M5N-ES-PLN-PWD-0041-03

Report to

CDS

Blast Management Strategy - Stage 2 M5 (Kingsgrove to St.Peters)

Prepared By:

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October 2017

[redacted]

Distribution List:

CSDJV	:	1 Copy
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Project Details:

Project Number	:	HP1703-1
Date Completed	:	October, 2017
File Name	:	WestConnex Stage 2 M5 Blast design management and control Final V3.doc
Date Saved	:	30/10/2017 6:57:00 AM

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COMPLIANCE TABLE

The blasting Conditions of Approval have been addressed in the Blast Management Plan. The following Table highlights the areas where each Condition is addressed:

Condition	*Description*	*Reference in Blast Management Strategy*
D28	Prepare a Blast Management Strategy demonstrating that all blasting will not generate unacceptable vibration impacts	This document
D29	The vibration levels for the blasting activities shall meet the requirements of D34 and D35	Section 1.3 - Performance Limits on Page 6
D30	Blasts shall be limited to an average of one single detonation per day per single receiver and maximum of six per week, unless otherwise agreed by the EPA	Section 1.1 - Revised Blasting Times on Page 8
D31	A series of initial trials at reduced scale shall be completed prior to production blasting to determine site specific blast response characteristics	Section 7.1 - Trial Blasting on Page 25
D32	Blasting associated with the project will only be undertaken during specified times	Section 1.1 - Revised Blasting Times on Page 8
D33	Where vibration levels exceed acceptable values, feasible and reasonable mitigation measures shall be implemented	Section 8 – Contingencies On Page 27
D34	Specified airblast criteria	Section 1.3 - Performance Limits on Page 6
D35	Ground vibration generated by blasting shall be limited to human comfort criteria	Section 1.3 - Performance Limits on Page 6
D36	The blasting criteria specified in conditions D34 and D35 do not apply where there is a written agreement with the relevant landowners. The blasting limit agreed to any under any agreement can at no time exceed 25mm/s or 125dBL	

1. BACKGROUND

Stage 2 of WestConnex – The New M5 – will run from the existing M5 East corridor at Kingsgrove via tunnel to St Peters, providing improved access to the airport, south Sydney and Port Botany precincts.

Key features of the New M5 include:

- new twin tunnels that are higher, wider and flatter, which will more than double capacity along the M5 East corridor and provide motorway access to north of Sydney Airport
- a new interchange at an industrial site at St Peters, which reduces the impact on nearby residential areas
- connections from the interchange to key roads in the area, including Campbell Road/Street, Euston Road and across the canal to Bourke Road
- widening of Campbell Road/Street and Euston Road through existing road widening reservations
- western tunnel entry and exit points at Kingsgrove.

This Blast Management Strategy report is prepared to provide a framework for the procedures to maintain best practice controls to manage potential environmental impacts during the blasting activities linked with developing the mainline tunnel and ramps, although will also apply to other areas where drilling and blasting may be required as method of excavation.

The objective of this document is therefore to:

- Describe how *CDS* propose to manage blasting activities and the related potential environmental impacts such as vibration. It sets out the performance requirements and procedures to ensure that potential environmental impacts associated with blasting activities are adequately identified and controlled for the project.
- This document is applicable to all the drilling and blasting activities during the construction phases of the project and will be equally applicable should other areas along the project alignment necessitate drilling and blasting activities. This document has been prepared to address the requirements of the project Environmental Management Plan (EMP).

In addition to this Blast Management Strategy Document, *CDS* will ensure that any engaged sub-contractor for the blasting activities will have developed their own comprehensive site blasting management regime. The contractor will have a comprehensive suite of procedures covering both workplace health and safety and safe blasting practices. Copies of these documents will be provided by the drill and blast contractor and reviewed by *CDS* prior to commencement of any blasting activities.

1.1. Baseline Conditions of Approval

In the Conditions of Approval, D28 indicates that should blasting be required, a Blast Management Strategy must be developed and in consultation with the Environmental Protection Agency (EPA) and this Blasting Management Strategy should be incorporated into the Construction Noise and Vibration Management Plan (CNVMP). The Strategy should be prepared with an aim to demonstrate that all blasting and associated activities will be undertaken in a manner that will not generate unacceptable noise and vibration impacts or pose a significant risk impact to residences and sensitive receptors. The Strategy also addresses the principles outlined in *Hazardous Industry Planning Advisory Paper No 6: Hazard Analysis* (Department of Planning January 2011) and *Assessment Guideline: Multi-Level Risk Assessment* (Department of Planning and Infrastructure May 2011) for the handling and storage of hazardous materials. Issues considered in the Strategy include, but not necessarily be limited to:

a) Details of blasting to be performed, including location, method and justification of the need to blast;

b) Identification of any potentially affected noise and vibration sensitive sites including heritage buildings and utilities;
c) Establishment of appropriate criteria for blast overpressure and ground vibration levels at each category of noise sensitive site;
d) Details of any storage and handling arrangements for explosive materials and the proposed transport of those materials to the construction site;
e) Identification of hazardous situations that may arise from the storage and handling of explosives, the blasting process and recovery of the blast site after detonation of the explosives;
f) Determination of potential noise and vibration and risk impacts from blasting and appropriate best management practices; and
g) Community consultation procedures.

Other relevant conditions in the Conditions of Approval include:

- D29 – The vibration levels for blasting activities, including both above ground and underground work, shall meet the requirements of D34 and D35.

- D30 – Blasts must be limited to an average of one single detonation in any one day per sensitive receiver, and a maximum of six per week, unless otherwise agreed by the EPA through consultation on the Blast management Strategy.

  For the purposes of this condition a single detonation may involve a number of individual blasts fired in quick succession in a discrete area

- D31 – For any section of tunnel construction where blasting is proposed, a series of trials at reduced scale shall be conducted prior to production blasting to determine site-specific blast response characteristics and to define allowable blast sizes to meet the Airblast overpressure and ground vibration limits in conditions D34 and D35.

- D32 – Blasting associated with the project shall; only be undertaken during the following hours:
  a) 9:00am to 5:00pm, Monday to Friday inclusive;
  b) 9:00am to 1:00pm Saturday; and
  c) At no time on Sunday or on a public holiday.

  This condition does not apply in the event of a direction from police or other relevant authority for safety or emergency reasons to avoid loss of life, property loss and/or prevent environmental harm.

- D33 – Where vibration levels exceed the acceptable vibration does values, feasible and reasonable mitigation measures shall be considered and implemented.

- D34 – Airblast overpressure generated by blasting associated with the project shall not exceed the criteria specified in Table 1 when measured at the most affected residence or other sensitive receiver.

- D35 – Ground vibration generated by blasting associated with the project shall not exceed the criteria specified in Table 2 when measured at the most affected residence or other sensitive receiver.

- D36 – The blasting criteria identified in conditions D34 and D35 do not apply where the proponent has a written agreement with the relevant landowner to exceed the criteria and the Secretary has approved the terms of the written agreement. In obtaining the Secretary's approval for any such agreement, the Proponent shall submit to the Secretary;

  a) Details of the proposed blasting program and justification for the proposed increase to blasting criteria including alternatives considered (where relevant);

b) An assessment of the environmental impacts of the increased blast limits on the surrounding environment and most affected residences or other sensitive receivers including, but not limited to noise, vibration and air quality and ay risk to surrounding utilities, services or other structures;
c) Details of the blast management, mitigation and monitoring procedures to be implemented; and
d) Details of consultation undertaken and agreement reached with the relevant landowners (including a copy of the agreement in relation to the increased blasting limits).

The following exclusions apply to the application of this condition:

i. Any agreements reached may be terminated by the landowner at any time should concerns about the increased blasting limits be unresolved;
ii. The blasting limit agreed to under any agreement can at no time exceed a maximum Particle Velocity vibration level of 25mm/s or Maximum Airblast Overpressure level of 125dBL;
iii. The provisions under this condition (to increase applicable blast criteria in agreement with the relevant landowners) do not apply where the property is a heritage property

1.2. Environmental Objectives

The environmental objectives for blasting are to:

- Minimise the impact of vibration from the blasting activities and to a lesser extent airblast overpressure to acceptable levels;
- Protect the amenity of residents and other building occupiers;
- Ensure the integrity of all infrastructure, including those buildings listed on the State or local heritage registers, is protected and not affected by the blasting activities;
- Prevent damage to adjacent public utilities, structures and buildings resulting from vibration and air overpressure;
- Comply with the project Environmental Management Plan.

In addition to the above mentioned environmental objectives and performance criteria, all blasting activities will meet the following objectives:

- Safety of all personnel;
- Secure environment;
- Control of flyrock;
- Fragmentation and diggability commensurate with excavating equipment.

1.3. Performance Limits

The Conditions of Approval are given for activities generating continuous, intermittent and impulsive type vibrations. The types of vibration require different methods of assessment and different applicable performance criterion. The performance limits are drawn from the "*DEC: Assessing Vibration: A technical guideline*[1]" or the Australian Standard AS2187.2: 2006. *"Explosives Storage and Use: Use of Explosives"*

Construction works that generate continuous or impulsive vibration values should comply with values specified in the DEC document. The DEC document provides information for continuous and impulsive vibration for different periods of the day/evening as well as different building uses (i.e. critical, residential, offices/workshops etc.). Whilst the limits are said to apply for impulsive events, blasting is excluded from this table.

[1] Department of Environment and Conservation NSW 92006), Environmental Noise Management, "Assessing Vibration: a technical guideline"

In terms of blasting related effects, the DEC refers to the ANZEC document that specifies vibration should be controlled to a limit of 5mm/s for 95% of occasions at any noise sensitive place. The level of overpressure should be controlled to 115dBL on 95%of measurement occasions. Importantly, the conditions do not differentiate between different building occupancies but rather group these together as a "*noise sensitive site*". No distinction or other values are given for commercial, industrial or other building occupancies where higher limits are often tolerated.

Conditions can also specify vibration criteria for blasting which are aligned with the recommendations of the Australian Standard. Importantly these are different from those indicated in the ANZEC document, being slightly less restrictive from blasting where the number of blasts is less than 20 as well as proposing limits that consider different building types. It is proposed that blasting will adopt performance limits which are consistent with the Australian Standard AS2187.2. The AS2187.2 limits are more commonly applied to construction projects with the ANZEC levels applied to blasting activities associated with longer term projects like quarries and mines.

The proposed levels are taken from Table J4.5(A) of the Australian Standard AS2187.2 and are based on human comfort criteria. The standard recognises human comfort and proposes acceptable levels of vibration based upon the duration of the blasting operations. A summary of these criteria are given in Table J4.5(A) and reproduced as the following Table 1.

Category	*Type of blasting operations*	*Peak component particle velocity (mm/s)*
Sensitive site	Operations lasting longer than 12 months or more than 20 blasts	*5mm/s for 95% blasts per year 10mm/s maximum unless agreement is reached with the occupier that a higher limit may apply*
Sensitive site	Operations lasting less than 12 months or less than 20 blasts	*10mm/s maximum unless agreement is reached with occupier that a higher limit may apply*
Occupied non-sensitive sites such as factories and commercial premises	*All blasting*	*25mm/s maximum value unless agreement is reached with occupier that a higher limit may apply. For sites containing equipment sensitive to vibration, the vibration should be kept below manufacturer's specification or levels that can be shown to adversely affect the equipment operation*

Table 1 – Ground vibration limits for human comfort (reproduced from AS187.2 2006)

The limits presented in Table 1 indicate a permissible level of vibration of 5mm/s, increasing to 10mm/s where the total number of blasts is fewer than 20, or the duration is less than 12 months. Whilst the total number of blasts and duration for the project will exceed these values, any affected property owner, resident, or building occupier is unlikely to be exposed to repeat blasting that would necessitate the lower 5mm/s criterion.

