APPENDIX E

Noise and Vibration Report

RENZO TONIN & ASSOCIATES
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THE NORTHERN BEACHES HOSPITAL

State Significant Infrastructure Application
SSI_6792
Noise and Vibration Report

13 NOVEMBER 2014

Healthscope

Appendix E Noise and vibration rev EX

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Document details

Detail	Reference
Doc reference:	Appendix E Noise and vibration rev EX
Prepared for:	Healthscope
Attention:	Mr Con Kolovos (Thiess)

Document control

Date	Revision history	Non-issued revision	Issued revision	Prepared	Instructed	Authorised
02.11.2014	EIS		0	GW	-	GW
03.11.2014	Revised EIS		1	GW	-	GW`
13.11.2014	For Exhibition		EX			

Executive summary

Renzo Tonin & Associates has been engaged to prepare an assessment of noise and vibration to support the Stage 2 works of The Northern Beaches Hospital (NBH). The assessment addresses the Director General's Requirements (DGRs) for application number SSI_5982 pertaining to noise and vibration emission during the construction and operation of the site.

The following outlines the specific scope of the noise and vibration assessment along with the relevant policies and guidelines addressed.

Assessment	Detail and relevant policies, standards or guideline	Report section
Construction noise and vibration	Assessment of noise during the excavation and construction phase of the development and its potential impact on surrounding development. Assessed in accordance with the NSW *Interim Construction Noise Guideline* [1] Assessment of vibration generated by any vibration intensive equipment used during the construction phase. Assessed in accordance with the NSW *Assessing Vibration: A Technical Guideline* [2]	Section 3 and 4
Site operational noise	Noise from operational activities on site including car park activities, loading docks and mechanical equipment and its potential impact on surrounding development. In accordance with the NSW *Industrial Noise Policy* [3]	Section 5
Helicopter operations	Both impact upon the NBH development and surrounding development has been assessed consistent with recent Hospital projects.	Section 6
Noise from road traffic generated on surrounding roads	Assessment of noise from road traffic generated by the development on surrounding roads and its potential impact on surrounding development has been assessed in accordance with the NSW *Road Noise Policy* [4]	Section 7
Road traffic noise impact upon development	Assessment of road traffic noise intrusion has been carried out in accordance with the State Environmental Planning Policy – Infrastructure 2007 [5] and the *Development Near Rail Corridors and Busy Road-Interim Guideline* [6]	Section 8

Construction noise and vibration

While a detailed Construction Noise and Vibration Sub-Plan will be prepared following approval and prior to commencement of works, an assessment based on the preliminary schedules and methodology has been carried out in accordance with the relevant policies.

Assessment in accordance with the NSW *Interim Construction Noise Guideline* (ICNG) revealed compliance with the highly noise affected target at all locations. However during excavation and construction activities where works are being carried out in close proximity to adjacent receptor locations, the 'noise affected' targets have the potential of being exceeded. Subject to further investigation of the use of noise receiver locations (eg Forest High School) and finalisation of excavation plant selection, if required, appropriate mitigation measures would be able to be proposed as part of the construction Noise and Vibration Sub-Plan

The predicted noise levels do not represent the continuous noise to be generated from the site during the approved hours, and periods of lower activity would be expected during the course of a given day.

Notwithstanding the above, as the noise affected targets were predicted to be exceeded at some locations, consideration has been given to reasonable and feasible mitigation measures in accordance with the NSW *Interim Construction Noise Guideline* (ICNG) and DGRs. Some of the key measures include provision of solid hoarding on the western and northern boundaries, minimising active equipment during each phase, use of electric crane rather than diesel and potential noise monitoring for sensitive locations.

- It is noted that the application seeks extended work hours for Saturday (7am to 5pm) from that nominated in the ICNG (8am - 1pm).

Close consultation with the Forest High School will be implemented from the beginning of the construction period. It proposed to extend Saturday working hours from that nominated in the ICNG (8am to 1pm) to 7am to 5pm for the Stage 2 works. The extended hours will allow potentially noise and vibration sensitive works in proximity to the school to be carried out in out of school hours and minimise any impact on school functions and activities.

Low level noise and vibration sensitive works which also anticipated to occur during the extended hours include site configuration (during the excavation phase) and internal fit-out works (during the construction phase).

The potential cumulative noise impacts during the construction phase, have also been considered in regard to concurrent works associated with RMS road works, Consistent with the discussion provided in the *Northern Beaches Hospital - Connectivity and Network Enhancements Stage 1 and Concept Proposal Noise and Vibration Assessment* (SLR, 2014), the NBH construction work should not result in significantly increased noise impacts at surrounding receivers, as road corridor works would be the dominant noise source given their closer proximity to the adjacent noise sensitive receptors. Notwithstanding, opportunities to collectively manage and minimise construction noise impacts may be identified through possible consultation with RMS and the road works contractor.

Operational noise emission

The primary operational noise generated by the development with potential to impact on surrounding development is mechanical services equipment and vehicular movements on site.

Regarding mechanical plant, the detailed specification of equipment and associated noise mitigation treatment will be determined during the detailed design stage of the project. However a qualitative assessment has been carried out to inform the current design. The proposal appropriately distributes plant equipment in locations so as to minimise concentration of noise emission to surrounding areas. Adequate provision has also been made for any required acoustic treatment, whether through plant room enclosures, screening or equipment specific attenuation.

With regard to vehicular movements on site, the loading dock is strategically located in the basement of the Hospital building with access via the southern side of the building, therefore being acoustically shielded from surrounding noise sensitive development. Concerning staff and visitor vehicular

movements, traffic generation and access is consistent with the concept planning for the site. Notwithstanding, site noise emissions during peak vehicular movements have been assessed as compliant at the nearest affected receptor locations. As potential impact onto the neighbouring Forest High School was raised as a particular concern in the DGRs, it is noted that the assessment conservatively adopted peak hour traffic movements that are not forecast to occur within school hours.

Helicopter noise to surrounding development

The helipad required for the NBH has been located as far as practical from surrounding sensitive development, minimising potential impact during approach and take off. The helipad has been situated in the south eastern corner of the Hospital rooftop, being removed from the neighbouring school and primary residential area to the north along Frenchs Forest Road West.

As the flight path is dictated by any on site or building obstructions, the design is such that an east west flight path is established. The possibility of directing the majority of approaches and departures to and from the east less sensitive commercial development would further reduce noise exposure to the neighbouring school and adjacent residential receptors. This is particularly desirable during the daytime period. Outside school hours, departures or arrivals from the west would have lesser impact on residential premises as they are further removed from NBH, at which point the helicopter would be at a higher altitude. Where flights are required over the school during day periods, the frequency and area of high noise exposure would be limited.

Both the location of the helipad and established flight path of helicopter operations reduce the potential noise impact on surrounding noise sensitive development.

Road traffic noise generated by development

While the access and traffic associated with the proposal is consistent with the concept plan, potential noise impact has nonetheless been assessed to confirm acceptability of the access arrangements for the site. Assessment in accordance with the NSW *Road Noise Policy* revealed compliance at surrounding noise sensitive development located along the main access routes of Frenchs Forest Road West and Warringah Road.

It is noted that both this assessment and the *Northern Beaches Hospital - Connectivity and Network Enhancements Stage 1 and Concept Proposal Noise and Vibration Assessment*, consider the increased road traffic on the local road network as a result of the road works and traffic generated by NBH.

Road and helicopter noise intrusion to NBH

Road noise impact upon the NBH has been carried out in accordance with the State Environmental Planning Policy (Infrastructure) 2007 (ISEPP) and Australian Standard 2107. Helicopter noise intrusion has also been considered in accordance with criteria adopted for other recent hospital developments.

Acoustic advice has been provided regarding the building envelope design to reduce noise intrusion to noise sensitive internal areas. The acoustic design of the building envelope will however be further developed during the detailed design with additional detailed measurements and noise modelling.

Conclusion

The noise and vibration assessment for The Northern Beaches Hospital has been assessed in accordance with the Director General's Requirements for SSI 13_5982. As required, the assessment has identified where specific noise and vibration mitigation and management measures are required to be implemented, or has otherwise found the development compliant with the required assessment polices, standards and guidelines.

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1 Introduction

Renzo Tonin & Associates has been engaged to prepare an assessment of noise and vibration to support the Stage 2 works of the Northern Beaches Hospital (NBH). The assessment addresses The Director General's Requirements for application number SSI 13_5982. Specifically, the report addresses the matters pertaining to noise and vibration emission during the excavation, construction and operation of the site.

