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APPENDIX X

Noise and Vibration Impact Assessment

Arup

Infrastructure New South Wales

Sydney Football Stadium Redevelopment

Stage 2 SSDA - Noise and Vibration Assessment

AC04

Issue | 31 May 2019

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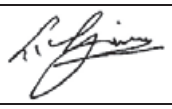
		Signature			
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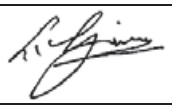
		Signature			
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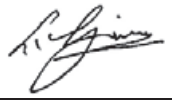
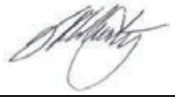
		Signature			
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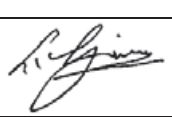
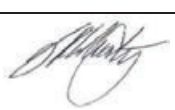
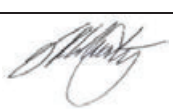
		Signature			
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Appendices

1 Introduction

This report supports a State Significant Development (SSD) Development Application (DA) for the redevelopment of the Sydney Football Stadium, which is submitted to the Minister for Planning pursuant to Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). The redevelopment is being conducted in stages comprising the following planning applications:

- **Stage 1** – Concept Proposal for the stadium envelope and supporting retail and functional uses as well as development consent for the carrying out of early works, including demolition of the existing facility and associated structures.
- **Stage 2** – detailed design, construction and operation of the stadium and supporting business, retail and functional uses.

Development consent was granted for the Concept Proposal and detailed approval to carry out early works and demolition (SSD 18_9249) by the Minister for Planning on 6 December 2018.

This report relates to the Stage 2 application and considers the detailed design, construction and operation of the new Sydney Football Stadium pursuant to the approved Concept Proposal.

Infrastructure NSW is the proponent of the Stage 2 DA.

A list of referenced documents is provided in Section 8.

A glossary of the acoustic terminology used in this report has been included in Appendix A.

1.1 Background

The Sydney Football Stadium (SFS) is a significant component of the sports facilities that comprise the Sydney Cricket and Sports Ground. Completed in 1988, the SFS has hosted numerous sporting events in its 30 years of operation for a number of sporting codes including football (soccer), rugby league and rugby union as well as occasional music concerts.

The NSW Stadia Strategy 2012 provides a vision for the future of stadia within NSW, prioritising investment to achieve the optimal mix of venues to meet community needs and to ensure a vibrant sports and event environment in NSW. A key action of the strategy included development of master plans for Tier 1 stadia and their precincts covering transport, integrated ticketing, spectator experience, facilities for players, media, corporate and restaurant and entertainment provision. SFS is one of three Tier 1 stadia within NSW, the others being Stadium Australia (Olympic Park) and the Sydney Cricket Ground.

To qualify for Tier 1 status, a stadium is required to include:

- Seating capacity greater than 40,000;
- Regularly host international sporting events;

- Offer extensive corporate facilities, including suites, open-air corporate boxes and other function/dining facilities; and
- Be the home ground for sporting teams playing in national competitions.

On 6 December 2018, development consent was granted for the Concept Proposal and Early Works/ Demolition stage of the SFS redevelopment (SSD 18_9249). This consent permitted the completion of demolition works on the site and established the planning and development framework through which to assess this subsequent Stage 2 application. Specifically, State Significant Development Consent SSD 18_9249 encompassed:

1. A Concept Proposal for:
    - A maximum building envelope for the stadium with capacity for 45,000 seats (55,000 patrons in concert mode) and 1,500 staff.
    - Urban Design Guidelines and a Design Excellence Strategy to guide the detailed design of the stadium at Stage 2.
    - General functional parameters for the design and operation of the new stadium, including:
        - Range of general admission seating, members areas, premium box/terrace, function/lounge and corporate suite options;
        - Administration offices;
        - New roof with 100% drip-line coverage of all permanent seating;
        - Flood lighting, stadium video screens and other ancillary fittings;
        - Food and beverage offerings;
        - Facilities for team, media, administration and amenity such as changing rooms, media rooms and stadium; and
        - Provision for ancillary uses within the stadium and surrounds.
    - Principles and strategies for transport and access arrangements.
    - Indicative staging of the development.
2. Detailed consent for the following works:
    - The demolition of the existing SFS and ancillary structures, including the existing Sheridan, Roosters, Waratahs and Cricket NSW buildings down to existing slab level.
    - Site and construction management, including use of the existing MP1 car park for construction staging, management and waste processing, and provisions for temporary pedestrian and vehicular access management.
    - The protection and retention of Tree 125 (Moreton Bay Fig adjacent to Moore Park Road) and Tree 231-238 cluster (Hills Weeping Fig and others near Paddington Lane) and all existing street trees located outside of the site boundary, with the removal of all other vegetation within the proposed future building footprint.
    - Works to make the site suitable for the construction of the new stadium (subject to this separate Stage 2 application).

1.2 Site description

The site is located at 40-44 Driver Avenue, Moore Park within the Sydney Cricket Ground Precinct. It is bound by Moore Park Road to the north, Paddington Lane to the east, the existing SCG stadium to the south and Driver Avenue to the west. The site is located within the City of Sydney local government area.

The site is legally described as Part Lots 1528 and 1530 in Deposited Plan 752011 and Lot 1 in Deposited Plan 205794. The site is Crown Land, with the SCSGT designated as the sole trustee under the *Sydney Cricket and Sports Ground Act 1978*. The site is wholly contained within designated land controlled by the Sydney SCSGT under Schedule 2A of the *Sydney Cricket and Sports Ground Act 1978*.

In a broader context, the site is largely surrounded by Centennial and Moore Parks, the Fox Studios and Entertainment Quarter precincts and the residential suburb of Paddington. Located approximately 3 km from the Sydney CBD and approximately 2 km from Central Station, the site is connected to Sydney's transport network through existing bus routes and will benefit from a dedicated stop on the soon to be completed Sydney CBD and South East Light Rail.

The locational context of the Site is shown in Figure 1, whilst the site boundaries and existing site features are shown in

Figure 2.

Figure 1: Regional site context

Figure 2: Site area and local context

1.3 Overview of proposed development

The application represents the next phase in the SFS redevelopment. It seeks consent for the detailed design, construction and operation of the new stadium as 'Stage 2' of the redevelopment, which includes:

- Construction of a new stadium with up to 45,000 seats (55,000 capacity in concert-mode), including playing pitch, grandstands, sports and stadium administration areas, food and drink kiosks, corporate facilities and all other aspects of a modern stadium;
- Operation and use of the stadium and surrounding site area for a range of sporting and entertainment events;
- Vehicular and pedestrian access and circulation arrangements, including excavation to deliver a partial basement level for storage, internal loading and servicing at the playing pitch level;
- Reinstatement of the MP1 car park following the completion of construction, including enhanced vehicle rejection facilities and direct vehicular connection to the new stadium basement level;
- Public domain improvements within the site boundary, including hard and soft landscaping, to deliver a range of publicly accessible, event and operational areas;
- Provision of new pedestrian and cycling facilities within the site;
- Signage, including building identification signage, business identification signage and a wayfinding signage strategy; and
- Extension and augmentation of physical infrastructure/ utilities for the development within the site.

The proposed development is consistent with the approved Concept Proposal pursuant to State Significant Development Consent SSD 9249.

1.4 Acoustic assessment requirements

This report addresses the acoustic assessment requirements as outlined in:

- State Significant Development Consent SSD 9249 - Schedule 2 Part B 'future assessment requirements' (see Table 1)

State Significant Development Consent SSD 9249 – Appendix 2, Stage 1 Mitigation Measures (see Table 2)

- State Significant Development SSD 9835 Secretary's Environmental Assessment Requirements (SEARs) (see Table 3).

Table 1: SSD 9249 – Schedule 2 Part B future assessment requirements

Condition	Acoustic aspect	Report section
PART C CONDITIONS TO BE SATISFIED IN FUTURE DEVELOPMENT APPLICATIONS		
Operation of the Stadium		

Condition	Acoustic aspect	Report section
C9. The future development application must estimate the maximum number of events. The development application must identify and assess all impacts of additional number of events and concerts in excess of 52 events per year and six concerts (with an average of four per year over any rolling five-year period between the Sydney Football Stadium and the Sydney Cricket Ground) including (but not limited to): *a) social and economic impacts on the surrounding residents and the wider region;* *b) impacts on the built environment of the locality including (but not limited to) traffic and noise;* *c) impacts on the natural environment of the locality including (but not limited to) bio-diversity; and* *d) impacts on the environmental amenity of the surrounding residents and occupiers / users of other existing land uses.*	Event Noise	Section 5.2
C10. The future development application must include details of all operational time restrictions including (but not limited to) sporting events, concerts, sound-testing, other outdoor events with sound amplification, non-event day operations and timings for waste collection vehicle, goods delivery vehicles and other heavy vehicles utilising Paddington Lane. The development application must identify and assess all impacts on the environmental amenity of the surrounding residents and occupiers / users of other existing land uses in the instances where alterations are proposed to the time restrictions identified in the Sydney Football Stadium Redevelopment Stage 1 SSDA - Noise and Vibration Impact Assessment Report prepared by ARUP dated 15 June 2018 as follows:	Operational and Event Noise	Section 4 Section 4.3.5
a) sporting events: 8am – 11pm; *b) concerts: 10am – 11pm (maximum length 5 hours);* *c) rehearsals on the day of the event: 10am – 7pm;* *d) sound tests on the day of the event: 10am – 7pm (maximum 60 minutes of continuous testing);* *e) other outdoor events with sound amplification: 10am – 8pm (days preceding working days);* *f) other outdoor events with sound amplification: 10am – 10:30pm (days not preceding working days); and*	Operational Noise – Operational Noise – the Stage 1 NVIA does not specify a requirement for rehearsals or sound tests to be conducted on the day of the event, therefore this requirement is self-contradictory. No requirement currently exists or is proposed for rehearsals or sound tests to be on the day of the event, with correct proposed time limits as indicated in Section 5.3.2.3	Section 5.3.2.3

Condition	Acoustic aspect	Report section
g) waste collection vehicles, goods delivery vehicles and other heavy vehicles utilising Paddington Lane: 7am – 10pm.	Operational Noise	Section 4.3.4
The assessment must also include a comparative analysis against the total number of, and time restrictions for sporting events and concerts including rehearsals and sound tests as prescribed in the statutory Notice of Preventive Action 1003904 (as at the date of the development application and as varied from time to time).	Event Noise	Table 39
Noise and Vibration		
C17. The proposed future stadium on the site must be designed, and mitigation and management measures proposed, to minimise noise emissions from events and 'outdoor entertainment activities'. Events and activities in relation to the future stadium should not exceed the noise level limits prescribed in the statutory Notice of Preventive Action 1003904 (as at the date of the development application and as varied from time to time).	Event Noise	Section 4.3.5
C18. The future development application can include an alternate quantitative noise impact assessment and noise management framework, not included in Schedule 2, C17. The noise impact assessment must be supported by evidence of consultation with EPA and the Department, as required by Schedule 2, condition B11.	Event noise	Section 5.3.2
C19. The alternate quantitative noise impact assessment must include a representative 'worst case' impact of amplified music and announcements to surrounding sensitive receivers from 'outdoor entertainment activities' undertaken at the stadium. The impact of noise from amplified music and announcements to surrounding sensitive receivers from 'outdoor entertainment activities' undertaken at the stadium must be assessed at intermediate locations in both Leq(5 minute) dB(A) and Leq(5 minute) dB(lin) in the 63 hertz 1/1 octave band metrics. The levels at the intermediate compliance points must be calculated so that they represent the extrapolated equivalence of the receiver-based levels prescribed in Notice of Preventive Action 1003904 (as at the date of the development application and as varied from time to time).	Event noise - locations and noise levels at intermediate compliance points are to be determined at a later stage of design.	Section 5.7

Condition	Acoustic aspect	Report section
C20. The future development application must include a Noise Management Plan (NMP) prepared in consultation with the EPA and the Department. The NMP shall describe, but not be limited to: *a) hours of operation, number and type of event;* *b) the events that will be deemed-to-comply and those for which an Event Acoustic Report is required;* *c) a definition of non-compliance and a breach of conditions;* *d) a chain of responsibility for management of noise in relation to the stadium activities;* *e) measures to minimise impacts of sound checks, rehearsals, 'bump-in' and 'bump-out' activities, goods delivery, post event clean-up activities, and waste collection services (including the noise impact of associated vehicular movements particularly any such movements occurring during the 'night period' or likely to activate reversing alarms, and stadium precinct grounds maintenance; and* *f) a procedure and guidance on the frequency, time of occurrence and duration of pyrotechnic displays, including a community notification strategy.*	Noise Management Plan	Appendix G
C21. The future development application must include a strategy (such as monitoring programmes) to validate the performance of and the predicted results in any adopted alternate compliance methodology, when the future stadium commences operation.	Noise Management Plan	Appendix G
C22. Each of the noise impacts assessments required by Schedule 2, conditions C17 to C21, may take into consideration of instances where identified sensitive receivers are not in use at the time the event occurs, have been mitigated for environmental noise impacts, have agreements to receive higher levels of noise, or have been designed for higher noise environments.	Noise Management Plan	Appendix G

Table 2: SSD 9249 – Appendix 2 Stage 1 Mitigation Measures

Ref.	Noise and Vibration	Report section
CP-NV1	A Noise and Vibration Assessment is to be prepared and submitted with the Stage 2 Development Application to assess the potential construction and operation noise and vibration impacts of the new stadium, having regard to the noise assessment framework and criteria outlined in the Noise and Vibration Assessment (Arup 2018) that accompanies this application	Throughout report
CP-NV2	The Stage 2 Development Application is to identify a framework and methodology for the ongoing monitoring of noise from the stadium.	Section 5.3.2.2
CP-NV3	The number of concerts at the stadium is not to exceed six (6) per calendar year.	Section 5.2
CP-WI2	The Noise and Vibration Assessment submitted with the Stage 2 Development Application is to include an assessment of the potential for the detailed stadium design to generate wind noise and any consequent impacts upon nearby sensitive noise receivers.	Section 4.3.5

Table 3: SSD 9835 SEARs

SEARs addressed	Acoustic aspect	Policy or guideline	Report section
Key Issue 20. Noise and Vibration			
Identify and provide a quantitative assessment of the main noise and vibration generating sources including details of the impacts on surrounding residences and other noise sensitive locations (including the adjoining UTS campus) during (but not limited to):	Construction and operational noise & vibration and event noise	NPI, ICNG, AVATG	Throughout report
• demolition of the existing slabs and footings, pavements and redundant in-ground services;	Construction noise & vibration	N/A – no demolition proposed	
• site preparation, piling, bulk earthworks, construction and construction-related activities and vehicle movements;	Construction noise & vibration	ICNG, AVATG	Section 3
• proposed on-site concrete crushing (if any)	Construction noise & vibration	N/A – no concrete crushing proposed	
• the likely noise impacts due to operation of the new stadium and associated facilities, particularly: o during events involving the use of sound amplification; o during pre and post event activities such as sound test, rehearsals, 'bump-in'/'bump-out', site clean-up, goods deliveries and waste collection including out-of-hours activities and vehicles accessing the basement;	Event noise	-	Section 4.3.5

SEARs addressed	Acoustic aspect	Policy or guideline	Report section
• the likely noise impacts of operation of the new stadium and associated facilities, in conjunction with existing facilities located on the Trust lands; and	Operational noise	NPI	Section 4
• identification of key noise mitigation and management measures that would inform the final design of the new stadium.	Event noise		Section 5.9
Outline the likely noise impacts during events involving pyrotechnic displays and include measures to manage any adverse acoustic impact on the surrounding noise sensitive locations during such events.	Event noise	-	Section 5.4.2
Outline measures to minimise and mitigate the potential noise impacts on surrounding occupiers of land including (but not limited to) acoustic details of the stadium structure, management of events / activities within and outside the stadium structure (within the open areas of the site outside the structure), restrictions to construction hours, appropriate location of the crusher, intra-day respite periods during noisy activities, noise barriers where needed and operational hours and restrictions.	Construction and operational noise & vibration and event noise	NPI, ICNG, AVATG	Section 3.7 Section 4.3 Section 5.9
Provide a clear / plain English explanation of the adopted noise levels under the proposed new noise management framework, referred to in the development consent for SSD 9249, and how they relate to the noise levels prescribed in Notice of Preventive Action 1003904 (as at the date of the development application and as varied from time to time).	Event noise	-	Section 5.3.2
Provide a justification as to why the proposed new noise management framework is the appropriate approach for the development.	Event noise	-	Section 5.3.2
Provide a draft Construction Noise and Vibration Management Plan that outlines measures to minimise and mitigate the potential noise impacts on surrounding occupiers of land.	Construction noise & vibration	Construction Noise and Vibration Management Sub-Plan	To be prepared by contractor

Key Issue 20 of the SEARs also references the following policies relevant to acoustics:

- NSW *Noise Policy for Industry*, EPA 2017 (NPI) [1];
- *Interim Construction Noise Guideline*, DECC 2009 (ICNG) [2];
- *Assessing Vibration: A Technical Guideline*, DEC 2006 (AVATG) [3]; and
- *Development Near Rail Corridors and Busy Roads – Interim Guideline, Department of Planning 2008 (DNRCBR)* [4].

It is noted that DNRCBR [4] is not relevant to the subject development, as it relates to the assessment of noise from rail and road traffic on residential uses, places of worship, hospitals, and educational establishments or childcare centres.

2 Existing acoustic environment

Traffic noise is the dominant acoustic feature of the area. The site is located adjacent to Moore Park Road to the north, with Anzac Parade located to the west beyond Moore Park East, and the Eastern Distributor located further west beyond Moore Park West.

The main noise sources in the local environment are:

- Road traffic along Moore Park Road and Anzac Parade
- CBD 'urban hum'
- Aircraft noise
- General activity noise from users of the existing facilities, and
- Infrequent event noise from Allianz Stadium and the SCG.

The above sources generally vary in level over the day.

Events have been a feature of the area for over 150 years, with the current Allianz Stadium constructed in 1988, which was built upon the former Sydney Sports Ground which opened in 1911.

Sporting events hosted at the site over the past 150 years have including athletics, rugby league, rugby union, soccer, motorcycle and car speedway racing.

2.1 Surrounding land-use

Maps showing the location of the site and the surroundings are included in Section 1.2 above.

Residential zones are located to the north and north-east in Paddington, east and south-east in Centennial Park, as well as west along South Dowling Street in Surry Hills and Redfern. Non-residential premises also surround the site, with scattered child cares, places of worship, educational facilities and Paddington Town Hall located in Paddington and Centennial Park, high schools located across Anzac Parade and various recreation areas nearby.

