal zoo opening hours.

The proposal will include:

- Demolition of the existing carnivore exhibit.
- Construction of a redeveloped African Savannah and Congo Exhibit, including:
 - Various exhibit areas for several species, including the Chimpanzee, Giraffes, Gorillas and Lions (re-introduced to Taronga Zoo in Mosman)
 - Holding dens
 - Containment fences
 - Landscaping, milling areas and signage
 - Two new exhibit public pedestrian pathways
 - Keeper safe corridors
 - Exhibit enrichment devices and visitor viewing areas
 - Ranger outpost
 - Office and staff amenities
 - Animal food preparation area and equipment store.
- A rebuilt and re-oriented walkway connecting the various exhibits with existing accessible walkways.

It is proposed that all road deliveries to the African Savannah and Congo Exhibit redevelopment will be made via the existing secure entrance on Whiting Beach Road or the southern entry off Bradley's Head Road.

The proposal is shown in Figure 1 below.



Figure 1: Plan view of the proposed redeveloped African Savannah and Congo Exhibit, including Off-Exhibit Enclosures and Back of House Areas

2.2 Key Acoustic Design Considerations

The key design considerations for the project are external noise emissions from operation of the following spaces and equipment associated with the African Savannah and Congo Exhibit redevelopment works:

- Breakout noise from building services and plant servicing the Offices, Amenities, Enclosures and Exhibits.
- Patron noise from inside the Exhibits.
- Patron noise from the outdoor waiting areas.
- Noise from lions roaring, particularly at night.

Noise emissions from each of these spaces / operations may need to be managed to limit environmental noise impacts on nearby residential receivers.

Construction activities may have a temporary noise impact on sensitive receivers inside and outside the zoo premises.

This noise impact assessment considers these in detail.

2.3 Operating Hours

The African Savannah and Congo Exhibit will be open and in use during zoo opening hours, every day of the year including Christmas Day. Hours are seasonal, as follows (source: taronga.org.au, accessed 01/10/2016):

- Generally from 9:30 am to 5:00pm
- Winter (May to August) from 9:30am-4:30pm
- New Year's Eve from 9:30am to 4:30pm

Maintenance of the facilities including care of the animals typically occurs outside of zoo opening hours, including weekends and public holidays. Internal cleaning occurs at night, and external cleaning commences at 6am. The zoo operates 24 hours and day, 7 days a week.

Zoo staff hours are typically from 6am to 5pm.

2.4 Site Details and Local Sensitive Receivers

The site is located within a suburban environment characterised by low to medium levels of activity throughout the day and decreasing noise levels in the evening and night.

Residential receivers dominate around the site. Existing neighbouring residential buildings that surround the site are over 80m distant from the proposal site, and are:

- Residential properties on Whiting Beach Road to the north.
- Residential properties on the southern end of Rickard Avenue, to the north-west.

Figure 2 shows the location of the zoo and the surrounding area. The green and blue shaded areas show the approximate zone of the proposed African Savannah and Congo Exhibit works (including associated changes to animal enclosures). The residential receivers that will potentially be most affected by the operation of the proposal are highlighted in red. The blue boxes indicate noise measurement positions, which are described in the following section.

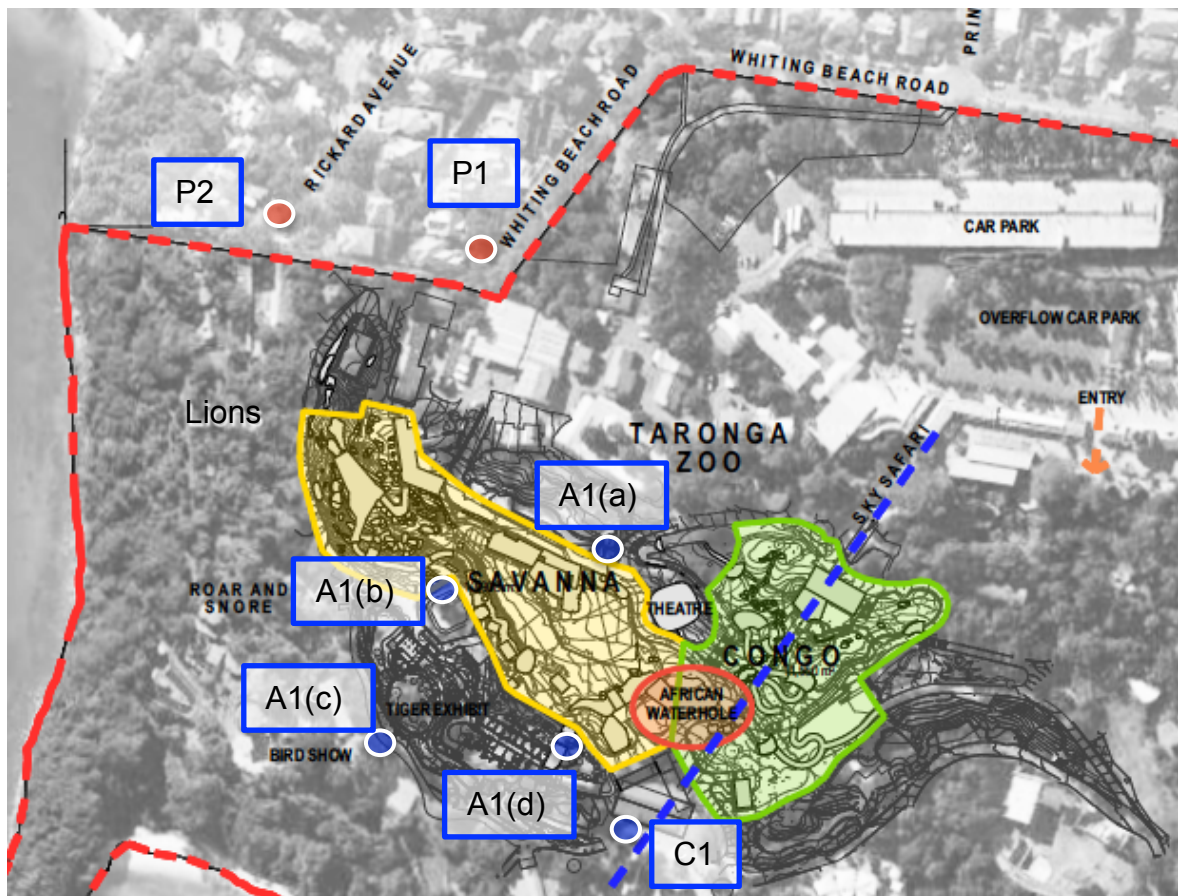


Figure 2: Location of proposed African Savannah and Congo Exhibit in relation to noise-sensitive receivers outside the zoo.

3 Existing Noise Environment

3.1 Noise survey approach

Environmental noise assessments for upgrade developments require an understanding of existing environmental noise in the absence of the development, to determine how audible and noticeable the development noise will be once the development is complete.

Noise surveys have been carried out by Acoustic Studio at the site and its surrounds in April and May 2015 and April and May 2017 to determine the ambient and background noise levels affecting the site and at the nearest noise sensitive receivers, and to measure the existing noise levels generated by the zoo.

Long-term (unattended) noise monitoring was carried out, in combination with attended observations.

3.2 Observations

Typically, road traffic around the site is governed by people driving to the zoo during the day, and by local residential traffic in the evening and night. Frog noise became audible after the afternoon measurements finished. Aircraft noise is relatively insignificant, and is generally restricted to a few commercial seaplanes, helicopters and passenger jets flying at a distance. Some ferry noise from the harbour may at times be indistinctly audible at quiet times during the night. There are no industrial noise sources in the near vicinity.

3.3 Noise Monitoring Locations

Noise surveys have been carried out by Acoustic Studio at the site and its surrounds in April 2015 and April 2017 to determine the ambient and background noise levels affecting the site and at the nearest noise sensitive receivers.

A residential construction site at Whiting Beach Rd was inactive for the duration of the 2015 monitoring, but was active in 2017 and was the reason for relocating the 2017 noise logger location to Rickard Avenue.

Long term unattended noise logging was conducted from Thursday 23th April to Tuesday 30th April, and Monday 4th May to Monday 11th May 2015, and 27th April to 5th May 2017. These noise monitoring periods were selected to obtain data from typical operations during school Term 2. The noise logging periods met the NSW Industrial Noise Policy requirement of obtaining seven days' worth of valid "school term" noise monitoring data.

A Brüel & Kjær Hand-held Analyser Type 2250, Serial Number – 2446899 was used to conduct attended noise monitoring. The calibration of the equipment was checked before and after the surveys with no variation in level observed.

Short-term attended measurements were carried out on two different occasions during April and May 2015 to obtain octave band data of the existing background and ambient noise levels in environmental receiver locations. Noise levels at key locations within the zoo were measured by Acoustic Studio in March 2014 for a previous Taronga Zoo project, and again in March 2017.

Environmental noise measurement times included the most sensitive period that the proposed spaces would be occupied, including for external maintenance and cleaning (ie external cleaning between 6:00 am and 6:00 pm, and internal cleaning at night).

Three attended measurement locations were selected as follows (refer to Figure 2):

- Location P1 - At street level, at the closest boundary of the Whiting Beach Road residences. This represents the existing noise environment at these residential property boundaries. Measurements were conducted in March 2014, April / May 2015 and March 2017. A residential construction site was inactive for the duration of the 2015 noise monitoring period; Acoustic Studio visited the site on four occasions to check this. Construction noise from the zoo premises was faintly audible during the March 2017 site. The March 2017 noise measurements indicated that the background noise levels have not changed significantly since the April 2015 detailed noise surveys, and the 2015 noise logger data are still relevant and usable for the purposes of this Acoustic Assessment.
- Location P2 - At street level, at the closest boundary of the Rickard Avenue residences to the north-west. This represents the existing noise environment at these residential property boundaries. Measurements were taken in March 2014.
- Location P3 – Within the zoo, at the existing walkway north of the proposed African Savannah and Congo Exhibit (north of the existing Giraffe exhibit). This location represents existing noise levels, to assess the change in noise level due to the project. The zoo was relatively quiet during the survey, and measurements represent typical lowest existing operational noise levels. Measurements were taken on a sunny, calm Saturday in March 2014.
- Location A1 – Within the zoo, near the various animal exhibits (in the vicinity of the proposed African Savannah and Congo Exhibit). The intent was to assess typical noise levels currently experienced by the animals and patrons during zoo operational hours. Measurements were taken in March 2014 and in March 2017.

Sav Shimada of Acoustic Studio Pty Ltd carried out the surveys.

3.4 Noise Monitoring Results

3.4.1 Long-term unattended noise monitoring

Unattended noise monitoring was carried out between 23rd and 30th April, and 4th and 10th May, 2015 at Location P1, to obtain overall A-weighted background and ambient noise levels. The April data set was measured using an RTA02 logger #0038, and the May data set was measured using an Airmet-DUO #10788.

The 2015 noise logger location was at the end of the cul-de-sac at Whiting Beach Road. A residential construction site was dormant at the time.

Additional noise monitoring was carried out between 27th April and 5th May 2017. The intent of the 2017 noise monitoring was to confirm that ambient and background noise levels have not changed since the 2015 monitoring. These measurements were taken using RTA02 logger #0038.

The 2017 noise logger location was at the end of the cul-de-sac at Rickard Avenue. In 2017, the Whiting Beach Road location was affected by residential construction site noise. While there are several residential construction sites around Rickard Avenue, the logger was located as far as possible from any active construction sites, and with line of sight blocked to any residential construction sites. Observations during March, April and May 2017 indicated that the Rickard Avenue site was generally unaffected by residential construction noise, apart from infrequent audible construction events from the residence near the Whiting Beach Road 2015 logger site.

Weather data was collected from the Bureau of Meteorology web site (www.bom.gov.au).

The measured noise levels were processed in accordance with the Industrial Noise Policy (see Section 5.2.1) to determine the Rating Background Level (RBL) and ambient noise conditions for Day, Evening and Night time periods. The INP method for determining RBLs was also applied for various construction scenarios, for standard construction hours and out of hours works. These levels are provided in Table 1 (Whiting Beach Road, 2015) and Table 2 (Rickard Avenue, 2017).

Date	Descriptor	Measured sound level, dB(A)		
		Day (07:00-18:00)	Evening (18:00-22:00)	Night (22:00-07:00)
Monday 27/4/15	Ambient, L_{eq}	Weather-affected	50	42
	ABL, L_{90}		33	32
Tuesday 28/4/15	Ambient, L_{eq}	Weather-affected	49	40
	ABL, L_{90}		31	30
Monday 4/5/15	Ambient, L_{eq}	(50 – not full data set)	46	45
	ABL, L_{90}	(36 – not full data set)	35	34
Tuesday 5/5/15	Ambient, L_{eq}	52	47	45
	ABL, L_{90}	42	41	34
Wednesday 6/5/15	Ambient, L_{eq}	51	47	46
	ABL, L_{90}	42	41	38
Thursday 7/5/15	Ambient, L_{eq}	(55 - Weather-affected)	51	49
	ABL, L_{90}	(44 – Weather-affected)	44	39
Friday 8/5/15	Ambient, L_{eq}	55	45	47
	ABL, L_{90}	37	37	37
Saturday 9/5/15	Ambient, L_{eq}	51	44	48
	ABL, L_{90}	41	40	37
Sunday 10/5/15	Ambient, L_{eq}	(50 - Weather-affected)	(50 - Weather-affected)	(60 - Weather-affected)
	ABL, L_{90}	(43 – Weather-affected)	(41 – Weather-affected)	(36 – Weather-affected)
Weekday construction period	RBL	41 (std hours)	41 (OOH)	37 (OOH)
Saturday construction period	RBL	41, 8am – 1pm (std hours) 40, 1 – 6pm (OOH)	40 (OOH)	37 (OOH)
Overall	Ambient, L_{eq}	53	48	47
	RBL, L_{90}	41	40	37

Table 1: Results of long-term unattended ambient & background noise monitoring – April and May 2015 – Whiting Beach Road.

Date	Descriptor	Measured sound level, dB(A)		
		Day (07:00-18:00)	Evening (18:00-22:00)	Night (22:00-07:00)
Thursday 27/4/17	Ambient, L_{eq}	56	48	50
	ABL, L_{90}	43	40	40
Friday 28/4/17	Ambient, L_{eq}	58	44	48
	ABL, L_{90}	41	37	38
Saturday 29/4/17	Ambient, L_{eq}	55	42	49
	ABL, L_{90}	40	38	37
Sunday 30/4/17	Ambient, L_{eq}	59	42	51
	ABL, L_{90}	40	37	37
Monday 1/5/17	Ambient, L_{eq}	54	48	48
	ABL, L_{90}	42	42	37
Tuesday 2/5/17	Ambient, L_{eq}	53	45	48
	ABL, L_{90}	41	40	38
Wednesday 3/5/17	Ambient, L_{eq}	54	44	51
	ABL, L_{90}	41	36	36
Thursday 4/5/17	Ambient, L_{eq}	55	43	49
	ABL, L_{90}	40	36	36
Weekday construction period	RBL	41 (std hours)	39 (OOH)	38 (OOH)
Saturday construction period	RBL	41, 8am – 1pm (std hours)	38 (OOH)	37 (OOH)
		39, 1 – 6pm (OOH)		
Overall	Ambient, L_{eq}	56	45	49
	RBL, L_{90}	41	38	37

Table 2: Results of long-term unattended ambient & background noise monitoring – April and May 2017 – Rickard Avenue.

Comparing the two sets of data show that:

- Day-time and night-time background noise levels are unchanged. These levels are the most important for assessing construction noise impacts (during standard day time hours), and sleep disturbance (during night time hours).
- Evening background noise levels were very similar, the Rickard Avenue RBL being 2dB below the Whiting Beach Road RBL.
- Ambient noise levels were within 3dB. Daytime and night time ambient noise levels at Rickard Avenue in 2017 were 2-3dB higher than those measured at Whiting Beach Road in 2015. Evening ambient noise levels at Rickard Avenue were 3dB lower than those measured at Whiting Beach Road in 2015. It is not clear what activities affect the ambient noise, particularly at night. Ambient noise levels do not affect the outcome of operational or noise assessments.

Importantly, the April-May 2017 unattended noise measurements demonstrate that background noise have not increased over the past two years (often termed “creeping background”).

3.4.2 Short-term Attended Measurements

Background and Ambient Noise Levels

Short-term noise monitoring was carried out in April and May 2015, and in March 2017, at Location P1 to obtain octave band background and ambient noise levels. These measurements were taken to augment and confirm noise logger data.

The measured noise levels at each location are provided in Table 3.

Location	Period	Date	Descriptor	Measured sound level, dB re 20 µPa									
				Overall dB(A)	Octave band centre frequency, Hz								
					31.5	63	125	250	500	1k	2k	4k	8k
P1: receiver	17:20-17:30 (Day)	Saturday 22/3/14	L _{eq}	41	52	48	54	39	35	33	28	26	24
			L ₉₀	35	48	43	35	32	31	31	26	18	17
P2: receiver	17:35-17:40 (Day)	Saturday 22/3/14	L _{eq}	39	50	48	52	38	34	32	26	25	24
			L ₉₀	34	47	41	35	31	31	30	26	16	16
P1: receiver	16:50-17:05 (Day)	Thursday 23/4/15	L _{eq}	50	56	58	55	51	47	43	41	34	26
			L ₉₀	35	49	43	36	31	31	30	28	18	16
P1: receiver	09:05-09:20 (Day)	Thursday 07/5/15	L _{eq}	54	62	60	53	57	44	39	40	45	37
			L ₉₀	48	54	54	48	42	39	35	30	28	25
P1: receiver	09:30-9:45 (Day)	Tuesday 28/3/17	L _{eq}	41	54	54	47	40	37	36	34	29	22
			L ₉₀	40	51	52	45	38	35	34	33	27	21
P2: receiver	11:30-11:45 (Day)	Tuesday 28/3/17	L _{eq}	55	67	63	55	51	51	51	47	40	33
			L ₉₀	54	63	59	54	49	49	50	45	38	31

Table 3: Results of short-term ambient & background noise monitoring at residential receivers.

