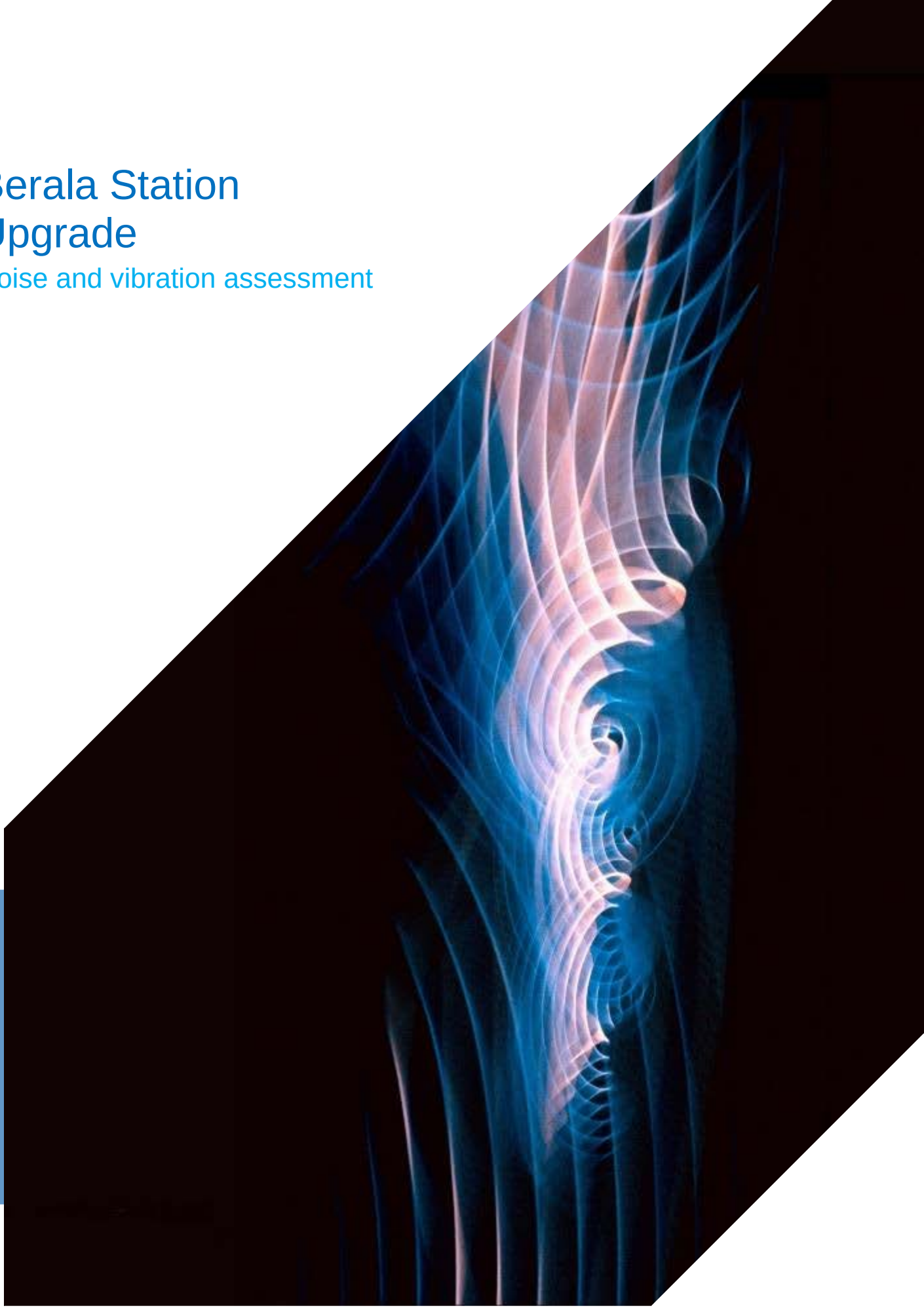
Berala Station Upgrade

Noise and vibration assessment



WSP | PARSONS BRINCKERHOFF

Berala Station Upgrade

Noise and vibration assessment

Project no: ACG1521200
Date: 08/02/2016

Prepared for: Transport for NSW
–

WSP | Parsons Brinckerhoff
Level 1, 41 McLaren Street
North Sydney
New South Wales 2060
Australia

Tel: +61 (02) 8907 0900
Fax: +61 (02) 9957 4127

acoustics@WSPgroup.com

WSP | Parsons Brinckerhoff Contacts:
Chris Marsh
Alex Campbell

Quality Management

Issue/revision	Issue 1	Revision 1	Revision 2	Revision 3
Remarks	Draft	Final		
Date	04/02/2016	08/02/2016		
Prepared by	P. Gangemi	P. Gangemi		
Signature				
Checked by	C. Marsh	C. Marsh		
Signature				
Authorised by	A. Campbell	A. Campbell		
Signature				
Project number	ACG1521200	ACG1521200		
Report number				
File reference				

Table of Contents

Executive Summary

This noise and vibration assessment has been prepared as part of the Review of Environmental Factors (REF) for the proposed upgrade of Berala Train Station as part of Transport for New South Wales (TfNSW) Transport Access Program (TAP).

The upgrade works provide modern and convenient facilities for commuters including a new lift to platform level, extension of the building canopy and refurbishment of the station building.

Berala Station is located 20 kilometres west of the Sydney CBD, on the Bankstown line between Lidcombe and Regents Park. The suburb of Berala is primarily medium to high density residential, with multi-level apartments and commercial properties located close to the station in addition to low to medium density residential properties on the southern side of the station.

Fourteen (14) residential properties and 20 non-residential receivers were selected to represent the nearest noise and vibration sensitive receivers to the proposal footprint.

The construction assessment was based on predicting the noise and vibration impacts from the proposed upgrade works at all of the representative sensitive receivers. The assessment considered 11 construction scenarios, with six scenarios analysed both with and without jackhammers. Construction works are expected to take place predominantly during standard hours and out of hours work periods during track possessions. There is also potential for out of hours works to be undertaken during a potential four week station shutdown.

Existing background noise levels were measured over one week at two representative locations. Operational and construction noise assessment criteria were derived for residential and non-residential land uses in accordance with the NSW *Industrial Noise Policy* (INP) (EPA 2000) and the *Interim Construction Noise Guideline* (ICNG) (DECCW 2009) based on the background noise monitoring. Vibration limits for human comfort were derived using the NSW guideline *Assessing Vibration, A Technical Guideline* (DEC 2006) and for building damage using the German Standard *DIN 4150-3: 1999 Structural Vibration – Part 3: Effects of vibration on structures*.

OPERATIONAL IMPACTS

Plant expected to be associated with the operation of the proposal would include a lift, lighting and electrical equipment including security cameras. Mechanical plant and equipment required for upgrade has not yet been selected. Mechanical plant selections for the operation of the lifts and other upgraded equipment would be identified during detailed design and would be selected in order to achieve the operational noise criteria derived from the INP as presented in the report.

CONSTRUCTION IMPACTS

Worst case construction noise levels were predicted at each representative receiver based on published equipment data. They were compared with noise management levels (NML) for the 11 construction scenarios proposed to take place during the day, evening or night.

The assessment indicates that:

- During standard working hours, only the nearest residential receivers are likely to experience noise levels in excess of the NMLs for the majority of construction scenarios.
- Works in the evening period are also predicted to exceed NMLs for the majority of the nearest residential receivers for the majority of construction scenarios.
- The NMLs are likely to be exceeded during all construction scenarios at the nearest sensitive receivers during the night period.
- When the jackhammer or concrete saw is not used, no residential receivers are expected to receive “highly noise affected” levels above 75 dBA, as defined in the ICNG. However, when the jackhammer is used, scenarios 2a-3a and four are expected to cause noise levels above the highly noise affected level at receivers represented by R2-R4.
- Sleep disturbance may be caused by activities in scenarios 2a to 2d and 3b, at receivers represented by R1-R4, R6-R9 and R12.
- Noise levels are predicted to exceed the NMLs during the day at non-residential receivers including C1, C3, H1, H2, H4, W1, Y1 and Y2.

- Receivers C3 and W1 may also be in use during the evening and night periods. The predicted noise levels indicate that noise levels would be above the NMLs for these receivers during these periods.
- Adverse construction vibration impacts are not expected at the nearest off site residential or non-residential receivers.
- Construction vibration impacts at the heritage component of Berala Station are not expected where the safe working distances and controls within this assessment are implemented.

SAFEGUARDS AND MANAGEMENT MEASURES

Based on the predicted impacts, it is recommended that a Construction Noise and Vibration Management Plan (CNVMP) is implemented to ensure environmental controls are implemented before, during and following the proposed work. A number of noise and vibration controls have been recommended to reduce the potential impact from the works. These controls include restricting use of jackhammers and concrete saws during evening and night periods and providing respite periods for noise intensive works.

When these controls have been specified, the adoption of additional mitigation measures as detailed in the *Construction Noise Strategy* (CNS) (TfNSW 2013) should be considered. By implementing these measures in response to predicting the worst case impact, it is considered that the impacts of the construction works can be reduced.

Noise and vibration levels are to be confirmed prior to construction commencing, once the contractor's construction methodology is confirmed.

1 Introduction

WSP | Parsons Brinckerhoff has been engaged by Transport for NSW (TfNSW) to provide a noise and vibration assessment for the proposed upgrade of Berala Train station, NSW, as part of their Transport Access Program (TAP) (the proposal). This report has been prepared to support the Review of Environmental Factors (REF) for the proposed upgrade.

This report:

- identifies the noise and vibration assessment study area and associated sensitive residential and non-residential receivers
- describes the existing noise environment
- defines the assessment criteria adopted to assess the proposal's noise and vibration impacts
- presents the predicted noise and vibration emissions generated from the construction of the proposal
- tabulates predicted construction noise and vibration levels
- describes the proposed environmental safeguards and management measures to mitigate potential adverse impacts.

2 Project Description

TfNSW proposes to upgrade facilities and access at Berala Station. The proposal is located approximately 20 kilometres west of the CBD, with the proposal site shown in Figure 2-1.

The works will modernise Berala Station, upgrading facilities and outdated infrastructure for commuters. The key features of the station upgrade include:

- installation of a lift from the underpass level to the station platform level
- extension of the existing platform canopy to the new lift
- demolition of the existing ticket office
- refurbishment of existing platform building to include a family accessible toilet, staff office and amenities
- provision of interchange facilities along Campbell Street including formal kiss and ride zones, two accessible parking spaces on Campbell Street and an upgraded bus shelter
- installation of sheltered bicycle racks adjacent to the Campbell Street entrance
- ancillary works including adjustments to lighting and ticketing machines, improvements to station communication systems with new infrastructure (including additional CCTV cameras) and improved wayfinding signage.

A temporary construction compound would be required to accommodate a site office, amenities, laydown and storage area for materials. The following two locations are being considered for the location of the construction compound:

- Compound 1 - approximately 14 metres south-west of the station platform. The site is primarily on land owned by RailCorp (Lot 2 DP 803675) and partially within the road reserve managed by Auburn City Council.
- Compound 2 - approximately 25 metres east of the station platform on land owned by RailCorp (Lot 2 DP 803675).

A temporary storage/laydown area may also be required on the station platform.

Subject to approval, construction is expected to commence in mid-2016 and take approximately 18 months to complete. Due to access constraints at the site, an option is being considered to completely shut the station to the public for a period of four weeks in 2017.

Works are proposed to take place during both standard hours and outside of standard hours during track possessions. Standard construction hours are defined as:

- Monday to Friday, 7am to 6pm
- Saturday, 8am to 1pm
- Sunday and Public Holidays, no work

Certain works may need to occur outside standard hours and would include night works and works during routine track possessions.

Out of hours works would be required in some cases to minimise disruptions to customers, pedestrians and motorists; and to ensure the safety of railway workers and operational assets. It is estimated that at least six possessions would be required.

Out of hours works may also be scheduled outside possession periods. Berala Station may be closed to the community for a period of approximately four weeks. During this period, out of hours works, including night works, would also be undertaken.

The upgrade works are expected to consist of:

- site establishment, removal of vegetation and services relocation
- demolition of existing building structures

- platform modifications, lift shaft construction and lift installation
- internal building works
- resurfacing, painting and installation of lighting for station entrances
- landscaping, and adjustments to fencing and bollards.

No changes to rail operations are proposed.

Figure 2-1 – Proposed site location

3 Sensitive receivers

The proposal has the potential to impact a number of residential and commercial properties that are considered sensitive to noise and vibration.

3.1 Residential receivers

The closest residential receivers are located at the multi-storey apartment complex at 29 Burke Avenue, approximately 30 metres from the south east station entrance. Other nearby residential receivers are located along Campbell Street and Woodburn Road and Elizabeth Street. Residential receivers in the area are a mix of single storey houses and multi-level apartments. Figure 3-1 shows the location of the nearest residential receivers.

Figure 3-1 - Sensitive receiver locations

Representative receivers have been selected to represent the nearest and potentially most affected receivers to the proposal. The noise levels predicted at these receivers are expected to be similar to those in their vicinity. Table 3-1 presents the representative residential receivers.

Table 3-1 – Receivers representative of the nearest residential receivers to the proposal

ID	Address	Approximate minimum separation distance to nearest work location (metres)
R1	44 Campbell Street, Berala	130
R2	32 Campbell Street, Berala	50
R3	29 Burke Avenue, Berala	30
R4	26 Campbell Street, Berala	30
R5	20 McDonald Street, Berala	150
R6	14 Campbell Street, Berala	110
R7	1 Vivian Crescent, Berala	200
R8	32 Woodburn Road, Berala	175
R9	140 Woodburn Road, Berala	110
R10	25 The Crescent, Berala	170
R11	2B Elizabeth Street, Berala	230
R12	9 Elizabeth Street, Berala	220
R13	16 Elizabeth Street, Berala	350
R14	1 Kingsland Road, Berala	300

3.2 Non-residential receivers

A number of non-residential receivers are also located within close proximity of the proposal. Table 3-2 presents a summary of the nearest non-residential receivers, their type and approximate distance from the proposal.

Table 3-2 – Nearest non-residential receivers

Land use	ID	Address	Approximate minimum separation distance to nearest work location (metres)
Commercial/Retail	C1	28A Campbell Street, Berala	20
Commercial/Retail	C2	17 Burke Avenue, Berala	80
Commercial/Retail	C3	157 Woodburn Road, Berala	25
Commercial/Retail	C4	150 Woodburn Road, Berala	70

Land use	ID	Address	Approximate minimum separation distance to nearest work location (metres)
Commercial/Retail	C5	162 Woodburn Road, Berala	90
Commercial/Retail	C6	174 Woodburn Road, Berala	150
Health Building, Consulting Room	H1	30 Campbell Street, Berala	40
Health Building, Dental Clinic	H2	28 Campbell Street, Berala	25
Health Building, Consulting Room	H3	174 Woodburn Road, Berala	190
Health Building, Consulting Room	H4	27-29 Crawford Street, Berala	160
Health Building, Dental Clinic	H5	186 Woodburn Road, Berala	120
Active Recreation	A1	York Park, York Street, Berala	410
Place of Worship	W1	Lingyen Mountain Temple Australia, 21 Vivian Crescent, Berala	170
Place of Worship	W2	St James Anglican Church,19 Crawford Street, Berala	170
Child Care Centres	Y1	31/27 Burke Avenue, Berala	55
Child Care Centres	Y2	166 Woodburn Road, Berala	100
School	S1	Berala Public School, Harrow Road, Berala	390

3.3 Heritage items

Berala Railway Station Group is a heritage item listed on the RailCorp Section 170 Heritage and Conservation register. It is also identified as a “Heritage Item – Archaeological” under the *Auburn Local Environmental Plan 2010*.

Berala Station has heritage significance as the existing station represents the significant reconstruction of the original Lidcombe-Regents Park line, with its 1920’s station building, booking office and subway. The station building is one of the few remaining extended rafter types, and its elevated position is clearly visible from surrounding streets.

4 Existing environment

Long term unattended and short term attended measurements were carried out to establish the existing ambient and background noise environment at potentially affected receivers.

4.1 Noise measurement methodology

Long term unattended noise measurements were performed at two locations between 11 and 18 December 2015. The noise monitoring was conducted with reference to Australian Standard AS 1055 *Acoustics, Description and Measurement of Environmental Noise*. Table 4-1 describes the noise monitoring equipment and Figure 3-1 shows the monitoring locations.

Table 4-1 – Noise measurement equipment

Equipment Description	Location	Manufacturer & Type No.	Serial No.
Environmental Noise Monitor	2B Elizabeth Street, Berala	ARL EL-316	16-302-490
Environmental Noise Monitor	30 Campbell Street, Berala	ARL EL-316	16-302-485
Calibrator	All	Pulsar Model 105	55041

The data was gathered over a period of typical traffic movement and activity in the area (i.e. outside of public school holiday periods). The monitoring equipment was fitted with windshields and field calibrated before and after monitoring. No significant drifts in calibration (± 0.5dB) were noted.

The weather conditions at the time of monitoring were recorded at Bankstown Airport (Bureau of Meteorology station number 066137), which is located approximately 6.5 kilometres south-west of the proposal.

Periods of inclement weather (wind speeds greater than 5 m/s and significant rainfall) and extraneous noise that were identified to adversely affect the noise monitoring were excluded from the monitoring data.

In addition, operator attended noise surveys and observations were conducted at the noise monitoring locations on 18 December 2015. The primary purpose of the attended monitoring is to characterise the existing ambient environment based on a short term noise measurement sample.

4.2 Noise measurement results

4.2.1 Unattended noise monitoring results

Table 4-2 summaries the unattended noise monitoring results. The data is reported as the average equivalent continuous average sound levels ($L_{eq,15min}$) and rating background levels (RBL) as defined in the NSW *Industrial Noise Policy* (INP) (EPA, 2000).

Graphs of the long term measurement results are presented in Appendix A.

Table 4-2 – Unattended noise measurement results, dBA

Location ID	Address	Day[1]		Evening[1]		Night[1]	
		$L_{eq,15min}$	RBL	$L_{eq,15min}$	RBL	$L_{eq,15min}$	RBL
BG1	2B Elizabeth Street, Berala	55	41	55	44	49	35
BG2	30 Campbell Street, Berala	60	46	58	46	56	42

Note 1: Day is defined as Monday to Saturday 7am to 6pm; 8am to 6pm Sundays and Public Holidays, Evening is 6pm to 10pm and Night is the remaining periods.

4.2.2 Attended noise monitoring results

Table 4-3 presents the short term noise attended noise monitoring results.

Table 4-3 – Attended noise measurements

Location	Date	Start time	$L_{eq,15min}$ dBA	$L_{90,15min}$ dBA	Comments
BG1	18/12/2015	13:26	49	44	The dominant ambient noise was cars on Elizabeth Avenue and Woodburn Road. Contributions to ambient noise also came from cars as people parked/opened their doors, or accelerated away from their parking spots on Elizabeth Street. General community noise and occasional aircraft also contributed to the background noise environment.
BG2	18/12/2015	12:45	57	47	The dominant ambient noise source was vehicles along Campbell Street, particularly travelling over and accelerating away from the speed hump. Trains arriving and leaving Berala Station were also dominant ambient noise sources, but intermittent. Car doors and vehicles accelerating from the shops was also a significant component of the ambient environment. General community noise was also part of the background noise. Mechanical plant located at nearby shops was barely audible from the monitoring location.

The attended noise monitoring indicated that the dominant ambient noise source at both monitoring locations was traffic noise from nearby roads. Both monitoring locations were close to local shops, so contributions to ambient noise were made from vehicles parking, and accelerating when leaving their carpark spots. General community noise also contributed to the background noise levels. Aircraft flying overhead contributed to the background noise on an intermittent basis.

5 Assessment criteria

5.1 Operational noise

Noise impacts from railway station buildings and operations are assessed using the NSW *Industrial Noise Policy* (INP) (EPA 2000). The INP defines two criteria for the assessment of noise; the intrusive and amenity criteria. The more onerous criterion is then adopted as the project specific noise level (PSNL) which the proposal is assessed against.

The intrusive criterion is intended to protect residential receivers against intrusive noise in the short term. It is defined as $L_{eq,15min}$ dBA ≤ Rating Background Level plus 5 dBA. The RBL is the background noise level determined in accordance with Appendix B of the INP and as reported in Table 4-2.

The amenity criterion is intended to maintain noise amenity and limit cumulative noise increases for sensitive land uses. In Table 2.1 of the INP recommended amenity noise levels are defined for each day, evening and night period for each sensitive land use. The recommended amenity noise levels apply to noise from industrial noise only and where existing industrial noise exceeds or approaches the recommended amenity levels, a modifying factor (INP Table 2.2) is applied to limit the cumulative increase in total industrial noise at a receiver.

Residential receivers are defined as urban receivers as the noise environment is generally dominated by urban hum, road traffic noise, and is located close to commercial precincts.

Table 5-1 presents the criteria and project specific noise level for residential receivers.

Table 5-1 – Operational criteria for residential receivers

Receiver	Time period[3]	RBL dBA	Intrusive criteria $L_{eq,15min}$ dBA	Existing ambient noise level $L_{eq,15min}$ dBA	Amenity criteria[1] $L_{eq,period}$ dBA	PSNL $L_{eq,15min}$ dBA[2]
R1-R7, R14 (BG2)	Day	46	51	60	52	51
	Evening	46	51	58	48	48
	Night	42	47	56	46	46
R8-R13 (BG1)	Day	41	46	55	58	46
	Evening	41	46	55	45	45
	Night	35	40	49	39	39

Note 1: Set at 10 dB less than the existing ambient noise level for the evening and night periods.

Note 2: The PSNL has been set as a $L_{eq,15min}$ in order to provide a conservative assessment. Where compliance is achieved over a 15-minute period, it is therefore implied that compliance will also occur over the day, evening or night period.

Note 3: Day is defined as Monday to Saturday 7am to 6pm; 8am to 6pm Sundays and Public Holidays, Evening is 6pm to 10pm and Night is the remaining periods.

Table 5-2 presents the project specific noise level for non-residential receivers.

Table 5-2 – Operational criteria for non-residential receivers

Receiver	Time Period	Amenity Criteria[1] $L_{eq,period}$ dBA
Commercial	When in use	65
Active Recreation	When in use	55
School[2]	Noisiest 1 hour period when in use	45
Place of worship[2]	When in use	50

Note 1: The PSNL has been set as a $L_{eq,15min}$ in order to provide a conservative assessment. Where compliance is achieved over a 15 minute period, it is therefore implied that compliance will also occur over the day, evening or night period.

Note 2: As per the INP, a +10 dB correction has been added to convert internal to external noise criteria.

5.2 Construction noise

Noise impacts from construction noise are assessed using the *Interim Construction Noise Guideline* (ICNG) (DECCW, 2009). The ICNG defines noise management levels for residential and other sensitive land uses. At locations where the predicted construction noise levels exceed the noise management levels, the proponent should apply all feasible and reasonable work practices to minimise noise.

Table 5-3 defines NML as specified in the ICNG and how they are applied for residential receivers. NMLs are the level of noise above which receivers are considered to be 'noise affected'. They are based on the measured RBL as defined in the INP plus an additional allowance of 10 dB during standard hours and 5 dB outside of standard hours.

Where construction noise levels are above 75 dBA at residential receivers during standard hours, they are considered 'highly noise affected' and require additional considerations to mitigate potential impacts.

Table 5-3 – ICNG construction noise management levels for residential receivers and working hours

Time of day	NML $L_{eq,15min}$[1,2] dBA	How to apply
Recommended standard hours: **Monday - Friday** **7am - 6pm**	Noise affected RBL + 10 dB	The noise affected level represents the point above which there may be some community reaction to noise. ■ Where the predicted or measured $L_{eq,15min}$ dBA is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level. ■ The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.
Saturday 8am - 1pm **No work on Sundays or public holidays**	Highly noise affected 75 dBA	The highly noise affected level represents the point above which there may be strong community reaction to noise. Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noisy activities can occur, taking into account: 1. times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences) 2. if the community is prepared to accept a longer period of construction in exchange for restrictions on construction times
Outside recommended standard hours	Noise affected RBL + 5 dB	A strong justification would typically be required for works outside the recommended standard hours. The proponent should apply all feasible and reasonable work practices to meet the noise affected level. Where all feasible and reasonable practices have been applied and noise is more than 5 dBA above the noise affected level, the proponent should negotiate with the community.

Note 1: Noise levels apply at the property boundary that is most exposed to construction noise, and at a height of 1.5 m above ground level. If the property boundary is more than 30 m from the residence, the location for measuring or predicting noise levels is at the most noise-affected point within 30 m of the residence. Noise levels may be higher at upper floors of the noise affected residence.

Note 2: The RBL is the overall background noise level representing each assessment period (day/evening/night) over the whole monitoring period. The term RBL is described in detail in the INP.

Table 5-4 presents the construction noise criteria for residential receivers.

Table 5-4 – Construction noise management levels at residential receivers, dBA

Receiver	RBL			NML $L_{eq,15min}$		
	Day	Evening	Night	Day	Evening	Night
R1-R7, R14 (BG2)	46	46	42	56	51	47
R8-R13 (BG1)	41	41	35	51	46	40

Note: Time periods are defined as described in the INP.

Table 5-5 lists the NMLs that have been adopted for non-residential sensitive receivers.

Table 5-5 – Construction noise management levels at sensitive land uses (other than residences)

Land use	NML $L_{eq,15\ min}$ dBA (applies when properties are being used)
Commercial/Retail	70
Health building, Consulting Room[2]	55
Health building, Dental clinic[2]	55
Active Recreation	65
Place of Worship[1]	55
Child Care Centres[1]	55
School[1]	55

Note 1: As per the ICNG, a typical difference between internal and external noise levels is typically 10dB with windows open for adequate ventilation

Note 2: Nearby consulting rooms and dental clinics have been identified as possible sensitive land users. As per the ICNG, noise criteria has been set using the 'maximum' noise levels in AS 2107 *Acoustics – Recommended design sound levels and reverberation times for building interiors*.