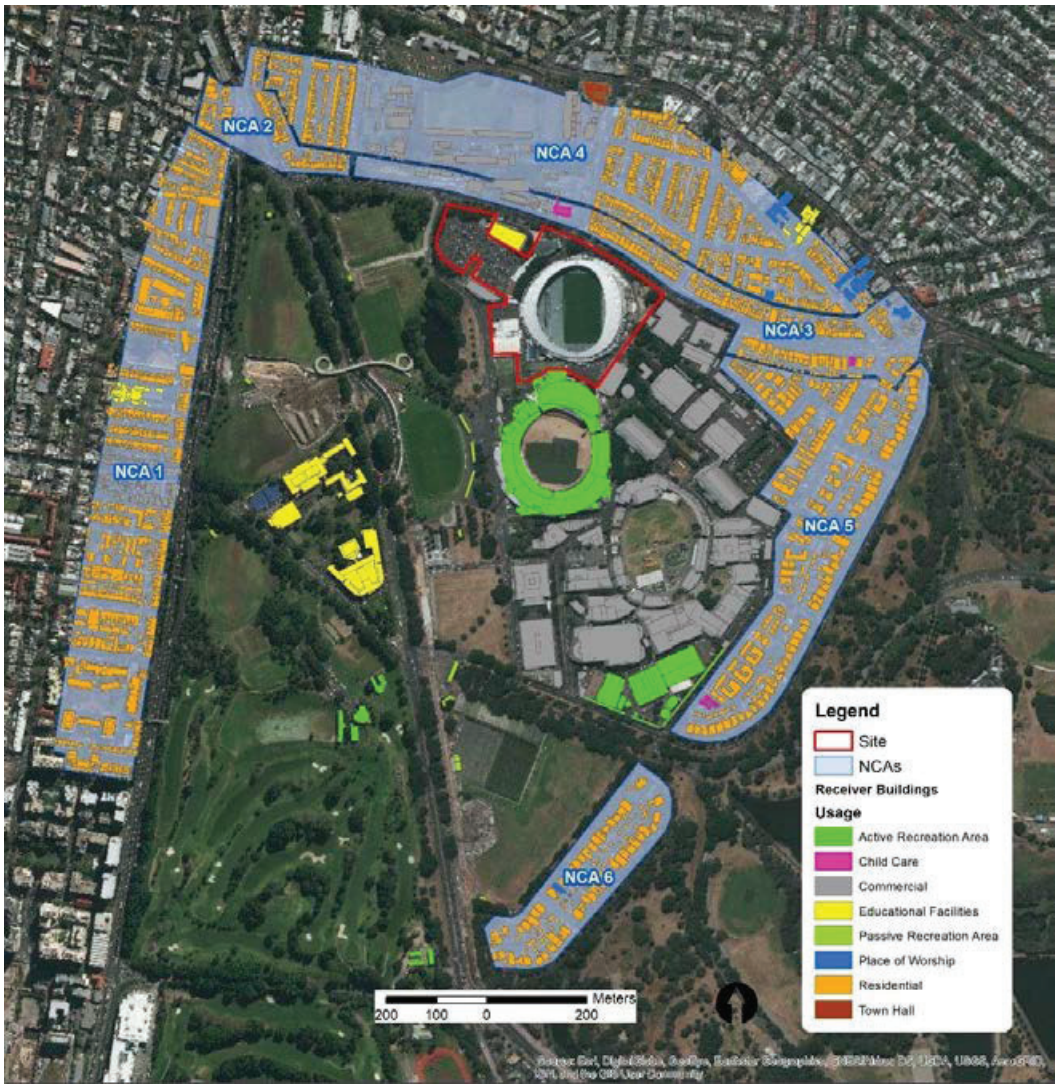

Figure 3: Noise sensitive receiver locations and NCAs

Residential receivers located within similar environments and with comparable relationship to surrounding noise sources have been grouped into Noise Catchment Areas (NCAs), also shown in Figure 3 and described in Table 4.

Table 4: NCAs and description

NCA	Description	NSW NPI area classification
NCA 1	Surry Hills & Redfern along South Dowling Street	Urban
NCA 2	Surry Hills intersection between Anzac Parade and Flinders Street	Urban
NCA 3	Paddington, Moore Park Road	Urban
NCA 4	Paddington local roads	Urban
NCA 5	Centennial Park Lang Road and local roads	Suburban
NCA 6	Centennial Park Robertson Road and local roads	Suburban

NCA boundaries have been determined from site observations and attended measurements, which are detailed in Table 52. Classifications of NCAs 1, 2, 3 and 4 as 'Urban' are based on on-site observations, and based on the NPI, given that these areas have '*through-traffic with characteristically heavy and continuous traffic flows during peak periods'*. and NCAs 5 and 6 are categorised as 'Suburban' having *'local traffic with characteristically intermittent traffic flows'* and have the following characteristic: '*evening ambient noise levels defined by the natural environment and human activity*' (NPI [1]).

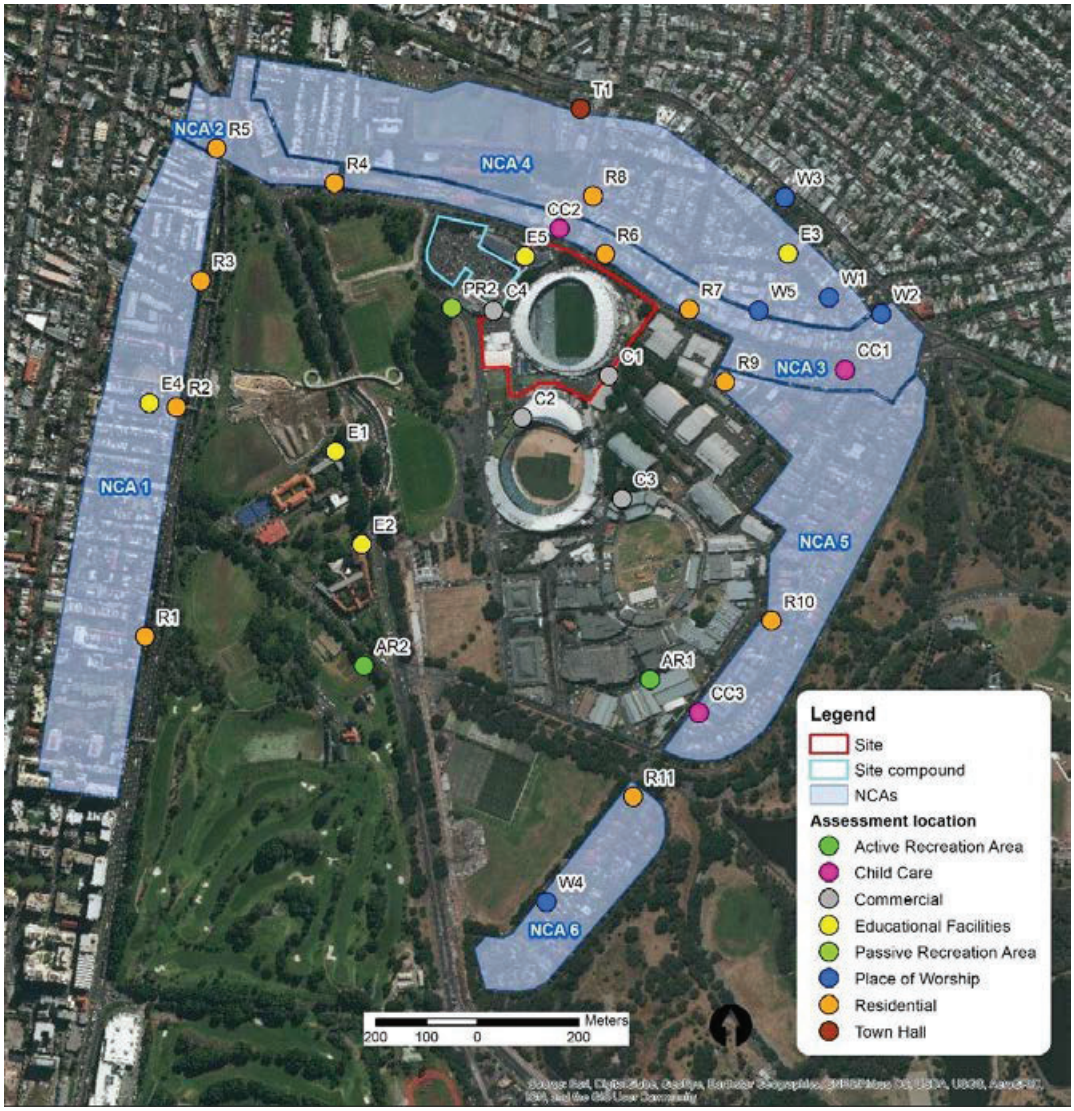

Figure 4: Assessment locations and NCAs

2.2 Assessment locations

In accordance with the NPI the reasonably most-affected residences have been identified in each NCA have been identified and are presented in Table 5. While noise predictions have been carried out to each receiver, for clarity, the assessment of residential receivers presented in this report is isolated to the reasonably most-affected receivers.

Table 5: Reasonably most-affected residential receivers

Receiver ID	Address	No. of floors	NCA
R1	749 South Dowling Street, Redfern	2	1
R2	635 South Dowling Street, Surry Hills	3	1
R3	553 South Dowling Street, Surry Hills	3	1
R4	111 Greens Rd, Paddington	2	2
R5	479 South Dowling Street, Surry Hills	3	2
R6	252 Moore Park Road, Paddington	2	3
R7	314 Moore Park Road, Paddington	2	3
R8	45 Oatley Road. Paddington	2	4
R9	5 Poate Road, Paddington	2	5
R10	107 Cook Road, Centennial Park	2	5
R11	2 Martin Road, Moore Park	3	6

A list of all non-residential noise sensitive receivers within the study area is presented in Table 6.

Table 6: Non-residential receivers

Receiver ID	Name	Address	No. of floors
Active Recreation Area			
AR1	Centennial Parklands Equestrian Centre	114-120 Lang Road, Moore Park	2
AR2	Moore Park Golf Course	Cleveland Street, Moore Park	0
Commercial			
C1	Fox Studios	38 Driver Avenue, Moore Park	2
C2	Sydney Cricket Ground	Driver Avenue, Moore Park	3
C3	Entertainment Quarter	122 Lang Road, Moore Park	3
C4	NRL building	Moore Park Road and Driver Avenue, Moore Park	3
Child Care			
CC1	Gumnut Gardens Early Learning and Long Day Care Ce	61 Moore Park Road, Centennial Park	1
CC2	Kira Child Care Centre	230 Moore Park Road, Paddington	1
CC3	Bambini's Child Care Centre	157/159 Cook Road, Centennial Park	2

Receiver ID	Name	Address	No. of floors
Educational Facilities			
E1	Sydney Boys High School	556 Cleveland Street, Moore Park	3
E2	Sydney Girls High School	Corner of Anzac Parade and Cleveland Street, Surry Hills	2
E3	Paddington Public School	399-435 Oxford Street, Paddington	2
E4	Bourke Street Public School	590 Bourke Street, Surry Hills	2
E5	University of Technology Sydney Rugby Australia	Moore Park Road and Driver Avenue, Moore Park	5
Passive Recreation Area			
PR1	Moore Park	Moore Park	0
Town Hall			
T1	Paddington Town Hall	249 Oxford Street, Paddington	2
Place of Worship			
W1	St Francis of Assisi Catholic Church	64 Gordon Street, Paddington	3
W2	St Mattias Anglican Church	471-475 Oxford Street, Paddington	2
W3	Paddington Uniting Church	395 Oxford Street, Paddington	2
W4	St. Vladimir's Russian Orthodox Church	31 Robertson Rd, Centennial Park	2
W5	Kingdom Hall of Jehovah's Witnesses	20 Leinster St, Paddington	2

2.3 Measurement of existing noise levels

Criteria for the assessment of operational and construction noise are usually derived from the existing noise environment of an area, excluding noise from the subject development.

2.3.1 Noise measurement locations

Noise measurements are ideally carried out at the nearest or most potentially affected locations surrounding a development. An alternative, representative location should be established in the case of access restrictions or if a safe and secure location cannot be identified. Furthermore, representative locations may be established in the case of multiple receivers as it is usually impractical to carry out measurements at all locations surrounding a site.

The short-term and long-term measurement locations are outlined in Table 7 and shown in Figure 5.

Table 7: Measurement summary

ID	NCA	Measurement location	Measurement type	Comment on location suitability
Meas. 1	1	587 South Dowling Street	Long and short term	Noise from South Dowling Street was noted as consistent along the length of NCA 1, therefore this location is considered representative of background noise levels at the worst affected receivers within NCA 1.
Meas. 2	2	24 Moore Park Road	Long and short term	Considered representative of reasonably most-affected residences, at south-eastern corner of NCA 2.
Meas. 3	3	256 Moore Park Road	Long and short term	Considered representative of reasonably most-affected residences, directly opposite the SFSR site along Moore Park Road.
Meas. 4	4	43 Stewart Street	Long and short term	Monitoring location was considered representative of reasonably most-affected residences within NCA 4. Noise levels along Stewart Street were observed as consistent, being shielded from Moore Park Road by intervening buildings. Measured noise levels may be slightly lower than those at the western end of Stewart Street, however this would result in slightly conservative RBL based criteria.
Meas. 5	5	11 Furber Road	Long and short term	Monitoring location was considered representative of reasonably most-affected residences within NCA 5. Noise levels throughout NCA 5 were observed as consistent, being shielded from Moore Park Road by intervening buildings. Measured noise levels may be slightly lower than those at the western end of NCA 5, however this would result in slightly conservative RBL based criteria.
Meas. 6	6	17 Robertson Road	Long and short term	Considered representative of reasonably most-affected residences, at a similar distance from Anzac Parade.
Meas. 7	-	Sydney Boys High School	Long and short term	-

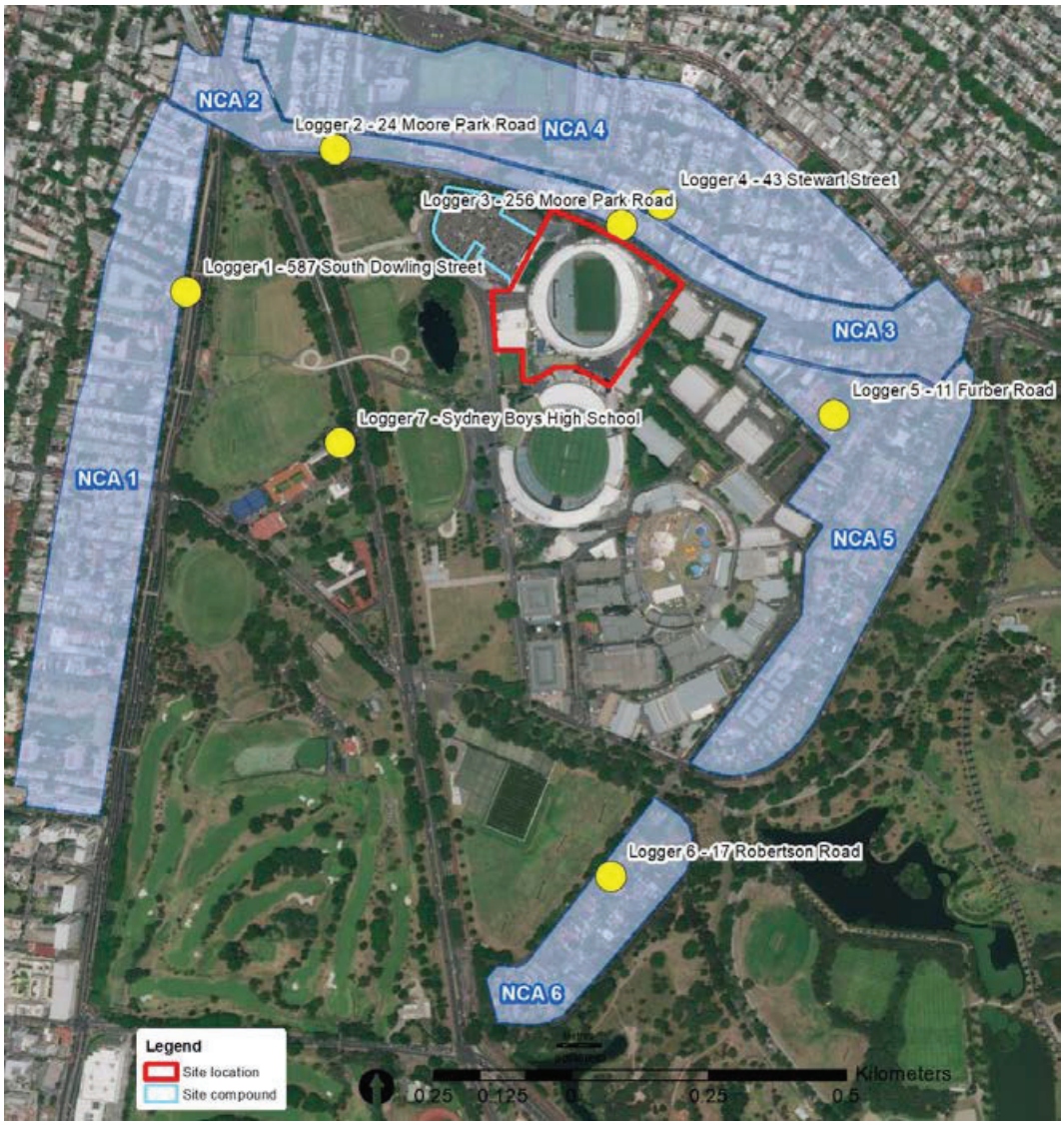

Figure 5: Measurement locations and NCAs

2.3.2 Results

Measurements were conducted as part of the Stage 1 SSDA NVIA [5]. A full set of measurement results is presented in Appendix B.

3 Construction noise and vibration

This report addresses the noise and vibration associated with construction of the new stadium. Demolition of the existing SFS was assessed and approved as part of the Stage 1 SSDA.

Stage 2 construction activities are not proposed to occur concurrently with Stage 1 early works demolition activities, except for the removal of the cricket tent, which would not involve any significant noise and vibration generating activities. On this basis, no cumulative acoustic emissions are anticipated and the following assessment addresses only the Stage 2 works.

3.1 Construction noise criteria

The ICNG provides recommended noise levels for airborne construction noise at sensitive land uses. The guideline provides construction management noise levels above which all 'feasible and reasonable' work practices should be applied to minimise the construction noise impact. The ICNG works on the principle of a 'screening' criterion – if predicted or measured construction noise exceeds the ICNG levels then the construction activity must implement all 'feasible and reasonable' work practices to reduce noise levels.

The ICNG sets out management levels for noise at noise sensitive receivers, and how they are to be applied. These management noise levels for residential receivers are reproduced below, in Table 8 and other sensitive receivers in Table 9 below.

Table 8: Construction noise management levels at residential receivers

Time of day	**Management level** [1] $L_{Aeq\ (15\ min)}$	**How to apply**
Recommended standard hours: Monday to Friday 7am to 6pm Saturday 8am to 1pm No work on Sundays or public holidays	Noise affected RBL + 10dB	The noise affected level represents the point above which there may be some community reaction to noise. Where the predicted or measured $L_{Aeq\ (15\ min)}$ is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level. The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details.

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

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.

2 – See Table for definition of outside standard hours definitions

Table 9: Construction noise management levels at other noise sensitive land uses

Land use	Where objective applies	Noise Management level $L_{Aeq(15\ min)}$[1]
Passive recreation areas	External noise level	60 dBA
Active recreation areas	External noise level	65 dBA
Educational institutions	Internal noise level	45 dBA
Place of worship	Internal noise level	45 dBA
Town hall	Internal noise level	45 dBA[2]
Commercial premises	External noise level	70 dBA

1 - Noise management levels apply when properties are in use.

2 - Based on AS/NZS2107:2016 max design level for Municipal building – function area

3.1.1 Project construction noise targets

Construction noise criteria are set based on noise catchment areas relative to proposed construction works. These catchment areas are defined for the project in Section 2.1.

Measured noise data obtained at the logger location most representative of each noise catchment area has been used to derive appropriate noise management levels for the project. These are summarised in Table 10.