At this Project Proposal stage, while there are aspect that require more detailed design development, this report nonetheless outlines the primary acoustic considerations and design responses for the development, including:

- identification of noise and vibration sensitive development surrounding the site
- existing ambient and background noise levels at sensitive receptor locations
- relevant noise and vibration criteria applicable to the development
- establishment of project noise goals
- potential noise and vibration impacts from construction and operation of the development, and
- methods by which noise and vibration can be managed and mitigated in accordance with the relevant policies and guidelines

The work documented in this report was carried out in accordance with the Renzo Tonin & Associates Quality Assurance System, which is based on Australian Standard / NZS ISO 9001. Appendix A contains a glossary of acoustic terms used in this report.

1.1 Overview of proposed development

The proposal is for construction of a world class health care facility on a 6.3 hectare site at Frenchs Forest.

The NBH site has three road frontages, with Frenchs Forest Road West to the north, Wakehurst Parkway to the east and Warringah Road to the south. The eastern boundary of the site is adjacent to The Forest High School. Bantry Bay Road currently divides the subject site between Frenchs Forest Road West and Warringah Road. Figure 1 presents an aerial photograph of the subject site.

Figure 1: Aerial photograph of subject site

1.2 Acoustic assessment requirements

1.2.1 Director Generals requirements

The Director General's Environmental Assessment Requirements issued for application number SSI_5982 (Stage 2) contain the following specific noise and vibration requirements:

5 Noise and Vibration

- *Identify and provide a quantitative assessment of the main construction and operational noise and vibration generating sources and activities.*
- *Outline measures to prevent, control, minimise and mitigate noise and vibration impacts on surrounding occupiers of land, including The Forest High School.*
- *Consideration of feasible and reasonable operational noise mitigation and management measures, including noise barriers, location of emergency services vehicle access, loading dock and waste collection activities and location and operation of mechanical plant and equipment.*

The DP&E advised on 10 November 2014 that the Stage 2 NBH SSIA and EIS should be lodged under project title reference 'SSI 6792'.

1.2.2 Relevant Policies and Guidelines

The following policies and guidelines have been used in the assessment:

- NSW Industrial Noise Policy [3]
- Interim Construction Noise Guideline [1]
- Assessing Vibration: A Technical Guideline [2]
- The NSW Road Noise Policy [4]
- State Environmental Planning Policy (Infrastructure) 2007
- Development near Rail Corridors and Busy Road-Interim Guideline [6]

The above policies and guidelines have been addressed in this report as follows:

Policy or Guideline	Assessment outline	Report section
NSW Industrial Noise Policy	Operational noise from the development and its potential impact on surrounding development	Section 2 and 5
Interim Construction Noise Guideline	Assessment of noise during the excavation and construction phase of the development and its potential impact on surrounding development	Section 3
Assessing Vibration: A Technical Guideline	The primary potential for vibration impact generated by the development is during the excavation and construction phase.	Section 4
The NSW Road Noise Policy	Assessment of road traffic generated by the development on the local road network and its potential impact on surrounding development.	Section 7
State Environmental Planning Policy – Infrastructure 2007	Assessment of noise onto the development from busy roads corridors.	Section 8
Development Near Rail Corridors and Busy Road-Interim Guideline	Supporting guideline for the State Environmental Planning Policy – Infrastructure 2007.	Section 8

1.3 Scope of assessment

The following sets out the primary acoustic consideration for the project along with the sections of this report in which they are discussed.

Acoustic consideration	Report section
Excavation and construction noise and vibration	Section 3 and 4
Operational site noise emission from normal operations	Section 5
Noise from road traffic generated by the development	Section 7
Noise from helicopter operations on surrounding development	Section 6
Noise intrusion to proposed development - road traffic and helicopter noise	Section 6 and 8

2 Nearest receivers and existing noise environment

2.1 Nearest receivers

The nearest potentially affected receivers to excavation and construction and operational noise associated with the NBH development are presented in Table 1 and graphically in Figure 2.

Table 1: Nearest receivers

Receiver type	Receiver ID	Receiver location	Distance from boundary of site (Approx. m)
Residential	R1	Residences to the north across Frenchs Forest Rd West	22
	R2	Residences to the south across Warringah Rd	37
Commercial	C1	Commercial premises to the south across Warringah Rd	27
Other sensitive receiver	E1	The Forest High School	15

Notes: Distance from boundary of site to receiver calculated to nearest façade of receiver

2.2 Existing noise environment

Criteria for the assessment of construction and operational noise are usually derived from the existing noise environment of an area, excluding noise from the subject development. Appendix B of the NSW EPA *Industrial Noise Policy* (INP) outlines two methods for determining the background noise level of an area, being 'B1 – Long-term background noise method' and 'B2 – Short-term background noise method' [3]. This assessment has used a combination of long-term and short-term noise monitoring.

Long-term noise measurements have previously been undertaken by Acoustic Logic for the Stage 1 EIS [7]. As access was not possible during this tender phase for the undertaking of independent long-term noise measurements, the Acoustic Logic data has been relied upon for this initial assessment. Details of the long-term noise monitoring undertaken by Acoustic Logic are presented below.

Supplementary short-term attended measurements were undertaken by Renzo Tonin & Associates to provide additional detail of the surrounding noise environment. All background noise data used for the establishment of operational and construction noise goals will be subject to review. Detailed measurements of the surrounding noise environment are to be carried out for the detailed construction Noise & Vibration Management Sub-Plan and to inform the operational design of the project.

As the noise environment of an area almost always varies over time, background and ambient noise levels need to be determined for the operational times of the proposed development. For example, in a suburban or urban area the noise environment is typically at its minimum at 3am in the morning and at its maximum during the morning and afternoon traffic peak hours. The INP outlines the following standard time periods over which the background and ambient noise levels are to be determined:

- Day: 07:00-18:00 Monday to Saturday and 08:00-18:00 Sundays & Public Holidays
- Evening: 18:00-22:00 Monday to Sunday & Public Holidays

- Night: 22:00-07:00 Monday to Saturday and 22:00-08:00 Sundays & Public Holidays

2.3 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 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 long-term and short-term measurement locations are outlined in Table 2 and shown in Figure 2.

Table 2: Noise monitoring locations

ID	Address	Description
Long-term noise monitoring		
La	Northern Beaches Hospital	Monitoring carried out by Acoustic Logic [7]. The monitor was installed next to the school building nearest the hospital site. Noise levels at this logger will be indicative of ambient noise levels at the Frenchs Forest School and at the residential development on Frenchs Forest Road to the north of the site
Lb	Northern Beaches Hospital	Monitoring carried out by Acoustic Logic [7]. The monitor was installed on the school property boundary, towards the southern end of the site. Noise levels at this logger will be indicative of ambient noise levels on Warringah Road.
Short-term noise monitoring		
S1	112A Frenchs Forest Road West	The sound level meter was positioned approximately 3m from road kerb and 5m from residential boundary, 1.5m above the ground level in the free field.
S2	Wakehurst Parkway	The sound level meter was positioned approximately 3m from road kerb and 1.5m above the ground level in the free field.
S3	Corner of Hilmer Street and Warringah Rd	The sound level meter was positioned approximately 1m from Warringah Road kerb and 1.5m above the ground level in the free field.

Figure 2: Nearest receivers and noise monitoring locations

2.4 Long-term noise measurement results

The long-term noise monitoring undertaken by Acoustic Logic was conducted between Tuesday, 2 July and Tuesday, 9 July 2013. While the tabulated background noise levels presented in the Stage 1 acoustic report are for day-time hours only, noise levels graphs are presented for the complete monitoring period [7]. Estimated Rating Background Levels (RBL) and representative ambient L_{eq} noise levels have been established for the evening and night time periods. Table 3 presents the overall single RBL and ambient L_{eq} noise levels for each assessment period, determined in accordance with the INP.

Table 3: Long-term noise monitoring results, dB(A)

Monitoring location	L_{A90} Rating Background Level (RBL)			L_{Aeq} ambient noise levels		
	Day	Evening	Night	Day	Evening	Night
La - north (Frenchs Forest Rd West)	44	43	39	52	46	43
Lb - south (Warringah Rd)	52	49	42	56	53	48

Notes: Day: 07:00-18:00 Monday to Saturday and 08:00-18:00 Sundays & Public Holidays
Evening: 18:00-22:00 Monday to Sunday & Public Holidays
Night: 22:00-07:00 Monday to Saturday and 22:00-08:00 Sundays & Public Holidays
As required by the INP, the external ambient noise levels presented are free-field noise levels. [ie. no façade reflection]

2.5 Short-term noise measurement results

Short-term noise measurements were undertaken on Wednesday, 12 March 2014 between 2:30pm and 11:00pm, in order to provide greater detail of the surrounding noise environment, particularly during evening and night time hours.

