SMEC
Member of the Surbana Jurong Group

local people
global experience

Artist's Impression

Environmental Impact Statement – Chapter 19: Noise and vibration

Warragamba Dam Raising

Reference No. 30012078
Prepared for WaterNSW
10 September 2021

SMEC INTERNAL REF. 30012078

Contents

List of Tables

List of Figures

19 Noise and vibration

This chapter provides an assessment of noise and vibration during construction and operation of the Warragamba Dam Raising. The relevant Secretary's Environmental Assessment Requirements (SEARs) are shown in Table 19-1.

Table 19-1. Secretary's Environmental Assessment Requirements: Noise and vibration

Desired performance outcomes	Secretary's Environmental Assessment Requirements [1]	Where addressed
11. Noise and Vibration - Amenity Desired performance outcome: Construction noise and vibration (including airborne noise, ground-borne noise and blasting) are effectively managed to minimise adverse impacts on acoustic amenity. Increases in noise emissions and vibration affecting nearby properties and other sensitive receivers during operation of the project are effectively managed to protect the amenity and well-being of the community.	1. The Proponent must assess construction and operational noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must include consideration of impacts to sensitive receivers including small businesses, and include consideration of sleep disturbance and, as relevant, the characteristics of noise and vibration (for example, low frequency noise).	Section 19.4 Section 19.5
	2. The Proponent must demonstrate that blast impacts are capable of complying with the current guidelines, if blasting is required.	Section 19.5
12. Noise and Vibration - Structural Desired performance outcome: Construction noise and vibration (including airborne noise, ground-borne noise and blasting) are effectively managed to minimise adverse impacts on the structural integrity of buildings and items including Aboriginal places and environmental heritage. Increases in noise emissions and vibration affecting environmental heritage as defined in the Heritage Act 1977 during operation of the project are effectively managed.	1. The Proponent must assess construction and operation noise and vibration impacts in accordance with relevant NSW noise and vibration guidelines. The assessment must include consideration of impacts to the structural integrity and heritage significance of items (including Aboriginal places and items of environmental heritage).	Section 19.4 Section 19.5
	2. The Proponent must demonstrate that blast impacts are capable of complying with the current guidelines, if blasting is required.	Section 19.5

1 Note: this chapter specifically addresses SEARs 11 and 12 in addition to those general requirements of the SEARs applicable to all chapters and as identified as such in Chapter 1 (Section 1.5, Table 1-1).

The noise and vibration impact assessment is supported by detailed investigations, which are documented in Appendix L - Noise and Vibration Assessment Report (ERM 2020).

The proposed management and mitigation measures in this chapter are collated in Chapter 29 (Environmental impact statement synthesis, Project justification and conclusion).

19.1 Project overview

19.1.1 Project description

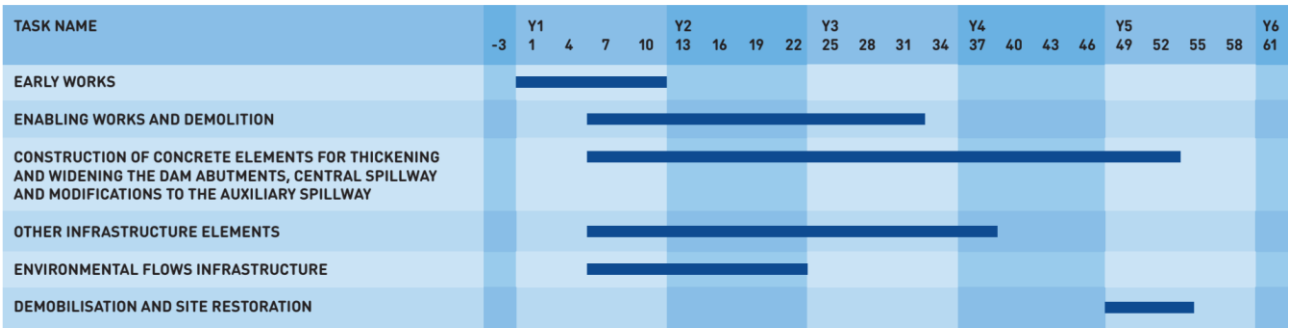
The Project would provide additional capacity to facilitate flood mitigation by increasing the crest level of the central spillway by approximately 12 metres and the auxiliary spillway crest by around 14 metres above the existing full supply level for temporary storage of inflows. The spillway crest levels and outlets control the extent and duration of the temporary upstream inundation. There would be no change to the existing maximum volume of water stored for water

supply. The current design includes raising the dam side walls and roadway by 17 metres to provide for adaptation to projected climate change. The Project includes the following main activities and elements:

- demolition or removal of parts of the existing Warragamba Dam, including the existing drum and radial gates
- thickening and raising of the dam abutments
- thickening and raising of the central spillway
- new gates or slots to control discharge of water from the flood mitigation zone (FMZ)
- modifications to the auxiliary spillway
- operation of the dam for flood mitigation
- environmental flow infrastructure.

A preliminary construction program is presented in Figure 19-1 with construction anticipated to be completed within four to five years.

Figure 19-1. Preliminary construction program



The Project would delay downstream flooding, which would reduce current downstream flood peaks and increase the time taken for downstream water levels to recede. The dam would be subject to the following operational regimes, depending on the water level.

Normal operation

Normal operations would apply when the reservoir level is at or lower than the full supply level (FSL), which is when the water level in the dam is at or below 116.7 mAHD.

Flood operation

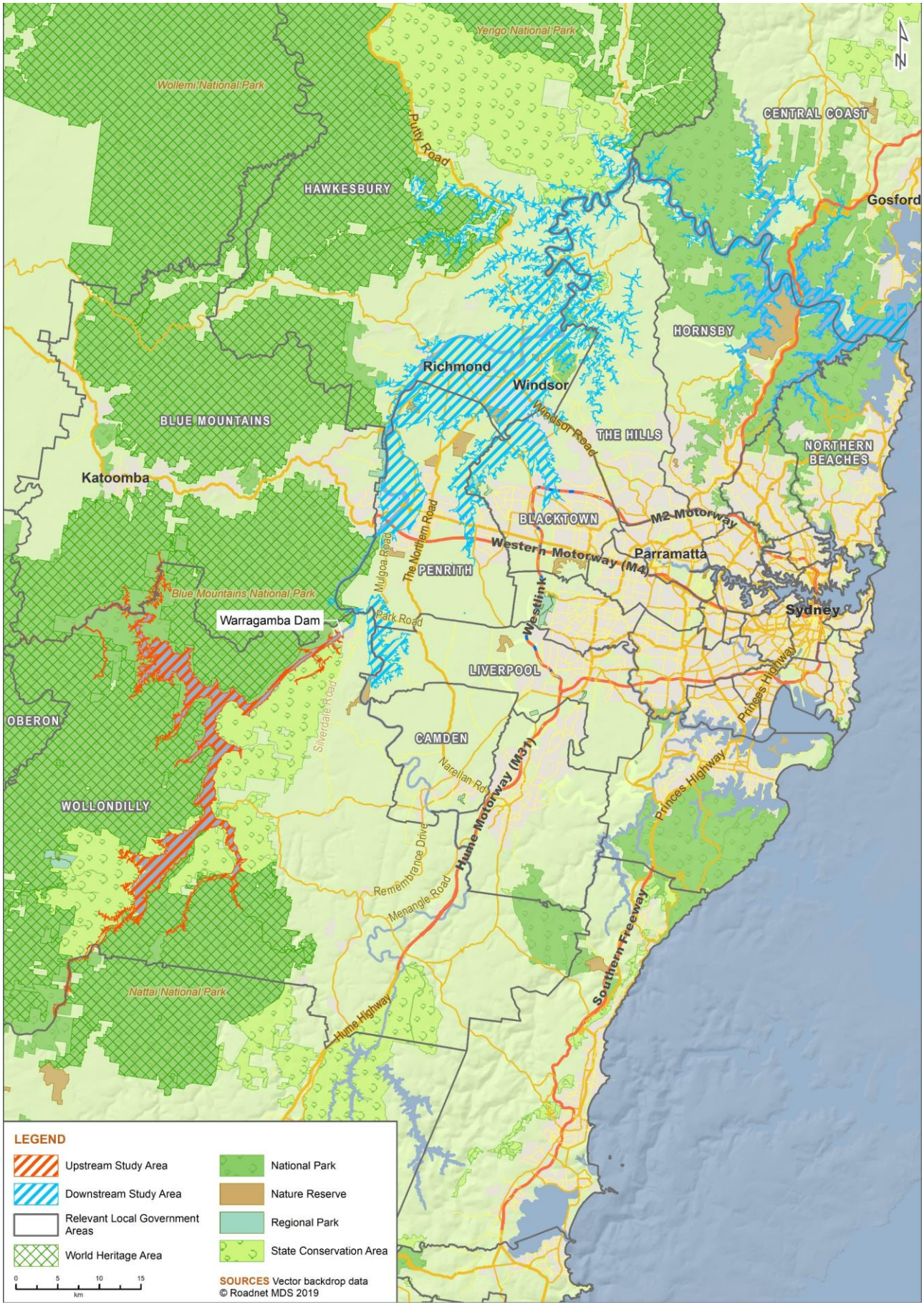
Flood operations would apply when the water level is higher than the FSL. The FMZ would have sufficient storage to accommodate up to a 1 in 40 chance in a year flood. For larger floods the FMZ would be filled and uncontrolled discharge would occur over the central spillway, and potentially, auxiliary spillway of the dam. Operational objectives are to:

- maintain the structural integrity of the dam
- minimise risk to life
- maintain Sydney's water supply
- minimise downstream impact of flooding to properties
- minimise environmental impact
- minimise social impact.

19.1.2 Project location and study area

The Project location and study area are shown on Figure 19-2. Warragamba Dam is located approximately 65 kilometres west of Sydney in a narrow gorge on the lower section of the Warragamba River, 3.3 kilometres before it joins the Nepean River. The township of Warragamba is located approximately one kilometre east of the dam wall. The upstream environment includes the reservoir formed by Warragamba Dam (Lake Burragorang) and its tributaries, and comprises of approximately 5,280 hectares, broadly equating to the area between the existing FSL and the Project probable maximum (PMF) flood level. The downstream environment includes a short section of the Warragamba River, the Hawkesbury-Nepean River and its floodplain, and some of the tributaries of the Hawkesbury-Nepean River (such as South Creek) that experience backwater flooding effects.

Figure 19-2. Project location and study area



The noise and vibration assessment addresses both construction and operational phases, however most of the assessment was focused on the the dam construction area near the township of Warragamba, which broadly covers an area of about 105 hectares. The construction study area includes the dam and the areas in and around the existing Warragamba Dam, including auxiliary access roads and site buildings. The township of Warragamba and areas immediately upstream and downstream of Warragamba Dam, as well as the immediate road network, are included in the construction study area because they are likely to be impacted during construction.

The construction footprint and surrounding areas are shown on Figure 19-3.

19.2 Methodology

19.2.1 Legislation and policy context

Legislation and guidelines relevant to the assessment and management of noise and vibration are addressed in Chapter 2 (Statutory and planning framework) and Appendix L (Noise and Vibration Assessment Report, Section 4). These are summarised below.

19.2.1.1 Protection of the Environment Operations Act 1997

This Act regulates noise, waste, soil pollution, air pollution, and water pollution in NSW. Under Chapter 3 of the Act, an Environment Protection Licence (EPL) may be issued to allow the carrying out of scheduled activities which cause pollution.