5.3 Road traffic noise

The *Road Noise Policy* (RNP) (EPA 2011 provides guidance on the assessment of noise impacts from road traffic noise on sensitive receiver types.

The RNP application notes state that 'for existing residences and other sensitive land uses affected by additional traffic on existing roads generated by land use developments, any increase in the total traffic noise level as a result of the development should be limited to 2 dB above that of the noise level without the development. This limit applies wherever the noise level without the development is within 2 dB of, or exceeds, the relevant day or night noise assessment criterion.'

The RNP criteria apply to traffic generated by construction activities. The existing road surrounding the station are a mix of collector and local roads. Collector roads are assessed over day (7am-10pm) and night (10pm-7am) periods and local roads are assessed over a one hour period. Table 5-6 presents a summary of the noise level criteria for collector and local roads affected by additional traffic from land use developments and construction activities.

Table 5-6 - Road traffic noise criteria for receivers on existing roads affected by additional traffic from land use developments

Road type	Road traffic noise criteria	
Collector	60 $L_{eq,15hr}$ dBA	55 $L_{eq,9hr}$ dBA
Local road	55 $L_{eq,1hr}$ dBA	50 $L_{eq,1hr}$ dBA

Where the existing road traffic noise levels increase by more than 2 dBA as a result of the project, mitigation would be required.

5.4 Sleep disturbance

Operations during the night time have the potential to disturb people's sleep patterns. The ICNG references the *Road Noise Policy* (RNP) (EPA 2011), for the assessment of sleep disturbance.

The RNP suggests a screening level of $L_{1,1min}$ dBA, equivalent to the RBL + 15 dB, below which sleep disturbance is unlikely. Where this level is exceeded, further analysis should be carried out. Furthermore, Section 5.4 of the RNP states that:

- maximum internal noise levels below 50-55 dBA would be unlikely to result in people's sleep being disturbed
- if the noise exceeds 65-70 dBA once or twice each night the disturbance would be unlikely to have any notable health or wellbeing effects.

The guidance within the RNP indicates that internal noise levels of 50-55 dBA are unlikely to cause sleep awakenings. Therefore at levels above 55 dBA, sleep disturbance would be considered likely. Assuming that receivers may have windows partially open for ventilation, a 10 dB outside to inside correction has been adopted as indicted in the ICNG. Therefore a sleep disturbance screening criterion of L_{max} 65 dBA has been adopted in this report.

5.5 Construction vibration

Construction vibration can lead to:

- cosmetic and structural building damage
- loss of amenity due to perceptible vibration, termed human comfort.

Importantly, cosmetic damage is regarded as minor in nature; it is readily repairable and does not affect a building's structural integrity. Damage of this nature is typically described as hairline cracks on drywall surfaces, hairline cracks in mortar joints and cement render, enlargement of existing cracks, and separation of partitions or intermediate walls from load bearing walls. If there is no significant risk of cosmetic damage then structural damage is not considered a significant risk and is not further assessed.

5.5.1 Cosmetic building damage

There is currently no guidance in NSW specifically addressing cosmetic damage to buildings from vibration. Two international standards are typically referenced for the assessment of cosmetic damage in buildings; British Standard BS 7385-2: *1993 Evaluation and measurement for vibration in buildings* and German Standard *DIN 4150-3: 1999 Structural Vibration – Part 3: Effects of vibration on structure*

The guidance CNS refers to BS 7385 for safe working distances to avoid cosmetic damage of buildings. The standard provides guidance on the 'evaluation and measurement of vibration in buildings' and defines guidance for categorising building damage in terms of 'cosmetic', 'minor' and 'major'; providing limits for each (refer to Table 5-7).

Table 5-7 – BS7385 Cosmetic damage criteria, peak component particle velocity, mm/s [1]

Group	Type of structure	4–15 Hz	15–40 Hz	40 Hz and above
1	Reinforced or framed structures Industrial or heavy commercial buildings		50	
2	Un-reinforced or light framed structures Residential or light commercial buildings	15 – 20[2]	20 – 50	50

Note 1: Values referred to are at the base of the building, on the side of the building facing the source of vibration (where feasible).

Note 2: At frequencies below 4 Hz, a maximum displacement of 0.6 mm (zero to peak) should not be exceeded.

These peak vibration limits are set so that the risk of 'cosmetic' damage in residential or commercial buildings is minimal. They have been set at the lowest level above which damage has been credibly demonstrated. The

limits also assume that the equipment causing the vibration is only used intermittently, however if the equipment is used continuously, then the limits may need to be reduced by up to 50 per cent. For 'minor' or 'major' vibrational damage to occur, the standard states that vibration need to be two times and four times (respectively for group 1 and group 2) the values shown in Table 5-7.

Guidance in BS 7385 also suggests that unless structurally unsound, heritage items should not be considered to be more sensitive than dwellings for the purposes of assessment.

Vibration limits given in DIN 4150 are more conservative than BS 7385 and specifically address heritage items as being more sensitive. Table 5-8 presents a summary of the vibration limits from DIN 4150.

Table 5-8 – Guideline values for short term vibration on structures (DIN 4150-3), guideline values for velocity, (mm/s)

Type of structure	1Hz to 10Hz	10Hz to 50Hz	50Hz to 100Hz
Buildings used for commercial purposes, industrial buildings and buildings of similar design.	20	20 to 40	40 to 50
Dwellings and buildings of similar design and/or occupancy.	5	5 to 15	15 to 20
Structures that, because of their particularly sensitivity to vibration, cannot be classified under lines 1 and 2 and are of great intrinsic value (for example heritage listed buildings).	3	3 to 8	8 to 10

In this assessment, the DIN 4150 limits have been adopted for residential, non-residential and heritage structures as they represent the more conservative limits.

5.5.2 Human comfort (amenity)

Table 5-9 presents the limits (vibration dose values) above which there is considered to be a risk that the amenity and comfort of people occupying buildings would be affected by construction work. The limits are taken from *Assessing Vibration: A Technical Guideline* (DEC, 2006).

Table 5-9 – Vibration limits (human exposure), Vibration dose value, $m/s^{1.75}$

Location	Assessment period	Preferred values	Maximum values
Critical areas	Day or night time	0.10	0.20
Residences	Daytime	0.20	0.40
	Night time	0.13	0.26
Offices, schools, educational institutions, and places of worship	Day or night time	0.40	0.80
Workshops	Day or night time	0.80	1.60

6 Operational noise assessment

The upgrade to Berala Station is expected to result in additional operational noise sources including mechanical plant associated with the new lift, and lighting and electrical equipment including security cameras.

It is likely that the noise from the lighting and electrical equipment would not significant noise sources. The potential noise from the operation of the lift would not be expected to of a level that exceed the INP criteria at the nearest receivers.

The potentially most affected residential receiver to the proposed lift would be receiver R3 which is 62m from the lift location. Assuming no shielding, the sound power level from the lift should be no greater than $L_{eq,15min}$ 90 dBA to exceed the noise criteria of $L_{eq,15min}$ 46dBA at the receiver. Sound power levels of lift equipment can typically be controlled to below 90 dBA.

The noise emission from any mechanical plant installed as part of the upgrade should be confirmed during the detailed design stage and be selected in order to achieve the site specific INP criteria as presented in Section 5.1.

7 Construction noise assessment

7.1 Noise modelling methodology

A noise model was created using SoundPLAN modelling software to predict noise levels at the nearest receivers. The model used accounts for geometrical spreading, ground effects, barriers and topographical effects based on the ISO 9613 calculation method. A three dimensional representation of the site was developed and included the following inputs:

- Digitised two metre height contours for the terrain of the project area have been used.
- Buildings and structures digitised with receivers established at 1.5 metres above ground level for ground floor and at further three metre increments for subsequent floors. Existing fences have not been included in the model. Receivers were modelled at varying heights representative of the number of storeys present.
- Construction plant and equipment have been modelled to operate simultaneously for assessment of potential worst case noise impacts.
- A usage factor has been applied to each construction source to represent typical usage in a 15 minute period.
- Ground coverage has been assumed to be partially reflective and modelled with a 0.5 absorption coefficient.

The predicted noise levels at individual receivers are dependent upon the plant location and the number of plant operating during each activity. Noise impacts have been determined for a worst case 15 minute scenario where all plant are in simultaneous operation. Where fewer plant and machinery are in operation or undertaken at greater separation distance to nearest receivers, noise levels would be significantly reduced.

7.2 Assessment scenarios

Eleven construction scenarios representing each construction stage have been considered. The six construction stages have been separated into eleven stages based on the location and equipment used. This allows noise impacts from activities within stages that occur at different locations to be determined for the nearest receivers.

Table 7-1 presents the scenarios considered in the assessment. Construction works are planned during both standard hours and outside of standard hours. The time periods are defined in the CNS as follows:

Standard hours:

- Monday to Friday 7am to 6pm
- Saturday 8am to 1pm.

Outside of Standard Hours Work (OOHW) Period 1:

- Monday to Friday 6pm to 10pm
- Saturday 7am to 8am and 1pm to 10pm.

Outside of Standard Hours Work (OOHW) Period 2:

- Monday to Friday 10pm to 7am
- Saturday 10pm to 8am
- Sunday and Public Holiday 6pm to 7am.

It is assumed that the deliveries would either take place opposite the station entrance or at the potential compound locations. The location of the crane is assumed to be in the potential Compound 2 location.

Table 7-1 – Construction assessment scenarios

Scenario	Description	Working times
1a – Site establishment and enabling works (establishment)	• establishment of site compound (erect fencing, tree protection zones, site offices, amenities and plant/material storage areas) • establishment of temporary alternative pedestrian access, as required	Standard hours, OOHW Period 1
1b – Site establishment and enabling works (vegetation removal)	• removal of trees and vegetation	Standard hours
1c – Site establishment and enabling works (services)	• services relocation	Standard hours
2a – New lift and platform upgrade (demolition)	• demolition of existing structures as required	Standard hours OOHW Period 1 OOHW Period 2
2b – New lift and platform upgrade (modifications)	• platform modifications including piling and foundations for lift shaft	Standard hours OOHW Period 1 OOHW Period2
2c – New lift and platform upgrade (construction)	• construction of columns, stairs, fencing and new canopy • construction of lift shaft from the underpass to the platform level • installation of lift • installation of fixtures, lighting, signage and CCTV cameras for the station areas	Standard hours OOHW Period 1 OOHW Period 2
2d– New lift and platform upgrade (resurfacing)	• platform resurfacing (only 20 % of the platform areas are required to be resurfaced) as required	Standard hours OOHW Period 1 OOHW Period 2
3a – Station building works (reconfiguration)	• reconfiguration of internal station building to allow for new communications/equipment room, staff facilities and new family accessible toilet	Standard hours
3b – Station building works (painting)	• refresh of station building including painting works	Standard hours OOHW Period 1 OOHW Period 2
4 – Interchange works (modifications)	• modifications and making good the existing pedestrian underpass including resurfacing, lighting and painting • creation of formal taxi waitiung areas,kiss and ride, sheltered bike racks and accessible car spaces	Standard hours
5 – Finalisation	• installation of wayfinding signage • upgrade of electrical and power supply • replanting/landscaping and fencing adjustments and bollards	Standard hours

7.3 Equipment noise levels

Noise levels for the equipment proposed to be used is presented in Table 7-2. Noise levels were taken from published literature, including the CNS, Australian Standard AS2436 *Guide to noise and vibration control on construction, demolition and maintenance sites*, the UK's Department of Environment, Food and Rural Affairs (DEFRA) (2006) construction noise database and published reports for similar activities.

Table 7-2 – Equipment sound power levels per construction scenario

Equipment	SWL dBA	1a	1b	1c	2a	2b	2c	2d	3a	3b	4	5
Trucks	107	X	X	X	X	X	X	X	X		X	X
Hand Tools	102	X	X	X	X	X	X	X	X	X	X	X
Generator	99	X			X	X	X	X				
Bobcat	105	X	X		X			X				
Mulcher	115		X									
Chainsaw	105		X									
Excavator	106			X	X	X	X	X	X		X	
Jackhammer [1]	121				X	X	X	X	X		X	
Demolition saw	117				X	X	X		X		X	
Lighting tower	80				X	X	X			X		
Franna crane	105				X	X	X					
Grinder	109				X		X	X	X			
Manitou	105				X		X					
Scissor Lift	105				X		X			X		
Mobile crane	104				X		X			X		
Concrete pump	103					X	X				X	
Piling rig	110					X						
Concrete truck	109					X	X				X	
Hydreama/Hirail	85					X	X	X				
Wacker packer	113							X				
Nail gun	116								X			
Coring Machine	113											X
Scenario Sound Power Level [2]		107	115	107	118	118	118	118	117	107	117	109

Note 1: During use of the jackhammer, a +5 dB penalty is added to the noise level at receivers to account for annoying characteristics as required by the ICNG

Note 2: Total scenario sound power levels incorporate expected equipment duration per 15 minute period.

7.4 Predicted noise levels

Construction noise levels at residential receivers were predicted for each scenario during the applicable time period (daytime, evening or night time). Table 7-3, Table 7-4 and Table 7-5 present the noise levels predicted in the day time, evening and night time respectively.

Noise contour maps of the predicted noise levels are presented in Appendix B.

Table 7-3 – Predicted daytime construction scenario noise levels, residential receivers, $L_{eq,15min}$ dBA

ID	Daytime NML	1a	1b	1c	2a[1]	2b[1]	2c[1]	2d[1]	3a[1]	3b	4[1]	5
R1	56	**72**	**62**	54	**59 (70)**	**61 (72)**	**60 (72)**	**63 (72)**	**60 (71)**	54	**57 (69)**	**58**
R2	56	**59**	**69**	**62**	**66 (77)**	**68 (78)**	**67 (78)**	**69 (78)**	**66 (77)**	**60**	**65 (77)**	**64**
R3	56	**57**	**71**	**64**	**70 (81)**	**71 (82)**	**70 (81)**	**73 (82)**	**69 (81)**	**64**	**66 (78)**	**68**
R4	56	**61**	**76**	**67**	**72 (83)**	**71 (82)**	**71 (82)**	**73 (82)**	**69 (81)**	**64**	**69 (81)**	**68**
R5	56	49	55	46	55 (60)	56 (61)	55 (61)	**58 (62)**	54 (61)	50	47 (55)	52
R6	56	**69**	**65**	56	**66 (74)**	**64 (73)**	**66 (74)**	**64 (73)**	**60 (72)**	**61**	**59 (70)**	**58**
R7	56	**59**	**59**	51	**59 (67)**	**57 (67)**	**58 (67)**	**58 (67)**	54 (66)	53	54 (65)	52
R8	51	**57**	**56**	49	**59 (67)**	**58 (68)**	**59 (68)**	**59 (68)**	**56 (67)**	**53**	**53 (63)**	**54**
R9	51	**60**	**59**	**52**	**64 (71)**	**61 (70)**	**62 (70)**	**61 (70)**	**58 (69)**	**56**	**57 (66)**	**56**
R10	51	51	47	40	**54 (60)**	50 (60)	51 (60)	51 (60)	48 (59)	46	43 (53)	46
R11	51	49	48	44	50 (58)	**54 (64)**	**53 (64)**	**56 (64)**	**52 (63)**	46	50 (57)	50
R12	51	**58**	**57**	49	**54 (65)**	**56 (66)**	**55 (66)**	**57 (66)**	**54 (65)**	48	**52 (64)**	**52**
R13	51	50	44	40	42 (51)	47 (55)	47 (54)	45 (53)	42 (52)	34	46 (53)	41
R14	56	45	48	40	47 (52)	47 (53)	46 (53)	49 (53)	46 (52)	40	42 (49)	44

Note 1: The ICNG requires a +5 dB correction to be added to predicted noise levels to account for the annoying characteristics of the jackhammer, grinder or demolition saw used in this scenario.

Note 2: Values are highlighted in bold text exceedances of the daytime NMLs. Text is highlighted in red bold and underlined where noise levels are above the 75 dBA “highly noise affected” level.

Note 3: Noise levels are presented without the use of jackhammers, with noise levels presented in brackets describing noise scenarios that include jackhammers.

Table 7-4 – Predicted evening construction scenario noise levels, residential receivers, $L_{eq,15min}$ dBA

ID	Evening NML	1a	2a[1]	2b[1]	2c[1]	2d[1]	3b
R1	51	**72**	**59 (70)**	**61 (72)**	**60 (72)**	**63 (72)**	**54**
R2	51	**59**	**66 (77)**	**68 (78)**	**67 (78)**	**69 (78)**	**60**
R3	51	**57**	**70 (81)**	**71 (82)**	**70 (81)**	**73 (82)**	**64**
R4	51	**61**	**72 (83)**	**71 (82)**	**71 (82)**	**73 (82)**	**64**
R5	51	49	**55 (60)**	**56 (61)**	**55 (61)**	**58 (62)**	50
R6	51	**69**	**66 (74)**	**64 (73)**	**66 (74)**	**64 (73)**	**61**
R7	51	**59**	**59 (67)**	**57 (67)**	**58 (67)**	**58 (67)**	**53**
R8	46	**57**	**59 (67)**	**58 (68)**	**59 (68)**	**59 (68)**	**53**
R9	46	**60**	**64 (71)**	**61 (70)**	**62 (70)**	**61 (70)**	**56**
R10	46	**51**	**54 (60)**	**50 (60)**	**51 (60)**	**51 (60)**	46
R11	46	**49**	**50 (58)**	**54 (64)**	**53 (64)**	**56 (64)**	46
R12	46	**58**	**54 (65)**	**56 (66)**	**55 (66)**	**57 (66)**	48
R13	46	**50**	42 (51)	**47 (55)**	**47 (54)**	45 (53)	34
R14	51	45	47 (52)	47 (53)	46 (53)	49 (53)	40

Note 1: The ICNG requires a +5 dB correction to be added to predicted noise levels to account for the annoying characteristics of the jackhammer, grinder or demolition saw used in this scenario.

Note 2: Values are highlighted in bold text exceedances of the evening NMLs. Text is highlighted in red bold and underlined where noise levels are above the 75 dBA “highly noise affected” level.

Note 3: Noise levels are presented without the use of jackhammers, with noise levels presented in brackets describing noise scenarios that include jackhammers.

Table 7-5 – Predicted night time construction scenario noise levels, residential receivers, $L_{eq,15min}$ dBA

ID	Night time NML	1a	2a[1]	2b[1]	2c[1]	2d[1]	3b
R1	47	**72**	**59 (70)**	**61 (72)**	**60 (72)**	**63 (72)**	**54**
R2	47	**59**	**66 (77)**	**68 (78)**	**67 (78)**	**69 (78)**	**60**
R3	47	**57**	**70 (81)**	**71 (82)**	**70 (81)**	**73 (82)**	**64**
R4	47	**61**	**72 (83)**	**71 (82)**	**71 (82)**	**73 (82)**	**64**
R5	47	**49**	**55 (60)**	**56 (61)**	**55 (61)**	**58 (62)**	**50**
R6	47	**69**	**66 (74)**	**64 (73)**	**66 (74)**	**64 (73)**	**61**
R7	47	**59**	**59 (67)**	**57 (67)**	**58 (67)**	**58 (67)**	**53**
R8	40	**57**	**59 (67)**	**58 (68)**	**59 (68)**	**59 (68)**	**53**
R9	40	**60**	**64 (71)**	**61 (70)**	**62 (70)**	**61 (70)**	**56**
R10	40	**51**	**54 (60)**	**50 (60)**	**51 (60)**	**51 (60)**	**46**
R11	40	**49**	**50 (58)**	**54 (64)**	**53 (64)**	**56 (64)**	**46**
R12	40	**58**	**54 (65)**	**56 (66)**	**55 (66)**	**57 (66)**	**48**
R13	40	**50**	**42 (51)**	**47 (55)**	**47 (54)**	**45 (53)**	34
R14	47	45	47 (52)	47 (53)	46 (53)	**49 (53)**	40

Note 1: The ICNG requires a +5 dB correction to be added to predicted noise levels to account for the annoying characteristics of the jackhammer, grinder or demolition saw used in this scenario.

Note 2: Values are highlighted in bold text exceedances of the night time NMLs. Text is highlighted in red bold and underlined where noise levels are above the 75 dBA “highly noise affected” level.

Note 3: Noise levels are presented without the use of jackhammers, with noise levels presented in brackets describing noise scenarios that include jackhammers.

The NMLs for non-residential receivers apply when the premises are in use. All receivers are assumed to be potentially in use during the daytime. Receivers C3, C4 and W1 and W2 may also be in use during the evening or night period

Predicted construction noise levels for all non-residential receivers during the daytime are presented in Table 7-6. Predicted noise levels for receivers in use during the evening and night time are presented in Table 7-7 respectively.

Table 7-6 – Predicted daytime construction scenario noise levels, non-residential receivers, $L_{eq,15min}$ dBA

ID	Daytime NML	1a	1b	1c	2a[1]	2b[1]	2c[1]	2d[1]	3a[1]	3b	4[1]	5
C1	70	58	**81**	**74**	**77 (87)**	**80 (87)**	**80 (87)**	**77 (85)**	**75 (85)**	66	**80 (88)**	**74**
C2	70	53	53	49	57 (63)	55 (65)	56 (65)	57 (66)	53 (65)	52	50 (63)	52
C3	70	63	61	55	66 **(73)**	69 **(81)**	68 **(80)**	**72 (81)**	68 **(80)**	62	58 (68)	67
C4	70	47	55	47	54 (64)	56 (67)	55 (66)	58 (67)	54 (66)	49	49 (61)	53
C5	70	49	53	46	52 (62)	55 (65)	54 (65)	57 (66)	53 (65)	47	49 (60)	51
C6	70	55	51	43	47 (57)	52 (62)	51 (62)	53 (62)	50 (61)	44	47 (56)	48
H1	55	**58**	**71**	**65**	**68 (79)**	**71 (79)**	**70 (79)**	**71 (80)**	**67 (79)**	**61**	**69 (79)**	**66**
H2	55	**58**	**80**	**72**	**75 (86)**	**78 (85)**	**78 (85)**	**75 (84)**	**73 (83)**	**65**	**77 (86)**	**72**
H3	55	49	49	43	47 **(57)**	52 **(62)**	51 **(62)**	53 **(62)**	50 **(61)**	44	47 **(56)**	48
H4	55	55	51	47	50 (59)	**56 (65)**	**55 (65)**	**57 (66)**	53 **(65)**	47	53 **(60)**	52
H5	55	42	45	37	44 (48)	46 (51)	45 (51)	48 (52)	44 (51)	39	40 (47)	42
A1	65	37	42	36	42 (46)	46 (51)	45 (51)	48 (52)	44 (51)	38	42 (45)	42
W1	55	**65**	**61**	52	**61 (69)**	**59 (68)**	**61 (69)**	**60 (68)**	**56 (67)**	**56**	55 **(67)**	54
W2	55	48	51	39	44 (54)	49 **(60)**	48 **(60)**	52 **(61)**	48 **(60)**	42	42 (52)	46
Y1	55	48	**57**	52	54 **(64)**	**57 (67)**	**56 (67)**	**59 (68)**	55 **(67)**	49	54 **(66)**	53
Y2	55	50	51	46	51 **(60)**	54 **(65)**	53 **(65)**	**56 (65)**	53 **(64)**	47	49 **(59)**	51
S1	55	39	37	33	40 (42)	40 (44)	39 (44)	40 (44)	37 (43)	32	37 (40)	35

Note 1: The ICNG requires a +5 dB correction to be added to predicted noise levels to account for the annoying characteristics of the jackhammer, grinder or demolition saw used in this scenario.

Note 2: Values have been highlighted in bold where they exceed the NMLs.

Note 3: Noise levels are presented without the use of jackhammers, with noise levels presented in brackets describing noise scenarios that include jackhammers.

Table 7-7 – Predicted evening and night construction scenario noise levels, non-residential receivers, $L_{eq,15min}$ dBA

ID	Evening and night NML	1a	1b	1c	2a[1]	2b[1]	2c[1]	2d[1]	3a[1]	3b	4[1]	5
C3	70	63	61	55	66 **(73)**	69 **(81)**	68 **(80)**	**72** **(81)**	68 **(80)**	62	58 (68)	67
C4	70	47	55	47	54 (64)	56 (67)	55 (66)	58 (67)	54 (66)	49	49 (61)	53
W1	55	**65**	**61**	52	**61** **(69)**	**59** **(68)**	**61** **(69)**	**60** **(68)**	**56** **(67)**	**56**	55 **(67)**	54
W2	55	48	51	39	44 (54)	49 **(60)**	48 **(60)**	52 **(61)**	48 **(60)**	42	42 (52)	46

Note 1: The ICNG requires a +5 dB correction to be added to predicted noise levels to account for the annoying characteristics of the jackhammer, grinder or demolition saw used in this scenario.

Note 2: Cells highlighted in blue indicate exceedances of the evening and night time NMLs.

Note 3: Noise levels are presented without the use of jackhammers, with noise levels presented in brackets describing noise scenarios that include jackhammers.

7.5 Sleep disturbance

Noise from intermittent peak noise events has the potential to cause sleep disturbance at the nearest residential receivers. These events were assessed assuming the L_{max} is approximately 5 dBA higher than the total sound power level of each scenario that takes place during the night period. Table 7-8 presents an assessment of the likelihood of sleep disturbance.

