In the matter of the Melbourne Metro Rail Project

Planning Panels Victoria

Proponent: Melbourne Metro Rail Authority

Expert Witness Statement of John Heilig

Expert of Melbourne Metro Rail Authority

1 Name and address

My name is Dr. John Herbert Heilig and I am the Principal of Heilig & Partners Pty Ltd., a consulting engineering company based in Brisbane Australia. I reside at 91 Burdekin Drive, Sinnamon Park, Queensland.

2 Qualifications and experience

I hold the qualifications of Bachelor of Engineering (BE) with Honours and a Doctor of Philosophy (PhD), both from the University of Queensland in Australia with the latter awarded in 1988.

I have worked in the industry for more than 30 years and have extensive domestic and international experience in the measurement, assessment and impact of vibration and regenerated noise from blasting and mechanical activities from civil construction projects. I have been associated extensively with design, vibration analysis and prediction at more than 800 sites throughout the world. I have also consulted to government agencies on acceptable vibration criteria for a variety of projects. I have provided, or am continuing to provide, advice and extensive design input into many of the tunnels developed or presently being constructed in Australia, including the three major tunnels in Brisbane, the four current significant tunnelling projects in Sydney as well as the Western Distributor presently under consideration for Melbourne. I have been involved with the review of two other tunnels in Auckland.

Annexure A contains a statement detailing my qualifications and expertise and addressing the matters set out within Planning Panels Victoria‘s Guide to Expert Evidence.

I confirm that I have read the Code of Conduct for expert witnesses and that I agree to comply with it. I confirm that I have considered all the material facts that I am aware of that might alter or detract from the opinions I express. In particular, unless I state otherwise, this evidence is within my sphere of expertise and I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.

3 Scope

3.1 Role in Preparation of the EES

Aurecon Jacobs Mott MacDonald (AJM) was responsible for the preparation of the technical assessment of the expected levels of vibration and regenerated noise from the construction of the Melbourne Metro Rail Project. The assessment was documented and presented as technical Appendix I – Melbourne Metro Rail Project - Noise and Vibration Impact Assessment (NVIA) to the Environmental Effects Statement (EES). I had no direct input into the analyses or the preparation of NVIA or the EES.

My role in the project was to provide advice to the Melbourne Metro Rail Authority (MMRA) in relation to the following:

- Undertake a high-level review of the vibration aspects of the Noise and Vibration Impact Assessment (NVIA), including appendices, and the inputs into the assessments presented, including the modelling;

- Comment on the assumptions, methodology assessment criteria and scope applied by AJM;
- Advise whether there are any gaps or matters where I disagree with the assessment completed by AJM identify any further work that should be undertaken.

3.2 Instructions

I have been engaged to prepare a witness statement, to prepare responses to relevant submissions and to give evidence to the Inquiry and Advisory Committee on vibration and regenerated (ground borne) noise associated with the construction project.

3.3 Process and Methodology

I have assessed and reviewed the technical report titled "*Melbourne Metro Rail Project – Noise and Vibration Impact Assessment*" which is presented as Technical Appendix I to the Environmental Effects Statement (EES) for the Melbourne Metro Rail Project.

In assessing the NVIA, I have relied upon my own experiences associated with tunnelling, including a substantial data base of information from projects on which I have consulted.

I have visited each of the areas along the alignment with the MMRA Precinct Managers to better understand the proposed construction methods, the proximity of the existing infrastructure and any other construction activities occurring in the vicinity of the project.

I reviewed those sections of the EES relevant to my area of expertise in particular the NVIA and Chapter 13 of the Main Volume of the EES, the Historical Heritage Impact Assessment (HHIA), and additional geological information referred to below. The review focussed on two broad areas which I consider the fundamental deliverables of an EES. These included:

- The proposed Environmental Performance Requirements (EPR) and whether these are appropriate to ensure the vibration and regenerated noise impacts are aligned with internationally adopted values, limited to levels that preserve amenity and therefore acceptable to the vast majority of persons, protective of building integrity and are appropriate for protecting sensitive equipment;
- The predicted vibration and regenerated noise impacts in the NVIA, including the calculation methods used to determine the level of impact, together with the levels of vibration and regenerated noise from the construction of the rail tunnel, portals and station caverns.

I have met with the AJM engineers who completed the modelling analyses to better understand the approach that had been followed in predicting the vibration and regenerated noise impacts.

I have also been asked to review the submissions to the EES provided to me by Herbert Smith Freehills and where necessary respond to these submissions.

MMRA's response to a request for information made by the Inquiry and Advisory Committee (IAC) on the 13th July and other modifications to the concept design were presented as MMRA Technical Notes. I have been asked to review these Technical Notes, insofar as they relate to my area of expertise. My comments on these Technical Notes are addressed later in this witness statement.

As a result of my discussions with the MMRA, I have also been asked to review a preliminary draft residential impact mitigation guidelines for construction document prepared by MMRA and my comments on this preliminary document are included in this witness statement.

4 Findings

4.1 Summary of Opinions

I have concluded that the concept design, the proposed construction methodology and the recommended EPRs, are all consistent with that typical of other similar use tunnel developments. I therefore conclude that the process of assessing the potential environmental risks and impacts is consistent with best practices and well aligned with the procedures adopted for other successfully managed large scale construction projects.

Save where otherwise indicated I concur with the assessment of construction related vibration and regenerated noise impacts documented in the NVIA and this has informed my evidence.

In assessing the thoroughness of the vibration and regenerated noise assessment, I have considered four key components. These include:

- The effects of vibration and regenerated noise
- The Environmental Performance Requirements (EPRs)
- The predicted impacts
- The mitigation options

The Melbourne Metro tunnelling in perspective

Whilst the Melbourne Metro is a large scale tunnelling project, the nature and extent of the noise and vibration impacts associated with the Project are not unique in an urban environment.

The complexity, challenges and economics generally preclude tunnelling in all except urban areas where surface disturbance must be kept to a minimum. Tunnelling therefore typically occurs beneath populated areas. In my experience this project is not unique in terms of the tunnel or station depth, proximity to residential and commercial properties, hospitals and medical facilities, heritage buildings, or other significant infrastructure and assets. Therefore the modelled vibration and regenerated noise impacts as presented in the NVIA are comparable to other tunnelling and construction projects I have been associated with. Many of these tunnels have been developed in Australia.

In addition to tunnels, other large scale construction and building projects that have used similar construction equipment to that planned for the Melbourne Metro have been successfully developed. Some of these projects have utilised small scale drilling and blasting techniques within tens of metres of buildings, including hospitals, without impact on amenity, building integrity or equipment operation.

EPRs that protect personal amenity, ensure building integrity and allow businesses to operate contemporaneously with the project construction activities are therefore a necessary component of the environmental specifications. Projects that have specified performance criteria, assessed the construction activities against these criteria, identified any necessary mitigation measures, incorporated an extensive community program and compiled the information into a Construction Noise and Vibration Management Plan (CNVMP) have in my experience been effective in managing the impacts of vibration and regenerated noise.

In my opinion, the construction related vibration and regenerated noise Guideline Targets in the EPRs are in the range and in many cases more restrictive than criteria adopted for other projects I have been associated with.