19.2.1.2 Noise assessment guidelines

The noise and vibration impact assessment has referenced the following documents:

- *Technical Basis for Guidelines to Minimise Annoyance due to Blasting Overpressure and Ground Vibration* (ANZEC 1990)
- *Interim Construction Noise Guideline* (ICNG) (DECC 2009)
- *Assessing Vibration, A Technical Guideline* (Vibration Guideline) (DEC 2004)
- *Industrial Noise Policy* (INP) (EPA 2000)
- *Road Noise Policy* (RNP) (EPA 2011)
- *Noise Policy for Industry* (NPI) (EPA 2017)
- *Construction Noise and Vibration Guideline* (RMS 2016)
- *Construction Noise Strategy* (TfNSW 2017).

19.2.2 Assessment methodology

Potential noise and vibration impacts for construction and operation of the Project have been assessed using the following methodology:

- identification of sensitive receivers with the potential to be adversely affected by noise and vibration impacts
- characterisation of the existing acoustic environment through:
  - collection of short term (attended) noise measurements
  - collection of long term (unattended) noise measurements
  - review of weather conditions during noise monitoring periods
- reviewing the construction and operational aspects of the Project with the potential to generate noise and vibration impacts
- determining noise and vibration assessment criteria
- noise modelling has been undertaken using the ISO 9613 Acoustics – Attenuation of sound during propagation outdoors (International Organisation for Standardisation (ISO) 1996) algorithms, as implemented within the CadnaA 4.5 acoustic modelling package. As the Project is in a forested gorge and the landscape between the Project and Warragamba township is also forested, noise modelling has assumed that these areas are non-reflective of sound. The lake surface and dam was assumed to be 100 percent reflective.

  A model sensitivity test for more reflective ground conditions (50 percent) and ground absorption, for example if the surrounding landscape was cleared or burnt off in a bushfire, indicated noise levels approximately 1dB higher than presented in this assessment at the nearest residential areas ranging to approximately 2dB higher at the most distant receivers in Warragamba

Figure 19-3. Construction area

- blasting overpressure and ground vibration assessment
- identifying appropriate mitigation and management measures, as necessary.

19.3 Existing environment

19.3.1 Sensitive receivers

Potential noise sensitive receivers located in the Project area include:

- residential areas
- Warragamba Dam Visitors Centre
- Warragamba Dam lookout
- Warragamba public school
- neighbourhood centre
- Warragamba workers club
- Sacred Heart Catholic Church
- Saint Paul's Anglican church
- preschool
- Town Hall
- commercial premises, police station, fire and rescue
- sporting ovals and swimming pool.

Of the above, residential receivers are the nearest potentially impacted receivers to construction activities. As the noise management requirements for residential receivers are more stringent than other categories of receivers, assessment and management of noise impacts has been based off residential receivers. This will provide a conservative assessment for other receivers.

Noise sensitive receivers in Warragamba have been grouped into sensitive receiver noise catchment areas (NCA) (A-F). Noise receivers within the same location have been grouped as they are anticipated to receive similar impacts during construction works. Locations of NCA A to NCA F are shown in Figure 19-4.

The nearest residence is located approximately 600 metres northwest of the main dam wall and the nearest access point by road is approximately four kilometres away at the Nepean River Lookout, in the Blue Mountains National Park.

There are a number of vibration-sensitive heritage receivers near the proposed construction works including:

- Warragamba Supply Scheme dam infrastructure
- Warragamba Dam Visitor Centre
- Haviland Park
- Aboriginal heritage sites.

19.3.2 Noise monitoring

A combination of short term (attended) and long term (unattended) noise monitoring was used to characterise the existing acoustic environment of the study area.

The results of attended noise monitoring showed that the primary influence on ambient noise levels are local community activities, fauna (birds) and insects, and intermittent traffic on Farnsworth Road and Silverdale Road.

Noise emissions from dam operations or industrial activities were not audible during attended noise monitoring.

19.3.2.1 Monitoring methodology

Unattended noise monitoring was undertaken in the suburbs of Wallacia, Warragamba and Silverdale (map grid of Australia (MGA) zone 56) on two occasions between 12-19 March 2018 and 22-29 June 2018. Unattended background noise monitoring was carried out at the five locations shown in Figure 19-4 and detailed in Table 19-2.

Noise loggers were installed to quantify the existing acoustic environment in residential areas potentially impacted by construction activity and construction traffic. Loggers were set to record A-weighted noise levels every 15 minutes and set to 'fast' response time.

Short term noise measurements were also carried out at the monitoring locations. Measurements were undertaken over 15-minute intervals with consideration to AS1055:1997 Description and Measurement of Environmental Noise. Field calibration was checked before and after each measurement occasion with no significant drift (±0.5 dB) observed.

Observation of the weather conditions (recorded at the Badgerys Creek weather station no. 67109 and onsite weather conditions) were reviewed to identify periods of potentially adverse weather that could influence the noise measurements, and these periods were excluded from the noise monitoring data collected. Details of monitoring equipment are provided Appendix L (Noise and Vibration Assessment Report, Section 3.3).

Table 19-2. Noise monitoring locations MGA Zone 56

Location ID	Address	Suburb	Easting (m)	Northing (m)
L1	11 Green Street	Wallacia	281949	6250125
L2	20 Farnsworth Avenue	Wallacia	279571	6248543
L3	37 Thirteenth Avenue	Warragamba	278354	6248177
L4	South West end of Farnsworth Road (Near 2 Nineteenth Street)	Warragamba	278041	6247289
L5	15 Warradale Road	Silverdale	279016	6246505

Figure 19-4. Noise catchment areas and noise monitoring locations

19.3.2.2 Attended noise monitoring results

Background noise levels are given in Table 19-3 and were identified as being consistent with a quiet suburban or rural residential area with low levels of transport-related noise. Background levels were typically between 31−37 dB(A) in daytime periods, 31-35 dB(A) during the evening periods and 26−32 dB(A) during the night time period. Intermittent traffic noise, occasional aircraft noise, occasional community noise and local fauna noise sources were also observed. Noise levels followed diurnal patterns with the ambient noise levels decreasing from day time to night time. L3 was an exception to this, however as this logger was deployed during a warmer part of the year and was potentially impacted by insect noise during the night time.

Table 19-3. Attended noise monitoring summary

Date and time	Location	Measured noise level dB(A)				Noise sources identified during monitoring
		LA_1	LA_{10}	LA_{90}	LA_{eq}	
09/03/18 14:10	L3 - 37 Thirteenth Street, Warragamba	58	49	33	47	Plane overhead 65 dB(A), birds 64-74 dB(A), ambient, distant traffic, insects, birds 34-37 dB(A), distant people talking 40 dB
09/03/18 15:15	L4 - 2 Nineteenth Street, Warragamba*	53	47	36	45	Ambient – insects, distant traffic, birds 38-41 dB(A), Bird 50-60 dB(A), Dog barking 52 dB(A)
12/03/18 15:23	L3 - 37 Thirteenth Street, Warragamba	56	51	39	48	Distant birds – constant 46-52 dB(A), Distant airplane 44 dB(A), Ambient – trees, birds, traffic 43-46 dB(A), Bird nearby 58 dB(A), Distant airplane 53 dB(A), Plane overhead 43 dB(A)
19/03/18 12:29	L4 2 Nineteenth Street, Warragamba*	44	44	39	42	Dog bark - neighbour's air conditioner, birds, insects 39-41 dB(A), Dog barking louder 41-53 dB(A), Birds, car passing 45-47 dB(A), Distant airplane 49 dB(A), Bird screech 52 dB(A)
19/03/18 12:59	L3 - 37 Thirteenth Street, Warragamba	52	40	31	44	Constant birds 50-60 dB(A), lull – only insects 34-36 dB(A), Car take-off 44 dB(A).
22/06/18 11:58	L1 - 11 Green Street, Wallacia	58	49	37	48	Birds 45 dB(A), Trucks (Distant) 50-60 dB(A), Airplane flyover 45-48 dB(A), Dog barking 55-60 dB(A)
22/06/18 12:31	L2 - 20 Farnsworth Avenue, Wallacia	60	53	35	50	Cars passing 60 dB(A), Airplane flyover 40 dB(A), Alarm siren (distant), 38 dB(A), Birds 35 dB(A), Truck passing (distant) 45 dB(A), Distant traffic/birds 35-38 dB(A)
22/06/18 14:10	L4 - Farnsworth Avenue (Closest to 2 19th Street, Warragamba)	50	44	41	43	Intermittent music from construction activities 40-45 dB(A), Birds 40 dB(A), Construction noise hammering) 45 dB(A), Airplane flyover 50-55 dB(A)
22/06/181 4:41	L5 - 15 Warradale Road, Silverdale	59	54	34	48	Cars passing 50-55 dB(A), Background ambience/birds 35 dB(A), Cars passing 40-45 dB(A), Airplane flyover 35-42 dB(A), Distant traffic 36-38 dB(A)

* Attended only monitoring location

The results of the attended monitoring indicate that the passing of occasional vehicles influenced the noise environment at all the monitoring locations. Background noise levels were observed to range from 30−40 dB(A) with no industrial influences audible or affecting the measurements. Operational noise was not audible during attended monitoring. Noise levels were found to be consistent at each monitoring location across the Project area.

19.3.2.3 Unattended noise monitoring results

The unattended noise monitoring results indicate background noise levels were found to be typical of a rural area, ranging between 26 dB(A) and 37 dB(A), as shown in Table 19-4.

Table 19-4. Unattended noise monitoring results

Location	NCA	Measured noise level, dB(A)								
		Day			Evening			Night		
		L_{10}	Rbl	L_{eq}	L_{10}	Rbl	L_{eq}	L_{10}	Rbl	L_{eq}
L1	N/A	53	35	50	48	35	43	49	30	42
L2	N/A	59	37	53	56	34	50	56	30	48
L3	1	58	31	55	56	33	48	51	32	46
L5	N/A	55	32	50	53	31	47	46	26	43

Notes: The noise logger at L4 had noticeable signs of tampering, so was excluded from the dataset.

19.4 Noise and vibration assessment criteria

People's reactions to noise can vary widely depending on multiple factors including their perception of the activity that produces the noise. The measure of a person's response to noise is described as their relative level of 'annoyance'. Sound is measured in decibels dB(A) and the noise criterion is presented as L_{Aeq} which is the average sound level over a given period (for example 24 hours).

19.4.1 Construction noise criteria

The *Interim Construction Noise Guideline* (ICNG) (DECC 2009b) provides noise management levels (NML) for the control of noise from construction. The NMLs for residential receivers and other sensitive receivers are based on the rating background level (RBL) (refer to Table 19-5).

The ICNG recommends standard hours for construction activities as Monday to Friday: 7am to 6pm, Saturday: 8am to 1pm and no work on Sundays or public holidays. The proposed construction activity would generally be limited to the day time period and as such a noise goal of RBL + 10 dB(A) would apply at residential receivers. However, it is anticipated that some concrete pours during the summer months may extend into the night time period and operation of chilling plant for concrete curing may also occur 24 hours per day during warmer months. These activities are therefore assessed using out of hours (OOH) noise criteria.

Table 19-5. NML for sensitive receivers

Land use	Construction NML ($L_{Aeq(15min)}$)
Residential – recommended standard hours ▪ Monday to Friday, 7.00am to 6.00pm ▪ Saturday, 8.00am to 1.00pm ▪ No work on Sundays or public holidays	Noise affected level (RBL plus 10 dB(A)) Highly noise affected level – 75 dB(A)
Residential – outside of recommended standard hours (Night)	Noise affected level (plus 5 dB(A))
School classrooms	45 dB(A) internal noise level
Places of worship	45 dB(A) internal noise level
Active recreation	65 dB(A) external noise level
Commercial premises	70 dB(A) external noise level

19.4.1.1 Sleep disturbance

The *Noise Policy for Industry* (EPA 2017) states that 'the potential for sleep disturbance from maximum noise level events from premises during the night time period needs to be considered. Sleep disturbance is considered to be both awakenings and disturbance to sleep stages.'

