Report to

Robert Bird Group
Member of the Surbana Jurong Group

Review of Piling Activities for Lot 2 Above the Cross River Rail – Albert Street

Prepared By:

Heilig & Partners Pty. Ltd.

May, 2023

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Executive Summary

Protection of the *Cross River Rail* infrastructure from vibration damage associated with the piling and vibratory activities at the planned Albert Street project site has been assessed by comparing the level of induced vibration complies with an appropriate vibration limit. A review of the literature and vibration limits applied for other successfully completed projects in Australia, suggest limits up to 50mm/s will continue to ensure the *Cross River Rail* infrastructure integrity is maintained. However, based on the sensitivity of the structure, it is considered appropriate to restrict the level of vibration to the 10mm/s initially presented in the Design Criteria Report. An increase in the permissible level could however be adopted subject to a review of the measured vibration data, correlation with other monitoring and assessment systems installed on the *Cross River Rail* infrastructure and confirmation by a structural engineer.

Compliance with a conservative permissible vibration limit of 10mm/s allows for a high factor of safety. It also allows for some flexibility and variation in the predicted vibration levels from the piling and vibratory activities.

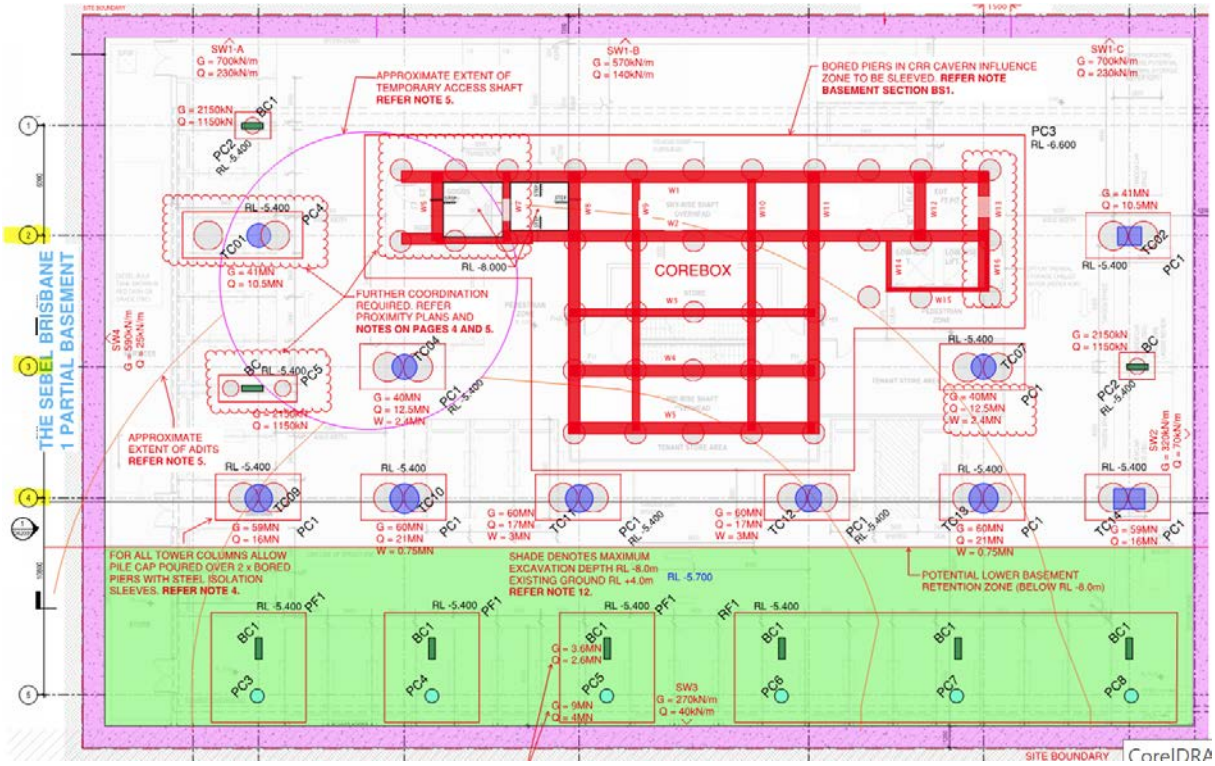
In the absence of site data relating vibration level to distance and piling energy, a review of other sites with similar geology around the Brisbane CBD have provided an approximate relationship for piling assessment. It is predicted that the level of vibration of 10mm/s for the bored piling works will be met at less than 1 metre. The vibratory piling works with a 646kN centrifugal force head unit will necessitate a minimum separation distance of 6 metres for the same10mm/s limit. The bored piling activities are modelled to induce lower levels of vibration than the vibratory piling works.

It is recommended that the piling works are pro-actively monitored at the *Cross River Rail* by installing vibration sondes and having the vibration level continuously assessed. Where the level approaches the permissible value of 10mm/s, or the lower warning level of 5mm/s, a warning light, SMS or email will alert key persons. The data will be regularly analysed to confirm the relationship between vibration level, distance and piling energy. For those locations where piling vibration exceeds the permissible value, the option of a reduced energy unit should be considered.

Table of Contents

1. BACKGROUND

RPC, Robert Bird Group and others are in the final pre-construction stages to enable the development of an OSD building at Albert Street Brisbane City. As part of the project investigation strategy, RPC through the Robert Bird Group has requested an investigation to assess vibration implications. To this, Heilig & Partners have prepared this technical assessment based upon the planned piling activities. The piling locations are shown in the following figure.



1.1. Report Requirements

The key issues to be addressed include:

a) Confirmation of an acceptable level of vibration for the *Cross River Rail* infrastructure given the knowledge of its condition, the proposed understanding of the construction methods, and guidance provided in the appropriate vibration standards.

b) The expected vibration levels from the piling activities and how these compare to the permissible values to confirm the piling can be completed without impact on the integrity or serviceability of the *Cross River Rail* infrastructure.