Table 10: Residential Noise Management Levels during intended working hours, $dBL_{Aeq\ 15minute}$

Location	NCA	Highly noise affected	Noise Management Level
Standard construction hours			
R1	NCA 1	75	58
R2	NCA 1	75	58
R3	NCA 1	75	58
R4	NCA 2	75	56
R5	NCA 2	75	56
R6	NCA 3	75	52
R7	NCA 3	75	52
R8	NCA 4	75	43
R9	NCA 5	75	39
R10	NCA 5	75	39
R11	NCA 6	75	47

Noise Management Levels for non-residential receivers are presented in Table 11.

Table 11: Non-residential Noise Management Levels during intended working hours

Usage	Rec. ID	Name	Time period	Assess. location	External NML, $dBL_{Aeq\ 15minute}$
Active recreation area	AR1	Centennial Parklands Equestrian Centre	When in use	External	65
	AR2	Moore Park Golf Course	When in use	External	65
Commercial premise	C1	Fox Studios	When in use	External	70
	C2	Sydney Cricket Ground	When in use	External	70
	C3	Entertainment Quarter	When in use	External	70
	C4	NRL building	When in use	External	70
Child Care	CC1	Gumnut Gardens Early Learning and Long Day Care Ce	When in use	External	70
	CC2	Kira Child Care Centre	When in use	External	70
	CC3	Bambini's Child Care Centre	When in use	External	70
	E1	Sydney Boys High School	When in use	Internal	45

Usage	Rec. ID	Name	Time period	Assess. location	External NML, $dBL_{Aeq\ 15minute}$
Educational institution	E2	Sydney Girls High School	When in use	Internal	45
	E3	Paddington Public School	When in use	Internal	45
	E4	Bourke Street Public School	When in use	Internal	45
	E5	University of Technology Sydney Rugby Australia	When in use	Internal	45
Passive recreation area	PR1	Moore Park	When in use	External	60
Town hall	T1	Paddington Town Hall	When in use	Internal	45
Place of worship	W1	St Francis of Assisi Catholic Church	When in use	Internal	45
	W2	St Mattias Anglican Church	When in use	Internal	45
	W3	Paddington Uniting Church	When in use	Internal	45
	W4	St. Vladimir's Russian Orthodox Church	When in use	Internal	45
	W5	Kingdom Hall of Jehovah's Witnesses	When in use	Internal	45

3.2 Construction traffic criteria

Increased traffic generated on the surrounding road network due to either construction activities or by the operation of the SFSR is assessed in accordance with the NSW Road Noise Policy (RNP). Table 3 of the RNP which sets out the assessment criteria for particular types of project, road category and land use, shown in Table 29 below.

Table 12: Road traffic criteria for traffic generating development - residential receivers

Road category	Type of project / land use	Assessment criteria – dB(A)	
		Day (7:00am-10:00pm)	Night (10:00pm-7:00am)
Freeway/arterial/sub-arterial roads - Moore Park Road	Existing residences affected by additional traffic on existing freeways / arterial / sub-arterial roads generated by land use developments	$L_{Aeq,(15\ hour)}$ 60 (external)	$L_{Aeq,(9\ hour)}$ 55 (external)

Notes: These criteria are for assessment against façade corrected noise levels when measured in front of a building façade.

Regarding the application of the assessment, the RNP states:

> *In assessing feasible and reasonable mitigation measures, an increase of up to 2 dB represents a minor impact that is considered barely perceptible to the average person.*

3.3 Construction vibration criteria

Vibration criteria for construction works are established in the following sections. Vibration management measures have been recommended in Section 3.8.

3.3.1 Human comfort

The NSW EPA's *Assessing Vibration – A Technical Guideline* [3] provides vibration criteria for maintaining human comfort within different space uses. The guideline recommends 'preferred' and 'maximum' weighted vibration levels for both continuous vibration sources, such as steady road traffic and continuous construction activity, and for impulsive vibration sources. The weighting curves are obtained from BS 6472-1:2008 [6].

For intermittent sources (e.g. passing heavy vehicles, impact pile driving, intermittent construction), the guideline uses the vibration dose value (VDV) metric to assess human comfort effects of vibration. VDV considers both the magnitude of vibration events and the number of instances of the vibration event. Intermittent events that occur less than 3 times in an assessment period (either day, 7 am to 10 pm, or night, 10 pm to 7 am) are counted as 'impulsive' sources for the purposes of assessment.

As noted in the Guideline, situations exist where vibration above the preferred values can be acceptable, particularly for temporary disturbances, such as a construction or excavation projects. Notwithstanding, the recommended vibration limits for maintaining human comfort in residences and other relevant receiver types are given for continuous/impulsive and intermittent vibration in Table 13 and Table 14 respectively.

Table 13: Preferred and maximum weighted root-mean-square (rms) values for continuous and impulsive vibration acceleration (m/s²) 1-80 Hz

Location	Period	Preferred Values		Maximum Values	
		z-axis	x- and y-axes	z-axis	x- and y-axes
Continuous Vibration					
Critical areas[1]	Day- or Night-time	0.005	0.0036	0.01	0.0072
Residences	Daytime 0700-2200h	0.010	0.0071	0.020	0.014
	Night-time 2200-0700h	0.007	0.005	0.014	0.010
Offices, schools, educational institutions and places of worship	Day- or Night-time	0.020	0.014	0.040	0.028
Impulsive Vibration					
Critical areas[1]	Day- or Night-time	0.005	0.0036	0.01	0.0072
Residences	Daytime 0700-2200h	0.30	0.21	0.60	0.42
	Night-time 2200-0700h	0.10	0.071	0.20	0.14
Offices, schools, educational institutions and places of worship	Day- or Night-time	0.64	0.46	1.28	0.92

1. Criteria for sensitive areas are only indicative, and have been provided as guidance to acceptable vibration levels for the use of sensitive equipment, eg. camera equipment at Fox Studios.

Table 14: Acceptable vibration dose values for intermittent vibration ($m/s^{1.75}$)

Location	Daytime 0700-2200 h		Night-time 2200-0700 h	
	Preferred Value	Maximum Value	Preferred Value	Maximum Value
Critical areas[1]	0.10	0.20	0.10	0.20
Residences	0.20	0.40	0.13	0.26
Offices, schools, educational institutions and places of worship	0.40	0.80	0.40	0.80

1. Criteria for sensitive areas are only indicative, and there may be a need to assess intermittent vibration against impulsive or continuous criteria.

3.3.2 Building damage

Potential structural or cosmetic damage to buildings as a result of vibration is typically assessed in accordance with British Standard 7385 Part 2-1993 and/or German Standard DIN4150-3. British Standard 7385 Part 1: 1990, defines different levels of structural damage as:

- *Cosmetic - The formation of hairline cracks on drywall surfaces, or the growth of existing cracks in plaster or drywall surfaces; in addition, the formation of hairline cracks in mortar joints of brick/concrete block construction.*
- *Minor - The formation of large cracks or loosening of plaster or drywall surfaces, or cracks through bricks/concrete blocks.*
- *Major - Damage to structural elements of the building, cracks in supporting columns, loosening of joints, splaying of masonry cracks, etc.*

Table 1 of BS7385-2 sets limits for the protection against cosmetic damage, however the following guidance on minor and major damage is provided in Section 7.4.2 of the Standard:

> *7.4.2 Guide values for transient vibration relating to cosmetic damage*
>
> *Limits for transient vibration, above which cosmetic damage could occur are given numerically in Table 1 and graphically in Figure 1 (reproduced below).*

Table 1 — Transient vibration guide values for cosmetic damage

Line (see Figure 1)	Type of building	Peak component particle velocity in frequency range of predominant pulse	
		4 Hz to 15 Hz	15 Hz and above
1	Reinforced or framed structures Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
2	Unreinforced or light framed structures Residential or light commerical type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

NOTE 1 Values referred to are at the base of the building (see **6.3**).

NOTE 2 For line 2, at frequencies below 4 Hz, a maximum displacement of 0.6 mm (zero to peak) should not be exceeded.

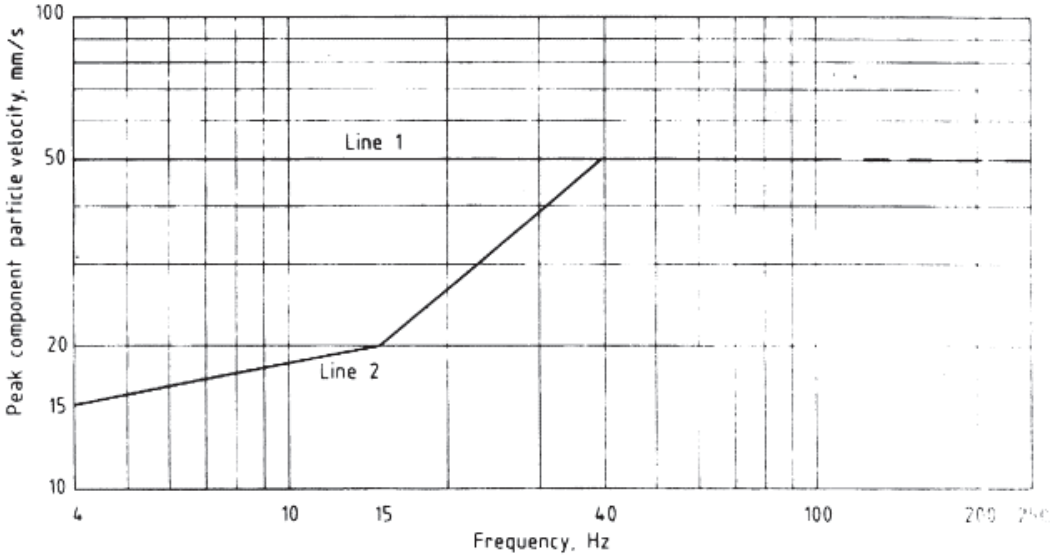

Figure 1 — Transient vibration guide values for cosmetic damage

In the lower frequency region where strains associated with a given vibration velocity magnitude are higher, the guide values for the building types corresponding to line 2 are reduced. Below a frequency of 4 Hz, where a high displacement is associated with a relatively low peak component particle velocity value a maximum displacement of 0.6 mm (zero to peak) should be used.

Minor damage is possible at vibration magnitudes which are greater than twice those given in Table 1, and major damage to a building structure may occur at values greater than four times the tabulated values.

Within DIN4150-3, damage is defined as “any permanent effect of vibration that reduces the serviceability of a structure or one of its components” (p.2). The Standard also outlines:

"that for structures as in lines 2 and 3 of Table 1, the serviceability is considered to have been reduced if

- *cracks form in plastered surfaces of walls;*
- *existing cracks in the building are enlarged;*
- *partitions become detached from loadbearing walls or floors.*

These effects are deemed ‘minor damage." (DIN4150.3, 1990, p.3)

While the DIN Standard defines the above damage as 'minor', the description aligns with BS7385 cosmetic damage, rather than referring to structural failures.

British Standard BS7835-2

BS7385-2 [7] is based on peak particle velocity and specifies damage criteria for frequencies within the range 4–250 Hz, and a maximum displacement value below 4 Hz is recommended. Table 15 sets out the BS7385 criteria for cosmetic, minor and major damage. Regarding heritage buildings, British Standard 7385 Part 2 (1993, p.5) notes that “a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive”.

Table 15: BS 7385-2 structural damage criteria

Group	Type of structure	Damage level	Peak component particle velocity, mm/s1		
			4 Hz to 15 Hz	15 Hz to 40 Hz	40 Hz and above
1	Reinforced or framed structures Industrial and heavy commercial buildings	Cosmetic	50		
		Minor[2]	100		
		Major[2]	200		
2	Un-reinforced or light framed structures Residential or light commercial type buildings	Cosmetic	15 to 20	20 to 50	50
		Minor[2]	30 to 40	40 to 100	100
		Major[2]	60 to 80	80 to 200	200

Notes

1 - Peak Component Particle Velocity is the maximum Peak particle velocity in any one direction (x, y, z) as measured by a tri-axial vibration transducer.

2 - Minor and major damage criteria established based on British Standard 7385 Part 2 (1993) Section 7.4.2

All levels relate to transient vibrations in low-rise buildings. Continuous vibration can give rise to dynamic magnifications that may require levels to be reduced by up to 50%.

German Standard DIN 4150-3

German Standard DIN 4150 - Part 3 'Structural vibration in buildings - Effects on Structure' (DIN 4150-3) [8] are generally recognised to be conservative. DIN 4150-3

presents the recommended maximum limits over a range of frequencies (Hz), measured in any direction, and at the foundation or in the plane of the uppermost floor of a building or structure. The criteria are presented in Table 16.

Table 16: DIN 4150-3 structural damage criteria

Group	Type of structure	Vibration velocity, mm/s			
		At foundation at frequency of			Plane of floor uppermost storey
		1 Hz to 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz	All frequencies
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design	20	20 to 40	40 to 50	40
2	Dwellings and buildings of similar design and/or use	5	5 to 15	15 to 20	15
3	Structures that because of their particular sensitivity to vibration, do not correspond to those listed in Group 1 or 2 and have intrinsic value (eg buildings under a preservation order)	3	3 to 8	8 to 10	8

3.3.3 Buried services

DIN 4150-2:1999 [8] sets out guideline values for vibration effects on buried pipework and reproduced in Table 17 below.

Table 17: Guideline values for short-term vibration impacts on buried pipework

Pipe material	Guideline values for vibration velocity measured on the pipe, mm/s
Steel (including welded pipes)	100
Clay, concrete, reinforced concrete, pre-stressed concrete, metal (with or without flange)	80
Masonry, plastic	50

Note:
For gas and water supply pipes within 2m of buildings, the levels given in Table 16 should be applied. Consideration must also be given to pipe junctions with the building structure as potential significant changes in mechanical loads on the pipe must be considered.

In addition, specific limits for vibration affecting high-pressure gas pipelines is provided in the UK National Grid's Specification for Safe Working in the Vicinity of National Grid High Pressure Gas Pipelines and Associated Installations – Requirements for Third Parties (report T/SP/SSW/22, UK National Grid, Rev 10/06, October 2006). This specification states that no piling is allowed within 15 m of a pipeline without an assessment of the vibration levels at the pipeline. The PPV at the pipeline is limited to a maximum level of 75 mm/s, and where PPV is predicted to exceed 50 mm/sec the ground vibration is required to be monitored.

Other services that may be encountered include electrical cables and telecommunication services such as fibre optic cables. While these may sustain vibration velocity levels from between 50 mm/s and 100 mm/s, the connected services such as transformers and switchgear may not. Where encountered, site specific vibration assessment in consultation with the utility provider should be carried out.

3.3.4 Heritage structures

Heritage structures which have been identified in the vicinity of the SFSR include Busby's Bore, sections of the SCG, and some buildings within Fox Studios. Regarding heritage buildings, BS7385-2 notes that '*a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive*'. As the SCG and Fox Studios buildings are not considered to be structurally unsound, these heritage structures are not considered to be more vibration sensitive than other surrounding structures.

Regarding Busby's Bore, a methodology statement, 'SFS Response to Submissions (SSD9249) Attachment 8 – Methodology Statement – Working Near Busby's Bore' [9], outlines the methodology developed during Stage 1 works for undertaking vibration intensive works in the vicinity of to minimise the risk of structural damage and is presented in Appendix C. This methodology will remain for the Stage 2 construction works.

3.4 Construction noise assessment

3.4.1 Hours of works

General construction works will be undertaken within the hours outlined in Table 18, in accordance with ICNG standard hours of construction.

Table 18: Preferred Hours of Construction

Day	Proposed construction hours
Monday to Friday	7.00 am to 6:00 pm
Saturdays	8.00 am to 1:00 pm
Sundays or Public Holidays	No construction

In some cases, after-hours permits may be sought from the relevant authorities where special requirements exist, for example oversized deliveries.

3.4.2 Activities

It is not proposed for Stage 2 construction activities to occur concurrently with Stage 1 early works demolition activities, except for the removal of the cricket tent, during which no significant noise generating activities are proposed. No cumulative acoustic emissions are therefore anticipated.

Assumed construction equipment to be used for redevelopment works are provided in Table 19 (refer to Construction Management Plan).

Equipment sound power levels have been determined by reference to AS2436 [10], DEFRA [11], and Arup's measurement database. The equipment below has been assumed

to operate concurrently and continuously over a full 15-minute period (a typical worst-case assumption).

The locations of equipment have been based on the locations of the construction works around the precinct.

Table 19: Construction equipment usage and associated sound power levels (L_w)

Approx. duration	Description of works in sub-stage	Equipment	Total number of units on site	No. operating within worst case 15-min	Sound Power dBL_{eq} (15min)
Phase 1 – Stadium Bowl Construction					
18 months	Transport and pumping of concrete, excavation, crane operation	Trucks	10	3	98
		40 tonne excavators	8	2	115
		Bobcats	4	1	104
		250 tonne cranes	4	1	106
		Concrete Pumps	3	1	109
		Concrete Trucks	40	10	109
		Forklifts	2	1	106
		Hand tools	12	3	102
		Air compressors	2	1	110
		Concrete float / vibrators	3	1	113
		Angle Grinder	2	1	111
		Impact Drill	4	1	121
Phase 2 – Stadium Roof Construction					
18 months	Steel cutting, crane operation	Trucks	10	3	98
		250 tonne cranes	4	1	106
		Forklifts	2	1	106
		Hand tools	6	2	102
		Angle Grinder	2	1	111
		Impact Drill	3	1	121
Phase 3 – Infrastructure Works					
12 months (indicative)	Jackhammering, steel cutting, excavation, crane operation	Trucks	2	1	98
		40 tonne excavators	4	1	115
		Bobcats	2	1	104
		Concrete Pumps	1	1	109
		Concrete Trucks	2	1	109
		Forklifts	2	1	106
		Hand tools	6	2	102

Approx. duration	Description of works in sub-stage	Equipment	Total number of units on site	No. operating within worst case 15-min	Sound Power dBL_{eq} (15min)
		Electric Saw	2	1	118
		Angle Grinder	2	1	111
		Jackhammering	2	1	113
		Impact Drill	1	1	121
Phase 4 – Concourse Finishes					
12 months (indicative)	Installation of concourse features, steel cutting	Trucks	2	1	98
		Bobcats	2	1	104
		Forklifts	3	1	106
		Hand tools	12	3	102
		Electric Saw	4	1	118
		Concrete float / vibrators	2	1	113
		Angle Grinder	1	1	111
		Impact Drill	4	1	121
Phase 5 – Internal Finishes					
18 months	Installation of internal building elements, crane operation	Trucks	4	1	98
		Electric Saw	4	1	115
		250 tonne cranes	2	1	106
		Forklifts	3	1	106
		Hand tools	12	3	102
		Impact Drill	4	1	121

3.4.3 Assessment methodology

Noise emissions from construction activities associated with the SFSR have been assessed to criteria outlined in Section 3.1.

Noise emissions have been modelled using SoundPlan 8 in accordance with ISO9613-2 algorithms. The model included:

- Construction noise sources listed in Section 3.4.1;
- SFS and surrounding buildings;
- Receivers listed in Table 5; and
- Ground terrain and absorption.

Noise emissions have been modelled on the following conservative assumptions:

- Equipment, staging and durations are based on information provided by Lendlease. A review of predicted emissions should be conducted when final construction details

are available as part of the development of the Construction Noise and Vibration Management Plan.