The following limits for sleep disturbance are applied to the night time noise levels generated from the Project at the nearest residential location:

- $L_{Aeq,15min}$ 40 dB(A) or the prevailing RBL plus 5 dB, whichever is the greater, and/or
- L_{AFmax} 52 dB(A) or the prevailing RBL plus 15 dB, whichever is the greater.

Thus the sleep disturbance criteria for residential receivers would be $L_{Aeq,15min}$ 45 dB(A) and L_{AFmax} 52 dB(A).

19.4.1.2 Road noise criteria

The assessment of road traffic noise impacts on public roads is assessed under the NSW *Road Noise Policy* (RNP) (DECCW 2011).

Construction of the Project would result in an increase in traffic on local roads associated with construction vehicle movements. Road access to the Project will be via Park Road, Silverdale Road, Farnsworth Avenue and Production Avenue which are classed as collector or sub-arterial roads. The RNP details noise assessment criteria for various road categories and land uses, including residential as shown in Table 19-6. The assessment criteria for external noise levels apply at one metre from the façade of the affected residential receiver.

Operational traffic is expected to be similar to current levels.

Table 19-6. RNP residential road traffic noise criteria

Road category	Type of project/land use	Assessment criteria – dB(A)	
		Day (7am to 10pm)	Night (10pm to 7am)
Freeway/arterial/sub-arterial roads	Existing residences affected by additional traffic on existing freeways/arterial/sub-arterial roads generated by land use developments.	$L_{Aeq,15hr}$ 60 (external)	$L_{Aeq,9hr}$ 55 (external)

For existing residences and other sensitive land uses affected by additional traffic on existing roads generated by land use developments, the RNP states that any increase in the total traffic level should be limited to 2 dB above the road traffic noise level without the development. The RNP states that this limit should be applied wherever the noise level without the development is within 2 dB of or exceeds the noise assessment criteria.

Where existing noise levels are more than 2 dB below the criteria, any increase due to the Project should be limited to 12 dB above the existing noise level with the criteria as the upper limit. Where existing noise levels are either within 2 dB of or above the absolute criteria, any increase due to the Project should be limited to 2 dB above the existing noise level.

19.4.1.3 Summary of noise management levels

The Project specific construction noise management levels for sensitive receivers are presented in Table 19-7 and are based on the background noise levels calculated from the noise monitoring.

Table 19-7. Construction noise management levels

Location	NCA (A) to NCA (F) Management level dB(a) $LA_{eq\ 15minute}$
Background noise level	
RBL standard hours	31
RBL Day (OOH)	31
RBL Evening (OOH)	31
RBL Night (OOH)	30
Construction noise management levels	
Standard Hours	41
RBL Day (OOH)	36
RBL Evening (OOH)	36
RBL Night (OOH)	35
Sleep Disturbance, L_{Aeq} (L_{Amax})	45 (52)

1. Construction noise criteria calculated as Leq,15min = RBL+ 10 dB for day and Leq,15min = RBL + 5 dB for evening and night.
2. Standard hours: Monday to Friday 7am to 6pm Saturday 8am to 1pm. OOH day: Saturday 1pm to 6pm Saturday, 7am to 6pm Sunday. OOH evening: Monday to Sunday 6pm to 10pm. OOH Night time: Monday to Saturday 10pm to 7am Sunday & public holidays 10pm to 8am.
3. Night time noise criteria has adopted the background noise level from the north east of the dam wall as NCA data was collected during warmer months with potentially greater insect activity.

19.4.2 Construction vibration criteria

Impacts from vibration have been assessed in terms of effects on building occupants (human comfort) and the effects on the building structure (building damage). Of these potential impacts, the human comfort limits are the more stringent. Therefore, for occupied buildings, if compliance with human comfort limits is achieved, it will follow that compliance will be achieved with the building damage criteria.

19.4.2.1 Human comfort

Human comfort vibration criteria have been set in accordance with *Assessing Vibration: A technical guideline* (DECC 2006). British Standard BS 6472 – 1992, Guide to Evaluation of Human Exposure to Vibration in Buildings (one Hz to 80 Hz) is recognised by the Environment, Energy and Science Group of the Department of Planning, Industry and Environment as the preferred standard for assessing the 'human comfort'.

Sources of vibration are defined as either 'Continuous', 'Impulsive' or 'Intermittent'. The preferred and maximum values for continuous, impulsive and intermittent vibration for the Project are compared against the preferred maximum levels for human comfort set out in *Assessing Vibration: A technical guideline – Table 2.2* (DECC 2006). Where vibration is intermittent, such as for construction sources, a vibration dose is calculated, and acceptable values are shown in Table 19-8.

Table 19-8. Acceptable vibration dose values for intermittent vibration

Location	Day time[1]		Night time[1]	
	Preferred value ($m/s^{1.75}$)	Maximum value ($m/s^{1.75}$)	Preferred value ($m/s^{1.75}$)	Maximum value ($m/s^{1.75}$)
Critical areas [2]	0.10	0.20	0.10	0.20
Residences	0.20	0.40	0.13	0.26
Offices, schools, educational institutions and places of worship	0.40	0.80	0.40	0.80
Workshops	0.80	1.60	0.80	1.60

1. Day time is 7am to 10pm and night time is 10pm to 7am.
2. Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring. These criteria are only indicative and there may be a need to assess intermittent values against the continuous or impulsive criteria for critical areas. Source BS 6472-1992.

19.4.2.2 Building structural damage criteria

Safe limits for construction- generated vibration have been determined using the vibration limits set out in the German Standard DIN 4150 Part 3-1999 Structural Vibration in Buildings – Effects on Structures. The minimum 'safe limit' of vibration at low frequencies for commercial and industrial buildings is 20 mm/s. For dwellings it is five mm/s and for particularly sensitive structures (for example, heritage listed buildings), it is 3 mm/s. These limits increase as the frequency of vibration increases. These values are presented in Table 19-8 and are generally recognised to be conservative.

The recommended limits (guide values) from DIN 4150 for transient vibration to ensure minimal risk of cosmetic damage to residential and industrial buildings are presented in Table 19-9. The sensitivity of a structure is dependent on the type of construction and the frequency of the vibration source. Structures that are more sensitive to lower frequency vibration, require a lower criteria level.

Table 19-9. Guideline vibration criteria for structural damage

Type of structure	Guideline values for velocity (mm/s)			
	1 to 10 hz	10 to 50 hz	50 to 100 hz	Vibration at horizontal plane of highest floor at all frequencies
Commercial and industrial building	20	20-40	40-50	40
Dwellings and buildings of similar occupancy or design	5	5-15	15-20	15
Structures that, because of their particular sensitivity to vibration cannot be classified under rows 1 and 2 and are of great intrinsic value (e.g. heritage buildings)	3	3-8	8-10	8

19.4.2.3 Blasting overpressure and vibration

Blasting overpressure and ground vibration has been assessed using the ANZECC *Technical Basis for Guidelines to Minimise Annoyance Due to Blasting Overpressure and Ground Vibration* (ANZECC guidelines) (ANZECC 1990). These guidelines set limits for overpressure and ground vibration levels. Where compliance is achieved, the risk of annoyance is minimised. The limits are presented in Table 19-10.

The guidelines recommend that blasting is carried out between 9am and 5pm Monday to Friday and should not be carried out outside of these times, including on Sundays and Public Holidays. The guideline levels contained within AS 2187: Part 2-2006 Explosives – Storage and Use – Part 2: Use of Explosives is discussed in Appendix L (Noise and

Vibration Assessment Report, Section 5.5) and is generally consistent with the human comfort levels described in the ANZECC guidelines.

Table 19-10. ANZECC guideline blasting limits

Criteria	Overpressure dB (linear peak)	Ground vibration PPV (mm/s)
Recommended Maximum (95% of all blasts)	115	5
Level not to be exceeded	120	10
Long term goal for ground vibration	-	2

Notes: Overpressure limits apply where measurement equipment has a cut-off frequency of 2 Hz or less. Where equipment has a high cut-off frequency, 5 dB should be added to all levels.
PPV – peak particle velocity.

WaterNSW has the following Project-specific limits for ground vibration on nearby water infrastructure during construction, as shown in Table 19-11. Although the dam infrastructure has been identified as a heritage item, it is not considered a vibration sensitive structure as per Table 19-9 or Table 19-10.

Table 19-11. WaterNSW dam infrastructure ground vibration limits during construction

Structure	PPV (mm/s)
Concrete less than 7 days old	10
Concrete after 7 days	25
Concrete after 28 days (including existing concrete structures or concrete placed as part of the works).	50
Pressure grouted foundations	20
Pipelines	50
Power pylon near spillway crest	100

19.4.3 Operational noise criteria

The NSW Government's policy and guidelines for the assessment of industrial noise are presented in the *Noise Policy for Industry* (NPI) (EPA 2017). The policy is applied to premises which generate noise including 'utility generation/reticulation services premises' and has been applied to set noise targets from potential operational noise sources associated with the Project.

The NPI recommends intrusiveness criteria for residential receivers to address the potential for intrusive noise and amenity criteria to maintain acoustic amenity appropriate to the relevant land use category of the area. The criteria set out in the NPI are non-mandatory, however it is emphasised that all reasonable and feasible measures should be implemented to attempt to achieve the criteria. Where the criteria are not met, additional considerations may apply.

Intrusive noise level criteria have been determined based on background results plus 5 dB(A). Noise criteria equivalent to the minimum Project intrusiveness noise levels of 40 dB for the day time and 35 dB for the night time period would apply. A summary of the intrusive noise levels is shown in Table 19-12 for receivers potentially impacted by dam operations in each NCA.

Table 19-12. Intrusive noise criteria

Time of day	Background noise level	Minimum Project intrusiveness noise levels (L_{Aeq},15min dB(A))
Day: 7am to 6pm	31	40
Evening: 6pm to 10pm	31	36
Night: 10pm to 7am	30	35

Amenity noise levels are also applied to limit continuous increases in industrial noise when only an intrusive criterion is applied. Noise sensitive receivers located within a suburban area range from 55 dB(A) for the day time period to 40 dB(A) during the night time. In this situation the intrusive limit is the controlling level for the Project.

19.5 Assessment of potential construction impacts

The assessment of construction noise impacts was based on the stages shown in Table 19-13.

It is anticipated that construction would generally be limited to standard hours in accordance with the ICNG however, it is anticipated that some concrete pours during warmer periods may occur into the night time period. Operation of chilling plant for concrete curing may also occur 24 hours per day during warmer periods.

Table 19-13. Construction stages modelled

Construction stage	Works activities
Early works	Laydown area clearing Minor roadworks Utilities investigations
Enabling works and demolition (including environmental flow infrastructure)	Batch plant(s) installation Coffer dam installation Minor structures demolition
Main construction works	Spillway and abutments widening and thickening preparation and construction works Auxiliary spillway works Other infrastructure Environmental flow infrastructure
Demobilisation and site restoration	Batch plant decommissioning, landscaping, removal of coffer dams, minor works

Construction impacts modelling

Noise modelling has been undertaken using the ISO 9613 Acoustics – Attenuation of sound during propagation outdoors (ISO 1996) and CONCAWE's Special Task Forces in Noise Propagation (CONCAW 1981) algorithms, as implemented within the CadnaA 4.5 acoustic modelling package.