It is proposed that the 10mm/s for residential properties is adopted, possibly increasing to 25mm/s for commercial properties where there are no other impacts, such as sensitive equipment, that necessitate imposing a lower limit.

The proposed permissible vibration values do not apply where there is a written agreement with the relevant land owner to exceed the criteria and the EPA/Secretary has approved the terms of the written agreement.

In addition, Table J4.4.2.1 of the Australian Standard suggests levels for the prevention of minor or cosmetic damage occurring to structures from ground vibration generated by blasting. The standard defines *cosmetic* damage as the formation of hairline cracks on drywall surfaces, the growth of existing cracks in plaster or drywall surfaces or the formation of hairline cracks in the mortar joints of brick/concrete constructions. *Minor* damage is defined as the formation of cracks or loosening and falling of plaster or drywall surfaces, or cracks through brick/concrete blocks. The table is reproduced as follows:

Type of Building	*Peak component particle velocity in frequency range of predominant pulse*	
	4Hz to 15Hz	*15 Hz and above*
Reinforced or framed structures. Industrial and heavy commercial buildings	50mm/s at 4 Hz and above	
Un-reinforced or light framed structure. Residential or light commercial type buildings	*15mm/s at 4 Hz increasing to 20mm/s at 15Hz*	*20mm/s at 15 Hz increasing to 50mm/s at 40 Hz and above*

Table 2 – Transient vibration guide values for cosmetic damage (reproduced from AS2187.2-2006)

Alternatively, construction vibration goals to eliminate structural damage may also be required to comply the levels set out in the German Standard DIN4150-3 "*Structural Vibration – Effects of Vibration on Structures*" rather than the equivalent table within the Australian Standard. It is considered appropriate to apply the levels in Table 2 for those blasting applications where blasting occurs adjacent to an unoccupied buildings where protection of the structure is important, although personal amenity is irrelevant.

The Australian Standard AS2187.2 makes no distinction for heritage structures or any suggestion that they should be addressed with a lower permissible vibration limit. It is therefore proposed that "*heritage*" listed properties will not be distinguished from these other commercial or residential properties by imposing a lower vibration limit, but rather the potential sensitivity of these structures will be addressed by undertaking an increased scale of monitoring, in particular:

- Detailed condition surveys, including both high resolution digital images;
- Dedicated vibration monitoring instrumentation on selected "*heritage*" properties;
- Where required, glass slides placed over a selection of open cracks or discontinuities and photographed weekly to confirm that there are no adverse effects of the blasting activities;
- As an additional precautionary measure for particularly sensitive sites, use of electronic strain gauges.

Table 3 indicates the Airblast overpressure criteria applicable for the above ground and underground blasting.

Airblast overpressure (dBL)	*Allowable Exceedance*
115	5% of total number of blasts over a 12 month period
120	0%

Table 3 – Airblast overpressure criteria

Overpressure levels for the underground tunnel blasting when measured at the nearest sensitive receivers will be negligible and indistinguishable from background values.

As per best practice, for any section of construction where blasting is proposed, a series of initial trials at a reduced scale shall be conducted prior to production blasting to determine site specific blast response characteristics and to define allowable blast sizes to meet airblast overpressure and ground vibration limits in the approval.

1.1. Revised Blasting Times for Arncliffe

The D30 and D32 conditions for the project limit the frequency of blasting. The intent of the condition is to ensure the amenity of adjacent persons are not unduly affected by repeated elevated levels of vibration. For reference the conditions D30 and D32 are given in Section 1.1.

The intent of D30 and D32 conditions is appropriate for long term projects, but is considered unnecessarily restrictive for a civil operation with a spread of work areas like the Arncliffe site. Blasting in different areas of the Arncliffe project area would be sufficiently separated to allow the vibration from different blasts to attenuate to low levels of vibration with respect to amenity. The questionable element of concern is the clause of D30 which limits the vibration *"per sensitive receiver"*. Although the works within the Arncliffe site are located such that some persons will perceive some level of vibration from the spaced different potential blast sites, it is fully expected that a resident would receive elevated vibration from only one area and significant lower, possibly "*imperceptible*" or "*barely noticeable"*, from blasts within other construction areas with Arncliffe. The intent of Condition D30 is therefore considered overly restrictive with respect to maintaining amenity.

The scale of blasting for any planned works within the Arncliffe area will necessarily be small scale as consequence of the small blasthole diameter. It is unlikely that blasting with a blasthole diameter greater than 51mm diameter would be used for development, shaft or bench blasting. This restricts the maximum explosive weight contributing to the peak level of vibration to less than 7 kilograms.

The modelling of vibration levels from the recent Arncliffe production blasting has shown that at the closest separation distance between the second decline blasting and the residents of around 150 metres, the level of vibration is typically less than 3 to 4mm/s. At other possible blasting locations at Arncliffe where the separation distance increases to the same group of properties of more than 300 metres, the level of vibration reduces to less than 1mm/s, or classed as barely noticeable according to documents like the British Standards BS5228.

The following Figure 1 shows the expected upper level of vibration from blasting at the Arncliffe site with an explosive weight of 7 kilograms. At a separation distance between the blast and the nearest receiver of say 125 metres, the expected maximum level of vibration is around 4.7mm/s (as shown by the blue line). If a second blast were initiated in a second area that was a further 100 metres from the same receiver, the expected level from this second blast would reduce to 1.8mm/s (as shown by the orange line). Should this separation distance increase by around 200 metres as a result of the Arncliffe site geometry, then the expected level is around 1mm/s (as shown by the grey line).

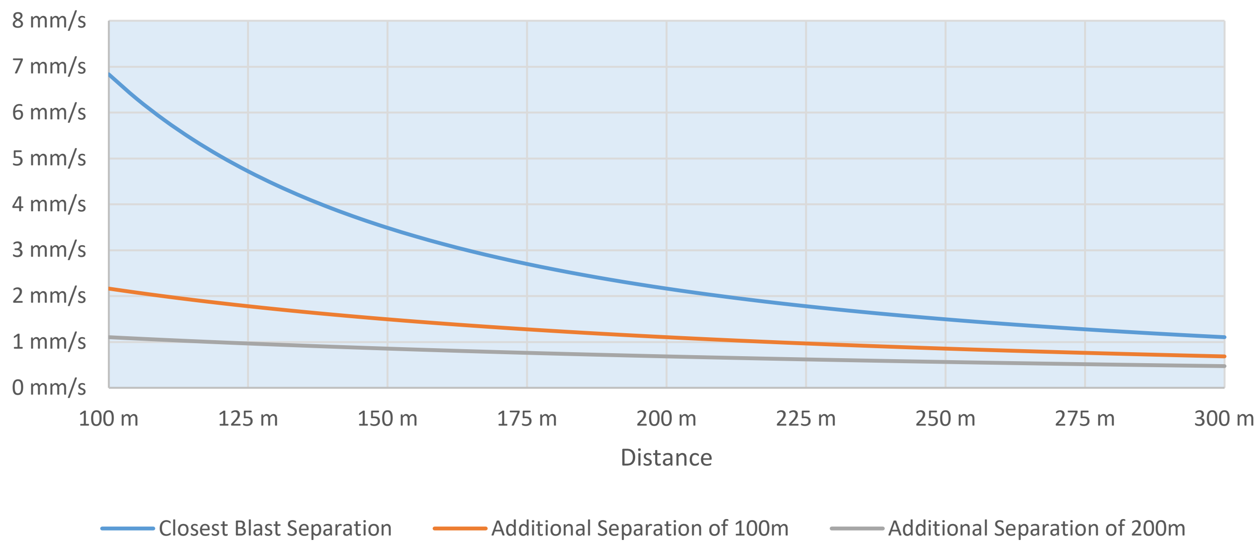


Figure 1 – Relationship between vibration level and distance for separated blast events

The above graph indicates that whilst receivers around the Arncliffe area may perceive blasting, it is most likely to be associated with one blast, irrespective of the number of blasts, as any other additional blasts that occur on the site would induce significantly lower levels of vibration. It would only be when two or more blasts were initiated very close to each, within say 50 metres, would the level of vibration from the separate blasts be considered comparable and therefore better aligned with the intent of Condition D30.

The option of initiating blast patterns sequentially with only a small delay between each, and therefore according to Condition D30 be classed as a "*single detonation*", is not recommended as a safe practice for a site intending on initiating separated blast patterns where line of sight cannot be maintained.

Based upon the successful blast trials, subsequent production blasts and engineered assessments showing the feasibility of blasting other areas with the Arncliffe site, it is suggested that discussions with the EPA are initiated with respect to the restrictive nature of Condition D30. The analyses indicate that receivers around the Arncliffe area to the north of Marsh Street are most likely to perceive only one blast with any other blasts initiated in different areas of the project inducing significantly lower levels of vibration.

It is proposed that a relaxation of two hours either side of the D30 condition specified window of 9:00am to 5:00pm window to 7:00am to 7:00pm would allow multiple blasts with each day to be completed. Whilst it may be possible to schedule multiple blasts in the existing 8 hour window, the shorter period is likely to be associated with a reduced degree of QA and possible negative impact on the overall environmental performance. It would also be appropriate to consider a relaxation of the Saturday firing window to permit a 10 hour window between 8:00am and 6:00pm although maintaining the same four hour window on Sunday between 9:00am and 1:00pm is proposed.

Discussions with local residents will occur several days prior to blasting to minimise disturbance.

1.2. Licence Condition Variations

Based upon the above discussions, the following Table 4 indicates the proposed variations to the Licence Conditions.

Please refer to approved licence conditions (EPL 20772)

[redacted]

[redacted]

Table 4 – Licence condition variation

Please refer to approved licence conditions (EPL 20772).

2. TUNNEL, RAMP AND CROSS PASSAGE BLAST AREAS

The possible blasting areas for the project are modelled to extend over the full length of the tunnel, Arncliffe cavern and the Westbound On and Eastbound Off ramps. The location of the blasts within the tunnel and/or ramps will however be determined by considering what sections can be excavated using mechanical methods. The size and depth of the blast in each case will vary to ultimately achieve a platform level consistent with the grade of the planned tunnels and ramps. The blast areas covered by the modelling within this Management Plan are shown in the following Figure 2. All areas where blasting will be undertaken will be remodelled prior to the commencement of blasting.