The Effects

Vibration

Vibration effects will necessarily occur as a result of the mechanical excavation of the rock mass with a Tunnel Boring Machine (TBM), road header or hydraulic hammers mounted to excavators. Vibration produced by these sources is described by periods of activity, which can persist for tens of minutes, followed by periods of little or no impact as the equipment re-sets, re-grips or relocates to other areas. Despite the nature of this type vibration, these sources of vibration are generally considered continuous in their assessment. Blasting produces impulsive vibration which is short term, typically persisting for not more than 10 seconds and once per day, and is assessed using different criteria to that applied for mechanically generated vibration.

Relationships that describe the decay of vibration with distance for each equipment type are applied to determine the impacts at varying distances from the construction activities. Blast vibration relationships also include a third parameter that includes the quantity of explosive contributing to the vibration.

Vibration, if sufficiently high, can cause superficial damage to nearby buildings. The results of well documented studies linking vibration levels and observed building damage have been published in the international journals and have subsequently been incorporated into vibration standards that are universally applied. Compliance with these limits virtually ensures the project can be free of vibration related damage.

Low levels of vibration, much lower than those that can result in building damage, are readily perceived by persons and can be sometimes considered as impacting upon their personal amenity. The human body can detect vibration much lower than those levels that can cause superficial building damage. Where buildings are occupied, vibration impacts are typically assessed against personal amenity criteria as a starting point. Compliance with these limits virtually ensures no impact in terms of building integrity. It is commonly accepted within vibration industry that vibration will be personally intolerable to building occupants well before any damage to the building or its contents may occur. Some highly calibrated and specialised scientific or medical apparatus maybe affected by levels of vibration that are lower than human thresholds of perception.

Regenerated Noise

Regenerated noise, or what is described in the EES as ground-borne noise, occurs as a result of vibration that induces momentary deflections, generally less than a few microns, into the floors, walls, ceilings and other hard surfaces of buildings. An estimate of the level of regenerated noise is difficult given that it requires firstly an estimate of the level of vibration plus additional estimates detailing how the vibration pulse manifests as audible noise effects. Influences such as the geological conditions and the soft soil profile, the type of structure and whether it is slab on ground, strip footings or piered foundations, whether the building is single or multi storey, the type of floor or wall coverings and whether carpet, timber or tiles are a few of the many factors affecting the level of regenerated noise inside a building. Regenerated noise will only affect people inside a building. It is necessary to apply a uniform approach to the occupants and buildings along the tunnel alignment. There is some variability in regenerated noise predictions applied to particular properties.

Each of these potential effects has been adequately assessed as part of the NVIA and I note that the EPRs require further predictions to be carried out at the final design stage (NV3). This will increase the level of certainty of the predicted regenerated noise impacts and the identification of affected properties.

The Performance Criteria

The use of Guideline Targets in the EPRs

EPRs are proposed for different vibration and regenerated noise sources, operational times, building types, occupancies and equipment characteristics. The performance criteria for the Melbourne Metro project are considered complete and adequately cover the range of equipment usage and potentially sensitive receivers. The criteria address personal amenity, infrastructure damage and equipment sensitivity measured as exceedances of Guideline Targets which trigger a management response that should be set out in CNVMP.

The EPRs for vibration from mechanical equipment, such as the TBM, road headers and hydraulic hammers, are expressed as Guideline Targets. This is consistent with the terminology adopted in the guidelines upon which the EPRs are based. The values for blasting generated vibration are presented as recommended limits. I am comfortable with the EPRs being expressed as Guideline Targets on the basis that the monitoring and mitigation measures are fully addressed in the CNVMP. The plan should discuss in detail the processes that will be followed when the target values are approached. This flexible method has been successfully implemented for other large scale projects and allows interaction between the contractor and sensitive receivers, often permitting activities to continue when the vibration is in excess of the EPRs, and on other occasions, requiring an adjustment to practices when levels are less than the permissible criteria.

Vibration

Criteria to protect against building damage are drawn from the German Standard DIN4150. This standard has international acceptance and addresses different building types and occupancies as well as the frequencies of vibration. The proposed values also consider long and short term vibration effects, differentiated according to whether fatigue effects are possible.

The human comfort criteria for continuous vibration are drawn from the NSW Guidelines which essentially replicate the British Standard BS6472 recommendations. The vibration criteria are referenced against dosage limits for both daytime (7am to 10pm) and evening (10pm to 7am) in terms of preferred and maximum values to limit “adverse comment”. The dosage criteria severely penalises elevated vibration values and attempts to restrict the overall exposure of affected persons by ensuring that any instances of elevated vibration are accompanied by extended periods of lower vibration values. The calculations of vibration dosage values (VDV) are complex and provide a true measure of compliance only at the end of the assessment period, which is typically between 10pm and 7am each day. A prediction of the VDV can however be estimated by VDV over a shorter monitoring period. Performance criteria in the peak or RMS velocity domain are often preferable as they allow an immediate review as to whether any adjustments to practices are required. It would be reasonable however for the VDV to form the basis of performance criteria expressed in other domains, such as the peak particle velocity (PPV).

This approach is supported by the British Standard BS5528. The British Standard BS5528 recognises the VDV concept provided in BS6472 although suggests “whilst the assessment of the response to vibration in BS6472-1 is based on the VDV and weighted acceleration, for construction it is considered more appropriate to provide guidance in terms of the Peak Particle Velocity PPV, since this parameter is likely to be more routinely measured based upon the more usual concern over potential building damage. Furthermore, since many of the empirical vibration predictors yield results in terms of PPV, it is necessary to understand what the consequences might be of any predicted levels in terms of human perception and disturbance”.

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) vibration performance criteria for sensitive scientific, electrical and medical equipment are conservative and compliance with these values should ensure their

continued operation. These may however be onerous in terms of both monitoring requirements and the ability to comply with these criteria as they are likely to be exceeded through normal day to day activities.

The vibration limits for sensitive medical equipment are commonly provided by the Original Equipment Manufacturer (OEM) and will identify criteria amongst other values for continued operation and transport. The OEM values define nil impact (the equipment can continue to be used with no effect on its calibration) or other criteria may refer to potential damage. Where the values are particularly onerous, the equipment is commonly vibration isolated to prevent exceedances by activities such as foot falls or doors slamming and so on.

The proposed ASHRAE limits are considered onerous, but very protective of equipment usage. The planned criterion for microsurgery, eye surgery, neurosurgery and other sensitive activities, is 25µm/s per one-third octave which will equate to peak values of around 0.2mm/s for a combined frequency sweep. Whilst it is complex to measure, adherence to the proposed targets will ensure there are no negative impacts on the day to day activities within the hospital precinct. Other more sensitive equipment has been identified in the assessment with targets around half the surgery values. My experience would suggest that the recommended targets are likely to be exceeded through normal day to day activities, such as walking, closing doors, moving objects and so forth, and I therefore expect that further discussions prior to construction with the various groups will be necessary to better define these equipment performance criteria.

It is my recommendation that a panel is established to interface between the construction team and the sensitive Parkville institutional uses.

Predicted Impacts in the NVIA

The predicted impacts in the NVIA have been calculated using standard and supportable formed equations. The vibration distance relationships are based upon generic data sets rather than specific information for the Melbourne Formation and other rock types. An increase in the variability between the predicted and measured values could occur. Based upon my analyses, the distances in the NVIA at which the varying vibrations are predicted are aligned with my expectations.