Table 7-8 – Predicted construction scenario noise levels for assessment of sleep disturbance, L_{max} dBA

ID	Screening criteria L_{max} dBA	Scenario 2a	Scenario 2b	Scenario 2c	Scenario 2d	Scenario 3b
R1	65	64 **(70)**	**66 (72)**	65 **(72)**	**68 (72)**	59
R2	65	**71 (77)**	**73 (78)**	**72 (78)**	**74 (78)**	65
R3	65	**75 (81)**	**76 (82)**	**75 (81)**	**78 (82)**	**69**
R4	65	**77 (83)**	**76 (82)**	**76 (82)**	**78 (82)**	**69**
R5	65	60 (60)	61 (61)	60 (61)	63 (62)	55
R6	65	**71 (74)**	**69 (73)**	**71 (74)**	**69 (73)**	**66**
R7	65	64 **(67)**	62 **(67)**	63 **(67)**	63 **(67)**	58
R8	65	64 **(67)**	63 **(68)**	64 **(68)**	64 **(68)**	58
R9	65	**69 (71)**	**66 (70)**	**67 (70)**	**66 (70)**	61
R10	65	59 (60)	55 (60)	56 (60)	56 (60)	51
R11	65	55 (58)	59 (64)	58 (64)	61 (64)	51
R12	65	59 (65)	61 **(66)**	60 **(66)**	62 **(66)**	53
R13	65	47 (51)	52 (55)	52 (54)	50 (53)	39
R14	65	52 (52)	52 (53)	51 (53)	54 (53)	45

Note 1: Values in bold indicate exceedances of the sleep disturbance screening criteria.

Note 2: Noise levels are presented without the use of jackhammers, with noise levels presented in brackets describing noise scenarios that include jackhammers.

7.6 Assessment of predicted noise levels

The following section provides a discussion of the predicted noise levels. Exceedances of the assessment criteria were predicted and the consideration of mitigation measures is recommended. These measures as discussed further in Section 11.

7.6.1 Residential receivers

The worst case predicted noise levels in Table 7-3 indicate that exceedances of the NMLs are expected for the majority of the scenarios at the representative receivers, especially the nearest receivers located on Campbell Street, London Road and Woodburn Road.

Receivers along Elizabeth Street, Lidbury Street, Crawford Street, Berala Street, Burke Avenue and Hyde Park Road are generally predicted to experience lower noise levels and in some cases comply with the NMLs due to the additional shielding provided by intervening buildings.

When jackhammers or demolition saws are used, scenarios 2a to 3a and 4 are expected to cause noise levels above the highly noise affected level at receivers represented by R2 to R4. When the jackhammers or demolition saws are not used, residential receivers are not predicted to experience noise levels in excess of the 75 dBA “highly noise affected” level.

Exceedances of the daytime NMLs for all construction scenarios are expected at receivers represented by R2, R3, R4 and R9. Receivers represented by R2 and R4 are the two closest single storey residential receivers to the works, while R3 and R9 represent the three storey apartment blocks nearest to construction activities.

Exceedances of the evening and night NMLs was predicted for the majority of the representative receivers for all scenarios that take place out of hours.

The greatest exceedance of the NMLs was predicted at receiver R4 during scenario 2d, where the NMLs are exceeded by 17 dB, or 26 dB when a jackhammer is used.

The receivers represented by R13 and R14 are not expected to exceed the NMLs during standard hours, but are expected to exceed the OOHW Period 1 and Period 2 NMLs during scenario 2d.

7.6.2 Non-residential receivers

It is expected that all of the non-residential receivers would be in use during the daytime. During the evening and night time the places of worship (receivers W1 and W2) and the commercial receivers at C3 and C4 have the potential to be in use.

During the daytime exceedance of the NML was predicted during all scenarios at the health care receivers H1 and H2 and during scenarios 2b to 2d for receiver H4.

For commercial receivers, the predicted daytime noise levels exceed the NMLs at C1 during all scenarios except 1a and 3b and at C3 during scenario 2d.

The predicted daytime noise levels at the place of worship W1 are predicted to exceed the NMLs in all scenarios except 1a, 4 and 5.

Child care centres Y1 and Y2 are predicted to experience noise levels in excess of the NMLs during the daytime. At Y1 exceedances were predicted during scenarios 1b, 2b, 2c, 2d and at Y2 during scenario 2d.

Evening and night time exceedances of the NMLs are predicted at C3 and W1, which have the potential to be in use during these periods.

The greatest exceedance of the NMLs at non-residential receivers was identified at C1. The greatest exceedance is 11 dB during scenario 1b and 18 dB when the jackhammer is used during scenario 4.

7.6.3 Sleep disturbance

The predicted noise levels in Table 7-8 indicate that sleep disturbance may be caused by activities in scenarios 2a to 2d and 3b. Table 7-8 indicates that residential receivers represented by R1 to R4, R6 to R9 and R12 may experience sleep disturbance effects due to these activities.

A number of short-term noisy activities (such as deliveries, concreting, excavating and engine start and stopping) that cause sleep disturbance effects are required throughout the construction phase. These activities may also be required on consecutive nights and generate short duration high noise levels throughout the night that are typically associated with sleep disturbance effects. As such, it is considered that sleep disturbance effects may occur at the nearest receivers identified in this assessment.

8 Road traffic noise

Increases in road traffic noise as a result of additional vehicles travelling to and from the station during the operational and construction stage have the potential to impact surrounding sensitive receivers.

The upgrades to the traffic and parking arrangements include formal kiss and ride zones, two accessible parking spaces on Campbell Street and an upgraded bus shelter.

The potentially affected roads include Campbell Street, London Road, Georges Avenue and Woodburn Road. These roads are considered to be collector roads and are assessed over the 15 hour day (7am-10pm) and 9 hour night (10pm-7am) period.

Typically an increase in traffic noise of more than 2 dB requires an increase in traffic volumes of more than 60 per cent. As the upgrades are proposed to improve the configuration, safety and access and not to increase traffic volumes, it is considered that the operation of the upgraded station would significantly increase traffic volumes on the existing roads above their existing volumes and therefore impacts above the RNP criteria are not expected.

The construction phase of the project would involve additional heavy and light vehicles accessing the site during the day and night, depending on the construction stage. It is estimated that up to five trucks or ten light vehicles would travel to the site per hour.

It is expected that the estimated number of vehicles accessing the site would not constitute an increase of more than 60 per cent of the existing traffic on the roads surrounding the station. As a result, construction traffic noise would be expected to comply with the RNP criteria.

To minimise the construction noise levels and reduce the risk of impacts occurring, construction traffic should be considered as part of the noise and vibration management plan.

9 Construction vibration assessment

Construction scenarios that involve the use of jackhammers, wacker packers or bored piling rigs have the potential to result in vibration impacts on nearby sensitive receivers, if appropriate mitigation measures are not implemented.

Table 3 of the CNS provides the safe working distance for significant vibration generating equipment. For jackhammers and bored piling rigs, an indicative safe working distance of two metres would minimise the risk of cosmetic damage for standard structures and disturbance to amenity.

For wacker packers (assumed to have a similar vibration level as a small roller), a safe working distance of 20 metres should satisfy both the human comfort and cosmetic building damage limits.

As off-site sensitive receivers are located at least 20 metres or greater from the proposed works, vibration levels are not expected to be significant at nearby receivers, and human comfort (amenity) and cosmetic damage limits are expected to be satisfied for off-site receivers.

The heritage components of the Berala Station have been assessed for the potential to sustain cosmetic damage from construction works.

Table 9-1 presents indicative safe working distances for the most significant vibration generating plant. The distances are based on meeting the 3 mm/s limit from the German Standard DIN4150-3 which is considered to be a conservative limit.

Where work is required within these distances, site-specific safe working distances should be developed on-site through vibration monitoring prior to the works commencing.

Table 9-1 – Indicative vibration levels

Item	Typical PPV (mm/s)[1]	Data source	Indicative safe working distance for heritage items[2]
Jackhammer	0.5 at 10m	*Environmental Noise Management Manual* RMS 2001	3m
Bored Piling	0.5 at 10m	Calculated based on the CNS safe working distances for cosmetic damage	3m
Wacker Packer	1 at 10m	No data available, assumed to be similar to small roller.	5m

Note 1: Vibration levels are indicative only and may vary on site and are dependent on individual equipment, mode of operation and ground conditions.

Note 2: Indicative distance required to meet the DIN 4150-3 mm/s heritage item limit.

10 Summary of environmental impacts

The predicted impacts as a result of the proposal have each been assigned a rating. The rating considers the likelihood of the impact occurring and the magnitude of the impact on the receiving environment. The ratings are defined where one or more of the following conditions are satisfied:

Negligible: where the predicted changes are not sufficient to affect ambient noise or vibration levels beyond natural variations

Minor: where there is predicted to be some level of generated noise and vibration or there is a perceptible change that would occur for less than a week during construction

Moderate: where there is predicted to be a perceptible change in noise and vibration lasting more than a week, an exceedance of the 'noise affected' noise management levels, the potential for sleep disturbance to occur at some point during construction or the potential for ground-borne vibration to cause cosmetic damage or to result in 'annoyance' at some point during construction.

Major: where there is predicted to be a notable change in noise and vibration lasting more than three weeks, an exceedance of the 'highly noise affected' noise management levels, the risk of long-term sleep disturbance during construction or an accepted certainty that ground-borne vibration would have an impact on people or buildings.

Table 10-1 – Summary of noise and vibration impacts

Source	Assessed impact	Recommended mitigation
Operational noise	Minor	See Section 6
Operational vibration	Negligible to minor	Not applicable
Operational road traffic	Negligible	Not applicable
Construction noise: daytime	Minor to major	See Section 11
Construction noise: evening and night-time	Minor to major	See Section 11
Construction vibration: building damage	Minor	See Section 10
Construction vibration: human perception	Minor	Not applicable
Construction road traffic	Minor	See Section 10

11 Safeguards and management measures

A construction noise and vibration management plan should be developed for the project, prior to commencement of works. The management plan would utilise detailed construction methodologies of the contractor. The management plan would include at a minimum include:

- identified nearby residences and other sensitive land uses
- approved hours of work and what work will be undertaken
- significant noise and vibration generating activities
- details of noise mitigation and management measures to be applied
- information for worker training to minimise noise impacts
- community consultation protocol(s)
- complaints handling protocol(s).

Construction works should be planned and carried out during standard construction hours wherever possible.

Table 11-1 presents the standard mitigation measured contained within the CNS which should be considered as mitigation measures as part of the noise management plan.

Table 11-1 – Transport for NSW *Construction Noise Strategy* standard mitigation measures

Action required	Details
Management measures	
Implement any project specific mitigation measures required	In addition to the measures set out in this table, any project specific mitigation measures identified in this report.
Implement community consultation measures	Periodic notification (monthly letterbox drop or equivalent), website, Project Infoline, Construction Response Line, email distribution list.
Site inductions	All employees, contractors and subcontractors are to receive an environmental induction.
Behavioural practices	No swearing or unnecessary shouting or loud stereos/radios on site. No dropping of materials from height, throwing of metal items and slamming of doors.
Noise Monitoring	A noise monitoring program is to be carried out for the duration of the works in accordance with the *Construction Noise and Vibration Management Plan* and any approval and licence conditions.
Source controls	
Construction hours and scheduling	Where feasible and reasonable, construction should be carried out during the standard daytime working hours. Work generating high noise and/or vibration levels should be scheduled during less sensitive time periods.
Construction respite period	High noise and vibration generating activities may only be carried out in continuous blocks, not exceeding three hours each, with a minimum respite period of one hour between each block.
Equipment selection	Use quieter and less vibration emitting construction methods where feasible and reasonable.
Maximum noise levels	The noise levels of plant and equipment must have operating sound power or sound pressure levels that would meet the predicted noise levels.
Rental plant and equipment	Noise emissions should be considered as part of the selection process.

Action required	Details
Use and siting of plant	Avoid simultaneous operation of noisy plant within discernible range of a sensitive receiver. The offset distance between noisy plant and adjacent sensitive receivers is to be maximised. Plant used intermittently to be throttled down or shut down. Plant and vehicles to be turned off when not in use. Noise-emitting plant to be directed away from sensitive receivers.
Plan works site and activities to minimise noise and vibration	Plan traffic flow, parking and loading/unloading areas to minimise reversing movements within the site.
Non-tonal reversing alarms	Non-tonal reversing beepers (or an equivalent mechanism) must be fitted and used on all construction vehicles and mobile plant regularly used on site and for any out of hours work.
Minimise disturbance arising from delivery of goods to construction sites	Loading and unloading of materials/deliveries is to occur as far as possible from sensitive receivers. Select site access points and roads as far as possible away from sensitive receivers. Dedicated loading/unloading areas to be shielded if close to sensitive receivers. Delivery vehicles to be fitted with straps rather than chains for unloading, wherever possible.
Path controls	
Shield stationary noise sources such as pumps, compressors, fans etc.	Stationary noise sources should be enclosed or shielded whilst ensuring that the occupational health and safety of workers is maintained.
Shield sensitive receivers from noisy activities	Use structures to shield residential receivers from noise such as site shed placement; earth bunds; fencing; erection of operational stage noise barriers (where practicable) and consideration of site topography when situating plant.

In addition to the standard mitigation measures identified in the CNS, the following specific mitigation measures have been developed as a result of the predicted impacts associated with the proposal.

To minimise noise levels, the following work practices should be implemented:

- Work is to be scheduled during standard construction hours where feasible and reasonable.
- Where feasible, the use of jackhammers, grinders and demolition saws should be confined to standard hours or should be scheduled to be carried out early in the evening or night period.
- Provide periods of respite from the use of demolition saws and jackhammers. Respite periods should be defined by those periods where the community is less sensitive to noise such as avoiding early morning and late afternoon.
- Orientate generators, concrete trucks and concrete pumps away from sensitive receivers.
- Utilise vehicles, obstacles and stockpiles on site to provide shielding to receivers, especially for static noise sources: generators, lighting towers, mulchers, mobile cranes and the piling rig.
- Use equipment that has noise levels equal to or less than the sound power levels in Table 7-2.

To minimise the risk of vibration impacts, the following is recommended:

- Condition surveys of heritage buildings are to be undertaken in order to assess potential for increased susceptibility to building damage from vibration.

- Where possible, the use of less vibration intensive methods of construction or equipment should be considered where possible to reduce the potential for cosmetic damage.
- All equipment should be maintained and operated in an efficient manner, in accordance with manufacturer's specifications, to reduce the potential for adverse vibration impacts.
- Ensure that safe working distances provided in Table 9-1 are complied with.
- Site-specific safe working distances are to be established on-site prior to the vibration generating works commencing.
- If vibration intensive equipment is to be used within the safe working distances, attended vibration measurements are to be undertaken when work commences to determine site specific safe working distances.
- Vibration intensive work should not proceed within the safe working distances unless a permanent vibration monitoring system is installed approximately one metre from the building footprint, to warn operators (via flashing light, audible alarm, SMS etc.) when vibration levels are approaching the peak particle velocity trigger levels.
- Avoid direct contact with structures when using jackhammers or bored piling equipment.

To minimise the potential for sleep disturbance, where night works are proposed to be undertaken, the following controls should be implemented where feasible and reasonable:

- Avoid conducting noise intensive night works for more than two consecutive nights.
- Schedule noise intensive activities such as concrete sawing, grinding or jackhammering to before 10pm.
- Schedule activities which are likely to cause maximum noise events such as deliveries, moving material or equipment, compacting and demolition works to avoid the night time period (10pm to 7am).
- Avoid dropping tools or materials from height, striking materials, dragging materials or making metal on metal contact.
- Educate workers on the importance of minimising noise and avoid creating short duration high noise level events.
- Inform surrounding residents by mail of planned works prior to the works commencing.

11.1 Application of additional mitigation measures

According to the CNS, where there is potential for a project's construction noise objectives to be exceeded, a number of additional measures to mitigate such exceedances should be explored. The additional mitigation measures matrix (AMMM) is primarily aimed at pro-active engagement with affected receivers.

Table 11-2, reproduced from the CNS, outlines what measures may apply depending on how much the predicted noise levels exceed the measured RBLs, and the time of the day.

Additional mitigation measures that may be applicable to affected receivers include letterbox drops, noise monitoring, individual briefings, phone calls, specific notifications, proposal specific respite offers and alternate accommodation.

Specific additional mitigation measures will be identified for affected receivers at the CNVMP stage of the project.

Table 11-2 – Application of mitigation measures in addition to Transport for NSW *Construction Noise Strategy* standard mitigation measures

Time period		$L_{eq,15min}$ noise level assessment of above background (RBL) qualitative noise levels*			
		0 to 10 dBA Noticeable	10 to 20 dBA Clearly audible	20 to 30 dBA Moderately intrusive	> 30 dBA Highly intrusive
Standard	Mon-Fri (7am-6pm) Sat (8am-1pm) Sun/Pub (Nil)	-	-	LB, M	LB, M
OOHW Period 1	Mon-Fri (6pm-10pm) Sat (1pm-10pm) Sun/Pub (8am-6pm)	-	LB	M, LB	M, IB, LB, RO, PC, SN
OOHW Period 2	Mon-Fri (10pm-7am) Sat (10pm-8am) Sun/Pub (6pm-7am)	LB	M, LB	M, IB, LB, PC, SN	AA, M, IB, LB, PC, SN

Note: *The following abbreviations have been used –

- AA: Alternative accommodation
- M: Monitoring
- IB: Individual briefings
- LB: Letterbox drops
- RO: Proposal specific respite offer
- PC: Phone calls
- SN: Specific notifications.

12 Conclusion

This report presents the predicted noise and vibration impacts associated with the proposed upgrade of Berala Station.

The proposal includes an upgrade to the station facilities for commuters including the installation of a new lift from the underpass level to the platform level, extension of the building canopy, the demolition of the ticket office and the refurbishment of the station building.

Environmental noise monitoring was conducted on site at two locations representative of the surrounding receivers. Representative noise sensitive residential and non-residential receivers were identified in the vicinity of the proposal.

Assessment criteria for sensitive receivers were derived for operational noise, construction noise and vibration using the measurement data and the relevant NSW guidelines and international standards where applicable.

The operation of the upgraded Berala Station is expected to include additional noise sources from one lift, lighting and electrical equipment including security cameras. Mechanical plant required for operation of the lifts would be selected in order to achieve the operational noise criteria presented in this report. It is expected that the noise from the additional mechanical plant and equipment would be able to be controlled to meet the operational noise criteria.

The construction noise assessment considered a number of scenarios derived from each construction phase. Worst-case noise levels for each scenario were predicted at the surrounding sensitive receivers.

The predictions indicated that noise levels are likely to exceed the noise management levels at the majority of the closest receivers during the day, evening and night time periods. Where jackhammers are used, the nearest receivers were also predicted to experience noise levels in excess of the highly noise affected level. In addition, some of the nearest receivers to the works may experience sleep disturbance when works are carried out during the night.

The construction vibration assessment indicated that vibration levels are not expected to exceed human comfort or building damage limits at the nearest off-site receivers. For the heritage listed station buildings, indicative safe working protocols and distances were identified for significant vibration sources.

As a result of the predicted exceedances of the noise management levels, sleep disturbance screening criteria and the potential for vibration impacts on the heritage components of the station, management measures have been recommended, including a construction noise and vibration management plan.

13 References

Auburn Council Local Environmental Plan 2010

Australian Standard, 1997, AS1055.1 Acoustics – Description and measurement of environmental noise – Part1: General procedures.

Australian Standard, 2010, AS 2436 Guide to noise and vibration control on construction, demolition and maintenance sites.

British Standard, 1993, BS7385-2 Evaluation and measurement for vibration in buildings. Guide to damage levels from groundborne vibration.

Department of Environment, Food and Rural Affairs, UK, 2006, Update of Noise Database for Prediction of Noise on Construction and Open Sites.

German Standard, Deutsches Institut für Normung, 1999, DIN 4150: Part 3 Structural vibration – Effects of vibration on structures.

International Organization for Standardization, 1996 ISO 9613 Acoustics -- Attenuation of sound during propagation outdoors.

NSW Environment Protection Authority (formerly Department of Environment and Conservation NSW), 2006, Assessing Vibration: A Technical Guideline.

NSW Environment Protection Authority (formerly Department of Environment, Climate Change and Water), 2009, Interim Construction Noise Guideline.

NSW Environment Protection Authority, 2000, NSW Industrial Noise Policy.

NSW Environment Protection Authority, 2013, NSW Industrial Noise Policy Application Notes.

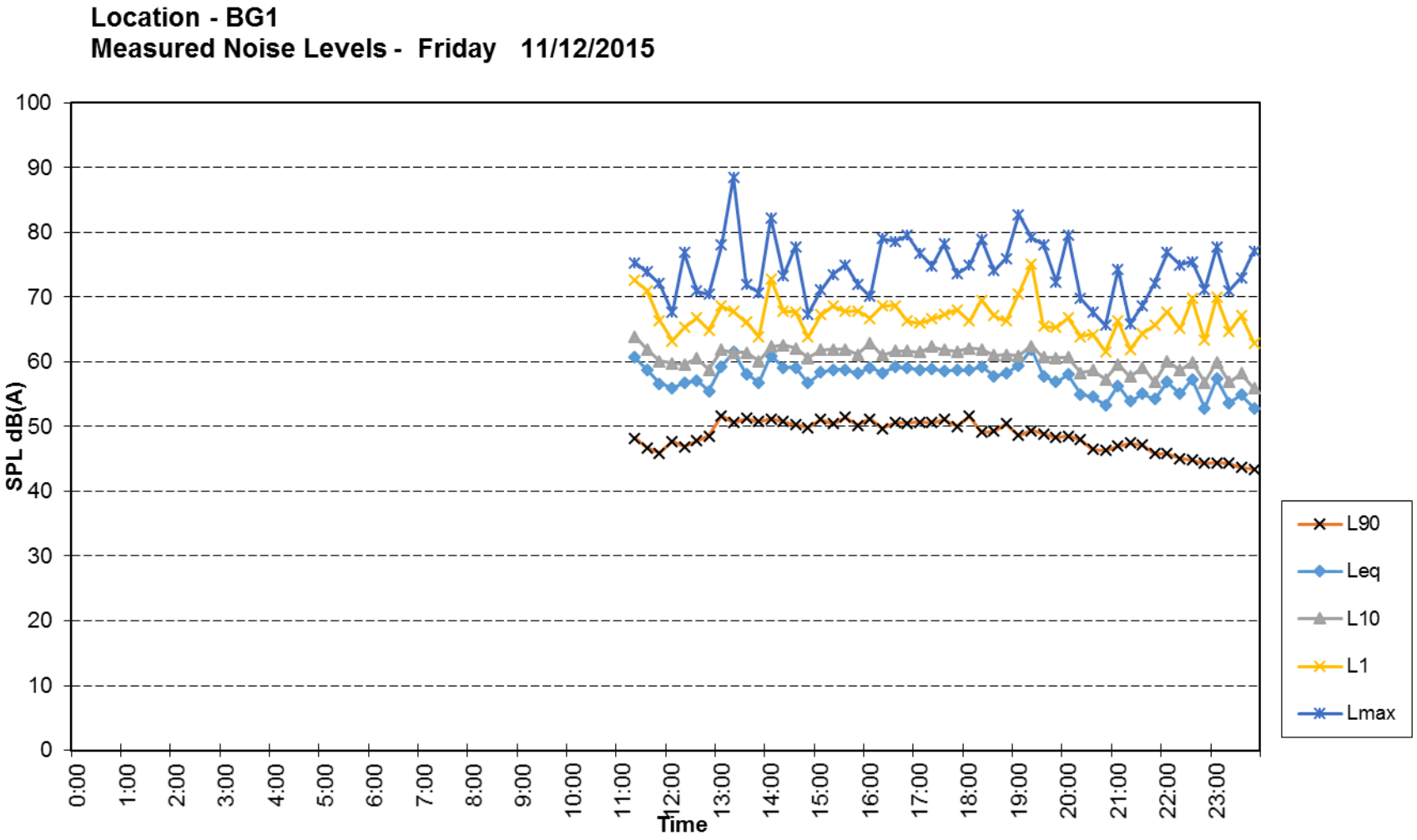
NSW Environment Protection Authority (formerly Department of Environment, Climate Change and Water), 2011, Road Noise Policy.