The equipment used for noise measurements was an NTi Audio Type XL2 precision sound level analyser which is a class 1 instrument having accuracy suitable for field and laboratory use. The instrument was calibrated prior and subsequent to measurements using a Bruel & Kjaer Type 4231 calibrator. No significant drift in calibration was observed. All instrumentation complies with AS IEC 61672.1 2004 "*Electroacoustics - Sound Level Meters*" and carries current NATA certification (or if less than 2 years old, manufacturers certification).

A summary of the short-term measurement results is presented in Table 4.

Table 4: Short-term noise monitoring results

Time	Measured Noise Level, dB(A)		Comments on measured noise levels
	L_{Aeq}	L_{A90}	
S1 – 112A Frenchs Forest			
14:31-14:51	65	51	The background L_{A90} was determined by distant road traffic. The ambient L_{Aeq} noise level was determined by local road traffic along Frenchs Forest Road West.
14:52-15:08	65	54	
21:49-22:04	58	45	
22:04-22:19	57	45	
S2 – Wakehurst Parkway			
15:12-15:27	68	55	The background L_{A90} was determined by distant road traffic. The ambient L_{Aeq} noise level was determined by local road traffic along Wakehurst Parkway.
S3 – Corner of Hilmer Street and Warringah Rd			
15:50-16:05	74	63	The background L_{A90} was determined by local and distant road traffic. The ambient L_{Aeq} noise level was determined by local road traffic along Waringah Road.
16:06-16:21	75	63	
22:30-22:45	69	54	
22:46-23:01 (008)	69	55	

2.6 Project assessment noise levels

The short-term noise measurements indicate that the prevailing noise levels at the nearest residential receivers, that front Warringah Road and Frenchs Forest Road West are exposed to noise levels higher than that recorded by the long-term unattended noise monitoring carried out for Stage 1 EIS [7]. This result is expected given that the long-term noise monitoring locations are set back from the road frontages.

While more detailed noise monitoring will be carried out for the purpose of informing the construction Noise and Vibration Management Sub-Plan and detailed design of operational noise, Table 5 outlines

the background and ambient noise levels used for determining preliminary noise criteria for construction and operational noise assessment.

Table 5: Residential equivalent long-term noise levels, dB(A)

Assessment location	L_{A90} rating background level (RBL)			L_{Aeq} ambient noise levels		
	Day	Evening	Night	Day	Evening	Night
R1 - Residences to the north across Frenchs Forest Rd West	51	45	41	65	57	54
R2 - Residences to the south across Warringah Rd	63	54	47	74	69	64

Notes: Day: 07:00-18:00 Monday to Saturday and 08:00-18:00 Sundays & Public Holidays
Evening: 18:00-22:00 Monday to Sunday & Public Holidays
Night: 22:00-07:00 Monday to Saturday and 22:00-08:00 Sundays & Public Holidays
As required by the INP, the external ambient noise levels presented are free-field noise levels. [ie. no façade reflection]

3 Construction noise and vibration objectives

Prior to commencement of construction activities a Construction Environmental Management Plan (CEMP) will be prepared. The CEMP establishes the overarching context for the effective environmental management of the site during all building and construction activities. The Noise and Vibration Management sub-plan will comprise a component of the overarching CEMP.

The following sections present the standards and guidelines relevant to the assessment of construction noise and vibration.

3.1 Construction noise objectives

3.1.1 NSW Interim Construction Noise Guideline (ICNG)

Construction noise management levels can be been determined using the NSW *Interim Construction Noise Guideline* (ICNG) [1]. Table 6 (reproduced from Table 2 of the ICNG) and Table 7 set out the noise management levels for various noise-sensitive land use developments, including residential and commercial premises.

Table 6: Noise management levels at residential receivers

Time of day	Management level $L_{Aeq\ (15\ min)}$	How to apply
Recommended standard hours: Monday to Friday 7 am to 6 pm Saturday 8 am to 1 pm No work on Sundays or public holidays	Noise affected RBL + 10dB(A)	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.
	Highly noise affected 75dB(A)	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	Noise affected RBL + 5dB(A)	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 5dB(A) above the noise affected level, the proponent should negotiate with the community. For guidance on negotiating agreements see section 7.2.2 of the ICNG.

Table 7: Noise management levels at other noise sensitive land uses

Land use	Where objective applies	Management level $L_{Aeq\ (15\ min)}$
Classrooms at schools and other educational institutions	Internal noise level	45 dB(A)
Hospital wards and operating theatres	Internal noise level	45 dB(A)
Places of worship	Internal noise level	45 dB(A)
Active recreation areas	External noise level	65 dB(A)
Passive recreation areas	External noise level	60 dB(A)
Community centres	Depends on the intended use of the centre.	Refer to the 'maximum' internal levels in AS2107 for specific uses.
Commercial premises	External noise level	70 dB(A)
Industrial premises	External noise level	75 dB(A)

Notes: Noise management levels apply when receiver areas are in use only.

3.1.2 Project noise targets

Based on the measured background noise levels presented in Table 3 and the criteria presented, Table 8 outlines the noise goals during excavation and construction.

Table 8: Project construction noise goals within standard hours

Receiver ID	Address	Noise affected target $L_{Aeq\ 15minute}$ dB(A)
Residential receivers		
R1	Residences to the north across Frenchs Forest Rd West	61 external
R2	Residences to the south across Warringah Rd	73 external
Commercial receivers		
C1	Commercial premises to the south across Warringah Rd	73 external*
Other sensitive receivers		
E1	The Forest High School	45 internal

Notes: * Not set lower than residential target

3.2 Construction vibration objectives

3.2.1 Disturbance to buildings occupants

Assessment of potential disturbance from vibration on human occupants of buildings is made in accordance with the DECCs '*Assessing Vibration; a technical guideline*' [2]. The guideline provides criteria which are based on the British Standard BS 6472-1992 [8]. Sources of vibration are defined as either 'Continuous', 'Impulsive' or 'Intermittent'. Table 9 provides definitions and examples of each type of vibration.

Table 9: Types of vibration

Type of vibration	Definition	Examples
Continuous vibration	Continues uninterrupted for a defined period (usually throughout the day-time and/or night-time)	Machinery, steady road traffic, continuous construction activity (such as tunnel boring machinery).
Impulsive vibration	A rapid build-up to a peak followed by a damped decay that may or may not involve several cycles of vibration (depending on frequency and damping). It can also consist of a sudden application of several cycles at approximately the same amplitude, providing that the duration is short, typically less than 2 seconds	Infrequent: Activities that create up to 3 distinct vibration events in an assessment period, e.g. occasional dropping of heavy equipment, occasional loading and unloading.
Intermittent vibration	Can be defined as interrupted periods of continuous or repeated periods of impulsive vibration that varies significantly in magnitude	Trains, nearby intermittent construction activity, passing heavy vehicles, forging machines, impact pile driving, jack hammers. Where the number of vibration events in an assessment period is three or fewer, this would be assessed against impulsive vibration criteria.

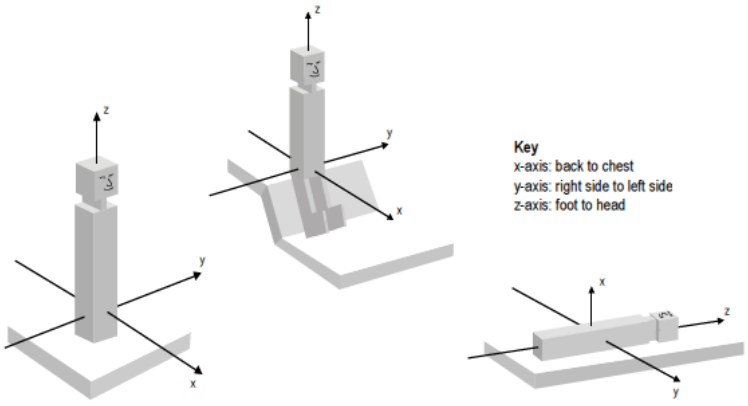
Source: Assessing Vibration; a technical guideline [2]

The vibration criteria are defined as a single weighted root mean square (rms) acceleration source level in each orthogonal axis. Section 2.3 of the guideline states:

> *'Evidence from research suggests that there are summation effects for vibrations at different frequencies. Therefore, for evaluation of vibration in relation to annoyance and comfort, overall weighted rms acceleration values of the vibration in each orthogonal axis are preferred* [8]*'*

When applying the criteria, it is important to note that the three directional axes are referenced to the human body, i.e. x-axis (back to chest), y-axis (right side to left side) or z-axis (foot to head). Vibration may enter the body along different orthogonal axes and affect it in different ways. Therefore, application of the criteria requires consideration of the position of the people being assessed, as illustrated in Figure 3. For example, vibration measured in the horizontal plane is compared with x- and y-axis criteria if the concern is for people in an upright position, or with the y- and z- axis criteria if the concern is for people in the lateral position.