Establishing whether compliance with the Guideline Target VDV in the EPRs can be achieved is based around these equations plus the percentage of time during which the construction equipment is in operation, referred to as the duty cycle. This is key to assessing compliance with the VDV and regenerated noise Guideline Targets. In the NVIA, the duty cycle for the road header is assumed as 60%, that is, meaning that it is assumed to operate for an average of about 40 minutes in every 1 hour period. The duty cycle for the TBM is conservatively placed at 100% which will lead to slightly elevated vibration dosage predictions. The TBM would typically operate for periods of tens of minutes followed by a delay during which time it re-positions, re-grips and so forth. The duty cycle assumptions are therefore reasonable, but conservative.

The NVIA assumed rates of advance of 11.5 metres per day for the TBM and 5 metres per day for the road header are reasonable, although in my experience perhaps considered conservative when compared to advance rates at other completed tunnelling projects. Increasing the advance rate will reduce the impact and the durations presented in the EES could therefore be considered maximum based on this aspect alone.

An estimate of the vibration impacts from blasting is based upon equations given in the Australian AS2187.2 for average blasting conditions. The proposed blasting vibration relationship has however been adjusted to reflect the percentile conditions given in the blasting performance criteria. While the relationship is not considered specific to Melbourne rock types, the calculated vibration levels at given distances for a particular explosive weight are reasonable and not dissimilar to the vibration levels predicted using more site specific vibration relationships for the Melbourne area rock types.

I note that the calculations given with respect to the scale of blasting consider very low through to higher, but reasonable, explosive quantities per blasthole. The low quantities are very likely to be considered uneconomical and not deliver the outcomes required in terms of fracturing the rock. It is therefore expected that in those areas where blasting has been assessed as requiring these smaller quantities, excavation will be completed with other means, quite possibly hydraulic hammers.

The chances of "adverse comment" is most likely to occur in those areas where extended construction activities are required, such as establishment of caverns, stations, boxes, cross passages and so on. It will be necessary that community liaison teams are active in these areas to ensure residents are well informed of the construction activities and the likely impacts.

The approach is typical of all large scale projects. The expected impacts are assessed and compared to the guideline values to identify the appropriateness of the initial estimates and the proposed construction method. During the initial stages of the construction, or possibly using other dedicated trials, the accuracy of the predicted data are confirmed. Where necessary, some sections of the project may be re-assessed and the requirement for alternative construction methods evaluated.

Mitigation

Mitigation measures commonly promoted for construction projects are less applicable for tunnelling projects. These include:

- Substitution of a high energy source with a lower energy source have been included in the assessment, although are of limited practicality;
- Increasing the separation distance is a high level control measure and requires adjustments to the project alignment, such as increasing the depth of the tunnel. This measure forms part of best practice in the iterative design process, however, is generally not feasible as a mitigation measure;
- Receiver control measures, such as vibration isolation, are limited to items of equipment rather than project wide. While airborne sound isolation is possible through practices such as double glazing, options for the reduction of regenerated noise on a large scale are impractical.

The more simplistic mitigation options that would potentially be available to a road use tunnel are less applicable to rail tunnels. Increasing the separation distance between the tunnelling activity and the above surface infrastructure by deepening the tunnel are challenged with stringent control issues on rail gradients. The requirement to interface with stations levels limit the design flexibility to a greater degree than available with vehicular use tunnels.

Reducing the effects of vibration and regenerated noise from a TBM is effectively limited to reduced operational hours or temporary relocation of building occupants. Whilst options such as reduced thrust or cutter head rotation speed for the TBM are possible options (as shown in Chapter 13 of the EES), the equipment is designed to operate within a range of particular machine variables and departure from these optimum values will necessarily lead to increased construction periods. A significant departure could lead to very inefficient and ineffective cutting. Unlike the example of an hydraulic hammer where the hydraulic hammer can be replaced with a smaller unit should any non-compliances occur, this is not possible with the TBM. Therefore a significant reduction in the vibration and regenerated noise levels from operation of the TBM is generally unlikely.

Smaller size excavators and hydraulic hammers necessarily induce lower levels of vibration and regenerated noise, but their use is limited for bulk excavation works.

Control of vibration from blasting can be achieved through changes to the explosive weight, although below some explosive quantity, blasting becomes ineffective and uneconomic as an excavation method. In such cases, blasting is normally replaced by hydraulic

hammering which may ultimately lead to a reduced level of personal amenity when compared to blasting that generates an elevated, but very short term, period of vibration.

Relocation of commercial tenants is typically viewed as cost prohibitive. It has been previously observed that early discussions with the affected tenants typically lead to a resolution that allows both the construction activities and the business to cooperate contemporaneously. Relocation generally only occurs as a result of night based construction activities causing sleep deprivation. These effects are eliminated with most commercial properties, aside from motels, hostels or hospitals and the like.

My experience at other tunnelling projects indicates that construction of the cross passages between tunnels, or other larger construction areas, can result in adverse comment and complaint. The development of the portals, boxes and stations are identified as key construction areas and generally positioned in areas to have minimum impact. The cross passages between tunnels are positioned according to regulatory separation distances and their position is not as flexible. They may therefore be located near to sensitive receivers. The construction method for the cross passages should be selected to ensure persons around these are not subjected to elevated levels of vibration and regenerated noise for extended periods.

Community education that provides information in advance to potentially affected asset owners and residents detailing the anticipated impacts, the duration, and how these will be perceived, is the most effective mitigation measure. The focus should be on education and monitoring. My experience at other projects is that the majority of residents are accepting of slightly elevated levels providing they are informed of the potential impacts. Establishing EPRs that are protective of both amenity and assets is always a key element.

4.2 Any Additional Work Undertaken Since Exhibition of EES

Since the EES for the project was finalised, I have requested that further information be provided. Amongst other matters, I have requested that MMRA provide further details on the following aspects of the project:

- An assessment of the impacts identifying the number of “affected property days” over the total alignment for which exceedance of the human comfort Guideline Targets for vibration and regenerated noise occur. This would allow an indication of the level of mitigation and risk encumbered on the project as well as informing residents of both the potential for effect and duration of the impact.
- An assessment of the expected vibration and regenerated noise from construction of cross passages between the two tunnels. Tunnel development occurs with a TBM that progresses at relatively quick advance rates and the impact on properties is of short duration. Developing the cross passages is a slower process and may result in longer periods of vibration and regenerated noise.

Since these requests and as part of my review, I have revisited the geological information and now expect that given the rock mass competency, the possible difficulties with extended construction durations in the cross passages are not as significant as my initial assessment concluded. Whilst I believe that a review of the construction of these cross passages should continue, I am not expecting the impacts to be as substantial as on some other projects I have been associated with.

Although not at my request, further in-fill geotechnical drilling has been completed since the initial program. These data have been analysed by Golder Associates and have indicated that through the CBD precincts, the quality of the weathered material extends deeper than inferred from the original drilling program. Whilst the revised geology may require an adjustment to the cavern design and support regime for the CBD station caverns, I have been informed that the general method of construction will remain unchanged. My view is there is no need to revise upward the predicted impacts given in the EES. If

anything, it is more likely that the altered geology will result in lower levels of vibration and regenerated noise.

This further work has not caused me to change my opinions in respect of the appropriateness of the proposed EPRs. Where I consider necessary, my evidence comments on the additional material that has been supplied in my responses to the submissions set out below.

4.3 Response to Submissions

I have read the submissions made to the IAC that were provided to me for comment on matters relevant my area of expertise. These included a number of submissions from residents as well as key submissions from larger local and state government agencies, including the City of Melbourne, City of Port Phillip, RMIT, University of Melbourne and Department of Health and Human Services. Submissions were also reviewed from representative groups such as the Kensington Association, Melbourne Hebrew Congregation Inc., Christ Church Grammar School, National Gallery of Victoria, Fed Square, Melbourne Grammar School, Domain Owners Association, and the North Melbourne Community Group submitters.