NSW RMS (formerly RTA), 2001, Environmental Noise Management Manual

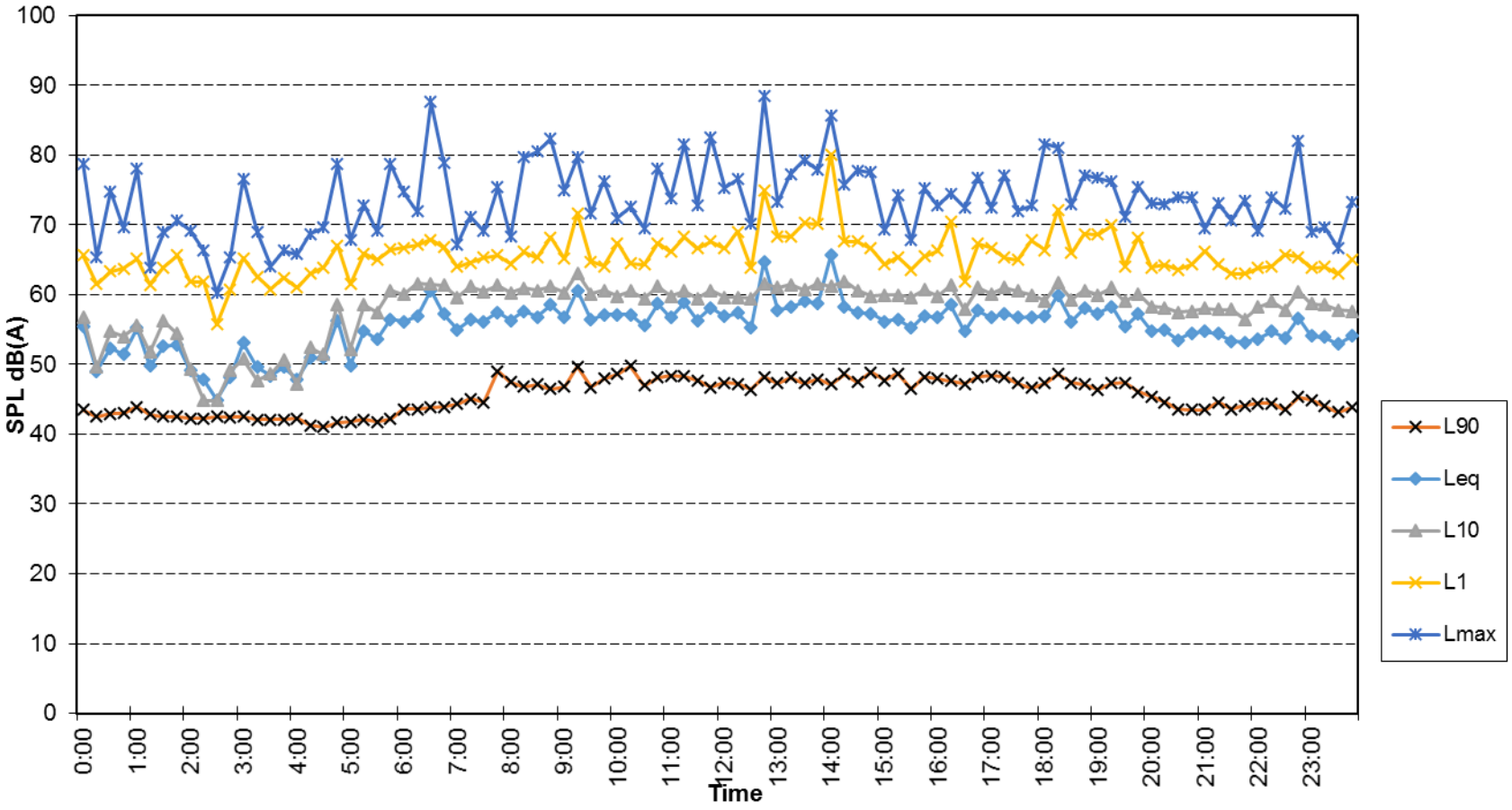
Transport for NSW (TfNSW), 2012, Construction Noise Strategy.

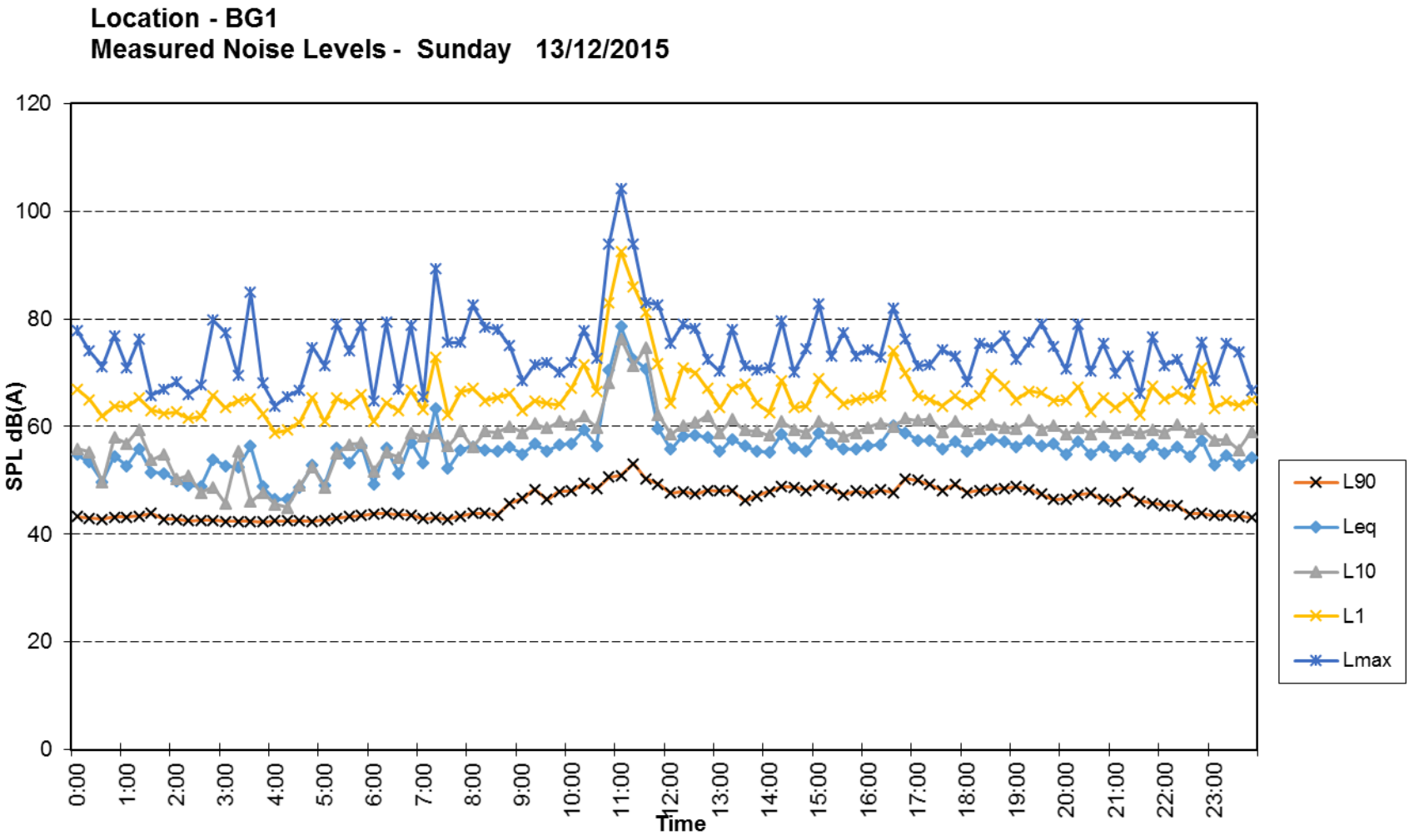
Transport for NSW (TfNSW), 2013, Section 170 Heritage and Conservation Register

Appendix A Noise monitoring results

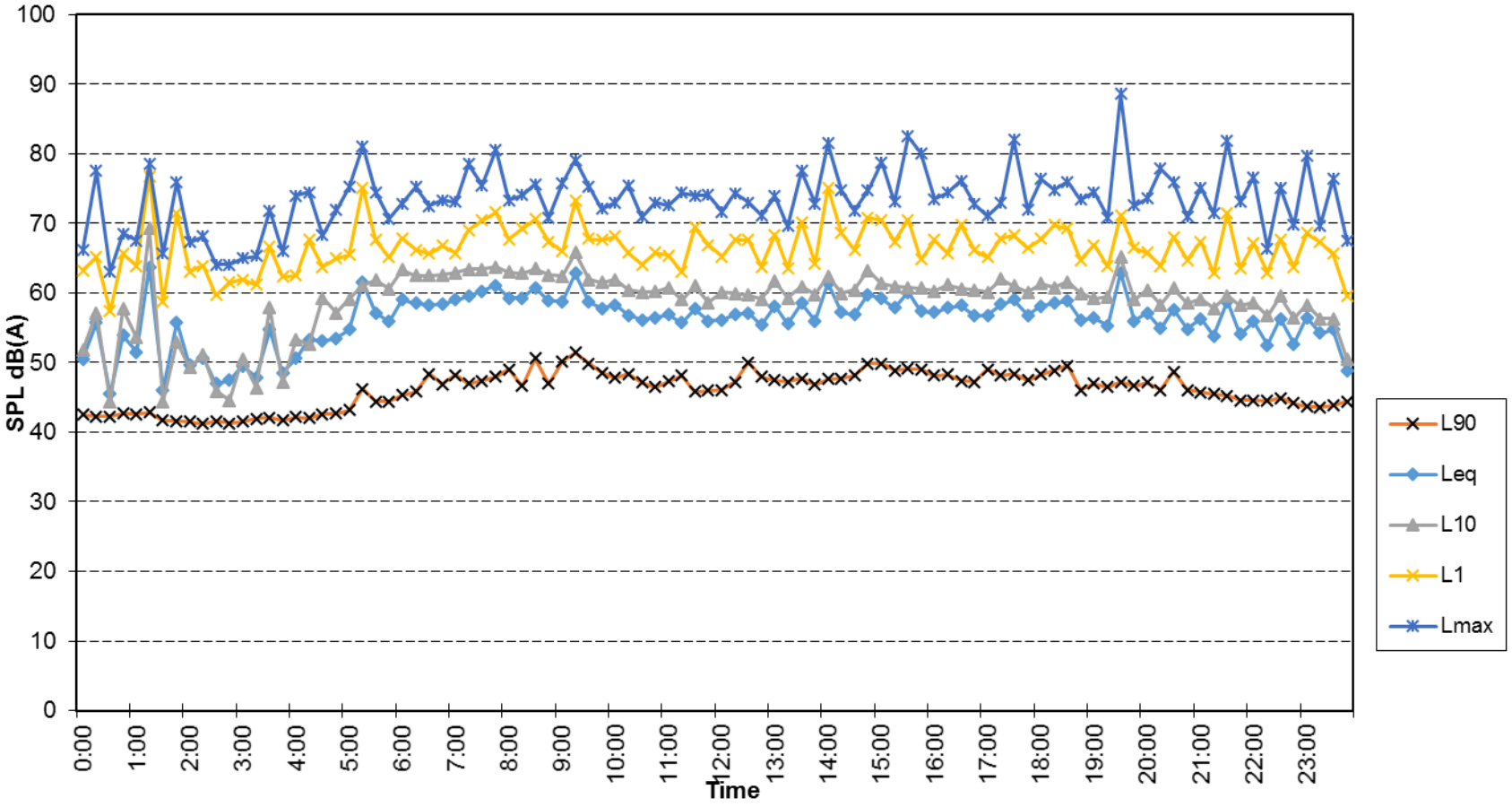


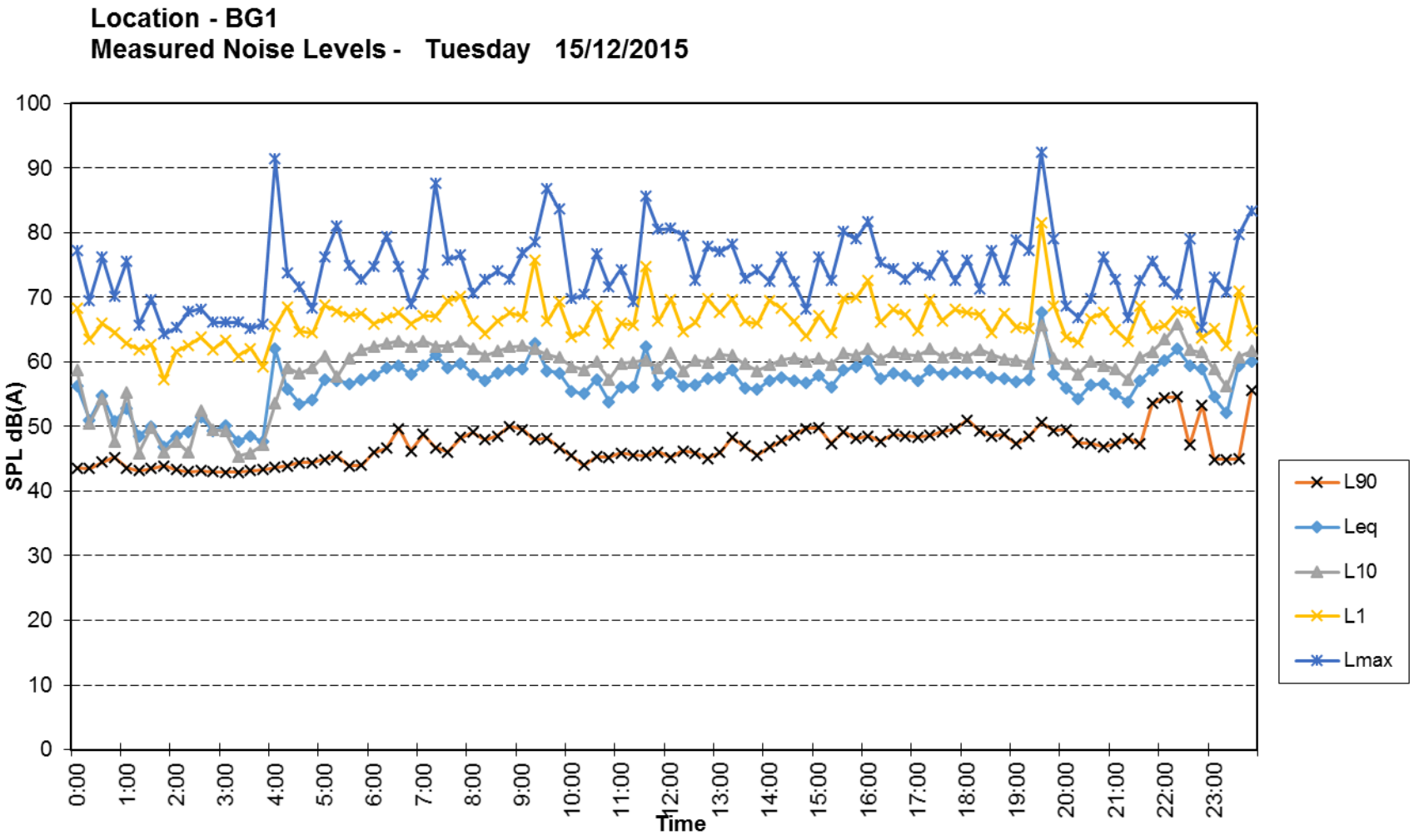
Location - BG1
Measured Noise Levels - Saturday 12/12/2015



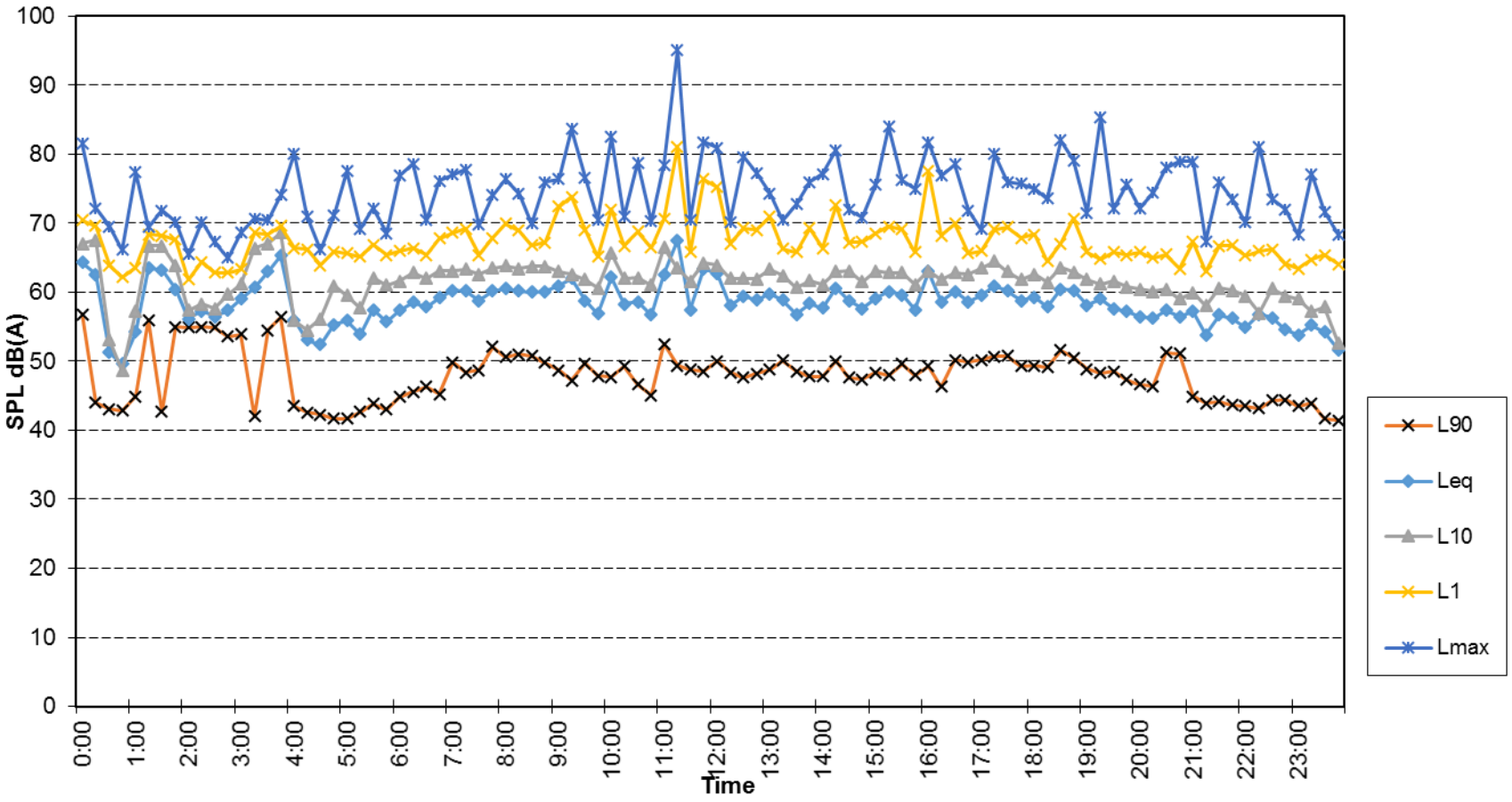

Location - BG1
Measured Noise Levels - Sunday 13/12/2015
SPL dB(A)
120
100
80
60
40
20
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time
L90
Leq
L10
L1
Lmax

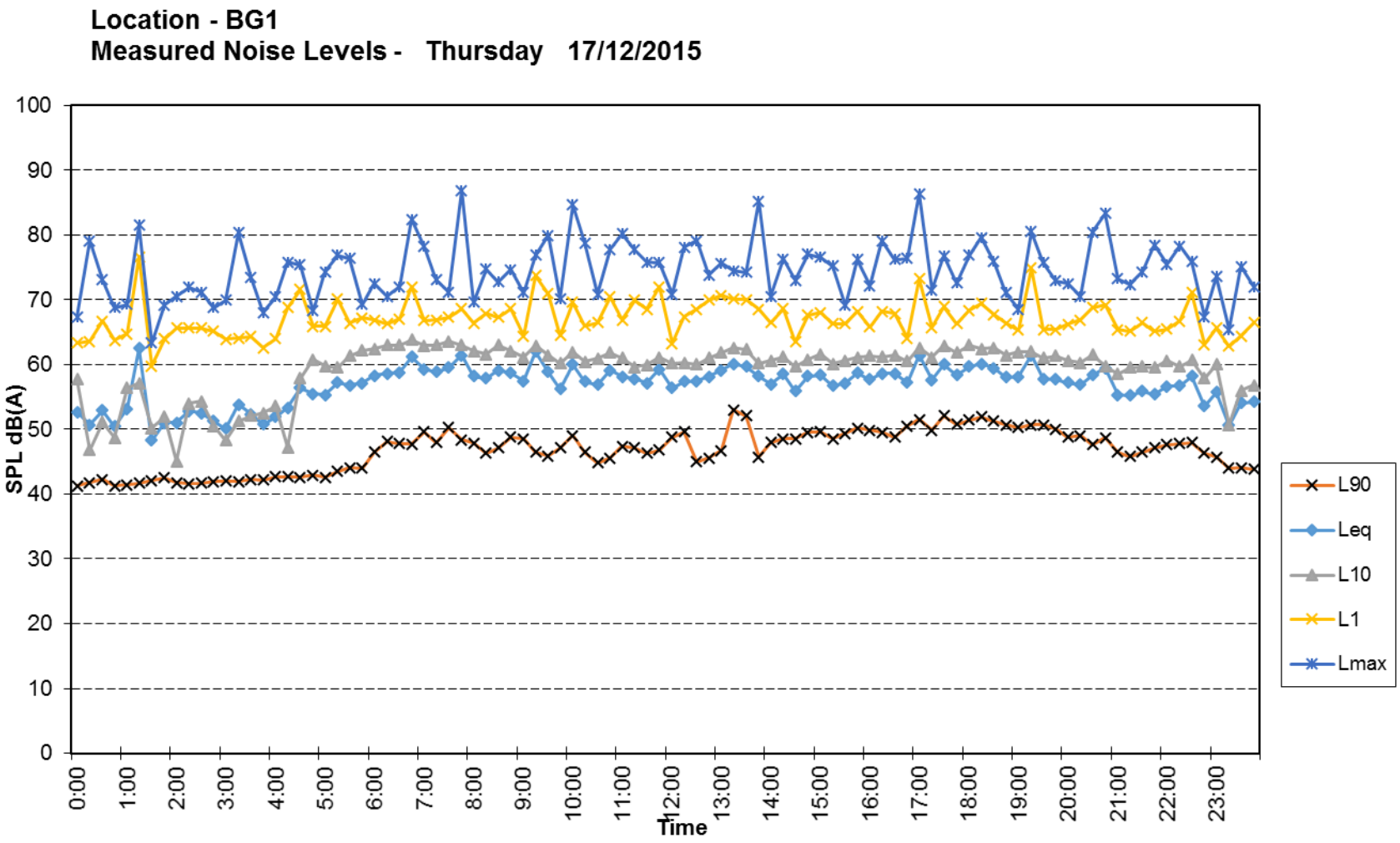
Location - BG1
Measured Noise Levels - Monday 14/12/2015

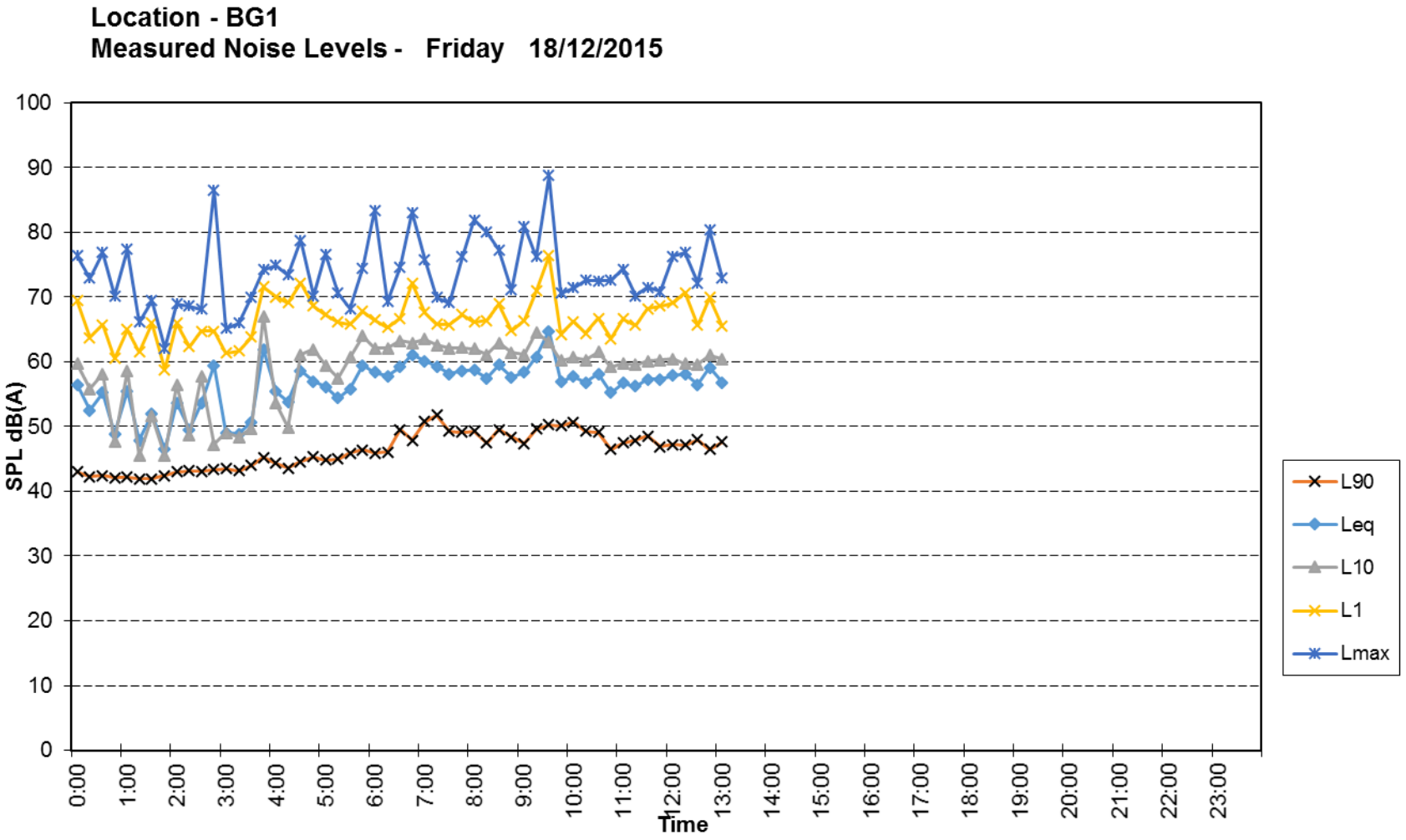


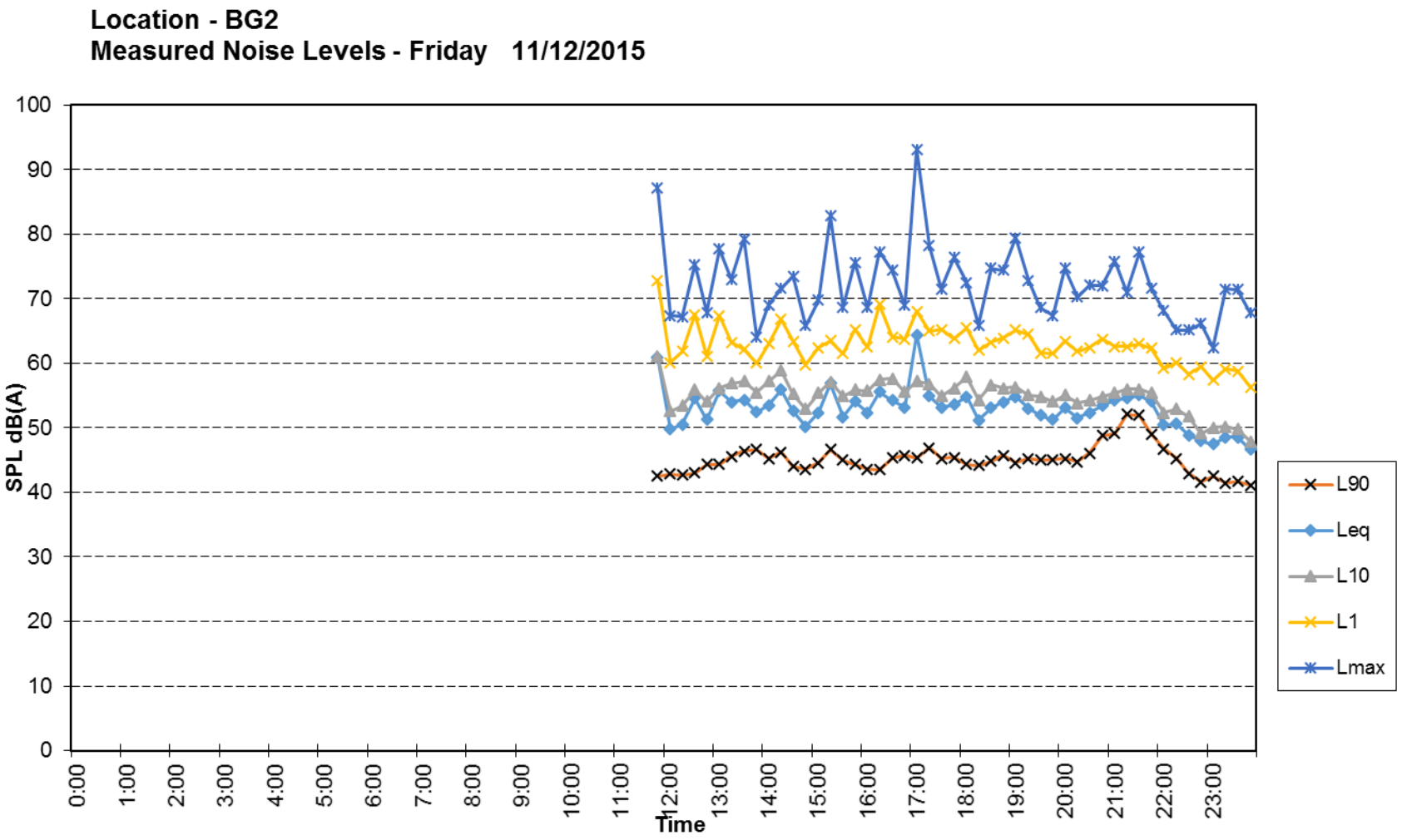

Location - BG1
Measured Noise Levels - Tuesday 15/12/2015
SPL dB(A)
100
90
80
70
60
50
40
30
20
10
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time
L90
Leq
L10
L1
Lmax