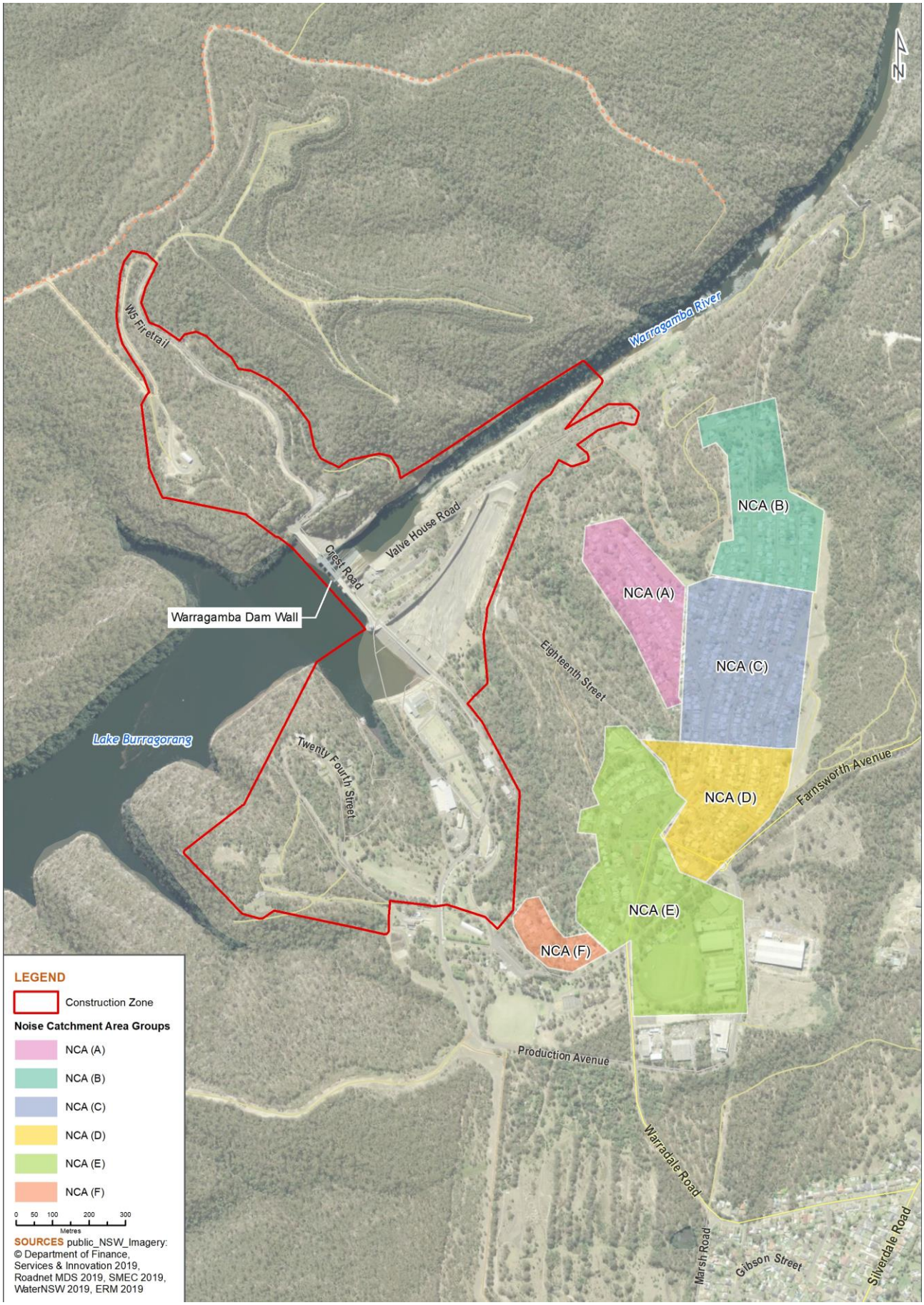
The noise modelling takes into consideration the sound power levels of the proposed site operations, activities and equipment, and applies adjustments based on local conditions. Sound power levels for plant used in each construction stage have been adopted based on UK DEFRA construction noise database (frequency spectrums) adjusted in line with typical construction plant sound power levels as described in the *Construction Noise Strategy* (TfNSW 2017a) and *Construction Noise and Vibration Guideline* (RMS 2016). Sound power levels for individual plant items are included in Appendix L (Noise and Vibration Assessment Report, Section 5).

19.5.1 Amenity impacts

Noise modelling provided predicted noise levels during site establishment, main construction works, and OOH works are described in Appendix L (Noise and Vibration Assessment Report, Section 5). Construction plant and equipment has been modelled assuming that plant would be operational at full utilisation for the modelled period however, it should be noted that construction equipment noise emissions can vary significantly depending on plant used, location, orientation, mode of operation and different models.

Results have been presented as a range of minimum and maximum noise levels in each NCA (refer Figure 19-5) to show the range of impacts from each stage (see Table 19-13) at residential receivers. Each NCA group (A-F) is anticipated to experience similar impacts during the proposed works.

Figure 19-5. Noise catchment area groups



Predicted noise levels have been presented with the magnitude of noise exceedances as per Table 19-14. Noise modelling inputs and results are provided in Appendix L (Noise and Vibration Assessment Report, Section 5).

Table 19-14. Impact rating key

Description	Exceedance above RBL, dB(a)	Predicted noise level, dB(a)	Magnitude key
Noticeable	0 – 10 dB(A)	-	
Clearly audible	10 – 20 dB(A)	-	
Moderately intrusive	20 – 30 dB(A)	-	
Highly intrusive	> 30 dB(A)	-	
Highly noise affected	-	> 75 dB(A)	

19.5.1.1 Noise impacts on receivers during standard hours

The results of the noise modelling predict that noise levels would exceed construction noise criteria during each construction stage, as shown in Table 19-15. The predicated construction noise levels are expected to range from noticeable to clearly audible across each of the catchment areas assessed in Warragamba. The nearest residential receivers on the western edge of NCA (E) and NCA (F) are predicted to experience noise levels up to 57-58 dB(A) during each construction stage.

Throughout the construction works program it is anticipated that there will be periods where rock breaking/jack hammering and drilling would be undertaken. When these activities are in use, a 5 dB penalty is applied to the predicted noise levels to take into account additional annoyance from these sources. That is a noise impact up to 62-63 dB at the nearest receivers.

Table 19-15. Predicted construction noise (standard hours)

Receiver Group	Criterion		Noise Level (dB(A)) for each construction stage			
	$L_{Aeq,15min}$ dB(A)		Early works	Establishing works and demolition	Main works	Demobilisation and site restoration
NCA (A)	41	Min	44	48	47	47
		Max	48	53	54	52
NCA (B)	41	Min	39	42	**41**	42
		Max	48	48	48	47
NCA (C)	41	Min	40	43	42	43
		Max	46	49	49	49
NCA (D)	41	Min	43	44	44	44
		Max	49	49	49	49
NCA (E)	41	Min	45	45	45	45
		Max	53	**57**	**56**	**57**
NCA (F)	41	Min	52	49	51	49
		Max	**58**	**52**	**57**	**53**

1. All levels presented as LAeq 15minute dB(A) Values denoted in **Bold** exceed the noise management level. Colour coding indicates predicted noise level above the RBL. Blue 0-10 dB, green 10-20dB, yellow 20-30dB.
2. Where highly annoying noise sources such as rock breaking are undertaken as part of the construction works, a 5dB penalty would be applied to the predicted levels presented in this table when these works are underway.

Noise contours for each construction stage modelled during standard hours are shown in Figure 19-6, Figure 19-7, Figure 19-8 and Figure 19-9. Based on the results of this assessment, noise management and mitigation measures have been recommended as presented in Section 19.6.