These submissions generally raise issues that have already been addressed in the EES and therefore do not affect my findings. A number of common themes emerge from these submissions and I have commenced my response by addressing these issues, in particular:

1. Concern regarding structural damage to buildings that would occur from the vibration produced by the construction activities. Approximately half of the submissions I have reviewed were concerned with this aspect of the project;
2. Concern regarding the extent of the condition surveys to confirm any deterioration of the infrastructure during the construction phase, as well as having access to these documents;
3. Concern regarding the loss of amenity for residents around construction areas that would occur as a consequence of the vibration and regenerated noise produced by the construction equipment. A number of submitters also equated loss of amenity with sleep disturbance and potential health issues. Approximately half of the submissions I reviewed were concerned with a reduction in their "quality of life";
4. Expressions that further consideration be given to the "*alternative reference design*" identified in respect of the Western Portal Precinct.

The EPRs for vibration and regenerated noise as generated by the construction methods that have been presented in the EES address these matters. In particular the two key issues of ensuring the vibration produced by the works prevent structural damage to the adjacent properties and ensuring the amenity of residents around the works is not unduly affected are addressed. The Guideline Targets in the EPRs are based upon Australian or other International Standards.

Property Damage

Approximately 60 submissions have expressed concern that vibrations could damage the surrounding properties. The possibility of damage to properties arising from the vibration generated during the construction phase is extremely low. I am unaware of damage to properties from vibration occurring as a result of the tunnelling activities on any of the other projects I have been involved with. Other naturally occurring environmental effects induce stresses that far exceed those produced by vibration. As an example, a small humidity change or summer/winter temperature fluctuations induce a level of stress equivalent to that generated by a vibration pulse more than ten times the Guideline Targets for vibration induced structural damage (NV6). Routine daily weather phenomena produce far greater stresses than the equivalent stress level induced by a level of vibration compliant with the EPRs.

There will be noticeable cracks to some properties during the tunnel construction period. These changes will however be no different or occur at any increased rate when compared to properties that lie well beyond the construction envelope. Where buildings are occupied, the Guideline Targets are very heavily biased towards human comfort criteria and therefore effectively prevent any opportunity for structural or superficial damage to infrastructure around or above the tunnel alignment.

The EPRs are consistent with the levels imposed on other recently completed tunnelling projects, such as the North South Bypass, the Airport Link, and Legacy Way in Brisbane, and the NorthConnex, WestConnex and WestConnex Stage 2 in Sydney and the CityLink and the previously proposed EastLink tunnels in Melbourne.

The integrity of older heritage structures and their susceptibility to damage from construction vibrations has been raised in several submissions. Vibration limits for heritage or aged infrastructure has been addressed in the EES and in my view these suggested Guideline Targets are conservative, but aligned with those initially imposed on heritage infrastructure from other projects. These limits are based upon data presented in the international standards, noting that the most recent version of the relevant Australian Standard AS2187 does not impose a more restrictive vibration criterion for heritage infrastructure, but rather considers it to be adequately protected by vibration criteria appropriate for recently constructed infrastructure. The British Standard BS7385 also indicates:

- Important buildings which are difficult to repair may require special consideration on a case by case basis. A building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive;
- Structures below ground are known to sustain higher levels of vibration and are very resistant to damage unless in very poor condition;
- There is little probability of fatigue damage in residential building structures due to normal construction vibration. The increase in the component stress levels due to the imposed vibration is relatively nominal and the number of cycles applied at a repeated high level of vibration is relatively low. Therefore unless the calculation indicates that the magnitude and the number of load reversals is significant (with respect to the fatigue life of the building), then none of the proposed vibration performance criteria should not be reduced for fatigue considerations.

Condition Surveys

It is appropriate that all structures and significant sub-surface infrastructure adjacent to, or in the immediate vicinity of, construction activities is assessed through a condition survey. Where the integrity of the infrastructure is shown to be susceptible to vibration, the mandatory vibration criteria should be set accordingly, or some other method of rectifying the susceptibility of the building considered. Similarly, should the condition survey show that the infrastructure is in a sound condition, a higher mandatory vibration criteria could be considered if there is shown to be mutual benefits to the parties, such as a reduced overall effect on amenity.

Some submitters are unclear as the requirement or extent of the condition surveys which would be required prior to the commencement of any works. The objective of a condition survey report is to provide an indicative representation of the condition of the infrastructure prior to the commencement of any earthworks/construction activities and therefore ensure that the contractor applies best practices that minimise the risk that of damage. The extent of the condition surveys (i.e. the distance the surveys are completed from the works) should be determined according to the type of equipment that will be used. It can either be determined according to a set distance from the works or according to the expected level of vibration, generally a percentage of the minimum performance criteria.

The condition survey therefore protects the property owner against inappropriate construction activities, as well as protecting the contractor against misappropriate claims.

Where condition surveys are undertaken, it is accepted practice for the results of the survey to be made available to the property owners. The surveys should be undertaken by an appropriately qualified person.

Amenity Impacts

Other submissions have addressed the perceptibility of construction vibrations and the possible effect on the "quality of life". Aside from the British Standard BS6472 dosage limits which have formed the basis of the amenity based vibration criteria, according to other peer reviewed documents, the vibration corresponding to the equivalent dosage levels for the evening would be classed as "barely noticeable" whilst vibration at the proposed daytime level would be classed as "noticeable", although not "easily noticeable" or "strongly noticeable". Based on these studies of a wide cross section of people, the international literature suggests that the majority of people are in fact tolerant of vibration levels that would be greater than the performance criteria that have been proposed.

Sensitive Receivers

A submission commented on the possible effect of the construction vibration on the wellbeing and comfort of patients at the hospital. The EPRs that have been proposed recognise different limits for amenity based upon the type of activity that occurs within the premises. Table 13-5 of the EES lists guideline targets for human comfort and although it does not provide a category that is more stringent than a residential location, the effect of the permissible residential criteria is to limit vibration values to that which are "barely noticeable" during the evening. This is considered appropriate. It may however be appropriate to consider an alternative criteria to that proposed in the EES that is more protective of the patient amenity than the current residential daytime criterion. It is also possible that other EPRs specific to the sensitive hospital equipment may restrict vibration to lesser levels than the presently proposed amenity criteria, negating any requirement to amend the current criteria.

Western Portal

Many submitters have stated their preference for the alternative location of the western portal area as it provides increased separation between their property and the tunnelling activities. Whilst the alternative location of the portal is further west and away from these residences, the tunnels will pass directly beneath a number of properties and the alternative portal location is expected to result in elevated vibration and regenerated noise during the final stages of the tunnel development for some residents.

Irrespective of the tunnel alignment that is ultimately constructed, the proposed EPRs are designed to be protective of amenity, building integrity and equipment operation.

Monitoring

A number of submitters have questioned the method of monitoring and reporting of vibration levels, in particular whether all properties around the work areas will be monitored, how the levels will be reported, and what recourse will be available where levels exceed the EPRs.