- The equipment Table 19 have been assumed to operate concurrently and continuously over a full 15-minute period
- The location of equipment will be towards the northern half of the site, closer to the nearest receivers along Moore Park Road to represent worst case emissions

3.4.4 Noise prediction results

Predicted construction noise levels at surrounding receivers are presented in Table 20, along with the relevant NML for the intended working hours, as presented in Table 10.

Graphical representations of construction noise emission are presented in Appendix D.

Table 20: Predicted construction noise levels, $dBL_{Aeq\ (15\ min)}$

Receiver	NML	Construction phase				
		1. Stadium Bowl Construction	2. Stadium Roof Construction	3. Infrastructure works	4. Concourse Finishes	5. Internal Finishes
		Highest predicted noise level				
Residential receivers						
R1 - 749 South Dowling Street, Redfern	**68**	50	46	49	48	47
R2 - 635 South Dowling Street, Surry Hills	**68**	53	49	52	51	50
R3 - 553 South Dowling Street, Surry Hills	**68**	55	52	54	54	53
R4 - 111 Greens Rd, Paddington	**66**	48	45	47	47	46
R5 - 479 South Dowling Street, Surry Hills	**66**	56	52	55	54	53
R6 - 252 Moore Park Road, Paddington	**62**	**77**	73	**76**	**75**	74
R7 - 314 Moore Park Road, Paddington	**62**	68	64	67	66	65
R8 - 45 Oatley Road. Paddington	**53**	61	58	60	59	58
R9 - 5 Poate Road, Paddington	**49**	59	56	58	57	56
R10 - 107 Cook Road, Centennial Park	**49**	51	48	50	50	48
R11 - 2 Martin Road, Moore Park	**57**	47	43	46	45	44
Non-residential receivers						
AR1 - Centennial Parklands Equestrian Centre	**65**	36	33	35	34	33
AR2 - Moore Park Golf Course	**65**	50	46	49	48	47
C1 - Fox Studios	**70**	73	70	72	72	70
C2 - Sydney Cricket Ground	**70**	59	56	58	58	56
C3 - Entertainment Quarter	**70**	58	54	56	56	55
C4 – NRL Building	**70**	64	61	63	62	61

Receiver	NML	Construction phase				
		1. Stadium Bowl Construction	2. Stadium Roof Construction	3. Infrastructure works	4. Concourse Finishes	5. Internal Finishes
		Highest predicted noise level				
CC1 - Gumnut Gardens Early Learning and Long Day Care Centre	**70**	57	53	55	55	54
CC2 - Kira Child Care Centre	**70**	70	66	69	68	67
CC3 - Bambini's Child Care Centre	**70**	37	34	36	36	34
E1 - Sydney Boys High School[1]	**45**	47	43	46	45	44
E2 - Sydney Girls High School[1]	**45**	47	44	46	45	44
E3 - Paddington Public School[1]	**45**	38	34	37	36	35
E4 - Bourke Street Public School[1]	**45**	39	36	38	38	36
E5 - University of Technology Sydney and Rugby Australia[2]	**45**	52	49	51	51	49
E6 - UNSW Art & Design[1]	**45**	42	38	41	40	39
PR1 - Moore Park	**60**	64	61	63	62	61
T1 - Paddington Town Hall[1]	**45**	51	48	50	50	49
W1 - St Francis of Assisi Catholic Church[1]	**45**	41	37	40	39	38
W2 - St Mattias Anglican Church[1]	**45**	36	32	35	34	33
W3 - Paddington Uniting Church[1]	**45**	38	35	37	37	36
W4 - St. Vladimir's Russian Orthodox Church[1]	**45**	36	33	35	34	33
W5 - Kingdom Hall of Jehovah's Witnesses[1]	**45**	44	41	43	43	41

- Levels shaded in grey indicate a notional exceedance of NMLs based on the worst-case assumptions noted above.
- Levels in **Bold Red** indicate 'highly affected' noise levels of 75dBA or above.

1. Internal noise levels conservatively predicted based on a 10dB noise reduction through an open window
2. Internal noise levels predicted based on external levels, façade constructions, room and façade dimensions

Results indicate that exceedances may occur at the nearest residential receivers located along Moore Park Road, Cook Road and the local streets of Paddington. Residence R6 at 252 Moore Park Road is predicted to be 'highly affected' during Stages 1 and 3 of construction works, i.e. experience noise levels of $L_{Aeq(15minute)}$ 75 dBA or above.

It should be noted that measured existing ambient noise levels, primarily due to road traffic noise from Moore Park Road, are frequently above $L_{Aeq(15minute)}$ 70 dBA and occasionally reach $L_{Aeq(15minute)}$ 75 dBA in the absence of construction noise.

The highest levels are predicted during use of equipment such as the impact drills, angle grinders and electric saws. These items are typically used over short durations and therefore may not be in operation concurrently as assumed in the predictions. Therefore, the noise levels predicted in Table 20 are expected to represent a conservative worst-case 15-minute period of each construction stage. In practice, noise levels during each stage are expected to be lower than that predicted.

A more detailed assessment of E5 – UTS, Rugby Australia was conducted to develop more accurate internal construction noise predictions. Exceedances of up to 7 dB are predicted within spaces in the UTS and Rugby Australia building, taking into account building envelope, room locations and room dimensions. Some disturbances to occupants within the affected buildings are predicted during the use of noisy equipment listed above. Noise impact will likely be most intrusive for lectures, tutorials or use of the laboratories within the UTS facilities. The learning spaces within UTS facilities are operational for the majority of the year excluding semester breaks, while formal exams are conducted off-site. Mitigation measures are proposed and outlined in Section 3.7.

Some exceedances are predicted at C1 – Fox Studios, however these exceedances of up to 3 dB are not considered major. Although the 'highly affected' status only applies to residential receivers, the noise levels at these receivers are not expected to exceed an $L_{Aeq\ (15minute)}$ of 75 dBA.

Exceedances at Paddington Town hall of up to 6 dB, and minor exceedances at both Sydney Boy's and Sydney Girl's High Schools are predicted, however these are based on the assumption that operable windows are open. Considering the ambient noise levels at each of these receivers due to road traffic noise in the area are similar or higher than predicted construction noise levels, disturbances as a result of construction noise are expected to be insignificant.

As noise predictions are conservative with respect to number of concurrent operating plant and durations, significant disturbance is not expected at other non-residential receivers.

At Moore Park, noise levels from construction activity could exceed passive recreation management levels. Exceedances of less than 5 dB are predicted during the loudest construction periods at the nearest location in Moore Park. Generally, these exceedances are not expected to prohibit the normal use of the park due to the likely infrequency, relatively small magnitude and location of the predicted exceedances only at the nearest sections of the park to site. Existing ambient $L_{Aeq(15min)}$ noise levels at Moore Park are generally above 65 dB(A) during the intended construction works period, being higher than predicted construction noise.

For any events to be held at Moore Park, it is recommended that coordination between event organisers and the Contractor occur to limit potential disruption.

Construction noise mitigation and management measures are discussed in Section 3.7.

3.5 Construction traffic assessment

Construction vehicles will be used for deliveries and to remove waste from the site, with the proposed access points to the site located at:

- Moore Park Road – construction vehicles travelling west with worst affected residential receiver located at 32 Moore Park Road

- Driver Avenue – construction vehicles travelling north to Moore Park Road or south to join Lang Road then west to Anzac Parade with worst affected residential receiver located at 2 Robertson Road

Proposed construction traffic routes and most potentially affected receivers, both residential, are presented in Figure 6.

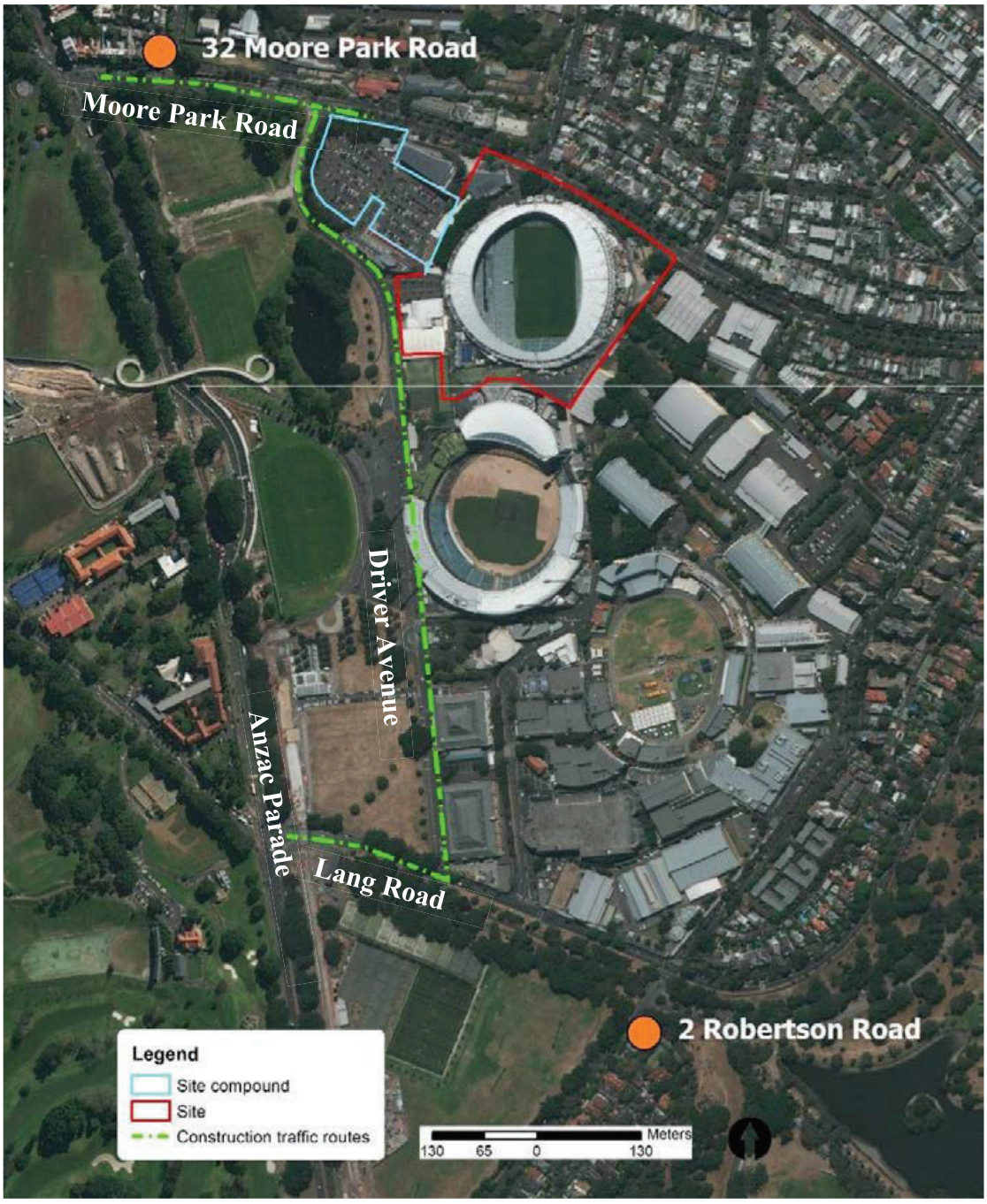

Figure 6: Construction traffic routes and worst affected residences.

Concrete pours are anticipated to require an average 30 concrete agitators (60 movements) per day, with a maximum of 60 trucks (120 movements) per day which would comprise:

- 30 concrete trucks
- 20 deliveries
- 10 other vehicles

100% of trucks could utilise either Moore Park Road or Driver Avenue on any given day.

Regarding the assessment of potential impact and consideration of mitigation and management measures, the RNP [12] states:

> *In assessing feasible and reasonable mitigation measures, an increase of up to 2 dB represents a minor impact that is considered barely perceptible to the average person.*

The assessment of construction related traffic noise is presented in Table 21.

Table 21: Construction traffic assessment

Traffic route	**Most potentially affected residential receiver**	**Existing traffic volumes**	**Daily construction movements**	**Predicted increase in road traffic noise, $L_{Aeq(15hour)}$[1]**	**Criteria**	**Comply**
Moore Park Road	32 Moore Park Road	Moore Park Road - 35,000	120	0.4 dB	< 2 dB	Yes
Driver Avenue / Lang Road / Anzac Parade	2 Robertson Road	Anzac Parade - >40,000	120	<0.4 dB[2]	< 2 dB	Yes

Note:

1. Based on 15 hour traffic proportion of 85%.
2. Calculation of noise level has included distance correction for construction traffic travelling along Lang Road relative to existing traffic along Anzac Parade.

Considering the high existing traffic numbers along Moore Park Road (approximately 35,000 vehicles per day) and Anzac Parade (greater than 40,000 vehicles per day) and the number of construction generated vehicles, the additional construction traffic created by construction is predicted to increase $L_{Aeq(15\ hour)}$ noise levels by 0.4 dB at both potentially most affected residences. This is less than the 2 dB 'minor impact' criteria, and therefore represents an insignificant effect on the ambient noise environment.

3.6 Construction vibration assessment

As no significant vibration intensive activities are proposed as part of the construction works, the likelihood of adverse impacts due to the proposed construction activities is low.

Consideration should be given to excavation works taking place directly over the heritage listed Busby's Bore. A methodology statement, "SFS Response to Submissions (SSD9249) Attachment 8 – Methodology Statement – Working Near Busby's Bore" [9], outlines the methodology developed to minimise the risk of structural damage in accordance with DIN 4150-3 [8] when undertaking vibration intensive works in the vicinity of Busby's Bore, and is presented in Appendix C. As part of the Stage 1 works, a review of the recommended vibration criteria is being conducted in order to prevent undue restrictions to works with outcomes of the assessment currently pending.

Recommended minimum work distances and construction vibration management recommendations are provided in Section 3.8 to minimise the risk of adverse vibration impacts.

No adverse vibration impact, either in terms of cosmetic damage or human comfort, are expected to occur at receiver buildings due to their distance from the subject works.

3.7 Construction noise mitigation measures

The contractor will have a key role in managing the noise and vibration levels during the works to reduce noise and vibration as far as is reasonably practicable. This will include:

Table 22: Construction noise mitigation measures

Item	Detail
Noise and vibration management plan	A Construction Noise and Vibration Management Plan shall be prepared prior to the issuing of a Construction Certificate. This will specify the actual plant to be used and will include updated estimates of the likely levels of noise and the scheduling of activities.
Staffing	Appointing a named member of the site staff who will act as the Responsible Person with respect to noise and vibration; Regularly train workers and contractors (such as at toolbox talks) to use equipment in ways to minimise noise; Ensuring good work practices are adopted to avoid issues such as noise from dropped items, noise from communication radios is kept as low as is practicable; Avoid the use of radios or stereos outdoors; and Avoid shouting and minimise talking loudly and slamming vehicle doors.
Plant and equipment	Where possible stationary equipment should be located behind structures such as demountable buildings or stockpiles to maximise shielding to receivers; Consider using electric / hydraulic equipment where possible Using the smallest equipment as is practical All plant and equipment used on site must be: • maintained in a proper and efficient condition; and • operated in a proper and efficient manner. Turn off all vehicles, plant and equipment when not in use Ensuring that the Responsible Person checks the conditions of the powered equipment used on site daily to ensure plant is properly maintained and that noise is kept as low as practicable.
Scheduling	Ensure that the Responsible Person controls the working hours on site to ensure that work is only done during the acceptable periods (7am to 6pm on weekdays and 8am to 1pm on Saturdays. No work on Sundays or public holidays)

Item	Detail
Work site training	'Toolbox talks' will be held at regular intervals with the contractor workers, including discussion of noise and vibration mitigation, monitoring and assessment. These topics will also be covered under induction processes. Operate two way radios at the minimum effective volume, and avoid shouting or whistling at the site. Identification of all reasonable and feasible noise mitigation methods will be conducted by the Responsible Person on a daily basis during noisy works. The Responsible Person will have the authority to modify work practices in response to complaints, where this is considered appropriate.
Scheduling	High noise activities will be programmed to occur during the daytime hours wherever possible and will be scheduled with due consideration to the nearest sensitive receivers. For approved out-of-hours work (refer Section 3.4.1), noisy activities should be scheduled early in the night to minimise the impact on adjacent residents. Limit number of consecutive nights receivers are impacted
Community liaison	Ensuring that the Responsible Person keeps the local community advised on expected activities and coordinates scheduling and locations of noisy works around any critical user events where practicable. This shall include face to face meetings with nearby receivers if requested and a letter box drop, and shall include close liaison with neighbours during construction, including Fox Studios, UTS, NRL and Rugby Australia. Maintaining appropriate records of complaints to include timing, reported issues, actions taken and measures to be included for on-going works. The complaints log will need to be filed with the Responsible Person.
Reversing alarms	The use of audible movement alarms of a type that would minimise noise impacts on surrounding noise sensitive receivers must be implemented. Where practicable, broadband, non-tonal reversing alarms should be utilised on site equipment. Ensure that the difference in volume between the reversing warning devices and the base machine noise level (at maximum governed speed under no load at any given test location) is minimised (in accordance with International Standard ISO9533:1989), and ensure that warning devices are no more than 5 dB above the Australian Standard level;
Material handling	Avoid dropping equipment/materials from a height or into trucks. Where practicable, use sound dampening material to cover the surfaces on to which any materials must be dropped.
Equipment Location	Site noisy equipment away from noise-sensitive areas. Plant known to emit noise strongly in one direction is to be orientated so that the noise is directed away from noise-sensitive areas; Locate site access roads and site compounds as far away as possible from noise sensitive receptors; Plan truck movements to avoid residential streets where possible;

3.8 Construction vibration management

The following guidance provides recommended minimum working distances for vibration intensive plant proposed as part of the construction works. These are based on international standards and guidance and reproduced in Table 23 below for reference.

Table 23: Recommended minimum working distances for vibration intensive plant

Plant Item	Rating / Description	Minimum working distance	
		Cosmetic damage (BS 7385)	Human response (OH&E Vibration Guideline)
Jackhammer	Hand held	1 m (nominal)	Avoid contact with structure

- More stringent conditions may apply to sensitive areas such as Fox Studios, based on sensitive equipment vibration criteria, and sensitive heritage structures.

The safe working distances presented are indicative and will vary depending on the particular item of plant and local geotechnical conditions. They apply to cosmetic damage of typical buildings under typical geotechnical conditions.

Vibration criteria established during Stage 1 works for Busby's Bore should be maintained for Stage 2. Procedures outlined in the Methodology Statement for Working Near Busby's Bore [9], prepared as part of Stage 1 works and presented in Appendix C, should be adhered to.

The contractor will be required to manage vibration as well as noise and make use of best practice in the management of vibration using simple and practicable techniques such as avoiding dropping heavy items.

Where vibration intensive works are required within the minimum working distances outlined in Table 23, vibration monitoring at the nearest potential affected building should be considered, where real-time alerts can be generated when measured vibration levels exceed criteria.

Given the distances between other receivers and the excavation works, vibration damage is not considered a significant risk for any vibration sensitive buildings.

4 Operational noise – excluding events

4.1 Overview

This section addresses noise sources associated with the operation of the SFS, excluding noise associated with events. An event is defined as entertainment activities carried out outdoors with sound amplification equipment used as part of the activity, including associated activities with sound amplification equipment such as rehearsals and sound checks

Primary operational noise sources associated with SFS, excluding event (addressed in Section 4.3.5), are identified, along with their associated policy, in Table 24 below.