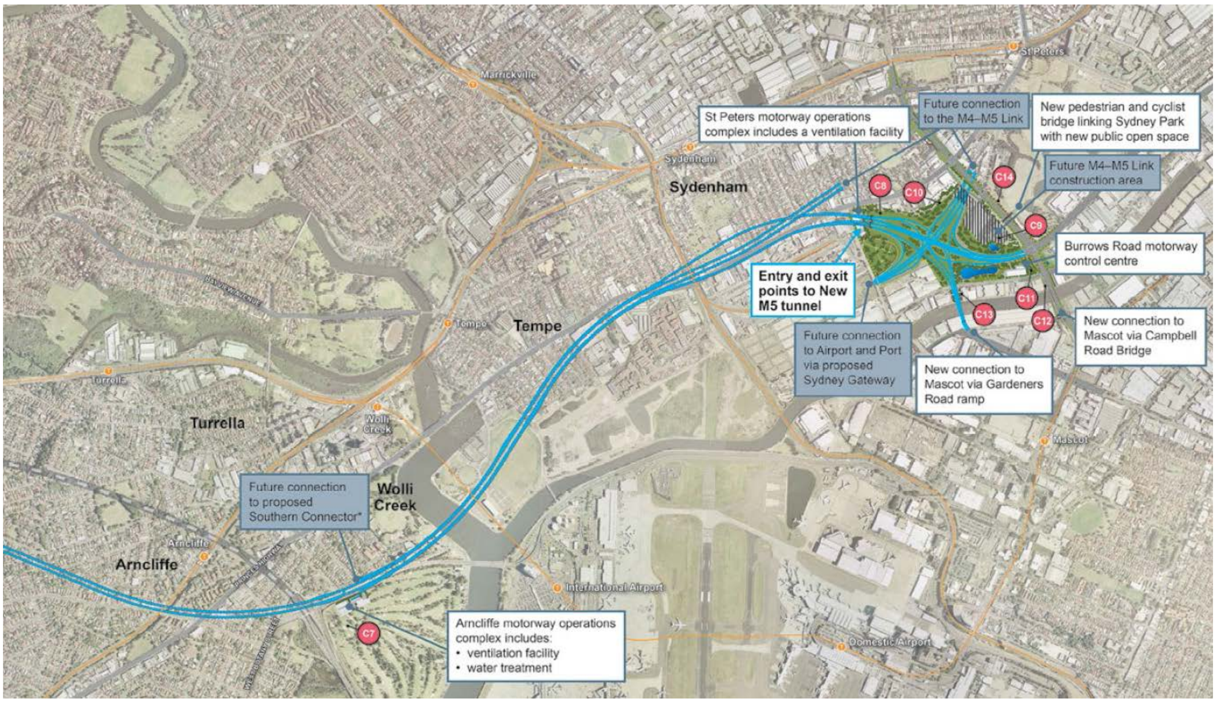


Figure 2 – Tunnel and ramp locations

Other blast areas may be required throughout the project although the details have not been identified at this stage of the project.

3. ADJACENT INFRASTRUCTURE

Potentially sensitive infrastructure is noted to exist around the tunnel alignment, including residential, commercial and industrial development together with some heritage infrastructure.

The Eastbound and Westbound Tunnels will be constructed beneath significant residential development. The initial 500 metres of the western portal is near to commercial buildings on both the north and southern sides of the M5 East Freeway.

3.1. Residential properties

The residential dwellings are of considerable age although a preliminary review of the external appearance suggests they are reasonably well constructed with some properties showing signs of disrepair. These will be reviewed as part of the condition survey assessment.

The dwellings are predominantly single storey and appear to be constructed from bricks or stone laid on a concrete course. While the dwellings are expected to be competent with respect to vibration effects and an ability to withstand elevated levels of vibration without damage, the type of construction is anticipated to offer minimal attenuation of vibration. For those properties with a large expanse of concrete or tiled areas (or generally any hard surfaces) there would be minimal further attenuation of the vibration compared with that expected from an elevated double storey dwelling constructed from timber or less dense materials.

Other multistorey residential complexes are located above the tunnels. These properties would also offer minimal attenuation between the ground vibration measured outside and those levels measured inside the property. Where the buildings have basement car parks, the level of vibration is expected to be elevated, although most likely of minor consequence with respect to personal amenity.

A detailed investigation of the types of residential properties and their susceptibility to vibration will be identified through the condition survey reports.

3.2. Commercial properties

Commercial properties are noted along the north and southern sides of the M5 east Freeway, and the southern side of the Princes Highway including the sections where the tunnel crosses approximately. A detailed investigation will be completed prior to construction to identify whether any additional vibration restrictions will be required as a consequence of potentially sensitive equipment that may be housed within the buildings. Impulsive vibration produced by any blasting within the tunnelling is not expected to jeopardise the building use, nor impact on the building integrity. Should there be any impact on these businesses, it is expected to be associated with quality of life issues or possible interactions with sensitive equipment.

A detailed investigation of the types of commercial properties and their susceptibility to vibration will be identified through the condition survey reports.

3.3. Heritage properties

There are a number of heritage properties listed on the State Heritage Register of NSW as well as multiple other properties listed in the Local Environment Plans (LEP) for the Rockdale, Marrickville and Sydney Councils. A preliminary assessment of the potential impact of the construction activities has been completed and those properties potentially affected by vibration have been identified. The analysed properties include those listed in Tables 4, 5 and 6.

Heritage, aboriginal or other sensiotue8v infrastructure has been provided and grouped according to:

- Aboriginal heritage infrastructure

- Potential aboriginal heritage infrastructure
- *Non-aboriginal heritage infrastructure*

Table 5 shows the "*Aboriginal heritage infrastructure*", including the AHIMS reference, site name, site type and potential impact.

Site Name	*AHIMS reference*	*Site type*	*Potential impact*
[redacted]		*Rockshelter*	*No direct or indirect impact due to distance from project.*
		Artefact scatter	*Artefact-bearing deposits may be present in areas adjacent to Alexandra Canal.* *Direct impact on subsurface deposits – Construction of two bridges across Alexandra Canal.*
		Edge-ground axes	
		Dugong bones	
		Midden	*No direct or indirect impact due to distance from project.*
		Rockshelter	*No direct or indirect impact due to distance from project.*
		Rockshelter	*Closest valid site to the project surface works (250 metres). No direct or indirect impact due to distance from project.*
		Rockshelter	*No direct or indirect impact due to distance from project.*
		Rockshelter	*No direct or indirect impact due to distance from project.*
		Rockshelter	*No direct or indirect impact due to distance from project.*
		Open artefact site	*No direct or indirect impact due to distance from project.*
		Rockshelter	*No direct or indirect impact due to distance from project.*
		Rockshelter	*No direct or indirect impact due to distance for project.*
		Rockshelter	*No direct or indirect impact due to distance from project.*
		Rockshelter	*No direct or indirect impact due to distance from project.*
		Rockshelter	*No direct or indirect impact de to distance from project.*
		PAD	*No direct or indirect impact due to distance from project.*
		Open artefact site	*No direct or indirect impact due to distance from project.*
		Open artefact site	*No direct or indirect impact due to distance from project.* *Comprises subsurface deposit. No surface artefacts observed.*

Table 5 - Aboriginal heritage infrastructure

A plate showing the location of the Aboriginal heritage infrastructure is given in Plate 1.

Table 6 shows the "*Potential aboriginal heritage infrastructure*", including the site name, site type and potential impact. The AHIMS number is "pending" given the potential status.

Site Name	*AHIMS reference*	*Site type*	*Potential impact*
[redacted]			*No direct impact.* *Indirect – settlement vibration and impacts from blasting (within 50m of main tunnel alignment).*
[redacted]			*No direct or indirect impact due to distance from project*
[redacted]			*No direct or indirect impact due to distance from project.*
[redacted]			*No direct or indirect impact due to distance from project.*
[redacted]			*No direct or indirect impact due to distance from project.*

Table 6 - Potential aboriginal heritage infrastructure

A plate showing the location of the Potential Aboriginal heritage infrastructure is given in Plate 2.

Table 7 shows the "*Non-aboriginal heritage infrastructure*", including the Item name, number, register, location and potential impact.

Number	*Item Name*	*Register*	*Location*	*Potential Impact*
I24	*Rosslyn Hospital*	*Rockdale LEP*	*30 Forest Road, Arncliffe*	*Secondary direct – possible vibration and settlement from tunnelling.*
I23	*St Francis Xavier Catholic Presbytery*	*Rockdale LEP*	*26 Forest Road, Arncliffe*	*Secondary direct – possible vibration and settlement from tunnelling.*
I22	*St Francis Xavier Church Group*	*Rockdale LEP*	*26 Forest Road, Arncliffe*	*Secondary direct – possible vibration and settlement from tunnelling.*
I18	*Street Plantings*	*Rockdale LEP*	*Firth Street, Arncliffe*	*Secondary direct – possible vibration and settlement from tunnelling.*
I35	*House*	*Rockdale LEP*	*31 Kyle Street, Arncliffe*	*Secondary direct – possible vibration and settlement from tunnelling.*
I22	*St Francis Xavier Church Group*	*Rockdale LEP*	*2-4 and 6 Forest Road, Arncliffe*	*Secondary direct – possible vibration and settlement from*

Number	Item Name	Register	Location	Potential Impact
				tunnelling
01647	*Western Outfall Main Sewer (Rockdale to Homebush) (part of SWSOOS)*	*SHR*	*Corner Marsh Street and M5 East Freeway, Tempe*	*Secondary direct – possible vibration from tunnelling and construction of the ventilation station and water treatment plant.*
4572728		*S170 (Sydney Water)*		*Indirect – visual impact from GGBF bridge structure.*
I303	*Moreton Bay Fig Tree*	*Marrickville LEP*	*43 South Street, Tempe*	*Secondary direct – possible vibration and settlement from tunnelling.*
01412 *I249*	*Timber Slab Cottage*	*SHR* *Marrickville LEP*	*44 Barden Street, Tempe*	*Secondary direct – Possible vibration and settlement from tunnelling*
I284	*Brick kerb and sandstone kerb guttering*	*Marrickville LEP*	*George Street, Henry Street* *Park Road, Park Lane,* *Railway Lane, Rowe Lane,* *Reilly Lane and Stewart Lane, Sydenham*	*Secondary direct possible vibration and settlement from tunnelling.*
I288	*Victorian filigree style sandstone faced residence, including interiors*	*Marrickville LEP*	*3-47 Railway Road, Sydenham*	*Secondary direct – possible vibration and settlement from tunnelling and the construction of the ramps.*
I312	*Service Garage*	*Marrickville LEP*	*Corner Canal Street and Princess Highway, St Peters*	*Primary direct – acquisition.*
				Secondary direct – possible vibration and settlement from construction of the ramps (surface works) and tunnelling.
				Indirect – visual.
I12	*Terrace Group*	*Sydney LEP*	*2-34 Campbell Road, Alexandria*	*Secondary indirect – possible vibration from construction of the ramps.*
				Secondary indirect – potential for at property acoustic treatment (subject to detailed design).
				Indirect – visual.
I1405	*Warehouse 'Rudders Bond Store'*	*Sydney LEP*	*53-57 Campbell Road, Alexandria*	*Primary direct impact – demolition is required for the construction of the*

Number	*Item Name*	*Register*	*Location*	*Potential Impact*
				ramps and St Peters interchange.
01621 *I1* *I3* *4571712* *M5EE-02*	*Alexandra Canal including M5EE-02*	*SHR* *Botany LEP* *Sydney LEP* *RNE* *S170 Register (Sydney Water)* *City Plan Heritage (2011)*	*General Holmes Drive (west of Engine Pond, within the boundary of Sydney (Kingsford Smith) Airport, Mascot*	*Primary direct – modification to the historical fabric and embankment, to enable new surface water discharge points and scour protection. Possible direct impact to the area of the archaeological remains of the old wharf.* *Secondary direct – potential changes to navigability of canal.* *Secondary direct – possible vibration and settlement from tunnelling and surface works in close proximity to the canal embankments.* *Indirect – visual impact due to introduction of three new bridges, including two road bridges and one dedicated pedestrian/cyclist bridge.*
I18 *4571730*	*Water Board Pump House (including interior and substructure)*	*Sydney LEP* *Sydney Water s170*	*48 Huntley Street, Alexandria*	*Secondary direct – possible vibration from surface works.* *Indirect – visual.*
C2	*Cooper Estate Conservation Area*	*Sydney LEP*	*Between Mitchell, Euston and Sydney Park Roads, Alexandria*	*Primary direct – change in heritage conservation area values.* *Secondary indirect – possible vibration from surface works.*
I20	*Industrial building 'Frank G Spurway'*	*Sydney LEP*	*20-30 Maddox Street, Alexandria*	*Secondary direct – possible vibration from surface works.* *Indirect – visual*
I281	*Town and Country Hotel, including interiors*	*Marrickville LEP*	*2 Unwins Bridge Road, St Peters*	*Secondary indirect – possible vibration from surface works.* *Indirect – visual*
I282	*Group of Victorian Filigree and Victorian Italianate terrace house – 'Narara'*	*Marrickville LEP*	*4-18 Unwins Bridge Road, St Peters*	*Secondary direct – possible vibration from surface works.* *Indirect – visual*