Vibration levels should in my view be monitored in accordance with the relevant standard and compared against the Guideline Targets or other relevant mandatory criteria in the CNVMP. It is not possible or economically justifiable to monitor all properties around the work areas, but rather a selection of representative properties should be chosen based upon:

- The proximity to the works area, ensuring that the monitoring sites are located as close as practically possible to the sensitive infrastructure;
- Monitoring locations that offer a secure area that minimise the possibility of interference from the public;
- Monitoring locations that provide an accurate indication of the vibration level.

Monitoring locations should be continually revised as the source of the vibration changes according to the construction schedule. Based upon other successfully completed large scale construction projects that have been undertaken near to sensitive areas, it is expected that the monitoring will be proactive with a system that analyses the measured levels continuously and alerts the contractor if vibration levels approach specified vibration values. This proactive approach permits a change in practices, methods or equipment sizes prior to any extended exceedances of the prescribed limits. An independent verifier is expected to review all measured vibration data.

City of Melbourne Heritage Assets

The City of Melbourne has identified a number of key sensitive buildings for consideration. I have visited these buildings and agree that where necessary, the construction methods must be selected to ensure vibration levels are maintained below the appropriate EPR values assessed on a building by building basis. This should be incorporated in the CNVMP for all heritage buildings.

The buildings of significance are within CBD Precincts 5 and 6 and include:

- City Baths, on the north east corner of Swanston Street and Franklin Street;
- The State Library, on the south east corner of Swanston Street and La Trobe Street;
- The Town Hall, on the north east corner of the intersection of Collins Street and Swanston Street; and
- St Paul's Cathedral, on the north east corner of the intersection of Swanston Street and Flinders Street.

The EES has considered these buildings, however given their potential sensitivity I have independently reviewed the effects of mechanical equipment as well as the potential effects of considering drilling and blasting (although it is unlikely that the rock mass will be of sufficient competency to require it as a method of excavation).

Whilst I have not undertaken an extensive review of the building condition, I have visited each building and relied upon the observed condition, together with my experience of vibration impacts on heritage infrastructure to assist with my assessment.

The condition of the buildings are reported in the HHIA as sound, although with a number of defects. My experience indicates that the expected level of vibration from the mechanical excavation with a TBM, road header or hydraulic hammer is unlikely to exacerbate the condition of any defects.

I have noted that the NVIA has assessed the impact of the construction works beneath the key City of Melbourne buildings through a comparison with the existing background environment. I have not relied upon these statements in my assessment as I consider the monitoring locations that were used to collect the background data not representative of the vibration environment that the various structures would be typically be exposed to.

The City Baths are unique in that whilst the building is immediately adjacent to the CBD North Station, the alignment and cavern method of construction maintains a vertical separation of around 25 metres to the roof of the cavern and approximately 33 metres to the invert of the tunnel. For the purposes of the exercise, I have calculated the expected level of vibration at the road level in the unlikely scenario that some rock is encountered and a hydraulic hammer is required and confirm the vibration at the City Baths is less than 20% of the vibration value suggested for a heritage listed structure. I consider that vibration related damage to the City Baths is extremely unlikely.

In addition to the CBD North Station main cavern excavated along Swanston Street, a second excavation for access extends from the surface to the station level along Franklin Street. The geotechnical data confirms that the material in this area is not sufficiently competent to warrant excavation with hydraulic hammers but rather is expected to be removed with an excavator. The vibration levels form the excavation will be low and remain

less than the applicable EPR Guideline Target for a heritage structure. Any competent material that may require a hydraulic hammer will be restricted to the lower levels that are further from the buildings and pool shell. In these areas, the maximum level of vibration will be similar to that predicted values for the cavern development. Based upon more recent geological interpretation, the possibility of drilling and blasting is unlikely.

The Melbourne City Town Hall is regarded as a key building. The vertical separation between the road surface and the invert of the tunnel of the concept design is approximately 24 metres and around 16 metres to the roof of the cavern. The additional horizontal separation increases the overall separation by a few metres. Based upon a similar analysis to that compiled for the City Baths, and if changes in the material require a small amount of hammering, I have modelled that the level of vibration will comply with the same 2.5mm/s heritage building Guideline Target in NV6 with a factor of safety of more than 2. Given the building use, it is however my recommendation that the CNVMP specifically address measures to accommodate times when levels of vibration and regenerated noise should be consistent with the requirements for performances or other key events.

St. Pauls Cathedral is a building of significance. The proposed construction methods at the CBD South Station and predicted impacts on this building for the building as shown in the NVIA are sound and there is no indication that any elements of the building would be potentially vulnerable to mechanically induced vibration at the amplitudes expected from construction. The increased horizontal separation between the church building and the tunnel offsets the reduced vertical depth of the tunnel in the southern CBD area. The distance between the closest point of tunnelling and the St. Pauls Cathedral on the western side is 23 metres and a vertical separation of approximately 15 metres. Mechanical excavation is predicted to produce vibration levels less than 0.5mm/s and have no impact upon the integrity. However, the vibration may be slightly perceptible or produce marginally audible levels of regenerated noise on some occasions. It is therefore suggested that the CNVMP recognise there may be special circumstances where the vibration and/or regenerated noise effects may require further consideration.

The State Library is a significant structure on the corner of Swanston and LaTrobe Streets. A review of the Historical Heritage Impact Assessment indicates there are no elements of the building that are more susceptible to vibration than would be the case for an equally sound, more recently constructed building. It is therefore proposed that the tunnelling activities will generate negligible vibration given the building is set-back horizontally more than 50 metres from the tunnel alignment.

Whilst it is highly unlikely that blasting will be undertaken in the station caverns throughout the CBD Precincts, should this occur, the level of vibration will necessarily be greater than that induced by the mechanical activities. The EPRs have identified a low Guideline Target level of 3mm/s drawn from the German Standard DIN4150 applicable for heritage structures. I support this level as being protective of the building fabric however my calculations suggest that it will be difficult to comply with this limit whilst achieving an economically feasible scale of blasting. The required explosive weights will be low and prohibit effective and efficient blasting. Whilst it may be beneficial for the project to consider an elevated limit, this should be carefully considered and adopted only with the introduction of specific monitoring procedures to ensure the integrity of the key City of Melbourne assets are protected.

It is my recommendation that the CNVMP includes a section that specifically addresses key infrastructure and identifies the expected vibration levels and the timing of these activities. Any mitigation measures that are planned for these structures should be detailed in the CNVMP. Monitoring of these structures should necessarily be required, possibly using assessment methods not limited to vibration but including crack gauges, extensometers or other systems that could detect any changes to the building condition.

Sensitive Equipment

The proximity of the hospitals and other research facilities in the Parkville Precinct may result in particular management responses. I have recommended that a panel be formed to interface with the contractor in this Precinct. As part of this approach, there should be investigation of the existing levels of vibration, methods of monitoring, and possibly even conducting test to replicate varying levels of vibration in order to assess the effects. Given my support for this representative approach, I have not discussed matters particular to the Parkville Precinct and the sensitive equipment as I consider these would be better addressed through the forum.

RMIT has prepared a submission that lists a number of recommendations with respect to vibration and noise. I consider the responses provided in the EES and other sections of my witness statement to be adequate, although I comment on the following further matters.

Recommendation 4 of the submission suggests that the baseline measurements are inadequate. I agree that the locations of the baseline measurements may not be representative of the impacts within the RMIT building. I consider the baseline measurements of relevance with respect to assessing potentially sensitive equipment and identifying any challenges in administering vibration criteria as well as identifying appropriate Guideline Targets for sensitive equipment.

