Appendix H

Construction Noise and Vibration Assessment

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Sydney Opera House Trust

Bennelong Drain Diversion Project

Construction Noise and Vibration Assessment

January 2010

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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Glossary – Acoustic terms

dB	Decibel is the unit used for expressing the sound pressure level (SPL) or power level (SWL) in acoustics.
dB(A)	Frequency weighting filter used to measure 'A-weighted' sound pressure levels, which conforms approximately to the human ear response, as our hearing is less sensitive at very low and very high frequencies.
$L_{Aeq(period)}$	Equivalent sound pressure level: the steady sound level that, over a specified period of time, would produce the same energy equivalence as the fluctuating sound level actually occurring.
$L_{A10(period)}$	The sound pressure level that is exceeded for 10% of the measurement period.
$L_{A90(period)}$	The sound pressure level that is exceeded for 90% of the measurement period.
L_{Amax}	The maximum sound level recorded during the measurement period.
Noise sensitive receiver	An area or place potentially affected by noise which includes: ◗ a residential dwelling; ◗ a, educational institution, library, childcare centre or kindergarten; ◗ a hospital, surgery or other medical institution; ◗ an active (e.g. sports field, golf course) or passive (e.g. national park) recreational area; ◗ commercial or industrial premises; or ◗ a place of worship.
Rating Background Level (RBL)	The overall single-figure background level representing each assessment period (day/evening/night) over the whole monitoring period.
Vibration	The variation of the magnitude of a quantity which is descriptive of the motion or position of a mechanical system, when the magnitude is alternately greater and smaller than some average value or reference. Vibration can be measured in terms of its displacement, velocity or acceleration. The common units for velocity are millimetres per second (mm/s).
Peak Particle Velocity	Peak Particle Velocity (PPV), is the maximum vector sum of three orthogonal time-synchronized velocity components regardless of whether these component maxima occurred simultaneously.
VDV	Vibration Dose Value (VDV) - As defined in BS6472 – 1992, VDV is given by the fourth root of the integral of the fourth power of the frequency weighted acceleration.

1. Introduction

1.1 Purpose of this report

The Sydney Opera House Trust is proposing to divert the Bennelong Drain from its existing route to a new route discharging at Farm Cove (referred to as 'the project' for the purposes of this document).

This report has been prepared by GHD Pty Ltd (GHD) as part of the environmental assessment of the project. The Sydney Opera House Trust is the proponent of the project, and the environmental assessment is being prepared by GHD in accordance with the requirements of Part 3A of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act).

This report assesses the potential construction noise and vibration impacts of the project.

The construction works are located within the City of Sydney local government area. The assessment has been undertaken with consideration to the following guidelines and policies:

- *City of Sydney Code of Practice: Construction Hours / Noise within the Central Business District (1992);*
- *Department of Environment and Climate Change (DECC) NSW Interim Construction Noise Guideline (CNG) (July 2009); and*
- *DECC Assessing Vibration: a technical guideline (2006).*

1.2 Project outline

The project involves the construction of a new section of drain from the point where the Bennelong Drain enters the Sydney Opera House site, adjacent to the air intake structure for the Sydney Opera House car park. The Sydney Opera House Car Park is a separate entity owned by the State Property Authority and leased by the Trust Company of Australia.

The new section of drain would run in an easterly direction close to the Tarpeian Wall, around the southern side of the exhaust air shaft for the Sydney Opera House car park, extending to the proposed discharge point at Farm Cove

The new section of drain would take the form of a box culvert measuring approximately 1.5 m wide by 1.5 high (internal dimensions) or 1.8 m wide by 1.9 m high (external dimensions) at the junction point, increasing to approximately 2.4 m wide by 1.8 m high (internal dimensions) or 2.7 m wide by 2.2 m high (external dimensions) along the majority of the diversion route. A 4.39 m deep junction pit would be constructed as the junction between the existing drain and the new section of drain. The junction pit would include an access cover for maintenance access. The access cover would be located within a narrow strip of feature garden located at the southern extreme of the Sydney Opera House site against the base of the Tarpeian Wall.

An area of approximately 8 m by 8 m would need to be excavated around the area of the proposed new junction to construct and install the required infrastructure. Excavation would also be required along the route of the proposed diversion, an excavation width approximately 2m to 3.2 m wide (dependant on the size of the drain) would be required to allow sufficient space for the drain to be laid.