Table 24: Operational noise sources and associated policy

Noise source	Relevant policy
External mechanical plant and equipment	Noise Policy for Industry [1]
Staff carpark activities	Noise Policy for Industry [1] *and* Road Noise Policy [13]
Loading bay operations, including waste and recycling collection	Noise Policy for Industry [1] *and* Road Noise Policy [13]

The activation of the precinct surrounding the stadium bowl as a publicly accessible space is not expected to generate any significant noise at nearby receivers. A basketball court is proposed for the north-eastern corner of the site, however noise generated by basketball games is expected to be significantly below existing ambient road traffic noise levels at all times of the day, therefore not considered to be an issue. No mitigation measures are therefore considered necessary.

4.2 Criteria

No existing operational noise criteria applies to the current Allianz Stadium. In the absence of this criteria, the following operational noise criteria have been developed in accordance with relevant NSW policy.

4.2.1 Noise Policy for Industry

Operational noise emissions from the SFS have been assessed in accordance with the NPI [1], which is primarily concerned with controlling intrusive noise impacts in the short-term for residences, and maintaining long-term noise level amenity for residences and other land uses.

The NPI sets out the procedure to determine the project noise trigger levels relevant to an industrial development. The project noise trigger level is a level that, if exceeded would indicate a potential noise impact on the community and so ‘trigger’ a management response.

Intrusive noise trigger level

The intrusiveness noise trigger level is applicable to residential premises only and is summarised as follows:

- $L_{Aeq,15minute} \leq$ Rating Background Level (RBL) plus 5 dB

  (where $L_{Aeq,15minute}$ represent the equivalent continuous noise level of the source)

Recommended and project amenity noise level

To limit continuing increases in noise levels from application of the intrusiveness level alone, the ambient noise level within an area from **all** industrial noise sources combined should remain below the recommended amenity noise levels specified in Table 2.2 of the NPI where feasible and reasonable. An extract from the policy pertinent to this assessment is given below in Table 25.

Table 25: NPI Recommended Amenity Noise Levels (RANLs)

Receiver	Noise amenity area	Time of Day[1]	Recommended amenity noise levels (RANLs) $L_{Aeq,}$ dBA
Residential	Suburban	Day	55
		Evening	45
		Night	40
	Urban	Day	60
		Evening	50
		Night	45
School classroom - internal	All	Noisiest 1-hour period when in use	35 (see notes for table)
Place of worship – internal	All	When in use	40
Area specifically reserved for passive recreation (e.g. national park)	All	When in use	50
Active recreation area (e.g. school playground, golf course)	All	When in use	55
Commercial premises	All	When in use	65

- The recommended amenity noise levels (RANLs) refer only to noise from industrial sources. However, they refer to noise from all such sources at the receiver location, and not only noise due to a specific project under consideration. The levels represent outdoor levels except where otherwise stated.

1 - The NPI defines day, evening and night time periods as:

- Day: the period from 7 am to 6 pm Monday to Saturday; or 8 am to 6 pm on Sundays and Public Holidays;
- Evening: the period from 6 pm to 10 pm; and
- Night: the remaining period.

(These periods may be varied where appropriate. In the case where existing schools are affected by noise from existing industrial noise sources, the acceptable L_{Aeq} noise level may be increased to 40 dB $L_{Aeq(1hr)}$

The recommended amenity noise levels (RANLs) represent the objective for total industrial noise at a receiver location, whereas the project amenity noise level (PANL) represents the objective for noise from a single industrial development at a receiver location.

To ensure that any new industrial source of noise is within the RANLs for an area, the PANL applies for each new source of industrial noise as follows:

- *Project Amenity Noise Level (PANL) = Recommended Amenity Noise Level (RANL) minus 5 dBA*

The NPI also provides the following exceptions to the above method for deriving the project amenity noise level:

1. *In areas with high traffic noise levels.*
2. *In proposed developments in major industrial clusters.*
3. *Where the resultant project amenity noise level is 10 dB or more lower than the existing industrial noise level. In this case the project amenity noise levels can be set at 10 dB below existing industrial noise levels if it can be demonstrated that existing industrial noise levels are unlikely to reduce over time.*
4. *Where cumulative industrial noise is not a necessary consideration because no other industries are present in the area, or likely to be introduced into the area in the future. In such cases the relevant amenity noise level is assigned as the project amenity noise level for the development.*

The area surrounding the site can be categorised as Urban and Suburban in accordance with the NPI, discussed in Section 2.1. According to attended measurements summarised in Table 52, the ambient noise levels at the majority of sensitive receivers is controlled by traffic. The NPI sets the PANLs to $L_{Aeq(period(traffic))}$ minus 15 dBA in the case that the level of transport $L_{Aeq(period(traffic))}$ exceeds the RANL by 10 dB or more. Table 26 summarises the RANLs and the PANLs applicable for the project.

Table 26: NPI RANLs and PANLs

NCA	Indicative Noise Amenity Area	Time of day[1]	Recommended Amenity Noise Level (RANL) $L_{Aeq(period)}$	Existing Traffic $L_{Aeq(period)}$ [2]	Project Amenity Noise Level (PANL) $L_{Aeq(period)}$
NCA 1	Urban	Day	60	69	55
		Evening	50	68	53[2]
		Night	45	66	51[2]
NCA 2	Urban	Day	60	67	55
		Evening	50	67	52[2]
		Night	45	62	47[2]
NCA 3	Urban	Day	60	68	55
		Evening	50	66	51[2]
		Night	45	62	47[2]
NCA 4	Urban	Day	60	57	55
		Evening	50	54	45

NCA	Indicative Noise Amenity Area	Time of day[1]	Recommended Amenity Noise Level (RANL) $L_{Aeq(period)}$	Existing Traffic $L_{Aeq(period)}$ [2]	Project Amenity Noise Level (PANL) $L_{Aeq(period)}$
		Night	45	49	40
NCA 5	Suburban	Day	55	60	50
		Evening	45	56	41[2]
		Night	40	45	35
NCA 6	Suburban	Day	55	57	50
		Evening	45	59	44[2]
		Night	40	50	35[2]

1 - The NPI defines day, evening and night time periods as:

- Day: the period from 7 am to 6 pm Monday to Saturday; or 8 am to 6 pm on Sundays and Public Holidays;
- Evening: the period from 6 pm to 10 pm; and
- Night: the remaining period.

2 - Traffic noise is the dominant source of noise at the receiver location:

a. the existing traffic noise is 10 dBA or more above the ANL for the area; and
b. it is unlikely that traffic noise will reduce over time.

Sleep disturbance

The NSW NPI recommends the following screening criteria for the assessment of potential sleep disturbance, for the period between 10 pm and 7 am:

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

NPI Project specific noise levels

Based on the background and ambient noise monitoring, Table 27 summarises the derived project specific noise levels based on the NPI.

Table 27: NPI Project specific noise levels

Receiver	Intrusive Level, $L_{Aeq(15minute)}$			Project Amenity Level $L_{Aeq,period}$			Sleep disturbance
	Day	Evening	Night	Day	Evening	Night	
R1	63	61	60	55	53	51	62
R2	63	61	60	55	53	51	62
R3	63	61	60	55	53	51	62
R4	61	57	56	55	52	47	57
R5	61	57	56	55	52	47	57
R6	57	54	54	55	51	47	52
R7	57	54	54	55	51	47	52
R8	48	46	46	55	45	40	52
R9	44	41	40	50	41	35	52

Receiver	Intrusive Level, $L_{Aeq(15minute)}$			Project Amenity Level $L_{Aeq,period}$			Sleep disturbance
	Day	Evening	Night	Day	Evening	Night	
R10	44	41	40	50	41	35	52
R11	52	52	50	50	44	35	56

Emergency equipment

The NPI allows increases to the environmental noise limits for events of short durations where no more than one event occurs in any 24-hour period. This is to allow for short and intermittent operation of equipment during testing and/or emergencies such as stair pressurisation fans. The allowances are summarised in Table 28.

Table 28: Adjustments to environmental noise limits for duration

Duration of noise (one event in any 24-hour period)	Increase in acceptable noise level at receptor, dBA	
	Daytime and Evening 7am-10pm	Night 10pm-7am
1-2.5 hours	2	Nil
15 minutes to 1 hour	5	Nil
6 minutes to 15 minutes	7	2
1.5 minutes to 6 minutes	15	5
less than 1.5 minutes	20	10

For the purposes of design, it is assumed that smoke exhaust fan tests would fall in the 15 minutes to 1 hour band during the daytime, and thus attract an allowable increase of 5 dBA to the limiting noise criteria for typical building daytime operation.

The scheduled testing of smoke exhaust fans would also be limited to occur during the daytime hours to avoid disruption to occupants within the building.

4.2.2 Road Noise Policy

Increased traffic generated on the surrounding road network due to either construction activities or by the operation of the SFSR is assessed in accordance with the RNP. Table 3 of the NSW Road Noise Policy (RNP) which sets out the assessment criteria for particular types of project, road category and land use, shown in Table 29 below.

Table 29: Road traffic criteria for traffic generating development - residential receivers

Road category	Type of project / land use	Assessment criteria – dB(A)	
		Day (7:00am-10:00pm)	Night (10:00pm-7:00am)
Freeway/arterial/sub-arterial roads - Moore Park Road	Existing residences affected by additional traffic on existing freeways / arterial / sub-arterial roads generated by land use developments	$L_{Aeq,(15\ hour)}$ 60 (external)	$L_{Aeq,(9\ hour)}$ 55 (external)

Road category	Type of project / land use	Assessment criteria – dB(A)	
		Day (7:00am-10:00pm)	Night (10:00pm-7:00am)

Notes: These criteria are for assessment against façade corrected noise levels when measured in front of a building façade.

Regarding the application of the assessment, the RNP states:

> *In assessing feasible and reasonable mitigation measures, an increase of up to 2 dB represents a minor impact that is considered barely perceptible to the average person.*

4.3 Noise assessment

4.3.1 Mechanical plant

The location, type and size of mechanical plant that may emit to the surrounding environment will be the subject of further design development during detailed design stage, and indicative advice provided at this stage will be revised once the mechanical services design package is finalised.

A preliminary mechanical design has been developed which indicates the primary external mechanical plant are four cooling towers to be located on the east side of the stadium, on a platform above the stadium façade (at a height of RL69m above sea level). The indicative cooling tower locations are shown in Figure 7 and Figure 8. The cooling towers are 4 m in height and surrounded by a 4.5 m high noise barrier on the north, west and south sides.

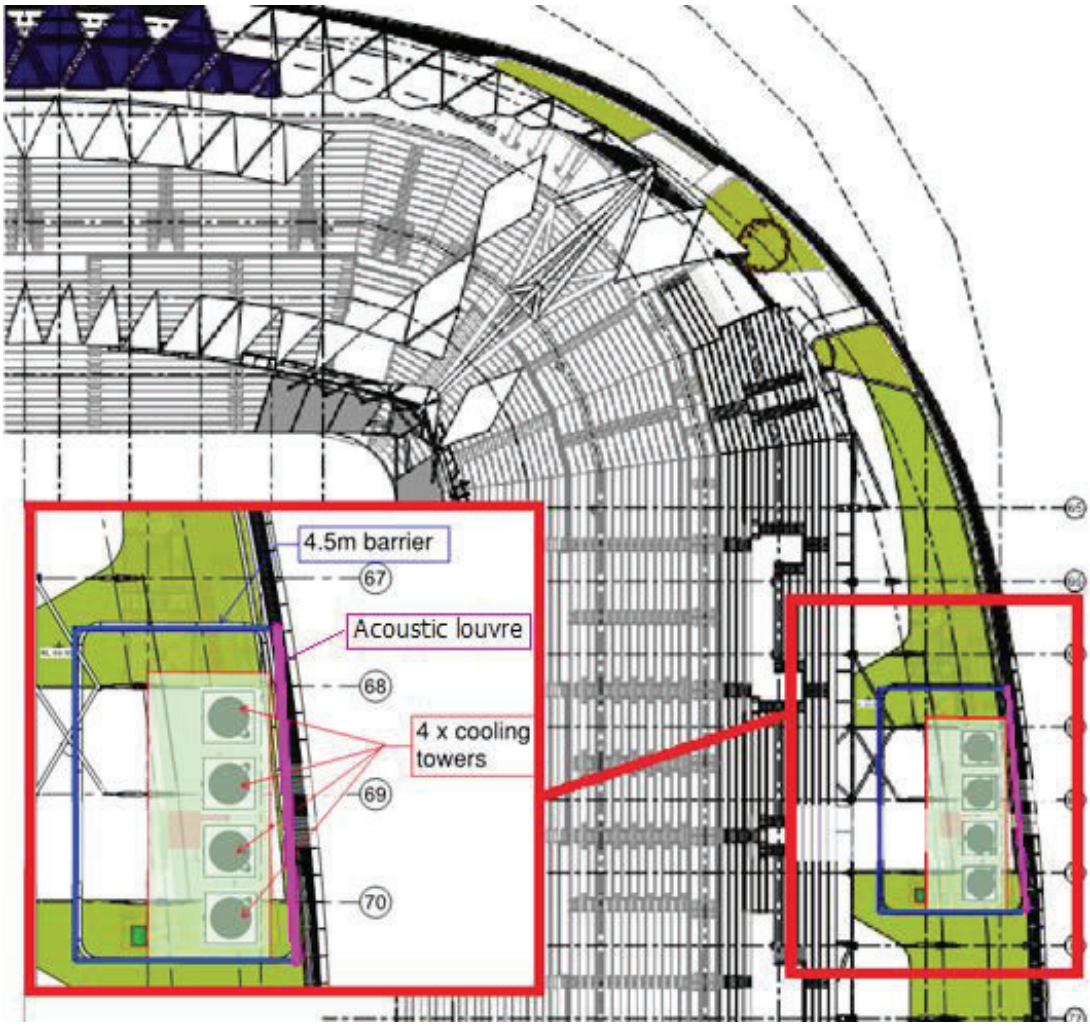

Figure 7: Cooling towers and barrier location – Plan view

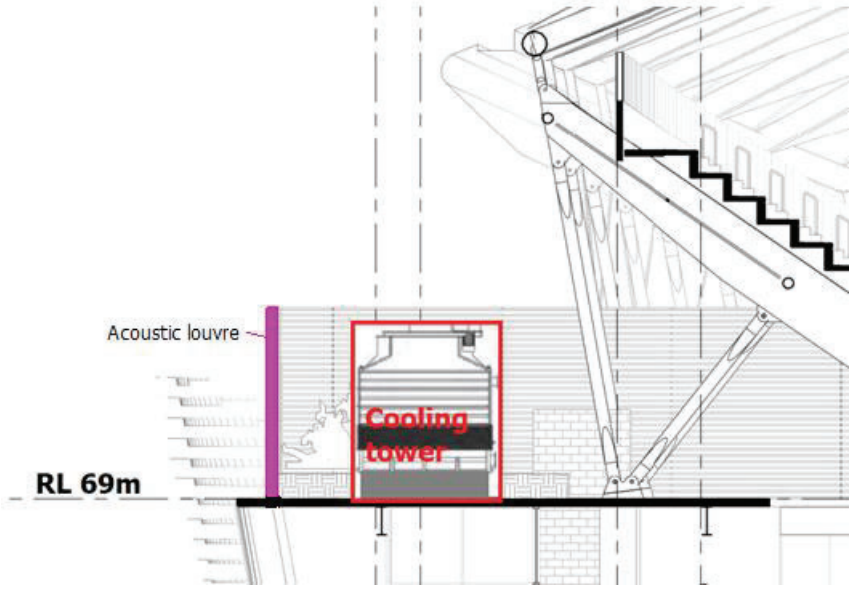

Figure 8: Cooling tower location – Section view

The sound power level of the cooling towers is given in Table 30. Cooling towers have conservatively been assumed to operate at 100% capacity at night, while actual capacity is likely to be lower, which would reduce noise levels.

Table 30: Cooling Tower Sound Power Data

Equipment	Overall L_w, dB(A)	Octave Band Sound Power – Hz, dBZ							
		63	125	250	500	1 k	2 k	4 k	8 k
Cooling Tower – one unit	98	109	107	102	94	90	84	79	70

Noise emission from the cooling towers has also been conservatively assessed against the NPI PANL night-time criteria. To meet the night-time criteria, acoustic louvres with the insertion loss indicated in Table 31 are recommended to be installed to the east of the cooling towers, shown in Figure 7.

Table 31: Cooling tower acoustic louvre - Minimum insertion loss

Basis of assessment	Octave Band Insertion Loss – Hz, dB							
	63	125	250	500	1 k	2 k	4 k	8 k
Insertion loss, eg. Fantech SBL1	-4	-7	-9	-13	-14	-12	-12	-8

Results with acoustic louvres installed on the cooling towers are presented in Table 32.

Table 32: Predicted Noise Levels - Cooling Towers – with acoustic louvres

Representative receiver	Predict. noise level, $dBL_{Aeq,period}$	Project Amenity Noise Level (PANL) $dBL_{Aeq,period}$	Comply
R1 - 749 South Dowling Street, Redfern	<20	51	Yes
R2 - 635 South Dowling Street, Surry Hills	<20	51	Yes
R3 - 553 South Dowling Street, Surry Hills	<20	51	Yes
R4 - 111 Greens Rd, Paddington	<20	47	Yes
R5 - 479 South Dowling Street, Surry Hills	<20	47	Yes
R6 - 252 Moore Park Road, Paddington	35	47	Yes
R7 - 314 Moore Park Road, Paddington	38	47	Yes
R8 - 45 Oatley Road. Paddington	25	40	Yes
R9 - 5 Poate Road, Paddington	31	35	Yes
R10 - 107 Cook Road, Centennial Park	<20	35	Yes
R11 - 2 Martin Road, Moore Park	<20	35	Yes

Results show the most stringent night-time criteria is expected to be met at each receiver. The extent to which compliance is demonstrated is also considered sufficient to allow for additional mechanical plant yet to be detailed at this stage of the project.

4.3.2 Operational car park activities

Noise emissions from activities within the external stadium car park, MP1, have been assessed. The proposed MP1 car park shown in Figure 9, largely covering the same footprint as the existing MP1 car park, is to have a total of 554 car park spaces.

Outside of event days, it is not anticipated that this car park would be full during the night period.