Number	Item Name	Register	Location	Potential Impact
	including interiors			
I280	*Waugh and Josephson industrial buildings former, showroom, officer and workshop, including interiors*	*Marrickville LEP*	*1-7 Unwins Bridge Road, St Peters*	*Secondary indirect – possible vibration from surface works.* *Indirect – visual*
C16	*Goodsell Estate Conservation Area*	*Marrickville LEP*	*Between Bedwin Road, May Street, Caroline and May Lanes and the rail line, St Peters*	*Primary direct – acquisition* *Primary direct – change in heritage conservation area values.* *Secondary direct – possible vibration and settlement from tunnelling and surface works.*
I289	*St Mary/St Mina Coptic Orthodox Church, including interiors*	*Marrickville LEP*	*24A Railway Road, Sydenham*	*Secondary direct – possible vibration and settlement from tunnelling.*
00032 *I275* *1716*	*St Peters Anglican Church*	*SHR* *Marrickville LEP* *RNE*	*187-209 Princess Highway, St Peters*	*Secondary direct – possible vibration from surface works*
I271	*St Peters Public School, including interiors*	*Marrickville LEP*	*St Peters*	*Secondary direct – possible vibration from surface works.* *Secondary direct – potential for at property acoustic treatment (subject to detailed design)*
16240	*St Peters Brickpit Geological Site*	*RNE*	*Between Canal, Burrows and Campbell Road and the Princess Highway, St Peters*	*Primary direct – modification through construction of St Peters Interchange and shared path along northern boundary of interchange.* *Secondary direct – possible vibration from surface works.* *Indirect – visual*
4801898	*Bexley North Railway Station Group*	*S170 Register (Railcorp)*	*Bexley Road, Bexley North*	*Secondary direct – possible vibration and settlement from tunnelling and surface works.* *Indirect – visual*
4805728 *I1*	*Arncliffe (Forest Road)*	*S170 Register (Railcorp)*	*Forest Road, Arncliffe*	*Secondary – possible vibration*

Number	*Item Name*	*Register*	*Location*	*Potential Impact*
	Overbridge	*Rockdale LEP*		*and settlement from tunnelling.*
4305629	*House*	*S170 Register (Roads and Maritime)*	*28-44 Campbell Street, St Peters*	*Primary direct – demolition to enable widening of Campbell Street.*
4305643	*House*	*S170 Register (Roads and Maritime)*	*82 Campbell Street, St Peters*	*Primary direct – demolition to enable widening of Campbell Street.*
I51	*Victorian semi-detached dwelling*	*Rockdale LEP*	*26 Stanley Street, Arncliffe*	*Secondary direct – possible vibration and settlement from tunnelling.*
I50	*Victorian house*	*Rockdale LEP*	*22 Stanley Street, Arncliffe*	*Secondary direct – possible vibration and settlement from tunnelling.*
I49	*Victorian house*	*Rockdale LEP*	*20 Stanley Street, Arncliffe*	*Secondary direct – possible vibration and settlement from tunnelling.*
I48	*Victorian house*	*Rockdale LEP*	*16 Stanley Street, Arncliffe*	*Secondary direct – possible vibration and settlement from tunnelling.*
102085	*Welfare Avenue Urban Conservation Area*	*RNE*	*Beverly Hills*	*Primary direct – change in heritage conservation area values.*
				Secondary direct – possible vibration from surface works.
				Indirect – visual
#01076 *I1* *#4801150*	*Arncliffe Railway Station Group*	*SHR* *Rockdale LEP* *Sydney Trains* *Section 170 register*	*Arncliffe*	*Secondary direct – possible vibration and settlement from tunnelling.*
I13	*Bard of Avon, 39 Eden Street, Rockdale*	*Rockdale LEP*	*Rockdale*	*Secondary direct – possible vibration and settlement from tunnelling.*
I15	*Californian bungalow house, 7 Fairview Street*	*Rockdale LEP*	*Fairview Street, Arncliffe*	*Secondary direct – possible vibration and settlement from tunnelling.*
I16	*Californian bungalow house, 21 Fairview Street*	*Rockdale LEP*	*Fairview Street, Arncliffe*	*Secondary direct – possible vibration and settlement from tunnelling.*
19170 *I19*	*Arncliffe Post Office*	*RNE* *Rockdale LEP*	*Rockdale*	*Secondary direct – possible vibration and settlement from tunnelling.*
I21	*Victorian shop and dwelling – 45 Firth Street, Rockdale*	*Rockdale LEP*	*Rockdale*	*Secondary direct – possible vibration and settlement from tunnelling.*
I56	*House, 73 West Botany*	*Rockdale LEP*	*Rockdale*	*Secondary direct – possible vibration*

Number	Item Name	Register	Location	Potential Impact
	Street, Rockdale			*and settlement from tunnelling.*
I61	*House, 148 Wollongong Road, Rockdale*	*Rockdale LEP*	*Rockdale*	*Secondary direct – possible vibration and settlement from tunnelling.*
I165	*Stotts Reserve*	*Rockdale LEP*	*Rockdale*	*Secondary direct – possible vibration and settlement from tunnelling.*
I81	*Stone Federation House – 15 East Street, Rockdale*	*Rockdale LEP*	*Rockdale*	*Secondary direct – possible vibration and settlement from tunnelling.*
102071	*Clemton Park Urban Conservation Area, Homer Street*	*RNE*	*Clemton Park*	*Primary direct – change in heritage conservation area values.* *Secondary direct – possible vibration from surface works.* *Indirect – visual*
102106	*Bardwell Park Urban Conservation Area*	*RNE*	*Bardwell Park*	*Secondary direct – possible vibration and settlement from tunnelling.*
I273	*Terrace housing including interiors -119 May Street, Marrickville*	*Marrickville LEP*	*Marrickville*	*Secondary direct – possible vibration from surface works.* *Indirect – visual*
I277	*Southern Cross Hotel*	*Marrickville LEP*	*Marrickville*	*Secondary direct – possible vibration and settlement from tunnelling and surface works.* *Indirect – visual*

Table 7 - Non-aboriginal heritage infrastructure

A plate showing the location of the Non-aboriginal heritage infrastructure is given in Plate 3.

No detailed investigation of these heritage structures, their condition or susceptibility to vibration is available at this stage. The proposed vibration criteria discussed in Section 1 are considered appropriate for heritage structures in all but the most distressed condition. *CDS* will confirm if there are heritage structures that would need special attention.

A detailed investigation of the types of heritage infrastructure and their susceptibility to vibration will be identified through the condition survey reports.

Buildings or other above ground structures that may be in poor condition would be adequately protected by the vibration criteria applicable for heritage infrastructure.

3.4. Sensitive building contents

Buildings adjacent to the tunnelling works area may house vibration-sensitive equipment. This type of equipment may require vibration protection beyond that calculated by personal amenity and standard vibration criteria. Such equipment may include medical imaging equipment, telecommunications networks or scientific apparatus. Buildings and businesses that could potentially contain sensitive equipment will be identified. The details of the sensitive equipment will be identified through correspondence with the relevant building owners prior to construction activities in the area. On review of the equipment, an acceptable vibration criteria will be defined. The impact of the blasting activities will be determined on a case-by-case basis, although in general, only the most sensitive of electronic equipment is affected by vibration and in these cases, the equipment is commonly vibration-isolated through false floors or purpose-designed spring balance systems.

The effect of vibration is most often observed by rattling of small objects or trinkets on hard surfaces which occurs at vibration levels around 1mm/s. At similar levels of vibration, loosely secured objects, such as pictures, plates and blinds, can be disturbed and these items would also be identified in a condition survey, with measures such as their temporary removal required in some unusual circumstances.

3.5. Services

Telecommunications (fibre and copper), gas, electricity, water, drainage and sewer services may exist along the alignment. Correspondence with asset owners will confirm a permissible vibration value, commonly of 50mm/s, for the services. This is consistent with value imposed on the same services for the other blasting, construction or tunnelling projects. The 50mm/s level is higher than the vibration limits for residential and commercial properties. The scale of any blasting activity is therefore controlled by the properties rather than the services.

In some instances, an assessment of the condition of services within the project boundary may be required by the asset owner prior to the commencement of works. If the condition of the infrastructure is poor, the proposed level of vibration will be reviewed and, where necessary, the effects of the activities remodelled. In some cases, the review may necessitate a CCTV scan to ascertain the condition of the service and justify and appropriate vibration criterion.

4. TUNNEL BLAST DESIGN

In general, the scale of blasting within the tunnel will be controlled by the requirement to comply with vibration criteria at the adjacent infrastructure around the tunnel. The blast design is therefore based upon:

- A small blasthole diameter, most likely less than 64mm, drilled using mechanical equipment;
- A nominal blasthole length of up to 3 metres although shorter blastholes will be required depending upon excavation geometry, particularly adjacent to the walls of the excavation. It may be appropriate to leave a pillar of rock adjacent to edges of the excavation that will be excavated mechanically;
- A nominal blasthole pattern with a burden and spacing of less than 1 metre to 1.5 metres depending upon rock strengths, blasthole diameter and allowable explosive quantity;
- A single explosive charge per blasthole, independently sequenced to restrict the maximum explosive quantity per delay to achieve vibration compliance;
- The excavation sequence is expected to involve blasting the tunnel in two separate left and right sides to permit access ahead of the blast area for the road header to excavate the upper sections of the tunnel heading.

Blast patterns for the tunnelling works will based on two criteria:

- The powder factor which provides an indication of the expected level of fragmentation and is expressed in terms of the kilograms of explosive per cubic metre of rock. A value of 0.6 kg/m^3 in the Hawkesbury Sandstone for blasting in a benching configuration is expected to yield fragmentation amenable to excavation without extensive use of a hydraulic hammer. As a comparison, a value of 0.2 kg/m^3 can be used to precondition the rock and improve hammer efficiency.

- The maximum explosive weight per delay (MIC) determines the level of vibration generated at the adjacent sensitive receivers. As the quantity of explosive increases, so too does the level of vibration. For a given vibration criteria, like the 5mm/s or 10mm/s, as the distance to a sensitive receiver decreases, the explosive quantity per blasthole must also decrease to ensure compliance with the vibration criteria.

As the explosive weight per delay reduces, the distance between the blastholes (referred to as the burden and spacing) must also decrease to maintain a constant powder factor. Where the blasting is further from a sensitive receiver (i.e. residential property) as a result of the depth of the tunnel or a greater horizontal separation distance, and larger explosive weights per delay can be used, the distance between blastholes can increase.

The use of small explosive weights less than 0.5 kilograms does not generally permit cost effective blasting at a powder factor of 0.6kg/m^3. At these lower explosive weights it is most appropriate to precondition the rock mass only. It is expected that blasting in the Hawkesbury Sandstone material will require a powder factor in the region of 0.6kg/m^3. A powder factor less than 0.6kg/m^3 may be possible although the fragmentation and diggability of the blasted rock will be challenged. The following Table 8 shows the range of explosive weights as a function of the blast results that could be used. Where the explosive weight per delay is less than 0.5kg, the use of other non-explosive methods should be considered.