An approximately 8m long section of the original Bennelong Drain would need to be removed to allow construction of the junction between the Bennelong Drain and the new section.

The discharge point for the new section of box culvert drain would be located within the seawall at Farm Cove, immediately above the sea bed between the Royal Botanic Gardens Queen Elizabeth II gate and the Man O' War jetty.

The existing section of drain will be blocked off at the diversion point.

The construction of the project would take approximately six to nine months and construction would occur during recommended standard hours for construction work (as per DECC's CNG) as outlined in Section 3.1 of this report.

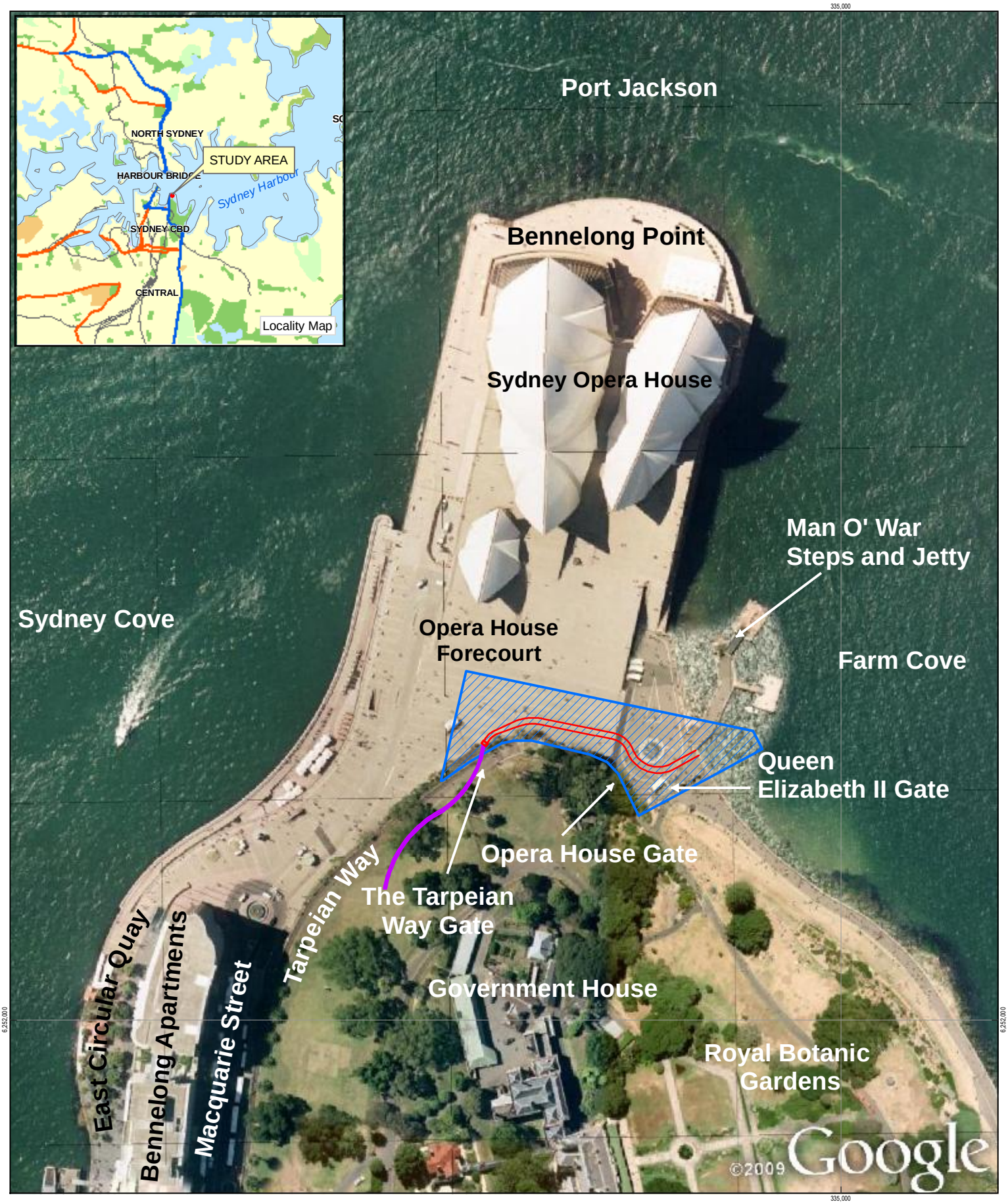
1.3 Location of project

The site for the project is located within the forecourt area of Sydney Opera House, at the northern end of the Sydney CBD, on Bennelong Point. Bennelong Point is located between Sydney Cove and Farm Cove, both of which form part of Sydney Harbour. The project is located within the City of Sydney local government area (LGA).