2. EFFECTS FROM PILING ON THE CROSS RIVER RAIL INFRASTRUCTURE

The integrity of the adjacent *Cross River Rail* infrastructure can be ensured through compliance with the vibration conditions that are commonly specified in standards, such as the Australian Standards, other international standards, conditions or peer reviewed documents. Compliance with these limits ensures the effects of vibration from activities such as piling are unable to impact upon structural integrity. Piling activities which induce levels of vibration that exceed the specifications also do not necessarily indicate that damage will follow. Commonly, the limits are set at levels below which damage has not been observed rather than a level representing the onset of damage.

This document presents criteria that are based around infrastructure protection rather personal amenity. The recommended limits are based upon a review of the internationally peer reviewed

standards and published information, focusing on the former approach.

2.1. Australian Standard AS2187

In contrast to the superseded versions of the Australian Standard AS2187.2, the 2006 version explicitly recognises vibration limits appropriate for protection of infrastructure as opposed to personal amenity. A summary of these criteria are reproduced as the following Table 1, noting that it refers to blast generated vibration which may lie at the upper end of acceptable values given the short term nature of blasting and the higher vibration frequencies as opposed to the longer piling activities and lower frequency of vibration.

The Australian Standard AS2187.2 (2006) recommends maximum peak particle velocities for different types of structures with respect to damage from vibration. Table J4.4.2.1 of the standard suggests levels for the prevention of minor or cosmetic damage occurring to structures from ground vibration generated by blasting. The table is reproduced below:

Type of Building	*Peak component particle velocity in frequency range of predominant pulse*	
	4Hz to 15Hz	*15Hz and above*
Reinforced or framed structures. Industrial and heavy industrial buildings	50mm/s at 4 Hz and above	
Un-reinforced or light framed structure. Residential or light industrial 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 1 – Transient vibration guide values for cosmetic damage (reproduced from AS2187.2-2006)

The expected frequency band of vibration for the piling activities will lie above 20Hz at the closer distances to the infrastructure.

The standard further 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 same standard proposes limits for ground vibration for control of other damage to structures, albeit related to blasting generated vibration.

Category	*Type of Blasting Operations*	*Peak component particle velocity (mm/s)*
Other structures or architectural elements that include masonry, plaster and plasterboard in their construction	All blasting	Frequency dependent damage limit criteria as in Table J4.4.2.1
Unoccupied structures of reinforced concrete or steel construction	All blasting	100mm/s maximum unless agreement is reached with the owner that a higher limit may apply
Service elements, such as pipelines, powerlines and cables	All blasting	Limit to be determined by structural design methodology

Table 2 – Recommended ground vibration limits for control of damage (reproduced from AS2187.2-2006)

For the reinforced concrete, the Australian Standards AS2187.2 therefore suggests permissible limit of 100mm/s.

2.2. German Standard DIN4150

The German Standard is also commonly applied in Australia for the protection of infrastructure. The standard recognises both the influence of frequency upon possible damage to structures, but oriented towards cosmetic or minor damage such as cracking of plaster, rather than damage to reinforced concrete structures.

The German Standard (DIN4150) specifies a method for measuring and evaluating the effects of vibration on structures. Notably, the standard gives guideline values, which when complied with, will not result in damage that will have an adverse effect on the structure's serviceability, and further if damage nevertheless occurs, it is to be assumed that other causes are responsible.

The standard lists acceptable values for both short and long term vibration with the distinction based as to whether there may be any fatigue related failure of the structure. It also recognises the influence of frequency, recommending levels of 20 mm/s at a frequency of 10 Hz, increasing to 50 mm/s for a frequency of 100 Hz for commercial and industrial buildings. The standard is directed towards preventing cosmetic damage such as crack formation in plaster, rather than damage to reinforced concrete structures. The DIN4150 Standard provides three curves for permissible vibration limits, according to the type of structure under consideration (commercial, residential, and heritage).

Type of Structure	*Guideline values for velocity (mm/s)*			
	Vibration at the foundation at a frequency of			Vibration at horizontal plane of highest floor All frequencies
	1 to 10 Hz	*10 to 50 Hz*	*50 to 100 Hz**	
Buildings used for commercial purposes, industrial buildings, and buildings of similar design	20	20 to 40	40 to 50	40
Dwellings and buildings of similar design and/or occupancy	5	5 to 15	15 to 20	15
Structures that, because of their particular sensitivity to vibration, cannot be classified under lines 1 and 2 and are of intrinsic value (eg. Heritage buildings)	3	3 to 8	8 to 10	8
*At frequencies > 100 Hz, the values given in this column may be used as a minimum				

Table 3 - Guideline values for the vibration velocity to be used when evaluating the effects of short term vibration on structures

The German Standard also proposes levels for different structures based upon long term vibration where structural fatigue could occur. The proposed levels are shown in the following table:

Type of Structure	Vibration Velocity, mm/s (Peak Component Particle Velocity) in horizontal plane at all frequencies
Buildings used for commercial purposes, industrial buildings and similar design	10
Dwellings and buildings of similar design and/or occupancy	5
Structures that have a particular sensitivity to vibration eg heritage buildings	2.5

Table 4 - Guideline values for the vibration velocity to be used when evaluating the effects of long term vibration on structures

The following notes are referenced to the levels in the above table.

- Vibration levels marginally exceeding those in the table would not necessarily mean that damage would occur and further investigation is required would be required to determine if higher vibration levels can be accommodated without risk of damage.

- Long-term vibration means vibration events that may result in a resonant structural response which is not expected to occur.

- At frequencies above 100 Hz, the values given in this column may be used as minimum values

- For civil engineering structures (e.g. with reinforced concrete constructions used as abutments or foundation pads) the values for Type 1 buildings may be increased by a factor of 2.

- Short-term vibration is defined as vibration which does not occur often enough to cause structural fatigue and which does not produce resonance in the structure being evaluated.

For the reinforced concrete, the German Standard DIN4150 suggests a minimum permissible limit of 40mm/s with reference to 80mm/s for the engineered structures.