The March 2017 measurements at Whiting Beach Road were affected by construction noise from Taronga Zoo. Unlike previous attended measurements, the March 2017 measurements were made during a very quiet time, with no pedestrian or road traffic events. This enabled Acoustic Studio to directly measure the Taronga Zoo construction noise at the P1 and P2 location, with very little contribution from other ambient noise sources. The measured construction noise level at P1 was 41dB_{L_{Aeq}(15min)} and was only 1-2dB above the measured background noise level.

4 Relevant Standard and Guidelines

4.1 Guidelines used for the Operational Acoustic Assessment

The following standards and guidelines are considered relevant to the project and have been referenced in developing the project noise criteria:

- Mosman Council Development Control Plan (DCP) 2012 – particularly the DCPs for Open Space and Infrastructure (2012), Business (2013) and Residential (amended 2013).
- Mosman Council Local Environment Plan (LEP) 2012.
- Sydney Regional Environmental Plan (SEPP SREP) (Sydney Harbour Catchment) 2005.
- Protection of the Environmental Operations (POEO) Act 1997.
- Environmental Planning and Assessment (EP&A) Act 1979.
- State Environmental Planning Policy (Exempt and Complying Development Codes) 2008.
- NSW Industrial Noise Policy (INP) 2000.

The following documents have been referenced to derive numeric noise criteria where not explicitly provided in the local and state planning documents listed above.

- NSW Industrial Noise Policy (INP) Application Notes (Sleep Disturbance).
- City of Sydney (CoS) Standard Conditions of Development Consent (SCDC) 2012.
- Office of Liquor Gaming and Racing (OLGR) “Sound Advice, Reducing the Risk of Noise Disturbance” 2009.
- World Health Organisation (WHO) “Guidelines for Community Noise” 1999.

Applicable guidelines for road traffic noise impacts are:

- NSW EPA *Road Noise Policy* (2011)
- Australian Standard AS 3671-1989 *Acoustics – Road traffic noise intrusion – Building Siting and Construction* (for guidance only; applies to siting of the receiver buildings).

It is understood that regular zoo patron and staff numbers are unlikely to change due to this project.

4.2 Guidelines used for the Construction Acoustic Assessment

This acoustic report does not examine in detail the potential impacts from construction noise and vibration on residential receivers, since methodology and timing of works have not been developed. A full construction noise and vibration impact assessment would need to be prepared by the contractor once the likely construction methods are developed.

The primary references are:

- The EPA *Interim Construction Noise Guideline* (2009)
- The EPA *Assessing Vibration – a Technical Guideline* (2006)

It will be necessary to examine potential impacts from construction vibration on both residential receivers and the structures within the zoo premises. Early works will include demolition of existing buildings and structures, excavation, and potentially vibration-intensive construction activities such as piling.

Once the demolition and construction details for the early works are developed, the contractor would need to determine a construction methodology that will ensure no adverse effects on the any nearby sensitive structures inside the Zoo. Vibration effects on the adjacent residential receivers will be also assessed at this time.

Historic buildings and structures have particular requirements for managing vibration effects on their cosmetic finishes and structure. The sensitive structures are to be assessed against Australian and international guidelines and standards, such as:

- Australian Standard AS 2187:2-2006 *Explosives - Storage and Use - Part 2: Use of Explosives*
- British Standard BS 7385:2-1993 *Evaluation and measurement for vibration in buildings Part 2*
- German Standard DIN 4150: Part 3-1999 *Structural Vibration Part 3: Effects of Vibration on Structures*.

Vibration effects on buildings is a specialist acoustic field and will require careful collaboration between the acoustic specialist, the structural engineer, and the construction engineer.

5 Project Operational Noise Criteria

5.1 External Noise Emission Criteria - General

5.1.1 Local Development and Environment Plans

Mosman Council Development Control Plan (DCP) 2012 and Local Environment Plan (LEP) 2012 refer to environmental noise impacts in qualitative terms. The DCPs for Open Space, Business (2013), Residential (amended 2013), and Infrastructure (2012) have been referred to in preparing this acoustic report. In particular, the Infrastructure DCP 4.6 Objective 2: Acoustic privacy describes general noise considerations only.

Sydney Regional Environmental Plan (SEPP SREP) (Sydney Harbour Catchment) 2005 is relevant to developments in Taronga Zoo. Noise impacts are not explicitly mentioned in the SEPP SREP.

5.1.2 Environmental Planning and Assessment Act (EP&A) 1979

The Environmental Planning and Assessment Act 1979 (EP&A Act) regulates the majority of planning approval and environmental impact assessment (EIA) requirements in NSW. Section 111 of the Act requires examination and consideration to the fullest extent possible of all matters affecting or likely to affect the environment by reason of its activities. Acoustic impacts are a common community concern to be addressed in an EIA.

5.1.3 Protection of the Environment Operations Act (POEO) 1997

The *Protection of the Environment Operations Act 1997* enables the Government to set out explicit policies and premise-based Environment Protection Licences (EPLs) which are regulated by the Environment Protection Authority NSW (EPA).

Taronga Zoo activities are conducted in accordance with Environment Protection Licence 1677, which contains no specific noise limits. Where an EPL contains no specific noise limits, accepted practice is to determine criteria in accordance with the POEO Act general provisions against the generation of “offensive noise”, applying numerical criteria obtained from applicable environmental noise policies and guidelines.

Defining “offensive noise” for the purpose of an acoustic assessment is not a simple matter. The Protection of the Environment Operations (POEO) Act 1997 defines “Offensive Noise” as follows:

(a) *that, by reason of its level, nature, character or quality, or the time at which it is made, or any other circumstances:*

(i) *is harmful to (or is likely to be harmful to) a person who is outside the*

premises from which it is emitted, or

(ii) interferes unreasonably with (or is likely to interfere unreasonably with) the comfort or repose of a person who is outside the premises from which it is emitted, or

(b) that is of a level, nature, character or quality prescribed by the regulations or that is made at a time, or in other circumstances, prescribed by the regulations.

The “regulations” referred to in (b) above are the POEO (Noise Control) Regulations (2008). Very few of these apply to African Savannah and Congo Exhibit activities. Whether noise from the African Savannah and Congo Exhibit activity is “offensive” therefore reduces, in most cases, to a question of whether it meets part (a) of the definition. There are no clear-cut criteria for this, but consideration can be given to:

- Whether the level of noise exceeds applicable goals and guidelines,
- Whether the nature, character or quality of the noise is “offensive” due to such characteristics as tonality, impulsiveness or verbal content,
- Whether the time at which it is made is problematic, such that it could interfere with sleep, or school examinations, etc.

The EPA Noise Guide for Local Government (DECCW, 2009) provides a checklist for offensive noise which can be applied to any noise-generating activities. In addition to the considerations listed above, the EPA checklist asks:

- Is the noise loud in an absolute sense? Is it loud relative to other noise in the area?
- Does the noise occur at times when people expect to enjoy peace and quiet?
- Is the noise atypical for the area?
- Does the noise occur often?
- Are a number of people affected by the noise?

The remaining consideration relates to “reasonable measures”. It may be reasonable, for example, to manage a noise issue arising from animal enclosures which have been relocated, or re-introduced to the area. It may not be ‘reasonable’, on the other hand, to expect a significant reduction in noise from typical existing patron and animal noise during normal zoo operating hours.

5.1.4 Defining environmental noise criteria

The noise definitions and conditions provided by the Mosman Council DCP, LEP and POEO are generally focused around a subjective assessment.

Acoustic Studio recommends determining suitable objective criteria for assessing offensive noise, for noise emissions from mechanical plant, sound systems and patrons.

Compliance with the criteria described in sections 5.2 and 5.4 will ensure that the general noise conditions described in this section (5.1) will be met.

5.2 External Noise Emission Criteria - Mechanical Plant

5.2.1 New South Wales Industrial Noise Policy (INP)

The INP provides the framework and process for deriving noise goals for consents and licences that enable the EPA to regulate industrial premises that are scheduled under the *Protection of the Environment Operations Act 1997*. The EPA INP Application Notes provides additional guidance on elements of the INP, including assessment of changes to existing premises (infrastructure and / or operations).

The INP applies to fixed facilities, commercial premises and individual industrial sources such as heating, ventilating and air conditioning (HVAC) equipment. It is also typically applied for general maintenance noise such as cleaning activities. It provides guidance on the methodology for determining limiting noise criteria designed for external noise emissions typically associated with mechanical plant.

The NSW INP defines environmental industrial noise goals in two ways. The goals apply at the most-affected point on or within the residential boundary and are location-dependent. They also depend on the occupancy: residential, commercial, educational, etc.

The INP considers the following when establishing the criteria:

- The *time of day* that the noise generating development will be in operation, defined by the following:
 - Day (7am to 6pm)
 - Evening (6pm to 10pm)
 - Night (10pm to 7am)
- The existing *Ambient* (L_{eq}) and *Background* noise levels (L_{90}) that surround the site.
- The *type of noise source* and its characteristics. The INP provides modifying factors for noise sources with certain characteristics that may potentially cause greater annoyance than other noise sources of the same level.

The residential **intrusiveness** criterion aims to control short duration noise impacts and is based on the existing background noise level, and is defined as:

$$L_{Aeq,15 \text{ minute}} \text{ from new noise source} \leq \text{Existing long-term } L_{A90, \text{Day/Evening/Night}} + 5.$$

The residential **amenity** criterion aims to maintain noise amenity for a particular land use. It defines recommended noise levels, called Acceptable Noise Levels (ANL), for different neighbourhood types. For example, the suburban residential ANLs are:

- Night time (7am to 6pm): 40 dBL_{Aeq} (11hrs)
- Evening (6pm to 10pm): 45 dBL_{Aeq} (4hrs)
- Night time (10pm to 7am): 40 dBL_{Aeq} (9hrs)

Modification factors apply to the amenity criterion when existing industrial noise exceeds the acceptable noise levels (refer Table 2.2 and Section 2.2.3 of the NSW INP). No modification factors apply to the residential receivers surrounding Taronga Zoo.

The NSW INP applies “penalty” or “correction” factors to account for particular noise characteristics such as tonal, low frequency dominant, or intermittent noise (refer Table 4.1 of the NSW INP). No penalty factors have been applied in this assessment of plant noise, based on the assumption that mechanical plant will be controlled at source to avoid intermittent, tonal, or low-frequency-dominant noise emissions.

Any non-operational period is excluded from an INP assessment. For the African Savannah and Congo Exhibit, it is assumed that some mechanical plant may be in operation 24 hours a day (fridges, freezers and server room air conditioning units), and that there will be limited facility maintenance activities (such as external cleaning activities between 6am and 7am, and internal cleaning at night).

5.2.2 Sleep disturbance

The potential for high noise level events at night and effects on sleep should be addressed in noise assessments.

The World Health Organisation (WHO) “Guidelines for Community Noise” 1999 suggest external noise levels of 55dBLAeq will result in negligible sleep disturbance effects. This ideal level does not account for intermittent noise events, or periods of higher noise.

The INP Application Notes provide guidance on the assessment of sleep disturbance based on the predicted event L_{Amax} or $L_{A1,1minute}$ noise levels at the receiver.

Acoustic Studio typically suggests setting a Sleep Disturbance criterion of:

$$\text{Event } L_{Amax} \text{ or } L_{A1,1minute} > \text{Night time RBL (background noise level)} + 15 \text{ dB.}$$

If the criterion is exceeded, then further assessment of sleep disturbance effects is warranted.

Because the proposed African Savannah and Congo Exhibit will not operate during night-time hours between 10pm and 7am, risks of Sleep Disturbance does not require assessment. The only plant which may operate 24 hours a day produces a steady noise which will have to meet INP Intrusiveness and Amenity criteria at residential receivers, and would therefore be at least 10dB below the applicable Sleep Disturbance Screening Levels.

Based on experience with existing audio-visual displays and construction activities at the zoo, Taronga Zoo has advised that a Sleep Disturbance assessment is not specifically required for the zoo animals, and that a detailed animal disturbance assessment would be conducted based on observations during operation.

5.2.3 Mechanical plant noise audible in zoo premises

There is no particular guidance for managing plant noise for patrons, staff and animals in the zoo.

Acoustic Studio recommends adopting a 55dBLAeq criterion for plant noise emissions to walkways, outdoor public and staff areas, and animal enclosures.

5.2.4 Summary of environmental noise criteria for mechanical plant

Based on the measured noise levels detailed in Section 3.4, and in accordance with the methodology outlined in the NSW INP, Table 4 details the corresponding limits of allowable noise emission from mechanical plant and general maintenance activities associated with the development at the nearest receiver boundaries.

Since this is a particularly low noise area, the existing background and ambient noise levels are lower than the Acceptable Levels that define the Amenity Criterion. Therefore compliance with the more stringent Intrusiveness Criterion will also ensure compliance with the Amenity Criterion.

Period	Noise source / activities	INP Criteria, dBA		
		Amenity L _{eq} (period)	Intrusiveness L _{eq} (15-minute)	Sleep disturbance, L ₁ (1minute)
Day (7am-6pm)	Mechanical plant	55 (receiver, zoo)	46	n/a
Evening (6pm-10pm)		45 (receiver) 55 (zoo)	45	n/a
Night (10pm-7am)	Mechanical plant, Cleaning and maintenance	40 (receiver) 55 (zoo)	42	52

Table 4: INP project specific criteria for external noise emissions from cleaning and maintenance activities and mechanical plant

5.3 Traffic noise criteria

This report assesses changes in character, location and potential increase in traffic noise associated with the project.

It is understood that regular zoo patrons and staff numbers are unlikely to increase due to this project. However, based on the Sumatran Tiger Exhibit traffic noise studies, a similar temporary increase may be expected after the African Savannah and Congo Exhibit opens, potentially increasing patronage by 10%, from 1550-1910 vehicles to 1705-2100 vehicles per day¹. Traffic noise due to construction activities should also be assessed.

Any additional traffic generated by this proposal needs to be assessed in accordance with the following guidelines:

- NSW EPA *Road Noise Policy* (2011).
- Australian Standard AS 3671-1989 *Acoustics – Road traffic noise intrusion – Building Siting and Construction* (for guidance only; applies to siting of the receiver buildings).

The Road Noise Policy is applicable to traffic-generating developments including major road infrastructure developments. The emphasis is on achieving a reasonable balance between what is achievable on different road types and the sensitivity of different receiver types to road traffic noise. This is not directly relevant to the African Savannah and Congo Exhibit proposal as it does not include any new or upgraded road infrastructure.

The Australian Standard has a different emphasis, in that it aims to identify appropriate intrusive road traffic noise criteria in different building types. This is not applicable to the African Savannah and Congo Exhibit site as it is located well within the zoo grounds.

In the absence of directly applicable guidelines, policies or standards for assessing road traffic noise impacts from the African Savannah and Congo Exhibit, Acoustic Studio's approach is to examine the increase in traffic noise events and levels for most-affected sensitive receivers.

This acoustic report does not assess bus noise as the proposal will not change use of the existing bus operations serving the zoo.

¹ *Taronga Zoo Proposed Sumatran Tiger Adventure – Traffic Impact Assessment Issue C*, GTA Consultants 23/03/2015

5.4 External Noise Emission Criteria – Patrons and Sound Systems

5.4.1 Office of Liquor, Gaming and Racing – Licenced Premises

The OGLR has published guidance material on controlling noise from licenced premises. While it may not be directly applicable to the African Savannah and Congo Exhibit, it provides a method of determining quantitative noise targets for sound system and patron noise, which are not explicitly covered by the NSW INP.

Acoustic Studio considers that the OLGR environmental noise criteria for sound systems and patrons serve as a useful reference level for assessing noise emissions from the African Savannah and Congo Exhibit.

The OLGR suggests the following typical environmental noise criteria for patron and venue sound system noise. These criteria apply at the boundary of the nearest affected residential receivers.

- 7am to 12am (midnight): L_{A10} from the premises are not to exceed the existing background noise level by more than 5dB, in any octave band from 31.5Hz to 8kHz inclusive.
- 12am (midnight) to 7am: L_{A10} from the premises are not to exceed the existing background noise level, in any octave band from 31.5Hz to 8kHz inclusive.

Aspects to note regarding the application of the above are:

- Noise from the premises are defined as a statistical measure (the top 10% noise level), but there is no definition as to how long the premise noise is to be measured for. Acoustic Studio has adopted the 15-minute measurement period defined in the City of Sydney Standard Conditions of Development Consent condition 62 (general noise).
- The “background level” is not explicitly defined. Acoustic Studio determines the existing background noise level in accordance with the NSW Industrial Noise Policy (INP) 2000. The Day, Evening and Night time background noise levels are used to determine environmental noise criteria.