The forecourt area is situated to the south of Sydney Opera House, between the Monumental Steps and the Tarpeian Wall.

The proposed outlet or discharge point for the proposed new section of drain would be located within the seawall at Farm Cove, immediately above the sea bed between the Royal Botanic Gardens Queen Elizabeth II gate and the Man O' War jetty.

The site location is shown in Figure 1.1.



Legend

Study Area — Upstream Drain Alignment

Proposed Drain Realignment

0 10 20 40 60

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

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Bennelong Drain Diversion Project
Noise and Vibration Assessment

Location of Key Site Features and Surrounds

Job Number	21-18445
Revision	B
Date	Jan 2010

Figure 1.1

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Data source: Aerial Imagery from Google Earth Pro 2009; Locality Map Data, Navigate and Navteq, 2008.

1.4 Sensitive receivers

The site is zoned Parks and Community Places under the *Sydney Local Environmental Plan 2005* and is therefore considered a sensitive receiver area with consideration to noise and vibration.

Sensitive receivers in the area consist of the following:

- Government House;
- Bennelong Apartments,
- Sydney Opera House and forecourt;
- Royal Botanic Gardens; and
- Developments to the south-west of the site along Macquarie Street and around Circular Quay, which consist mainly of commercial and residential developments along the foreshore.

1.5 Operation of the project

Following construction of the project, no noise or vibration emissions, which have the potential to cause environmental harm, would be generated.

As such, potential noise and vibration impacts would be limited to the construction stages of the project.

1.6 Limitations

This report has been prepared for the Sydney Opera House Trust to assess the potential construction noise and vibration impacts associated with the project.

It is not the intention of the assessment to cover every element of the acoustic environment, but rather to conduct the assessment with consideration to the prescribed work scope for the project.

In conducting this assessment and preparing the report, current guidelines for noise and vibration were referred to. This work has been conducted in good faith with GHD's understanding of the client's brief and the generally accepted consulting practice.

No other warranty, expressed or implied, is made as to the information and professional advice included in this report. It is not intended for other parties or other uses.

2. Existing environment

2.1 Noise monitoring methodology

An attended background noise survey was undertaken on Thursday 23 April 2009 in order to quantify the ambient noise environment in the vicinity of the construction site and potentially affected receivers. Noise monitoring was undertaken with consideration to Australian Standard AS1055.1, *Acoustics – Description and measurement of environmental noise – Part 1: General Procedures.* The construction works are to be undertaken during recommended standard construction hours and are considered to be low risk, therefore 15-minute attended noise measurements were undertaken to establish background noise levels. A Bruel and Kjaer 2250 Type 1 Sound Level Metre (SLM) was used to undertake the attended measurements. The SLM was programmed to record 15-minute A-weighted sound levels, L_{A90}, L_{Aeq} and L_{A10}.

The equipment carries current calibration certification. A calibration check was performed before and after the noise logging and was within the acceptable limits of +/- 0.5 dB(A)

Site observations indicated that there were no adverse weather conditions at the time of monitoring.

2.2 Noise monitoring locations

Attended noise measurements were undertaken at the following locations in order to capture the ambient noise environment in the area:

- L1 – Macquarie Street roundabout near Bennelong Apartments.
- L2 – Sydney Opera House steps;
- L3 – Rear of Sydney Opera House;
- L4 – Tarpeian Way near Government House; and
- L5 – Northern end of the Royal Botanic Gardens.

The monitoring locations can be seen in Figure 2.1. Table 2.1 summarises the measured noise levels for the monitoring locations.