Recommendation 6 suggests that RMIT should participate in the development of Construction Noise and Vibration Management Plan. I agree that key asset owners along the alignment should be invited to identify aspects that should be addressed in the Management Plan, although any suggestion that these asset groups should also individually approve the CNVMP is expected to be unworkable and not required.

Domain Precinct

Melbourne Grammar School

The Melbourne Grammar School (MGS) has presented a submission setting out its concerns about the potential impacts of vibration on the school, and in particular the potential effects to its buildings and teaching environment. The submission suggests a number of changes to the EPRs. I have reviewed the submission in detail and consider the comments that relate to aspects such as damage and amenity to have been satisfactorily addressed in the EES and NVIA. I consider the following issues justify further comment.

The EPRs are appropriate and protective of both amenity and building condition and integrity. On this matter, the following should be noted:

- The EPRs (NV9) specifically note a vibration human comfort Guideline Target for schools and educational institutions. It is noted that the building on the corner of Domain and St. Kilda Roads is designated as a music teaching facility and may therefore necessitate under some circumstances a more stringent vibration and regenerated noise criteria than proposed for typical educational facilities. This should be specifically addressed in the CNVMP, such as through setting appropriate criteria, monitoring and proactive advice to the school about potentially disruptive construction activities;
- The vibration damage Guideline Targets specifically considers heritage structures and is added in response to the City of Melbourne submission above. For comparative purposes, the Australian Standard AS2187 and the British Standard BS7385 (which are identical in many areas) propose acceptable levels which range between 15mm/s and 50mm/s with the note that a building of historical value should not (unless it is structurally unsound) be assumed to be more sensitive.

I therefore consider the EPRs relating to vibration protective, if not slightly conservative, of MGS staff/students and assets.

The competency of the rock mass in the area near to Domain and St. Kilda Roads where the station works is proposed has been identified as “highly to moderately weathered Melbourne Formation”. Whilst it is very unlikely that high impact methods of excavation,

such as hydraulic hammers or drilling and blasting would be used as a routine excavation option, I consider the submission suggestion that drilling and blasting should be eliminated within precinct as unnecessary. The EPRs for blasting are adequately protective of both amenity and building integrity. I consider NV12 to be sufficient in the circumstances.

The section of the tunnel along St. Kilda Road for a distance of approximately 200 metres is within a 40 metre horizontal separation of the MGS. It is understood that the buildings along this area are administrative and not teaching based. Irrespective, the impacts generated by the tunnelling activities will be controlled to within the EPRs. The EPRs for vibration recognise educational and other office space environments and should tunnelling exceed the target values, it will be necessary to consider mitigation measures to ensure the school's activities are not compromised. The CNVMP is the appropriate place for discussion on mitigation measures which will most likely centre around operating times that generate the minimum impact.

The MGS submission has drawn attention to the distinction between Guideline Targets and mandatory limits. I have addressed the preference for Guideline Targets over limits and the consistency of this with other successfully completed projects in an earlier part of my statement.

MGS has proposed that it should be consulted during the development of the CNVMP. I am in agreement with this suggestion and consider that interaction with all key stakeholders during the preparation of the management plans promotes a preferable outcome in terms of managing effects.

The G12+ group of owner's corporations have presented a submission regarding the construction methodology. The submission addresses aspects such as the monitoring process and the CNVMP, including a framework as to how the noise and vibration mitigation and in particular the temporary relocations would be implemented. It is noted that several of the buildings where elevated levels of vibration and/or regenerated noise are predicted to occur within the vicinity of the G12+.

I consider that these have been appropriately addressed in the EES although I offer the following comments:

- A detailed CNVMP for the project that specifically addresses the concerns of the key stakeholders along the alignment is key to successful project delivery. The matters raised by the G12+ will equally apply elsewhere along the alignment. The CNVMP should address the issues listed in Section 6.1 in the G12+ submission and include sub plans specifically identifying the extent of the condition surveys;
- Detailed monitoring and mitigation measures should be included in the CNVMP. The CNVMP should identify the broad requirements for monitoring, including placements of sensors, transfer of data an frequency of reporting;
- A community consultation plan should be prepared and address key concerns regarding notifications, communication paths for issues of amenity and/or building damage and triggers for relocation and/or respite.

I note that the G12+ submission proposes that minimum separation distances for certain types of equipment are maintained. In my view, ensuring the EPRs and the CNVMP are complied with provides greater surety to the residents than stipulating critical distances. In the event that the ground conditions vary, elevated vibrated levels could occur at closer distances than originally specified in the separation distance calculations. I suggest that adhering to a vibration related EPR ensures that the onus is on the contractor to adjust their practices to comply with the performance criteria should ground conditions change.

The City of Port Phillip presented a submission supporting the requirements for condition surveys of adjacent properties. The submission also proposes that it may be necessary that the requirements of some individual receivers should be considered, presumably through adjustments in the CNVMP. I suggest that the plan adopts appropriate wording to allow this flexibility.

The Domain Hill submission focussed on the extent of condition surveys. My previous comments have covered these matters.

I note that Appendix F of the NVIA provides baseline measurements of both vibration and noise that were collected to provide an indication of pre-construction disturbance levels. Whilst these provide an indication of the existing environment, I consider these are better used for identifying any difficulties in administering the EPRs, that is, identifying any locations where the performance criteria are presently exceeded. Further background measurements of vibration should be carried out prior to the commencement, or during, of construction phase.

4.4 Review of MMRA Technical Notes

I have reviewed MMRA Technical Notes 1 – 8 that were prepared in response to the request for information made by the Inquiry and Advisory Committee (IAC). I have also reviewed MMRA Technical Notes 9 -18 which include potential modifications to the Concept Design or construction methods. My comments are as follows:

Technical Note 4 requests a copy of my initial draft review of Appendix I of the EES addressing the aspects of vibration and regenerated noise from the tunnelling activities. This review was dated 11th April, 2016. I have attached this draft technical review as Annexure C. Following publication of the EES, I finalised the review document and this is dated 7th May, 2016. This is also attached in Annexure C.

Technical Note 11 addresses an area being considered for an electrical adit. The adit would connect the northern end of the station box to the traction power transformer rooms located in the Franklin Street shaft. This adit passes under the City Baths at an approximate depth of 25 metres.

Based upon the revised geological model, and my understanding of a construction site opposite the City Baths that has a developed a deep multi-level basement excavation without any requirement for large scale hydraulic hammer or blasting, the adit will most likely be similarly developed using simple excavators without any requirement for a road header or hydraulic hammer. In my view, these works will have no impact on the integrity of the City Baths. In the event that rock is encountered at the lower levels, I have calculated that the vibration from small excavators fitted with a hydraulic hammer is modelled to produce a level of vibration less than half of the proposed heritage value of 2.5mm/s in NV6.

4.5 Review of RIMG

The MMRA have prepared a Draft Residential Impact Mitigation Guidelines for Construction (RIMG) in response to a finding in the EES that one of the potential mitigation measures is for residents to be relocated during the construction phase. The RIMG provides better definition around the criteria for determining which residents will be offered mitigation measures and the type of mitigation offered during the construction phase. The purpose of the document is to provide a framework for contractors to address the potential impacts on residential amenity.

The concept of the RIMG is positive and will provide residents some surety around the mitigation and other relocation options. It should address several of the questions raised in the submissions. I recommend that RIMG be further defined to give more clarity to its implementation.

4.6 Environmental Performance Requirements

I have reviewed the EPRs relevant to vibration and regenerated noise.