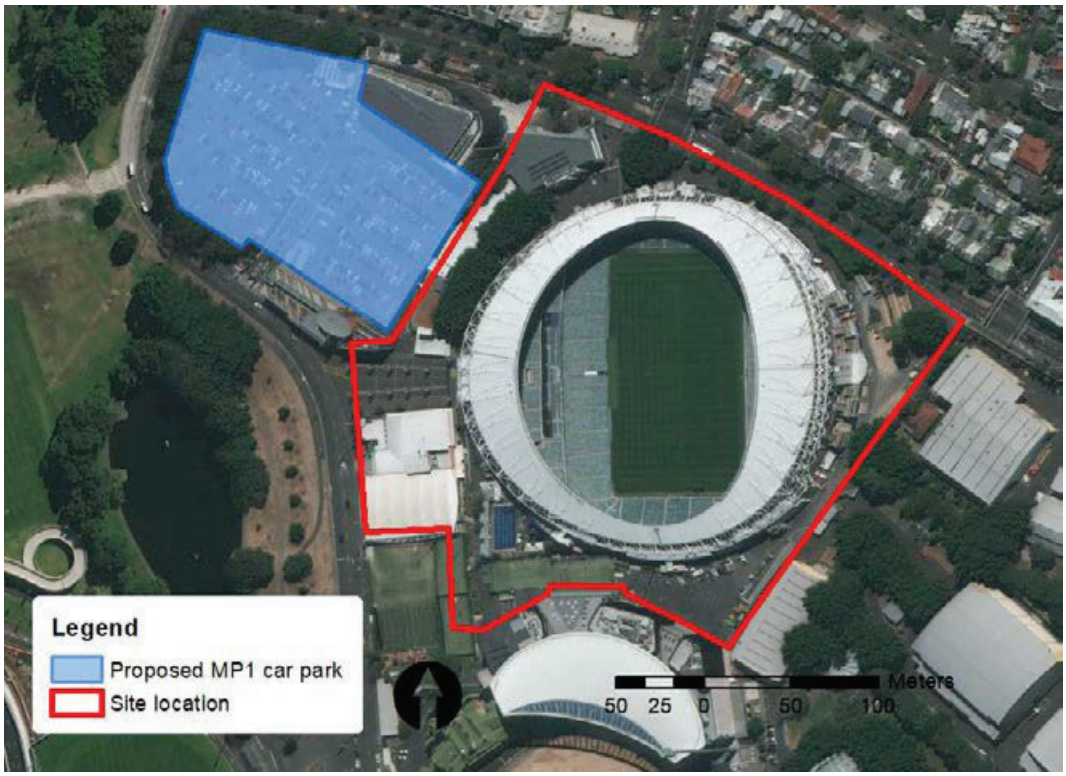

Figure 9: SFSR MP1 car park proposed location

Modelled car park noise sources are presented in Table 33.

Table 33: Car park noise sources and associated noise levels

Noise Source	Descriptor	Overall, dB(A)	Octave Band Centre Frequency, Hz, dB							
			63	125	250	500	1k	2k	4k	8k
Light vehicle travelling around car park	$L_{Aeq(15min)}$	68	82	71	66	64	61	62	56	52
Vehicle door slam	L_{Amax}	105	115	108	101	101	98	98	97	92

Predictions have been based on the conservative assumption that half the car park spaces filled within 15-minutes and it takes one minute per vehicle to enter site and park.

Noise due to car park activities has been assessed to night-time and sleep disturbance criteria at residential receivers. Results are presented in Table 34.

Table 34: Car park activity noise assessment

Representative receiver	Sleep disturbance assessment dBL_{Amax}			Intrusive/amenity assessment, $dBL_{Aeq\ (15min)}$		
	Predict. noise level	Criteria	Comply	Predict. noise level	Night Criteria[1]	Comply
R1 - 749 South Dowling Street, Redfern	25	62	Yes	<20	52	Yes

Representative receiver	Sleep disturbance assessment dBL_{Amax}			Intrusive/amenity assessment, $dBL_{Aeq\ (15min)}$		
	Predict. noise level	Criteria	Comply	Predict. noise level	Night Criteria[1]	Comply
R2 - 635 South Dowling Street, Surry Hills	30	62	Yes	<20	52	Yes
R3 - 553 South Dowling Street, Surry Hills	32	62	Yes	<20	52	Yes
R4 - 111 Greens Rd, Paddington	30	57	Yes	<20	47	Yes
R5 - 479 South Dowling Street, Surry Hills	43	57	Yes	<20	47	Yes
R6 - 252 Moore Park Road, Paddington	40	52	Yes	<20	42	Yes
R7 - 314 Moore Park Road, Paddington	19	52	Yes	<20	42	Yes
R8 - 45 Oatley Road. Paddington	26	52	Yes	<20	42	Yes
R9 - 5 Poate Road, Paddington	14	52	Yes	<20	37	Yes
R10 - 107 Cook Road, Centennial Park	15	52	Yes	<20	37	Yes
R11 - 2 Martin Road, Moore Park	22	52	Yes	<20	46	Yes

Note:

1 - The Intrusive Noise Criteria is considered to be most appropriate criteria given that the cars are likely to only be driving in the car park for a short duration relative to the overall period (in this case, the night-time period)

Results show compliance with sleep disturbance and intrusive/amenity noise criteria are predicted.

4.3.3 Operational traffic noise

The number of car park spaces is not proposed to increase under the SFS redevelopment. No increase in operational traffic is expected as a result of the redevelopment, as outlined in the Transport Assessment for Stage 2 Development Application [14]. No increase in noise from traffic generated by the day-to-day operations of the stadium is therefore anticipated.

4.3.4 Loading bay operations and waste & recycling collection

The loading bay is proposed in the basement of the stadium and, as such, noise generated by loading activities is not expected to impact upon surrounding development. Entry to the loading bay will likely be on the western end of the stadium, decreasing the likelihood of noise breakout affecting residences to the north.

There will be a requirement for Heavy Goods Vehicles (HGVs) to use specific routes for gaining access to the site, for both safety and noise management. HGVs will access the loading bay via Driver Avenue through the MP1 car park, shown in Figure 10:

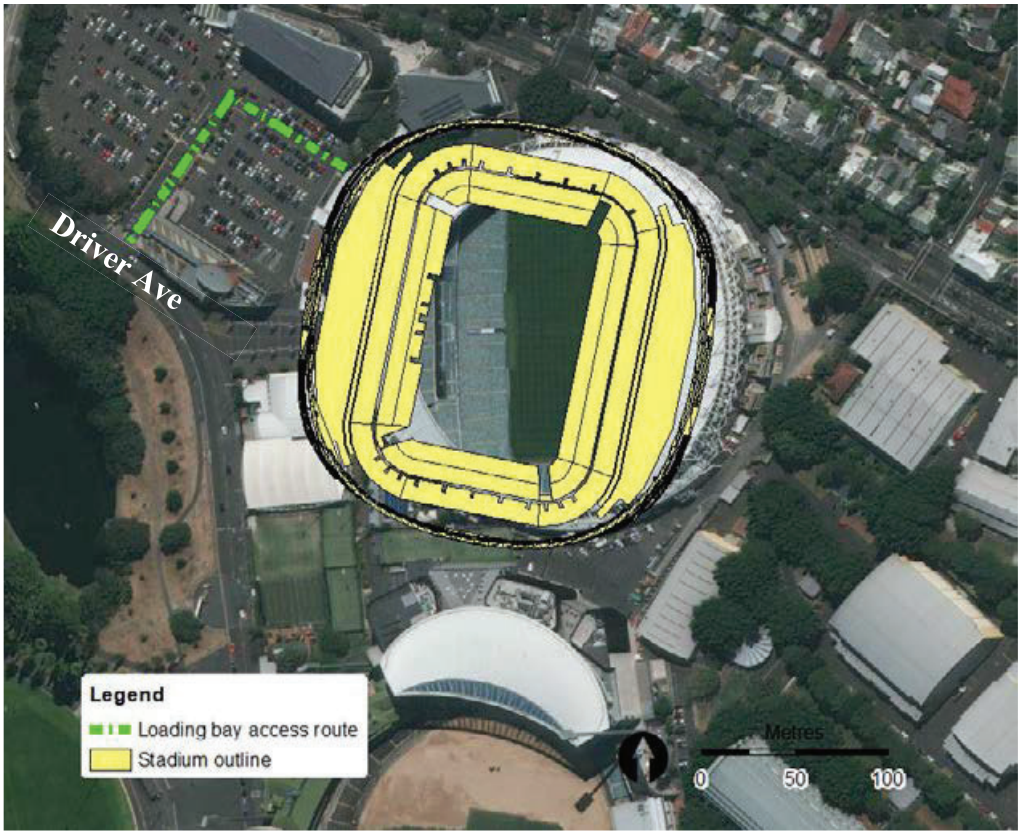

Figure 10: Loading bay access route

The following HGV movements are anticipated based on information provided by INSW:

- 2-3 per hour for typical event day and 1-2 per hour for non-event day
- A maximum of two vehicles in a 15-minute period, assuming one vehicle takes 1 minute to travel through the MP1 car park when arriving or leaving.

The noise from HGVs on-site has been based on Arup's project experience and measurement database and are presented in Table 35 and Table 36.

Table 35: Noise source levels – HGV accessing loading bay

Noise source	Noise descriptor	Sound power level based on continuous operation, dB(A)	Time corrected sound power level, dB(A)
HGV 14.5T waste removal truck driving forward at low speed	$L_{Aeq(15min)}$	92	83
	L_{Amax}	102	N/A

Table 36: HGV noise spectrum

Noise source	Overall, dB(A)	Octave Band Centre Frequency, Hz, dB							
		63	125	250	500	1k	2k	4k	8k
HGV	92	92	89	84	80	76	73	70	67

No impacts on sleep disturbance are anticipated as maximum noise levels due to HGV movements on site are not anticipated to be higher than noise from vehicle doors closing, assessed in Section 4.3.2.

The noise levels due to HGVs entering and leaving the loading bay via Driver Avenue at each receiver are presented in Table 37. An assessment against the most stringent night-time criteria is presented.

Table 37: Worst-care HGV predicted noise levels - accessing loading bay via MP1 car park

Representative receiver	**Night-time criteria[1]** $L_{Aeq,\ 15\ min}$	**Predicted noise level, dB(A)**	**Complies?**
R1 - 749 South Dowling Street, Redfern	52	<20	Yes
R2 - 635 South Dowling Street, Surry Hills	52	<20	Yes
R3 - 553 South Dowling Street, Surry Hills	52	<20	Yes
R4 - 111 Greens Rd, Paddington	47	<20	Yes
R5 - 479 South Dowling Street, Surry Hills	47	21	Yes
R6 - 252 Moore Park Road, Paddington	42	20	Yes
R7 - 314 Moore Park Road, Paddington	42	<20	Yes
R8 - 45 Oatley Road. Paddington	42	<20	Yes
R9 - 5 Poate Road, Paddington	37	<20	Yes
R10 - 107 Cook Road, Centennial Park	37	<20	Yes
R11 - 2 Martin Road, Moore Park	46	<20	Yes

Note:

1 - The Intrusive Noise Criteria is considered to be most appropriate criteria given that the vehicles are likely to only be driving on site for a short duration relative to the overall period (in this case, the night-time period)

Noise levels from HGVs leaving and entering the loading bay via the MP1 car park are expected to be well below night-time criteria. No specific noise management procedures are deemed to be required.

It should be noted that reversing movements by HGVs are not likely when the vehicles are entering or leaving the site due to the route configurations, and any noise due to reversing alarms will be contained within the underground loading bay.

4.3.5 Wind generated noise from stadium

There are many excitation mechanisms with the potential to generate wind-generated noise. There are two fundamental types of aero-acoustic noise: broad-band (a wide range of frequencies, general wind noise), and tonal noise (single frequency, whistling).

Broad-band noise

Broad-band is generated when flow passes over any sharp-edged obstruction such as a fin element. As flows are generally horizontally around a building, it is the number of vertical elements protruding from the façade that are of greater importance compared with horizontal elements. The more sharp-edges present along the facade, the greater the likely noise levels. Full-scale testing is not considered necessary for the mitigation of noise via this mechanism but a desktop review should be conducted.

Narrow-band noise

There are a large number of known mechanisms that can generate narrow-band, or 'tonal' noise, some of which include:

- whole-body vibration of elements through the vortex shedding process at a natural frequency in the audible range - this can occur on a range of elements from cables, similar to a stringed instrument, to larger plate elements, similar to a wobbleboard
- flow passing through small gaps and holes - the frequency of shedding can be in the audible range, and further amplified through the structural dynamic properties of the porous element
- flow passing over continuous slots – this produces a quarter-wave resonator, similar to blowing over an empty bottle
- flow through parallel plates - the vortex shedding frequency from parallel plates generates a resonant pressure effect, propagating upstream and downstream from the plates. This mechanism is dependent on geometry and air speed, and independent of the structural dynamic properties of the plates
- resonant pressure effects - such as Helmholtz resonators, similar to the noise generated in a car with a window slightly open

Recommendations to mitigate the occurrence of wind-induced façade noise are presented in Section 5.9.1.

5 Event noise

This section addresses noise sources associated with the events at the SFS, defined as entertainment activities carried out outdoors with sound amplification equipment used as part of the activity, including associated activities with sound amplification equipment such as rehearsals and sound checks.

5.1 Comparison to existing stadium

The existing Allianz Stadium is a multi-purpose sporting and entertainment venue which hosts a range of events throughout the year. A comparison of the proposed SFS with the existing Allianz Stadium is presented in Table 38.

Table 38: Allianz Stadium and Sydney Football Stadium comparison

Description	**Current Allianz Stadium**	**Proposed Sydney Football Stadium**
Capacity	45,000	45,000
Stadium shape	Saddle shape	Bowl shape
Event time restrictions	Table 39	No change
Number of concert events	4 per calendar year averaged over any five year period, and 6 over any 12-month period.	No change

While the proposed SFS will retain a capacity of 45,000, the change in shape from the current ‘saddle’ to a ‘bowl’, which has higher tiered seating stands and facades to the north and south, will reduce environmental noise emission to the surrounding environment. This is also anticipated to retain sound within the bowl, enhancing the overall acoustic atmosphere within the Stadium.

Like the current stadium operation, the most significant noise sources emanating from the new stadium are expected to include:

- Music and announcements from sound amplification systems during sporting and concert events; and
- Crowd noise during sporting and concert events.

5.2 Number of events

The combined number of concerts held on Trust land, which includes the SCG and the SFS, must not exceed an average of four (4) concerts per calendar year averaged over any five (5) year period, and must not exceed six (6) concerts over any twelve-month event period. For the purposes of this condition, the term ‘twelve-month event period’ means the period of twelve months after 1 January 2020, and each subsequent period of 12 months.

In line with the existing Notice of Preventative Action, and due to the more stringent noise limit for non-concert events and less ‘intrusive’ nature of non-concert event noise, no limit for the number of non-concert events applies. A noise management system for individual events is proposed for all events to take place at the SFS, and that the number of events will not increase the noise emissions on the locality on an event-by-event basis.

5.3 Noise criteria

5.3.1 Current stadium event criteria

A Notice of Preventative Action (1003904 18 January 2017) [15] outlines noise management measures required for Allianz Stadium (Development Consent Conditions (SSD 9249 6 December 2018), which are captured in the Allianz Stadium Noise Management Plan (NMP) [16].

The Notice of Preventative Action includes requirements pertaining to sporting events, concert events and other events held at the stadium, including:

- Requirement for a NMP and its contents
- Complaint management procedure
- Noise monitoring requirements
- Event time limits
- Noise limits
- Reporting requirements
- Agency and community notification requirements

5.3.2 Alternative management framework

A noise management framework is proposed for the SFSR, which will establish a more technically robust method of assessing noise egress from the SFSR in real time and provide a mechanism to respond to incidents rapidly, and potentially in a pre-emptive manner. This approach will give more control over regulation of noise to event operators and provide the community with confidence that compliance to limits can be achieved.

In accordance with Consent Conditions, appropriate noise limit parameters, as well as the proposed noise management system have been developed in consultation with the EPA and DPE. This is evidenced by:

- The provision of the memo “SFSR Alternative noise management framework” (Arup, March 2019) to the EPA and DPE, which presented a discussion of appropriate noise limit parameters, measurement data analysis, proposed event criteria and a management procedure.
- A meeting with the EPA and DPE on 5 April 2019 to discuss the outcomes of the memo.
- Receipt of key issues required to be addressed by the EPA in relation to the alternative noise management framework in an email from DPE to INSW (Sydney Football Stadium Stage 2 - alternative noise management framework, 16 April 2019).

Discussion pertaining to the development of the alternative noise management framework, developed in consultation with the DPE and EPA, is presented below.

A fact sheet summarising the existing and proposed management framework is presented in Appendix E.

5.3.2.1 Noise descriptor and period

Measurement descriptor

The current L_{max} descriptor is not considered ideal in assessing noise at nearby receivers due to its limitation in describing the noise exposure over time. The descriptor evaluates the sound level over a period less than 1 second and therefore excursions over a set limit may not be representative of the general trend of noise exposure. Use of the L_{max} parameter under the current Notice of Preventative Action [15], while not being ideally representative, is necessitated by the current management procedures which rely on attended noise monitoring at receiver locations that are affected by other noise. The influence of other ambient noise means that it is not possibly to readily separate event noise from the ambient condition over an extended period. Measurement of event noise only in quieter periods, such as between passing traffic, while challenging, is more readily achievable.

The L_{eq} descriptor, which represents the average noise energy over the relevant period of measurement, presents a better representation of on-going noise exposure over the course of an event, as it takes account of peak noise levels as well as the degree of noise fluctuation. This descriptor is most widely correlated with the subjective effect of noise (Miedema and Vos [17]), and is the primary assessment parameter used in assessment of industrial noise, construction noise, road traffic noise and rail noise in NSW, as well as the assessment of music noise for comparable venues such as Western Sydney Stadium. Use of the L_{eq} descriptor is enabled by the proposed adoption of a real-time noise monitoring system removed from other extraneous ambient noise.

Measurement period

When using an L_{Aeq} to assess noise exposure, the time-period of averaging becomes relevant. Typically, environmental noise measurements are made over a period of 15 minutes or longer, however for a concert this may only equate to 8 or 10 measurements.

A measurement period of 5-minutes is considered more appropriate for event noise, and it will provide more regular intervals of assessment and evaluation. This shorter measurement period will also facilitate a quicker response process for the management of noise emission.

Equivalent $L_{Aeq(5min)}$ noise limit

To determine the appropriate conversion from previous L_{Amax} levels to $L_{Aeq(5min)}$ levels, the difference between L_{Amax} and L_{Aeq} noise levels for concert noise was quantified based on the most recent events at Allianz Stadium. 4 minute noise measurements were conducted during concert events, which are materially equivalent to 5 minute data.

The difference between $L_{Amax(4min)}$ and $L_{Aeq(4min)}$ levels from the most recent measurement data from concert events at Allianz Stadium was plotted against $L_{Aeq\ (4min)}$ levels. Plots showing these relationships as well as lines of best fit in red are presented for four concert events in Figure 11.