Figure 19-6. Noise contours predicted during demobilisation

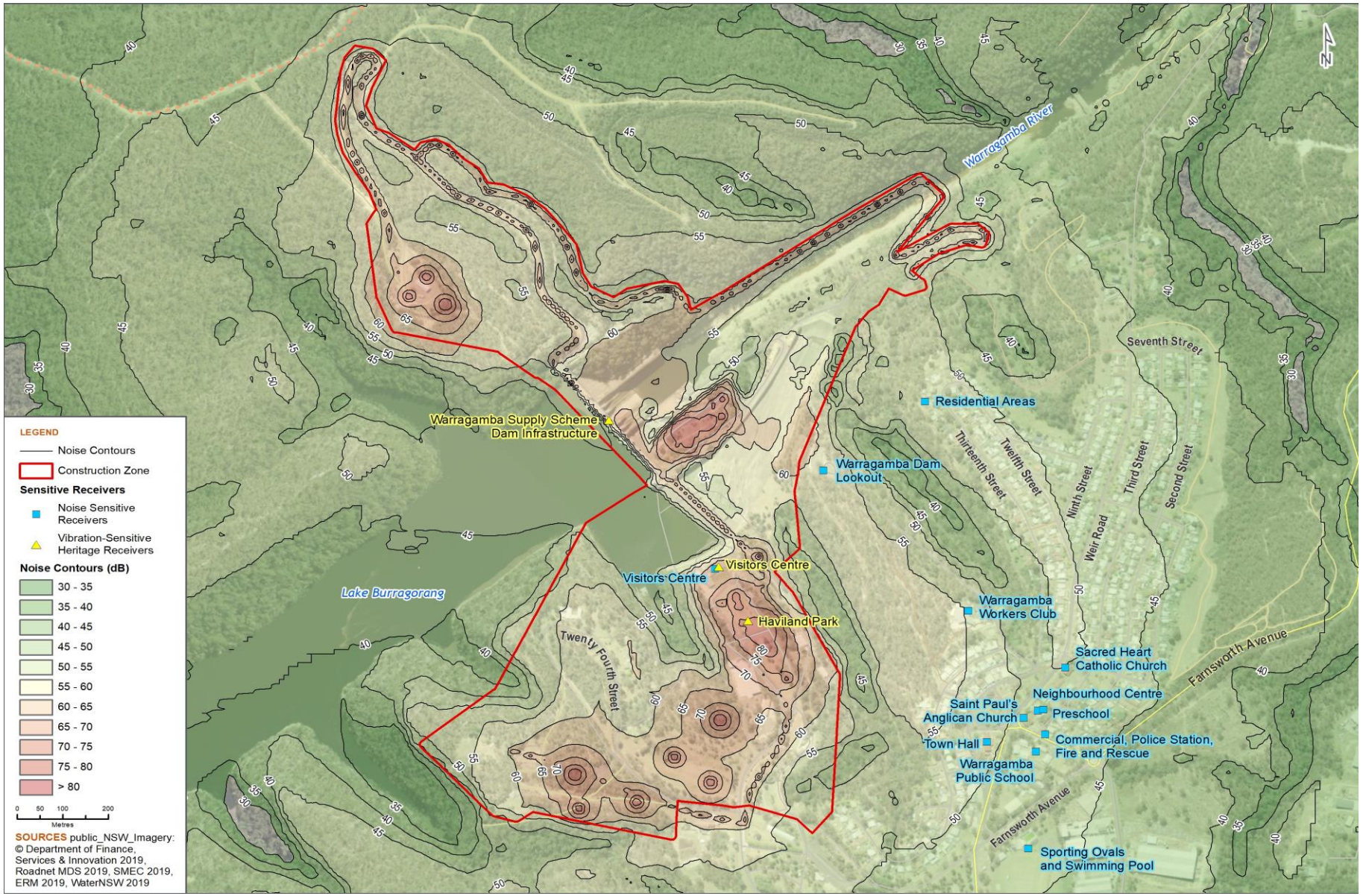


Figure 19-7. Noise contours predicted during early works

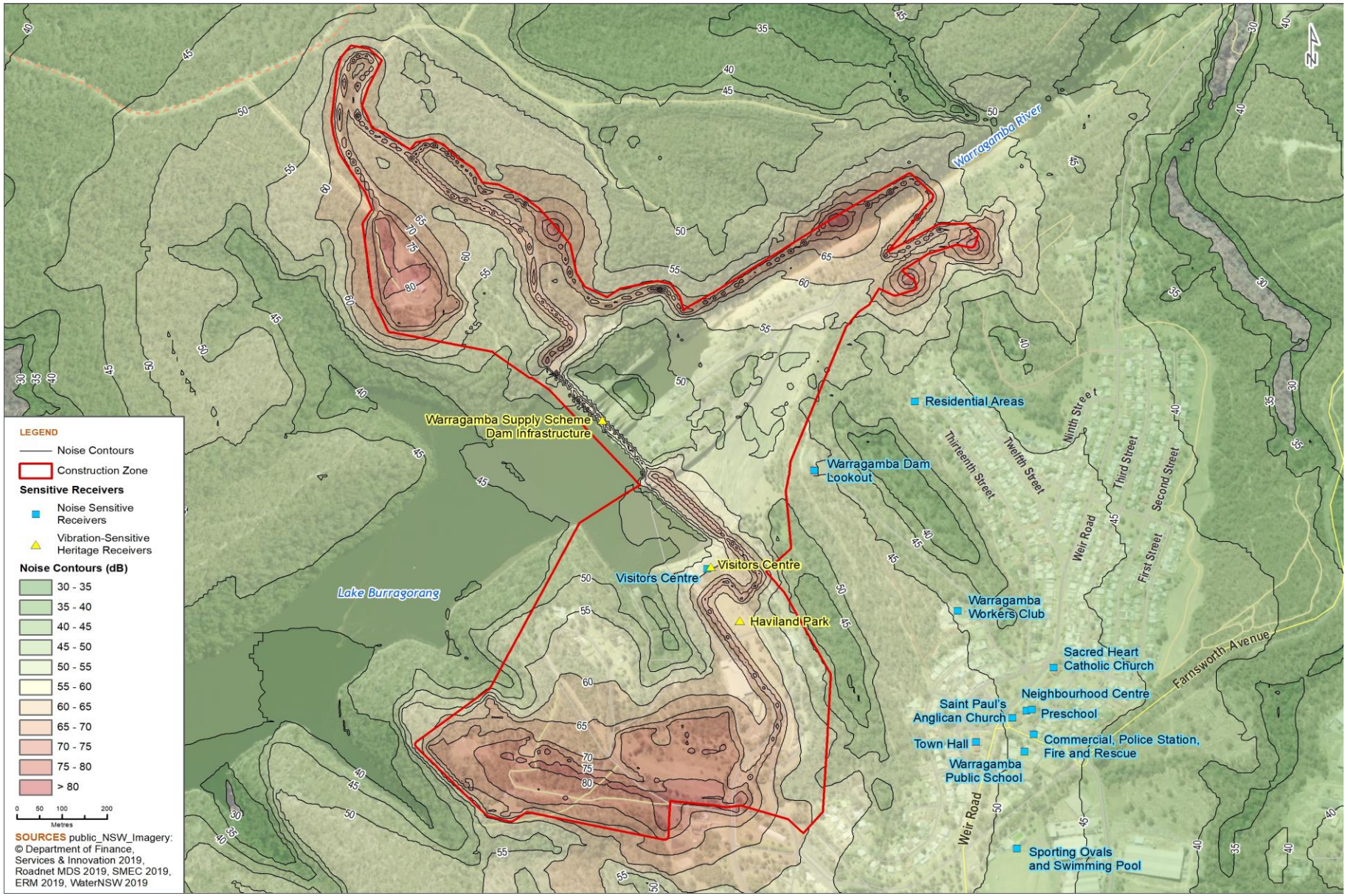


Figure 19-8. Noise contours predicted during enabling works and demolition

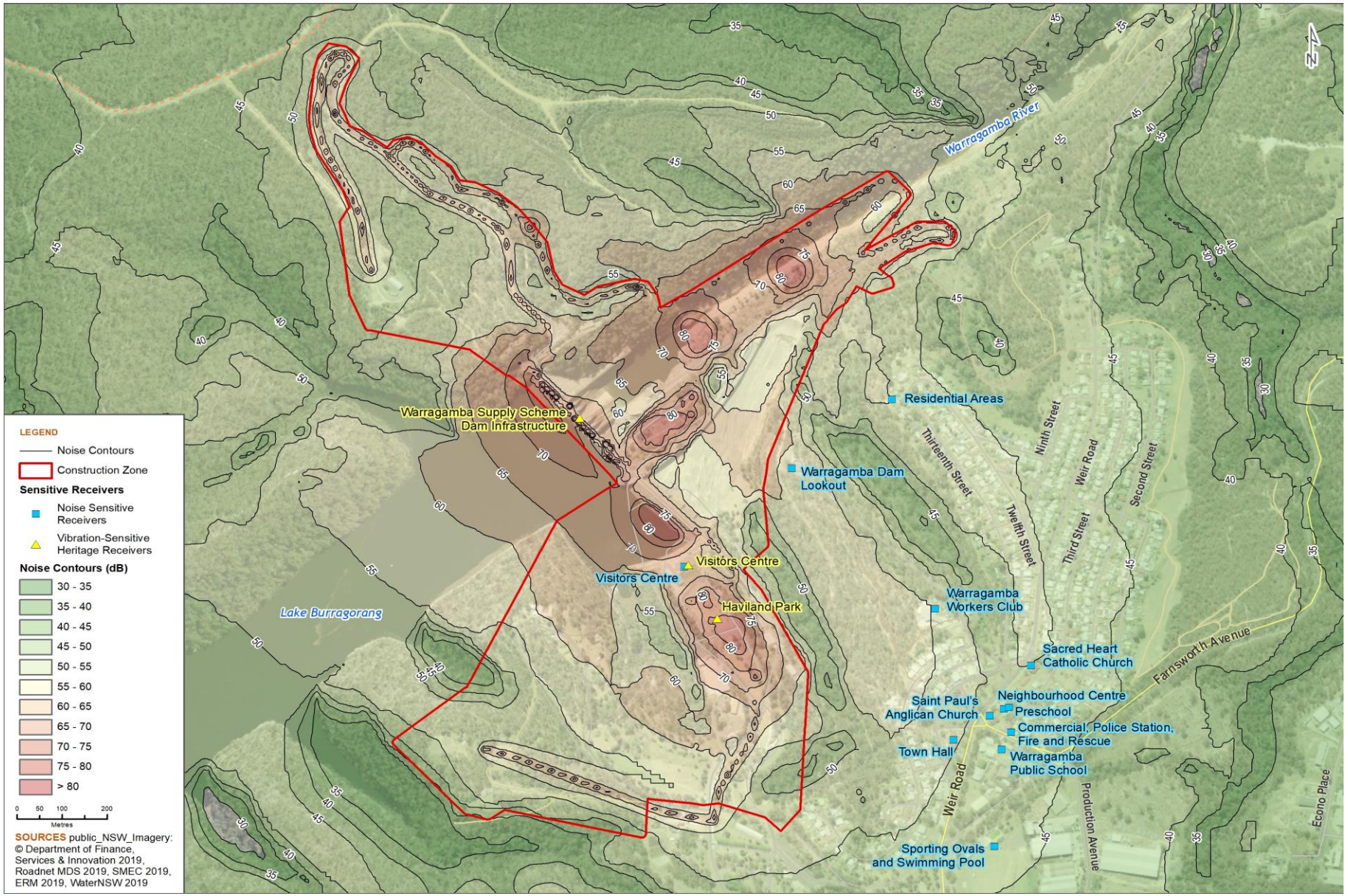
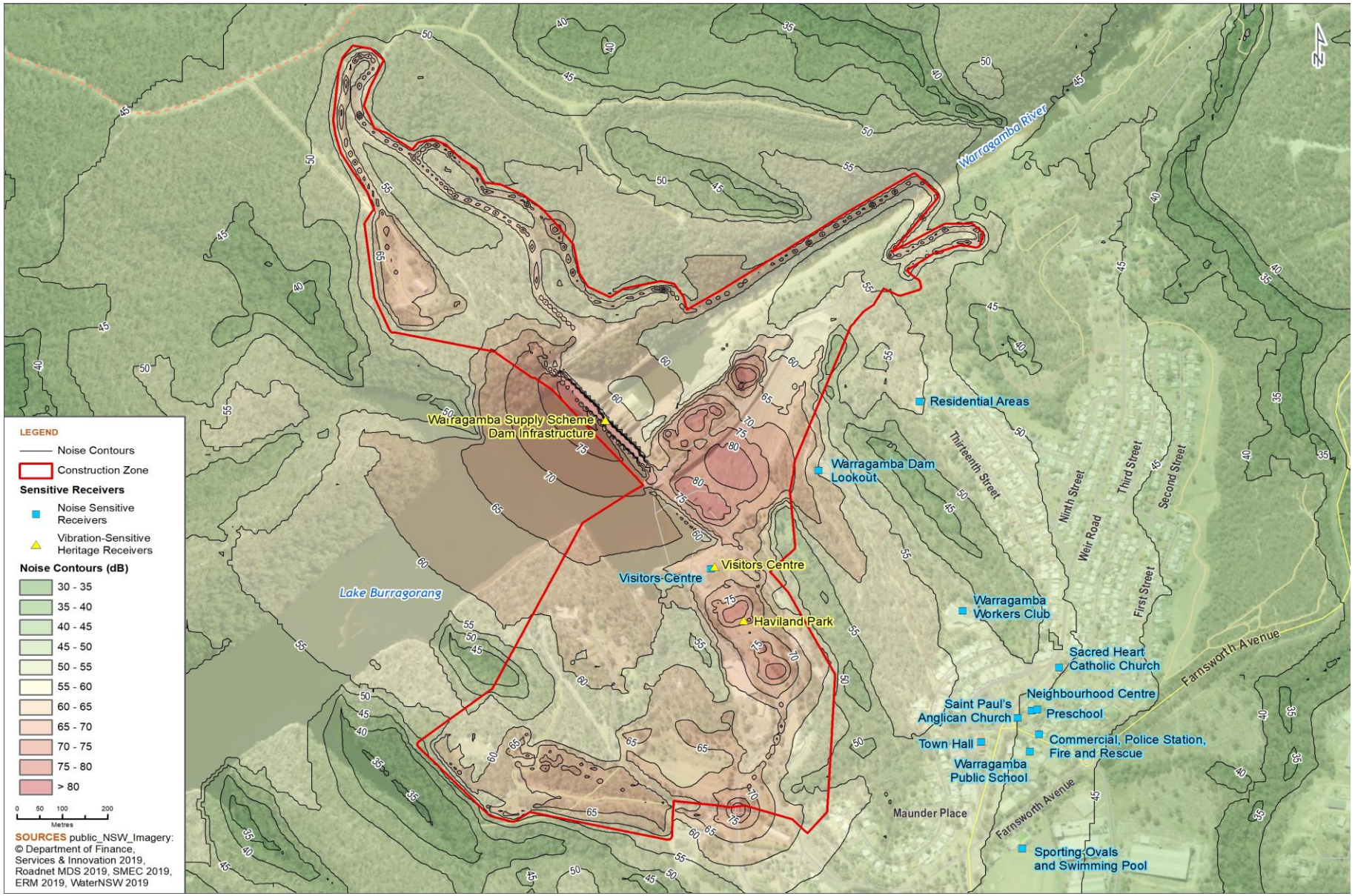


Figure 19-9. Noise contours predicted during main works



19.5.1.2 Noise impacts on receivers during OOH works

Works outside standard hours may be required due to the construction methodology and concrete pour requirements. The results of the noise modelling indicate that activities occurring outside of standard hours would potentially result in noise exceedances of NMLs, as shown in Table 19-16. Specific out of hours works management and mitigation measures would therefore be required (and are discussed in Section 19.6).