Location - BG1
Measured Noise Levels - Wednesday 16/12/2015

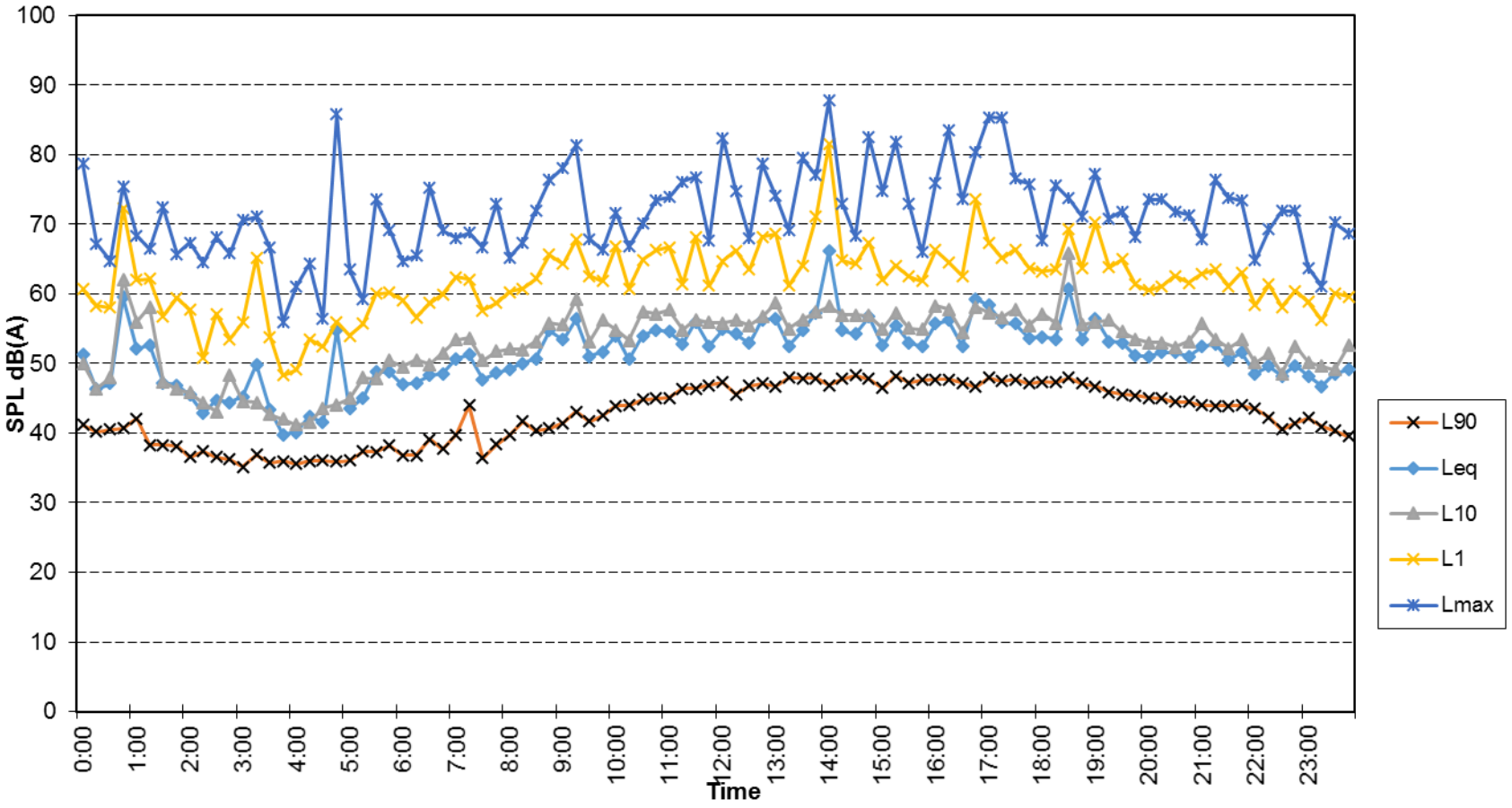



Location - BG1
Measured Noise Levels - Thursday 17/12/2015
SPL dB(A)
100
90
80
70
60
50
40
30
20
10
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time
L90
Leq
L10
L1
Lmax

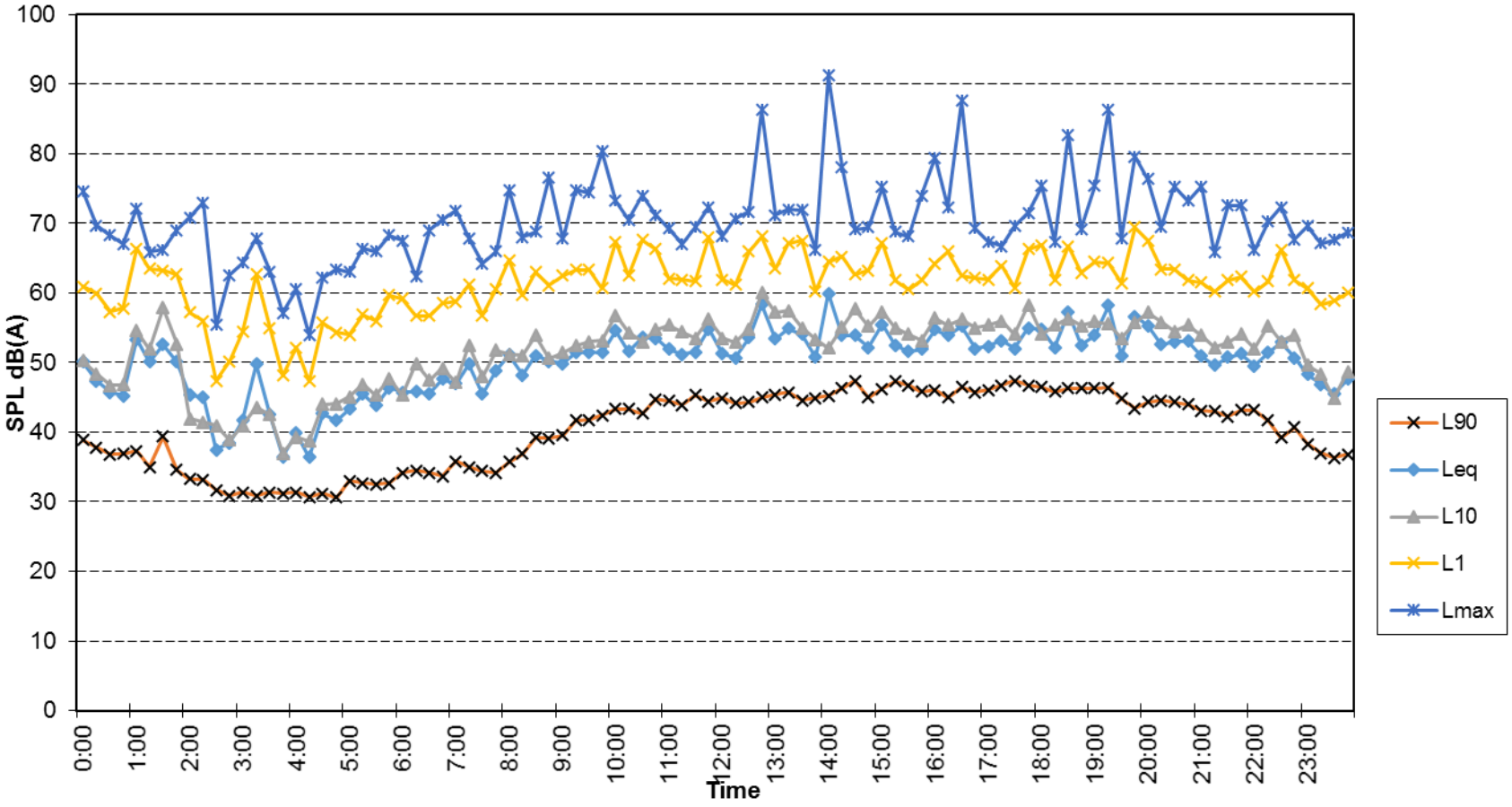

Location - BG1
Measured Noise Levels - Friday 18/12/2015
SPL dB(A)
100
90
80
70
60
50
40
30
20
10
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time
L90
Leq
L10
L1
Lmax


Location - BG2
Measured Noise Levels - Friday 11/12/2015
SPL dB(A)
100
90
80
70
60
50
40
30
20
10
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time
L90
Leq
L10
L1
Lmax

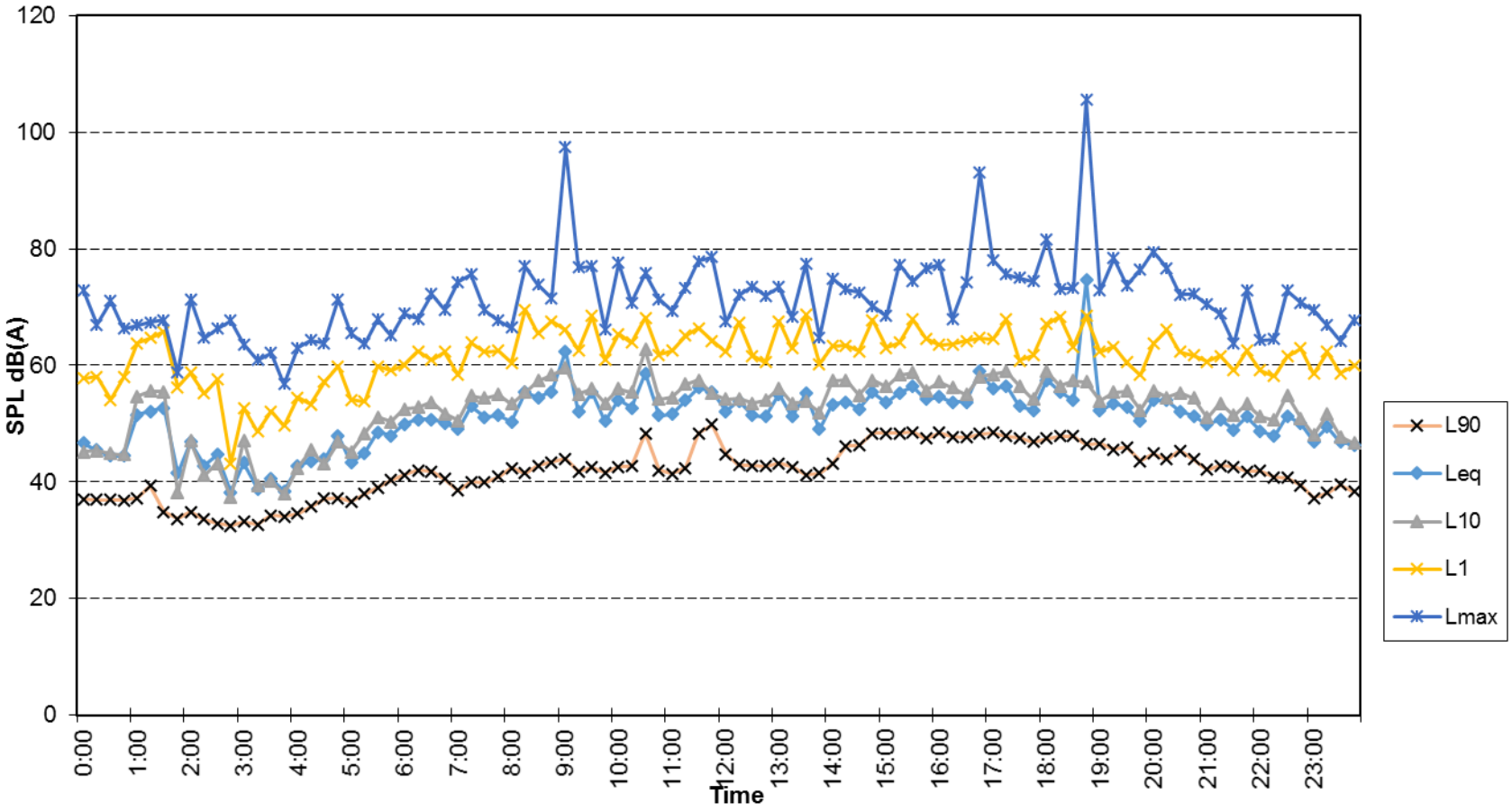
Location - BG2
Measured Noise Levels - Saturday 12/12/2015



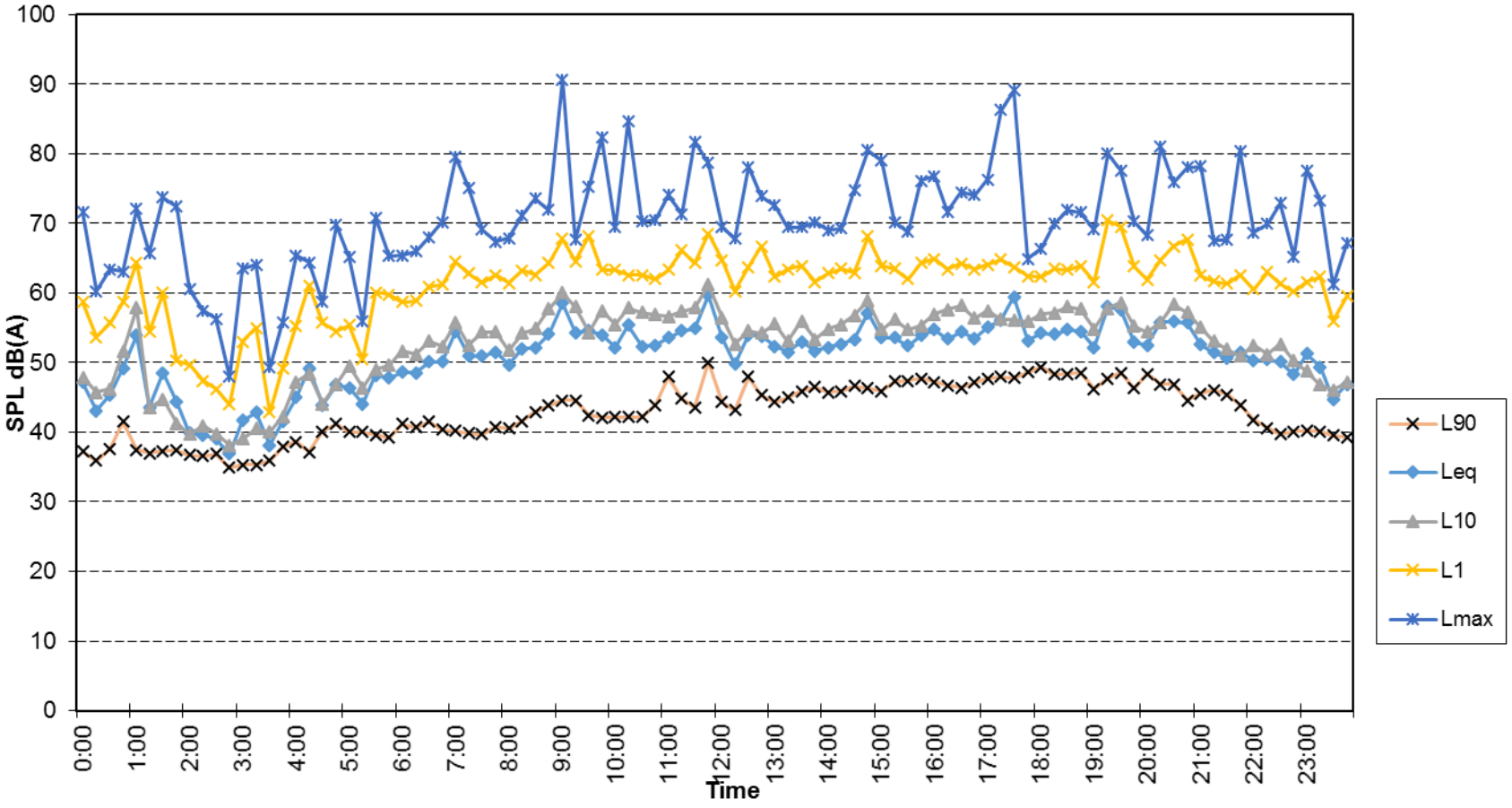
Location - BG2
Measured Noise Levels - Sunday 13/12/2015



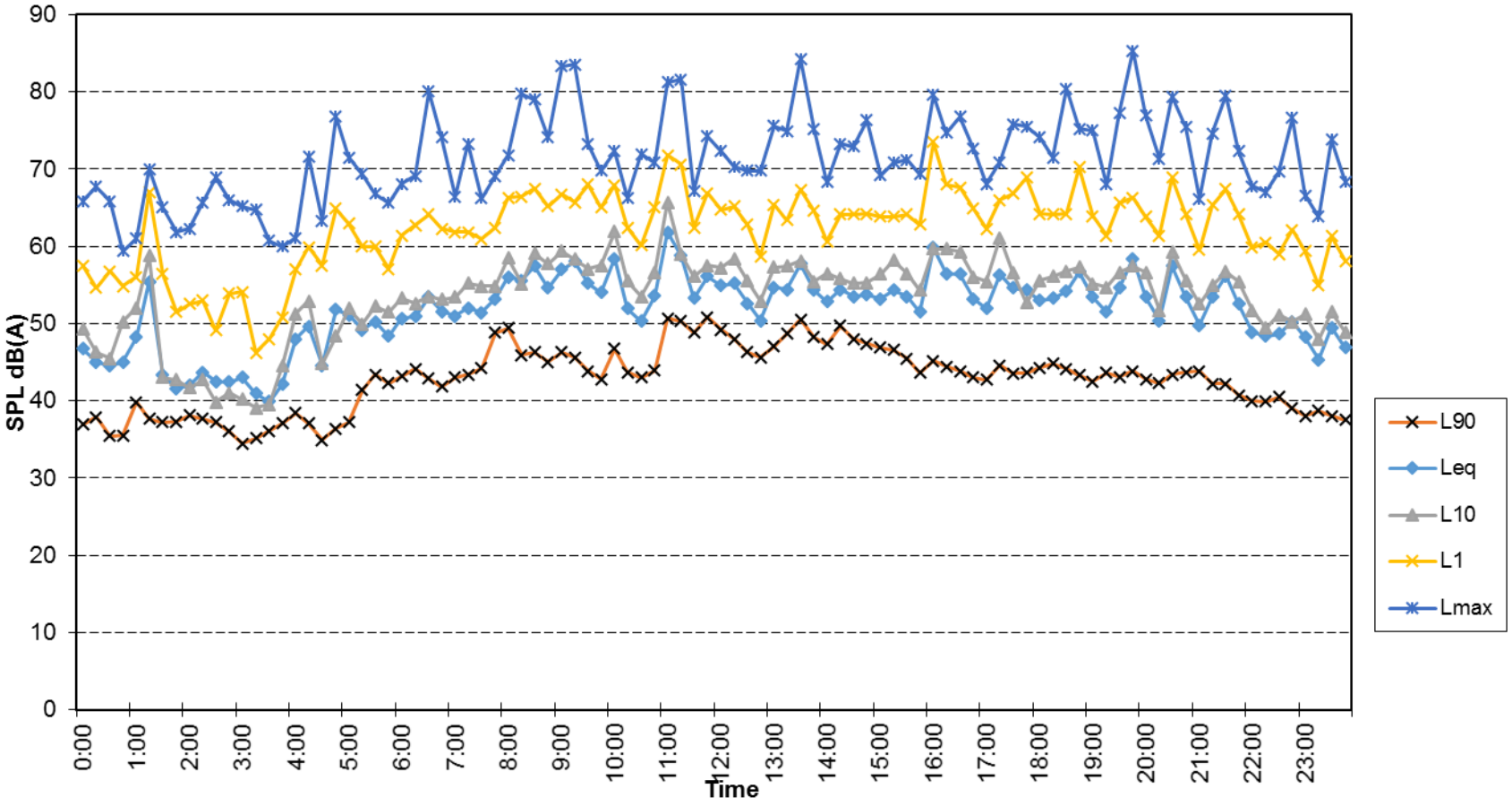
Location - BG2
Measured Noise Levels - Monday 14/12/2015



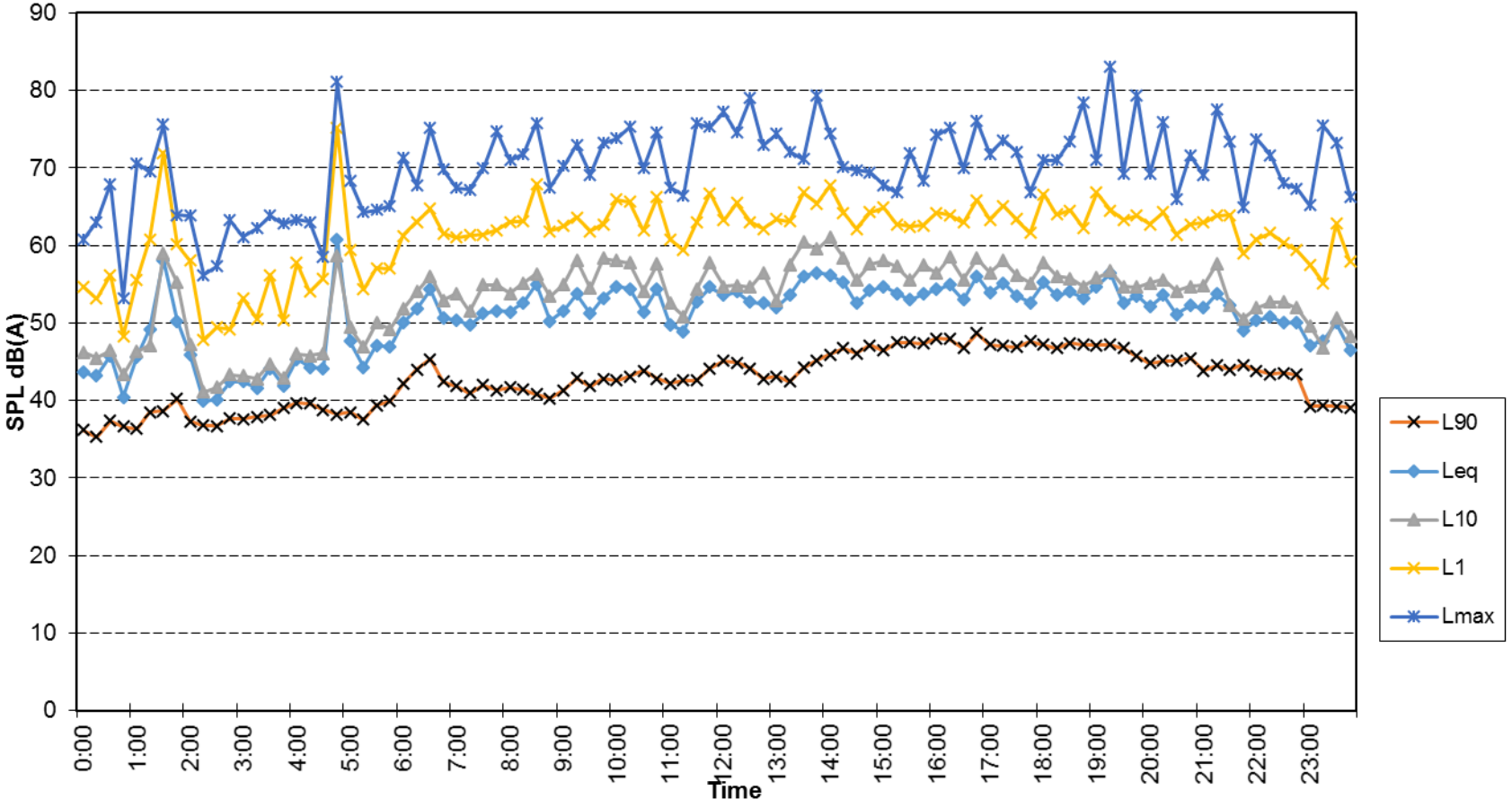
Location - BG2
Measured Noise Levels - Tuesday 15/12/2015