5.4.2 City of Sydney - Standard Conditions of Development Consent (CoS SCDC)

The CoS SCDC offers a relevant reference for noise emissions from entertainment venues, as it provides measurement periods not defined by the OLGR. The African Savannah and Congo Exhibit will operate as an unlicensed premise.

General

The CoS SCDC notes the following general requirements for noise control.

“...(62) *NOISE – GENERAL*

- (a) *The emission of noise associated with the use of the premises including the operation of any mechanical plant and equipment shall comply with the following criteria:*
- i. *The LAeq, 15minute noise level emitted from the use must not exceed the background noise level LA90, 15minute by more than 5dB when assessed at the boundary of any affected residence.*
 - ii. *The LAeq, 15minute noise level shall be adjusted for modifying factors in accordance with Appendix 2 of the Noise Guide For Local Government published by DECCW.*
 - iii. *The background noise level shall be measured in the absence of noise emitted from the use in accordance with Australian Standard AS 1055.1-1997-Description and measurement of environmental noise.*
 - iv. *The use of the premises shall be controlled so that any emitted noise is at a level so as not to create an "offensive noise" as defined in the Protection of the Environment Operations Act 1997 to any affected residence.*

5.4.3 Sleep Disturbance Criteria

Some short-duration noises that occur at night may comply with the criteria described above, and yet be undesirable because of the sleep arousal effect, particularly between the hours of 10pm and 7am.

Since the African Savannah and Congo Exhibit will close to visitors by 4:30pm, a sleep disturbance assessment for patron and sound system noise is not required.

5.4.4 Noise Emission Criteria for African Savannah and Congo Exhibit (patrons and sound systems)

All patrons will have left the Taronga Zoo premises by 6pm. Therefore only the Day-time criteria are assessed.

The adopted OLGR criteria for the African Savannah and Congo Exhibit, outdoor areas and walkway noise emissions are detailed in Table 4. As noted in section 5.4.1, the background noise level is determined in accordance with the INP, and noise criteria are determined for Day-time periods.

For assessment purposes, the lowest background noise levels measured in octave bands and the associated Project Criteria ($L_{10} \leq L_{90} + 5\text{dB}$) are detailed in Table 5. If the INP approach is taken to determine 7am to 6pm background noise levels, then the applicable OLGR criterion would be up to 7dB above the conservative project criteria presented in Table 5.

Location	Period	Description	Measured sound level, dB re 20 μ Pa									
			dB(A)	Octave band centre frequency, Hz								
				31.5	63	125	250	500	1k	2k	4k	8k
Nearest Residential Receiver Boundary	7am to 6pm (Day)	Lowest Measured Day-time Background Noise Level, L ₉₀	34	47	41	35	31	31	30	26	16	16
		Project Criteria, L ₁₀	39	52	46	40	36	36	35	31	21	21

Table 5: Patron and sound system noise recommended criteria at nearest residential receiver boundary (based on OLGR 7am to midnight, with lowest background levels measured 7am to 6pm)

5.5 External Noise Emission Criteria – Lions

5.5.1 New South Wales Industrial Noise Policy (INP) – for reference

As discussed in Section 5.2.1, the NSW INP applies to fixed facilities, commercial premises and individual industrial sources such as heating, ventilating and air conditioning (HVAC) equipment, and provides guidance on the methodology for assessing external noise emissions from mechanical plant.

The NSW INP is not strictly applicable to zoo activities and particularly animal noise sources. In the absence of directly applicable noise guidelines on animal noise, however, the INP serves as a useful framework for assessing the impacts of lions roaring, at any time of the Day, Evening or Night.

Of particular relevance is the application of a “penalty” or “correction” factors to account for particular noise characteristics which are known to be annoying or disturbing such as tonal, low frequency dominant, or intermittent noise (refer Table 4.1 of the NSW INP).

An “intermittent” noise penalty would be applied to events from lions roaring at night. This means that when the time-averaged equivalent noise level ($L_{Aeq(15min)}$ or $L_{Aeq(Day/Evening/Night)}$) is predicted, a 5dB penalty is added to the predicted level before comparing with applicable criteria.

There are no criteria applying to lion noise; however the NSW INP Amenity and Intrusiveness Criteria presented in Table 4 serve as a useful reference.

5.5.2 Sleep Disturbance Criteria

A potential sleep disturbance noise source is lions roaring at night. Given that the Lion Enclosure will be located near the western boundary of the Zoo, relatively close to residential streets, the impact of night-time lion roars needs to be assessed.

The INP Application Notes provide guidance on the assessment of sleep disturbance based on the predicted event L_{Amax} or $L_{A1,1minute}$ noise levels at the receiver. It suggests setting a Sleep Disturbance criterion of:

$$\text{Event } L_{Amax} \text{ or } L_{A1,1minute} > \text{Night time RBL (background noise level)} + 15 \text{ dB.}$$

If the maximum noise emergence above background is less than 15 dB, then the noise is considered unlikely to cause sleep disturbance. If the screening test level is exceeded, then further assessment of sleep disturbance effects is warranted.

At the nearest residential receivers at Rickard Avenue and Whiting Beach Road, the sleep disturbance screening level is $37+15 = 52\text{dB(A)}$.

The sleep disturbance criterion $L_{A1, (1 \text{ minute})}$ not exceeding the $L_{A90, (15 \text{ minute})}$ by more than 15 dB(A) is a screening criterion, not an absolute goal for the purpose of assessing impact from a project. It applies outside bedroom windows during the night-time period.

If the Sleep Disturbance screening criterion is exceeded, the detailed analysis should cover the extent to which the maximum noise level exceeds the background level and the number of times this happens during the night-time period. Some guidance on possible impact is contained in the review of research results in the NSW *Road Noise Policy* (2011).

Other factors that may be important in assessing the extent of impacts on sleep include:

- How often high noise events will occur
- Time of day (normally between 10pm and 7am)
- Whether there are times of day when there is a clear change in the noise environment (such as during early morning shoulder periods).

A further consideration for sleep awakening is whether the environmental noise has changed. The NSW *Road Noise Policy* (RNP, 2011) Section 5.3 “Response to a Change in Noise Level” states:

While people may express a certain tolerance for their existing noise environment, they may feel strongly about increases in noise. [...] The difference in reported awakenings from sleep was equivalent to a difference of 7 dB in maximum noise levels.

The RNP Section 5.4 “Sleep Disturbance” states that from the research on sleep disturbance to date it can be concluded that:

- Maximum internal noise levels below 50–55 dB(A) are unlikely to awaken people from sleep
- One or two noise events per night, with maximum internal noise levels of 65–70 dB(A), are not likely to affect health and wellbeing significantly.

The internal noise levels provided in the RNP are related to potential sleep awakenings.

Typically noise impact assessments consider the worst case scenario, when residential receivers have windows open sufficiently to provide natural ventilation. This would result in approximately 10dB attenuation from outside to inside, through the open window. This situation is considered likely during warmer seasons.

When windows are closed, the likely sound attenuation through standard windows with poor seals (common in older houses) is approximately 20dB.

Based on a minimum attenuation of 10dB(A) with windows open, the first conclusion of the RNP suggests that short term external noises of 60 to 65 dB(A) are unlikely to cause awakening reactions. In addition, external levels of 75 to 80dB(A) are unlikely to affect health and wellbeing significantly, provided that these events occur no more than twice in one night.

5.6 Summary of Operational Noise Emission Criteria for the African Savannah and Congo Exhibit

Table 6 below summarises the overall A-weighted environmental noise criteria for all noise sources from the African Savannah and Congo Exhibit. They apply at the most-affected residential receiver boundaries.

Period	Mechanical plant, cleaning and maintenance		Sound systems / patrons	Lions
	Amenity $L_{eq}(\text{period}), \text{dBA} \leq \text{ANL}$	Intrusiveness $L_{eq}(15\text{-minute}), \text{dBA} \leq \text{RBL} + 5\text{dB}$	OLGR, $L_{10}(15\text{minute}), \text{dBA} \leq \text{RBL} + 5\text{dB}$	Sleep Disturbance $L_1(1\text{min}), \text{dBA} \leq \text{RBL} + 15\text{dB}$
Day (7am-6pm)	55 (nearest receiver) 55 (zoo outdoor areas)	46	46	n/a
Evening (6pm-10pm)	45 (nearest receiver) 55 (zoo outdoor areas)	43	43	n/a
Night (10pm-7am)	40	42	42 (n/a)	Sleep Disturbance 52 Sleep Awakening 65

Table 6: Summary of project noise criteria (overall levels) at nearest residential receivers

6 Operational Assessment and Recommendations

The proposal has been assessed based on information provided by Taronga Zoo Conservation Society.

6.1 Operational Assessment Methodology

The acoustic assessment has considered the following:

- The African Savannah and Congo Exhibit will generally be open and in use during zoo opening hours, and will close by 5pm. Some cleaning and maintenance activities may take place between 5pm and 10pm (evening).
- Noise levels from the Exhibits and outdoor areas have been considered as continuous source over a 15-minute assessment period to provide a worst-case.
- Noise predictions at the nearest residential receiver boundaries consider the total noise contribution from all noise sources.
- Distance attenuation, with conservative estimates for attenuation due to shielding from buildings, intervening topography and ground absorption.
- Lowest measured background noise levels have been used to provide a worst-case scenario.
- Operational noise impacts on staff, patrons and animals are considered to be minimal as the zoo has been operating for almost 100 years with similar animals, and interactive experiences using sound systems have been used for well over 15 years.

6.2 Mechanical Plant Noise Compliance

Plant associated with the operation of the African Savannah and Congo Exhibit should be controlled to ensure external noise emissions are not intrusive and do not impact on the amenity of nearby receivers, including receivers within the zoo such as staff offices, public walkways and open spaces, and animal enclosures.

At this stage, final plant selections and locations have not been made; therefore a detailed assessment has not been carried out.

Most plant will operate during visitor hours. Fridges, freezers and server room air conditioning units will operate 24 hours a day.

In the absence of preliminary plant noise data or locations, Acoustic Studio makes the following general comments:

- The most restrictive criteria for the plant is 55dB(A) on open walkways and outdoor spaces nearest any mechanical inlet, outlet or outdoor unit. The nearest residential receiver is over 80m distant, with topographical screening. Achieving the 55dB(A) criterion within the zoo premises will ensure compliance with the relevant criteria at all other receivers.
- Attenuation and / or internally-lined ductwork may be required for fans in order to meet the both internal and environmental noise criteria.
- Noise emissions from the external plant may be controlled via a combination of:
 - locating the units as far from transient or occupied areas as possible;
 - with natural screening provided by existing zoo buildings, structure and topography; and
 - additional localised acoustic screening as required.

During the detailed design stage, the acoustic consultant should provide detailed design advice to the architect and mechanical engineer to ensure that noise emissions from mechanical plant are effectively controlled to meet the relevant criteria at the nearest receiver boundaries.

Noise emissions from general maintenance and cleaning activities may need management controls such as time restrictions particularly for external area maintenance activities.

6.3 Patron and Sound System Noise

6.3.1 Source Noise Levels

Table 7 shows typical sound levels expected from different uses and sources in the African Savannah and Congo Exhibit.

The patron source noise levels are considered to be very conservative (ie higher than expected in practice), as it is generally unlikely that all patrons will be speaking at once – there will generally be at least one listener for each speaker. However this conservative approach has been adopted to account for the potential for worst-case scenario.

Voice generate directional sound, which is frequency dependent. As a conservative screening estimate, no directional attenuation has been accounted for in the environmental noise predictions. This is unrealistic but simplifies the calculations to assist in identifying any potential of environmental risk. If the simple screening calculation without directivity

shows no excess of environmental noise criteria, then it is safe to assume that the actual noise levels will be lower and will also comply.

Description	Sound pressure level, dB re 20µPa									
	Overall dB(A)	Octave band centre frequency, Hz								
		31.5	63	125	250	500	1k	2k	4k	8k
L ₁₀ of 1 adult male speaking with moderate voice	59	38	42	52	58	60	52	46	43	37
L ₁₀ of 1 adult male speaking with raised voice	68	50	52	56	62	67	64	57	52	45
L ₁₀ of 100 patrons speaking all at once	+20	+20	+20	+20	+20	+20	+20	+20	+20	+20
Measured L ₁₀ of a group of approximately 30 children	76	55	58	55	50	53	66	74	53	41

Table 7: Sound levels (L₁₀) likely to be generated by patrons visiting the African Savannah and Congo Exhibit

6.3.2 Patron noise assessment

Patron noise from the African Savannah and Congo Exhibit and associated outdoor areas and walkway has been estimated for the following scenario.

- General patron noise from up to 100 people, speaking in raised voices, waiting *in the outdoor area outside the Lion Enclosure* during zoo opening hours. This is unlikely to occur due to space limits. However this scenario has been assessed as a worst case situation which may occur for the first few months after the lions are re-introduced to Taronga Zoo Mosman, as they are expected to be a major attraction when the exhibit opens;
- Noise *from the walkway* has been estimated for 60 people walking along a distributed path, speaking in moderate voices as they walk to or from the African Savannah and Congo Exhibit during zoo opening hours.

The residential receivers are shielded from the African Savannah and Congo Exhibit and associated walkways by natural topography. A conservative 5dB sound attenuation due to screening has been applied to account for this.

Period	Location and condition	Description	Sound pressure level, dB re 20 µPa									
			dB(A)	Octave band centre frequency, Hz								
				31.5	63	125	250	500	1k	2k	4k	8k
7am to 6pm (Day)	Outdoor area, 100 people, raised voices	External Sound Level, L ₁₀	83	67	69	72	77	82	78	72	67	60
		Predicted Level at receiver, L ₁₀	34	22	22	25	30	35	31	25	21	13
		Environmental Project Criteria, L ₁₀	39	52	46	40	36	36	35	31	21	21
		Complies?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Walkway, 60 people, moderate voices	Estimated Sound Level at walkway, L ₁₀	73	53	57	67	72	74	65	60	57	51
		Predicted Level at receiver, L ₁₀	27	9	11	21	26	28	19	14	11	5
		Environmental Project Criteria, L ₁₀	39	52	46	40	36	36	35	31	21	21
		Complies?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 8: Predicted patron noise levels (L₁₀) at the nearest residential receiver due to African Savannah and Congo Exhibit operations

6.3.3 Interactive experience noise

Noise generated within the African Savannah and Congo Exhibit may include sound system noise from Public Address systems, interactive audio-visual displays, and educational audio experiences. This acoustic assessment assumes that many of the speaker systems are either fully open to the environment or located in buildings with doors that are often left open.

Allowable levels for the sound system, amplified music and speech, are provided as part of the assessment.

Period	Location and condition	Description	Sound pressure level, dB re 20 µPa									
			dB(A)	Octave band centre frequency, Hz								
				31.5	63	125	250	500	1k	2k	4k	8k
7am to 6pm (Day)	African Savannah (west)	Internal Direct Sound Power Level, L ₁₀	86	90	90	85	85	85	85	80	70	70
		Maximum Predicted Level at receiver, L ₁₀	35	44	43	37	35	35	34	29	19	19
		Environmental Project Criteria, L ₁₀	39	52	46	40	36	36	35	31	21	21
		Complies?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Congo (east)	External Sound Level, L ₁₀	90	95	95	90	90	90	85	80	75	75
		Maximum Predicted Level at receiver, L ₁₀	37	44	43	38	37	37	31	26	21	21
		Environmental Project Criteria, L ₁₀	39	52	46	40	36	36	35	31	21	21
		Complies?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 9: Allowable sound levels (L₁₀) sound systems at the African Savannah and Congo Exhibit, to meet environmental noise criteria at residential receiver locations

Table 9 indicates that the OLGR criteria (7am to 6pm) would be complied with for all scenarios at all octave bands.

It is noted that predictions are based on background noise criteria for the worst-case scenario (lowest measured existing background noise level) and the source noise levels are also assumed to be a worst-case scenario (i.e. noisiest likely), with contributions from simultaneous use / activities where applicable.

Therefore all scenarios are expected to comply with all criteria at the receiver boundaries at all times.

While the sound system levels provided above would meet environmental noise targets at residential receivers, further consideration of noise impacts on zoo staff, patrons and animals will be required during detailed design.

The sound system set up will most likely use directional speakers and volume inhibitors to minimise disturbance to zoo patrons outside the African Savannah and Congo Exhibit, zoo staff, and to animals in nearby enclosures. Careful design will also be required to ensure that noise transfer between African Savannah and Congo Exhibit sound systems will not be intrusive, and that the interactive experiences in each Exhibit are adequately protected from external noise.

6.3.4 Lion noise

Although lions have been part of the Mosman Taronga Zoo experience for many years, they were relocated to Taronga Western Plains Zoo on 12 December 2015. The proposal is for the lion enclosure to be moved to a location which is approximately 90m nearer to residences to the west than the previous enclosure, and with less topographic shielding.

Lions communicate through roaring behaviour. The available literature suggests that lions in the wild roar particularly at night when they are most active. Although Taronga Zoo staff have advised Acoustic Studio that the lions in captivity at Taronga Zoo rarely roar at night, but mainly roar morning and evening, for completeness an assessment of potential sleep disturbance due to lions' roaring has nevertheless been conducted as part of the operational noise assessment.