Noise monitoring results and site observations indicate that the ambient noise environment is typical of an urban environment and consisted of the following noise sources:

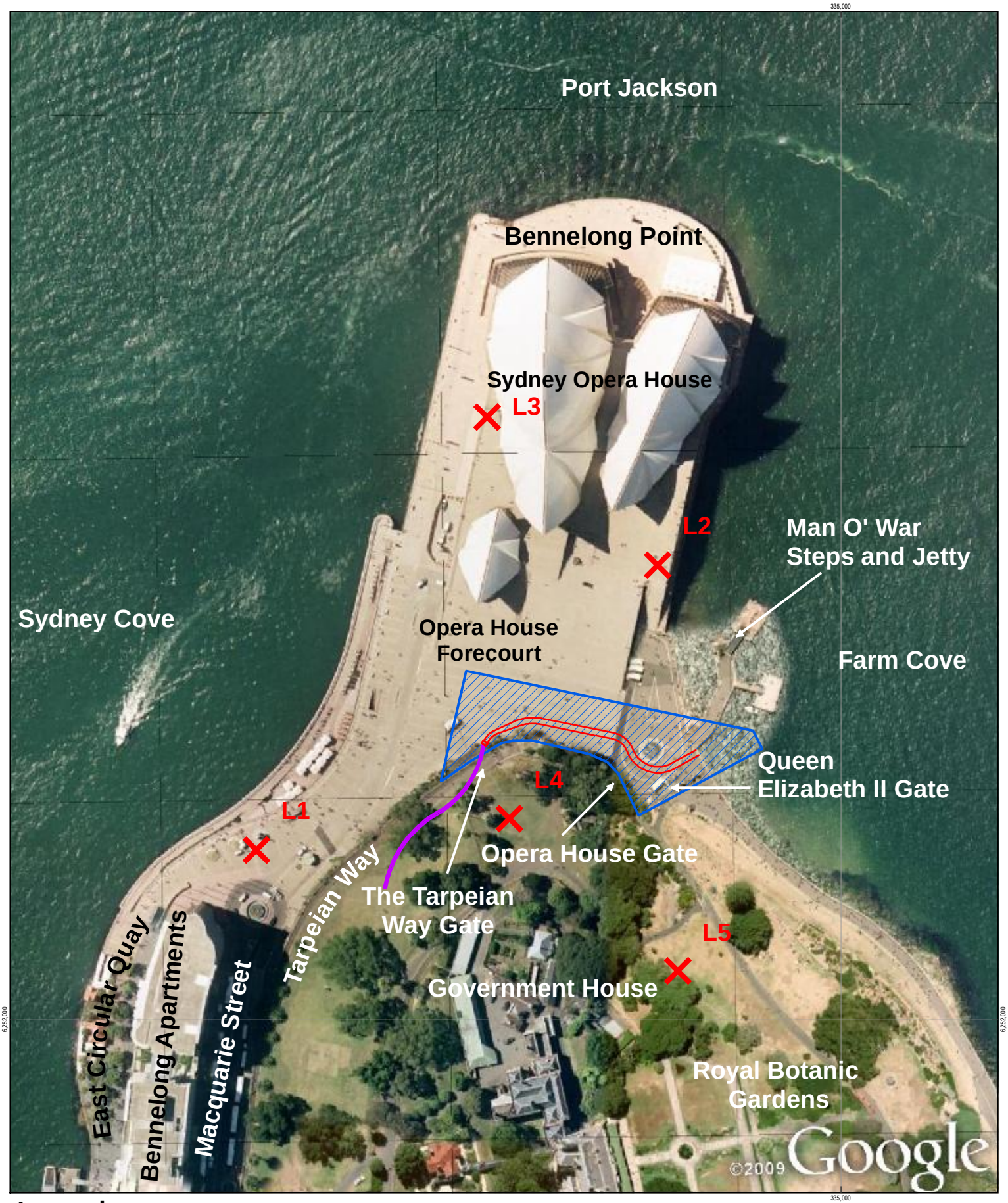
- Road traffic noise form the Sydney Harbour Bridge, Cahill Expressway and Macquarie Street;
- Harbour vessel traffic noise;
- Seagull noise;
- Tourist related noise;
- Loading dock noise; and
- Existing construction noise near the Macquarie Street roundabout and Queen Elizabeth II gate.

