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2019-09-06

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Dear Fiona

**NOTICE OF REQUIREMENT TO ALTER CITY RAIL LINK DESIGNATION 1, AUCKLAND UNITARY PLAN REFERENCE 2500-1, CONDITION 63, OPERATIONAL VIBRATION, ASSESSMENT OF ENVIRONMENTAL EFFECTS**

## 1 Introduction

City Rail Link Limited (CRLL) gives notice of a requirement (NoR), pursuant to section 181(1) of the Resource Management Act 1991 (RMA), for alteration to the City Rail Link (CRL) designation 1 (Auckland Unitary Plan ref 2500 1).

The NoR is set out in the accompanying Form 18 and attachments.

The alteration includes changes to conditions 63.1, 63.2 and ,63.4 and the addition of condition 63.5 to CRL designation 1.

The following assessment has been prepared pursuant to section 181(1) of the RMA. It is intended to provide the information necessary for a full understanding of the NoR, the associated works and any actual or potential effects the proposed alteration may have on the environment.

The NoR proposes a change to the metric for measurement of ground borne vibration, as contained in condition 63. No change to the re-radiated noise levels or means of measuring these levels, as currently contained in condition 63, is proposed by this NoR. As such no increase in the potential for adverse effects related to re-radiated noise will result from the proposed changes to condition 63.

A technical memorandum prepared by Pulse Acoustics Ltd (Pulse) is attached in regard to the operational rail vibration criterion (**Attachment 1**).

To assist in the understanding of the proposed changes to condition 63, the following definitions are applied:

- Ground-borne Noise (also referred to as regenerated or re-radiated noise or structure borne noise): This term relates to vibration that is radiated by the building structure, and for rail operations, becomes audible as a low frequency rumbling noise.
- Ground-borne Vibration:
    - Tactile Vibration: This term relates to vibration as it is felt and perceived by humans with respect to human comfort.
    - Cosmetic Damage: This term relates to vibration as it affects the building structure with respect to cosmetic damage.

# 2 Background

## 2.1 City Rail Link Limited

The CRL project was originally an Auckland Transport (AT) project but is now being delivered by CRLL, a Crown entity established on 1 July 2017 and jointly owned by the Crown and Auckland Council (the CRL project sponsors). CRLL has governance, operational and financial responsibility for design and construction of the CRL project – including works within the Britomart Transport Centre. On 10 August 2017, CRLL was approved as a requiring authority for the purposes of the CRL project. Responsibility for the CRL designations was transferred from AT to CRLL on 12 October 2017.

## 2.2 City Rail Link

The CRL project comprises the construction, operation and maintenance of a 3.4 km underground passenger railway (including two tracks, two new underground stations, modification of Britomart Station and substantial redevelopment of the existing Mt Eden Station located within an open trench) running between Britomart Station and the North Auckland Line (NAL) in the vicinity of the existing Mt Eden Station. These works include an additional 850m of track modifications within and adjacent to the NAL.

The CRL is provided for by six designations (designations 1 to 6), confirmed by the Environment Court on 10 November 2015, and include a suite of conditions intended to mitigate the potential adverse effects associated with the construction, operation and maintenance of the CRL.

## 2.3 CRL Project Objectives

The wider CRL project objectives apply to this NoR (unchanged), attached to this NoR as **Attachment 2**. The CRL has previously been confirmed as reasonably necessary to achieve the objectives of AT and by default now CRLL. The NoR represents a technical correction to the existing condition set. As part of the CRL project, this NoR is consistent with the CRL project objectives.