The literature and research available on lion's roaring behaviour appears to be limited to observations of lion prides in the wild, such as at Serengeti and Ngorongoro National Parks in Tanzania². It is not clear from the available literature whether the roaring behaviour of lions in the wild differs from that in captivity. Taronga Zoo staff advise that their experience is that lions in captivity roar very infrequently at night. For the purposes of this environmental noise assessment, it is conservatively assumed that lions in the zoo will behave similar to lions observed in the wild.

Lion roaring behaviour is described by McComb *et al* as follows:

Female lions deliver their roars in bouts which generally last less than a minute and consist of several soft introductory moans, a series of full throated roars and a terminating sequence of grunts. When pride members roar together the bout is delivered in chorus, one individual initiating and others joining in a the bout progresses by adding their roars in an overlapping fashion.

Acoustic Studio observed this behaviour at Perth Zoo, with a lion and lioness together in a single exhibit area. Typically the lion (male) initiated the roaring behaviour and the lioness (female) joined in. Each of the five roaring behaviour events lasted for 40-50 seconds.

McComb *et al* and Grinnell & McComb describe up to 18 adult females and their dependent offspring in a single pride, and one to nine resident males forming a "coalition group". Each group marks their territory through scent marking and roaring.

McComb *et al* suggest that female prides roar relatively infrequently unless encountering other prides when they may have approximately 1 roaring bout in every three hours. Males, on the other hand, tend to roar more frequently than females, with up to two roaring

² *Roaring and social communication in African lions: the limitations imposed by listeners*, J Grinnell & K McComb, *Animal Behaviour* 2001, 62, 93-98; *Roaring and Numerical Assessment in contests between groups of female lions, Panthera leo*, K McComb, C Packer, Anne Pusey, *Animal Behaviour* 1994, 47, p379-387.

bouts per hour at night. This could potentially mean eighteen roaring events over a night-time period, although as stated previously it is likely that lions in captivity roar far less frequently than those in the wild.

A literature review of lions' roar noise levels indicates that the sound level may be up to 110-114dB(A) at 1m.

Acoustic Studio has visited the Perth Zoo lion exhibit and measured five lion roaring events on 3 October 2016. These measurements presented in Table 10 showed that there was very little variation in the five roaring event noise levels, at 84-89dB_{LAeq(45-60sec)} and 100-104dB_{LAmax} at 1m. These measured levels at Perth Zoo were approximately 10-14dB below the 114dB(A) maximum level which is often quoted in the literature on lions' roars.

Measured sound level, dB _{LAeq(60sec)} , dB re 20 µPa									
Overall dB(A)	Octave band centre frequency, Hz								
	31.5	63	125	250	500	1k	2k	4k	8k
87	(65)	(75)	92	91	87	76	(66)	(43)	(50)
85	(69)	(80)	95	91	76	78	(66)	(56)	(47)
84	(81)	(78)	88	87	84	76	(66)	(57)	(58)
84	(66)	(66)	87	84	85	76	(65)	(60)	(50)
89	(78)	(80)	96	92	88	82	(69)	(65)	(68)

Table 10: Results of sound pressure level measurements of lion roaring behaviour at Perth Zoo, with derived estimates in parentheses where ambient noise levels were within 10dB of measurements during lions' roars.

The distance attenuation between the Lion Enclosure and the nearest residential receiver 80m away is 38dB. The shielding due to topography is conservatively assumed to be 5dB.

This means that a single lion's roar may be as loud as 71dB(A) but would more typically be 58-61dB(A) at the nearest receiver window. This is above the 52dB(A) Sleep Disturbance Screening Level, which means that further assessment is warranted.

The highest predicted level from a lion's roar outside a window is 6-11dB above the Sleep Awakening Level. This means that sleep awakening events due to lion's roars is a potential risk for the proposal when receiver bedroom windows are kept open. Typical roaring, as measured by Acoustic Studio for five events at Perth Zoo, is below the Sleep Awakening Level. In addition, Taronga Zoo staff advise Acoustic Studio that it is their experience that lions at the zoo do not exhibit roaring behaviour at night, when they are kept in their enclosures in temperature-controlled comfortable conditions quite different to the wild.

The lion noise has also been assessed against night time INP criteria, as a guide for the assessment of noise impact; lion noise is not considered to be "industrial" type noise. Each

roaring event was measured as lasting 45 seconds and with a sound energy average of 84-89dB_{L_{Aeq}(45-60sec)}.

If the lions roar twice an hour, which is the maximum observed in wild populations by Grinnell & McComb, the overall night-time noise generated by the lions at the nearest residential receiver would be 39dB_{L_{Aeq}(9hour,Night)} or 42dB_{L_{Aeq}(15min)}. These levels comply with the INP Amenity Level (40dB_{L_{Aeq}(9hour,Night)}) and the Intrusiveness Level (42dB_{L_{Aeq}(15min,Night)}). It is noted that these calculations assume that lions roar as loud as possible each time, which appears to be unlikely based on the far lower levels measured by Acoustic Studio at Perth Zoo.

In order to manage the potential for Sleep Awakening, ideally any mitigation proposed would reduce the level at the receiver to be less than the Sleep Disturbance Screening Level. This requires at least 18dB overall level difference afforded by the noise mitigation approach.

An important acoustic feature of the lion's roar is the low frequency content, which is generally poorly attenuated by shielding (such as that afforded by the natural topography, or any solid fences). The fundamental one-third octave band centre frequency of lions' roars have been measured at approximately 180-195Hz for males and 200-210 Hz for females³.

This was confirmed during Acoustic Studio's measurements of lions roaring at Perth Zoo on 3 October 2016, which showed peaks at 125Hz and 250Hz.

Thus the most important attenuation octave band centre frequency for any noise mitigation structure is 125Hz and 250Hz. Approximately 10dB reduction at 125Hz and 19dB reduction at 250Hz is required to meet night time background + 15dB levels at these frequencies.

Taronga Zoo has advised Acoustic Studio that lions are kept overnight in enclosures. A full enclosure should achieve an overall level difference of 20dB, even through standard construction windows and solid core doors with basic brush or weather seals. However to improve the low frequency sound attenuation performance, north- or west-facing door systems (door leaf, frame and seals) should be at least R_w35.

The enclosures should be constructed of solid brick or 100mm solid (core-filled) concrete block masonry to achieve a minimum sound insulation performance of R_w40 with 25-30dB R at 125-250Hz.

The roof of the lion's enclosures should not compromise the sound insulation performance of the doors and walls. Ideally the roof construction would achieve a performance of R_w40.

³ J Grinnell, C Packer, AE Pusey, *Cooperation in male lions: kinship, reciprocity or mutualism*, 1995 *Animal Behaviour* 49, pp. 95-105

Mitigation of noise within the enclosure would be important for both zoo staff and the lions themselves. A reverberant environment inside the enclosure could raise the perceived internal noise level. Typical bedding materials will reduce reverberant sound build up, and fibrous thermal insulation treatments to the underside of the roof would assist with reducing reverberant sound build up within the enclosure.

For lions in outdoor areas, a reduction of 18dB is not achievable through screening. Although the lions will be kept overnight in their enclosures, they are released early in the morning and this may occur prior to 7am, ie during the standard definition of Night time hours.

Methods to assist with reducing environmental noise levels from lions roaring in outdoor areas include:

- Locating lion outdoor areas as far from residential receivers as possible, or with more topographical shielding, ie locate buildings / enclosures between the outdoor areas and the zoo boundary.
- Locating night-time enclosures away from the zoo boundary, and orient doors and windows to face away from the zoo boundaries.
- Install weather-proof sound absorptive screening on walls and structures facing the outdoor lion areas. Examples are 100mm thick rockwool behind wire mesh. This should be located behind a protective screen so that lions cannot access the sound absorptive material.
- Install solid walls or fences to act as sound barriers. The aim is to improve the sound attenuation through shielding to 10-15dB at mid- to high-frequencies, and 5-10dB at low frequencies. Noise barriers are typically more effective either close to the source or close to the receiver. However the local topography may allow for an alternative location which effectively blocks the lion noise from receivers. The potential for visual impacts would need to be considered for any noise barrier that is visible from outside the Zoo premises.
- Partial enclosures, with solid walls facing the Zoo boundaries and solid (eg colourbond) canopies may assist with keeping noise from outdoor areas from propagating toward residential areas. Sound absorptive treatments on the underside of the canopy and walls would control sound reflections back into Zoo areas.

6.4 Traffic noise compliance

Based on the traffic noise assessment produced for the Sumatran Tiger Exhibit, it is understood that regular zoo patron and staff numbers are unlikely to change due to this

project⁴. However, it is expected that a similar 10% increase in patronage may occur temporarily after the redeveloped African Savannah and Congo Exhibit is opened. This translates to 25 to 30 additional vehicles per hour in the months after the new exhibit is opened.

Therefore a worst case noise scenario for traffic noise associated with the African Savannah and Congo Exhibit redevelopment is that all 30 cars will arrive or depart in one hour, at average speeds of 40-50km/hr on approach or departure along Bradleys Head Road.

Acoustic literature and guidelines, including the Association of Australian Acoustical Consultants' *Child Care Centre Guidelines* (2010) suggests using a sound power level for cars of 85-90dB_{L_{Aeq}(30sec)}, and for delivery trucks of 85-95dB_{L_{Aeq}(30sec)}. These sound levels have been adopted for this quantitative assessment of traffic noise.

Truck deliveries would be scheduled to occur outside the busiest traffic periods.

The temporary additional 10% traffic increase would total 120 seconds per hour. The resultant noise level increase due to the 10% additional cars introduced by the proposed development is 0.4 dB $L_{Aeq}(1hr)$, which is a small increase. The 30 additional cars over a one hour period when 300 cars typically pass by would not normally be noticeable.

6.5 Summary of predicted operational noise compliance

Table 11 summarises the zoo activities associated with the current proposal, and demonstrates compliance with the applicable noise criteria for general operational noise.

Temporary increases in road traffic noise during the first months of opening indicate negligible noise impacts to nearby residential receivers.

Residual noise impacts may occur from lions roaring at night. Although Taronga Zoo staff have advised that lions in captivity rarely roar in the night when housed in their temperature-controlled enclosures, they do roar when they are let out in the early morning and therefore the potential for sleep disturbance has been assessed and reviewed.

The loudest roaring behaviour from males may lead to Sleep Awakening events at night when windows are open at residential bedrooms, but not with windows closed. More typical measured levels from lion roaring behaviour at Perth Zoo were 6-8dB less than the peaks described in the literature, suggesting that Sleep Awakening events are unlikely to be caused by more typical roaring behaviour exhibited by lions in captivity.

⁴ *Taronga Zoo Proposed Sumatran Tiger Adventure – Traffic Impact Assessment Issue C*, GTA Consultants 23/03/2015

Period		Mechanical plant, cleaning and maintenance		Sound systems / patrons
		Amenity Leq (period), dBA	Intrusiveness, Leq (15minute), dBA ≤ RBL+ 5dB	OLGR, L10 (15minute), dBA ≤ RBL+ 5dB
Day (7am-6pm)	Criterion	55	46	45
	Complies?		Yes	Yes
Evening (6pm-10pm)	Criterion	45	43	n/a
	Complies?		Yes	n/a
Night (10pm- 7am)	Criterion	40	42	n/a
	Complies?	Yes	Yes	n/a

Table 11: Summary of compliance with project noise criteria at nearest residential receivers

7 Construction noise and vibration criteria

This acoustic report presents a high level review of the potential impacts from construction noise and vibration on residential receivers, as work methods and plans are not yet developed. A full construction noise and vibration impact assessment and management plan will be prepared by the contractor once the structure and likely construction methods are developed further.

7.1 Airborne noise management levels

7.1.1 Airborne noise management levels for residential receivers

The EPA *Interim Construction Noise Guideline* (ICNG, 2009) defines standard construction hours during which the construction Noise Management Level (NML, $L_{Aeq,15min}$) is 10dB above the applicable period background noise level. A strong justification is required for conducting works outside standard construction hours, and the NML during these periods is significantly lower.

The ICNG also defines “Highly Affected” levels for daytime works, above which point there may be a strong community reaction against the noise. Acoustic Studio has assumed Evening Highly Affected Levels equal to 10dB below the Day-time Highly Affected Level. Night time Highly Affected Noise Levels are set to 5dB below the Sleep Disturbance screening test level.

Table 12 summarises the applicable residential construction noise criteria for different time periods during the week.

Period	Monday to Friday	Saturday	Sunday / Public Holiday	Highly Affected Level
Day: Standard construction hours	51 (7am – 6pm)	51 (8am – 1pm)	-	75
Day: Out of hours	-	44 (1pm-6pm)	45 (7am-6pm)	75
Evening (6pm-10pm)	44	43	42	65
Night (10pm-7am)	43	42	42	52

Table 12: Construction noise criteria (overall levels, $L_{Aeq,15min}$) at nearest residential receivers

7.1.2 Airborne noise management levels for non-residential receivers

Construction noise impacts on zoo staff and patrons need to be assessed.

The Taronga Food Market is located between the African Savannah and Congo Exhibits, and would be considered a commercial receiver within the zoo. The ICNG provides recommends a $70\text{dB}_{\text{Leq}(15\text{min})}$ external construction noise management levels for commercial premises surrounding construction sites. This level is applicable to Food Market.

For internal noise levels, the ICNG refers to AS2107 as guidance. AS2107:2016 recommends a range of noise levels from continuous sources such as air conditioning, of 50-55dB(A) for supermarkets, and 45-55dB(A) for food courts. Generally ICNG internal airborne noise management levels are set 5dB above the AS2107 levels. Acoustic Studio recommends an airborne construction noise management level inside the Food Court of $55\text{dB}_{\text{Leq}(15\text{min})}$.

For pedestrian walkways, Acoustic Studio recommends applying a construction noise management level of $60\text{-}65\text{dB}_{\text{Leq}(15\text{minutes})}$. This is 5-10dB higher than recommended levels in outdoor recreation areas in various environmental noise guidelines including the NSW EPA rail and road noise guidelines. It is also 8-11dB above measured background noise levels, and 2-8dB above ambient levels with groups of children, measured inside Taronga Zoo in March 2017. Due to the temporary nature of the construction and the transient use of the walkways, this is considered an appropriate target.

7.2 Ground borne noise management levels

The ICNG recommends ground-borne noise management levels at residences affected by nearby construction activities. Ground-borne or structure-borne noise is noise generated by vibration transmitted through the ground or structure and is re-radiated as audible airborne noise.

The ground-borne noise levels presented in Table 13 below are for evening and night-time periods only, as the objectives are to protect the amenity and sleep of occupants during the more sensitive time periods.

Time of Day	Management level $L_{\text{eq}}(15\text{ min})$
Evening (6pm to 10pm)	40 dB(A) - Internal
Night (10pm to 7am)	35 dB(A) - Internal

Table 13: Residential construction noise criteria for ground-borne noise

Acoustic Studio considers that it is highly unlikely that structure-borne noise will be audible above airborne noise for commercial receivers at the Zoo. There is no risk of structure-borne noise at the nearest residential receivers due to the distance attenuation

through ground between works and receiver buildings. Therefore structure borne noise has not been predicted and assessed in detail in this report.

7.3 Vibration effects on structures

Once the structural details for the works are developed, a construction methodology will be determined that will ensure no adverse effects on any sensitive structures and sites.

Typically the applicable vibration criteria for cosmetic damage to historic or heritage structures are taken from German Standard DIN 4150: Part 3-1999 *Structural Vibration Part 3: Effects of Vibration on Structures*. A short-term vibration velocity limit of 3mm/s (<10Hz) and 3-8mm/s (10-50Hz) is typically applied to historic or heritage buildings. Swiss Standard SN 640-312:1978 suggests slightly lower limits for steady state vibration. The duration of the works must be considered when determining the most relevant criteria.

Acoustic Studio recommends adopting German Standard DIN4150 criteria for heritage or historic structures. This should be the limiting criterion on site, and meeting this criterion will ensure that commercial vibration criteria are also met.

Figure 3 below summarises vibration targets to protect buildings from cosmetic building damage. If vibration measurements are conducted in third octave bands (Hz), then the on-site limit curve shall apply. If vibration measuring equipment is only capable of measuring overall peak levels, then a peak particle velocity limit of 3mm/s (rms) shall apply on site.