'Urban hum', which is defined as the aggregated sound of many unidentifiable noise sources, was present at each monitoring location and is typical of the site.

Site observations indicate that the monitoring locations are representative of the ambient noise environment of the area including the potentially affected receivers. However, it should be noted that the background noise environment would vary depending on localised ambient noise sources.

Table 2.1 Measured background noise levels, dB(A) 15 minute

Monitoring location	L_{A90}	L_{Aeq}	L_{Amax}
L1 – Macquarie Street roundabout (Bennelong Apartments)	60	63	73
L2 – Sydney Opera House steps	53	55	68
L3 – Rear of Sydney Opera House	58	60	69
L4 – Tarpeian Way near Government House	52	55	69
L5 – Northern end of the Royal Botanic Gardens	47	50	73



Legend

Monitoring Location

Upstream Drain Alignment

Proposed Drain Realignment

0 10 20 40 60

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

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Bennelong Drain Diversion Project
Noise and Vibration Assessment

Noise Monitoring Locations

Job Number	21-18445
Revision	B
Date	Jan 2010

Figure 2.1

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3. Noise and vibration criteria

3.1 Construction noise criteria

The DECC CNG provides guidance for assessment of construction noise. The guidelines recommend standard hours for construction activity as follows:

- Monday to Friday: 7 am to 6 pm;
- Saturday: 8 am to 1 pm; and
- No work on Sundays or Public Holidays.

The CNG provides noise management levels for both residential and other sensitive land uses. For non-residential sensitive land uses, the management levels apply only at times when the sensitive land use is occupied. For this assessment the non-residential sensitive land use in the vicinity of the works is mostly passive recreational areas, therefore the management level is 60 dB(A)$L_{Aeq,15min}$.

The management levels at residences are to be calculated based on the adopted rating background level (RBL) and are shown in Table 3.1. The minimum measured background noise level was used to establish noise criteria.

Table 3.1 CNG Construction noise criteria at residences, dB(A)

Time period	Background level $L_{A90(period)}$	CNG Management level $L_{Aeq(15\ min)}$
Recommended standard hours	Between 47 dB(A) and 60 dB(A)	Noise affected level – 57 dB(A) Highly noise affected level - 75 dB(A)

The *noise affected level* of 57 dB(A) represents a point at which there may be some reaction to noise by the community. The *highly noise affected level* of 75 dB(A) represents a point where there may be a strong reaction to noise from the community.

The City of Sydney *Code of Practice: Construction Hours / Noise within the Central Business District* provides noise criteria for residential receivers. Sydney Opera House falls within the area to which the Code applies. The City of Sydney criteria for residential receivers are:

- 7 am – 8 am – Background + 5 dB(A);
- 8 am – 7 pm – Background + 10 dB(A);
- 7 pm – 11 pm – Background + 3 dB(A); and
- 11 pm - 7 am – Background.

During general construction hours the noise criteria are identical to those in the CNG except for the period between 7 am and 8 am where it is 5 dB(A) less at residential receivers.

3.2 Construction vibration criteria

Vibration criteria have been set with consideration to the DECC *Assessing Vibration: A Technical Guideline, 2006*. BS 6472 – 1992, *Guide to Evaluation of Human Exposure to Vibration in Buildings (1 Hz to 80 Hz)* is recognised by the DECC as the preferred standard for assessing the 'human comfort criteria'.

The BS 6472 human comfort peak vibration limits are shown in Table 3.2 for the frequency range of 1 Hz to 80 Hz, which is applicable to construction works. These values are limits that may cause loss of amenity to the occupant, however for short duration construction projects they are considered conservative.

BS 6472 also recognises that higher vibration levels are tolerable for short-term construction projects as undue restriction on vibration levels can significantly prolong construction works and result in greater annoyance.

Table 3.2 BS 6472 human comfort vibration limits from 1 Hz to 80 Hz (mm/s Peak[1])

Receiver type	Period[2]	Continuous vibration (mm/s Peak[3])	Impulsive vibration (mm/s Peak)	Intermittent vibration dose value (VDV) ($m/s^{1.75}$)
Residential	Day	0.28	8.6	0.2
	Night	0.20	2.8	0.13

[1] Based on sinusoidal vibration sources

[2] Day is between 7 am and 10 pm and night is between 10 pm and 7 am.