Description	*Powder Factor*	*Acceptable range of explosive weights per delay*
Fragmentation in the Hawkesbury sandstone material sufficient to allow cost effective removal	0.6 kg/m^3	*>1.5 kg*
Fragmentation and diggability of the blasted rock will require use of rock hammers or rippers to remove	*0.2 kg/m^3*	*0.5 kg to 1.5 kg*

Table 8 - Summary of limiting explosive weight criteria

Based on the allowable explosive quantity produced from the modelling results (determined by the vibration criteria and the proximity to sensitive receivers), the burden and spacing can be calculated to the given powder factor.

A typical blast plan for tunnel blasting showing explosive quantities, bench height, burden and spacing is provided in Figure 3 although will necessarily vary according to the tunnel profile, vibration compliance conditions.

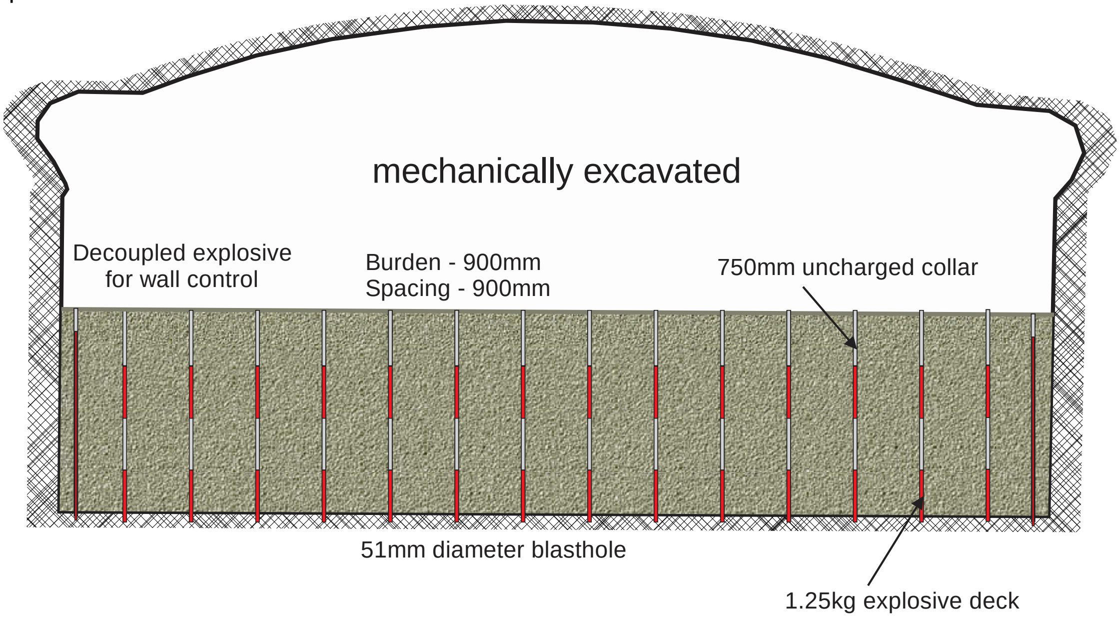


Figure 3 – Typical blast plan for tunnel blasting - Explosive quantities, bench height, burden and spacing will vary according to vibration compliance conditions

Blasthole diameter will be small to accommodate reasonable explosive columns with the low explosive weights. A blasthole diameter greater than 64mm is not expected. Where explosive weights are around 2 kilograms and it is desirable to excavate material in slices that are greater than 2.5 metres, it is feasible to "*deck*" blastholes. This involves placing two columns of explosive into the blasthole: a lower deck of explosive into the bottom of the blasthole and an upper deck separated by a column of inert stemming material.

5. CROSS PASSAGE BLAST DESIGN

Blasting of the cross passages may utilise small scale horizontal or slightly inclined blasting specifically undertaken to provide access between the tunnels. The blast design and effects with respect to vibration do not significantly differ from those for the tunnel/bench blasting, although the potential effects are likely to be less as a result of the lesser explosive quantities.

The key aspects of the cross passage blasting include:

- *Blasthole diameter*: Cross passage blasting utilises a small blasthole diameter commonly in the range of 45mm to 51mm;
- *Blasthole length*: The maximum blasthole length for a cross passage blast is around 3 metres compared with longer lengths up to 5 metres for the bench blasting;
- *Blast yield*: The yield from a cross passage blast is typically less than 250 tonnes compared with the greater tonnages for the bench blasting;
- *Blast duration*: Cross passage blasts are initiated over a 10 second window compared with bench blasts which are complete within several seconds;
- *Explosive quantity:* Cross passage blasts typically use up 150 kilograms of explosive in total with each blasthole containing up to 4 kilograms of explosive. Production blasts may contain several hundred kilograms of explosive in total with each hole containing up to 40 kilograms.

With respect to the vibration generated by the different types of blasting, cross passage blasting commonly produces lower levels of vibration than that produced by bench blasting by virtue of the lesser explosive quantity (smaller diameter blasthole and the smaller length of blasthole). The lower level vibration however persists longer than that produced from a bench blast due to the different initiation systems.

Three cross passage blasting scenarios are considered as shown in Table 9.

Scenario	*Description*	*Explosive Quantity per Blasthole*
A	45mm diameter blasthole drilled to length of **1.5** metres with a 500 mm uncharged collar and pneumatically loaded with ANFO (0.95g/cm^3) or 38mm cartridge emulsion	1.5 kilograms
B	45mm diameter blasthole drilled to length of **2** metres with a 500 mm uncharged collar and pneumatically loaded with ANFO (0.95g/cm^3) or 38mm cartridge emulsion	2.5 kilograms
C	45mm diameter blasthole drilled to length of **3** meters with a 500 mm uncharged collar and pneumatically loaded with ANFO (0.95g/cm^3) or 38mm cartridge emulsion	4 kilograms

Table 9 – Summary of development blasting scenarios

The level of vibration from the cross passage activities will be controlled by adjusting the scale of blasting. This will be achieved through monitoring and where necessary, changing the blasthole diameter, the length of the blasthole or the type of explosive.

6. SHAFT BLAST DESIGN

The WestConnex project may also consider the development of the access shafts using conventional drilling and blasting methods. Shaft blasting is similar to the cross passage blasting in terms of both blasthole diameter, explosive quantities and blast durations, with the exception that blastholes are drilled vertically rather than horizontally.

A number of blasting options for the shafts have been considered, including:

1) A conventional parallel hole full face burn cut design;
2) A wedge-cut design where the burn cut is replaced with a series of angled blastholes to create an initial void for the remaining firing blasthole
3) A full face design where the burn cut has been replaced by a larger relief drilled from surface. The relief hole extends the full depth of the shaft, backfilled with sand and blown clear for the depth of each blast;
4) A benching design where the blast alternates from side to side to eliminate the requirement for a burn cut void.

A typical shaft blast design based upon a conventional parallel hole full face design is shown in Figure 4.

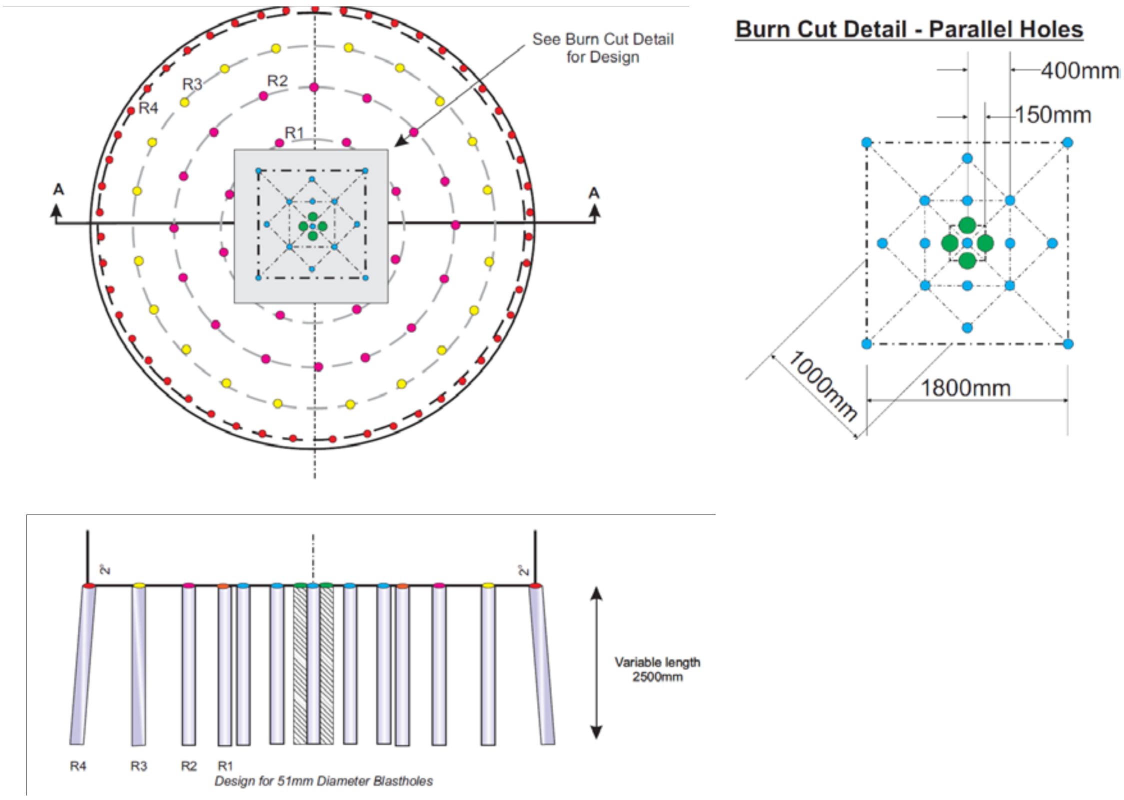


Figure 4 – Shaft blast design based upon a conventional parallel hole burn cut

The advance per blast is typically around 2.5 metres in vibration sensitive environments. Large advances may be possible dependent upon vibration compliance restrictions. The options of increasing the length of advance or reducing the number of blastholes will be reviewed once the blasting commences and an assessment of the vibration levels undertaken.

The initiation sequence for the blast designs could be based around the use of conventional non-electric delay elements however given the requirement for vibration control and the relatively shallow rates of advance, the use of the electronic elements is likely to be used.

Bulk explosive could be used however is unlikely based upon the small scale of blasting, a small bulk emulsion systems like that considered used for the bench blasting would be feasible.

The control of vibration as a consequence of adjacent sensitive receivers will be achieved through adjustments to the blasthole length. Where the explosive weight cannot be reduced to sufficiently low vibration levels, a reduction in the blasthole diameter is feasible.

7. BLAST VIBRATION ANALYSES

The primary factors known to influence the level of ground vibration from blasting include:

a) The weight of explosive per delay;
b) The distance between the blastholes and the point of measurement;
c) The local geological conditions and the influence of geology and topography on vibration attenuation.

Consistent with the recommendations of the Australian Standard AS2187.2 – Use of Explosives[2], the most common form of the vibration equation to predict the amplitude of ground vibration from blasting at any distance from the blasthole and is given as:

$$PPV = K\left(\frac{d}{\sqrt{w}}\right)^{-\beta}$$

where d is the distance between the blastholes and the point of measurement;
w is the maximum instantaneous charge weight per delay;
K and β are site specific constants.

Based on the above equation, the expected level of ground vibration can be determined for a given distance and maximum charge weight.

A relationship between the level of vibration, the quantity of explosive and the distance from the blast has been estimated from other vibration measurements from blasting activities in rock types consistent with the sandstone rock masses. An equation consistent with the format described above has been developed. In accordance with Condition D31, a series of initial trials at a reduced scale will be undertaken to confirm the site-specific blast vibration equations.