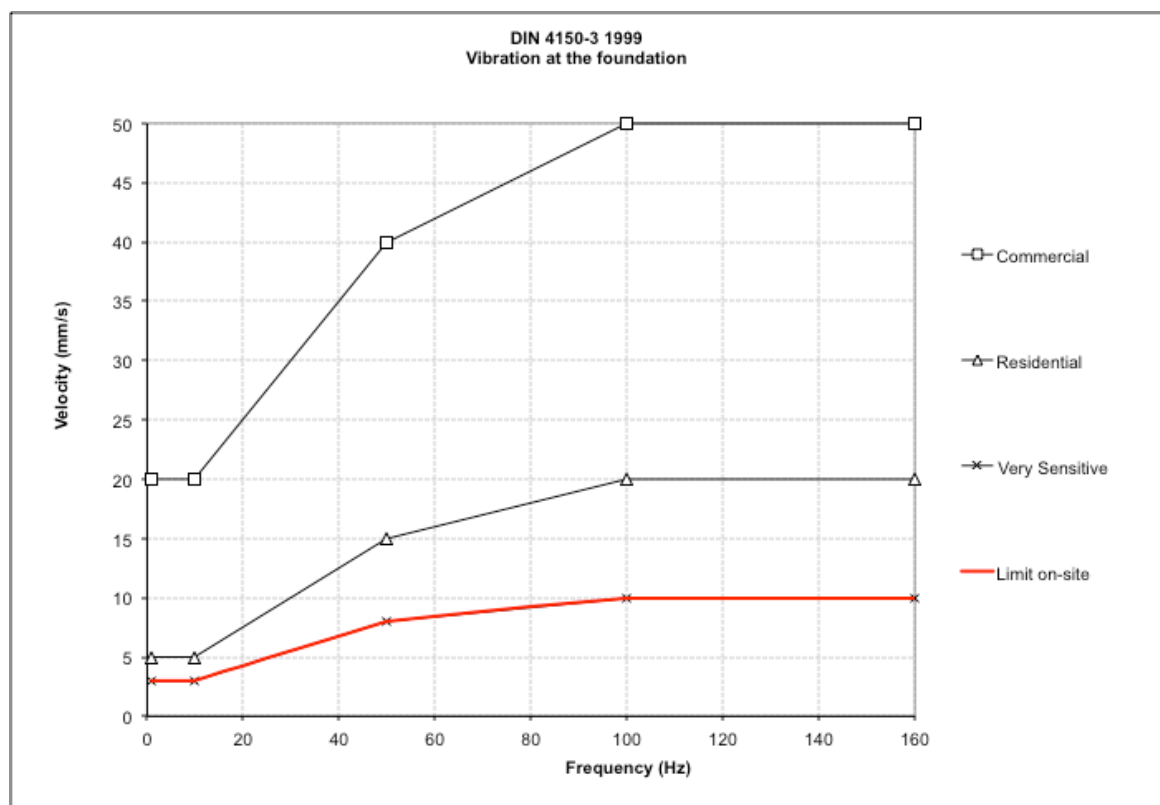


Figure 3: Vibration targets for protecting heritage and historic structures ("very sensitive"), and typical residential and commercial receivers.

7.4 Vibration effects on humans

The DEC guideline “*Assessing Vibration: a technical guideline, 2006*” provides suitable criteria that can be applied to the assessment of vibration and human comfort. The guideline makes reference to the British Standard BS 6472: 1992, which shares many similarities to the Australian Standards AS 2670.2: 1990.

The guideline provides vibration levels for which there is a low probability of comment or disturbance to building occupants. The criterion also considers the type of vibration being assessed, namely continuous, impulsive and intermittent vibration. Examples of these vibration types are provided in Table 14 below.

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

Table 14: Examples of vibration source types

There are no direct references for allowable vibration levels for Zoo exhibits and back of house areas. However, a useful reference is the criteria for human exposure to continuous and impulsive vibration are detailed in Table 15 that follows. Vibration levels are assessed through the consideration of the summation of effects for vibration levels at frequencies from 1 to 80 Hz for all axes.

Location	Assessment period	Preferred Values		Maximum Values	
		z-axis	x- and y-axes	z-axis	x- and y-axes
Continuous vibration					
Offices, schools, educational institutions	Day or night time	0.020	0.014	0.040	0.028
Workshops	Day or night time	0.04	0.029	0.080	0.058
Impulsive vibration					
Offices, schools, educational institutions	Day or night time	0.64	0.46	1.28	0.92
Workshops	Day or night time	0.64	0.46	1.28	0.92

Table 15: Preferred and maximum weighted rms values for continuous and impulsive vibration acceleration (m/s²) 1-80 Hz

Note: Daytime is 7am-10pm and night time is 10pm to 7am.

Human exposure to intermittent vibration is assessed using the Vibration Dose Value (VDV). The VDV accumulates the vibration energy experienced over an extended period (daytime and night-time periods) from intermittent events. Table 16 sets out the acceptable VDV values for intermittent vibration in similar uses of building to back of house and exhibit areas at Taronga Zoo.

Location	Daytime		Night-time	
	Preferred value	Maximum value	Preferred value	Maximum value
Residences	0.20	0.40	0.13	0.26
Offices, schools, educational institutions	0.40	0.80	0.40	0.80
Workshops	0.80	1.60	0.80	1.60

Table 16: Acceptable vibration dose values for intermittent vibration ($\text{m/s}^{1.75}$)

8 Construction noise assessment and recommendations

8.1 Construction sequence

The proposal is to be carried out in three stages:

- Stage 1 – site preparation
- Stage 2 – demolition, excavation and rockbreaking, tipping fill, piling
- Stage 3 – construction of new exhibits
- Stage 4 – landscaping.

The main stages of work have been broken up in terms of the following “noise scenarios”. A scenario is a work phase, characterised by the type of plant and equipment used, concurrent activities, location of works, and timing of works.

The works phases shown below are indicative only. The Contractor is responsible for preparing a Works Plan and Schedule, including updated noise and vibration impact assessments for proposed methods and timing of each stage of work.

Noise Scenario / Activity Description	List of plant	Notes about subjective impact
A. Site preparation and set up, including site amenities	Generators Trucks Hammers Hand tools	High vibration: N Tones or impulses: Y - reversing alarms
B. Demolition of existing buildings and structures, excavation, piling	Rockbreaking Concrete saws Piling Tipping fill Sledgehammers, Jackhammers Removal of building waste	High vibration: Y Tones or impulses: Y
C. Construction of new buildings and enclosures	Truck Crane Hand tools Removal of building waste	High vibration: Y - piling Tones or impulses: Y - reversing alarms
D. Landscaping	Truck Crane Diggers, excavators Hand tools	High vibration: Y – digger / excavator Tones or impulses: Y - reversing alarms

Table 17: Indicative work phases and subjective impact considerations

8.2 Hours of work

The hours of work affect community noise impacts. This is due to the fluctuations of ambient noise through the day, and the type of activities typically conducted by the community during Day, Evening and Night. Impacts on zoo patrons, animals and staff are influenced by the day-to-day activity during opening hours and after-hours animal care and zoo maintenance.

Standard construction hours defined in the *Interim Construction Noise Guidelines* (7am – 6pm, Monday to Friday, and 8am – 1pm, Saturday) are considered the least sensitive times of day.

The proposed works hours for this project are:

- Weekdays 7am to 6pm (Standard construction hours)
- Saturdays 7am to 1pm (7am to 8am is outside standard construction hours; works will only take place during this hour if inaudible at affected residential receivers).

Construction vehicles may enter the zoo during the following hours:

- Weekdays 6am to 5pm
- Saturdays 7am to 1pm.

It is noted that for the purposes of road traffic noise assessments, the hours before 7am are considered to be “night time” and are typically considered to be times when residential receivers are more sensitive to road traffic noise. For the purposes of construction noise assessments, the hours before 8am are considered to be more noise-sensitive.

The Contractor’s Construction Noise and Vibration Management Plan must state the hours of work, and any deviations to the schedule must be assessed and approved prior to commencing the altered works schedule.

9 Construction noise assessment considerations

9.1 Noise and Vibration Sources

Potential noise sources during the construction stage are identified in Table 16. Typical airborne noise levels associated with each noise source have been extracted from AS 2436-2010. For this assessment a conservative approach has been taken, which has applied the levels provided in the standard as $L_{eq,T}$ noise sound power levels.

The ICNG imposes a 5dB penalty for sources with a tonal noise content, or associated with high vibration levels. A 5dB penalty is also applied to vehicles with tonal reversing alarms. Non-tonal or broadband reversing alarms do not attract this 5dB penalty. The 5dB penalty is added to the predicted construction noise level at the receiver boundary. These activities have been identified in Table 18.

Table 18 also identifies potential sources of perceptible vibration. Vibration levels associated with plant typically depend on the material being worked on. For example jackhammers used on age-hardened concrete or hard rock will generate higher levels of vibration than the same jackhammers used on soft limestone or brick.

Noise Source / Plant	Sound Power Level, $L_{eq,T}$ dB(A)	Sound Pressure Level, $L_{eq,T}$ dB(A), at 10m
Dump Truck (tipping material)	117	89 (+5dB penalty – tonal reversing alarm)
Truck, Forklift (<i>vibration source</i>)	107	79 (+5dB penalty– tonal reversing alarm)
Front end / Wheeled loader (<i>vibration source</i>)	111	83 (+5dB penalty– tonal reversing alarm)
Piler (bored)	111	83
Piler (impact sheet) (<i>vibration source</i>)	137	109 (+5dB penalty)
Piler (vibratory) (<i>vibration source</i>)	125	97 (+5dB penalty)
Rock breaker (<i>vibration source</i>)	118	90 (+5dB penalty)
Excavator (<i>vibration source</i>)	107	79
Vibratory roller (<i>vibration source</i>)	108	80
Asphalt Paver (<i>vibration source</i>)	108	80
Asphalt Rotomill (scabbler)	111	83
Skidsteer loader (½ tonne) (<i>vibration source</i>)	104	76
Generator, 4 stroke portable petrol	103	75
Generator, diesel	113	85
Compactor (<i>vibration source</i>)	113	85
Concrete Saw, handheld (<i>vibration source</i>)	117	89 (+5dB penalty)
Jack Hammer (<i>vibration source</i>)	121	93 (+5dB penalty)
Hammer / percussive drill (<i>vibration source</i>)	112	84 (+5dB penalty)
Electric drill (<i>vibration source</i>)	91	63
Electric hand tools	102	74
Welder	105	77
Mobile crane	106	78

Table 18: Typical mid-point sound power and pressure levels of plant typical to proposed construction. These sound level values do not include the 5dB penalty noted for some types of work. The 5dB penalty is added to the predicted sound level at the receiver.

9.2 Methodology

The assessment considers the noise impact from each category of major works as follows:

- Noise predictions at receiver boundaries have been carried out for each piece of equipment that may be used during major works.
- Each piece of equipment is modelled as a point noise source.
- To provide a worst case $L_{eq(15min)}$ prediction, it is assumed that equipment is used continuously over the assessment period. However, for dump trucks, it is assumed

that the noise from this particular piece of equipment is not used continuously and has been assessed to generate noise for 3 minutes out of a 15-minute assessment period.

- Predictions only consider the distance attenuation between source and receiver unless otherwise specified below:
 - Noise predictions at the Taronga Food Market assume no sound shielding from existing structures, once these structures have been demolished. One method of noise mitigation may be in staging construction works such that early erection of structures near the Taronga Food Market may assist with sound shielding during remaining works.
- It is assumed that works activities in various parts of the site may be carried out simultaneously.
- In accordance with the proposed work hours, noise predictions are to be compared with weekday Day-time, Saturday 6-7am, and Saturday 7am to 1pm noise management levels.
- Vibration levels are difficult to predict without detailed material and structural information which affects the vibration at source (related to the material being worked on), and the vibration transmission through the receiving structure. Therefore vibration risks have been assessed at a high level, based on measurements taken at other construction sites.
- It will be necessary to confirm vibration through monitoring early in the any works phase that involves high-vibration activities such as excavating, to re-assess whether levels are expected to exceed applicable criteria at heritage or historically significant structures.

10 Predicted Construction Noise Levels

Table 19 details the predicted construction noise levels from the African Savannah and Congo Exhibit redevelopment, at the following receivers:

- R1: nearest residential receivers, over 80m distant. Apply residential noise management levels ($51\text{dBL}_{\text{Aeq}(15\text{minute}),\text{Day}}$).
- C1: at the Taronga Food Market, located 10m from the nearest worksites, between the African Savannah and the Congo Exhibits. Apply commercial noise management levels ($70\text{dBL}_{\text{Aeq}(15\text{minute}),\text{Day}}$).
- A1: at Taronga Zoo walkways. Apply best-practice noise management levels ($65\text{dBL}_{\text{Aeq}(15\text{minute}),\text{Day}}$).

Noise and vibration risks are discussed in the accompanying text.

The tables provide noise level predictions for individual pieces of equipment and the combined contribution for activities that may occur simultaneously. Noise levels have been based on the typical mid point noise levels detailed in Section 9.1.

External airborne noise at the Taronga Food Market is predicted at the southern façade where public have access to the building verandah. Internal noise levels assume that the façade doors can be closed (if desired) and achieve a 15dB sound reduction through the door. This is a conservative assumption based on poor door seals and standard glazed door construction. Achieving a $70\text{dBL}_{\text{Aeq}(15\text{minute})}$ external noise management level would therefore achieve the recommended internal level $55\text{dBL}_{\text{Aeq}(15\text{minute})}$ with the façade doors closed.

All the predicted levels presented below are for the nearest work sites. This is a large site and the predicted levels at the receivers will vary with distance. As a guide, the distance attenuation as works are conducted farther from the receivers is approximately 6dB with every 10m from the site. Some works will be conducted over 200m distant from the sensitive receivers.

Table 19 below shows conservatively predicted noise levels at residential and zoo receivers, without any noise mitigation measures applied. Since predicted noise levels exceed applicable targets, **Table 20** presents levels predicted when basic mitigation measures are applied, which are the use of hoarding, petrol generators, and bored piling.

Noise Scenario / Activity Description	List of plant	Highest Predicted Level at Receivers – without noise mitigation			Comments
		Residential	Zoo Markets	A1: Zoo walkway	
A. Site preparation and set up, including site amenities, on eastern end of site	Generators (75 petrol, 85 diesel) Trucks (79) Hammers (70) Hand tools (74)	R1: 44-50 / 54-60 R1: 48-54 R1: 39-45 R1: 43-49	C1: 53-75 / 85 C1: 57-79 C1: 48-70 C1: 52-74	A1: 61-75 / 71-85 A1: 65-79 A1: 56-70 A1: 60-74	Exceeds NML within the Zoo. Hoarding will reduce noise by approximately 10dB. Use petrol generator rather than diesel, and plan truck access routes and times to minimise impacts.
B. Demolition of existing buildings and structures, excavation	Rock breaker (90) Excavator (79) Concrete saws (89) Piling (bored 83 / vibratory 97 / impact 109) Truck (tipping fill) (89) Sledgehammers (80) Jackhammers (93) Hammer / Percussive drill (84) Removal of building waste (84) Compactor (85)	R1: 59-65 R1: 48-54 R1: 58-64 R1: 58 / 73 / 84 R1: 50 R1: 62-68 R1: 53-59 R1: 53-59 R1: 54-60	C1: 68-90 C1: 57-79 C1: 67-89 C1: 61-83 / 75-97 / 87-109 C1: 67-89 C1: 71-93 C1: 62-84 C1: 62-84 C1: 63-85	A1: 76-90 A1: 65-79 A1: 75-89 A1: 69-83 / 83-97 / 95-109 A1: 68-89 A1: 79-93 A1: 70-84 A1: 70-84 A1: 71-85	Exceeds NML within the Zoo. Hoarding will reduce noise by approximately 10dB. Consider quieter methods for piling, cutting / breaking rock or masonry, tipping fill, and for collecting and removing waste.
C. Construction of new buildings and enclosures	Truck (79) Crane (78) Hand tools (74) Removal of building waste (84)	R1: 54 R1: 53 R1: 49 R1: 59	C1: 57-79 C1: 56-78 C1: 52-74 C1: 62-84	A1: 63-79 A1: 64-78 A1: 60-74 A1: 70-84	Significant excesses above NML, particularly at A1. Hoarding will reduce noise by approximately 10dB.
D. Landscaping	Truck (79) Truck (tipping fill) (89) Compactor (85) Crane (78) Diggers, excavators (79) Hand tools (74) Asphalt paver (80)	R1: 54 R1: 50 R1: 60 R1: 53 R1: 54 R1: 49 R1: 55	C1: 57-79 C1: 67-89 C1: 63-85 C1: 56-78 C1: 57-79 C1: 52-74 C1: 58-80	A1: 65-79 A1: 68-89 A1: 71-85 A1: 64-78 A1: 65-79 A1-4: 60-74 A1-4: 66-80	Significant excesses above NML, particularly at A1. Hoarding will reduce noise by approximately 10dB to comply at R1. Consider quieter methods for compacting and tipping fill.

Table 19: Predicted construction noise levels at representative receivers, for indicative works phases and activities. These predicted levels assume no noise mitigation measures have been adopted.