2.3. Summary of permissible vibration values

A review of standards and completed projects confirm that concrete elements like the tunnel linings and so forth, can withstand high levels of vibration before the on-set of cracking or other damage that could impact upon the longevity of the infrastructure. A value up to 50mm/s is considered the minimum value that could be applied but values more than 100mm/s could equally be applied. A 50% reduction in the proposed values is however sometimes applied to address the semi-continuous nature of the vibration, rather than the short duration impulsive vibration that could represent the tests under which the vibration values were reported.

A screening vibration value of 10mm/s has however been proposed in the Design Criteria Report and the above information serves to demonstrate that compliance with these levels will ensure the integrity and serviceability of the *Cross River Rail* assets are protected. The 10mm/s level is conservative. It is expected that higher levels of vibration may also have no impact upon the integrity of the infrastructure although it is proposed that for consistency, the works progress based on compliance with the initially proposed 10mm/s criterion.

An increase in the permissible level could be adopted subject to a review of the measured vibration data, correlation with other monitoring and assessment systems installed on the *Cross River Rail* infrastructure and confirmation by a structural engineer.

3. S1 SEWER

The reports for the project indicate that there is a 450mm diameter sewer that runs below Albert Street at an approximate depth of 3 metres. This is regarded as a piece of sensitive infrastructure. The sewer service pre-dates the *Cross River Rail* station works that involved significant blasting and excavation in rock. During the station construction, a vibration limit of 25mm/s was applied to this service and the blasting works were completed with no known impact.

Given the nature of the proposed works for the Albert Street site, the vibration from the mechanical works is expected to be complaint and not necessitate any further assessment and monitoring.

4. EXPECTED VIBRATION LEVELS FROM PILING AND VIBRATORY SHEETING

Vibration relationships from bored piles and vibratory piling have been developed for other sites and have been used to estimate the level of vibration as a function of distance and the overall potential for damage to infrastructure The variability between these different equations reflects amongst other parameters, the different geology, piling energies and pile types. No vibration data from piling activities

in the Albert Street area have been reviewed but rather the modelling parameters that were used for the *Cross River Rail* analyses have been again applied. These vibration relationships have also been confirmed from other projects.

As vibration from the cutter of the bored piling string propagates through the ground strata, regardless of its source, the amplitude decreases. High modulus, high competency ground masses exhibit a low internal friction, while unconsolidated spoil types have high frictional losses and a more rapid attenuation of vibrational energy.

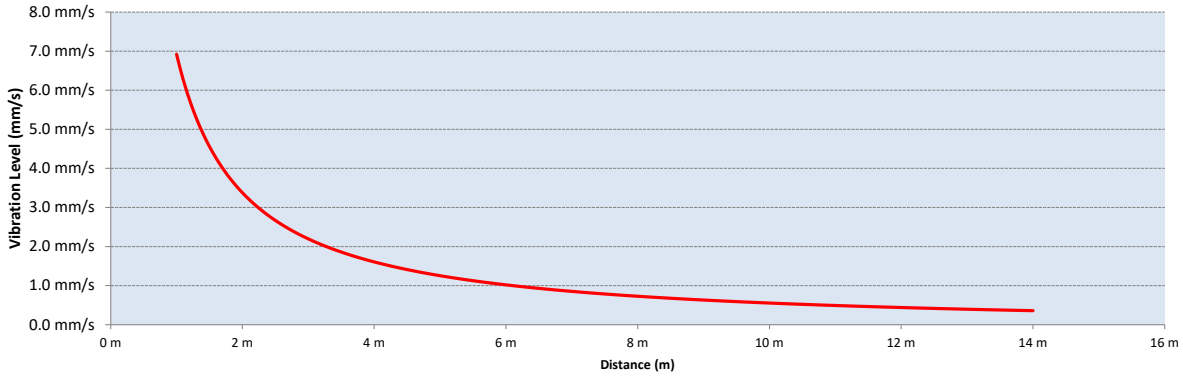
Equations used to describe the loss in amplitude vary however a relationship used to represent the level of vibration for the site simplifies to:

$$PPV = \frac{K}{d} e^{-\alpha d}$$

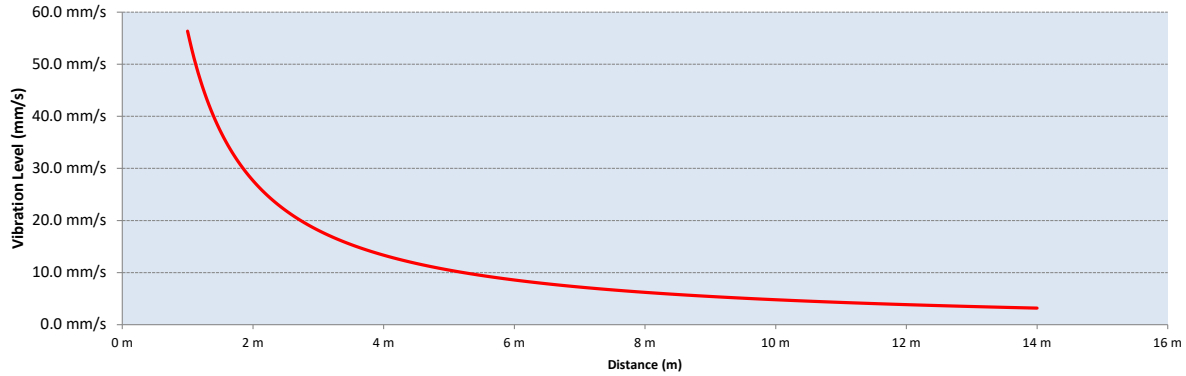
where:

- PPV is the velocity of vibration measured in mm/s
- d is the distance between the source of vibration and the point of measurement measured in metres, and
- K and α are site specific constants which address the level of vibration very near to the source and the degree of attenuation respectively. A higher K value generally refers to a more energetic source. An increased α value normally refers to a ground mass where the level of vibration attenuates more rapidly as the vibration pulse travels from the source.

The vibration assessment is based upon measurements from the sensors at different distances from bored piling activities. The following graph shows the distance vs vibration data that was recorded from other sites around Brisbane CBD. The red line represents the effective maximum vibration level as a function of distance.