[3] Based on sinusoidal vibration sources

4. Assessment of impacts

4.1 Construction noise impact assessment

The noise emissions from construction have been assessed at the surrounding potentially affected receivers during the general construction hours. A quantitative assessment has been undertaken with consideration to the CNG.

A list of construction equipment has not yet been determined as this is largely dependent on the construction contractor. Typical noise generating equipment to be used on site has been estimated as follows:

- 18 tonne 90 kW wheeled excavator;
- 5 tonne dump truck;
- Hand-held circular saw cutting paving slabs;
- Concrete Saw; and
- 67 kW hydraulic rock breaker.

Sound power levels, including frequency content, are provided in Table 4.1 for all equipment. This data has been sourced from British Standard BS 5228-1:2009, *Code of practice for noise and vibration on construction and open sites – Part 1: Noise.*

Table 4.1 Construction noise sources – sound power levels, dB(A)

	Frequency [Hz]									
Plant Item	**63**	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**	**A**	**lin**
18 tonne 90 kW wheeled excavator	66	72	82	89	90	86	80	72	94	98
5 tonne dump truck (idling)	70	68	66	74	80	79	70	59	84	97
Hand-held circular saw cutting paving slabs	75	79	89	93	101	107	107	104	112	112
Concrete Saw[4]	No spectrum available								117	
67 kW hydraulic rock breaker	88	92	97	102	109	112	111	108	117	119

[4] Sourced from the RTA Environmental Noise Management manual

Construction noise predictions were undertaken using Computer Aided Noise Abatement (CadnaA) to predict the effects of construction noise at the surrounding potentially affected receivers.

CadnaA is a computer program for the calculation, assessment and prognosis of noise propagation. CadnaA calculates environmental noise propagation according to ISO 9613-2, *Acoustics – Attenuation of sound during propagation outdoors*. Ground absorption, reflection, terrain and relevant shielding objects are taken into account in the calculations. The noise predictions do not consider adverse meteorological effects, as this is not a requirement of the CNG.

The following assumptions were made in regards to the noise model:

- Noise receivers were modelled 1.5m above ground level, unless otherwise specified;
- The equipment on site is located on the centreline of the proposed drain;
- Digital ground topography was included in the model at 2 metre intervals;
- The equipment was modelled at ground level, however sawing and rock breaking will be undertaken below the surface level, which will provide additional shielding;
- For conservatism boarding around the site was not modelled;
- The rock breaking and concrete sawing activities will not occur simultaneously. Since the noise levels are approximately the same the rock breaking noise source has been modelled as a frequency spectrum is available, and
- Equipment was modelled as operating continuously at their defined output.

The predicted noise levels for the surrounding potentially effected receivers are shown in Table 4.2 and the predicted noise contours are shown in Figure 4.1.

Table 4.2 Predicted construction noise levels, dB(A)

Potentially affected receiver	Noise criteria	Noise level
Government House	57 (52)[5]	48
Bennelong Apartments[6]	57 (52)[4]	51
Sydney Opera House	Internal Criteria	63
Sydney Opera House forecourt	60	See contour map (Figure 4.1)
Royal Botanic Gardens	60	