Operation of chilled water plants is not expected to result in noise exceedances when operated overnight.

Potential sleep disturbance impacts were also identified at receivers closest to construction works required at night time.

To reduce potential impacts during these periods, it is recommended that high noise generating activities be limited and an out of hours works protocol be developed.

Table 19-16. Predicted construction noise (outside of standard hours)

Receiver group	OOH Criteria ($L_{Aeq, 15min}$ (dB(A))				Noise level ($L_{Aeq,}$ (dB(A))					L_{Max}
	Day/ Evening	Night	Sleep disturbance		Batch plant 1	Batch plant 2	Dam wall works	Cooling plant 24-hr operation	Sum	Night time max
NCA (A)	36	35	40 (52 L_{Max})	Min	**41**	43	**38**	26	46	47
				Max	47	47	43	33	50	52
NCA (B)	36	35	40 (52 L_{Max})	Min	35	**37**	33	20	40	42
				Max	**41**	43	**39**	28	46	48
NCA (C)	36	35	40 (52 L_{Max})	Min	34	**38**	34	20	41	42
				Max	42	46	42	28	49	49
NCA (D)	36	35	40 (52 L_{Max})	Min	35	40	35	22	42	43
				Max	41	45	40	26	47	48
NCA (E)	36	35	40 (52 L_{Max})	Min	**36**	42	**36**	21	44	44
				Max	47	**53**	47	33	**55**	**55**
NCA (F)	36	35	40 (52 L_{Max})	Min	42	46	**41**	24	49	49
				Max	46	**50**	45	27	**53**	**53**

Note: Values denoted in **Bold** exceed the noise management level. Colour coding indicates predicted noise level above the RBL. Blue 0-10 dB, green 10-20 dB, yellow 20-30 dB based on the day/evening for construction works and night time Lmax criteria.

Noise contours for operation of the batch plant outside of standard hours are shown in Figure 19-10 and for the cooling plant outside of standard hours are shown in Figure 19-11.

Figure 19-10. Noise contours predicted at the batch plant during night works

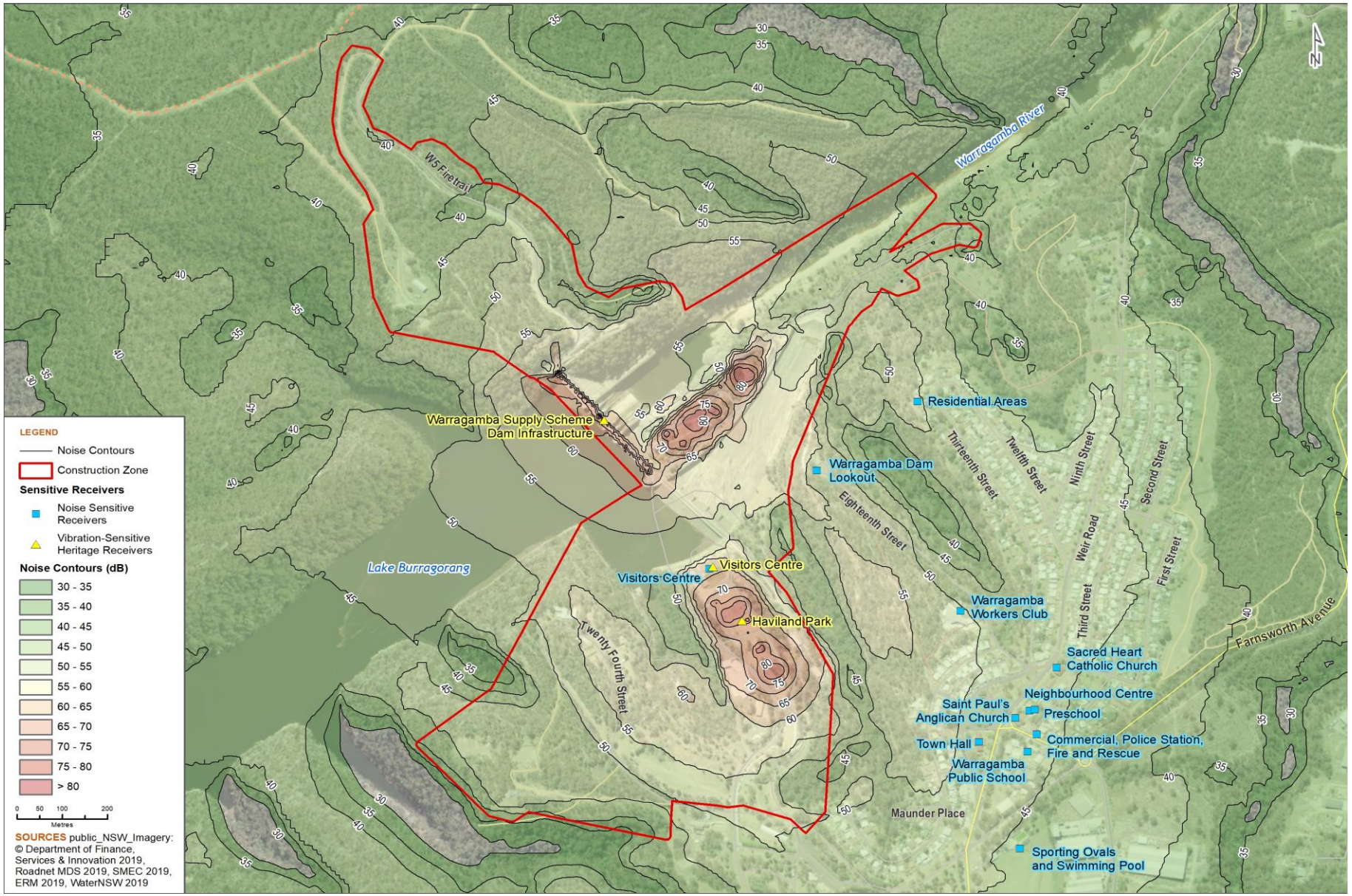
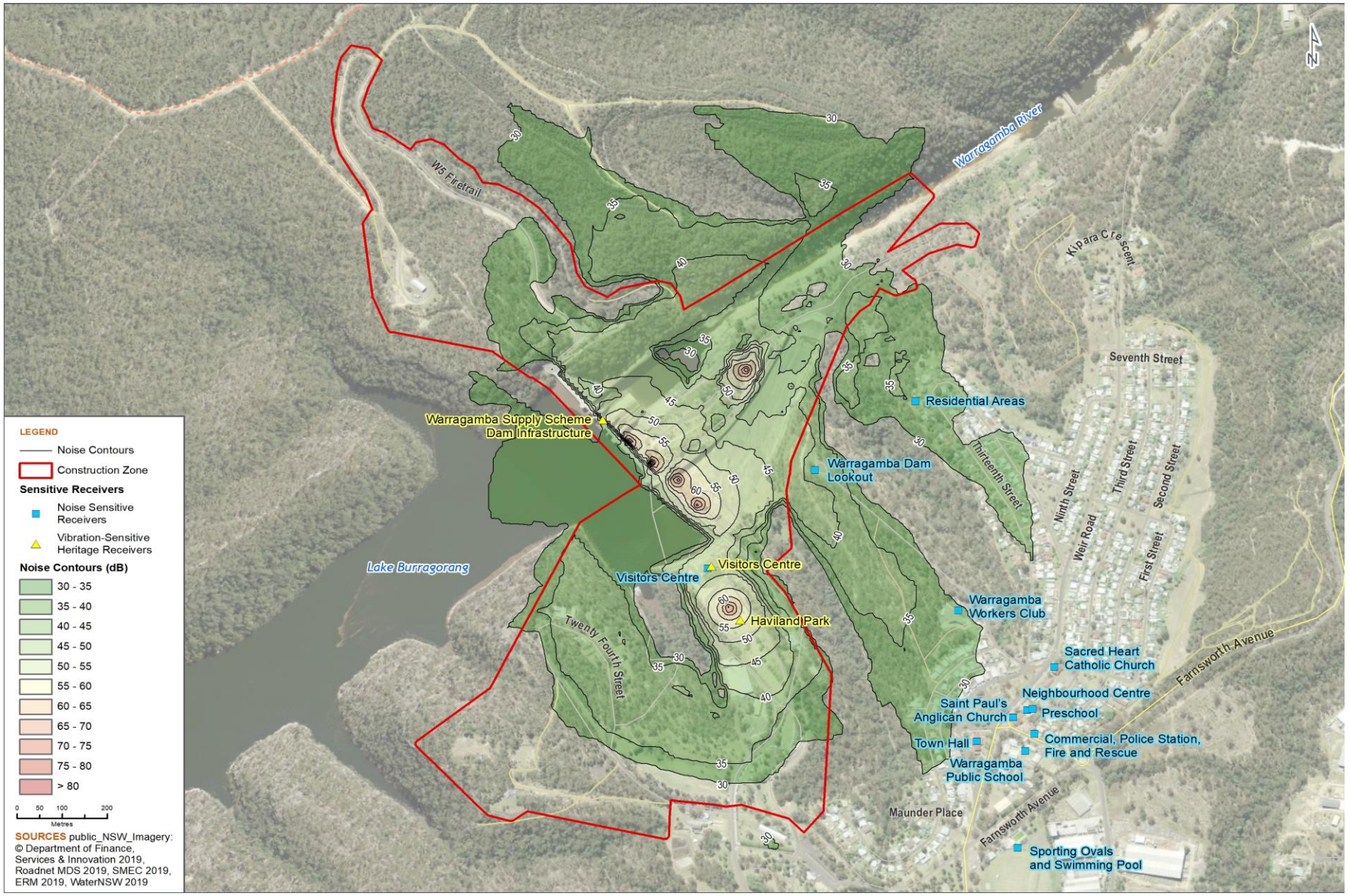


Figure 19-11. Noise contours predicted at cooling plant during night works



19.5.1.3 Noise impacts on receivers due to construction traffic

Potential impacts from additional traffic generating noise from the Project construction were estimated using the Calculation of Road Traffic Noise (CoRTN) model. Traffic volumes were based on information provided in Appendix O (Traffic and Transport Assessment). Up to 208 heavy vehicle movements may occur over the day time construction period and up to 250 light vehicle movements may occur during the morning and afternoon peak hours during the peak construction phase from workers traveling to and from the project. Additional traffic movements anticipated during construction of the proposal would generally be limited to day time working hours.

Traffic noise modelling was completed using predicted construction traffic volume data for the following public road transport routes:

- Park Road
- Silverdale Road
- Farnsworth Avenue.

These roads have been classed as collector or sub arterial roads due to their function of providing connections between local roads and carrying through traffic.

The assessment of road noise impact was completed at the nearest receivers to the above roads, including R1 (17 metres from Park Road), R2 (23 metres from Silverdale Road) and R3 (24 metres from Farnsworth Road). The results are shown in Table 19-17.