With respect to the vibratory piling activities, the following graph shows the expected level of vibration from a medium size vibratory head unit, such as the ICE416, which produces a maximum centrifugal force of 646kN. Other smaller units with reduced centrifugal forces will produce lower levels of vibration.



Shown in Plates 1 to 8 are the modelled levels of vibration from the piling and vibratory component activities respectively. The model is three dimensional and considers the depth of the pile in the distance calculations with estimates of vibration based upon the expected attenuation relationships. The modelling results in these plates show the maximum vibration expected, that is, when either the piling or sheeting is at the closest point to the modelled contour.

Generally, the plates show:

a) The level of vibration is presented as a series of contours with contour levels ranging between 5mm/s and 25mm/s. The contours indicate the expected level of vibration measured on the surface and other specific horizons between RL-10m and RL-30m.

b) The modelling indicates that when the pile tip for the bored piles is approximately 10 metres below ground, the vibration level at ground level will be imperceptible and for the vibratory piling the same imperceptibility at the surface occurs at around 25 metres.

The modelling shows that the drilling of the bored piers will have minimal influence in terms of elevated vibration values. The levels at the adjacent *Cross River Rail* infrastructure are minor and not would not impact upon the integrity of the structures. The vibratory component from the installation of the steel tubes with a medium to moderate energy head will however lead to elevated vibration values and the effects dependent upon the proximity of these works to the *Cross River Rail* infrastructure. Should the installation of the steel liners be required, further works may be required to assess the significance of the vibration levels. This would include possibly justifying a higher a permissible level of vibration and/or a particular size vibratory head unit.

4.1. Mitigation options

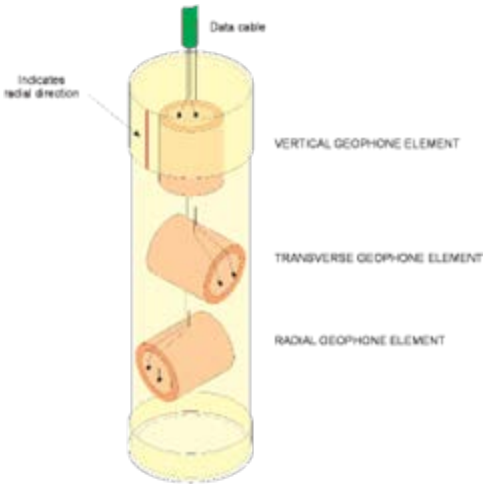
The analyses have reasonably guaranteed that the bored piling will comply with the vibration criteria. No impact on the integrity of surrounding *Cross River Rail* infrastructure is expected from the scale of works due to their distance from the planned activities and the general low level of impact by the bored piling units.

The vibration from the vibratory component of the piling works is elevated and is expected to necessitate consideration for other lower energy vibratory heads. As the energy of the units reduces, so too does the component of energy transmitted through the rock and into the adjacent infrastructure. It is suggested that those piles furthest from the sensitive *Cross River Rail* infrastructure are assessed for vibration to establish where the alternative lower energy vibratory head may be required to maintain vibration compliance.

5. PROPOSED MONITORING PROGRAM

The analyses presented in this report should be supported by detailed monitoring. In particular, vibration monitoring should be undertaken from both the piling and vibratory operations to confirm the predicted levels and also to establish a database of vibration levels as a function of distance and piling energies.

Given that some vibration may occur at the tunnels, adits, shafts, ground support systems or adjacent buildings from the proposed piling works at the Albert Street construction site, a vibration monitoring system will be installed and consist of multiple monitors either installed at depth into various boreholes or on other structure mounted locations. The choice will depend upon access but importantly ensure that the vibration sensors are appropriately positioned to assess the key infrastructure around the piling works.



The vibration monitors will have three recording channels with an external geophone (transducer) that monitors ground vibration in three directions (transverse, vertical and longitudinal particle velocities) and reports the level in mm/s. A schematic of the borehole sonde arrangement is shown adjacent.

Vibration levels occurring from the works will be monitored continuously and the maximum value recorded for each sample period, generally taken to be 30 seconds although smaller intervals could be appropriate where detailed analyses are required. During each 30 second period, the level of vibration is sampled 30,000 times and the maximum level stored electronically. The levels, as a function of time, are given in a graph of time versus vibration level. Statistics of vibration, including average, minimum, maximum and 90 percentile limits are also calculated.

Should the monitoring results indicate that the level of vibration approaches or exceeds the permissible limit, the monitoring equipment will be linked to a system to permit automatic notification of the elevated data. In addition, recorded vibration data will be uploaded at set times during the day and the measured data analysed and compared against vibration criteria. Where levels are shown to approach the vibration criteria, emails or SMS alerts will be sent to key persons within the project.

5.1. Initial Assessment of Vibration

The vibration predictions will be verified through initial on-site measurements. These trials will involve attended measurement of the level of vibration during the initial piling works and at a range of locations.

The data will be regressed to confirm the vibration relationship and establish whether any re-modelling is required. Where necessary, the results of the initial trial will be documented and presented in a separate technical letter and made available to the key parties.

When the piling or other vibratory works for the excavation occur very near to the key *Cross River Rail* infrastructure, an appropriate amount of site-specific vibration data will have been measured and analysed to verify the confidence in the predictions.

5.2. Vibration Monitoring Locations

Vibration monitoring locations have been proposed in the Design Criteria Report and include monitoring in the station cavern with one unit placed on the mezzanine level closest to the proposed station development. The locations can be further discussed with Robert Bird Group after an initial site visit. It is initially proposed that monitoring units will be placed at the two locations for assessing the adits, shafts, tunnels. It may be necessary to consider a third short term location at the adjacent *Sebel* Hotel for the period of the piling/construction works.

The Australian Standard AS2187.2 specifies details the type of geophone (triaxial with a low frequency capability of 4Hz) that should be used for the vibration monitoring.

Monitoring will be consistent with previous developments in Brisbane where building as occurred in the immediate vicinity of the key infrastructure.