Figure 3: Orthogonal axes for human exposure to vibration



The preferred and maximum values for continuous and impulsive vibration are defined in Table 2.2 of the guideline and are reproduced in Table 10.

Table 10: Preferred and maximum levels for human comfort

Location	Assessment period [1]	Preferred values		Maximum values	
		z-axis	x- and y-axis	z-axis	x- and y-axis
Continuous vibration[3] (Weighted RMS acceleration, m/s^2, 1-80Hz)					
Critical areas [2]	Day or night time	0.005	0.0036	0.010	0.0072
Residences	Daytime	0.010	0.0071	0.020	0.014
	Night time	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
Workshops	Day- or nighttime	0.04	0.029	0.080	0.058
Impulsive vibration [3] (Weighted RMS acceleration, m/s^2, 1-80Hz)					
Critical areas [2]	Day or night-time	0.005	0.0036	0.010	0.0072
Residences	Daytime	0.30	0.21	0.60	0.42
	Night-time	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
Workshops	Day or night-time	0.64	0.46	1.28	0.92
Intermittent vibration [4] (Vibration Dose Values, VDV, $m/s^{1.75}$, 1-80Hz)					
Critical areas[2]	Day or night-time	0.10		0.20	
Residences	Daytime	0.20		0.40	
	Night-time	0.13		0.26	
Offices, schools, educational institutions and places of worship	Day- or night-time	0.40		1.60	
Workshops	Day or night-time	0.80		1.60	

Notes: 1. Daytime is 7:00am to 10:00pm and night-time is 10:00pm to 7:00am

2. Examples include hospital operating theatres and precision laboratories where sensitive operations are occurring. There may be cases where sensitive equipment or delicate tasks require more stringent criteria than the human comfort criteria specify above. Stipulation of such criteria is outside the scope of their policy and other guidance documents (e.g. relevant standards) should be referred to. [8]

3.2.2 Structural damage to buildings

Currently there is no Australian Standard for assessment of vibration induced structural damage. Therefore, reference is made to relevant British and German Standards.

3.2.2.1 British Standard

British Standard 7385: Part 2, can be used as a guide to assess the likelihood of building damage from ground vibration [9]. BS7385 suggests levels at which 'cosmetic', 'minor' and 'major' categories of damage might occur.

BS7385 is based on peak particle velocity and specifies damage criteria for frequencies within the range 4Hz to 250Hz, being the range usually encountered in buildings. At frequencies below 4Hz, a maximum displacement value is recommended. Table 11 sets out the BS7385 criteria for cosmetic damage.

Table 11: BS 7385 cosmetic structural damage criteria

Group	Type of structure	Peak component particle velocity, mm/s		
		4Hz to 15Hz	15Hz to 40Hz	40Hz and above
1	Reinforced or framed structures Industrial and heavy commercial buildings	50		
2	Un-reinforced or light framed structures Residential or light commercial type buildings	15 to 20	20 to 50	50

The values set in the Standard relate to transient vibrations and to low-rise buildings. Continuous vibration can give rise to dynamic magnifications due to resonances and may need to be reduced by up to 50%.

The levels set by BS 7385 are considered 'safe limits' up to which no damage due to vibration effects has been observed for certain particular building types. Damage comprises minor non-structural effects such as hairline cracks on drywall surfaces, hairline cracks in mortar joints and cement render, enlargement of existing cracks and separation of partitions or intermediate walls from load bearing walls. 'Minor' damage is considered possible at vibration magnitudes which are twice those given and 'major' damage to a building structure may occur at levels greater than four times those values.

3.2.2.2 German Standard

German Standard DIN 4150 - Part 3 also provides recommended maximum levels of vibration that reduce the likelihood of building damage caused by vibration and are generally recognised to be conservative [10].

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 vibration limits increase as the frequency content of the vibration increases. The criteria are presented in Table 12.

Table 12: DIN 4150-3 structural damage criteria

Group	Type of structure	Vibration velocity, mm/s			
		At foundation at frequency of			Plane of floor uppermost storey
		1Hz to 10Hz	10Hz to 50Hz	50Hz to 100Hz	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

Group	Type of structure	Vibration velocity, mm/s			
		At foundation at frequency of			Plane of floor uppermost storey
		1Hz to 10Hz	10Hz to 50Hz	50Hz to 100Hz	All frequencies
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

4 Construction noise and vibration assessment

4.1 Proposal

4.1.1 Projected program and schedule

Table 13 presents the development program for excavation and construction of the site.

Table 13: Construction program

Phase	Detailed breakdown	Time period
Excavation	Levelling the site and hospital bulk earthworks	Early 2015 to early 2016
	Car park bulk excavation and substructure	Mid 2016 to late 2016
Structures	Hospital structure	Early 2016 to mid-2017
	Car park structure	Late 2016 to Late 2017
Fitout	Hospital fitout and other works	Mid 2016 to Late 2018
	Car park fitout and other works	Mid 2017 to early 2018

4.1.2 Construction hours

The proposed hours of excavation and construction works are:

- Monday to Friday: 7:00am to 6:00pm
- Saturday: 7:00am to 5:00pm
- Sunday/ Public holiday: No work

Close consultation with the Forest High School will be implemented from the beginning of the construction period. It proposed to extend Saturday working hours from that nominated in the ICNG (8am to 1pm) to 7am to 5pm for the Stage 2 works. The extended hours will allow potentially noise and vibration sensitive works in proximity to the school to be carried out in out of school hours and minimise any impact on school functions and activities.

Low level noise and vibration sensitive works which also anticipated to occur during the extended hours include site configuration (during the excavation phase) and internal fit-out works (during the construction phase).

4.1.3 Construction traffic

The Hospital will be located on the corner of Warringah Freeway and Wakehurst Parkway. The Roads and Maritime Services (RMS) identify Warringah Freeway as having an average annual daily traffic (AADT) greater than 40,000, and Wakehurst Parkway to have an AADT between 20,000 and 40,000 [11].

Primary entrance to the site will be from Bantry Bay Road during the bulk earthworks and Warringah Freeway for the remaining works. The forecast traffic generated during the construction phase is minimal in comparison to the existing road traffic surrounding the site and therefore be negligible in terms of additional noise.

Various options were considered for construction access into the site and the most suitable location reducing noise and vibration impact was from the south of the site from Warringah Road. This addresses potential noise and vibration impacts to acoustic sensitive receivers or residential premises to the north side of the site.

4.1.4 Excavation and construction equipment

Noise generated from the site will vary depending on the level and specific type of activity carried out, as well the number of items of plant equipment operating at any one time. At this early stage of the development, the full details of excavation and construction are unknown. However, an indication of plant and equipment to be used during the works is provided in Table 14.

Table 14: Major construction equipment and sound power levels, dB(A)

Equipment type	Indicative size	L_{Aeq} Sound power level
Excavation		
Anchor Rig	-	102
Backhoe with Hydraulic Breaker (deep trenches only)	67 kW	116
Bulldozer	D8R	116
Excavator	20t	103
Excavator	12t	102
Piling Drilling Rig		111
Shotcrete pump	-	106
Truck & Dogs	-	96
Construction - structures - external plant		
Air Compressor - Silenced	8 kW	109
Bobcat	4 t	110
Cherry Picker	6 t	106
Concrete Pump	6 t	103
Concrete Vibrator	2 kW	97
Crane - Mobile	55t	98
Crane - Electric	-	95
Generator - Diesel	10 kVA	94
Hoist - Twin cage high speed Alimak	0.5 t	96
Truck - Cement Mixer	12 t	104
Welders - welding & cutting steel piles	-	101
Forklifts	Manitou 10t	90

4.2 Noise assessment

Based on the excavation and construction procedures and proximity of the nearest receivers, it is possible that the target levels may be exceeded during the peak excavation and construction activities.