Noise Scenario / Activity Description	List of plant	Highest Predicted Level at Receivers – with hoarding and simple equipment selection controls			Comments
		Residential	Zoo Markets	A1: Zoo walkway	
A. Site preparation and set up, including site amenities, on eastern end of site	Generators (75 petrol) Trucks (79) Hammers (70) Hand tools (74)	R1: 34-40 R1: 48-54 R1: 29-35 R1: 33-39	C1: 43-65 C1: 57-79 C1: 38-60 C1: 42-64	A1: 51- 65 A1: 65-79 A1: 46-60 A1: 50- 64	Assumes hoarding and petrol generators are used. Compliance at residential receivers expected if truck routes well managed. Plan truck access routes and times to minimise impacts. For zoo receivers, use local enclosures around generator, hammer and hand tools when within 30-40m of animal receivers.
B. Demolition of existing buildings and structures, excavation	Rock breaker (90) Excavator (79) Concrete saws (89) Piling (bored 83) Truck (tipping fill) (89) Sledgehammers (80) Jackhammers (93) Hammer / Percussive drill (84) Removal of building waste (84) Compactor (85)	R1: 49- 55 R1: 38-44 R1: 48-54 R1: 48 R1: 39-45 R1: 40 R1: 52- 58 R1: 43-49 R1: 43-49 R1: 44-50	C1: 58- 80 C1: 47- 69 C1: 57- 79 C1: 51- 73 C1: 48-70 C1: 57- 79 C1: 61- 83 C1: 52- 74 C1: 52- 74 C1: 53- 75	A1: 66-80 A1: 55- 69 A1: 65-79 A1: 56- 70 A1: 59- 73 A1: 58- 79 A1: 69-83 A1: 60- 74 A1: 60- 74 A1: 61-75	Assumes hoarding and bored piling are used. Rockbreaking and jackhammering may exceed residential criteria. Consider quieter methods and scheduling least sensitive times for cutting / breaking rock or masonry, compacting, and for collecting and removing waste. Use local enclosures around saws, drills, sledgehammers, and jackhammers.
C. Construction of new buildings and enclosures	Truck (79) Crane (78) Hand tools (74) Removal of building waste (84)	R1: 44 R1: 43 R1: 39 R1: 49	C1: 47-69 C1: 46-68 C1: 42-64 C1: 52- 74	A1: 53- 69 A1: 54- 68 A1: 50- 64 A1: 60- 74	Compliance at residential receivers expected. Plan truck access routes and times, and quieter methods for collecting and removing waste.
D. Landscaping	Truck (79) Truck (tipping fill) (89) Compactor (85) Crane (78) Diggers, excavators (79) Hand tools (74) Asphalt paver (80)	R1: 44 R1: 40 R1: 50 R1: 43 R1: 44 R1: 39 R1: 45	C1: 47-69 C1: 57- 79 C1: 53- 75 C1: 46-68 C1: 47-69 C1: 42-64 C1: 48-70	A1: 55- 69 A1: 58- 79 A1: 61-75 A1: 54- 68 A1: 55- 69 A1: 50- 64 A1: 56- 70	Assumes hoarding is used. Compliance at residential receivers expected. Consider quieter methods for compacting and tipping fill.

Table 20: Predicted construction noise levels at representative receivers, for indicative works phases and activities with basic noise mitigation implemented. These predicted levels assume hoarding, petrol generator, and bored piling are used. Noise mitigation measures to control residual impacts are recommended.

General comments are as follows.

Local hoarding around the worksite is recommended for all external works. The primary reason is managing noise on the walkways. When works are moving around the site, including mobile cranes, jackhammers, and concrete saws, local “noise curtains” such as EchoBarrier will assist with reducing noise near the source. To break the line-of-sight between source and receiver, a partial enclosure with roof may be required for some activities due to the local topography.

If generators are required for the site set-up, petrol generators should be used instead of diesel.

Piling has the potential to cause significant noise impacts. The method of piling also needs to consider vibration effects on the historic structures nearby. The piling method needs to be selected to minimise both noise and vibration impacts and therefore bored or screw type piling methods should be implemented.

Truck access should be limited to designated time periods and site access gates should be as far as possible from sensitive enclosures and well-used walkways. Vehicle pathways around the site should be arranged to minimise the need for reversing. Where reversing is necessary, the contractor should consider whether non-tonal reversing alarms are an acceptable safety alternative to tonal “beeper” alarms.

Further noise and vibration controls are discussed in detail in the following sections.

11 Noise Management and Mitigation Measures

11.1 General noise control elements

The noise and vibration objectives, management and mitigation measures in environmental assessment documentation are based on an initial design and construction methodology. It is expected that the works methodology and staging may be altered. Consequently it may be necessary to update the assessment and associated noise management plan at several stages throughout the project.

As a general rule for best practices, prevention and elimination of noise would be applied as universal work practice during construction, especially when construction works are to be undertaken outside recommended standard hours.

Where elimination and prevention are not feasible options, the reduction of the noise at the source and the control of transmission path between the construction site and the receiver are the preferred options for noise minimisation through engineering and or administration controls. Providing treatments at the affected residences or other sensitive land uses would only be implemented as a last resort.

Construction noise would be managed by implementing the strategies listed below:

- Plant and equipment
 - Use quieter work methods.
 - Use quieter equipment.
 - Use low noise and vibration piling methods such as bored or screw piling.
 - Use mobile noise curtains for external works with noisy hand-held tools
 - For noisy works, consider carrying out in continuous blocks not exceeding 3 hours each, with a minimum respite period of one hour between each block
 - Operate plant in a quiet and effective manner.
 - Plant used intermittently to be throttled down or shut down.
 - Use mains power supply where possible, rather than use generators.
 - Use one larger generator to power multiple plant items (ensuring safe cabling). Use petrol generators instead of diesel generators.
 - Switch off generators when not in use, particularly during out-of-hours work periods.

- Maintain equipment regularly.
- Where appropriate, obtain acoustic test certificates for equipment
- On site noise management
 - Strategically locate equipment and plant. Locate generators away from sensitive receivers.
 - Avoid the use of reversing alarms through site layout to minimise reversing, or provide for alternative systems such as non-tonal reversing alarms.
 - Maximise shielding in the form of existing structures or temporary barriers.
 - Enclose the work site as far as possible from receivers, and use hoarding. Noise reductions of at least 10dB are expected due to hoarding.
 - Schedule the construction of barriers and structures so they can be used as early as possible.
 - Consider signage at walkways affected by construction noise.
 - Manage waste removal from the site to minimise noise impacts.
 - Reduce noise from metal chutes and bins by placing damping material in the bin.
 - Locate waste deposit bins as far as possible from sensitive receivers.
 - Where possible, carry out noisy fabrication work at another site (for example, within enclosed factory premises) and then transport to site.
 - Delivery vehicles should be fitted with straps rather than chains for unloading, wherever possible.
 - Keep windows closed during all internal works.
- Consultation, notification and complaints handling
 - Provide information to affected neighbours and zoo patrons before and during construction as required.
 - Maintain good communication between the community and project staff.
 - Have a documented complaints process and keep register of any complaints.
 - Give complaints a fair hearing and provide for a quick response.
 - Implement all feasible and reasonable measures to address the source of complaint.
- Work scheduling
 - Schedule activities to minimise noise impacts.
 - Ensure periods of respite are provided in the case of unavoidable maximum noise levels events.
 - Avoid simultaneous operation of noisy plant within discernible range of a sensitive receiver. Ensure noisy plant schedules are clear in Works Plan.

- Keep truck drivers informed of designated routes, parking locations and delivery hours.
- Schedule deliveries to planned construction hours only.
- Mandatory site rules of conduct
 - Avoid the overuse of public address systems, radios or stereos outdoors.
 - No swearing or unnecessary shouting.
 - No unnecessary dropping of materials from height, throwing of metal items, and slamming of doors.
 - No extended periods of engine idling.

11.2 Communication and complaints

The following procedures are an example of the procedures that would be specifically adopted for complaints relating to noise.

Upon receipt of a complaint The Contractor would:

- Try to ascertain from the complaint which appliance is causing the problem i.e. inside or outside the site and in what position;
- Establish from the monitoring equipment if the allowable noise levels have been complied with;
- Establish if the appliance positioning has previously been highlighted as a problem area. If not and the noise levels are above the allowable limit, then the equipment and its position shall be noted;
- Move machinery if the allowable levels have been exceeded or take other acoustic remedial action.

If the activity is occurring outside normal working hours, the activity would be immediately stopped. Where stopping the activity would create a safety issue the activity may be permitted to continue only as long as is necessary to make the area safe. The activity would then cease.

Any activity which is directed to cease due to excessive noise would not recommence until the Project Manager is satisfied that the requirements of the relevant criteria can be met and has given permission to recommence the activity.

The Site Supervisor would ensure that a report of any incident is provided to the Project Manager.

The Project Manager would provide a report on the incident to the relevant stakeholders.

The Contractor would provide a 24 hour telephone contact number and this number would be prominently displayed on the site.

11.3 Timing of works

The assessment of proposed construction activities has indicated noise levels are likely to exceed the relevant criteria at zoo receivers surrounding the site. The following noise control measures together with best practices detailed in the previous sections would be considered in order to minimise the noise impacts.

- Construction activities would typically occur during the prescribed standard hours (at the least sensitive times of the day).
- Where work must be carried out during noise sensitive periods, residents and commercial receivers would be informed and management principles would be in place to ensure a minimal amount of impact. This may include:
 - Do not use noise sensitive equipment likely to exceed the relevant criteria i.e piling rigs, rock-breakers, concrete cutters and sledgehammers.
 - Where possible limit construction works to those internal to buildings so as to contain the noise and minimise noise emissions externally.
 - Outside standard hours, only carry out activities at locations where compliance with the criteria (RBL+5) can be achieved.

11.4 Equipment and plant selection

This assessment has been based on typical noise sources defined in AS 2436-2010. The contractor would aim to choose the quietest pieces of equipment where feasible and reasonable. If the final equipment selection varies significantly from items specified in Table 17, it is recommended that an additional assessment be carried out for noise sources other than those included in this report and revisions made to the noise management plan where necessary.

Based on the results of the assessment, key pieces of equipment have been noted to dominate the overall noise contribution at the receiver position including piling rigs, concrete saws, jackhammers and dump trucks.

Where possible alternative methods or selection of quieter equipment would be considered. Lessening the time in use and ensuring equipment is not used simultaneously will further reduce the noise impact at residents.

Where possible, reduce the number of noise sources/activities running simultaneously at the same location.

Limit the number of site vehicles such as dump trucks at any one time.

A screen or enclosure would be used when carrying out external building works that are predicted to exceed the noise management level at environmental receivers. Typically

screens and enclosures constructed with plywood would be sufficient. Reference shall also be made to specific screening and enclosures detailed in Appendix F of AS 2436:2010.

11.5 Vibration Management Measures

It is the contractor's responsibility to identify potential vibration generating sources in the proposed work methods.

The contractor shall refer to the demolition and landscaping plans to determine where rock cutting, excavation, piling, or other vibration-generating activities are to occur. The contractor shall refer to the Structural Engineer's report and plans to identify structurally sensitive or historic or sensitive structures requiring protection from vibration.

The Contractor would carry out a review of vibration generated by construction activities. The levels of vibration generated will be site specific and will depend upon the type of activity, the particular equipment used, and the proximity of the construction activity to the nearest occupied spaces within the affected properties. The Contractor would carry out a preliminary vibration survey, which will determine whether a means of vibration mitigation will be necessary on the site.

11.5.1 Works requiring a vibration assessment

A preliminary vibration assessment is to be carried out for each key vibration generating activity, ie:

- Piling
- Rock breaking
- Concrete saw cutting
- Sledgehammer demolition
- Jackhammering
- Percussive / Hammer drilling
- Concrete and brick drilling
- Any other activities proposed by the contractor which is likely to generate perceptible vibration.

These activities should also be monitored for the risk of cosmetic damage.

When considering the measured vibration impact associated with construction works, the following would be taken into account.

- The layout of the site, including the location of static sources of vibration.
- Techniques used in construction to minimise generated vibration levels.
- Hours of work with regard to the nature of operations in the affected receivers and the duration of the works.

11.5.2 Dilapidation survey

Vibration-intensive activities such as piling often warrant condition surveys and monitoring.

The Contractor would be required to conduct a dilapidation survey up to 50m from the work site prior to high vibration works.

11.5.3 Vibration monitoring inside the Zoo

Preliminary vibration monitoring is to be carried out for each key vibration generating activity, ie:

- Concrete saw cutting
- Sledgehammer demolition
- Jackhammering
- Percussive / Hammer drilling
- Concrete and brick drilling
- Percussive piling
- Any other activities proposed by the contractor which is likely to generate perceptible vibration.

The purpose of the vibration monitoring is to assess the risk of potential structural damage to historic structures within the premises.

Monitoring is also required in situations where there are changes in equipment and activities or work procedures that might affect existing vibration control measures. The monitoring procedure would be carried out with appropriate equipment so as to provide results that are readily comparable to the preliminary survey and relevant criteria provided in Section 7.3 and 7.4.

11.6 Noise monitoring and reporting

11.6.1 Airborne noise monitoring

During any stage in construction that is expected to exceed the recommended noise management level by more than 5dB even with mitigation measures in place, the Contractor may implement environmental noise monitoring at a minimum of one location, namely the southern boundary of residential noise receivers R1.

Additional positions may also be selected or the monitor could be relocated at different stages of construction to correspond with the location construction activities progress to different locations within the development site.

It is recommended that noise monitoring be carried out for a minimum of 1 week during the period where the greatest impacts are expected, or for the duration of the noisy works

(whichever is less). Monitoring results can be reviewed at the end of the week, however could be reviewed on more regular intervals depending on the type of work and level of noise expected. The requirement for further monitoring would be reviewed after this time or sooner if deemed necessary by the Acoustic Consultant and Project Manager.

11.7 Construction noise and vibration compliance

This report establishes applicable noise criteria for the proposed works. Potential vibration effects have been identified.

Works that will require careful noise and vibration management include pneumatic breakers during demolition, rockbreaking, percussive piling, concrete pumps, and dumping spoil into trucks. This list is not exhaustive.

The contractor will need to prepare a detailed Construction Noise and Vibration Noise Management Plan for the works once the demolition and construction method is more progressed. This Plan will need to outline the proposed stages of work, plant and equipment to be used, and times of day during each week that construction is expected to occur. The Plan will need to demonstrate that all feasible and reasonable measures will be applied to meet the relevant Noise Management Levels.

All feasible and reasonable measures to meet the applicable Noise Management Levels will need to be identified and applied.

Any expected excess above the Highly Affected Level will require a detailed analysis of construction methods. Respite periods may be needed if high noise levels are expected for several days in a row. Community consultation is likely to be required.

Acoustic Studio strongly recommends that works are conducted during standard construction hours where possible. However, where the works are expected to be inaudible at the most affected residential receivers, some out of hours works may be necessary. Such flexibility would ensure that public safety within zoo premises is not compromised by construction activity, while still maintaining acoustic amenity for local residents.

Particular consideration of construction-related road traffic noise impacts is required. Construction vehicles are only to use Beach Road access gate, near residential receivers, during zoo opening hours. They are restricted to Bradleys Head Road (south) access gates outside zoo opening hours. Zoo traffic management policy restricts heavy vehicles moving spoil or waste to between 7:30am to 4:30pm Mondays to Fridays, and 7:30am to 1pm on Saturdays⁵.

Dilapidation surveys are recommended for nearby historic structures.

⁵ *Taronga Zoo Proposed Sumatran Tiger Adventure – Traffic Impact Assessment Issue C*, GTA Consultants 23/03/2015

12 Summary and Conclusions

A noise assessment has been carried out for the proposed African Savannah and Congo Exhibit redevelopment at Taronga Zoo, Mosman.

External noise emissions associated with the operation of the African Savannah and Congo Exhibit have been assessed. The assessment has adopted methodology from relevant guidelines to assess particular noise sources and expected worst-case impacts as follows:

- External mechanical plant and maintenance noise emissions – NSW Industrial Noise Policy (INP) overall A-weighted noise criteria.
- Noise emissions from patrons and sound systems –Office of Liquor, Gaming and Racing (OLGR) octave band noise criteria (7am to midnight).

Short-term and week-long ambient noise monitoring has been carried out to establish the existing background noise levels of the neighbourhood, and to establish typical octave band frequency spectra of the existing background noise levels at the residential boundaries of the nearest affected residential premises.

Source noise levels and spectra for the African Savannah and Congo Exhibit patrons have been based on patron noise measured by Acoustic Studio in Taronga Zoo and acoustic literature on male and female voices.

The noise impacts have been predicted at the most sensitive boundary positions, taking into account distance attenuation, building and ground reflections, directivity and, where applicable, shielding by the zoo buildings / structures. These calculations show that all the relevant criteria (OLGR and NSW INP) for patron and sound system noise emissions will be met.

A general operational environmental noise assessment has been carried out for mechanical plant and cleaning and maintenance activities. These noise sources are likely to be effectively controlled through:

- Appropriate design and location of the mechanical plant system during the detailed design stage: responsibility of the architect, builder and mechanical and acoustic consultants; and
- Management controls for the timing of cleaning and maintenance activities, and for closing doors if required for cleaning the inside of the enclosures.

The potential for Sleep Disturbance to nearby residents, due to night-time lions' roaring, has been assessed. This report concludes that there is potential for lions' roars to wake residents when their bedroom windows are open, typically during warmer seasons. This is unlikely to occur often during the night as measured noise levels from lions at Perth Zoo were significantly quieter than peak noise levels assumed for the noise predictions, and Taronga Zoo practice is to keep lions inside enclosures at night until early morning.