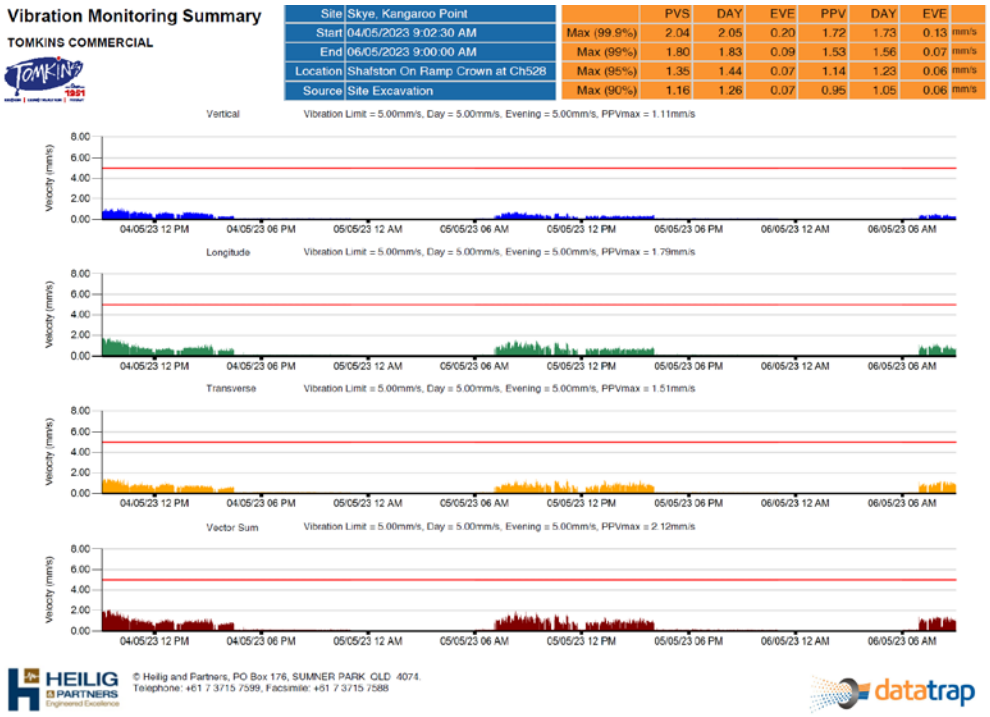
The vibration will be monitored continuously via an acquisition system which will report the data daily, or more frequently if required, through to the Heilig & Partners servers. During the works, the data and the results will be provided to relevant persons daily. The data will be assessed automatically and where the levels approach the recommended safe vibration trigger criteria, emails or SMS alerts, and a flashing light to alert the equipment operator will be enabled for key persons to advise of the recorded vibration levels. As a guide, a strobe light could be configured to flash at 90% of $PPV_{Critical}$ which will alert the operator of the equipment that the levels are approaching the $PPV_{Critical}$ and caution should be exercised. The flashing light will be enabled within 1 second of the recorded vibration level exceeding the trigger value. The email/SMS will be sent immediately however a small delay would be expected because of GSM network efficiency.

This pro-active approach ensures that vibration levels are kept below key threshold values by identifying areas of the site or equipment types that generate elevated levels of vibration. These are identified in advance of reaching or exceeding the vibration limits. The key trigger vibration limits are as follows:

Trigger Level	*Key Vibration Monitoring*	*Responses*
Green	PCPV<5mm/s	Proceed with works. Daily (or more frequently if required) presented to various key stakeholders
Orange	5mm/s<PCPV< 10mm/s	Log vibration and alert relevant personnel. Access activity and modify if possible, to reduce vibration impacts. Consider the use of alternative or lower energy equipment if feasible
Red	PCPV>10mm/s	Works associated with the elevated vibration values to cease onsite. Organise a meeting with key stakeholders present to agree how methods can be altered & work restarted. Different authorities may require site representation. If required this representative will have authority to permit or prohibit excavations and/or the equipment used.

Where the vibration level triggers the orange alert (50% of $PPV_{Critical}$), the works will temporarily cease and a meeting arrangement with the relevant parties arranged to determine the most appropriate piling/excavation process that will ensure compliance with the appropriate limit.

The format of the daily vibration report is as per the example shown below. The graph will display the vibration statistics associated for each day/week events. As well as a daily graph, a weekly and monthly report graph will also be presented to the client.



5.3. Tilt/displacement (static) Monitoring

In addition to dynamic effects, such as the stresses/strains that result from the emitted vibration wave from the piling or other excavation activities, other longer term, gradual movement/displacement impacts (i.e. settlement) can also occur under specific conditions and it is proposed that these are also monitored with an automated system.

The proposed approach for this static monitoring is to install multiple high accuracy bi-axial tilt sensors on the key structural elements and have these report the values every few hours. The results would be displayed in a similar daily/weekly/monthly chart to the vibration assessment that shows any variation in the tilt positioning (less than 0.01º), effectively identifying changes in the integrity of the element on which the sensor is mounted. The tilt monitoring system would be fitted with an alert to notify key persons of any elevated changes. The arrangement would be similar to that shown adjacent:

The tilt monitoring equipment requirements would be specific to the type of infrastructure that will be monitored. It is proposed that a discussion with the key stakeholders is undertaken to identify the preferred and most suitable locations.

5.4. Key Roles and Responsibilities

The monitoring program will involve liaising with several groups with different responsibilities to ensure the monitoring data are collected and analysed appropriately such that any relevant actions are implemented should elevated vibration or displacement values occur. The key persons are as follows:

RPC/Robert Bird Group : Consulting engineers responsible for the project. Responsible group for implementing the project plan and confirming monitoring locations and permissible vibration and or displacement values.

Heilig & Partners : RPEQ engineers responsible to installing, maintaining and reporting on vibration and displacement levels. Provide additional expertise in response to elevated vibration and the appropriate mitigation that would be employed as well identifying appropriate criterion for protecting the infrastructure.

Piling Contractor: Contractor responsible for the piling works and will follow the plan to ensure that all operators, including any sub-contractors, are aware of the key infrastructure including the alerts procedures (flashing lights, email/SMS) and the requirement to cease work when alerts are activated.