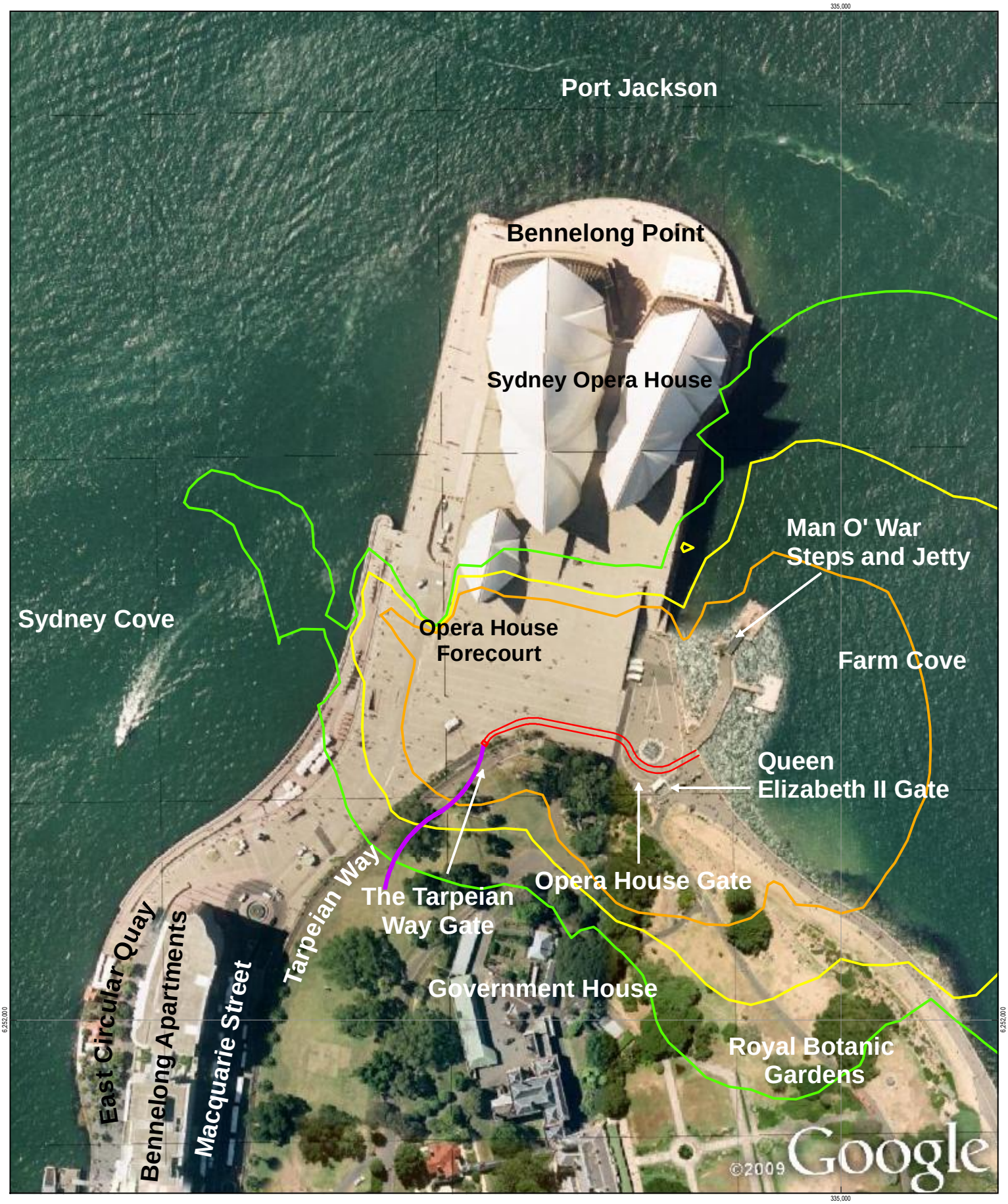
[5] City of Sydney Criteria 7 am to 8 am

[6] Receiver height at top floor (maximum impact)

The noise levels at the Bennelong Apartments and Government House are predicted to comply with the noise criteria, therefore the project should not adversely impact any residences.

There are no specific external noise criteria for Sydney Opera House but rather an internal noise level requirement that should be achieved. The predicted noise level at Sydney Opera House's nearest façade is 63 dB(A), which is below the maximum noise levels measured in the area. Therefore there is unlikely to be any significant increase in noise levels inside of Sydney Opera House.

The noise levels at the Sydney Opera House forecourt area and the northern end of the Royal Botanic Gardens are predicted to exceed the CNG noise criteria of 60 dB(A) $L_{Aeq(15min)}$ in some areas as shown in Figure 4.1. The exceedance is not considered significant since the background noise levels in the area are already high and only a small area of the Sydney Opera House forecourt and Royal Botanic Gardens exceed the criteria. However, since construction noise is expected to exceed noise criteria for parts of the forecourt area and northern end of the Royal Botanic Gardens, it is recommended that the mitigation measures detailed in Section 5 be implemented where feasible and reasonable to reduce potential noise impacts.