A high level construction environmental noise assessment has been carried out, based on assumptions about the type of equipment that would be used on site. These noise sources are likely to be effectively controlled through:

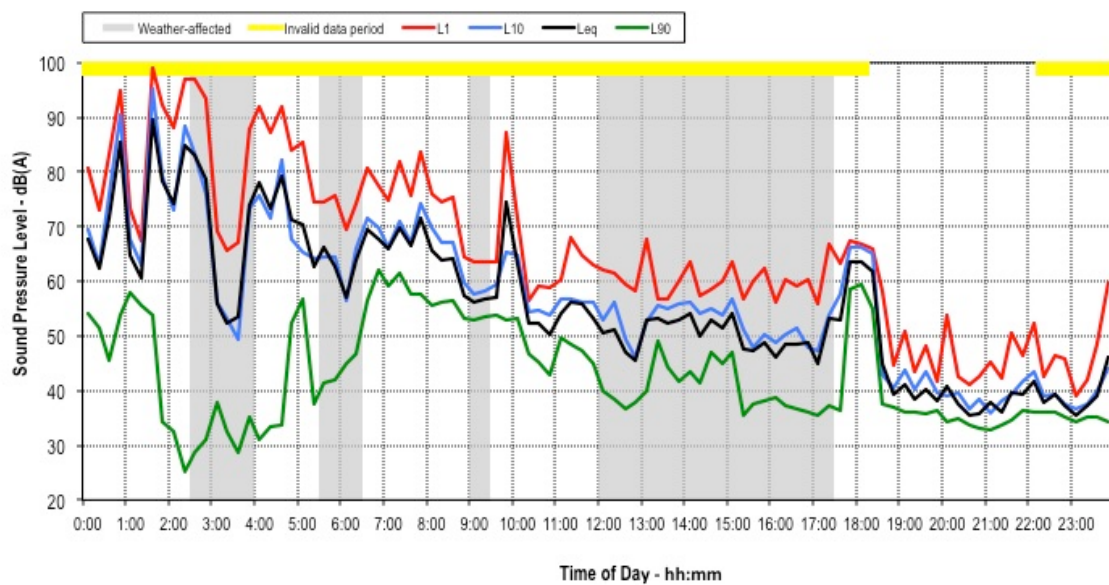
- Hoarding around the work site, and local enclosures of noisy plant or activities;
- Selection of quieter plant, including a commitment to use petrol rather than diesel generators if generators are required;
- Selection of quieter methods where possible and appropriate, particularly for piling;
- Selection of low vibration work methods where possible and appropriate;
- Vibration monitoring and management controls for historic structures.

Provided the recommendations detailed in this report are correctly implemented, it is anticipated that the African Savannah and Congo Exhibit construction and operations will have no adverse noise impact at the nearest residential receivers.