5.5. Equipment Calibration

The vibration monitoring units deployed for the project will have been calibrated by an independently certified group. Original calibrations certificates for each monitor will be kept in the Heilig & Partners offices and contain the following information:

- Report number
- Make and model of recording instrument
- Monitor serial number
- Geophone serial number
- Calibration date
- Test equipment references
- Compliance with relevant standard
- Signature of person performing calibration and date of service.

5.6. Training

Any site personnel involved with the vibration and displacement monitoring equipment will be trained and demonstrate appropriate capabilities prior to providing comment on the measured vibration or displacement values. In all cases, the equipment will be installed and configured by Heilig & Partners.

5.7. Management Measures and Mitigation

The level of vibration and displacement will be managed throughout the project. Where elevated values occur, the management and mitigation options could include:

- Adjusting the size of the piling equipment (vibration energy) to control the level of vibration at the *Cross River Rail* infrastructure or other properties near to the works.
- Comparison of the measured levels with the predicted values to determine whether there should be any reassessment of future impacts and proposed mitigation measures.

- Review of the displacement data to confirm whether there is any longer-term gradual movement or displacement of key infrastructure elements.

- Consultation.

The proposed commentary above should be considered preliminary and will continue to be refined based upon discussion with key infrastructure groups as well as being informed by the modelling outcomes.

Dr. John Heilig
Principal: Heilig & Partners Pty Ltd
RPEQ #6304

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SCALE

0 5 10 15 20 25m

Vibration Levels

- 5 mm/s Vibration Contour
- 10 mm/s Vibration Contour
- 15 mm/s Vibration Contour
- 20 mm/s Vibration Contour
- 25 mm/s Vibration Contour

PROJECT DESCRIPTION Albert St Piling - Modelled vibration levels and associated vibration contours from piling activities involving bored tower columns (1600mm), core box piles (1200mm) and basement columns (900mm) from surface level to toe-of-pile. Vibration contours are shown at surface level and represent maximum expected values from piling.

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Plate No. 1

Revision History
R1: Original

Date Drawn: 19 May 2023

Ref No: Albert St Piling Robert Bird Group

Job No: HP2305-2

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 a 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.

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Vibration Levels

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Plate No. 2

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Vibration Levels

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PROJECT DESCRIPTION Albert St Piling - Modelled vibration levels and associated vibration contours from piling activities involving bored tower columns (1600mm), core box piles (1200mm) and basement columns (900mm) from surface level to toe-of-pile. Vibration contours are shown at RL-20 and represent maximum expected values from piling.

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Plate No. 3

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Job No: HP2305-2

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SCALE

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Vibration Levels

- 5 mm/s Vibration Contour
- 10 mm/s Vibration Contour
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PROJECT DESCRIPTION Albert St Piling - Modelled vibration levels and associated vibration contours from piling activities involving bored tower columns (1600mm), core box piles (1200mm) and basement columns (900mm) from surface level to toe-of-pile. Vibration contours are shown at RL-30 and represent maximum expected values from piling.

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Revision History
R1: Original

Ref No: Albert St Piling Robert Bird Group

Job No: HP2305-2

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 a 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.

Created using TunnelTRAP Software

SCALE

0 5 10 15 20 25m

Vibration Levels

- 5 mm/s Vibration Contour
- 10 mm/s Vibration Contour
- 15 mm/s Vibration Contour
- 20 mm/s Vibration Contour
- 25 mm/s Vibration Contour

PROJECT DESCRIPTION Albert St Piling - Modelled vibration levels and associated vibration contours from vibratory pile hammering of bored tower columns (1600mm), core box piles (1200mm) and basement columns (900mm) from surface level to toe-of-pile with an ICE 416 or equivalent. Vibration contours are shown at surface level and represent maximum expected values from vibratory pile hammering.

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Robert Bird Group
Member of the Surbana Jurong Group

Plate No. 5

Date Drawn: 19 May 2023

Revision History
R1: Original

Ref No: Albert St Piling Robert Bird Group

Job No: HP2305-2

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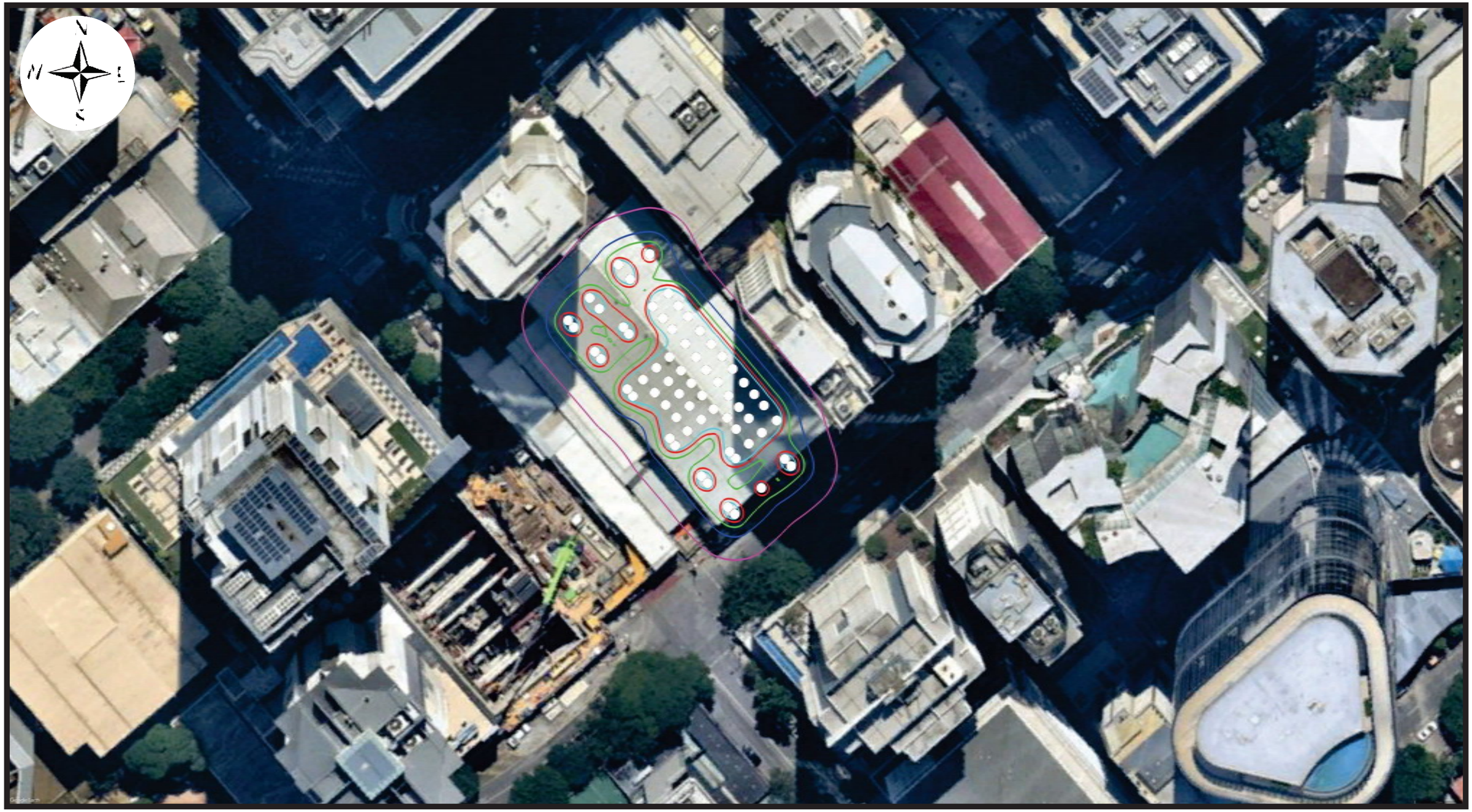