Noise prediction calculations have been carried out to determine worst case scenario noise levels of excavation and construction works at the subject site. Noise predictions have been assessed on the basis of the following:

- all plant and equipment for each stage operating concurrently for conservative assessment
- plant and equipment distributed across the site
- the Forest High School assessment assumes that the nearest building is a classroom, and a 20dB(A) reduction from outside to inside with closed windows. This assessment would be subject review should the building accommodate less sensitive uses, and
- 2.4m high site hoardings on western and northern boundary.

Table 15 presents the predicted L_{Aeq} noise levels for peak activities during each stage of development.

Table 15: Predicted noise levels at nearest affected receivers

Receiver location	Predicted L_{Aeq} noise levels, dB(A)			'Noise affected' targets	Highly noise affected' targets
	Hospital excavation	Car park excavation w/ structures	Structures		
R1 - Residences to the north - Frenchs Forest Rd West	70	71	67	61	75
R2 - Residences to the south - Warringah Rd	67	69	64	73	75
C1 - Commercial premises - Warringah Rd	67	69	64	73	75
E1 - The Forest High School (inside nearest building)	48	54	49	45	55

Based on the assessment, noise emission from construction activities is expected to comply with relevant noise targets at locations along Warringah Road. While compliance with the highly noise affected target is predicted at all other locations, the 'noise affected' targets have the potential to be exceeded at Forest High School and residential locations along Frenchs Forest Road West. The higher noise exposures are predicted to occur during car park excavation and hospital structures work however the overall noise level is determined by the car park excavation which is limited to three months. . Noise levels will be lower during the construction phase, particularly during fit-out works.

The predicted noise levels also do not represent the continuous noise to be generated by the site, and periods of lower activity would be expected during the course of a given day. Periods of lower activity would be expected to be at least 5-10dB(A) lower than that predicted.

Notwithstanding the above findings, as the noise affected targets are predicted to be exceeded at some locations, consideration should be given to reasonable and feasible noise mitigation and management measures, for which potential measures are presented in Section 4.4.

The potential cumulative noise impacts during the construction phase, have also been considered in regard to concurrent works associated with RMS road works, Consistent with the discussion provided in the *Northern Beaches Hospital - Connectivity and Network Enhancements Stage 1 and Concept Proposal Noise and Vibration Assessment* (SLR, 2014), the NBH construction work should not result in significantly increased noise impacts at surrounding receivers, as road corridor works would be the dominant noise source given their closer proximity to the adjacent noise sensitive receptors. Notwithstanding, opportunities to collectively manage and minimise construction noise impacts may be identified through possible consultation with RMS and the road works contractor.

4.3 Vibration assessment

4.3.1 Vibration sensitive receivers

The nearest vibration sensitive receiver is presented in Table 16. The Forest High School assessment assumes that the nearest building is a classroom. This assessment would be subject review should the building accommodate less sensitive uses.

Table 16: Nearest vibration receivers

Location ID	Receiver description
R1	Residences to the north across Frenchs Forest Rd West
R2	Residences to the south across Warringah Rd
C1	Commercial premises to the south across Warringah Rd
E1	The Forest High School

4.3.2 Vibration sources

The vibration generated from excavation and construction works will vary depending on the level and type of activity carried out at each site during each activity. Typical plant and equipment in use have been identified in Table 14.

As no demolition is required on site, hammering will be limited to limited occasions where excavation is required for deep service trenches and footings and will otherwise be within the Hospital footprint, away from any structures.

Table 17 below identifies the dominant vibration generating plant and equipment. Potential vibration generated to receivers is dependent on separation distances, the intervening soil and rock strata, dominant frequencies of vibration and the receiver structure. Typical levels of ground vibration from these sources are shown in Table 17.

Table 17: Construction plant vibration levels

Plant equipment	Indicative size	PPV Vibration (mm/s) at distance from plant					
		5m	10m	15m	20m	30m	40m
Excavator & Breaker	Heavy	10.5	2.5	-	-	-	-
Excavator (travelling)	Heavy	8.0	3.4	1.6	-	-	-
Piling - Rotary bored cast in-situ	-	11.4	6.4	-	5.6	-	-
Roller - Vibratory (pad foot)	12t	15.1	10.3	3.2	-	-	-
Truck & Trailer	≤45t net	14.5	10.3	3.4	-	-	-

4.3.3 Indicative minimum working distances for vibration intensive equipment

As a guide, indicative minimum working distances for typical items of vibration intensive plant and equipment are provided in Table 18. The minimum working distances are quoted for:

- cosmetic damage, based on the British Standard 7385; and
- human comfort, based on the DECC's '*Assessing Vibration; a technical guideline*'.

Table 18: Recommended minimum working distances for vibration intensive equipment

Plant Item	Rating/ Description	Minimum Working Distance, m	
		Cosmetic Damage (BS 7385)	Human Response (DECC Guideline)
Vibratory Roller[2]	<50 kN (Typically 1-2 tonnes)	5	15 - 20
	<100 kN (Typically 2-4 tonnes)	6	20
	<200 kN (Typically 4-6 tonnes)	12	40
	<300 kN (Typically 7-13 tonnes)	15	100
	>300 kN (Typically 13-18 tonnes)	20	100
	>300 kN (Typically >18 tonnes)	25	100
Compactor[1]	852G	10	20
Dozer[1]	(D810) with ripper	2 (nominal)	10
Excavator[1]	<=30 Tonne (travelling/ digging)	10	15
Grader[1]	<= 20 tonne	2 (nominal)	10
Small Hydraulic Hammer[2]	300kg (5-12 tonne excavator)	2	7
Medium Hydraulic Hammer[2]	900kg (12-18 tonne excavator)	7	23
Large Hydraulic Hammer[2]	1600kg (18-34 tonne excavator)	22	73
Pile Boring[2]	≤ 800 mm	2 (nominal)	N/A
Jackhammer[2]	Hand held	1 m (nominal)	Avoid contact with structure
Truck Movements[1]	-	-	10m

Notes: More stringent conditions may apply to heritage or other sensitive structures

The minimum working distances are indicative and will vary depending on the specific equipment and geotechnical conditions.

They apply to cosmetic damage of buildings and have been derived from measured vibration data from a range of projects available in our database under varying geotechnical conditions. Vibration monitoring should be undertaken to confirm the safe working distances at specific sites where considered necessary.

Given the distance to surrounding sensitive development, works are not expected to impose any risk of cosmetic damage to surrounding buildings.

4.4 Recommendations

4.4.1 Noise control measures

The following at-source control and management measures should be considered for the management of noise from construction works to reduce potential noise impacts. Noise reductions of between 3-8dB(A) for individual plant items could be expected where alterative process or localised noise barriers are practical. In other area, the management measures are focused on minimising unnecessary noise generation from the site and the extent and duration of peak noise levels.

Table 19: Construction noise control measures

Measure	Detail
Source controls	
Noise barriers	Where possible, stage development so that structures provide acoustic shielding to sensitive receiver locations. Construct the proposed solid site hoarding as soon as practical. Where possible, stationary equipment should be located to make most use of the solid hoarding. Barriers or enclosures around stationary plant should also be considered where it is required to be located in close proximity to sensitive receivers.
Location equipment	Loading/unloading zones and stationary plant such as generators should where practicable be located away from the most sensitive receivers, in this case the nearest buildings of the adjacent school.
Equipment selection	Use the quietest and least vibration emitting construction methods where feasible and reasonable, e.g. use of excentric rippers rather than rock hammers.
Limit equipment in use	Only the equipment necessary for the upgrade works will be used at any time. Avoid any unnecessary noise when carrying out manual operations and when operating plant Simultaneous operation of noisy plant and equipment within discernible range of a sensitive receiver should be avoided/ limited where possible.
Limit activity duration	Any equipment not in use for extended periods shall be switched off. For example, heavy vehicles should switch engines off whilst being unloaded.
Reversing alarms	Alternative reverse alarm, such as 'quackers' should be installed where feasible and reasonable.
Management measures	
Implement community consultation measures	Inform community of construction activity and potential impacts
Develop good relations	Good relations with building occupants should be established at the beginning of the works and be maintained throughout the project, as this is of paramount importance. Keeping people informed of progress and taking complaints seriously and dealing with them expeditiously is critical. The person selected to liaise with the building occupants should be adequately trained and experienced in such matters.
Dilapidation surveys	Dilapidation surveys are to be undertaken of sensitive structure prior to undertaking of vibration generating works.
Work staging	Where practical, stage works so that that intrusive works are carried out at least noise sensitive periods, eg. extended work hours on Saturdays for most intrusive works in proximity to the school buildings. Also consider timetable for school exam periods and, where practical, adjust construction activities accordingly