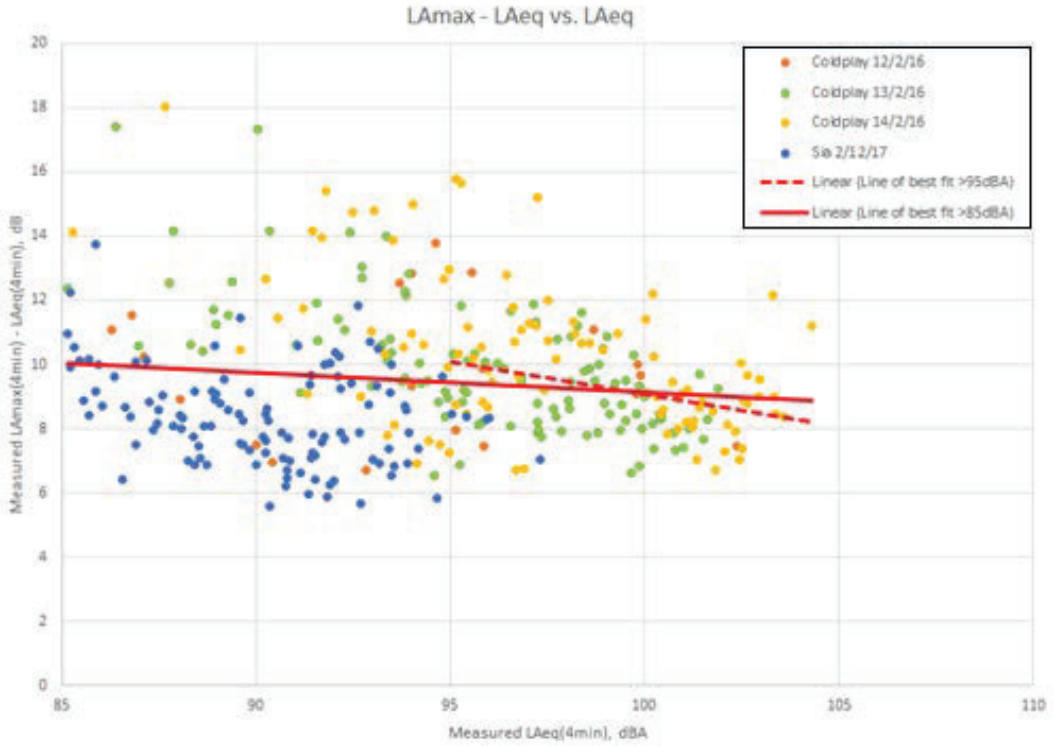

Figure 11: Measured FOH L_{Amax} - L_{Aeq} plotted against L_{Aeq}, recent concerts at Allianz Stadium

Figure 11 shows that $L_{Amax} – L_{Aeq}$ levels vary largely, as expected. Differences of up to 18 dB are measured, however these higher differences correlate with lower L_{Aeq} levels. High noise levels (above 95 dBL_{Aeq}) are more critical as they relate to the higher exposures at surrounding receivers. Accordingly, a separate line of best fit is presented for this data set.

The both lines of best fit decrease from approximately 10 dB to below 9 dB at the highest recorded L_{Aeq} levels.

The downward trending line of best fit indicates that the higher the L_{Aeq} level in a concert event, the smaller the difference between L_{Amax} and L_{Aeq}. The average difference between L_{Amax} and L_{Aeq} levels is shown to be between approximately 10 dB and 9 dB, with a smaller difference at higher overall noise levels.

Accordingly, the proposed $L_{Aeq(5minute)}$ noise limits have been set 10 dB lower than the existing L_{Amax} limits.

Low-frequency noise

To quantify the low-frequency component of noise emissions (‘bass’), the C-weighting scale, rather than the A-weighting scale, is utilised in the existing Notice of Preventative Action [15] as it is in the NSW Noise Policy for Industry [1].

However, in consultation with the EPA and Department of Planning and Environment, a single 63 Hz 1/1 octave $dBL_{Zeq(5min)}$ has been nominated as their preferred low-frequency assessment parameter, siting the following reasons:

- Front-of-house measurements taken during recent concerts at Allianz Stadium (Table 42) show that the dominant octave band noise levels occur at the 63 Hz octave band. The dominance of this octave band over higher octave bands, would be more

pronounced at the nearest receivers, due to propagation and shielding effects from the stadium bowl. This is confirmed by the noise modelling carried out for the SFSR.

- To support the proposed remote noise monitoring system, which are to be located on the stadium, the noise level difference between the intermediate monitoring location and nearest receiver will be more easily established for a single octave band than for a broadband noise level.
- For typical concert noise sources, the 63 Hz 1/1 octave $dBL_{Zeq(5min)}$ is considered representative of the dB(C) weighted broadband level, as illustrated by noise measurement data in Table 42 where 63 Hz 1/1 octave $dBL_{Zeq(5min)}$ are within 3 dB of dB(C) levels, and generally within 1 or 2 dB. Existing noise limits for Allianz Stadium have a dB(C) minus dB(A) differential of 20 dB, therefore a 63 Hz 1/1 octave $dBL_{Zeq(5min)}$ minus $dBL_{Aeq(5min)}$ level is considered an equivalent conversion of existing requirements.
- Results in Table 45 show that a $dBL_{Zeq(5min)}$ minus L_{Aeq} difference of 20 dB is achievable.

Non-concert event noise limits

The existing noise limit for non-concert events such as sporting events is L_{Amax} 60 dBA, which is considered both too stringent and impractical to achieve at most potentially affected residential receivers along Moore Park Road. Measured L_{Amax} levels on Moore Park Road due to existing road traffic noise are generally over 80 dBA, and often over 90 dBA (detailed noise monitoring results in "2018-06-05 - AC01-v5_SFSR_Noise and Vibration Impact Assessment" [5]). The previous L_{Amax} noise limit of 60 dBA is therefore considered unnecessarily stringent when considering the existing ambient noise environment at sensitive receptor locations.

Additionally, the monitoring and regulation of L_{Amax} levels of 60 dBA is impractical, as PA noise emission at these levels would not be readily measurable in the existing ambient noise environment.

Consistent with the concert events criteria proposal, an $L_{Aeq(5min)}$ level is proposed for PA system noise at the nearest receivers.

An $L_{Aeq(5min)}$ 60 dBA is considered an appropriate noise limit for PA noise from regular (typically weekly) sporting events based on the following:

- Based on modelling and measurements at Allianz Stadium, PA noise levels at receivers along Moore Park Road are predicted to be up to $L_{Aeq(5min)}$ 60 dBA,
- Established criteria of RBL + 10 dB for the recent Western Sydney Stadium development, would result in a daytime criterion of 62 dBA and an evening and night time criteria of 59 dBA at the worst affected residential receivers along Moore Park Road.
- Existing ambient noise levels due to traffic along Moore Park Road of 68 dBA, 66 dBA and 64 dBA were measured during the day, evening and night respectively, i.e. $L_{Aeq(11hr)}$, $L_{Aeq(4hr)}$ and $L_{Aeq(9hr)}$.

5.3.2.2 Assessment method

To avoid the need for onerous attended noise monitoring at nearby receivers to determine event noise emissions, the use of permanent noise monitors within the site boundary,

specifically on or near the stadium façade or roof, are proposed. Noise monitors located at intermediate locations close to or within the stadium envelope can be established, with noise limits adjusted based on their closer proximity and relationship to the site. Such monitoring can provide indication of levels at receivers, while minimising the influence of extraneous noise such as pedestrians and passing traffic at the receivers.

The advantages of using a permanent noise monitoring system made up of several loggers installed within the site boundary are:

- Removing the need for onerous attended noise monitoring;
- Allowing assessment of noise emission at multiple assessment locations simultaneously;
- Minimising the influence of extraneous noise, e.g. traffic noise or pedestrian noise, affecting measurements;
- Allow for real-time feedback and a direct display of measured levels to event operators.
- Provide consistency and standardisation of measurement approach allowing for progressive review and refinement of the monitoring system.

Requirements of the technical specifications, implementation and maintenance of this system are presented in the draft NMP, Appendix G.

5.3.2.3 Times limits and length of events

Time limits of sporting, concert and other events are not proposed to change from those which currently apply to events at Allianz Stadium, outlined in the Notice of Preventative Action [15].

A summary of proposed event time limits is provided in Table 39.

Table 39: Event time limits

Descriptor	Time limits			Maximum length of event
	Not to commence before	Not to finish after	If delayed outside of the Trust's control, may continue till	
Sporting events	8:00 AM	10:30 PM	11:00 PM	-
Concerts	10:00 AM	10:30 PM	11:00 PM	5 hours
Rehearsals	10:00 AM	7:00 PM	-	Kept to absolute minimum
Sound tests	10:00 AM	7:00 PM	-	Kept to absolute minimum
Other outdoor event with sound amplification – days preceding working days	10:00 AM	8:00 PM	-	-

Descriptor	Time limits			Maximum length of event
	Not to commence before	Not to finish after	If delayed outside of the Trust's control, may continue till	
Other outdoor event with sound amplification – days **not** preceding working days	10:00 AM	10:30 PM	-	-

5.3.2.4 SFSR proposed event noise limits

Event noise limits are proposed in the form of $L_{eq(5min)}$ levels based on the considerations presented in the Sections above.

Proposed event noise limits for noise sensitive receivers are presented in Table 40.

Table 40: Event noise limits for noise sensitive receivers

Receivers	Descriptor	Amplified sounds during concert event		Amplified sounds during sporting / other event
		dBA	1/1 octave, 63Hz dBZ	dBA
Property boundary of all noise sensitive receivers[1]	$L_{eq(5min)}$	70	90	60

1. Identified in Section 2.1.

Consistent with the existing noise limits for Allianz Stadium, noise limits for events at the SFS apply to noise from amplified sound systems only. This reflects the community's sensitivity to amplified noise, as well as the venue's capacity to control amplified noise, as opposed to crowd noise for which opportunities are more limited. Although no noise limits apply to crowd noise emissions from the SFS, no increase in noise levels are anticipated compared to the existing Allianz Stadium.

A proposed methodology for assessing noise from amplified sound systems is described in the draft NMP, presented in Appendix G

5.4 Noise sources

5.4.1 Amplified sound systems

For the assessment of the SFSR against the modelled amplified sound system sources are:

Sporting events

- Announcements and music over the in-house Public Address (PA) system.

Concert events

- Music playing over concert sound system

Noise measurements were conducted by Arup at the existing Allianz Stadium. A summary of measured event sound pressure levels is presented in Table 41 and Table 42.

Table 41: Sporting event noise measurement summary (Allianz Stadium)

Description	Duration, mins	Measured L_p in crowd, dBL_{Aeq}	Approx. contribution of PA noise dBL_{Aeq}	Measured sound pressure level in crowd, dBL_{Zeq}								
				Octave band, Hz								
				31.5	63	125	250	500	1k	2k	4k	8k
Anzac Day Rugby League match - 25-Apr-18												
Post-try music and announcements including crowd noise.	2:11	85	82	67	79	84	81	82	80	78	71	60
	1:33	82	79	68	81	81	80	81	76	74	68	58
	1:30	86	83	66	80	77	79	83	83	79	72	62
	1:52	86	83	64	76	75	78	83	82	79	75	62
Waratahs vs. Stormers Rugby Union match - 24-Feb-18												
Half time music and announcements including crowd noise.	10:08	83	80	35	51	59	69	78	79	75	69	56
Second half resuming announcements including crowd noise.	0:54	83	80	45	59	62	73	78	78	75	70	58
Post-try music and announcements including crowd noise.	0:55	84	81	45	58	61	69	79	79	78	71	57
	0:33	81	78	40	54	58	66	75	77	77	68	57

Table 42: Concert event noise measurement summary

Event	Description	Measured front of house sound pressure level											
		90th percentile during event	Max. during event		Octave band, Hz								
					31.5	63	125	250	500	1k	2k	4k	8k
					Max. during event								
		$dBL_{Aeq(4min)}$	$dBL_{Aeq(4min)}$	$dBL_{Ceq(4min)}$	$dBL_{Zeq(4min)}$								
Coldplay - concert 12 Feb 2016	Dominated by music but included crowd noise. Loudest recorded 4 minutes[1] during concert	95	102	110	94	108	101	97	100	99	95	87	81
Coldplay - concert 13 Feb 2016		100	102	108	93	106	94	95	99	99	92	85	81
Coldplay - concert 14 Feb 2016		102	104	108	93	105	96	98	102	102	94	86	82
Sia - rehearsal 1 Dec 2017		89	93	108	96	107	100	89	91	85	82	78	77
Sia - concert 2 Dec 2017		92	97	109	98	109	99	92	90	95	88	80	78

Note:

1 – Based on available four minute measurement data, which is considered representative of five minute data..

5.4.2 Pyrotechnics

Pyrotechnics displays also occasionally take place during large events at the SFS. Noise management measures from these displays are recommended to be consistent with current procedures in the form of notification to the SCG Trust, community notification and time limits. and form part of the draft NMP, presented in Appendix G.

5.5 Stadium design and operation

The proposed SFS would be a three-tiered bowl design, with approximate capacities of 30,000 seats on the lower and mid tiers, and 15,000 seats on the upper tier, with a total of up to 45,000. In concert mode, additional patrons will be standing on the pitch raising the capacity to 55,000.

A detailed description of the acoustic modelling is given in Section 5.6.1.

5.5.1 Stadium roof

The stadium will incorporate a ring-style roof which will cover the seating areas. The roof material shall be Polytetrafluoroethylene (PTFE) which is effectively acoustically transparent. Accordingly, a roof has not been included in the noise modelling of the stadium.

If a solid roof was to be provided, preliminary designs indicate that it would have a vertical opening between the underside of the roof and the upper tier seating, in the order of 5 metres. This conceptual design was also modelled and revealed noise level reductions at the nearest affected receivers of less than 2 dB, being a barely perceptible change to the average person.

The stadium roof is not considered a reasonable or feasible mitigation measure for the control of noise emissions.

5.5.2 Operational modes

Sporting events

The SFS is proposed to operate in two modes when hosting sporting events; championship mode and club mode, representing both a full stadium and a crowd of approximately 30,000 respectively (top tier not occupied). Since only noise from the in-house PA system has been assessed, only one sporting event scenario has been modelled with music and announcements playing over the in-house PA system.

A notional configuration of an in-house PA system has been included in the model, modelled along the inside edge of the roof directed towards the crowd. A rendering of the stadium noise model showing the locations of the in-house PA system is shown in Figure 5.

Concert events

Concert events to take place at the SFS will involve the main concert event with patron attendance, as well as associated sound test and rehearsals. These activities will utilise a concert sound system, which will be provided by the event promoters/producers.

Three notional configurations for concert sound system setups have been used for noise emission modelling:

1. Typical configuration: speakers are located at the north facing south, away from the nearest most potentially affected receivers along Moore Park Road.
2. Non-typical configuration A: Speakers located at the centre
3. Non-typical configuration B: Speakers located at the south of the stadium.

In both the north and south scenario, four front of house speakers have been placed at the stage with three delay speakers located further back in the crowd, indicative of a typical sound system configuration for a large arena style concert.

All configurations are presented in Figure 12 below.

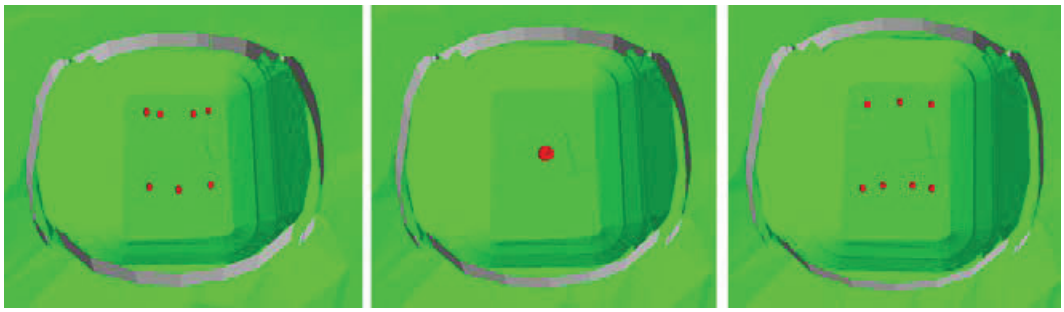

Figure 12: Speaker configuration located north facing south (left), centre facing outwards (middle) and south facing north (right)

The capacity of the stadium during concert events is 55,000.

5.6 Modelling methodology

Noise emissions from events taking place at the SFS have been assessed to noise limits outlined in Section 5.3.

Noise emissions have been modelled using SoundPlan 8 using the ISO 9613-2 algorithm, which is considered appropriate for this scenario with nearest receivers located within 100 metres of the noise sources.

The model included:

- Event noise sources listed in Section 5.4;
  - In-house PA speakers modelled as point sources as described in Section 5.5.2;
  - Concert sound systems have been modelled as point sources shown in Figure 12, and adjusted in the model to give representative sound levels within the crowd itself;
- SFS and surrounding buildings;
- Receivers listed in Table 5; and
- Ground terrain and absorption.

A 3D rendering of the noise model is presented in Figure 13.

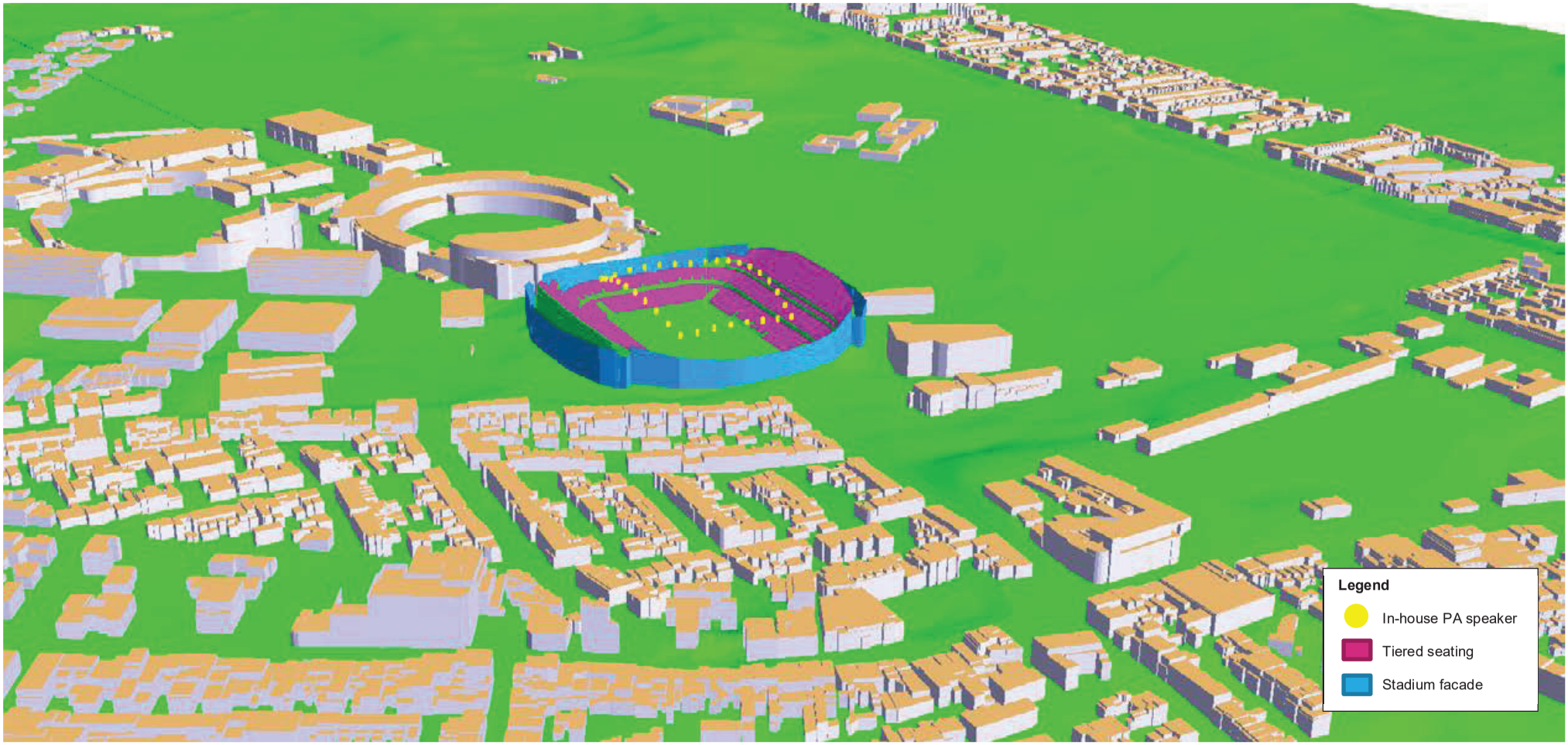

Figure 13: 3D render of noise model – facing south

5.6.1 Modelling assumptions

The following conservative assumptions have been made in the development of the noise model:

- Modern speaker arrays allow increasingly precise control over speaker directionality when placed in line arrays, such as in concert speakers stacks and possibly for in-house PA speaker configurations. Each speaker within the noise model has been assigned with directionality attributes for an individual speaker, where line arrays will be more directional, providing greater control of noise spill from the rear of speakers.
- A roof has not been modelled as discussed in Section 5.5.1. A minor reduction of 1-2 dB in noise emissions from predicted levels is expected from an acoustically opaque roof with a 5 m gap between the roof edge and top of facade.
- The ISO 9613-2 algorithm assumes a source to receiver wind speed between approximately 1 m/s and 5m/s at a height of 3 metres to 11 metres above the ground. Although this may not significantly affect noise predictions at the nearest receivers within 100 metres from the stadium, noise levels at further receivers are likely to be lower under neutral meteorological conditions.