The EES contains various EPRs that define the environmental outcomes that the Melbourne Metro Project must achieve during its construction and operation, regardless of any specific design solutions adopted for the Project.

Since the EES has been finalised and after reviewing the submissions allocated to me, I have not identified any new or modified EPRs that I recommend be adopted for the Project. I have however suggested some elements that should be considered in the CNVMP.

Whilst there may be a requirement for the contractor in some locations to restrict the operating times of certain pieces of equipment, limit the size of some equipment, or control the scale of any blasting that may be undertaken, the analyses that have been undertaken indicate that Concept Design can be developed in a way that will protect infrastructure integrity, personal amenity and continued equipment operation. Should the tunnel design that is finally implemented by the contractor differ from the Concept Design, the same EPRs that have been provided in the EES will be equally appropriate and protective of integrity and amenity.

Best practices indicate that prior to the commencement of any activity that induces measurable levels of vibration or regenerated noise, a vibration and noise assessment is undertaken and the activity confirmed as being able to comply with Guideline Targets (NV3). The outcomes of the modelling should be conveyed to potentially affected persons through the community liaison teams which could take the form of various options, such as information evenings, letter box drops, door knocking and so forth. This process allows the contractor to utilise different construction methods to that which have been considered in the EES but continues to provide the community with surety that independent of the type or source of the vibration, any alternative equipment types and construction methods will continue to comply with the EPRs specified for the project.

It is my view that the proposed EPRs addressing the level of vibration and regenerated noise induced by mechanical equipment or other impulsive vibration, such as produced by blasting activities, are aligned with those imposed on other successfully completed projects. In my opinion there is no reason to support the imposition of different Guideline Targets than those which have been proposed.

Through my witness statement, I have however suggested that the EPRs should be supplemented by the requirement for a CNVMP. Whilst standard practices by construction companies include the development of these plans, it is noted that there are no requirements for these documents in the EPRs. I recommend that if there is no other requirement for a CNVMP, the EPRs include a condition for the CNVMP and its minimum requirements. Some further explanation on the specific requirements and inclusions of these plans may have assisted some of the submitters with their understanding of the effects and how these will be managed.

Whilst a CNVMP identifies the minimum standards that must be complied with, as well as best practicable options for noise and vibration management for the Project, the plan is typically developed by the contractor, rather than a component of the EPRs. A requirement however on what the CNVMP should contain, and in particular comment on the consultation process, the noise and vibration complaints procedure as well as information on condition surveys and monitoring requirements would have been beneficial and could still be considered. This would provide surety to persons around the alignment that procedures with respect to measuring, controlling and managing impacts will be fully documented. The CNVMP is intended as a framework for the development of particular noise and vibration control practices and procedures to minimise effects on health and safety and to reduce the impact on the environment.

5 Conclusion

I conclude that the assessment of the vibration and regenerated noise impacts of constructing the project, comply with the scoping requirement. The assessment presented in the NVIA includes the information necessary to allow the impacts to be quantified. In particular, in my view:

- The EES and NVIA apply Australian and internationally accepted standards to derive the EPRs that are stringent, ensure amenity for persons around the project boundary, protective of building integrity including the heritage buildings that are of significance to Melbourne, and ensures that any sensitive equipment can continue to operate. Some of the proposed EPRs are however complex and some may be challenging to monitor and administer. Whilst the EPRs should remain unchanged, it may be necessary to consider alternative monitoring arrangements that deliver the same outcome, but allow an alternative measurement basis. The alternative monitoring arrangement should be detailed as a sub plan within the CNVMP.
- The estimate of the induced vibration and regenerated noise impacts from the different sources uses relationships are reasonable and the calculated levels are typical of that I would expect from the equipment used in the assessment, separation distances and rock types appropriate to the Melbourne Metro project.
- A comparison of the EPRs with the predicted levels has identified that complying with the Guideline Targets in some areas will be challenging, even with application of best practices. The challenging areas may necessitate a change in the construction methods or the operating times, and in some locations, the possibility of temporary relocation during the periods that works are undertaken.

Whilst it is accepted that the project will in some areas produce perceptible levels of vibration and/or audible levels of regenerated noise, the EPRs and recommended CNVMP should ensure the project is completed using techniques consistent with world's best practices that produce the minimum possible impact on amenity and ensure that infrastructure and equipment is appropriately protected.

6 Declaration

I have made all the inquiries that I believe are desirable and appropriate and no matters of significance which I regard as relevant have to my knowledge been withheld from the Panel.

Signed ……

Dated 11 August, 2016

Annexure A – Response to PPV Guide to Expert Evidence

I hold the qualifications of Bachelor of Engineering (BE) Honours in Mining and a Doctor of Philosophy (PhD), both from the University of Queensland in Australia. I have held these qualifications for more than 25 years.

I have worked in the construction industry and have extensive domestic and international experience in the measurement and analysis of vibration from mechanical equipment as well as the design, analysis, and performance of controlled rock blasting in civil construction projects. I have been associated extensively with vibration analysis and prediction at sites throughout the world.

My experience specifically in the vibration assessment from mechanical equipment or drilling and blasting practices includes large scale tunnelling projects throughout Australia and other countries. My review of the Melbourne Metro Rail Environmental Effects Statement (EES) and this evidence draws on experience gained at more than eight hundred sites worldwide in the areas of both equipment vibration and small scale controlled blasting.

I have been retained to advise on construction vibration and regenerated noise related aspects associated with the project. The following statement pertains to the effects of construction vibration and regenerated noise on personal amenity and potential damage to infrastructure. I have also investigated blasting, and in particular, the ability of the proposed project to comply with stringent vibration criteria. I have visited each of the precincts along the alignment. My evidence is based on those site visits and an analysis of the expected vibration levels from different construction methods. Where appropriate, my comments draw on experience from these other sites.

My assessment and evidence addresses the vibration and regenerated noise from the tunnelling, caverns and accesses. My analyses have not considered surface works that may generate vibration in other precincts. My analyses have also not addressed vibration from the operation of the tunnel or other traffic related vibration that may occur during the construction process.

In assessing the submissions for the project, it has been assumed that all submissions relevant to my area of expertise have been provided.

Annexure B – Curriculum Vitae

HEILIG & PARTNERS
Engineered Excellence

Condensed Curriculum Vitae for Dr. John Heilig

Dr John Heilig is an engineer with in excess of 25 years of extensive specialised international experience in blasting and vibration related engineering. John has a special skills in optimisation of hard rock excavation using drilling and blasting, application of specialised mining techniques and the measurement and analyses of vibration from mechanical excavation equipment. John has consulted to more than 500 projects in over ten countries. Specialised skills include:

- Optimisation of drilling and blast design for both underground and open-pit activities to maximise cost effectiveness, productivity and/or fragmentation;
- Auditing of drilling and blasting activities at mining, quarrying and civil operations, including preparation of technical reports discussing comparison of the operation's activities with respect to world's best practices;
- Structural and vibration monitoring from blasting or other mechanical construction activities with a comparison of measured vibration levels with Australian Standards or other criteria set to avoid structural damage and minimise human annoyance;
- Detailing of specialised excavation methods in areas where restrictive vibration criterion is applied or close proximity of infrastructure necessitates controlled techniques;
- Control and minimisation of ground and air borne vibrations from blasting activities linked with quarrying, mining or construction activities;
- Analysis, prediction and measurement of vibration produced from mechanical equipment such as tunnel boring machines (TBM), road headers, hydraulic hammers, pile driving, vibratory rollers etc;
- Measurement and analysis of regenerated noise from mechanised tunnelling equipment such as TBM's and roadheaders.
- Dilapidation surveys of infrastructure, including identifying the extent of the surveys and the area where dilapidation surveys should be undertaken.
- Application of computer based data acquisition instrumentation for monitoring and control purposes related to mining, quarrying and construction activities. Development of the flexible datatrap
- suite of software for analysis and presentation of monitoring results
- Preparation of technical documents and training seminars assessing the appropriateness of various excavation methods.
- Preparation of technical documents for submission to regulatory authorities for approving drill and blasting methods in built up areas. Reports discuss necessary control measures;
- Expert witness in field of vibration analyses from mechanical activities. Assessment of expected impacts from blasting, including vibration, air overpressure and flyrock

Surface Mining and Quarrying
Extensive experience including assessment of drilling and blasting designs. Outcomes for multiple projects have focussed on revising mining methods to reflect the site specific objectives (environmental, fragmentation, diggability, etc.). Optimised excavation methods near final walls to minimize the extent of damage to the slopes, crest and berms. Assessed new "green field" projects preparing documents submitted as part of the Environmental Effects Statement or Material Change of Use (MCU). Assessment of blast designs with respect to controlling vibration, air overpressure and flyrock.

Underground Mining
Consulted to projects at underground operations in Australia and overseas countries investigating the effect of explosive loading conditions on underground stability, production rates and fragmentation. Optimised drilling patterns to improve similar parameters. Presented seminars to mining industries on methods of optimising and assessing underground drill and blast practices. Extensive knowledge of methods of assessing drill and blast performance using high end vibration monitoring methods. Understanding of the influence of blast design parameters on raise performance.

Tunnelling
Analyses, predictions and application of detailed 3D models for the assessment of vibration and regenerated noise from TBM and road headers. Assessed drill and blast patterns to minimise drill and blast cycles times by way of optimising advance. Developed working procedures on tunnelling practices. Guided mining operations and research groups on instrumentation and techniques to monitor, analyse and optimise the performance of tunnelling patterns. Key recent local projects have included the North South Bypass (Clem 7), Airport Link Northern Busway, Legacy Way, East West Link, North West Rail Link, and the Eastern Busway.

QUALIFICATIONS
B.E. Mining (Hons), University of Queensland
PhD. Mining Engineering, University of Queensland
Registered Professional Engineer (RPEQ 6304)
Certificate IV in Training
Unrestricted Shotfirer's License - Queensland

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HEILIG & PARTNERS
Engineered Excellence

Condensed Curriculum Vitae for Dr. John Heilig

Civil

Widespread experience in multi-billion dollar civil projects, particularly those requiring excavation in near proximity to vibration sensitive equipment structures, slopes, services (water, gas, telecommunications). Assessed excavation requirements for portals, road cuttings, foundations and trenches with respect to adjacent sensitive equipment. Completed studies that have assessed the effectiveness of alternative methods in those areas where environmental criteria remains prohibits conventional excavation methods. Specification of appropriate of vibration criterion and monitoring procedures for the protection of structures and equipment, including heritage and cultural monuments. Developed models for the analysis and prediction of vibration from hydraulic hammers, pile driving, vibratory rollers and dozers.

Training

Training seminars to industry related professionals in the areas of surface and underground drilling and blasting methods and the measurement and analyses of the environmental effects of vibration and air overpressure. Training in the use and equipment required for the measurement of vibration from mechanical equipment

Legal Representation

Expert witness for presentation in the Environmental Courts, both nationally and internationally. Detailed knowledge of the processes involved with use of explosives, new quarry developments, extensions or Material Change of Use (MCU) applications. Knowledge of the relevant Australian and International standards referencing impulsive or continuous vibration and its effect on structural integrity and human perception.

Monitoring Equipment

Procurement of specialised monitoring equipment for the measurement of vibration and air overpressure from drilling and blasting activities. Specification of equipment for detailed assessment of vibration impacts related to construction activities with mechanical equipment. Configuration of automated data retrieval and management system for analysing data collected from blasting or mechanical equipment, such as TBM and road headers, in particular using the datatrap suite of software

Publications

In excess of 15 publications listed in national and international journals and conferences

Clients

Provided expertise in the areas of drilling and blasting, monitoring and the assessment of vibration from mechanical equipment and legal representation for both existing or planned activities. A selection of contracts have included:

- **Civil**: Leighton, Thiess, Baulderstone Hornibrook, John Holland, Abigroup, MacConnell Dowell, Watpac, EROC, MacMahon, BMD, Downer, Transfield, Walter, Lend Lease, Golding, L&D Contracting, Rosenlund, Seymour Whyte, Ghella, Acciona, Delta, Australand, Clough, Mainland Civil, Wagners, McNab, Australand, Laing O'Rourke, Multiplex, Matrix, Amalgamated Constructions, Dragage et Traveaux, Gammon, Roche, JJ MacDonald, Covecorp, Vecchio, MTRC, Queensland Rail
- **Dams:** Wyaralong Dam, Wivenhoe Upgrade, Borumba Dam, Burrinjuck Dam, Pindari Dam, Burnett River Dam, Burdekin Dam, Lake Manchester, Binga Dam, Linkwater
- **Key Local Projects**: North South Bypass (Clem 7), Airport Link Northern Busway, Legacy Way, Eastern Busway., East West Link, EBus2, C2C, Transcity, North West Rail Link, T2E, Citylink
- **Mining**: Newmont, BHP Billiton, BMA, AngloCoal, RioTinto, INCO, Falconbridge, Brunswick, Aquarius Platinum, Couer Gold, Olympic Dam, Noranda, Barrick, Adamus Resources, Solid Energy, Northern Gold Mining, Placer Dome, Newcrest, Keegan Resources, , PanAust, New Hope
- **Quarry**: Hanson, Boral, CSR, Stonemaster, Karreman, Brisbane City Council., Mansell, Wagners, Sunshine Coast, Hardrock, Gympie Regional, Suncoast
- **Drilling & Blasting**: Orica, Dyno Nobel, Maxam, CBS, Canex, Sequel Drill & Blast, Suncon Drill & Blast, AVKO, Roche Blasting Services, Pacific Drilling and Blasting, RJW Drilling
- **Legal**: Corrs Chambers Westgarth, Deacons, Connor O'Meara, Minter Ellison, Clayton Utz, Simpson Grierson, Robert Milne, Brisbane City Legal, p&e Law, Results Legal
- **Consultants**: Parson Brinckerhoff, Arup, Maunsell, Connell Wagner, SKM, Golder Associates, Fugro, Snowden, Sinclair Knight Merz, Cardno, GHD, Hyder, Itasca, Metso, Simmonds Bristow, Aecom, Coffey, AVKO, KBR, Noise Measurement, Noise Mapping, WBM, Ecoroc
- **Countries**: Australia, New Zealand, Papua New Guinea, United Kingdom, Singapore, Hong Kong, Philippines, China, Canada, United States, Alaska, Chile, Slovakia, South Africa, Ghana, Chile.

QUALIFICATIONS
B.E. Mining (Hons), University of Queensland
PhD. Mining Engineering, University of Queensland
Registered Professional Engineer (RPEQ 6304)
Certificate IV in Training
Unrestricted Shotfirer's License - Queensland

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Annexure C – Heilig & Partners review document