The following Figure 5 identifies vibration level as a function of distance from the blasthole for varying quantities of explosive.

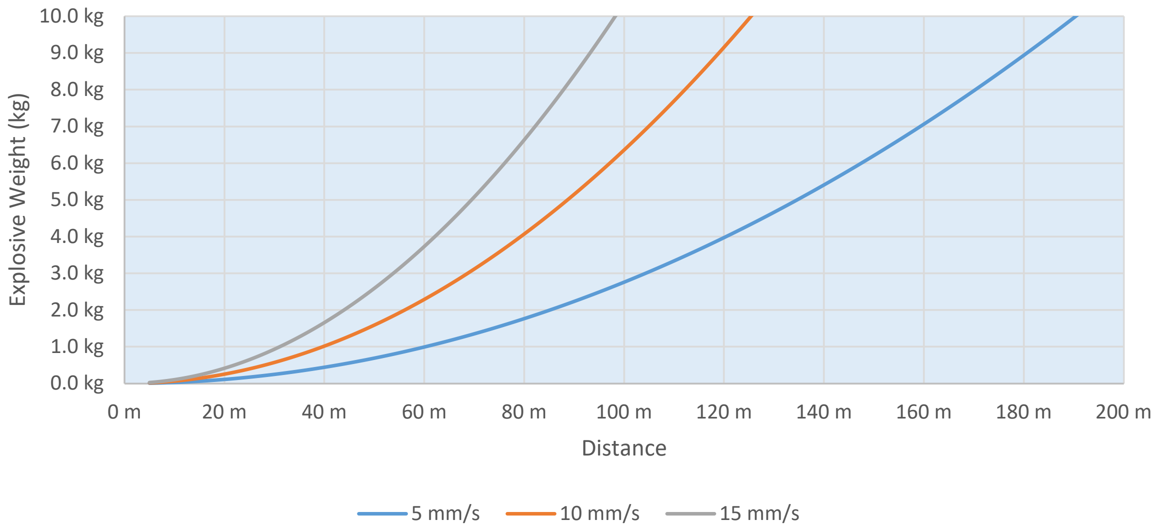


Figure 5: Estimated vibration level as a function of distance from varying explosive quantities per delay

[2] AS2187.2-2006, *"Explosives – Storage, transport and use Part 2: Use of explosives"*

Because of the proximity of blast area to possibly sensitive infrastructure, explosive quantities per blasthole will be small. The following shows explosive quantities per blasthole ranging up to 10 kilograms as a function of distance from the blast for three different permissible vibration criterion, 5mm/s, 10mm/s and 15mm/s. The data relate to the measurements recoded from the Second Decline study blasting and further confirmed during the initial stages of blasting.

To account for the variability in explosive performance and ground characteristics, it is accepted industry practice to design blast patterns using an equation that predicts the 95 percentile level (*ie*. a level which will exceed 95% of all measured values) and continually update and review practices according to the measured levels. If measured levels routinely exceed, or fall below, the predicted value, the equation is adjusted to reflect the different site conditions. This conforms to the recommendations of the Australian Standard AS2187.

7.1. Trial Blasting

Consistent with the Condition D31, a series of trial blasts will be undertaken at a reduced scale to confirm the site specific blast response characteristics. These data will be analysed to determine a relationship between vibration level, distance and explosive quantity. This site specific relationship will be compared to the proposed relationship identified in Section 5 (Figure 3).

The site trials will be small scale to ensure compliance with the permissible vibration criteria. The trial blast will involve a number (≈5) single-hole explosive charges with the resulting vibration levels measured at multiple locations (≈5 around the blast area. Between each trial, the measured vibration levels will be checked to confirm compliance and the explosive weights adjusted for subsequent trails.

Should the measured data differ significantly from the expected values, the blast areas will be remodelled on the basis of the site specific relationship.

7.2. Modelling Approach

The scale of blasting will be modelled for the tunnel and ramp alignment data based upon compliance with a 5mm/s and 10mm/s vibration limit. For the Eastbound and Westbound mainline tunnels, and each of the access and egress ramps, the analyses will identify the quantity of explosive that will achieve compliance with the permissible level of vibration. The modelling is based upon a relationship between explosive quantity, vibration level and distance consistent with blasting in a sandstone rock mass that has been determined from data collected from other Sydney projects. The vibration contours that identify the overall impacts of the blasting activities are also based upon this same relationship.

The modelling is three dimensional and uses the reduced level (RL) of the residential, commercial and heritage properties together with the surface topography identified from a digital terrain model (DTM). The tunnel and ramp alignments and their coordinates will be used to determine distances between the blasting and the nearest sensitive receivers.

The modelling considers each 1 metre square section of the tunnel or ramp blast area and identifies the nearest and most sensitive property to this area. Based upon the separation distance, the permissible vibration criterion and the relationship between these parameters and explosive quantity, an allowable explosive quantity is calculated. The explosive weights are coloured according to their values, allowing the modelled results to display which sections of the works may be impacted by having to reduce explosive quantities, and therefore the length of advance or depth of blasting to achieve vibration compliance. The model is three dimensional and considers the depth of the vertical separation between the tunnel and the properties as well as the horizontal separation.

The modelling results show both the expected explosive quantities and the expected level of vibration that would be measured on the surface. The results are shown as a series of vibration contours. For those locations further from the tunnel alignment than identified by the vibration contour, the level of vibration is modelled to have reduced to below this value. In simple terms, for locations closer to the tunnel than say where the 5mm/s contour is shown, the maximum level of vibration that would be measured over the entire project is expected to exceed 5mm/s. For locations further than the 5mm/s contour, the level of vibration is modelled to be less than 5mm/s.

The vibration contours will show the maximum extent of vibration. When blasting in the western end of the tunnel, the level of vibration towards the east will be less than that shown by the contours. As blasting advances towards the east, the vibration levels for the eastern properties will increase and approach the levels identified by the contours values.

In determining the scale of blasting, the analyses will consider the use of a small diameter blasthole. The modelling will however be based upon explosive weights. Different configurations of blasthole diameter, explosive density and length of the blasthole should produce similar vibration results provided the explosive quantity loaded into hole is equal.

7.3. Blast Modelling of Explosive Quantities

The analyses will given as a set of drawings. The drawings will show the expected maximum explosive quantities for blasting in based upon compliance with either a 5mm/s or 10mm/s at the nearest residential properties. The scale of blasting and corresponding bench heights can be related to the predicted quantities in these drawings. The modelling results are shown for any extent of blasting within the tunnels and ramps blast area.

The drawings will also show the expected location of vibration contours for blasting with the modelled explosive quantities, which is the maximum quantity of explosive that is predicted to comply at the nearest sensitive receivers. The contours are shown for 2.5mm/s, 5mm/s, 7.5mm/s and 10mm/s vibration levels.

The modelling will indicate that the scale of blasting can be controlled to achieve compliance at the adjacent properties. In particular, the properties immediately above the tunnel or ramp alignment will affect the quantity of explosive that can be initiated. The quantity of explosive will be low and less than a few kilograms.

Blast patterns will be designed according to the modelled explosive quantities. The measured vibration results after each blast will be analysed and adjustments to subsequent designs will be determined according to the recorded values.

7.4. Results for Eastbound and Westbound Tunnels

The following comments relate to blasting for the mainline Eastbound and Westbound tunnels:

- Blasting for the initial western section near the portal for approximately 300 metres of the Eastbound tunnel and 500 metres of the Westbound tunnel will require low explosive quantities that are less than 1 kilogram. Should blasting occur in these sections, the shallow depth of the tunnel necessitates that small explosive quantities are used;
- The 1500 metre sections of the tunnel between approximately 500 metres from the western portal through to around 2000m metres from the portal can be blasted with explosive quantities between 1 and 2 kilograms. There are some small isolated sections where the tunnel passes beneath the rail line and green open space along Shaw Street where greater explosive quantities are expected to be possible;
- For the approximate 1000 metre sections of the tunnel east Kingsland Road where the tunnels pass beneath the treed hill area and the Bardwell Valley Golf course, the expected explosive quantities range between 4 to 5 kilograms with a few smaller sections requiring 2 to 3 kilograms;
- For the section of the tunnel east of the Bardwell Valley Golf Course, explosive quantities of around 5 kilograms can predominantly be used. The depth of cover between the tunnel alignment and the properties allow of the greater explosive quantities;
- For the sections of the tunnels that pass beneath the Kogarah Golf Course, Cahill Park, Alexandria Canal and the Tempe Recreation Reserve, similar explosive weights of around 5

kilograms are expected as a result of both the depth of cover and the fewer properties above the alignment;
- For the 1800 metre section of the tunnels between the Tempe Recreation Reserve and Mary Street the properties along the Princess Highway restrict the explosive quantity.

The explosive quantities and vibration impacts will be confirmed once the initial data have been collected and analysed as per the standard trial blast procedures.

7.5. Results for Arncliffe Cavern

Blasting activities associated with the Arncliffe cavern are modelled as not being impacted by the vibration criteria and the associated properties. The depth of the tunnel and the Kogarah Golf course is expected to allow explosive 5 kilograms.

7.6. Results for the Westbound On Ramps and Eastbound Off Ramp

The following comments relate to blasting for the ramps. The proximity of the properties and the shallow depth of the ramps restrict the quantity of explosive that can be used. From the eastern most section of the ramp:

- Blasting for the initial 170 metre section will require the use of less than 1 kilogram;
- Blasting for the following 180 metre section allows the use of marginally elevated weights between 1 and 2 kilograms;
- Blasting for the next 240 metre section is modelled to allow explosive quantities up to 3 kilograms;
- Blasting for the remaining 350 metre section where it joins to the mainline tunnels allow explosive quantities varying from 3 kilograms up to the 5 kilograms.

8. CONTINGENCIES

The modelled results have assessed the levels of vibration from the blasting that will comply with the proposed 10mm/s criteria. In the event that the trial blast programme indicates that the modelling has underestimated the level of vibration, several mitigation procedures are available and could include:

- limiting the quantity of explosive by further reducing the length of the blasthole or the length of the explosive column;
- introducing additional explosive columns within the blasthole (ie decking);
- reducing the blasthole diameter;
- alternative explosive types, including both low density products and cartridge explosives.

9. CONDITION SURVEYS

Based on experience from other projects that supportable claims for damage from vibration induced by the construction activities are uncommon, unless the activity is very near to a property and the corresponding vibration is of a level that is intolerable to persons within the property, the onset of complaints about vibration damage is generally better aligned with the degree of perception. Table 10 shows the human perception as a function of vibration levels, as given in the International literature.

Vibration Range		*Effect*
Lower	*Upper*	
0 mm/s	0.5 mm/s	*Imperceptible*
0.5 mm/s	1.0 mm/s	*Barely Noticeable*
1.0 mm/s	5.0 mm/s	*Easily Noticeable*
5.0 mm/s	10.0 mm/s	*Distinctly Noticeable*
>10mm/s		*Strongly Noticeable*

Table 10 - Effect of vibration from blasting activities

It is therefore proposed to undertake condition surveys for properties where the expected effect ranges above "easily *noticeable*", or approximately 5mm/s as the upper point of "*easily perceptible*" range. The 5mm/s contour of vibration will be shown on each of the modelled drawings.

10. ENVIRONMENTAL MITIGATION MEASURES

Environmental mitigation measures will be incorporated into each blast to minimise the impact of the following effects of vibration and include:

- Ensuring the planned blast area has been properly analysed to determine scale of blasting required;
- Ensuring only exact quantity of explosives is used for each hole;
- Condition surveys for adjacent structures whose risk assessment has highlighted that vibration from blasting may cause complaints, or where the owner has expressed concern in relation to the possibility of damage, will be undertaken;
- Placing vibration monitors at strategic locations to record and confirm that vibrations being imposed are at or below design limits.