Created using TunnelTRAP Software

SCALE

0 5 10 15 20 25m

Vibration Levels

- 5 mm/s Vibration Contour
- 10 mm/s Vibration Contour
- 15 mm/s Vibration Contour
- 20 mm/s Vibration Contour
- 25 mm/s Vibration Contour

PROJECT DESCRIPTION Albert St Piling - Modelled vibration levels and associated vibration contours from vibratory pile hammering of bored tower columns (1600mm), core box piles (1200mm) and basement columns (900mm) from surface level to toe-of-pile with an ICE 416 or equivalent. Vibration contours are shown at RL-10 and represent maximum expected values from vibratory pile hammering.

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Plate No. 6

Revision History
R1: Original

Date Drawn: 19 May 2023

Ref No: Albert St Piling Robert Bird Group

Job No: HP2305-2

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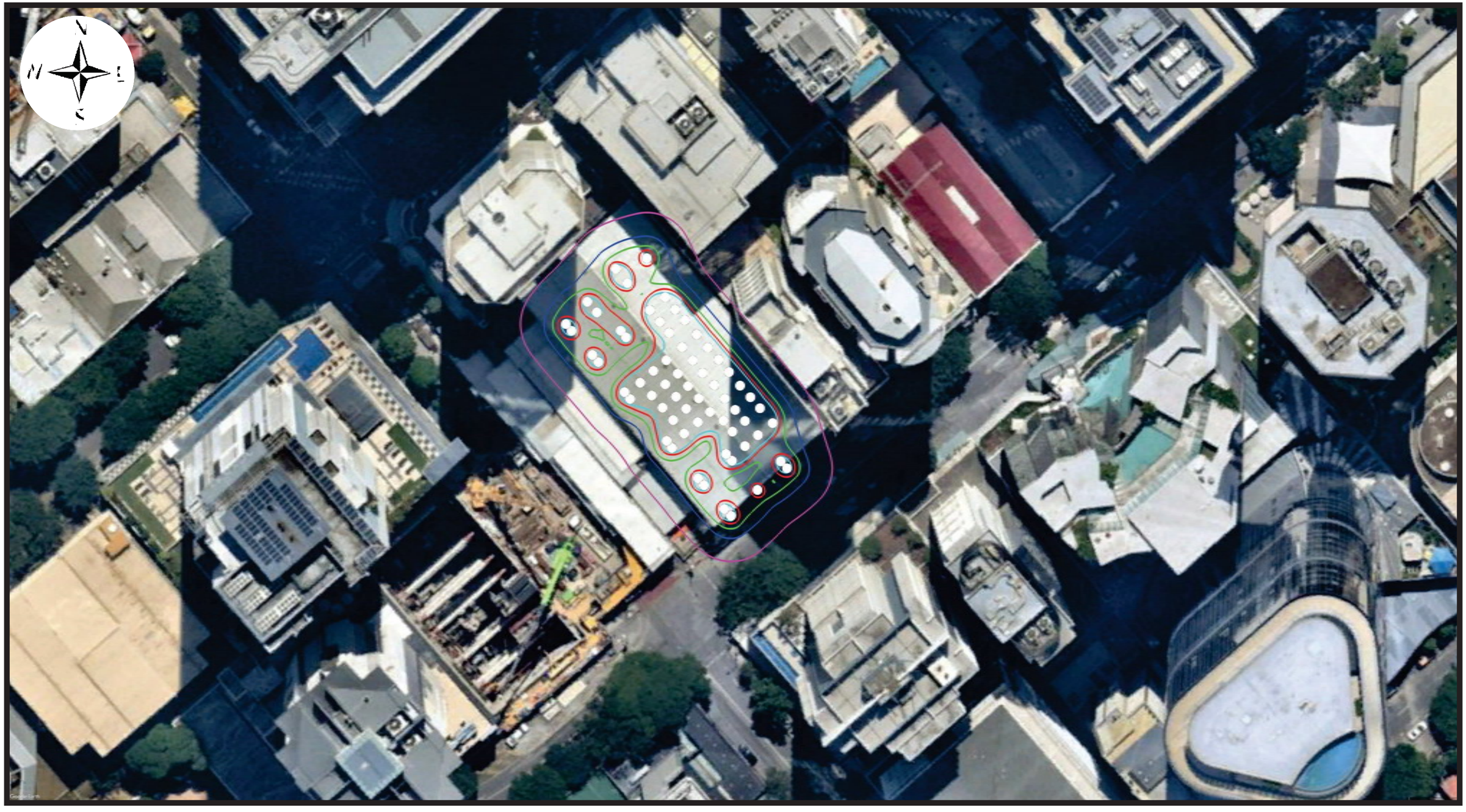