Legend

Noise Level LAeq(15min)

- Upstream Drain Alignment
- Proposed Drain Realignment
- 60dBA
- 50dBA
- 55dBA

0 10 20 40 60
Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 56

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Construction Noise Contours

Job Number	21-18445
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Figure 4.1

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Data source: Google Earth Image 2009, Sydney Water 2005. Created by: BAH

4.2 Construction vibration impact assessment

Energy from construction equipment is transmitted into the ground and transformed into vibrations, which attenuates with distance. The magnitude and attenuation of ground vibration is dependent on the following:

- The efficiency of the energy transfer mechanism of the equipment (i.e impulsive; reciprocating, rolling or rotating equipment);
- The frequency content;
- The impact medium stiffness;
- The type of wave (surface or body); and
- The ground type and topography.

Due to the above factors, there is inherent variability in ground vibration predictions without site-specific measurement data. The NSW Roads and Traffic Authority (RTA) *Environmental Noise Management Manual* provides typical construction equipment ground vibration levels at 10m. The rate of vibration attenuation can be calculated from the following regression analysis formula:

$V = kD^{-n}$, *where*

V = PPV

D = Distance

n = attenuation exponent. The value of n generally lies between 1 and 2 with a relatively common value of 1.5[7]

The excavator and breaker are the only items of equipment on site that are anticipated to generate appreciable vibration impacts. There is the potential for other equipment to cause ground vibrations, though these are expected to be minimal.

The predicted ground vibrations at various distances are shown in Table 4.3 for typical excavators and breakers.

Table 4.3 Estimated excavator vibration levels (mm/s Peak)

Plant Item	Vibration level at distances (mms Peak)				
	10 m	20 m	50 m	100 m	200 m
Excavator	3	1	0.3	0.1	0
Breaker	5	2	0.5	0.2	0.1

The Government House and Bennelong Apartments residences are located over 100 m from the construction activities therefore excavation activities are unlikely to produce levels of vibration that are perceptible at these receivers.

[7] Construction Vibrations: State of the Art, John Wiss, 1981

5. Recommended mitigation measures

The CNG provides a summary of potential mitigation measures. It is recommended that the following construction mitigation measures be included in the noise sub-plan of the construction environmental management plan for the project, to reduce the impact on surrounding receivers:

- As far as possible, the amount of materials that are dropped from heights should be minimised;
- Where practical, machines should be operated at low speed or power and should be switched off when not being used rather than left idling for prolonged periods;
- Where possible, equipment should be selected to minimise noise emissions, should be fitted with appropriate silencers and should be in good working order;
- An excavator likely to produce low noise emissions should be selected;
- Machines found to produce excessive noise compared to normal industry expectations should be removed from the site or stood down until repairs or modifications can be made;
- Noise emissions from reversing alarms should be minimised, though use of such alarms should still be satisfactory to achieve occupational health and safety requirements;
- Construction activities should be limited to the CNG recommended standard construction hours;
- All site workers should be made aware of the potential for noise impacts and encouraged to take practical and reasonable measures to minimise noise during the course of their activities; and
- Rock breaking activities should be minimised, where possible.
- Construction hoarding should be used, in accordance with standard practice for construction activities at Sydney Opera House.

6. Conclusions

The noise levels at the Bennelong Apartments and Government House are predicted to comply with the adopted noise criteria. Therefore the project should not adversely impact any residences.

The predicted noise level at Sydney Opera House is less than the maximum noise levels measured in the area; therefore the project is unlikely to generate any significant increase in noise levels inside Sydney Opera House.

The noise levels in the Sydney Opera House forecourt area and at the northern end of the Royal Botanic Gardens are predicted to exceed the CNG noise criteria of 60 dB(A) $L_{Aeq(15min)}$ at some locations. The exceedance is not considered significant, since the background noise levels in the area are already high and only a small area of the Sydney Opera House forecourt and the Royal Botanic Gardens exceeds the criteria. However, since construction noise is expected to exceed noise criteria for parts of the Sydney Opera House forecourt area and the northern end of the Royal Botanic Gardens, it is recommended that construction activities be limited to the CNG recommended standard construction hours and mitigation measures detailed in Section 5 be considered and implemented where feasible and reasonable to reduce potential noise impacts.

The Government House and Bennelong Apartments residences are located over 100 m from the construction activities, therefore excavation activities are unlikely to produce levels of vibration that are perceptible. Hence vibration impacts of the project are not considered significant.

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