11. BLASTING CONTROL MEASURES

The following instructions will be undertaken prior to the commencement of blasting. Whilst the blasting contractor will have procedures documenting the blasting steps, the following blast control measures are identified as key measures in completing blasting in an environmentally sensitive area.

11.1. Pre-Blast Activities

Prior to undertaking drilling and blasting, the following actions will be completed:

- Provide reasonable notice of intended blasting and the anticipated impacts on the nearby properties, occupants of these premises, authorities, affected public utilities owners and any service agencies that could be impacted by road control measures at the time of blasting;
- Blasting notification to the NSW WorkCover covering the jurisdiction of the proposed blasting activities for the intended period of blasting;
- A condition survey report of adjacent infrastructure, including an assessment of any increased susceptibility of the infrastructure to vibration related effects;
- Preliminary review assessing the expected maximum explosive quantities for control of vibration.

11.2. Blasting Notification

A blast notification form will be completed prior to undertaking blasting activities and submitted to the New South Wales WorkCover.

11.3. Community Consultation

Community Consultation will be undertaken as described in the Community Communication Strategy (Appendix B).

11.4. Preparation of Drilling Area

The area where blasting will be undertaken will be prepared to a condition to enable accurate drilling. Areas for drilling, particularly the drilling defining the perimeter of the tunnel will be surveyed in advance of the works.

11.5. Design and Layout of Blastholes

Drilling of blastholes will be completed using well maintained, hydraulic drill equipment supplied and operated by the drill and blast contractor. Key issues include:

- The drilling crew will establish a drilling pattern, including blasthole depths, and record the information on a blast pattern design worksheet;
- The quantity of explosive which will be loaded into each blasthole will be identified and clearly marked on the plan;
- The total quantity of explosive for each blast will be calculated and reconciled against the designed quantity;
- The blasthole burden and spacing will be measured as accurately as possible;
- The location of the perimeter blastholes will be determined by survey control.

The nearest distance to the closest property, or other sensitive receiver or infrastructure, will be used to calculate the expected level of vibration. An initial assessment of these data will be provided as part of the Blast Management Strategy Plan and will be attached in Appendix A.

11.6. Tunnel Wall Control

Protection of the walls of the tunnels may be improved through pre-splitting the perimeter of the excavation or the use of closely spaced blastholes with adjusted explosive loading. Closely spaced, possibly slightly angled small diameter holes with a centre to centre spacing of around 500mm to 1000mm will be drilled along the wall of the tunnel before the main production blast is initiated. The drill holes will be accurately set up in terms of their alignment to minimise drilling error over depth. Variation between the intended and actual location at the toe of the hole is expected to be less than several hundred mm.

The blastholes will be loaded with small diameter cartridge explosive or low density bulk emulsions and initiated prior to any production blasting.

11.7. Blasthole Drilling

Blasthole drilling will only be completed once the area has been cleared to establish a reasonable platform to ensure that blastholes can be accurately drilled, both in terms of their inclination as well as the depth. Careful placement of drill holes to ensure the tunnel profile is achieved is critical to the design.

On the completion of each blasthole, or group of blastholes, the driller will measure and confirm the depth of the hole and, if it is within tolerance, plug the collar of the hole. Variation in the depth, re-drilled holes or other amendments will be marked on the drilling loading sheet.

11.8. Transport and Storage of Explosives

Transport and storage requirements for blasting activities will be defined by the drill and blast contractor and in accordance with the NSW Explosives Act 2003 and the NSW Explosives Regulation 2013.

Explosives will be stored off site under the appropriate authority license and delivered to site as required. No explosive will be stored on site. The quantity of explosive and detonators will be transported on the day of the blast from the magazines in approved vehicles. Any unused explosive will be returned to the magazine at the completion of loading.

11.9. Priming and Loading of the Blasthole

The following key issues will be included as part of the blasthole priming and loading methods:

- Prior to priming a blasthole, the shotfirer will confirm the depth of the blasthole is consistent with the depth indicated on the blasting plan depth. The measured depth will be recorded on the blasthole loading plan;

- If a short hole is encountered, the shotfirer will ensure the depth is adequate to eliminate the possibility of flyrock that could damage services within the tunnel, or otherwise the blasthole will not be loaded;
- If any blastholes are loaded with loose poured ANFO, the quantity of explosive will be carefully measured and not estimated by pouring from a bag;
- Where blastholes are loaded with cartridge product, the diameter, length and number of cartridges will be recorded;
- Where the blastholes are loaded with bulk emulsion, the quantity of explosive will be carefully controlled and monitored to be consistent with the modelled quantities;
- Any overloaded blastholes will be not be blasted, but will have the explosive removed or in the case of ANFO, flushed with water;
- The quantity of explosive loaded into each blasthole, or deck, will be reported on the blast loading plan;
- The total quantity of explosive loaded into the blast will be reconciled against the quantity indicated on the submitted blast plan. Where the quantities differ, a comment for the variation will be included on the blast loading plan and confirmed as acceptable prior to initiating the blast.

11.10. Stemming of Blastholes

The stemming of blastholes will be undertaken with care. The bridging of stemming in a blasthole will result in stemming material ejecting, producing overpressure, flyrock and poor fragmentation. In addition:

- The stemming material will be imported to site and consist of a graded crushed aggregate with a diameter of around 10mm;
- The stemming length, and if required the length between individual decks of explosive, will be measured and written onto the blast loading sheet;
- All blastholes will be stemmed before the surface tie up commences.

11.11. Initiation

Blasting, including the loading, stemming and sequencing of blastholes will be completed in accordance with all appropriate NSW legalisation. Key issues include:

- The shotfirer will determine the tie up;
- The blast pattern will indicate the proposed tie up sequence, clearly identifying the different delay elements that will be used. This will be used to confirm the explosive quantity will comply with accepted vibration level at the nearest potentially sensitive receiver;
- A timing sequence will be shown and calculate the maximum instantaneous explosive quantity. This quantity of explosive (MIC) will be clearly identified on the loading plan;
- When the total shot has been tied in, all connections will be checked.

11.12. Additional Protection

Blasting near potentially sensitive equipment within the tunnel, or at the tunnel portal or shafts where there maybe possible flyrock, and to ensure that blasted material is not projected beyond the project boundaries or safe working areas, additional safety measures may be incorporated into the design. These will include one or more the following options:

- Placement of fill material (sand or similar), referred to as false overburden, on top of the blast area;
- Use of rubber matting placed to ensure no material can be ejected from the blast area;
- An increased uncharged stemming length (beyond the recommendations of the Australian Standard AS2187.2) will be incorporated into the design.

11.13. Firing

Firing of the blast will be under the control of the shotfirer. The following key issues will be confirmed:

- The community team have informed the potentially affected persons of the intent to blast;
- The area will be inspected to ensure all personnel are a safe distance from the blasting activities;
- *CDS* will place all control points to block access to the tunnel, including internal access other than ramps, at a safe distance from the blast area. The safe distance will be determined through standard risk assessment procedures;
- Prior to the blast, a siren of sufficient loudness will be sounded to alert all adjacent personnel of the immediate intention to blast.

11.14. Misfires

Should there be a cut-off (severing of the leads to the detonators, either surface or in-hole) during the blast, compliance with the NSW Explosives Act (2003) will be followed. The following checks for cut-offs will be implemented:

- After the blast is fired and the tunnel area has been adequately ventilated, the shotfirer will visually inspect entire shot for evidence of misfires.
- If found, the shotfirer will notify the *CDS* immediately along with the blast guards;
- The shotfirer will decide if it is safe to re-fire shot;
- The same method of initiation will be used.

If a misfire (unexploded explosive) is detected during excavation:

- Stay well clear;
- Warn all personnel in the area;
- The project area supervisor will notify the shotfirer immediately;
- A detailed and safe excavation plan will be formulated and implemented.

11.15. Reconciliations and Reporting

Prior to firing each blast, *CDS* will have in their possession the following documents:

- A pre-blast sheet confirming that the expected level of vibration at each of the nearest sensitive receivers complies with the vibration limits;
- A completed drilling sheet prepared by the shotfirer showing the measured depth of each blasthole. The sheet will identify and clearly mark any "*anomalous*" blastholes;
- A blast loading plan showing the depth of each blasthole, quantity of explosive in each blasthole and the uncharged stemming length. The initiation sequence will also be shown. Reconciled explosive quantities used versus the designed quantity will also be shown and any variations accounted for;
- A signed blast summary sheet showing that each of these forms been received and no variations between the intended and implemented design exist.

These requests are in accordance with the specifications listed in the Australian Standards AS2187.2 document.

12. TUNNEL CLEARANCE PROCEDURES

Safety of personnel within the tunnel and any adjacent work areas will be ensured through documented clearance procedures. Procedures will be completed for both the main production blasting and any secondary or smaller scale blasting that may be required.

12.1. Production Blasting Evacuation Procedure

All tunnel personnel will be evacuated to a safe working area prior to blasting within the tunnel. Safe working areas will be determined by the shotfirer and will comply with *CDS* risk management procedures. The safe areas for the main production blasting will be located outside of the tunnel portal at a distance determined by the shotfirer. It may be possible that at a safe work area for the smaller secondary blast to fragment oversize rock maybe within the tunnel, although at a safe distance from the blast. These areas will contain a permanent source of fresh air and maintain positive means of egress in the event of an emergency. These locations are to be risk assessed individually and comply with WorkCover NSW Work Health and Safety requirements.

Personnel evacuation and tunnel clearance will be controlled by *CDS* under the direction of the shotfirer. A tag on-tag off board will be the primary means of personnel accountability. All *CDS* personnel, sub-contractors and visitors will use of a tag board as part of the site specific tunnel induction for personnel entering the tunnel area of works.

Blast sentries will be positioned at entrances to the tunnel portal. These guards, under the supervision of the shot firer, will conduct a final tunnel clearance prior to initiation. Upon confirmation to the shotfirer and senior tunnel supervisors that all personnel are evacuated from the tunnel the direction to commence firing procedures will be given. Initiation of the blast will be conducted by the shot firer only when they are satisfied that it is safe to commence firing. The shot firer will have full discretion to terminate the blast sequence at any time if it is determined unsafe to proceed.

Following the blast, tunnel ventilation will allow blast fumes to clear. This complies with the NSW "*Tunnels Under Construction Code of Practice 2006*" air quality and ventilation systems guidelines. When it is determined safe, the shot firer will inspect the blast location and determine correct detonation. Upon confirmation that the tunnel is safe to enter the all clear will be given by the shot firer and personnel allowed to re-enter the tunnel.

If it is deemed unsafe to enter the tunnel the shot firer will make the area safe and determine actions required to neutralise and make safe the blast area before allowing personnel entry to the tunnel environment.

13. MONITORING OF BLASTING ACTIVITIES

The vibration monitoring system will consist of a series of individual monitors which will be positioned at key locations around the blast. Each vibration monitor will have a minimum of three recording channels. An external geophone (transducer) will monitor ground vibration in three directions (transverse, vertical and longitudinal particle velocities) and report the level in mm/s. For any blasting at the tunnel portals, an external microphone will also measure the level of overpressure, reporting the data in units of dBL. The monitors will be configured with a vibration threshold trigger to record blast events which exceed a minimum value, typically around 0.3mm/s. The recording duration will be set to exceed the duration of the blast.