Measure	Detail
Site inductions	All employees, contractors and subcontractors are to receive a Project induction. The environmental component may be covered in toolboxes and must include: • all relevant project specific and standard noise and vibration mitigation measures • relevant licence and approval conditions • permissible hours of work • any limitations on high noise generating activities • location of nearest sensitive receivers • construction employee parking areas • designated loading/unloading areas and procedures • site opening/closing times (including deliveries), and • environmental incident procedures
Complaints management procedure	A management procedure would need to be put in place to deal with noise complaints that may arise from construction activities. Each complaint would need to be investigated and appropriate noise amelioration measures put in place to mitigate future occurrences, where the noise in question is in excess of allowable limits.
Noise monitoring	A monitoring schedule is to be developed and implemented during high noise and vibration generating activities where required. Noise and vibration monitoring would be carried out for any identified sensitive works, where monitoring could be used to proactively identify noisy works that may be otherwise managed and mitigated. For example noise and vibration monitoring may be warranted at the Forest High School during excavation and construction associated with the multi-deck car park.
Noise and Vibration Sub-Plan	A specific Noise and Vibration Sub-Plan is to form part of the overall Construction Environmental Management Plan. The Sub-Plan will incorporate the findings and recommendations and management measures following additional background noise monitoring and investigations of noise receivers.
Consultation with RMS	Potential for consultation with RMS in consideration of cumulative impacts from road works being carried out concurrently with the NBH project.

4.4.2 Vibration control measures

Based on available data from a database containing vibration measurements from past projects and from library information, Table 20 below presents the recommended minimum working distances for high vibration generating plant.

Table 20: Vibration minimum working distances

Plant item	Rating / description	Minimum working distance, m	
		Cosmetic damage[2]	Human response[3]
Bobcat	Travelling	1 (nominal)	Avoid contact with structure
Jackhammer	Hand held	1 (nominal)	Avoid contact with structure
Large Hydraulic Hammer	1600 kg	5	73
Excavator	<=30 Tonne (travelling/ digging)	5	15
Truck Movements[1]	Travelling loaded	5	10
Vibratory Rollers	20t	25	100

Plant item	Rating / description	Minimum working distance, m	
		Cosmetic damage[2]	Human response[3]

Notes: Renzo Tonin & Associates project files, databases & library
Based on DIN4150.3 Group 1 Buildings
For residential receivers

Site specific buffer distances shall be determined where vibration significant plant items, in particular large rock hammers/breakers and vibratory rollers, operate within Cosmetic Damage minimum working distances detailed in Table 20. Where this occurs, minimum buffer distances to affected receivers shall be determined by site measurements prior to the commencement of the regular use of the vibration significant plant on site. The site specific minimum working distance shall be maintained in order to comply with relevant vibration limits.

5 Normal operations site noise assessment

5.1 Normal operational noise sources

The main noise sources associated with the proposed NBH development are considered to be:

- Mechanical plant and equipment
- Car park and loading dock activities

This section of the report addresses noise emission associated with these sources at the nearest noise-sensitive receivers in accordance with the DGRs and relevant noise requirements. Where necessary, noise mitigation and/or management measures will be identified.

5.2 Operational noise criteria

In accordance with the DGRs, noise impact from the standard operations of the proposed NBH development is to be assessed against the NSW INP. Based on the DGRs, INP and the measured background noise levels presented in Table 3, Table 21 presents the preliminary operational noise goals for the proposed NBH development. As noted in Section 2.6, the background noise levels and thus project noise goals are subject to review and further detailed noise monitoring.

Table 21: Operational noise goals (INP)

Receiver ID	Description	Intrusiveness criteria $L_{Aeq,15minute}$ dB(A)			Amenity criteria[1] $L_{Aeq,\ period}$ dB(A)		
		Day	Evening	Night	Day	Evening	Night
R1	Residences to the north across Frenchs Forest Rd West	56	50	46	60	50	45
R2	Residences to the south across Warringah Rd	68	59	53	64^	59^	54^
E1	The Forest High School - classrooms, internal	-			35 - noisiest 1 hour period when in use		
C1	Commercial premises	-			65 - when in use		

Notes: Residential locations have been categorised as 'Urban'.

No existing industrial noise contribution was identified for R1 residences.

^The high traffic noise environmental criteria has not been applied in the criteria above as noise level measurements were carried out at street level and lower noise levels are expected at upper levels of development.

Does not apply to emergency services or equipment

5.3 Assessment

5.3.1 Car park

Two car parking areas are proposed for the NBH. An at-grade car park at the eastern side of the site provides 41 spaces, while a multi-storey car park is located to the west of the site. The multi-story car

park provides 1346 spaces across two basement levels, a ground level, and seven upper levels. Entry to and exit from the multi-storey car park is provided at the north western corner.

The operational traffic assessment prepared by Hyder Consulting has been referenced for the noise assessment [12]. The assessment has been based upon the Peak Vehicle Trips (PVT) of 809 outlined in the traffic report. The PVT is expected to occur in the afternoon period coinciding with a staff shift change and the visiting hour's period. From studies carried out for the Stage 1 development, the peak staff would end at 3:30pm and therefore car park movements would be generated outside school hours [13, p. 16]. The assessment presented herein therefore presents a conservative assessment of impacts onto the adjacent school.

Noise predictions for car park activities were carried out in accordance with RLS90 as implemented by Cadna-A computer modelling software. The software takes into account sound radiation patterns, acoustic shielding and potential reflections from intervening building elements and noise attenuation due to distance. RLS90 is a German standard for car park and road traffic emissions which has been developed from extensive measurements of car park activities. Noise from the car park areas are modelled as area sources (for general parking areas). Modelling input for the area sources include the number of parking spaces and the number of park space changes on a per-space/per-hour basis.

Table 22: Car park traffic figures for noise modelling

Peak Vehicle Trips (PVT)			Car parking spaces			Car space change over (per space per hour)
IN	OUT	TOTAL	At-grade*	West multi-deck	Total	
162	647	809	62	1346	1408	0.3

Note * Includes eastern car park and drop off area.

Based on the above figures, Table 23 presents a summary of the noise assessment at the nearest most sensitive receiver locations to on site vehicular activities.

Table 23: Car park noise predictions, $L_{Aeq\ (15minute)}$

Location	Predicted Noise Level	Criteria (Day/Evening)
124 Frenchs Forest Road West	49	56/50
106 Frenchs Forest Road West	40	56/50
E1 - Forest High School (eastern most building)*	34 (internal)	35 (internal)

Notes: * Assessment assumes windows to classrooms are closed based on traffic noise exposure form Frenchs Forest Road. Conservative noise reduction of 20dB(A) via closed windows.

The noise level prediction based on the peak vehicle trips reveal compliance with the established noise criteria for the relevant time period. Concerning impacts on the adjacent school, it is noted that the predicted external noise level of 54dB(A) is comparable with the existing peak road traffic noise exposure from Frenchs Forest Road West. As outlined in Table 3, the average L_{Aeq} for the daytime period is 52dB(A). It is also noted that the site access and traffic generation are consistent with that determined in the concept plan. The predicted peak movements are nonetheless forecast to occur outside of school hours.

5.3.2 Loading dock

The shared back of house and loading dock are located within the basement of the NBH and accessed from the southern side of the Hospital building. Positioning the loading dock with in the basement of the NBH significantly reduces noise emission from loading dock activities to nearby sensitive receivers. Noise from vehicles entering the site will be negligible given the high traffic noise levels on surrounding road network. The location is therefore considered optimal, and activities should not contribute total site noise emissions.