Table 19-17. Predicted construction traffic noise levels

Address	Segment	Distance to receiver, m[1]	Period[2]	Criteria, L_{Aeq}	Existing	100% North	50/50 Route
						Noise level L_{Aeq}	Noise level L_{Aeq}
24 Park Road, Wallacia	Park Road	17	Day	60	64.9	65.5	65.3
			Night	55	58.5	59.2	59.2
16 Farnsworth Avenue, Wallacia	Farnsworth Avenue	24	Day	60	58.9	60.6	60.1
			Night	55	51.4	52.9	52.9
15 Warradale Road, Silverdale	Silverdale Road	11	Day	60	59.4	59.9	60.4
			Night	55	52.1	53.9	53.9

1 Receiver distances measured from centre line of road.

2. Day: 7am – 10pm, night: 10pm – 7am.

Comparison of the predicted noise levels with the RNP (DECCW 2011) criteria indicated existing traffic noise levels are potentially above traffic noise criteria for the nearest receivers to Park Road, Wallacia during both the day time and night time periods. Existing traffic noise levels were below the criteria for the nearest receivers to Farnsworth Road and Silverdale Road.

The results of the modelling showed that the addition of Project construction traffic would not result in a noise level increase greater than 2 dB, and as such would not result in a noticeable increase in traffic noise. The greatest noise increase is expected for Warradale Road residents where traffic noise levels would increase by 1.8 dB during the night time period (associated with early morning construction traffic) from additional passenger vehicle traffic.

As per the RNP (DECCW 2011; p21)

> *an increase of up to 2 dB represents a minor impact that is considered barely perceptible to the average person.*

Mitigation measures for construction traffic noise is therefore not expected to be required.

19.5.2 Structural

19.5.2.1 Vibration due to plant and equipment

The principal items of plant used during construction activities which have potential to generate vibration impacts at nearby receivers are a vibratory roller and hydraulic hammer. Vibration impacts as a result of blasting during construction are discussed in the following section.

Locations within the Project area and approximate distances to receivers are shown in Table 19-18.

Table 19-18. Equipment that may generate vibration and distances to nearby receivers

Item	Locations	Approximate distance to nearest receiver
Vibratory Roller (15 t)	Batch Plants	350 m (NCAE)
	Auxiliary spillway	540 m (NCAE)
	Upstream coffer dam	450 m (NCAE)
	Downstream coffer dam	550 m (NCAA)
Hydraulic Hammer	Batch plants	350 m (NCAE)
	Dam wall	600 m (NCAE)
	Auxiliary spillway	540 m (NCAE)

The results indicate that vibration from construction activities would not have a significant impact at the nearest sensitive receivers however, the *Construction Noise and Vibration Guideline* (RMS 2016) provides recommended safe working distances for a range of construction activities and should be followed. These are presented in Table 19-19 and provide for minimum safe working distances to prevent cosmetic damage and human response, and must be complied with at all times, unless additional assessment or monitoring is completed to determine site-specific safe working distances.

No buildings are located within the minimum safe working distance for jackhammers. No buildings are located within the minimum safe working distances for structural damage for key plant for each of the construction scenarios presented in Table 19-13.

Table 19-19. Recommended minimum safe working distances for vibration intensive plant (source: Construction Noise and Vibration Guideline (RMS 2016))

Item	Rating/description	Minimum safe working distance	
		Cosmetic damage (BS 7385)	Human response (OH & E vibration guideline)
Vibratory roller	< 50 kN (Typically 1-2 t)	5 m	15 m to 20 m
	< 100 kN (Typically 2-4 t)	6 m	20 m
	< 200 kN (Typically 4-6 t)	12 m	40 m
	< 300 kN (Typically 7-13 t)	15 m	100 m
	> 300 kN (Typically 13-18 t)	20 m	100 m
	> 300 kN (> 18 t)	25 m	100 m
Small hydraulic hammer	(300 kg - 5 to 12 t excavator)	2 m	7 m
Medium hydraulic hammer	(900 kg – 12 to 18 t excavator)	7 m	23 m

Item	Rating/description	Minimum safe working distance	
		Cosmetic damage (BS 7385)	Human response (OH & E vibration guideline)
Large hydraulic hammer	(1,600 kg – 18 to 34 t excavator)	22 m	73 m
Vibratory pile driver	Sheet piles	2 m to 20 m	20 m
Jackhammer	Hand held	1 m (nominal)	Avoid contact with structure

19.5.2.2 Vibration due to blasting

It is anticipated that blasting of approximately 58,000 m^3 of rock will be required at the toe of the dam and on the left abutment. Approximately 2,500 m^3 will be on the left abutment, with the remainder at the toe of the dam. The extent of the excavation that requires blasting varies from a depth of about 3-20 metres and a width of about 20 metres. Given the proximity to the dam, blasting will need to be controlled to meet vibration criteria for the existing structures.

Blasting overpressure and vibration have been calculated at the nearest sensitive receivers with consideration to Australian Standard AS 2187: *Part 2-2006 Explosives – Storage and Use – Part 2: Use of Explosives and the US Bureau of Mines*.

Representative maximum instantaneous charge (MIC) values have been estimated with consideration of likely hole diameter, column height, powder factor and number of holes fired instantaneously. It is expected that the blast design to minimise risk of damage to dam structures will be the limiting factor on the MIC.

Blast vibration and overpressure have been predicted for the following MIC values: 40 kilograms, 100 kilograms, and 350 kilograms.

Calculated blasting overpressure and vibration levels are shown in Table 19-20 at the nearest sensitive receivers in each noise catchment area. An indicative level is also provided for the Warragamba Dam Visitor Centre.

Table 19-20. Predicted blasting and overpressure levels

Nearest receiver	Distance	Vibration (mm/s)				Overpressure (dbl)			
	Metres[2]	Criterion	MIC-40 kg	MIC-100 kg	MIC-350 kg	Criterion	MIC-40 kg	MIC-100 kg	MIC-350 kg
NCA (A)	600	5	0.8	1.6	4.4	115	110	114	118
NCA (B)	940	5	0.4	0.8	2.1	115	106	109	113
NCA (C)	940	5	0.4	0.8	2.1	115	106	109	113
NCA (D)	1,085	5	0.3	0.6	1.7	115	104	107	112
NCA (E)	820	5	0.5	1.0	2.7	115	107	110	115
NCA (F)	1,030	5	0.3	0.7	1.9	115	105	108	112
Warragamba Dam Visitor Centre	390	5	1.5	3.2	**8.8**[3]	115	115	118	123
Haviland Park	450	5	1.2	2.6	**7.1**	115	114	117	121
Warragamba 135[1]	580	5	0.8	1.7	**4.7**	115	111	114	118
Warragamba 136[1]	470	5	1.2	2.4	**6.6**	115	113	116	121

1. Aboriginal heritage receivers
2. Distance is approximate
3. Levels exceeding the criteria are shown in bold;

The results show that a MIC of 100 kilograms and above is expected to exceed criteria at Warragamba Dam Visitor Centre, Haviland Park and both of the closest Aboriginal heritage receivers. A MIC of less than 40 kilograms is expected to meet criteria at the nearest receivers.

19.6 Assessment of potential operational impacts

Based on the existing environment noise survey, dam noise emissions were not identified as an audible noise source at locations representative of the nearest residential areas. There is no change to audibility expected after the dam wall has been upgraded. Extended releases from the FMZ are rare and cannot be practically mitigated for noise and vibration. As the impact is short term and unlikely to cause substantial annoyance to surrounding residences, an assessment has not been undertaken.

Project components with the potential to generate water flow noise during normal operations, including releases of environmental flows, are expected to be limited to the upgraded inflow infrastructure located within the wall structure and the outlet downstream of the dam wall. A cross section of this infrastructure is shown in Figure 19-12.

The environmental flow control infrastructure is housed within the existing infrastructure and within a new valve box. Water flow noise from the upgraded inlet and outlets is not expected to result in significant noise emissions and would not be expected to generate annoying characteristics as described in the NPI.

Based on the existing environment noise survey, which did not identify noise from the dam at the nearest sensitive receivers, and the similar arrangement of upgraded environmental flow infrastructure. Significant additional noise emissions from the environmental flow infrastructure are not expected, and have not been assessed further.

19.7 Environmental management measures

Management measures detailed in Table 19-21 have been developed to avoid, minimise or manage potential risks identified in Section 19.5 and Section 19.6. Management measures have been incorporated in the Environmental Management measures in Chapter 29 (EIS synthesis, Project justification and conclusion).