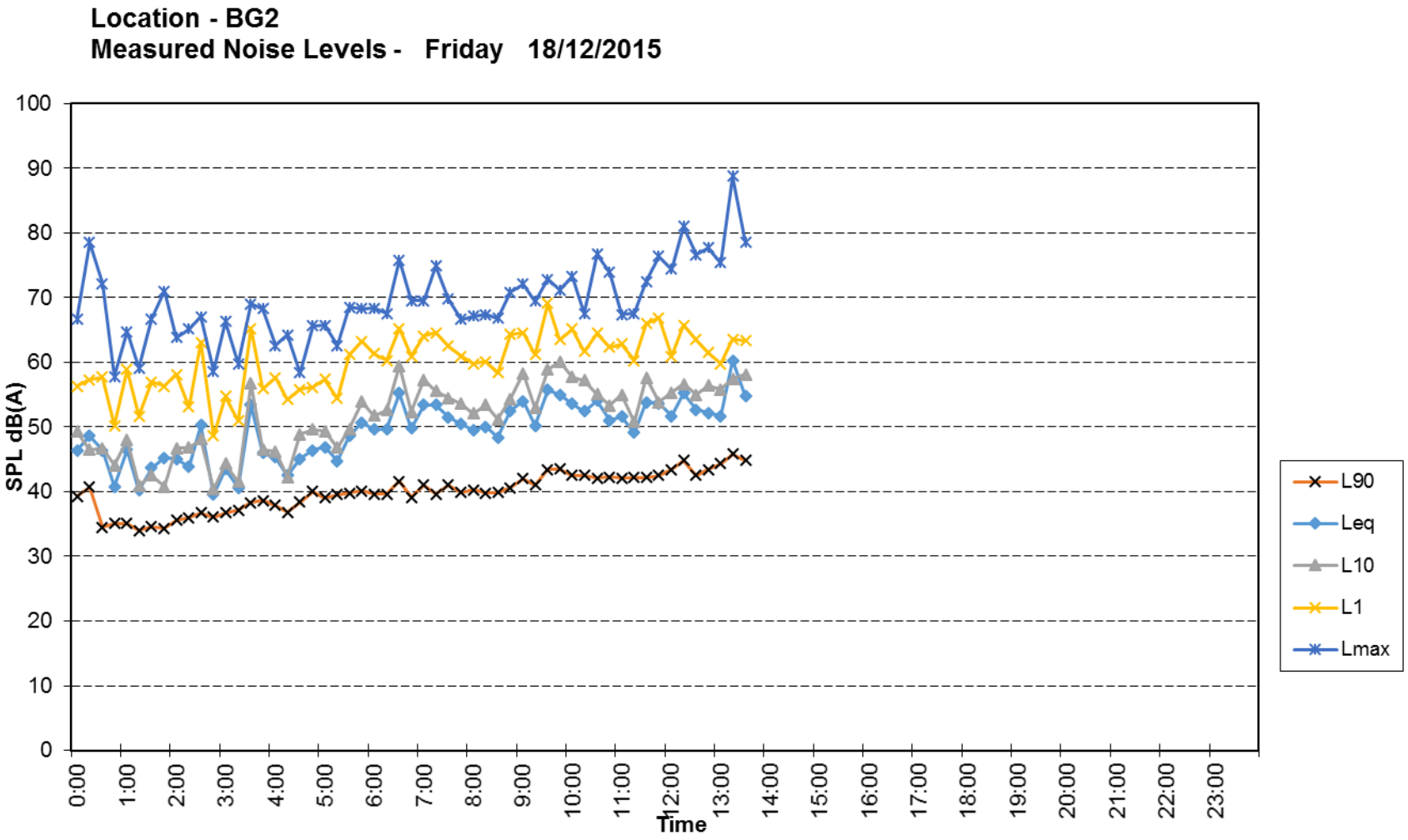


Location - BG2
Measured Noise Levels - Wednesday 16/12/2015

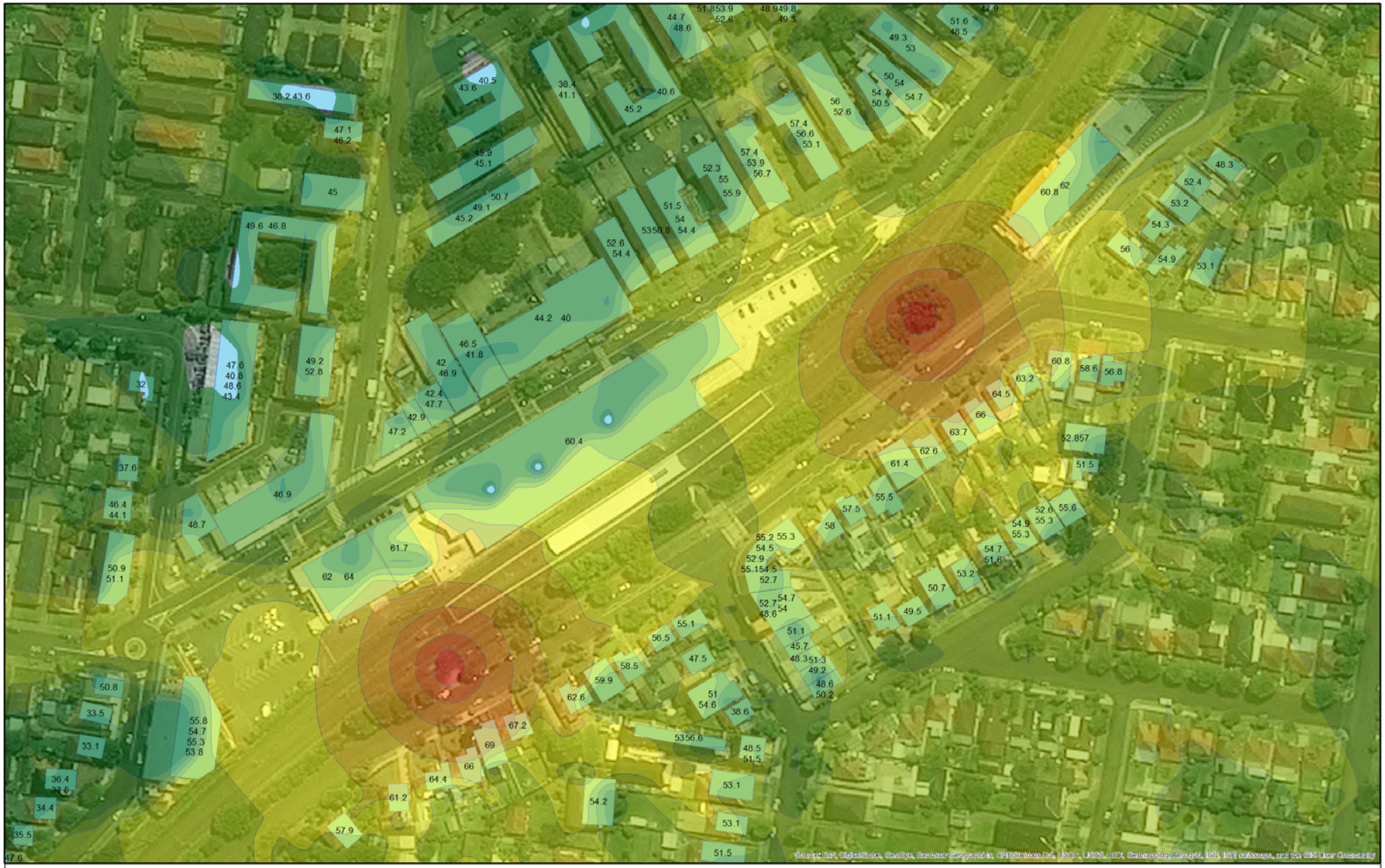


Location - BG2
Measured Noise Levels - Thursday 17/12/2015




Location - BG2
Measured Noise Levels - Friday 18/12/2015
SPL dB(A)
100
90
80
70
60
50
40
30
20
10
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time
L90
Leq
L10
L1
Lmax

Appendix B Construction noise contour maps



WSP | PARSONS BRINCKERHOFF

Legend

Free Field Level (dB)

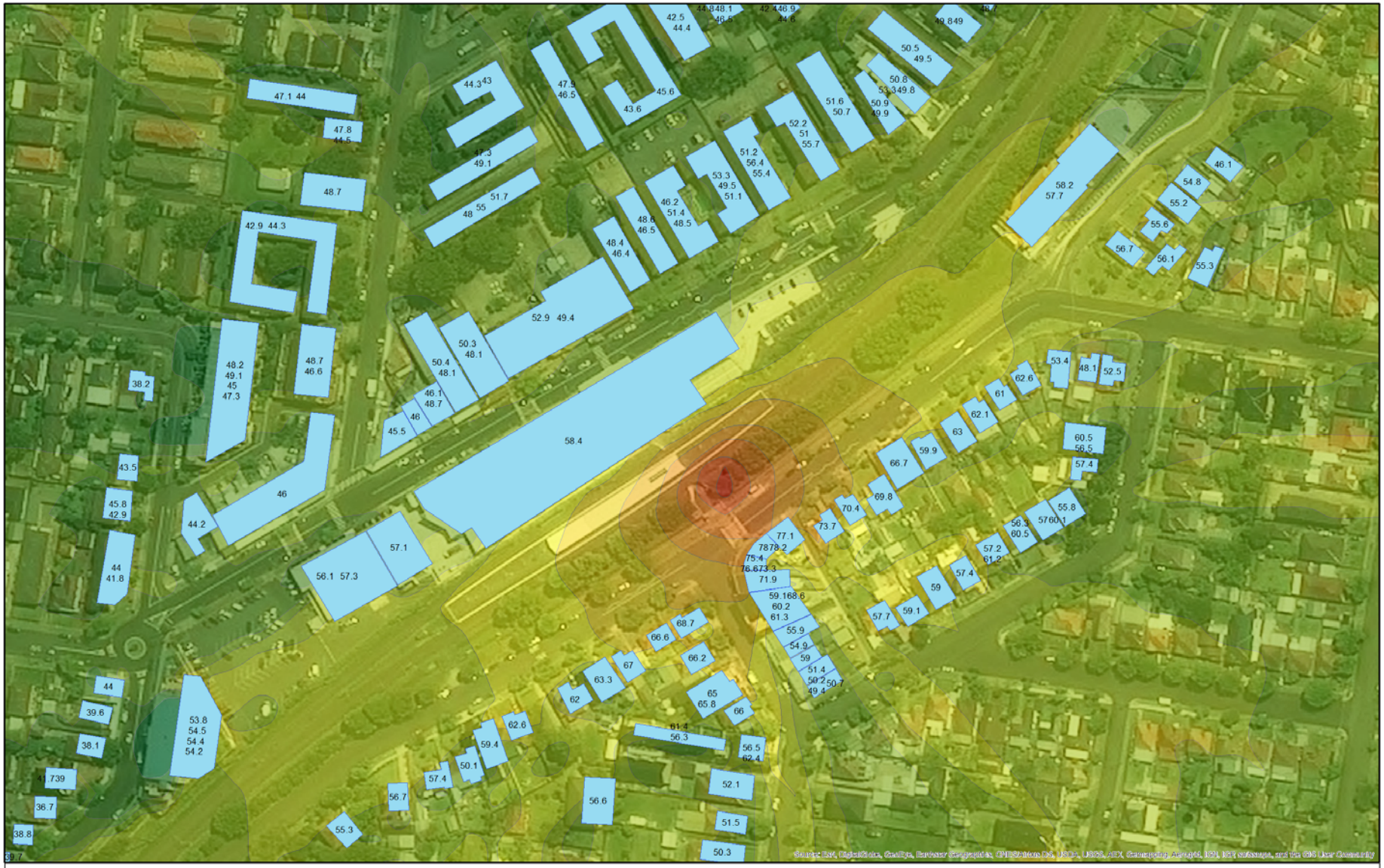
- 30-35
- 35-40
- 40-45
- 45-50
- 50-55
- 55-60
- 60-65
- 65-70
- 70-75
- 75-80
- 80-85
- 160112 Berala Scenario 1 FNM 1

Berala Station Upgrade
Construction Scenario 1a

January 2016

N

0 15 30 60 90 Meters



WSP | PARSONS BRINCKERHOFF

Legend

160112 Berala Scenario 2 FNM 1

Free Field Level (dB)

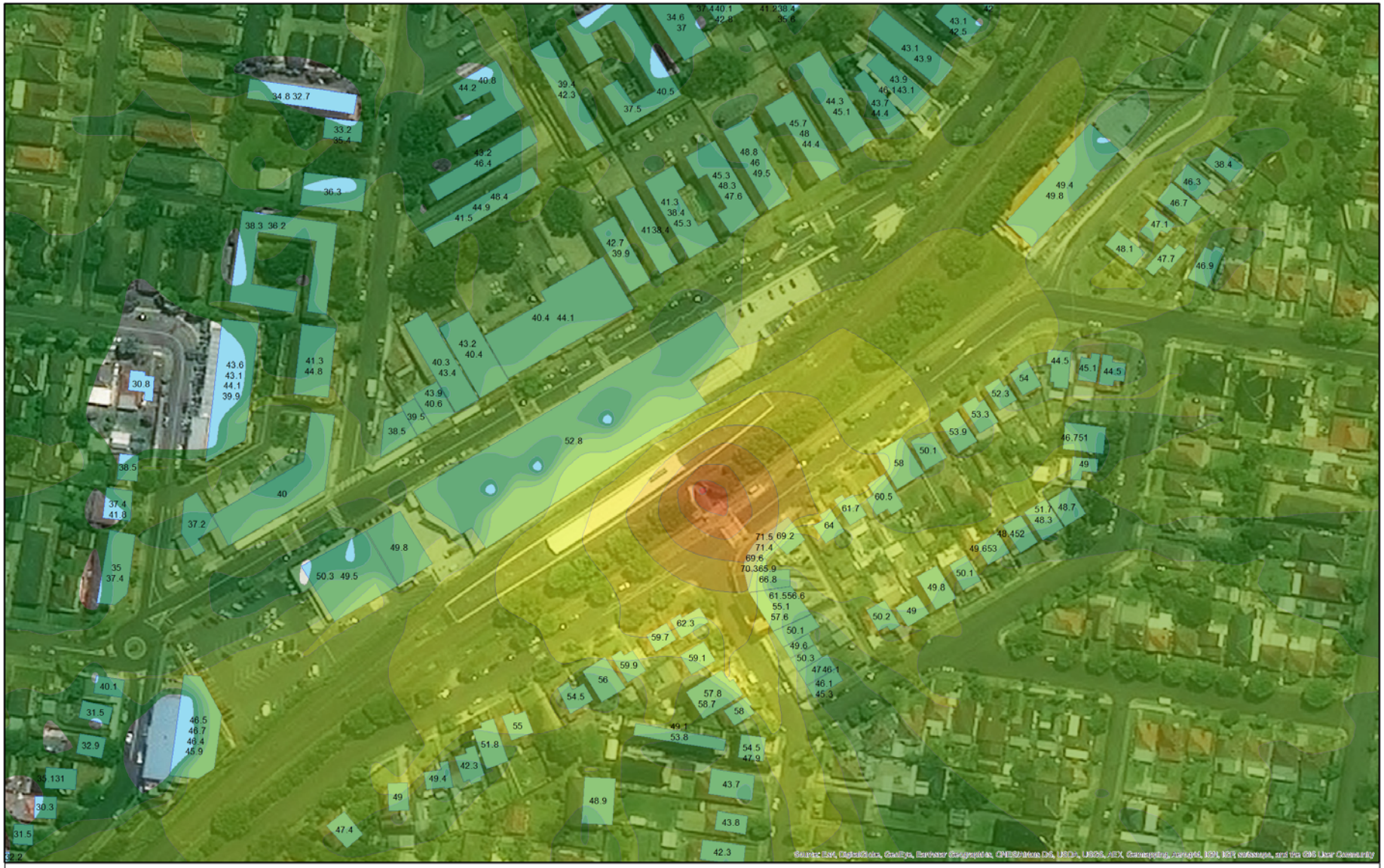
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95

Berala Station Upgrade
Construction Scenario 1b

January 2016

N

0 15 30 60 90 Meters



WSP | PARSONS BRINCKERHOFF

Legend

Free Field Level (dB)

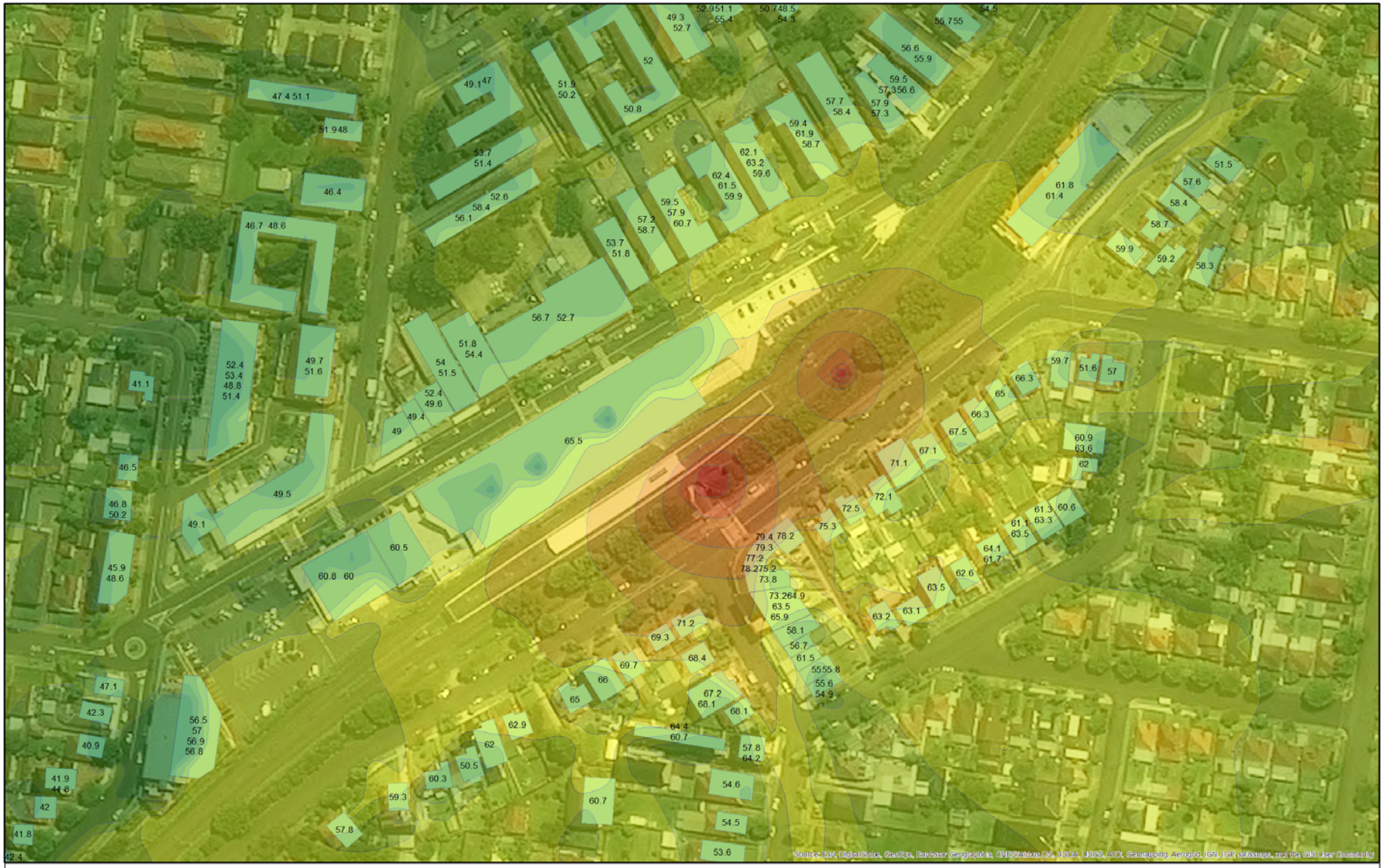
- 30-35
- 35-40
- 40-45
- 45-50
- 50-55
- 55-60
- 60-65
- 65-70
- 70-75
- 75-80
- 80-85
- 85-90
- 160112 Berala Scenario 3 FNM 1

Berala Station Upgrade
Construction Scenario 1c

January 2016

N

0 15 30 60 90 Meters



WSP | PARSONS BRINCKERHOFF

Legend

Free Field Level (dB)

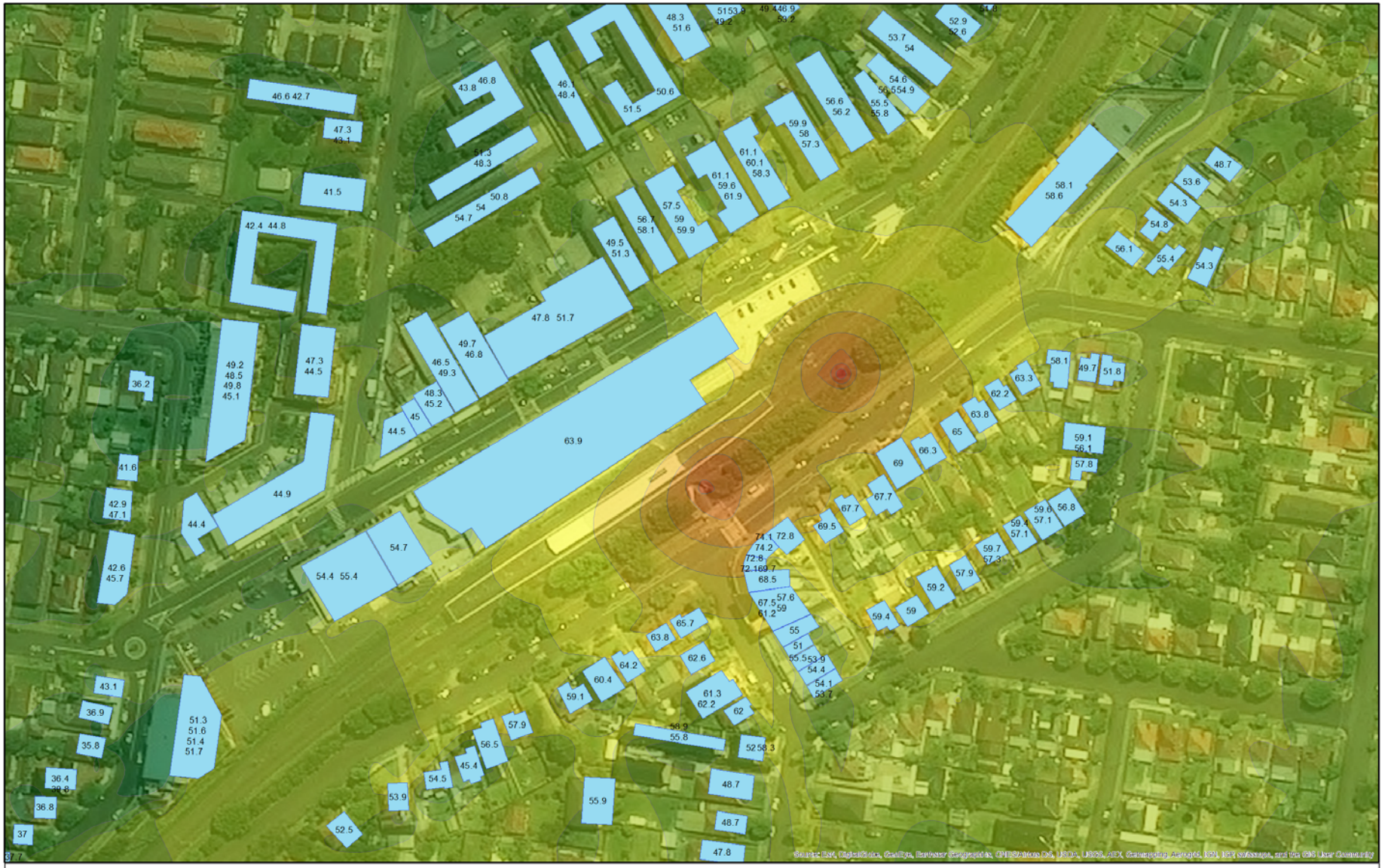
- 30-35
- 35-40
- 40-45
- 45-50
- 50-55
- 55-60
- 60-65
- 65-70
- 70-75
- 75-80
- 80-85
- 85-90
- 90-95
- 160112 Berala Scenario 4 Jack FNM 1

Berala Station Upgrade
Construction Scenario 2a (jackhammer)

January 2016

N

0 15 30 60 90 Meters



WSP | PARSONS BRINCKERHOFF

Legend

160112 Berala Scenario 4 No Jack FNM 1

Free Field Level (dB)