5.6.2 Modelled scenarios

Noise source spectra used in modelling of events is presented in Table 43, based on an average maximum noise event for a large scale concert and typical sports event measurements presented in Table 42. Sound power levels of each source have been set, such that Sound Pressure Levels (L_p) within the crowd match those presented in Table 44 below.

Table 43: Modelled event noise source spectra dBL_{eq5min}

Noise source	Overall		Octave Band Centre Frequency, Hz							
			63	125	250	500	1k	2k	4k	8k
	dBA	dBC	dBZ							
Concert noise - capacity crowd and music (Coldplay concert – Allianz Stadium) - L_p	104	115	115	102	99	99	101	96	89	83
Sports event noise - post-try music and announcements (Anzac Day rugby league match – Allianz Stadium) - L_p	80	84	74	79	76	77	75	73	66	55

The following event scenarios have been modelled to capture the loudest 5 minute event of an average sporting and concert events which may take place at the SFS.

Table 44: Modelled event scenarios and crowd noise levels

Event type	Modelled noise sources	Mode	Sound pressure level in crowd	
			$dBL_{Aeq(5min)}$	1/1 octave, 63Hz dBL_{Zeq}
Sporting	Sports event noise over directional point sources representing the House PA System	PA System only	80	74
Concert	Concert noise over directional point sources representing concert speaker arrays as presented in Figure 12	Speakers located north facing south	100	111
		Speakers located centre facing outwards	100	111
		Speakers located south facing north	100	111

5.7 Results

Predicted noise levels have been assessed to established noise limits below. Results are shown graphically in noise contour maps presented in Appendix F.

5.7.1 Concert events

5.7.1.1 Typical operational mode – Speakers at north end facing south

Predicted noise levels from concert events are presented in Table 45 below.

Table 45: Concert event noise assessment – Typical concert mode

Representative receiver	Predicted noise level[1]	
	$dBL_{Aeq5min}$	$dBL_{Zeq5min}$ at 63 Hz
Noise limit	**70**	**90**
R1 - 749 South Dowling Street, Redfern	68	85
R2 - 635 South Dowling Street, Surry Hills	65	83
R3 - 553 South Dowling Street, Surry Hills	63	81
R4 - 111 Greens Rd, Paddington	58	76
R5 - 479 South Dowling Street, Surry Hills	62	79
R6 - 252 Moore Park Road, Paddington	68	80
R7 - 314 Moore Park Road, Paddington	67	85
R8 - 45 Oatley Road. Paddington	62	73
R9 - 5 Poate Road, Paddington	67	85
R10 - 107 Cook Road, Centennial Park	68	86
R11 - 2 Martin Road, Moore Park	63	82

Notes:

1 - Noise levels shaded in grey indicate an exceedance of noise limit

Results show that during concert events, when speakers are located at the north of the stadium, predicted noise levels at all locations comply with both the $L_{Aeq5min}$ and $L_{Zeq5min}$ 63 Hz 1/1 octave noise limit at all receivers.

5.7.1.2 Non-typical operational mode – Middle / South speaker configuration

As part of the modelling process, alternative speaker locations were assessed to investigate flexible event scenarios. The scenarios represent the worst-case results based upon all investigated configurations. It should be noted that middle and southern speaker configurations are unlikely.

Two additional non-typical speaker layouts were assessed, speakers located in the middle of the stadium facing outwards, and speakers located at the south of the stadium facing north, as shown in Figure 12.

In non-typical loudspeaker configurations, the following was revealed:

- $L_{Aeq5min}$ criteria - exceedances of up to 9 dB are predicted at the worst affected receivers.
- $L_{Zeq5min}$ 63 Hz criteria - exceedances of up to 8 dB are predicted at the worst affected receivers.

Notwithstanding the above, it may be possible to operate with non-typical speaker configurations while complying with event noise limits should care be taken to adequately control noise emission through implementation of mitigation measures, which may include operating speakers at lower volume.

5.7.2 Sporting and other events

Predicted noise emissions from PA noise during sporting events are presented in Table 46 below.

Table 46: PA noise assessment

Representative receiver	**Predicted noise level - dB$L_{Aeq5min}$**
Noise limit	**60**
R1 - 749 South Dowling Street, Redfern	46
R2 - 635 South Dowling Street, Surry Hills	47
R3 - 553 South Dowling Street, Surry Hills	48
R4 - 111 Greens Rd, Paddington	47
R5 - 479 South Dowling Street, Surry Hills	52
R6 - 252 Moore Park Road, Paddington	60
R7 - 314 Moore Park Road, Paddington	56
R8 - 45 Oatley Road. Paddington	60
R9 - 5 Poate Road, Paddington	52
R10 - 107 Cook Road, Centennial Park	48
R11 - 2 Martin Road, Moore Park	43

Results indicate that during sporting events, PA noise emission at all locations can comply with noise limits.

5.7.3 Comparison of existing Allianz Stadium and proposed SFS

A comparison of the noise emission from the existing Allianz Stadium and the proposed SFS development has been carried out.

Noise emission at the reasonably most-affected receivers has been calculated using the following parameters:

- Measured internal noise levels in stadium. See Section 5.4;
- Acoustic performance of Allianz stadium's envelope, predicted using simultaneous measurements taken within stadium and at 252 Moore Park Road; and
- Acoustic performance of SFS's envelope, simulated using noise modelling, see Section 5.6. It should be noted this prediction is conservative, with assumptions outlined in Section 5.6.1.

It should be noted that sporting event noise emissions from the SFSR have been modelled based on noise from the in-house PA system alone, which is located along the inside roof line of the stadium, whereas noise sources present during measurements at Allianz Stadium included crowd noise. Predicted results are therefore considered conservative.

Table 47 presents the predicted noise levels at existing Allianz Stadium and proposed SFS at the worst affected receiver.

Table 47: Existing Allianz Stadium and proposed SFS comparison of sporting event noise emissions- dBL_{eq5min}

Noise source	Overall		Octave Band Centre Frequency, Hz							
			63	125	250	500	1k	2k	4k	8k
	dBA	dBC	dBZ							
Within stadium bowl										
Modelled L_p	80	90	89	82	78	77	77	71	57	40
At worst affected receiver -R6 – 252 Moore Park Road										
L_p based on measured transfer function - Allianz stadium	64	75	64	74	66	58	56	53	45	37
Predicted L_p - SFSR	60	61	36	47	51	57	56	53	43	21

The assessment indicates that the proposed SFS provides improvement to environmental noise control compared with the existing SFS.

5.7.4 Double header sporting events – SCG and SFS

Predictions have been carried out to quantify the cumulative noise emission from simultaneous sporting events occurring at both the SCG and proposed SFS. Concerts and sporting events however do not occur under double header scenarios.

As only PA noise is assessed during sporting events, noise levels from PA systems alone have been assessed.

Predicted noise levels at selected reasonably most-affected receivers are provided in Table 48 below.

Table 48: PA noise predictions for SCG and SFS – $dBL_{Aeq5min}$

Receiver	Predicted noise level		
	SCG – PA noise	SFS – PA noise	Combined noise level
R6 - 252 Moore Park Road, Paddington	35	61	61
R8 - 45 Oatley Road, Paddington	32	59	59
R9 - 5 Poate Rd, Paddington	36	53	53

Results indicate noise levels from the SCG are more than 10 dB below that emitted from the proposed SFS, and as presented, do not result in any cumulative emissions. Furthermore, the infrequency of double headers, along with the low likelihood of PA systems from both venues operating simultaneously mean the likelihood of cumulative emissions is very low.

5.8 Discussion

5.8.1 Overall assessment

Compared with the current Allianz Stadium, the SFS redevelopment is not expected to increase noise emission, and therefore no additional or significant acoustic issues are expected. This is supported by the noise assessment, which indicates compliance with established noise limits for concerts and sporting events.

Recommended event noise mitigation measures are outlined in Section 5.9.

In assessing the predicted noise emission from the proposed SFS, the following factors should be taken into consideration:

- Event noise is a feature of the area, with Allianz Stadium and the Sydney Cricket Ground both currently operational. The area has hosted sporting events for over 150 years;
- The proposed SFS will retain the same number of seats as the existing Allianz Stadium;
- Change to the shape of the stadium, namely from the ‘saddle’ shape to a more traditional ‘bowl’ with a higher tiered seating and façade at the north of the stadium, is not predicted to result in an increase in event noise levels to surrounding receivers;
- No changes to current event time limits for Allianz Stadium are proposed. Events are not to finish after 10:30 pm, with a possible extension to 11:00 pm if events are delayed outside of the Trust’s control, as presented in Table 39; and
- Aa number conservative assumptions have been made in this assessment methodology which are likely to mean noise emission may be lower than predicted in this assessment (discussed in Section 5.6.1).

It follows that no increases to current noise emission are predicted with redevelopment of the SFSR.

5.8.2 Concert events

Noise limits have been established based on the considerations discussed in Section 5.3. Predicted $L_{Aeq(5min)}$ noise levels indicate compliance with proposed noise limits at all receivers under a typical concert speaker configuration.

Under a non-typical speaker configuration, where speakers are not located at the north of the stadium facing south, noise emission is expected to increase by up to 9 dB for the same internal noise level within the stadium. If non-typical configurations are to be utilised, noise mitigation and management measures are required to comply with noise limits, which are outlined in Section 5.9.

Predicted noise levels from the SFSR have been compared with the exiting Allianz Stadium, and conservative predictions indicate noise levels at the reasonably most-affected receivers would be no worse for the proposed SFS.

Concurrent operation of the SCG would not occur during concert events at the SFS.

To manage noise levels during concerts, mitigation measures are outlined in Section 5.9.

5.8.3 Sporting events and other events

An assessment of noise emission from PA systems show compliance is predicted with the established $L_{Aeq(5min)}$ noise limits at all receiver locations. To manage noise levels from PA systems, recommendations are incorporated into a Draft Noise Management Plan for the SFSR , presented in Appendix G.

Assessment of double headers with the SCG indicate no cumulative emissions.

In line with the existing management regime, no noise limits apply to crowd noise, as it is generally considered less intrusive than music or PA announcement noise, and is not readily managed or mitigated. Predictions of noise from crowds at sporting events indicate noise levels are generally similar or below existing ambient noise levels due to traffic at the reasonably most-affected receiver locations.

5.9 Mitigation measures

5.9.1 Design considerations

At this stage of design, noise spill from the stadium bowl has been considered in the preliminary design on the stadium envelope. The height of the stadium façade has been maximised and penetrations in the façade have been minimised.

At detailed design stage, noise emissions from the final stadium design shall be assessed in accordance with established noise limits.

Aero-acoustic noise shall be considered at the detailed design stage with particular focus on the wind-induced noise mechanisms listed in Section 4.3.5. It is recommended to conduct an initial desktop assessment of the entire external façade and ancillaries to assess the potential for wind induced noise from each element type. The potential for wind-induced noise from each element would be qualitatively assessed, with a risk level

attributed to the element for the known aero-acoustic mechanisms. Where appropriate, potential concerns and mitigation measures would be provided for each element for consideration in the detailed design of the façade. The requirement of additional wind-tunnel testing shall be determined following this desktop assessment, in consultation with a wind-consultant.

Areas of consideration should include:

- Horizontal fins which are not attached to façade, allowing wind to pass over perpendicular to the façade.
- Louvres which are not directly adjoining the façade
- Cables supporting awnings
- Permanent fencing around the stadium

5.9.2 Noise Management Plan

As a venue designated under clause 90 of the POEO General Regulation, the Sydney Football Stadium is required to have a Noise Management Plan (NMP) in place, which comprises three elements:

- Preventive management – details of mitigation of noise emissions prior to the event such as stage orientation, barriers, sound limitation devices etc. and effective community consultation before the event;
- Reactive management – noise monitoring in real time (travellers and fixed locations), use of trigger levels set below limits, modes of communication between monitors and operators, noise mitigation in real time, complaints handling in real time and communication modes between complaints handling and operators; and
- Review – assessing the performance of: – community consultation (before/during /after) – monitoring in real time – mitigation, to inform the development and implementation of recommendations that will improve performance over time (continuous improvement).

A review of the current Sydney Cricket Ground and Allianz Stadium NMP [16] is recommended in the development of a NMP for the SFS.

In accordance with Consent Conditions, a draft NMP has been prepared in consultation with the EPA and DPE, with evidence of consultation provided in Section 5.3.2, and is presented in Appendix G. This draft NMP outlines the proposed structure and preliminary content for the working NMP for the SFSR. Details regarding the noise management measures, including but not limited to specifications of the noise monitoring system, intermediate noise monitoring locations and representative noise limits at these locations, trial periods for the NMP will require review upon further design development as well as operation of the stadium. This review and subsequent preparation of a working NMP shall be conducted in consultation with Consent Authorities, relevant stakeholders and a suitably qualified acoustic consultant.

The draft NMP includes the following mitigation and management measures:

Preventative management

- Noise sensitive receiver identification

- Number of concert events
- Event time limits
- Event noise limits
- Definition of non-compliance
- Notification to consent authorities
- Notification to community
- Noise monitoring
- Sound amplification system setup
- Pyrotechnics
- Staffing requirements

Reactive management

- Complaints handling

Review mechanism

- Community feedback
- Public access to NMP
- Review process of NMP
- Validation of noise monitoring system

6 Summary of mitigation measures

A summary of recommended construction, operational and event noise and vibration mitigation measures are presented in Table 49.

Table 49: Recommended noise mitigation and management measures

No.	Item	Detail
Construction noise and vibration		
1	Noise and vibration management plan	A Construction Noise and Vibration Management Plan shall be prepared prior to the issuing of a Construction Certificate. This will specify the actual plant to be used and will include updated estimates of the likely levels of noise and the scheduling of activities.
2	Staffing	Appointing a named member of the site staff who will act as the Responsible Person with respect to noise and vibration; Regularly train workers and contractors (such as at toolbox talks) to use equipment in ways to minimise noise; Ensuring good work practices are adopted to avoid issues such as noise from dropped items, noise from communication radios is kept as low as is practicable; Avoid the use of radios or stereos outdoors; and Avoid shouting and minimise talking loudly and slamming vehicle doors.
3	Plant and equipment	Where possible stationary equipment should be located behind structures such as demountable buildings or stockpiles to maximise shielding to receivers; Consider using electric / hydraulic equipment where possible Using the smallest equipment as is practical All plant and equipment used on site must be: • maintained in a proper and efficient condition; and • operated in a proper and efficient manner. Turn off all vehicles, plant and equipment when not in use Ensuring that the Responsible Person checks the conditions of the powered equipment used on site daily to ensure plant is properly maintained and that noise is kept as low as practicable.
4	Scheduling	Ensure that the Responsible Person controls the working hours on site to ensure that work is only done during the acceptable periods (7am to 6pm on weekdays and 8am to 1pm on Saturdays. No work on Sundays or public holidays)
5	Work site training	'Toolbox talks' will be held at regular intervals with the contractor workers, including discussion of noise and vibration mitigation, monitoring and assessment. These topics will also be covered under induction processes. Operate two way radios at the minimum effective volume, and avoid shouting or whistling at the site. Identification of all reasonable and feasible noise mitigation methods will be conducted by the Responsible Person on a daily basis during noisy works. The Responsible Person will have the authority to modify work practices in response to complaints, where this is considered appropriate.

No.	Item	Detail
6	Scheduling	High noise activities will be programmed to occur during the daytime hours wherever possible and will be scheduled with due consideration to the nearest sensitive receivers. For approved out-of-hours work (refer Section 3.4.1), noisy activities should be scheduled early in the night to minimise the impact on adjacent residents. Limit number of consecutive nights receivers are impacted
7	Community liaison	Ensuring that the Responsible Person keeps the local community advised on expected activities and coordinates scheduling and locations of noisy works around any critical user events where practicable. This shall include face to face meetings with nearby receivers if requested and a letter box drop, and shall include close liaison with neighbours during construction, including Fox Studios, UTS, NRL and Rugby Australia; and Maintaining appropriate records of complaints to include timing, reported issues, actions taken and measures to be included for on-going works. The complaints log will need to be filed with the Responsible Person.
8	Reversing alarms	The use of audible movement alarms of a type that would minimise noise impacts on surrounding noise sensitive receivers must be implemented. Where practicable, broadband, non-tonal reversing alarms should be utilised on site equipment. Ensure that the difference in volume between the reversing warning devices and the base machine noise level (at maximum governed speed under no load at any given test location) is minimised (in accordance with International Standard ISO9533:1989), and ensure that warning devices are no more than 5 dB above the Australian Standard level;
9	Material handling	Avoid dropping equipment/materials from a height or into trucks. Where practicable, use sound dampening material to cover the surfaces on to which any materials must be dropped.
10	Equipment Location	Site noisy equipment away from noise-sensitive areas. Plant known to emit noise strongly in one direction is to be orientated so that the noise is directed away from noise-sensitive areas; Locate site access roads and site compounds as far away as possible from noise sensitive receptors; Plan truck movements to avoid residential streets where possible;
11	Construction vibration	Adherence to minimum working distances presented in Table 23, and Methodology Statement for Working Near Busby's Bore [9].
Operational noise		
12	External plant	Noise emissions from any external mechanical plant shall be treated such that noise emission complies with NPI PANL criteria at all surrounding receivers. This may require the use of acoustic louvres, enclosures, barriers or attenuators.
13	Wind-induced façade noise	Consideration of aero-acoustic noise shall be considered at the detailed design stage with particular focus on the wind-induced noise mechanisms listed in Section 4.3.5. It is recommended to conduct an initial desktop assessment of the entire external façade and ancillaries to assess the potential for wind induced noise from each element type.

No.	Item	Detail
Event noise		
14	Event noise emissions	Full assessment of noise emissions from final stadium design to be undertaken at detailed design stage, noise emissions from the final stadium design shall be assessed in accordance with established noise limits.
15	Noise Management Plan	Development, implementation and review of a Noise Management Plan, to include specifications of the noise monitoring system, intermediate noise monitoring locations and representative noise limits at these locations, trial periods for the NMP. A review upon further design development as well as operation of the stadium is recommended. This review and subsequent preparation of a working NMP shall be conducted in consultation with Consent Authorities, relevant stakeholders and a suitably qualified acoustic consultant.