Created using TunnelTRAP Software

SCALE

0 5 10 15 20 25m

Vibration Levels

- 5 mm/s Vibration Contour
- 10 mm/s Vibration Contour
- 15 mm/s Vibration Contour
- 20 mm/s Vibration Contour
- 25 mm/s Vibration Contour

PROJECT DESCRIPTION Albert St Piling - Modelled vibration levels and associated vibration contours from vibratory pile hammering of bored tower columns (1600mm), core box piles (1200mm) and basement columns (900mm) from surface level to toe-of-pile with an ICE 416 or equivalent. Vibration contours are shown at RL-20 and represent maximum expected values from vibratory pile hammering.

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Plate No. 7

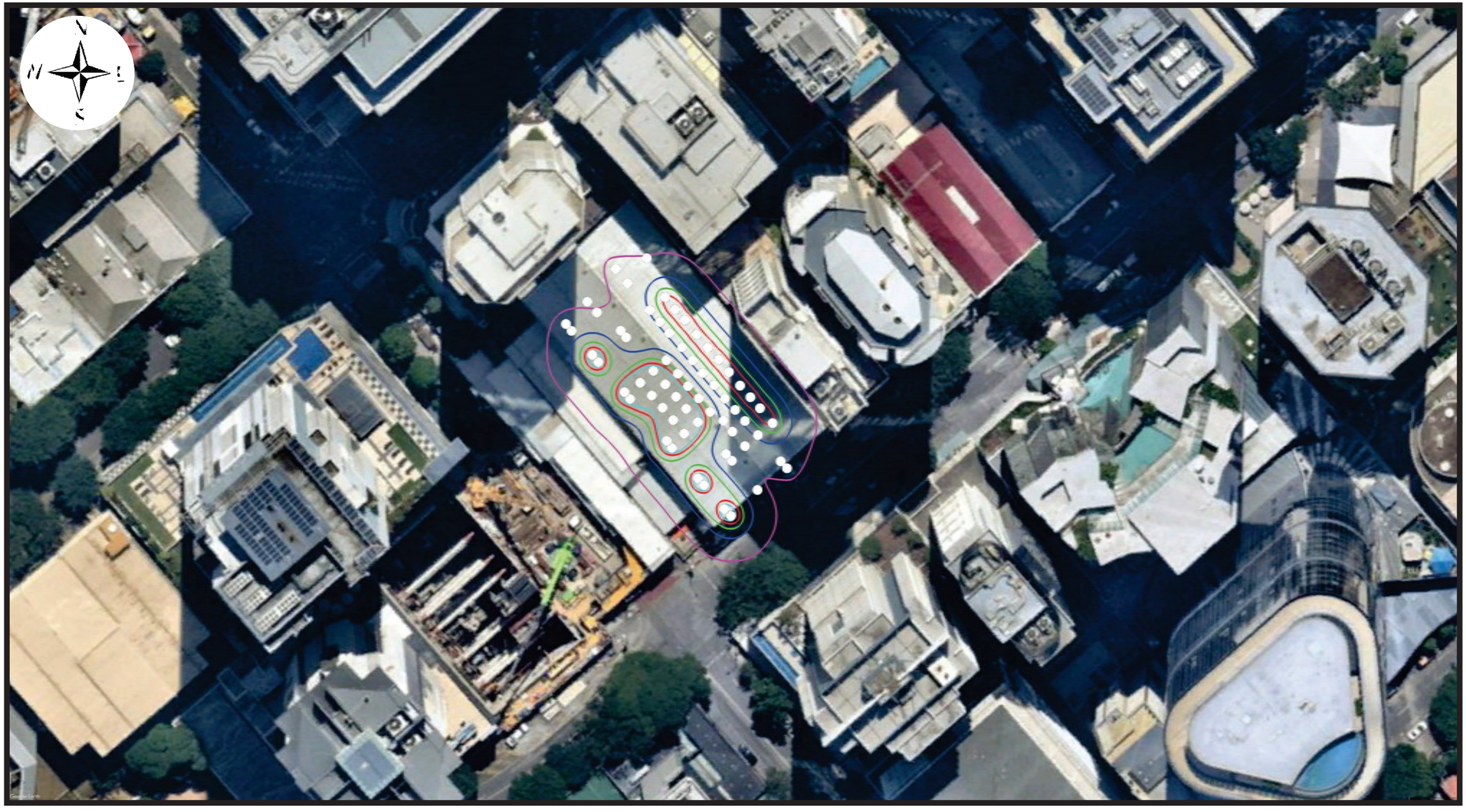
Revision History
R1: Original

Date Drawn: 19 May 2023

Ref No: Albert St Piling Robert Bird Group

Job No: HP2305-2

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 a 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.



Created using TunnelTRAP Software

SCALE

0 5 10 15 20 25m

Vibration Levels

- 5 mm/s Vibration Contour
- 10 mm/s Vibration Contour
- 15 mm/s Vibration Contour
- 20 mm/s Vibration Contour
- 25 mm/s Vibration Contour

PROJECT DESCRIPTION Albert St Piling - Modelled vibration levels and associated vibration contours from vibratory pile hammering of bored tower columns (1600mm), core box piles (1200mm) and basement columns (900mm) from surface level to toe-of-pile with an ICE 416 or equivalent. Vibration contours are shown at RL-30 and represent maximum expected values from vibratory pile hammering.

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Plate No. 8

Date Drawn: 19 May 2023

Revision History
R1: Original

Ref No: Albert St Piling Robert Bird Group

Job No: HP2305-2

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 a 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.