5.4 Recommendations

5.4.1 Mechanical plant and equipment

Mechanical plant associated with the development has the potential to impact on nearby noise sensitive properties. In order to carry out a quantitative assessment of mechanical equipment, a complete specification of equipment is required. At this stage of the development appropriate detail for mechanical plant is not typically available. A qualitative assessment has therefore been carried out and in-principle noise management measures outlined:

- Various items of mechanical plant and equipment are located throughout the development. Mechanical plant and equipment located in the basement level will reduce noise emission from the site to nearby sensitive receivers. Whilst discharge and intake will need to be ducted to external locations, sufficient scope is considered to be provided for any necessary acoustic treatment along these paths. For items of mechanical plant located on levels 2,7and 8 strategic location, selection of variable speed/load equipment and potential localised acoustic treatment is expected to be required for control of noise emission to sensitive receivers.
- Acoustic assessment of mechanical services equipment should be undertaken during the detail design phase of the development to ensure that the cumulative noise of all equipment does not exceed the applicable noise criteria.
- Noise control treatment can affect the operation of the mechanical services system. An acoustic engineer should be consulted during the initial design phase of mechanical services system to reduce potential redesign of the mechanical system.
- Mechanical plant noise emission can be controlled by appropriate mechanical system design and implementation of common engineering methods, which may include:
  - procurement of 'quiet' plant
  - strategic positioning of plant away from sensitive neighbouring premises to maximise intervening acoustic shielding between the plant and sensitive neighbouring premises
  - commercially available acoustic attenuators for air discharge and air intakes of plant
  - acoustically lined and lagged ductwork

  - acoustic barriers between plant and sensitive neighbouring premises
  - partial or complete acoustic enclosures over plant

- The specification and location of mechanical plant should be confirmed prior to installation on site, and
- Fans shall be mounted on vibration isolators and balanced in accordance with Australian Standard 2625 '*Rotating and Reciprocating Machinery – Mechanical Vibration*'.

6 Helicopter noise assessment

6.1 Criteria

6.1.1 Impact onto nearby sensitive development

No standard is applicable that specifies noise criteria for sensitive developments nearby helipads operating on hospitals, as noise associated with the use of emergency vehicles, including ambulances, is expressly excluded from compliance with acoustic controls.

However, for the purposes of assessing the noise impact from the operation of helicopters on nearby sensitive development, reference is made to the Air Services Australia document ' Environmental Principles and procedures for Minimising the Impact of Aircraft Noise. The relevant principle outlined in this document is reproduced below:

> *'Principle 7 - There should be a current agreed aircraft noise exposure level above which no person should be exposed, and agreement that this level should be progressively reduced. The goal should be 95 dB(A).'*

6.1.2 Impact onto hospital

No standard is applicable that specifies noise criteria for helipads operating on hospitals.

The UK Department of Health Technical Memorandum identifies that sporadic noise events such as vehicle sirens and helicopters may impact onto hospital developments and recommends that an appropriate strategy be devised to manage this noise, however, it does not set specific design goals [14].

AS/NZ 2021:2000 addresses aircraft noise intrusion from aircraft movements at nearby aerodromes [15]. The standard sets maximum internal noise levels from aircraft flyovers for buildings, including healthcare buildings. However, the standard is not intended for movements from a helipad located on or near a building impacting on that building and the criteria may be considered too stringent due to the close proximity to the building of the noise source and the sporadic nature of helicopter noise events.

In the absence of any specific criteria relating to noise intrusion from the operation of a helipad into a hospital, guidance has been sought from international publications, industry studies and criteria adopted for similar NSW Health developments.

An acoustic criteria of 70dB(A) has been adopted by similar projects for wards, treatment and consulting rooms with 65dB(A) adopted for operating theatres.

The criteria adopted by Healthscope are presented in Table 24.

Table 24: Maximum internal helicopter noise levels

Occupancy	Design noise level LAmax
Wards	70 dB(A)
Noise sensitive space (including wards, theatres, treatment, consult, offices)	70 dB(A)

6.2 Assessment

The design helicopter for the project is an Agusta Westland AW139. The following sound power level has been referenced from NDY acoustics report for Hornsby Ku-ringai hospital.

Table 25: Helicopter activities - maximum sound power levels (dB re 1 pW)

Octave bands (dB Hz)							
63	**125**	**250**	**500**	**1k**	**2k**	**4k**	**8k**
139	136	135	132	131	125	118	113

Based on the flight path obstruction provided by the upper level plant room, it has been assumed that the primary flight path for will be in an east-west direction, with the helicopter arriving and departing in either direction. A flight path of 7.5 degree departure and arrival has also been assumed.

With regard to impact upon the NBH site, acoustic specification of the building envelope is required to meet the recommended internal noise goals. In principle recommendations are provided in the following section.

Concerning noise impact on surrounding development, the noise modelling carried out by Rehbein Airport Consulting indicates that only departures to the south west may exceed the 95dB(A) max levels at locations off the site [16]. It is noted that the modelling was carried out on the basis of a louder helicopter than the design Agusta Westland AW139. The area of exceedance is limited to an area at the southernmost building The Forest High School.

6.3 Recommendations

The helipad required for the NBH has been located as far as practical from surrounding sensitive development, minimising potential impact during approach and take off. The helipad has been situated in the south eastern corner of the Hospital rooftop, being removed from the neighbouring school and primary residential area to the north along Frenchs Forest Road West.

As the flight path is dictated by any on site or building obstructions, the design is such that an east west flight path is established. The possibility of directing the majority of approaches and departures to and from the east over less sensitive commercial development would further reduce noise exposure to the neighbouring school and adjacent residential receptors. This is particularly desirable during the daytime period. Outside school hours, departures or arrivals from the west would have lesser impact on residential premises as they are further removed from the site at which point the helicopter would be at

a higher altitude. Where flights are required over the school during day periods, the frequency and area of high noise exposure would be limited.

Both the location of the helipad and established flight path of helicopter operations reduce the potential noise impact on surrounding noise sensitive development.

Regarding impact onto the NBH, detailed acoustic design of the building envelopes will be required during the design development stage. Preliminary assessment however has established specifications for the glazing, walls and roof of the buildings in accordance with the internal noise goals nominated for the project.

Glazing specification ranges from Rw 39 to Rw 33, with wall acoustic ratings generally 10-15dB higher. The upper level roof is recommended to have a minimum acoustic rating of Rw 55 for the Hospital building. In-principle constructions meeting the established acoustic performances have been incorporated into the base design of the NBH.

7 Road traffic generated by the development

7.1 Noise criteria

Noise impact as a result of increased traffic generated on the surrounding road network is required to be assessed in accordance with The NSW Road Noise Policy (RNP) [4]. The RNP was introduced in July 2011 and replaced the NSW *Environmental Criteria for Road Traffic Noise* (ECTRN). Table 3 of the RNP sets out the assessment criteria for residences to be applied to particular types of project, road category and land use. These criteria are for assessment against façade corrected noise levels when measured in front of a building façade. In Table 3, freeways, arterial roads and sub-arterial roads are grouped together and attract the same criteria. The roads surrounding the NBH are classified either arterial or sub-arterial roads under the RNP.

Table 26: Road traffic noise criteria for surrounding 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	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)

Where existing traffic noise levels are above the noise assessment criteria, the primary objective is to reduce these through feasible and reasonable measures to meet the assessment criteria. A secondary objective is to protect against excessive decreases in amenity as the result of a project by applying the relative increase criteria.

For existing residences and other sensitive land uses affected by *additional traffic on existing roads generated by land use developments*, any increase in the total traffic noise level should be limited to 2dB above that of the corresponding 'no build option'.

7.2 Assessment

The operational traffic assessment prepared by Hyder Consulting has been referenced for the noise assessment [12]. The noise assessment is to be based on the average traffic generated over the 15-hour day and 9-hour night period, however the traffic study forecasts only peak hour generation. On this basis, the traffic generation has compared for the AM and PM periods, and the noise levels averaged for the purpose of assessment. The Peak Vehicle Trips (PVT) of 809 and Morning Vehicle Peak (MVT) of 297 outlined in the traffic report have been used. Both periods are generally determined by staff shift changeovers and occur during the daytime traffic assessment period 7:00am to 10:00pm.

As the existing road traffic noise levels along Warringah Road and Frenchs Forest Road West exceed the base criteria of the RNP, the 2dB(A) allowance is used as the basis of assessment.

Table 27 presents the summary of the noise assessment. The results reveal compliance for all locations.