Figure 19-12. Environmental flows infrastructure

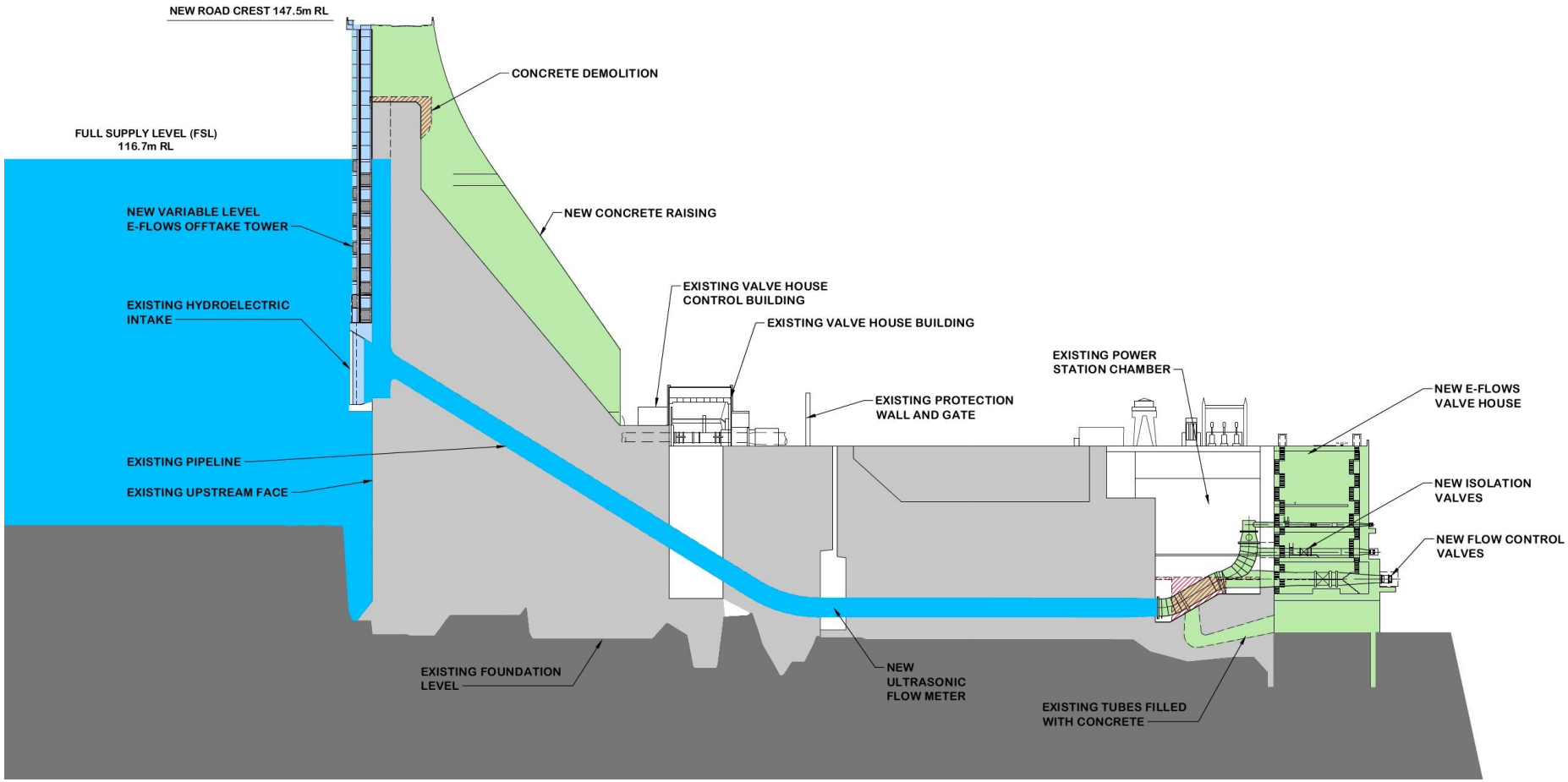


Table 19-21. Management measures

Impact	ID	Environmental management measure	Timing	Responsible
Construction noise and vibration	NV1	A Construction noise and vibration management plan (CNVMP) will be prepared. The CNVMP will include processes and responsibilities to assess, monitor, minimise and mitigate noise and vibration impacts during construction. The plan will: ▪ identify relevant performance criteria in relation to noise and vibration ▪ identify noise and vibration sensitive receivers and features in the vicinity of the Project ▪ include standard and additional mitigation measures from relevant guidelines and details about when each will be applied ▪ describe the process(es) that will be adopted for carrying out location and activity specific noise and vibration impact assessments to assist with the selection of appropriate mitigation measures ▪ consider cumulative construction noise impacts and construction noise fatigue ▪ include protocols that will be adopted to manage works required outside standard construction hours, in accordance with relevant guidelines including for management of respite periods ▪ detail monitoring that will be carried out to confirm Project performance in relation to noise and vibration performance criteria. The CNVMP will be implemented for the duration of the construction of the Project.	Pre-construction	WaterNSW
	NV2	Detailed noise assessments will be carried out for all ancillary facilities required for construction of the Project. The requirement for temporary noise walls within ancillary facilities and adjacent to construction works, and the requirement for other appropriate noise management measures, is to be assessed and implemented prior to the commencement of activities which have the potential to cause noise or vibration impacts.	Pre-construction	WaterNSW
	NV3	All residents affected by noise from the construction of the Project and whom may be expected to experience an exceedance of the construction NMLs, will be consulted about the Project prior to the commencement of the activity, with the highest consideration given to those that are predicted to be most affected by the works. The information provided to the residents will include: ▪ general sequencing and locations of construction work ▪ the hours of the Project works ▪ construction noise and vibration impact predictions for the works ▪ construction noise and vibration mitigation measures likely to be implemented on site.	Pre-construction	WaterNSW

Impact	ID	Environmental management measure	Timing	Responsible
		Community consultation regarding construction noise and vibration will be detailed in the Community and Stakeholder Engagement Plan for the construction of the Project and will include a complaint's handling process. The community will be able to provide feedback via a 24-hour, toll-free Project information and complaints line, a dedicated email address and postal address for the Project. For out of hours works, consultation with affected residents will take place with consideration to Strategy 2 of the ICNG.		
Impacts from out of hours works	NV4	Noisy work (as defined in the EPL) and vibration intensive activities (those activities that exceed the vibration criteria) will be scheduled to be undertaken during standard construction hours as far as possible. Works or activities that cannot be undertaken during standard construction hours will be scheduled as early as possible during the evening and/or night-time periods. Where required, respite measures will be implemented for noisy work and vibration intensive activities.	Construction	WaterNSW Construction Contractor
Construction vehicle noise	NV5	Construction vehicle movements (on and off site) will be managed to avoid or minimise noise impacts. Materials delivery to the construction site would only occur during the day. Mitigation measures for vehicle movements outside of standard construction hours are to be included in the CNVMP.	Construction	WaterNSW Construction Contractor
Vibration from construction activities	NV6	Vibration generating activities will be managed to minimise the potential for impacts on structures and sensitive receptor(s), including maximising safe working distances where practicable, or use of alternate methods to minimise vibration where safe working distances cannot be achieved. Where alternatives cannot be implemented, vibration monitoring will be undertaken and receivers notified in advance of works.	Construction	WaterNSW Construction Contractor
Impacts from blasting	NV7	A blast management plan (BMP) will be developed for the Project. This would provide for design and monitoring of trial blasts to confirm site specific conditions and validate local propagation characteristics (develop site specific "site laws") and confirm the MICs and blast designs to meet vibration and overpressure limits. The BMP would include: ▪ limiting criteria ▪ identified blast sensitive receivers (community and onsite structures) ▪ performance indicators ▪ monitoring protocols ▪ roles and responsibilities ▪ blasting controls ▪ protocols for community consultation, incidents and complaints	Pre-construction Construction	WaterNSW Construction Contractor

Impact	ID	Environmental management measure	Timing	Responsible
		▪ contingency protocols ▪ reporting requirements.		
	NV8	The BMP will consider the following with regard to overpressure and ground vibration: ▪ Blast timing: restriction of blasting to between the hours of 9.00 am to 5.00 pm Monday to Saturday with no blasting outside of these times, including on Sundays and Public Holidays. ▪ Blast monitoring and inspection including: monitoring at key sensitive sites and trial blasts to assist in the development of "site laws" based on monitoring data. ▪ Regular condition surveys and blast monitoring at heritage structures and modification of blast design to meet blast limits at these sites where required.	Pre-construction Construction	WaterNSW Construction Contractor
	NV9	Mitigation controls will be incorporated into design. A program will be developed for the ongoing monitoring and maintenance of plant and equipment.	Operation	WaterNSW

19.8 Risk assessment

An environmental risk assessment was carried out in accordance with the SEARs using the methodology detailed in Appendix C (Risk assessment procedure). A Project risk matrix was developed and risk ranking evaluated by considering:

- the likelihood (L) of an impact occurring
- the severity or consequence (C) of the impact in a biophysical and/or socio-economic context, with consideration of:
  - whether the impact will be in breach of regulatory or policy requirements
  - the sensitivity of receivers
  - duration of impact, that is, whether the impact is permanent or temporary
  - the areal extent of the impact and/or the magnitude of the impact on receivers.

The likelihood and consequence matrix is shown on Figure 19-13.

Once the consequence and likelihood of an impact are assessed, the risk matrix provides an associated ranking of risk significance: **Low**; **Medium**; **High** or **Extreme** as shown in Table 19-22**.** The residual risk was determined after the application of proposed mitigation measures.

The risk analysis for potential noise and vibration impacts is provided in Table 19-23. This includes the residual risk of the potential impact after the implementation of mitigation measures.

Table 19-22. Risk ranking definitions

Risk definitions	
Extreme 21 – 25	Widespread and diverse primary and secondary impacts with significant long-term effects on the environment, livelihood and quality of life. Those affected will have irreparable impacts on livelihoods and quality of life.
High 15 – 20	Significant resources and/or Project modification would be required to manage potential environmental damage. These risks can be accommodated in a project of this size, however comprehensive and effective monitoring measures would need to be employed such that Project activities are halted and/or appropriately moderated. Those impacted may be able to adapt to change and regain their livelihoods and quality of life with a degree of difficulty.
Medium 9 – 14	Risk is tolerable if mitigation measures are in place, however management procedures will need to ensure necessary actions are quickly taken in response to perceived or actual environmental damage. Those impacted will be able to adapt to changes.
Low 1 – 8	On-going monitoring is required however resources allocation and responses would have low priority compared to higher ranked risks. Those impacted will be able to adapt to change with relative ease.

Figure 19-13. Risk matrix

		Consequence				
		Negligible	**Minor**	**Medium**	**Major**	**Extreme**
	LEGAL	No legal consequences	No legal consequences	Incident potentially causing breach of licence conditions	Breach of licence conditions	Breach of licence conditions resulting in shutdown of Project operations.
	SOCIO-ECONOMIC	Impacts that are practically indistinguishable from the social baseline, or consist of solely localised or temporary/short-term effects with no consequences on livelihoods and quality of life.	Short-term or temporary impacts with limited consequences on livelihoods and quality of life. Those affected will be able to adapt to the changes with relative ease and regain their pre-impact livelihoods and quality of life.	Primary and secondary impacts with moderate effects on livelihoods and quality of life. Will be able to adapt to the changes with some difficulty and regain their pre-impact livelihoods and quality of life.	Widespread and diverse primary and secondary impacts with significant long-term effects on livelihoods and quality of life. Those affected may be able to adapt to changes with a degree of difficulty and regain their pre-impact livelihoods and quality of life.	Widespread and diverse primary and secondary impacts with irreparable impacts on livelihoods and quality of life and no possibility to restore livelihoods.
	HEALTH	No health consequences	Accident or illness with little or no impact on ability to function. Medical treatment required is limited or unnecessary.	Accident or illness leading to mild to moderate functional impairment requiring medical treatment.	Accident or illness leading to permanent disability or requiring a high level of medical treatment or management.	Accident, serious illness or chronic exposure resulting in fatality.
	ENVIRONMENT	Localised (on-site), short-term impact on habitat, species or environmental media	Localised or widespread medium-term impact to habitat, species or environmental media	Localised degradation of sensitive habitat or widespread long-term impacts on habitat, species or environmental media. Possible contribution to cumulative impacts.	Widespread and long-term changes to sensitive habitat, species diversity or abundance or environmental media. Temporary loss of ecosystem function at landscape scale. Moderate contribution to cumulative impacts.	Loss of a nationally or internationally recognised threatened species or vegetation community. Permanent loss of ecosystem function on a landscape scale. Major contribution to cumulative effects
		A - negligible	**B** - minor	**C** - medium	**D** - major	**E** - extreme
Expected to occur during the Project or beyond the Project	**a** - expected	**13**	**14**	**20**	**24**	**25**
May occur during the Project or beyond the Project	**b** - may	**8**	**12**	**19**	**22**	**23**
Possible under exceptional circumstances	**c** - possible	**6**	**7**	**11**	**18**	**21**
Unlikely to occur during the Project	**d** - unlikely	**4**	**5**	**10**	**16**	**17**
Rare or previously unknown to occur	**e** - rare	**1**	**2**	**3**	**9**	**15**

Risk Definition (see Table 19-22)	**Low**	**Medium**	**High**	**Extreme**

Table 19-23. Noise and vibration risk assessment

NOISE AND VIBRATION								
KEY IMPACTS	Risk before mitigation			MITIGATION AND MANAGEMENT	Risk after mitigation			RESIDUAL RISK
	L	C	R		L	C	R	
Construction								
Noise emissions resulting in nuisance, licence breaches and health issues: ▪ *Site establishment works* - land clearing - stockpiling - supporting infrastructure ▪ *Construction works* - vehicle movements - blasting - material movements and storage - concrete batching - general construction - Out of Hours work and sleep disturbance	b	C	19	NV1, NV2, NV3, NV4, NV5, NV6, NV7, NV8	c	C	11	Dam construction will be a significant undertaking over a period of approximately 4.5 years. The noise and vibration risk is assessed as High due to construction work activities that may need to be undertaken out of standard work hours, which could potentially result in exceedances of noise management levels and lead to sleep disturbance impacts at receivers close to construction works. Mitigation measures would substantially reduce potential noise and vibration impacts to a Medium risk, however it is expected that criteria levels may be exceeded on occasion, which will prompt further mitigation response. Noise and vibration will vary in accordance with the construction schedule, hence mitigation measures will require evaluation and modification on a regular basis.
Operation								
Noise emissions resulting in nuisance, licence breaches and health issues: ▪ general operations ▪ environmental flow structure ▪ traffic	c	B	7	NV9	d	B	5	Low residual risk not requiring significant additional mitigation measures.

Notes: L = likelihood
C = consequence
R = rating

local people
global experience

SMEC is recognised for providing technical excellence and consultancy expertise in urban, infrastructure and management advisory. From concept to completion, our core service offering covers the life-cycle of a project and maximises value to our clients and communities. We align global expertise with local knowledge and state-of-the-art processes and systems to deliver innovative solutions to a range of industry sectors.

www.smec.com