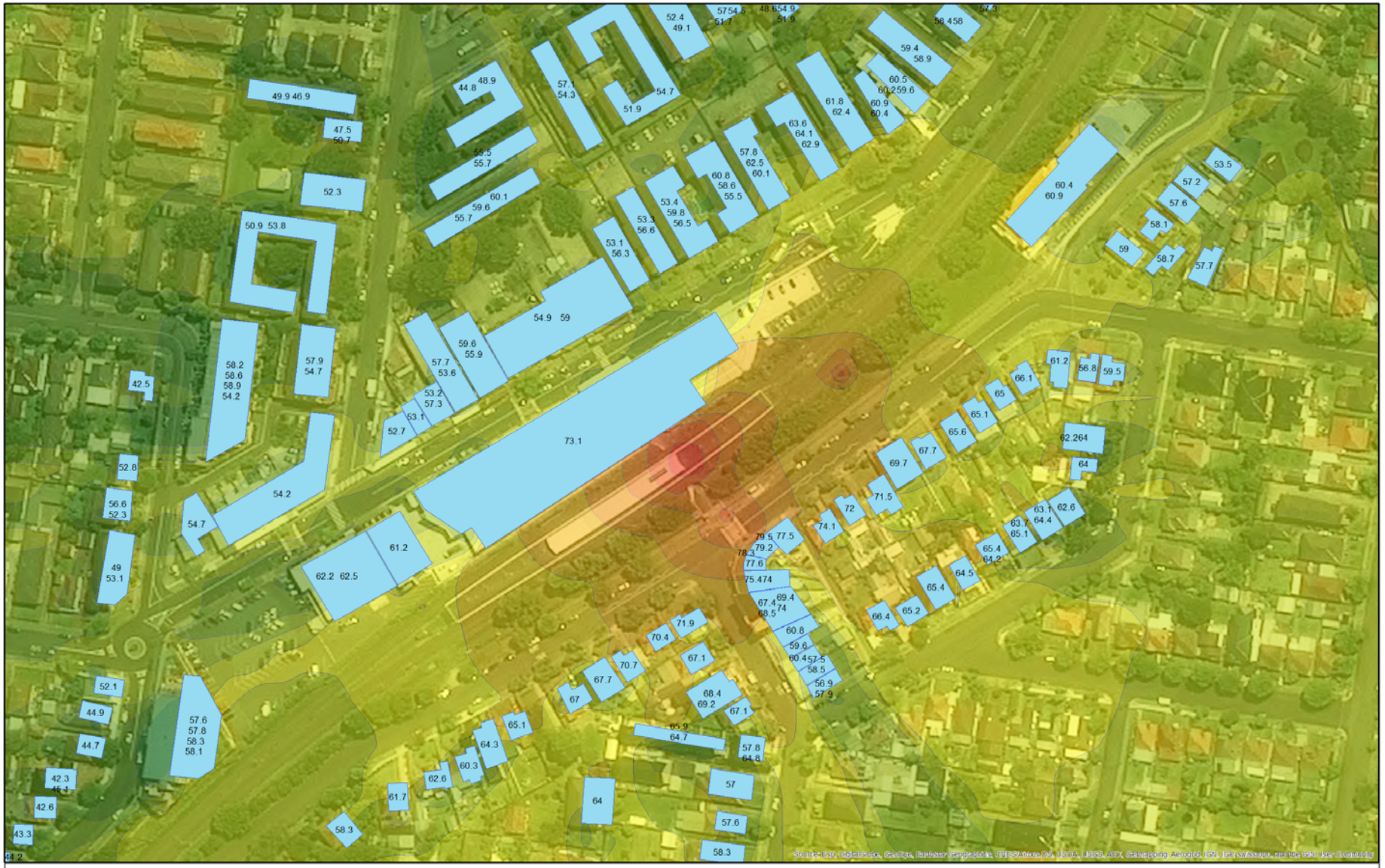
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95

Berala Station Upgrade
Construction Scenario 2a (no jackhammer)

January 2016

N

0 15 30 60 90 Meters



WSP | PARSONS BRINCKERHOFF

Legend

160112 Berala Scenario 5 Jack FNM 1

Free Field Level (dB)

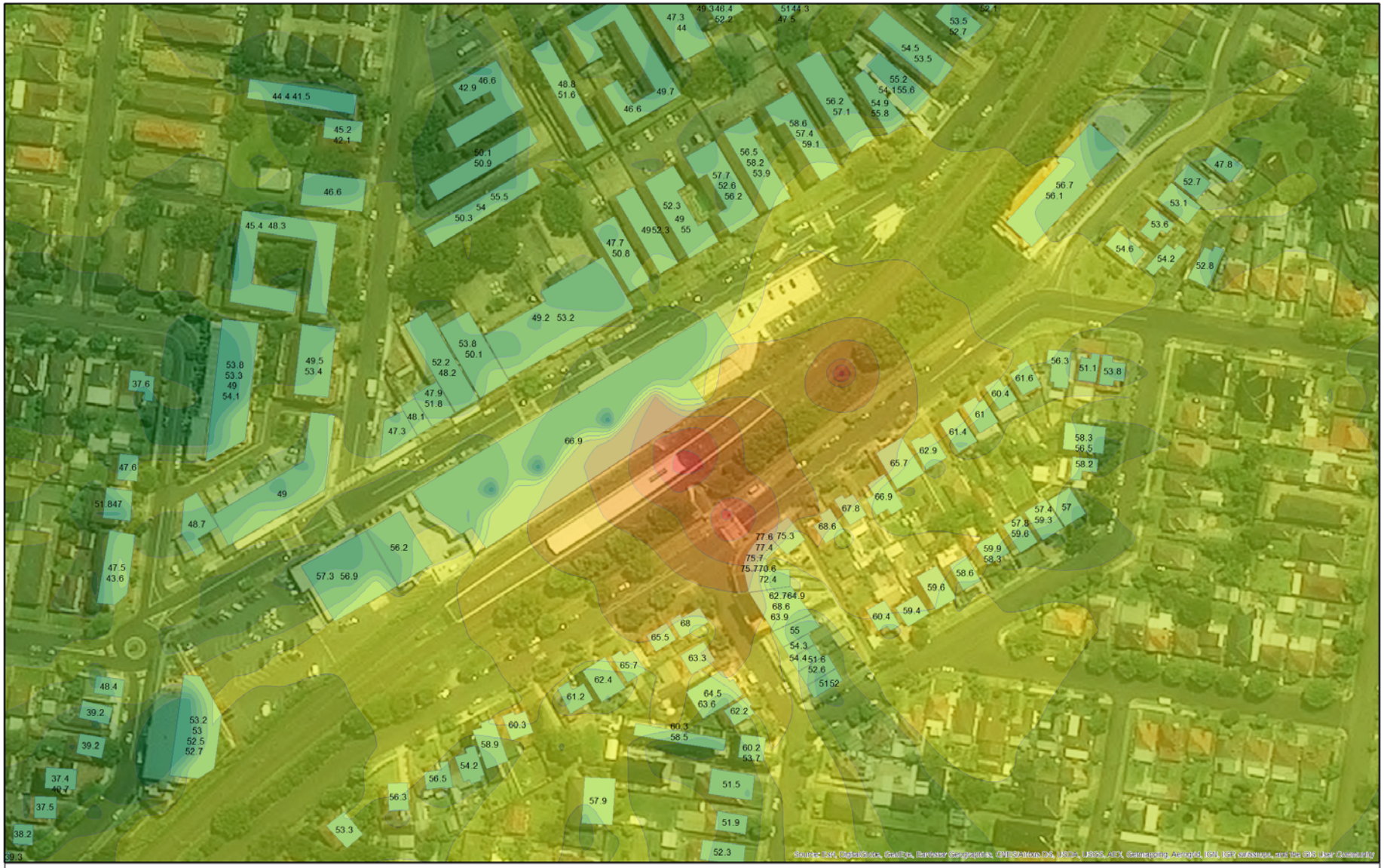
- 30-35
- 35-40
- 40-45
- 45-50
- 50-55
- 55-60
- 60-65
- 65-70
- 70-75
- 75-80
- 80-85
- 85-90
- 90-95

Berala Station Upgrade
Construction Scenario 2b (jackhammer)

January 2016

N

0 15 30 60 90 Meters



WSP | PARSONS BRINCKERHOFF

Legend

Free Field Level (dB)

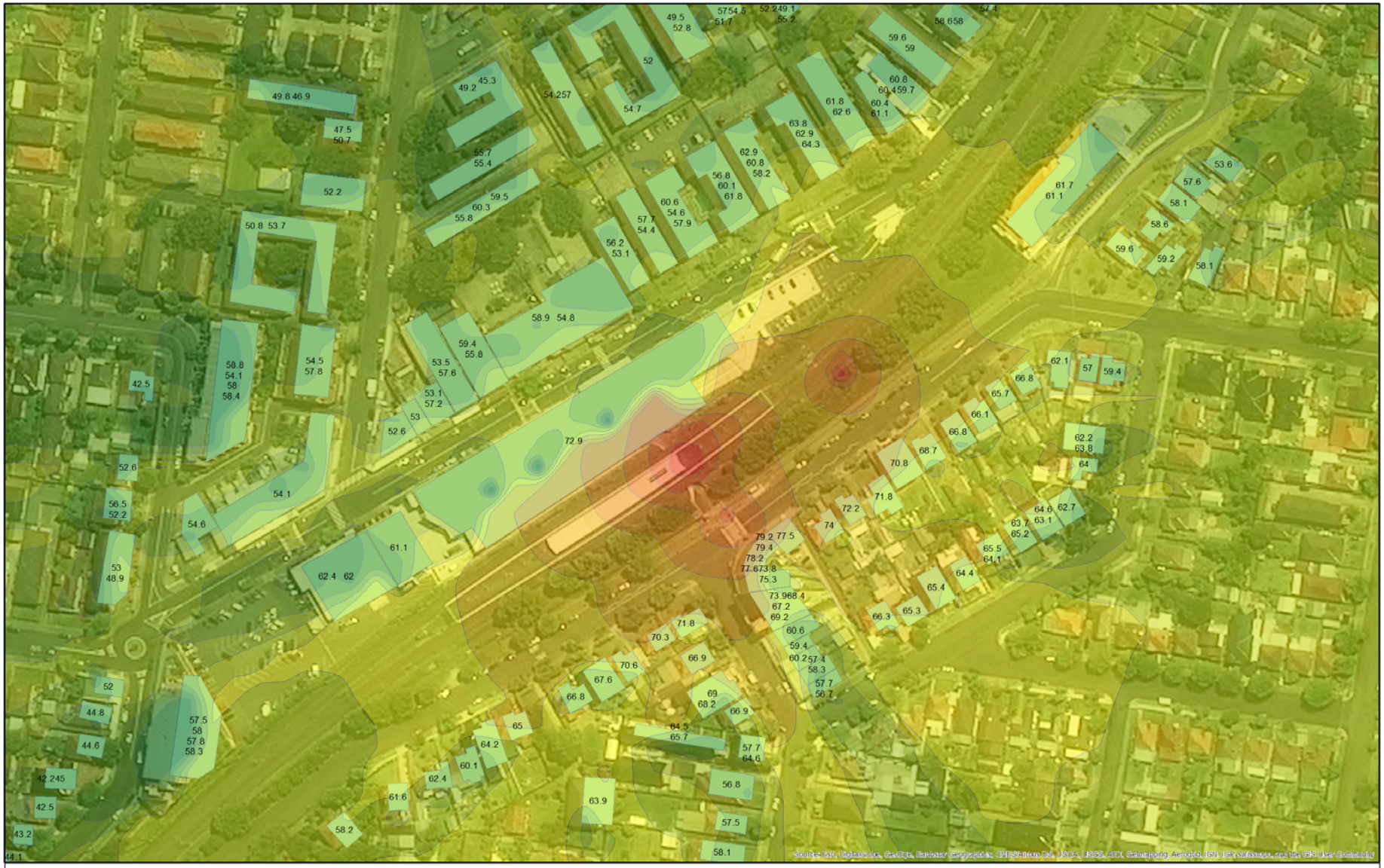
- 30-35
- 35-40
- 40-45
- 45-50
- 50-55
- 55-60
- 60-65
- 65-70
- 70-75
- 75-80
- 80-85
- 85-90
- 160112 Berala Scenario 5 No Jack FNM 1

Berala Station Upgrade
Construction Scenario 2b (no jackhammer)

January 2016

N

0 15 30 60 90 Meters



WSP | PARSONS BRINCKERHOFF

Legend

Free Field Level (dB)

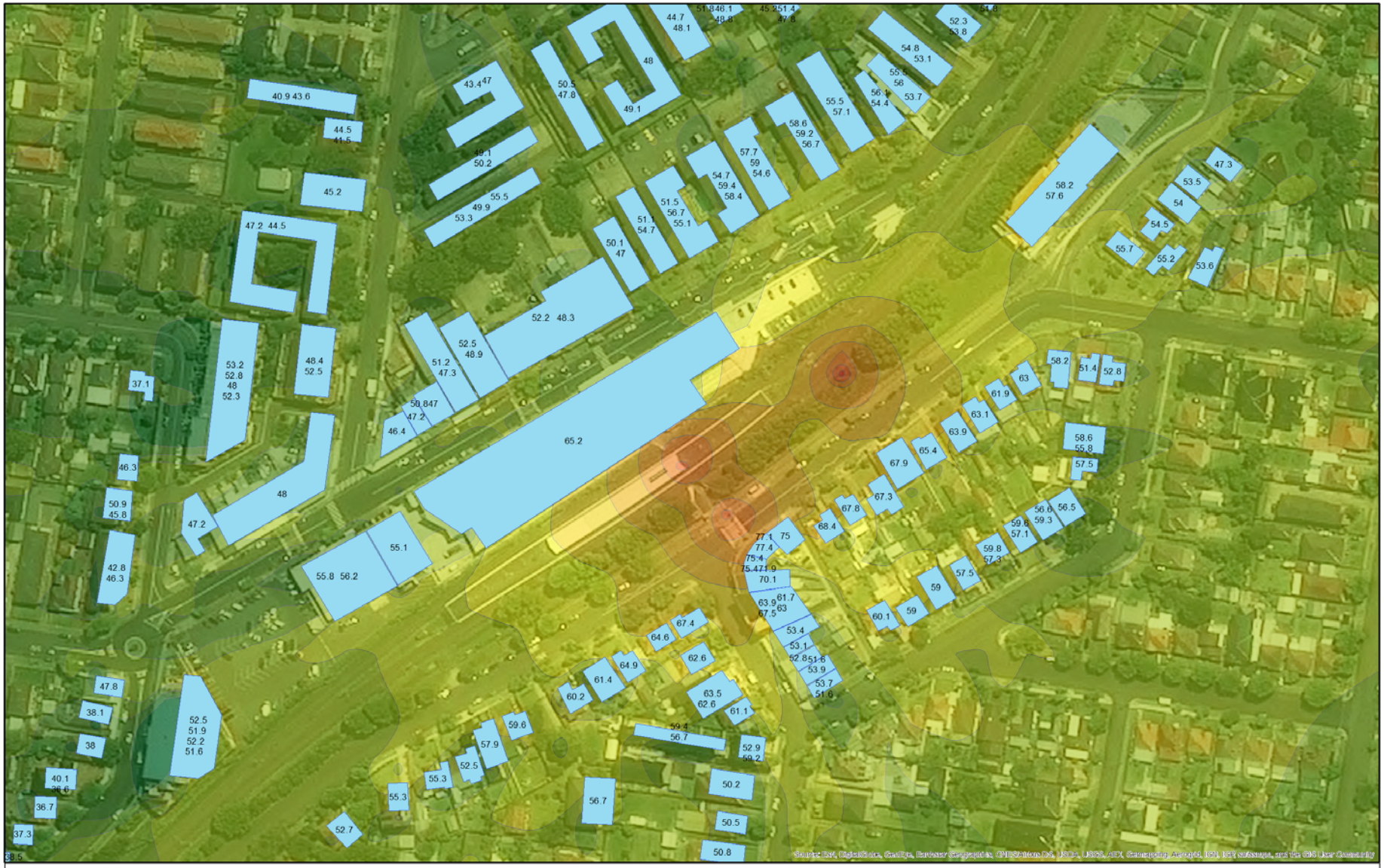
- 30-35
- 35-40
- 40-45
- 45-50
- 50-55
- 55-60
- 60-65
- 65-70
- 70-75
- 75-80
- 80-85
- 85-90
- 90-95
- 160112 Berala Scenario 6 Jack FNM 1

Berala Station Upgrade
Construction Scenario 2c (jackhammer)

January 2016

N

0 15 30 60 90 Meters



WSP | PARSONS BRINCKERHOFF

Legend

160112 Berala Scenario 6 No Jack FNM 1

Free Field Level (dB)

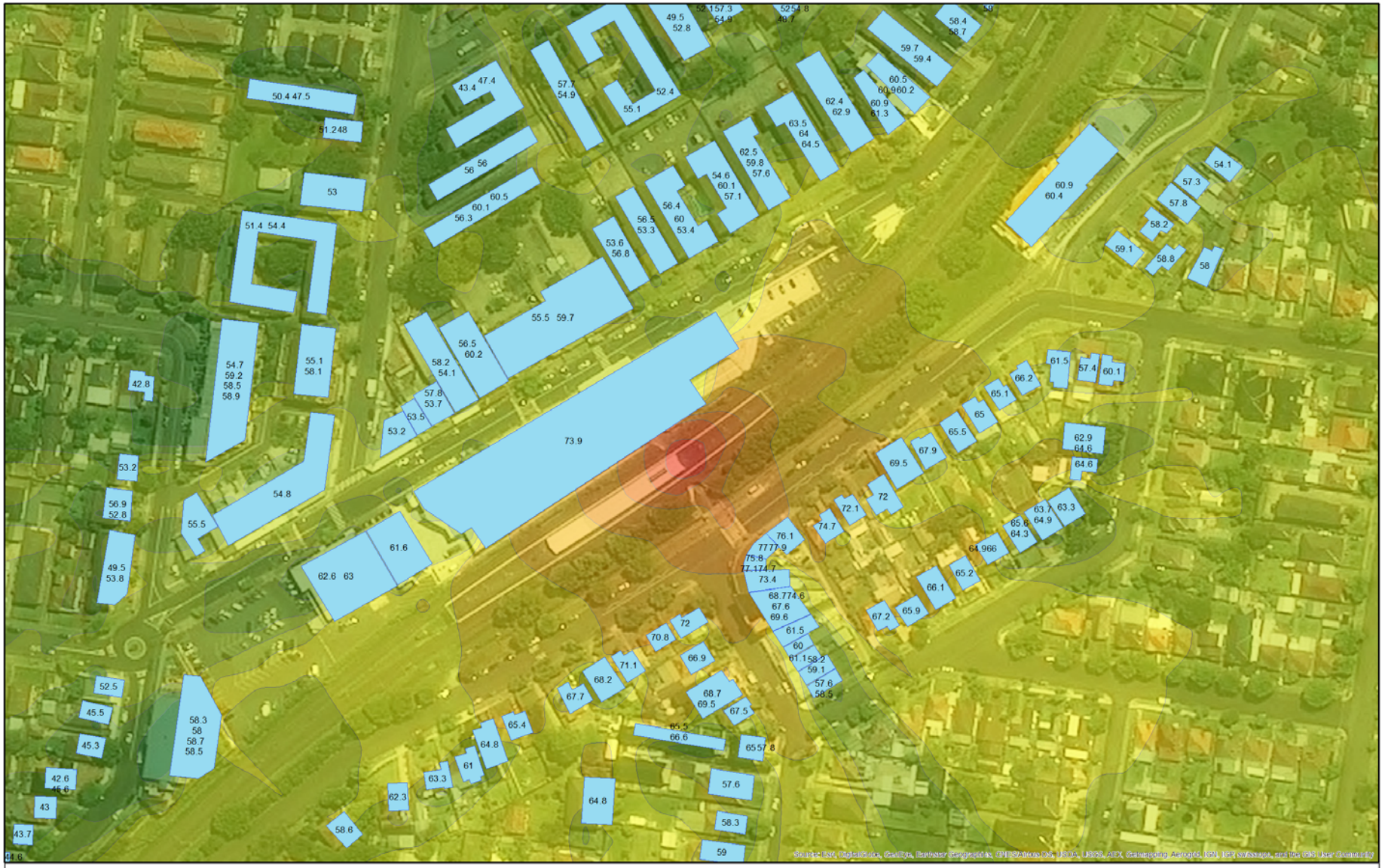
- 30-35
- 35-40
- 40-45
- 45-50
- 50-55
- 55-60
- 60-65
- 65-70
- 70-75
- 75-80
- 80-85
- 85-90
- 90-95

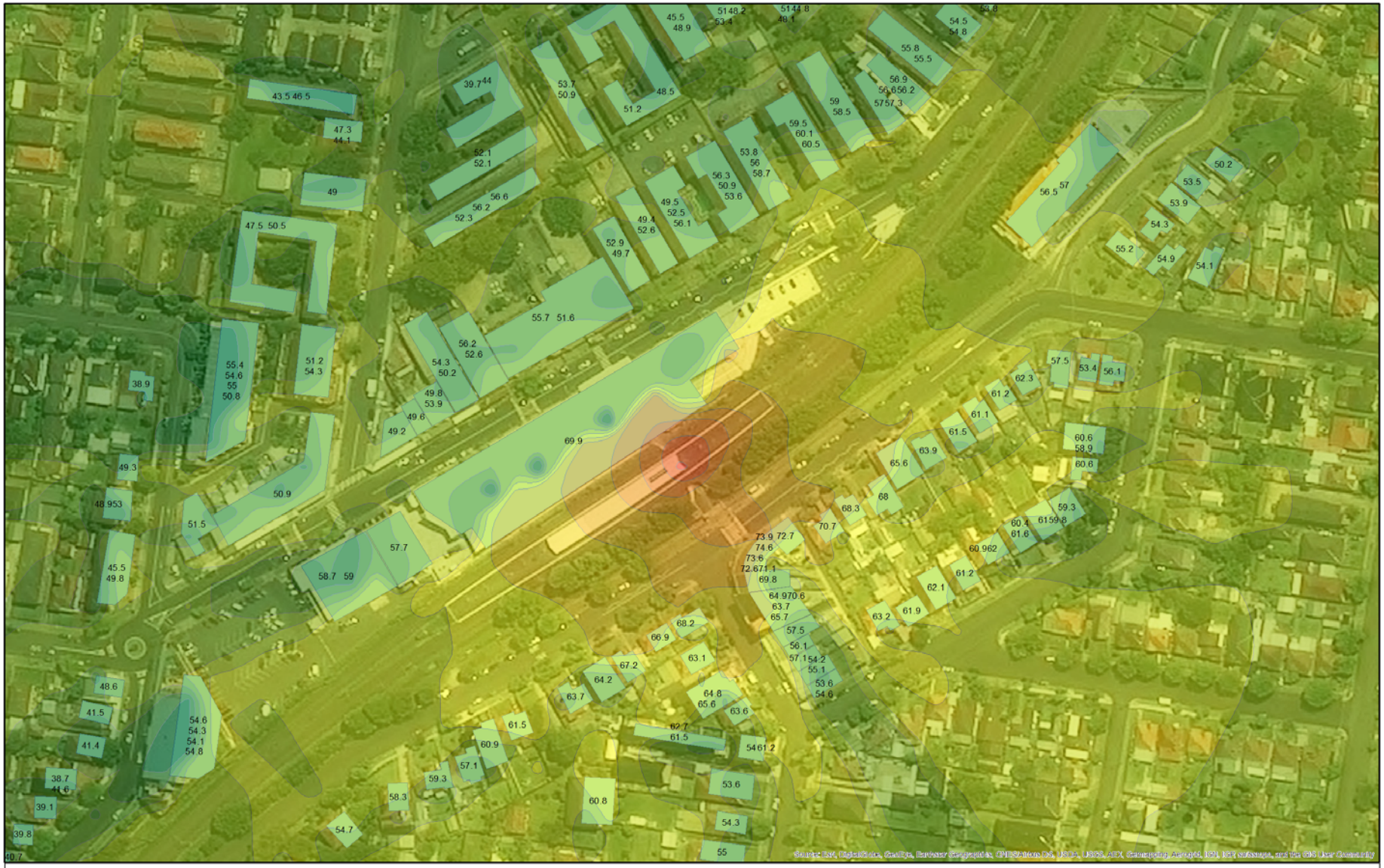
Berala Station Upgrade
Construction Scenario 2c (no jackhammer)

January 2016

N

0 15 30 60 90 Meters


50.4 47.5
51.248
53
51.4 54.4
42.8
53.2
56.9 52.8
55.5
49.5 53.8
52.5
45.5
45.3
42.6
43
43.7
58.3 58 58.7 58.5
54.7 59.2 58.5 58.9
55.1 58.1
54.8
61.6
62.6 63
58.6
62.3
63.3
61
64.8
65.4
43.4 47.4
56 56
56.3 60.1 60.5
57.7 54.9
55.1
52.4
49.5 52.8
52.1 57.3 54.9
52.5 4.8 49.7
55.5 59.7
56.5 60.2
58.2 54.1
57.8 53.7
53.5
53.2
73.9
53.6 56.8
56.5 53.3
56.4 60 53.4
54.6 60.1 57.1
62.5 59.8 57.6
63.5 64 64.5
62.4 62.9
59.7 59.4
58.4 58.7
60.5 60.9 60.2
60.9 61.3
60.9 60.4
54.1
57.3
57.8
58.2
59.1
58.8
58
61.5
57.4
60.1
66.2
65.1
65
65.5
67.9
69.5
62.9 64.6
64.6
72
72.1
74.7
63.7 64.9
63.3
65.6 64.3
64.966
65.2
66.1
65.9
67.2
76.1 77.7 79 75.8 77.1 74.7
73.4
68.7 74.6 67.6 69.6
61.5
60
61.1 58.2 59.1
57.6 58.5
72
70.8
66.9
71.1
68.2
67.7
68.7 69.5
67.5
65.2 66.6
65 57.8
57.6
64.8
58.3
59
Legend
160112 Berala Scenario 7 Jack FNM 1
Free Field Level (dB)
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
Berala Station Upgrade
Construction Scenario 2d (jackhammer)
January 2016
N
0 15 30 60 90
Meters