Table 27: Peak hour traffic noise assessment

Road - Section	Period	Traffic volumes		Noise level difference, dB	
		Existing peak	NBH generation	Individual period	AM/PM average
Warringah Rd - West of NBH entry	AM	3250	93	0.1	
	PM	3600	29	0.0	0.1
Warringah Rd - East of NBH entry	AM	3250	11	0.0	
	PM	3600	253	0.3	0.2
Frenchs Forest Rd West - West of NBH entry	AM	643	148	0.9	
	PM	546	125	0.9	0.9
Frenchs Forest Rd West - East of NBH entry	AM	643	46	0.3	
	PM	546	402	2.4	1.3

8 Road traffic noise intrusion

8.1 Noise criteria

The State Environmental Planning Policy (Infrastructure) 2007 (ISEPP) sets out statutory requirements for the assessment of noise sensitive development near major road and rail infrastructure. The relevant extract from the ISEPP states:

> *102 Impact of road noise or vibration on non-road development*
>
> *This clause applies to development for any of the following purposes that is on land in or adjacent to the road corridor for a freeway, a tollway or a transitway or any other road with an annual average daily traffic volume of more than 40,000 vehicles (based on the traffic volume data published on the website of the RTA) and that the consent authority considers is likely to be adversely affected by road noise or vibration:*
>
> – *a building for residential use,*
> – *a place of public worship,*
> – *a hospital,*
> – *an educational establishment or child care centre.*
>
> *Before determining a development application for development to which this clause applies, the consent authority must take into consideration any guidelines that are issued by the Director-General for the purposes of this clause and published in the Gazette.*

The Roads and Maritime Services (RMS) identify Warringah Freeway as having an average annual daily traffic (AADT) greater than 40,000 and therefore an acoustic assessment is mandatory. Wakehurst Parkway is identified to have an AADT between 20,000 and 40,000 for which it is 'recommended' that assessment also be carried out [11].

In accordance with the ISEPP the relevant guideline to be considered is the *Development in Rail Corridors and Busy Roads – Interim Guideline* released by the NSW Department of Planning [6]. The guideline presents the following criteria.

Table 28: Noise criteria for noise sensitive developments

Non–residential buildings / Type of occupancy		Recommended Max level dB(A)
Hospitals	- wards	35
	- other noise sensitive areas	45

Note: airborne noise is calculated as Leq (9h) (night) and Leq (15h)(day).
Excerpt of Table 3.1 of the guideline [6]

For other noise sensitive areas, the guideline recommends reference be made to AS2107:2000 [17]. The relevant criteria are presented in Table 29.

Table 29: Recommended design sound levels

Type of occupancy/activity	Recommended design sound level, L_{Aeq}, dB(A)	
	Satisfactory	Maximum
Conference rooms	30	40
General offices	40	45
Offices and meeting rooms	30	40
General offices	40	45
Consulting rooms	40	45
Interview/Counselling rooms	40	45
Physiotherapy	40	45
General Wards	35	40
Intensive Care Wards	40	45
Delivery Suites	45	50
Mental Health Wards	35	40
Operating theatres	40	45
Casualty Areas (Emergency)	40	45
Kitchen	50	55
Staff stations	40	45
Sterilising and Service areas	50	55
Staff common rooms	40	45
Corridors and lobbies	40	50
Waiting rooms, reception areas and foyers	40	50
Store rooms	45	50
Utility rooms	45	50

8.2 Assessment

The following noise monitoring results have been used for the preliminary assessment of road traffic noise intrusion.

Table 30: Traffic noise monitoring results, dB(A)

Location	Distance from kerb	$L_{Aeq\ 15hour}$ Day traffic (free field)
Lb - south, acoustically shielded in vegetated area.	80m	55
S2 - Wakehurst Parkway	5m	68
S3 - Cnr Hilmer and Warringah Rd	1m	72

The acoustic design of the building envelope will be developed during the detailed design with additional detailed measurements and noise modelling. The following however demonstrates the ability of the development to be designed in accordance with the relevant criteria, with assessment to the most sensitive ward locations.

Table 31: Traffic noise assessment for wards, dB(A)

Building	Façade / Road	Distance from façade to kerb (m)	$L_{Aeq\ 15hour}$ Day traffic (free field)	Indicative acoustic performance requirements for road traffic
Hospital	South / Waringah Road	90m	62	Rw33
	East / Wakehurst Parkway	95m	58	Rw30

Notes: Requirements for helicopter noise intrusion may exceed those nominated for road traffic noise impact.

9 Conclusion

Renzo Tonin & Associates has completed an assessment of noise and vibration to support Planning Proposal (PP) for the Northern Beaches Hospital (NBH). The assessment addresses The Director General's Requirements for application number SSI_5982. Specifically, the report has addressed the matters pertaining to noise and vibration emission during the excavation, construction and operation of the site.

Where relevant the report has presented recommended mitigation and management measures for the control of noise and vibration for both the construction and operational phases of the development. The report has also identified where additional detailed assessment may be required during the design development phase of the project.

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APPENDIX A Glossary of terminology

The following is a brief description of the technical terms used to describe noise to assist in understanding the technical issues presented.

Adverse Weather	Weather effects that enhance noise (that is, wind and temperature inversions) that occur at a site for a significant period of time (that is, wind occurring more than 30% of the time in any assessment period in any season and/or temperature inversions occurring more than 30% of the nights in winter).
Ambient Noise	The all-encompassing noise associated within a given environment at a given time, usually composed of sound from all sources near and far.
Assessment Period	The period in a day over which assessments are made.
Assessment Point	A point at which noise measurements are taken or estimated. A point at which noise measurements are taken or estimated.
Background Noise	Background noise is the term used to describe the underlying level of noise present in the ambient noise, measured in the absence of the noise under investigation, when extraneous noise is removed. It is described as the average of the minimum noise levels measured on a sound level meter and is measured statistically as the A-weighted noise level exceeded for ninety percent of a sample period. This is represented as the L90 noise level (see below).
Decibel [dB]	The units that sound is measured in. The following are examples of the decibel readings of every day sounds: 0dB The faintest sound we can hear 30dB A quiet library or in a quiet location in the country 45dB Typical office space. Ambience in the city at night 60dB CBD mall at lunch time 70dB The sound of a car passing on the street 80dB Loud music played at home 90dB The sound of a truck passing on the street 100dBThe sound of a rock band 115dBLimit of sound permitted in industry 120dBDeafening
dB(A)	A-weighted decibels. The ear is not as effective in hearing low frequency sounds as it is hearing high frequency sounds. That is, low frequency sounds of the same dB level are not heard as loud as high frequency sounds. The sound level meter replicates the human response of the ear by using an electronic filter which is called the "A" filter. A sound level measured with this filter switched on is denoted as dB(A). Practically all noise is measured using the A filter.
Frequency	Frequency is synonymous to pitch. Sounds have a pitch which is peculiar to the nature of the sound generator. For example, the sound of a tiny bell has a high pitch and the sound of a bass drum has a low pitch. Frequency or pitch can be measured on a scale in units of Hertz or Hz.
Impulsive noise	Having a high peak of short duration or a sequence of such peaks. A sequence of impulses in rapid succession is termed repetitive impulsive noise.
Intermittent noise	The level suddenly drops to that of the background noise several times during the period of observation. The time during which the noise remains at levels different from that of the ambient is one second or more.
L_{Max}	The maximum sound pressure level measured over a given period.
L_{Min}	The minimum sound pressure level measured over a given period.
L_1	The sound pressure level that is exceeded for 1% of the time for which the given sound is measured.
L_{10}	The sound pressure level that is exceeded for 10% of the time for which the given sound is measured.

L_{90}	The level of noise exceeded for 90% of the time. The bottom 10% of the sample is the L90 noise level expressed in units of dB(A).
L_{eq}	The "equivalent noise level" is the summation of noise events and integrated over a selected period of time.
Reflection	Sound wave changed in direction of propagation due to a solid object obscuring its path.
SEL	Sound Exposure Level (SEL) is the constant sound level which, if maintained for a period of 1 second would have the same acoustic energy as the measured noise event. SEL noise measurements are useful as they can be converted to obtain Leq sound levels over any period of time and can be used for predicting noise at various locations.
Sound	A fluctuation of air pressure which is propagated as a wave through air.
Sound Absorption	The ability of a material to absorb sound energy through its conversion into thermal energy.
Sound Level Meter	An instrument consisting of a microphone, amplifier and indicating device, having a declared performance and designed to measure sound pressure levels.
Sound Pressure Level	The level of noise, usually expressed in decibels, as measured by a standard sound level meter with a microphone.
Sound Power Level	Ten times the logarithm to the base 10 of the ratio of the sound power of the source to the reference sound power.
Tonal noise	Containing a prominent frequency and characterised by a definite pitch.