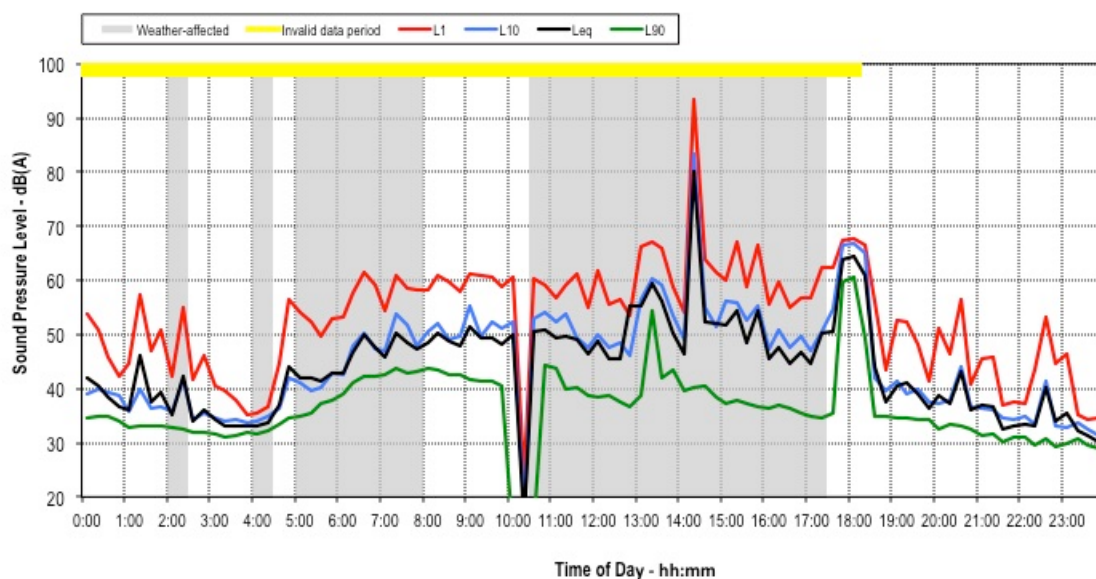
APPENDIX

Noise logger graphs

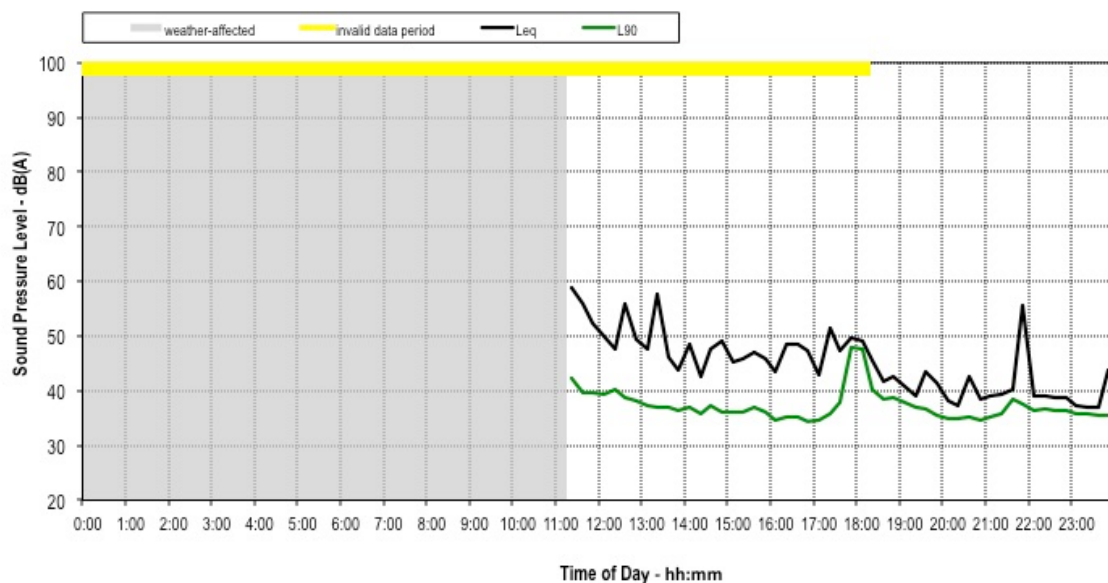
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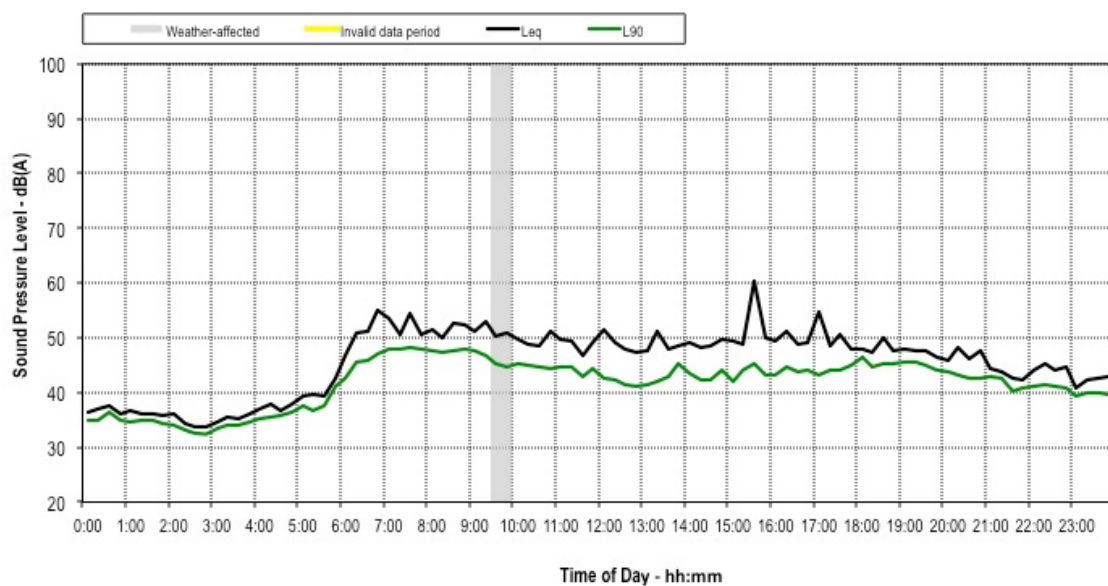
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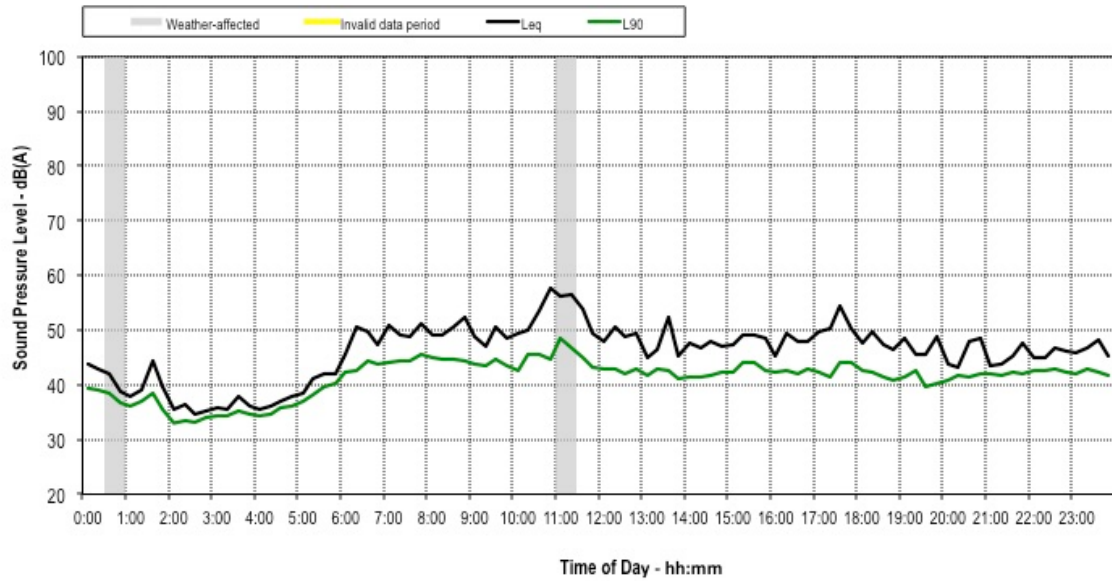
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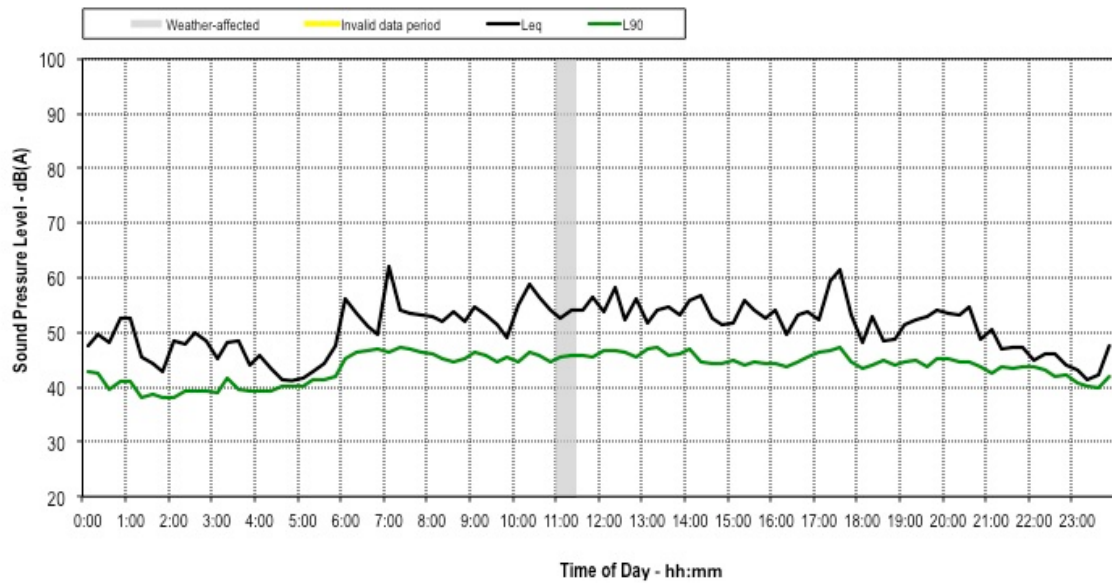
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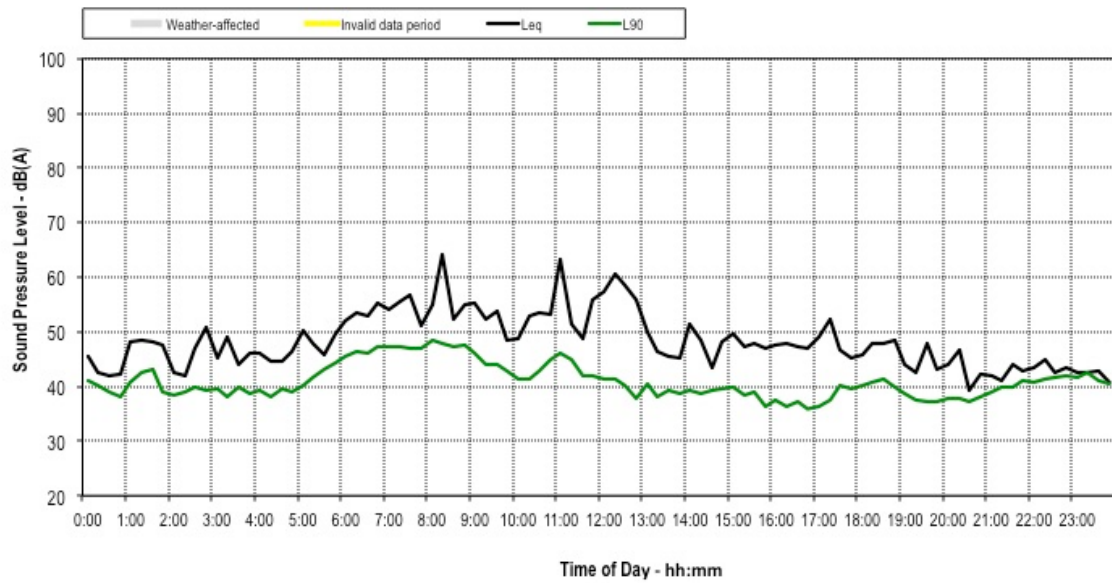
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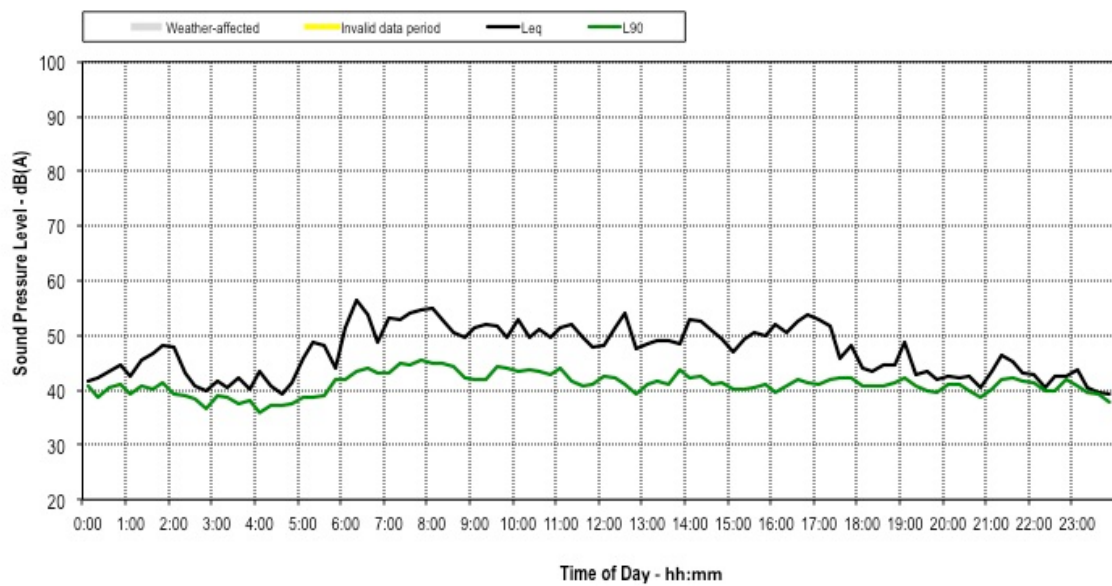
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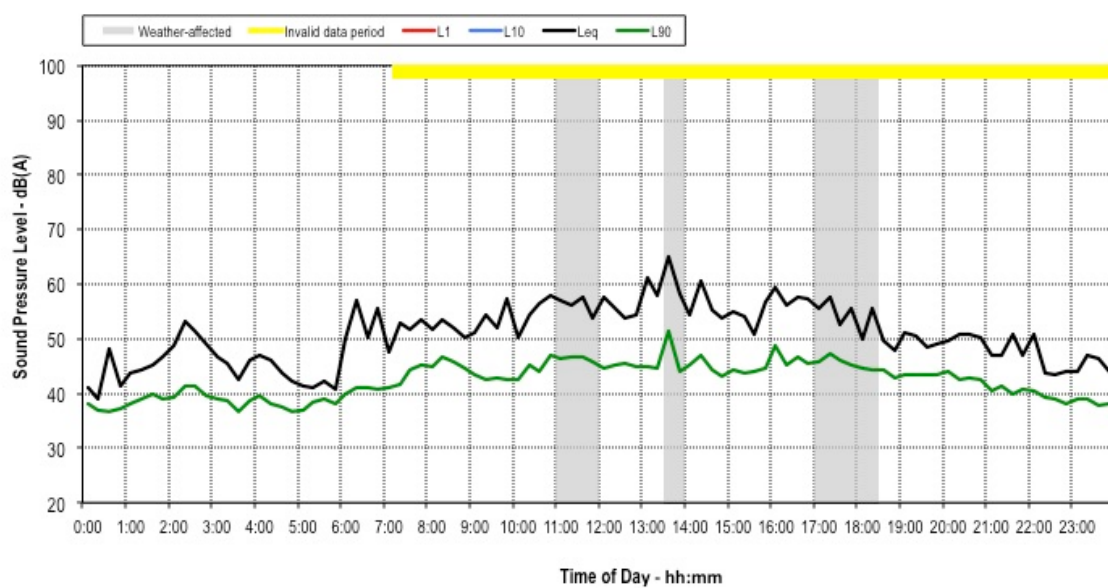
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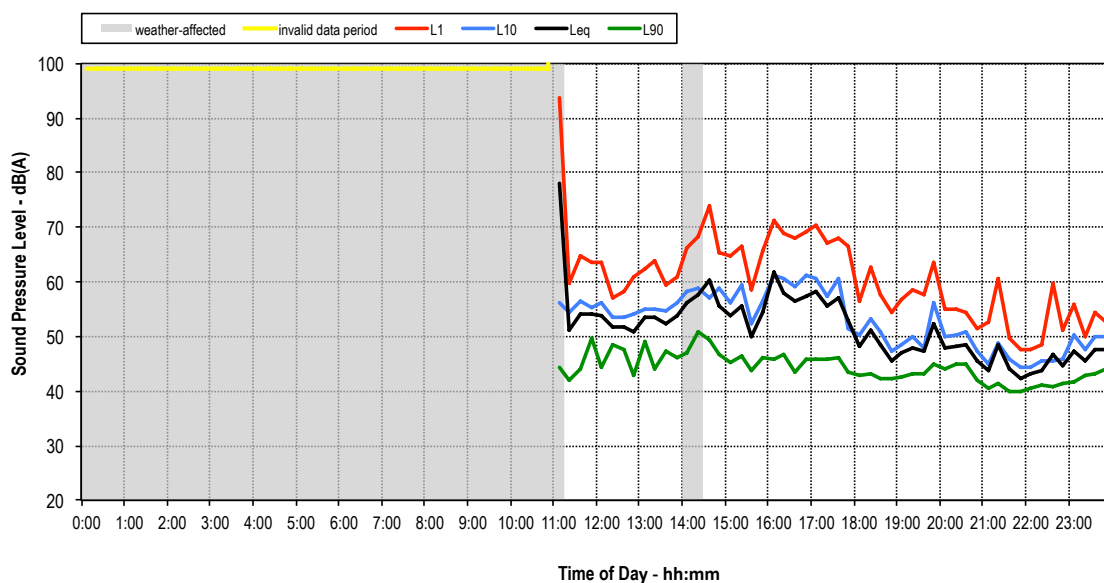
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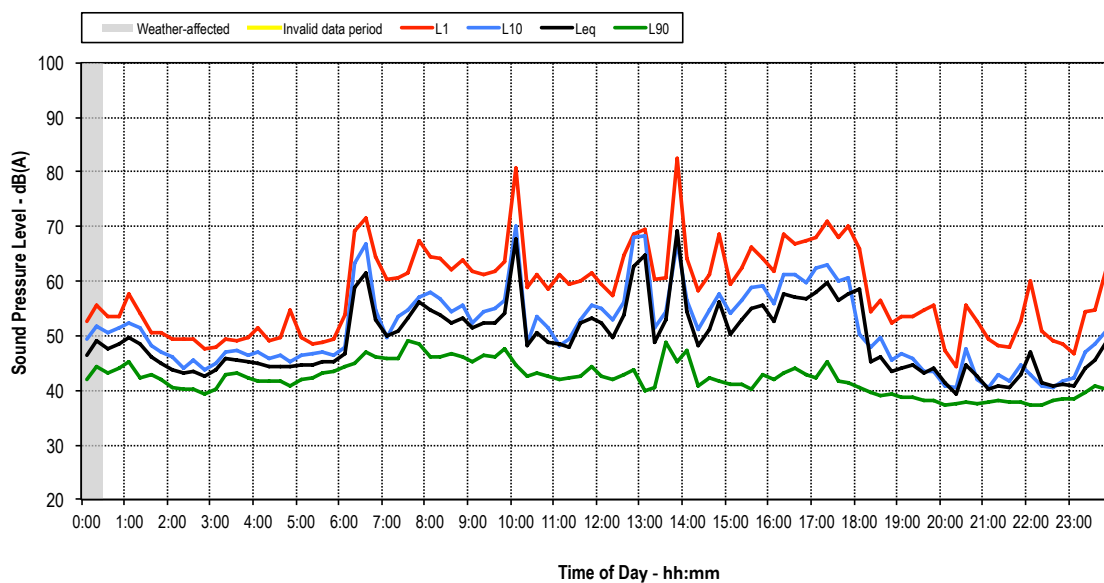
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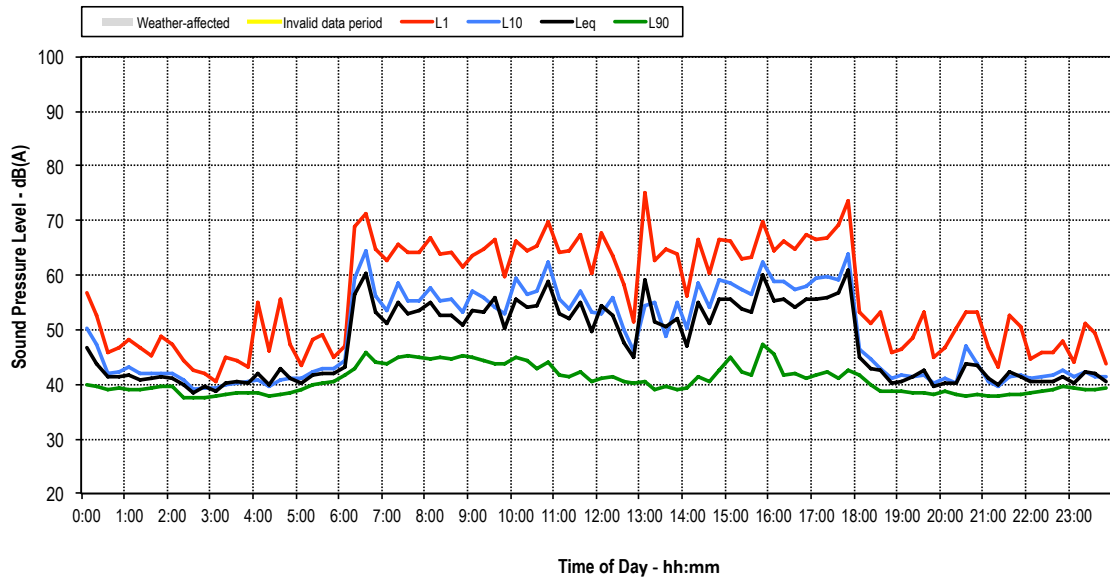
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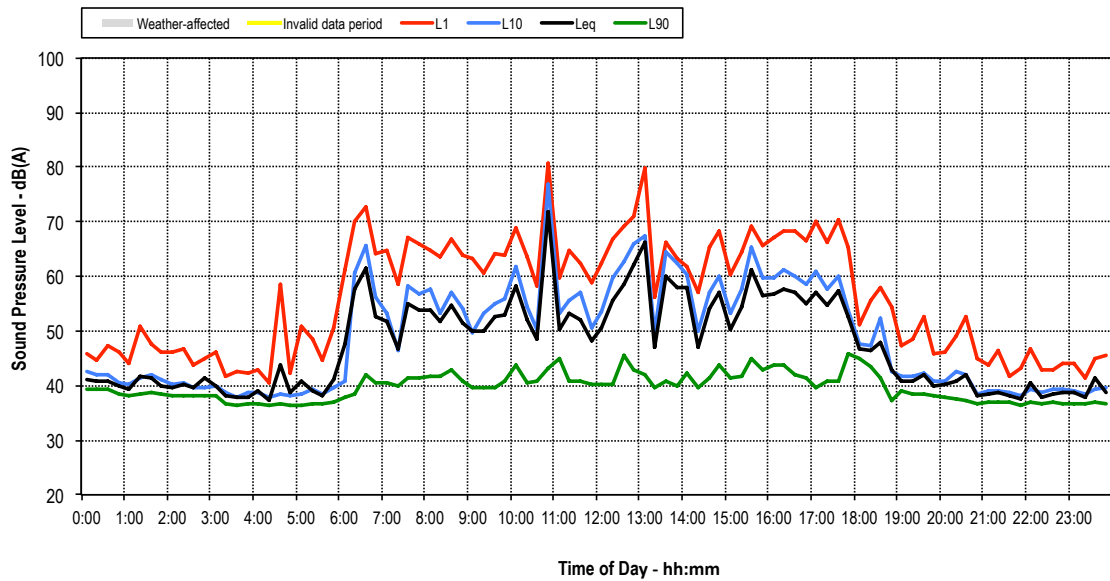
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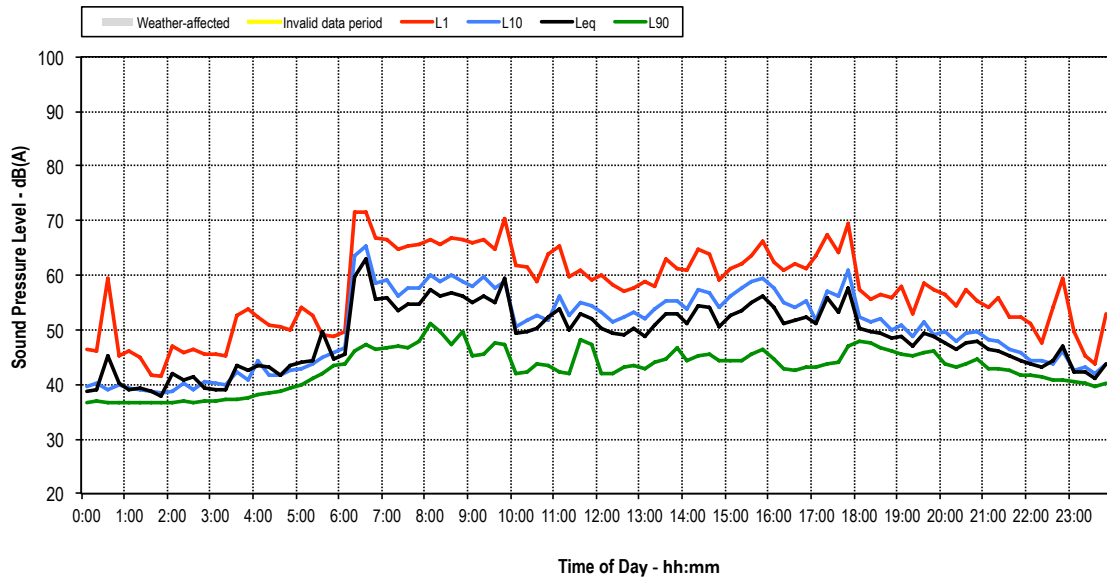
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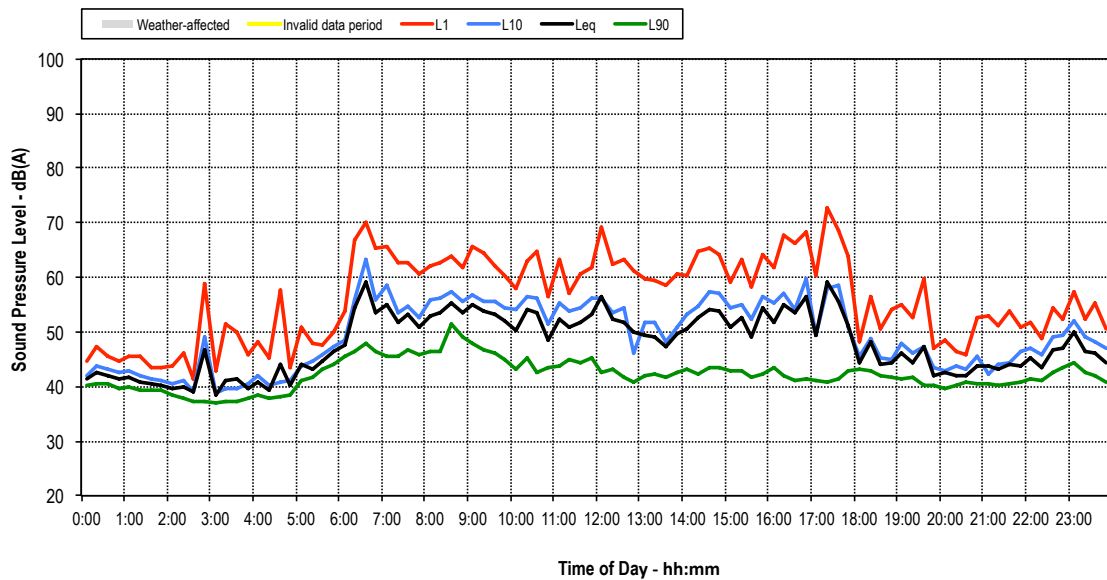
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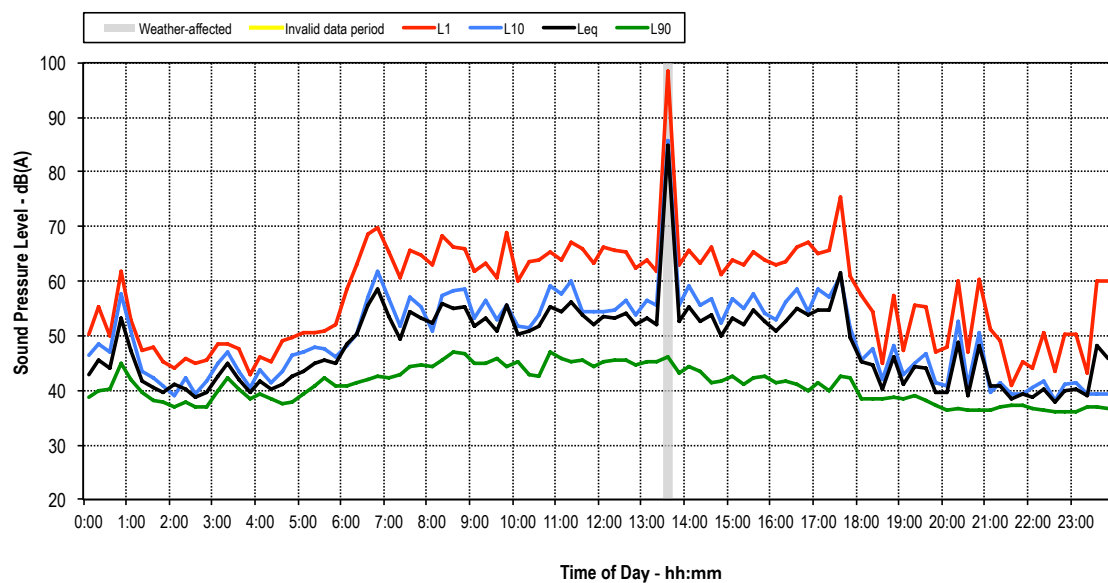
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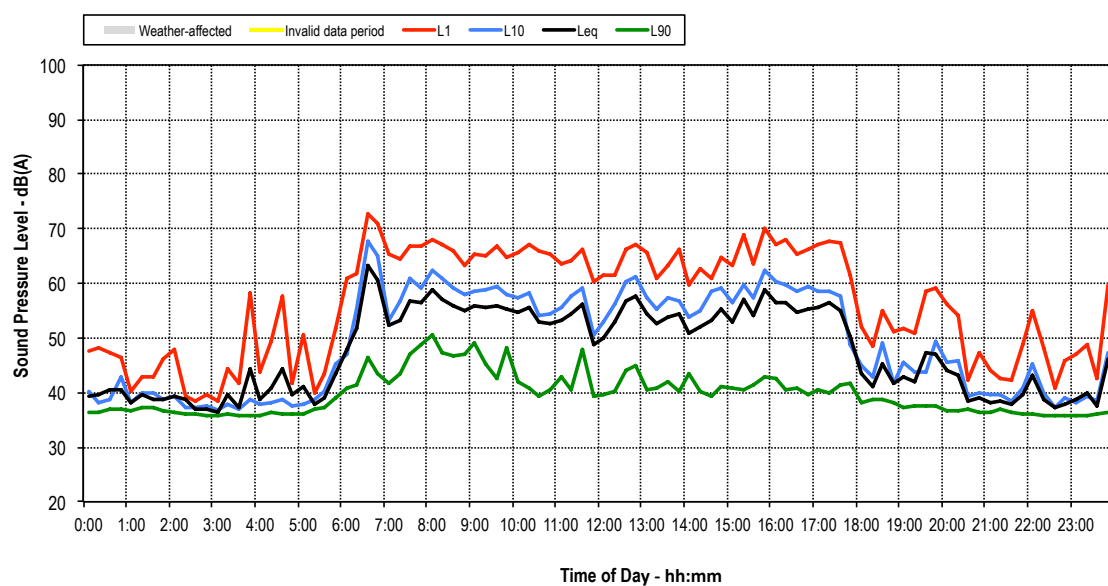
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Taronga Zoo - Rickard Rd - Friday 05 May 2017