WSP | PARSONS BRINCKERHOFF

Legend

Free Field Level (dB)

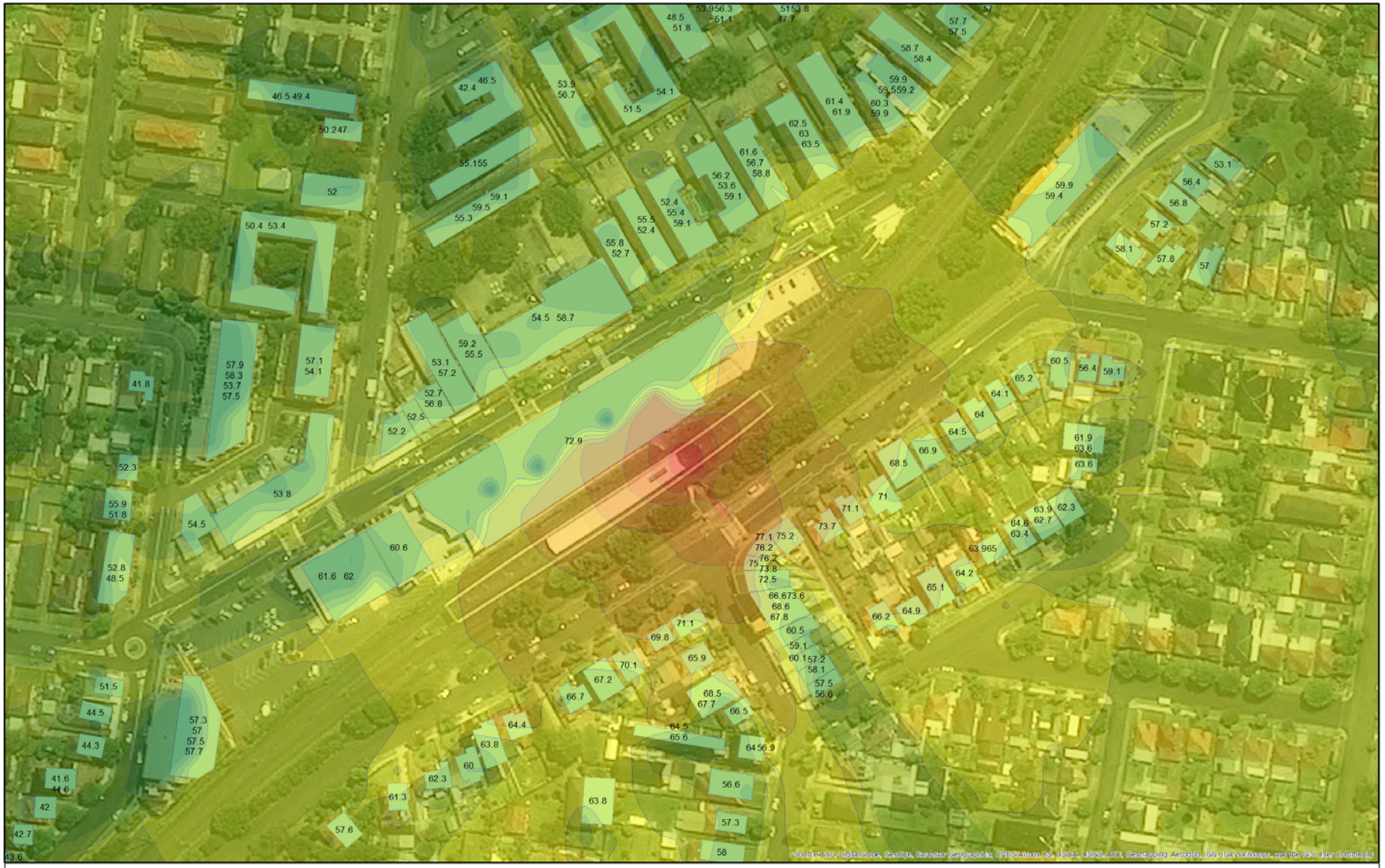
30-35	45-50	65-70	85-90
35-40	50-55	70-75	90-95
40-45	55-60	75-80	160112 Berala Scenario 7 No Jack FNM 1
	60-65	80-85	

Berala Station Upgrade
Construction Scenario 2d (no jackhammer)

January 2016

N

0 15 30 60 90 Meters



WSP | PARSONS BRINCKERHOFF

Legend

Free Field Level (dB)

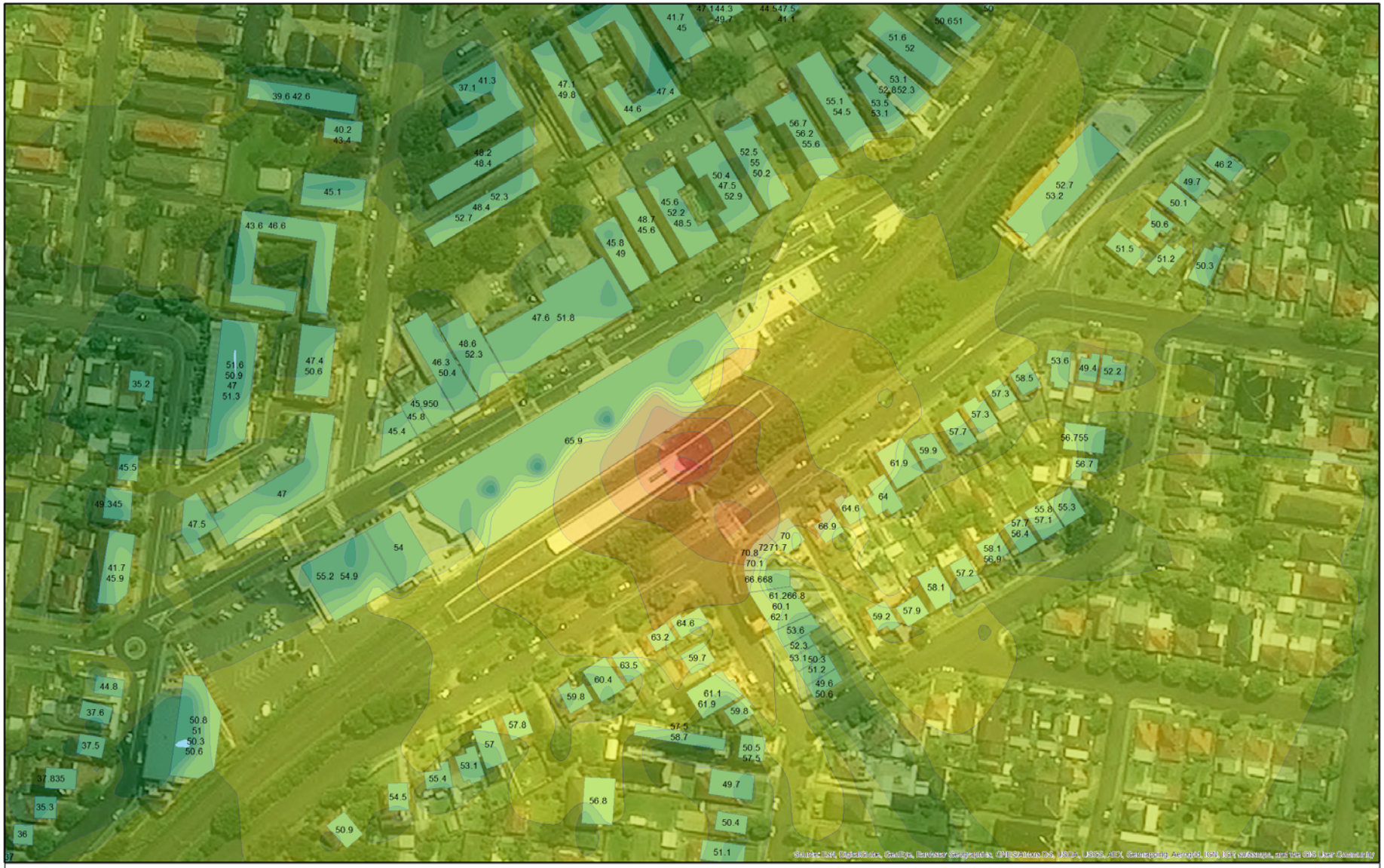
- 30-35
- 35-40
- 40-45
- 45-50
- 50-55
- 55-60
- 60-65
- 65-70
- 70-75
- 75-80
- 80-85
- 85-90
- 90-95
- 160112 Berala Scenario 8 Jack FNM 1

Berala Station Upgrade
Construction Scenario 3a (jackhammer)

January 2016

N

0 15 30 60 90 Meters



WSP | PARSONS BRINCKERHOFF

Legend

Free Field Level (dB)

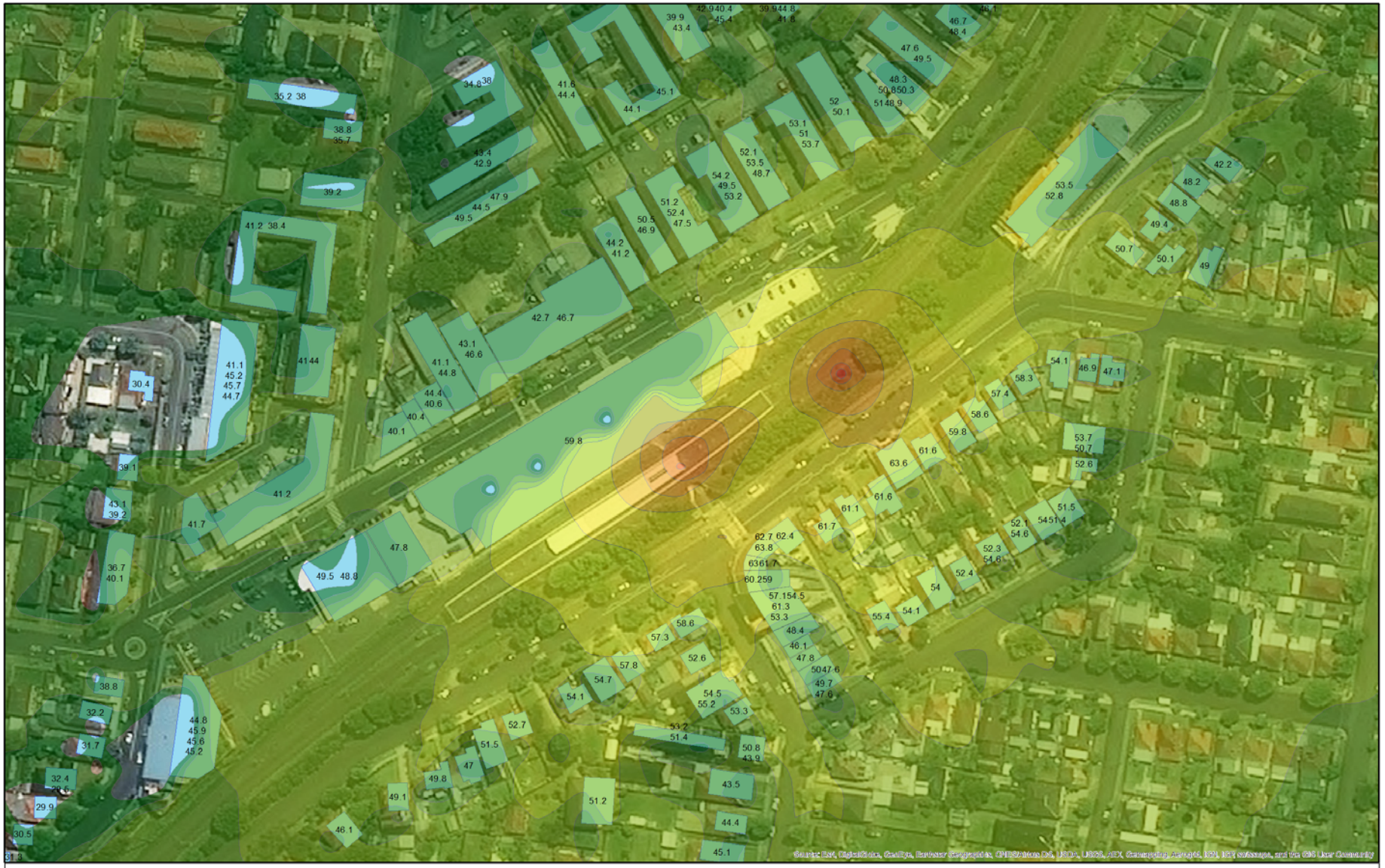
- 30-35
- 35-40
- 40-45
- 45-50
- 50-55
- 55-60
- 60-65
- 65-70
- 70-75
- 75-80
- 80-85
- 85-90
- 160112 Berala Scenario 8 No Jack FNM 1

Berala Station Upgrade
Construction Scenario 3a (no jackhammer)

January 2016

N

0 15 30 60 90 Meters



WSP | PARSONS BRINCKERHOFF

Legend

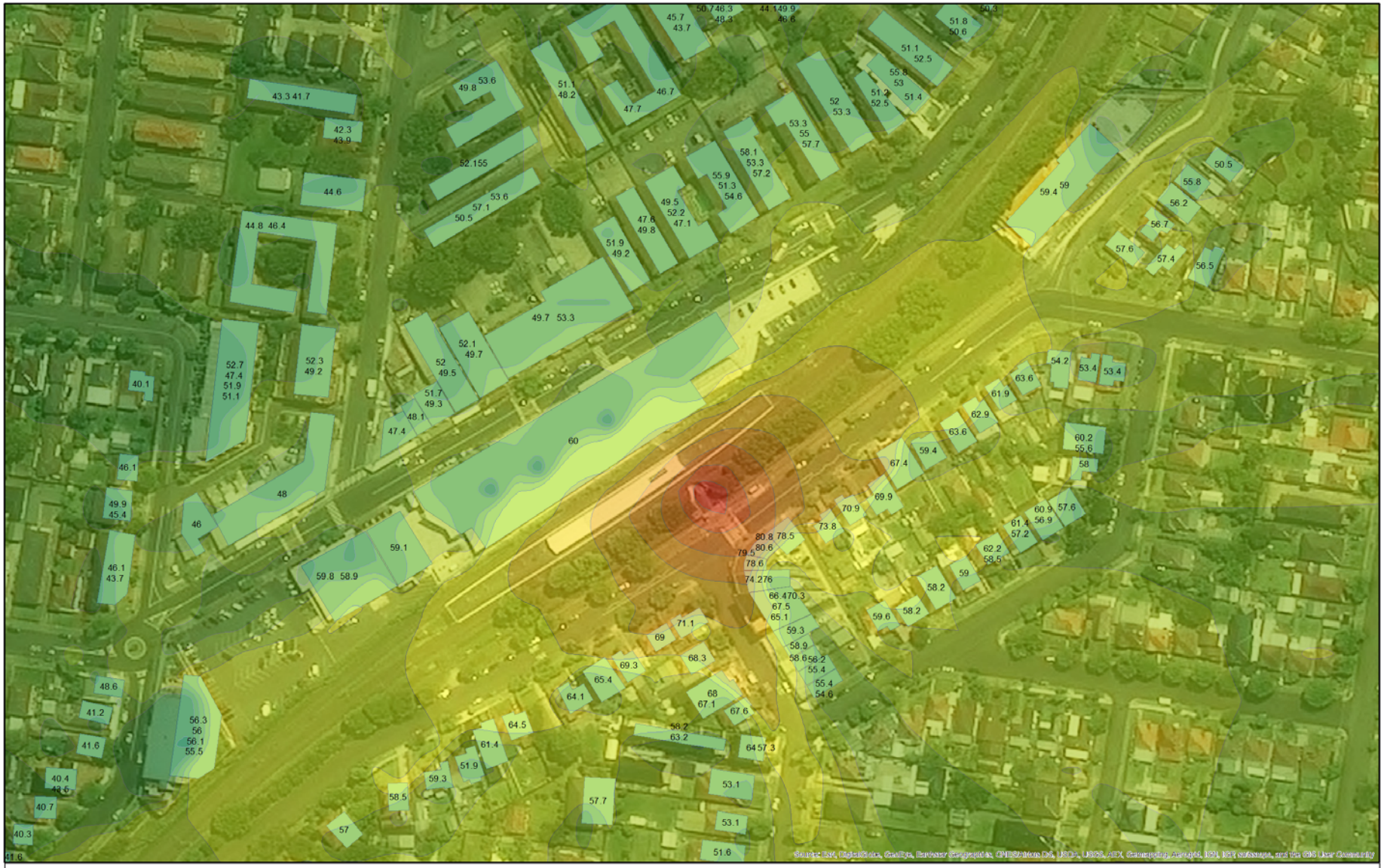
Free Field Level (dB)	45-50	65-70	85-90
30-35	50-55	70-75	160112 Berala Scenario 9 FNM 1
35-40	55-60	75-80	
40-45	60-65	80-85	

Berala Station Upgrade
Construction Scenario 3b

January 2016

N

0 15 30 60 90 Meters



WSP | PARSONS BRINCKERHOFF

Legend

Free Field Level (dB)

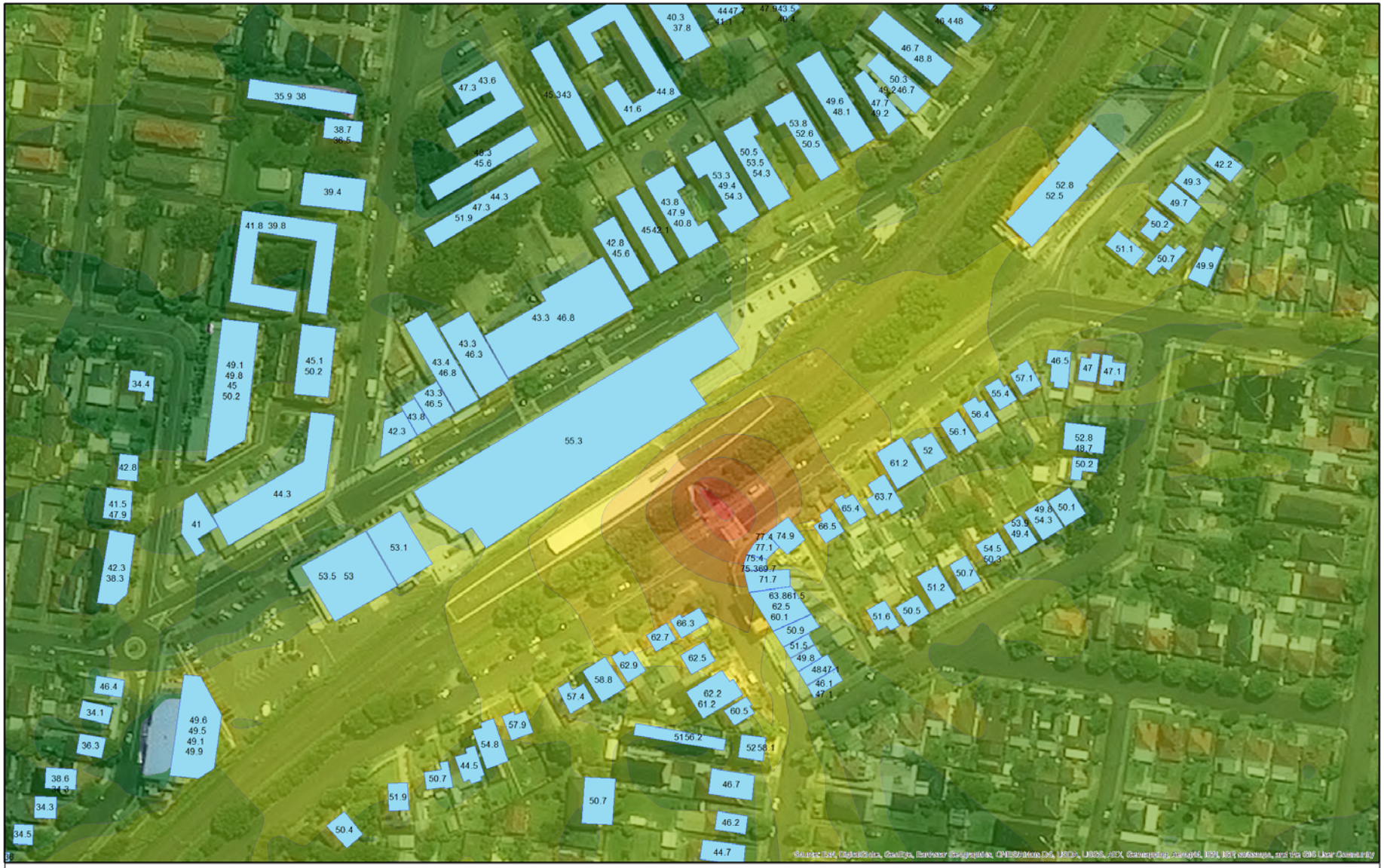
30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85
85-90
90-95
160112 Berala Scenario 10 Jack FNM 1

Berala Station Upgrade
Construction Scenario 4 (jackhammer)

January 2016

N

0 15 30 60 90 Meters



WSP | PARSONS BRINCKERHOFF

Legend

160112 Berala Scenario 10 No Jack FNM 1

Free Field Level (dB)

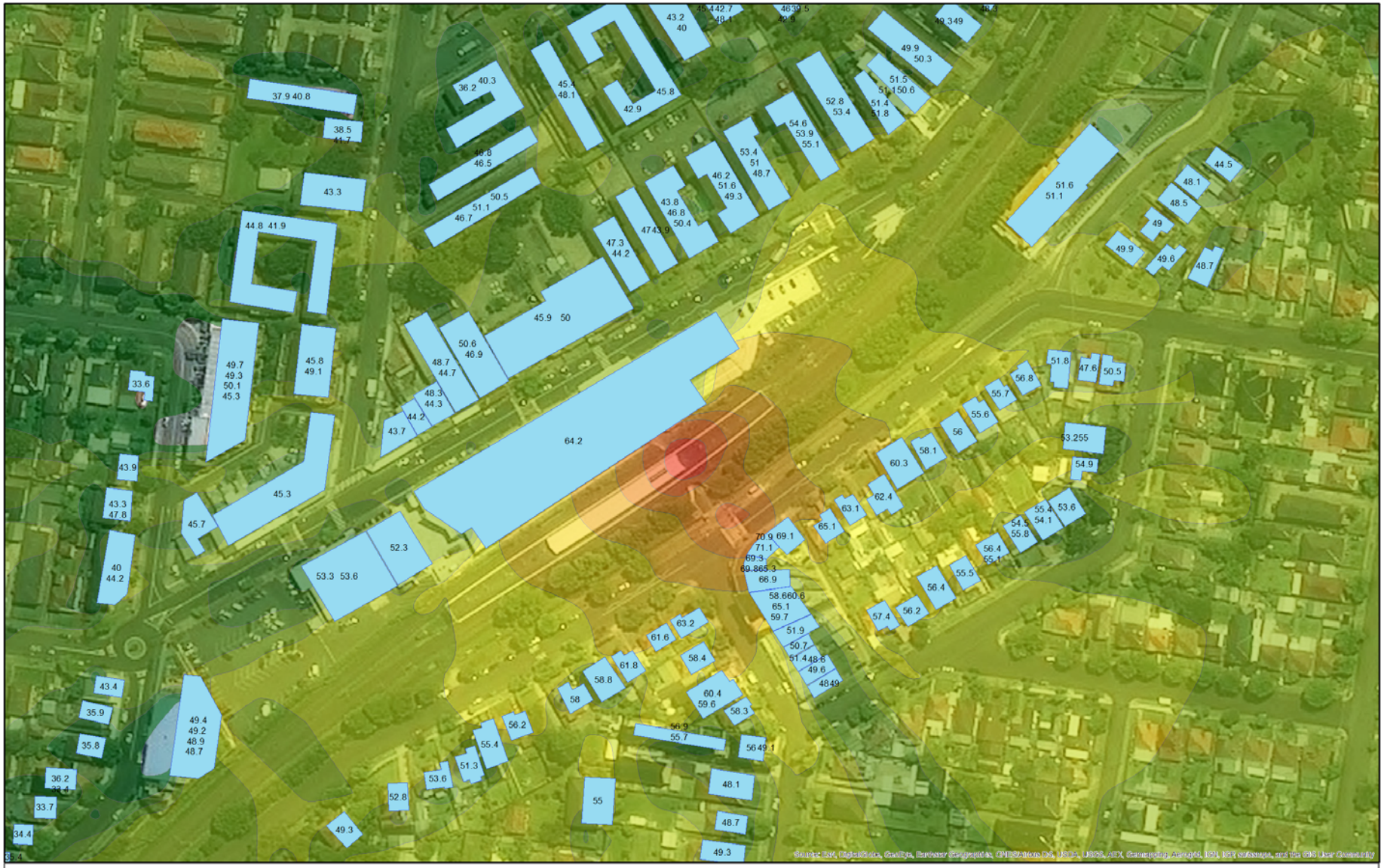
- 30-35
- 35-40
- 40-45
- 45-50
- 50-55
- 55-60
- 60-65
- 65-70
- 70-75
- 75-80
- 80-85
- 85-90

Berala Station Upgrade
Construction Scenario 4 (no jackhammer)

January 2016

N

0 15 30 60 90 Meters



WSP | PARSONS BRINCKERHOFF

Legend

160112 Berala Scenario 11 FNM 1

Free Field Level (dB)

30-35
35-40
40-45
45-50
50-55
55-60
60-65
65-70
70-75
75-80
80-85

Berala Station Upgrade
Construction Scenario 5

January 2016

N

0 15 30 60 90 Meters

Acoustics@WSPGroup.com

WSP | PARSONS BRINCKERHOFF