Monitoring locations for blasting will be identified prior to each blast. The proposed blast monitoring sites will include:

- Nearest four residential properties, generally a property towards the north, south, east and west of the blast zone;
- Any heritage property that is within 150 hundred metres of the blast area;
- Commercial property that contains potentially sensitive equipment, such as electronic or scientific apparatus or other equipment with tight tolerances for vibration impacts.

In the event that additional monitoring sites are required, these will be confirmed by the community relations team.

Blast monitoring will be undertaken in accordance with Australian Standard AS2187.2 recommendations.

Blast data will be made available after each blast for analysis, comment and close out. Blast monitoring results will be summarised in a monthly reports. The monthly report will contain details of blast monitoring including the following information:

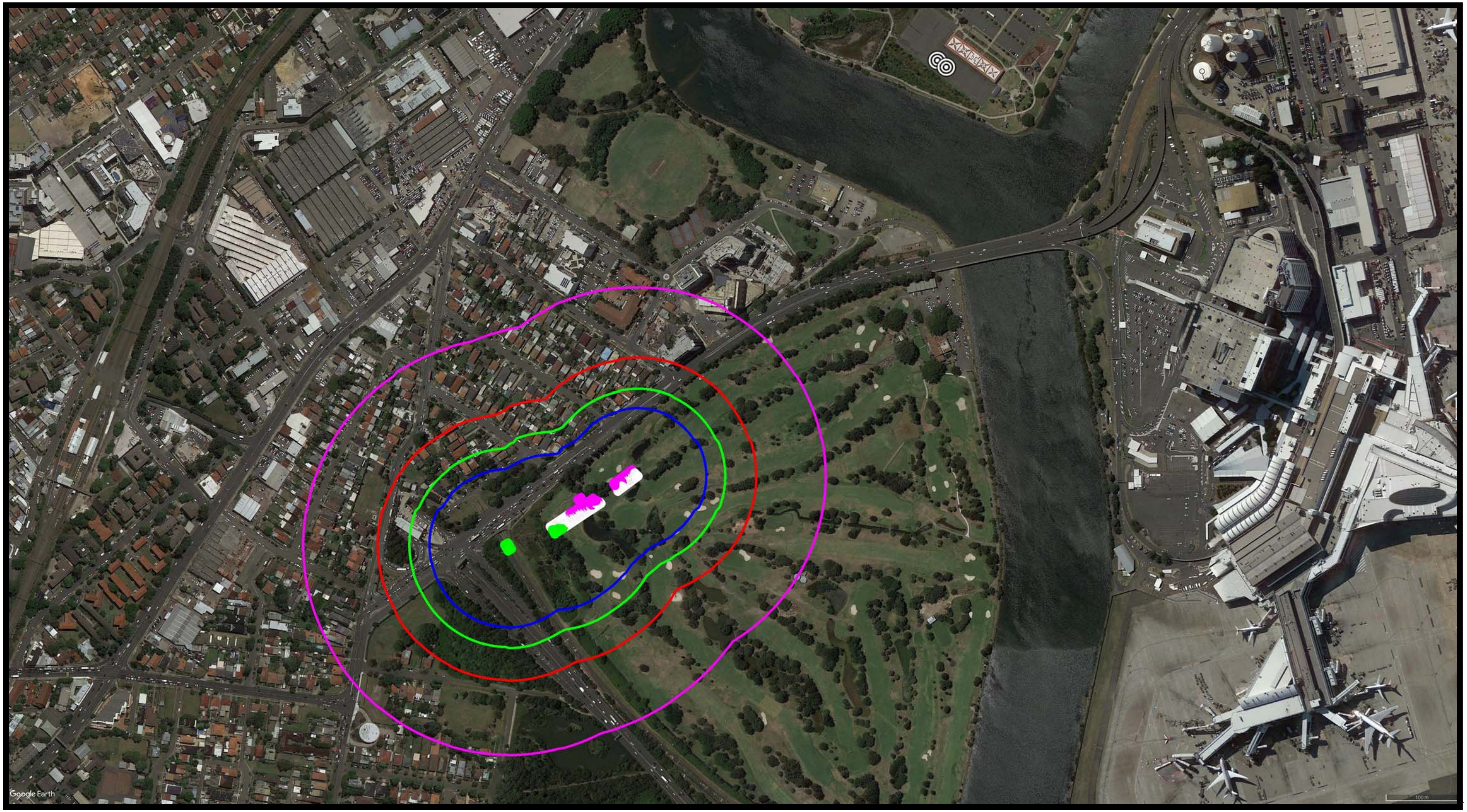
- Locations of the monitoring positions;
- The type, serial numbers and calibration details of the monitoring equipment used;
- Blast monitoring results;
- Date and time when testing was performed.

[redacted]

RPEQ 6304

14. APPENDIX A – EXPLOSIVE WEIGHT ANALYSES

A B C D E F G H I J K L M N



Created using TunnelTRAP Software

SCALE

0 50 100 150 200 250m

Vibration Levels

- Expected 2.5 mm/s Vibration Contour
- Expected 5 mm/s Vibration Contour
- Expected 7.5 mm/s Vibration Contour
- Expected 10 mm/s Vibration Contour

Airport Link

Explosive Quantities

- More than 10 kilograms
- Between 8 and 10 kilograms
- Between 6 and 8 kilograms
- Between 4 and 6 kilograms
- Between 2 and 4 kilograms
- Less than 2 kilogram

Project Description: WESTCONNEX NEW M5 - Arncliffe blasting with explosive weight based upon compliance with 10mm/s at adjacent receivers. Resulting vibration contours estimated based upon second decline vibration relationship

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CPB CONTRACTORS DRAGADOS SAMSUNG

Plate No. A

Revision History

V1: Original

Date Drawn: **7 November 2017**

Ref No: M5 Arncliffe Additional AL

Job No: HP1703-1

A B C D E F G H I J K L M N

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SCALE

0 | 50 | 100 | 150 | 200 | 250m

Vibration Levels

- Expected 2.5 mm/s Vibration Contour
- Expected 5 mm/s Vibration Contour
- Expected 7.5 mm/s Vibration Contour
- Expected 10 mm/s Vibration Contour

Airport Link

Explosive Quantities

- More than 10 kilograms
- Between 8 and 10 kilograms
- Between 6 and 8 kilograms
- Between 4 and 6 kilograms
- Between 2 and 4 kilograms
- Less than 2 kilogram

Project Description: WESTCONNEX NEW M5 - Arncliffe blasting with explosive weight based upon compliance with 10mm/s at adjacent receivers. Resulting vibration contours estimated based upon second decline vibration relationship

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SAMSUNG

Plate No. B

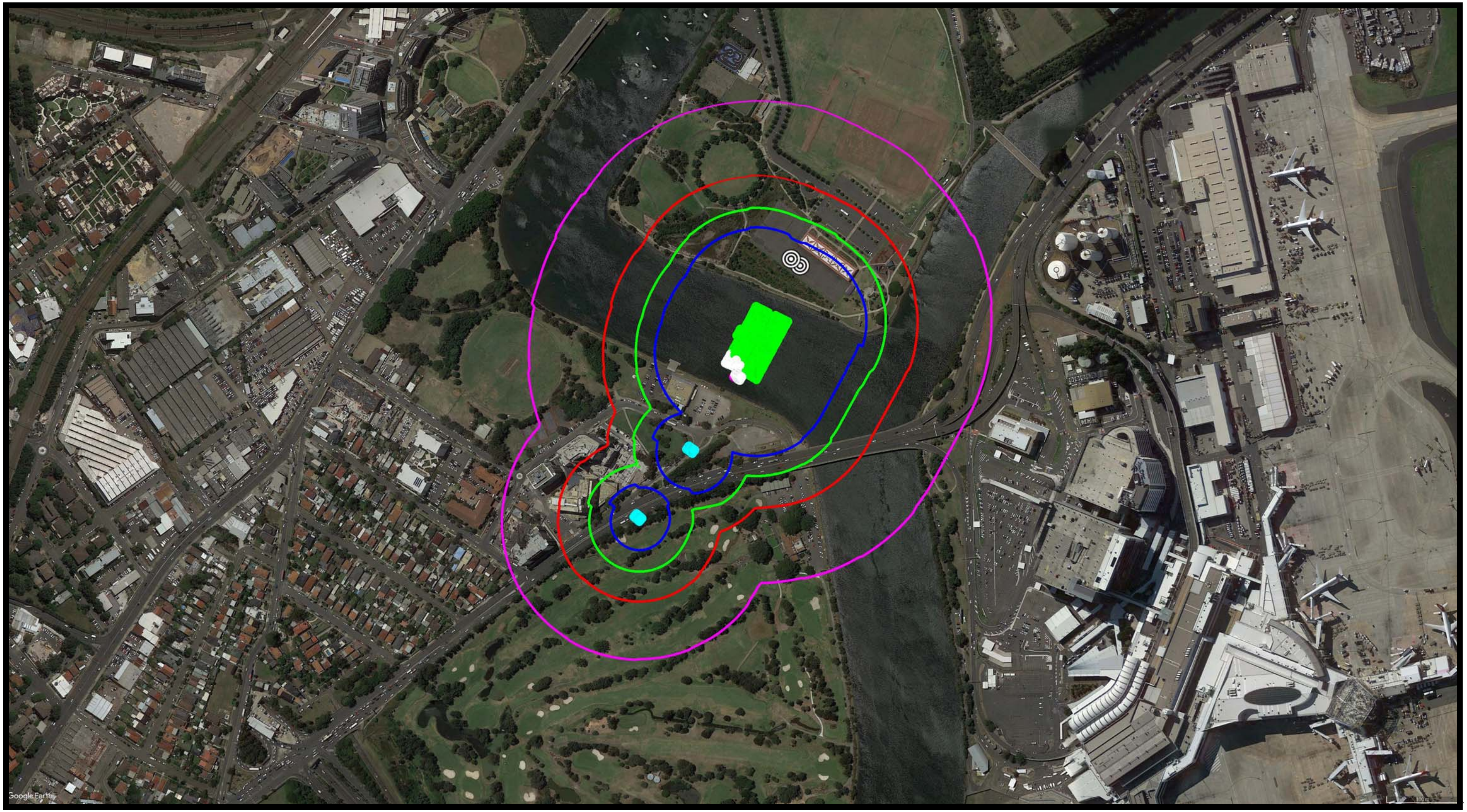
Revision History

V1: Original

Date Drawn: **7 November 2017**

Ref No: M5 Arncliffe Additional AL

Job No: HP1703-1



Created using TunnelTRAP Software

SCALE

0 | 50 | 100 | 150 | 200 | 250m

Airport Link

Vibration Levels

- Expected 2.5 mm/s Vibration Contour
- Expected 5 mm/s Vibration Contour
- Expected 7.5 mm/s Vibration Contour
- Expected 10 mm/s Vibration Contour

Explosive Quantities

- More than 10 kilograms
- Between 8 and 10 kilograms
- Between 6 and 8 kilograms
- Between 4 and 6 kilograms
- Between 2 and 4 kilograms
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Project Description: WESTCONNEX NEW M5 - Arncliffe blasting with explosive weight based upon compliance with 10mm/s at adjacent receivers. Resulting vibration contours estimated based upon second decline vibration relationship

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Plate No. C

Revision History
V1: Original

Date Drawn: **7 November 2017**

Ref No: M5 Arncliffe Additional AL

Job No: HP1703-1

In preparing this drawing, HP have made certain assumptions. We have assumed that all information and documents provided to us by the Client or as a result of a specific request were complete, accurate and up to date. Where we have obtained information from a Government register or database, we have assumed that the information is accurate. Where an assumption has been made, we have not made any independent investigations with respect to the matters the subject of that assumption. We are not aware why any of the assumptions are incorrect.