## 2.4 Britomart Designation 314 Notice of Requirement, 2015

During a statutory process to alter the Britomart Transport Centre (BTC) designation (lodged with Auckland Council in May 2015 and confirmed by AT on 4 April 2016) an error in the way that operational vibration was to be assessed under condition 34 of the BTC designation (which was initially proposed to follow the approach confirmed under CRL Designations 1 to 6) was identified. The error was in the use of peak particle velocity (PPV) levels to measure operational tactile vibration and assess against human comfort criteria. Condition 34 of the BTC designation was initially an exact duplication of CRL designation condition 63. This error was corrected through the BTC NoR process. Condition 34 of the BTC designation was altered to correspond with the specifications of the United States Federal Transit Administration *Transit Noise and Vibration Impact Assessment Manual 2006* (FTA *Manual*), by adopting the criteria recommended in the FTA *manual*, being root mean square (RMS) velocity levels for measurement of operational rail vibration. This was agreed by all parties in the BTC NoR process to be the correct approach to measuring and assessing CRL operational vibration. It was noted during the BTC NoR hearing that a corresponding correction would be required to the relevant conditions of the CRL designations.

AT's BTC designation is now referred to in the Auckland Unitary Plan (Operative in Part) as *Britomart Transport Centre Designation 1556.*

### 2.5 CRL Designation 2500-2, 4, 5 and 6 NoR to Alter Conditions 63 and 66

In September 2016 AT submitted a NoR to alter conditions 63 and 66 of CRL Designations 2, 4, 5 and 6. The alteration proposed amendments to condition 63, bringing the condition into line with condition 34 of the BTC designation. After the CRL designation was transferred to CRLL in October 2017, CRLL progressed the NoR to alter conditions 63 and 66. The NoR was limited notified and a hearing held on 14 March 2018 with the Council recommendation following on 29 June 2018. CRLL confirmed the NoR on 24 July 2018 and the amended conditions were incorporated into the Auckland Unitary Plan Operative in Part (AUP).

### 2.6 CRL Designation 2501 Britomart Transport Centre

On 9 February 2018 CRLL lodged a NoR for a duplicate designation over the existing AT BTC designation 1556. CRL designation 2501 for the Britomart Transport Centre was confirmed by CRLL on 18 June 2018. Condition 34 of designation 2501 manages the effects of operational rail vibration. This is an identical condition to AT's designation 1556 condition 34 which was an outcome of the 2015 process described in section 2.4 above.

## 3 Reasons for this proposed NoR to Alter Conditions 63 and 66

### 3.1 CRL Operational Vibration Project Criteria

In regard to the CRL designations, Marshall Day Acoustics (MDA) in their report titled *City Rail Link Noise and Vibration Assessment*, dated 13 August 2012, prepared to support the original CRL NoR to establish the CRL designations, identified the primary operational vibration effect of the CRL as being ground-borne noise. MDA noted there were no New Zealand standards that address human response to vibration or ground-borne noise from trains. MDA observed that as the CRL is the first significant underground rapid transit project in New Zealand there is little precedent in terms of vibration methodology or assessment.

To establish project criteria for CRL's operational rail vibration the FTA General Assessment Method performance standards were chosen for assessing vibration and ground-borne noise stemming from underground railways. These performance criteria were adopted as the CRL operational rail vibration criteria and carried through condition 63 of CRL designations 1, 2, 4, 5 and 6.

However, unlike the FTA criteria, the CRL operational vibration criteria were modified and expressed as PPVs rather than RMS velocity levels specified in the FTA *Manual*.

It has since been established through the NoR processes described in sections 2.4 and 2.5 above that using the PPV as originally expressed in conditions 63.1, 61.2 and 66.2 is three times more onerous than what is required to achieve the human comfort criteria according to the FTA *Manual*. In addition, it was identified that it would be extremely difficult to achieve the PPV criteria originally specified in condition 63.1, 63.2 and 66.2 and retaining these criteria would significantly increase the level of rail isolation above that necessary to mitigate regenerated noise. In other words, the original performance standard was likely to be unworkable, while delivering no benefits in terms of human response. As such it was determined that the PPV criteria be replaced with the RMS criteria specified in the FTA *Manual*.

### 3.2 Condition 63 of the CRL Designation 1

Condition 63 of the CRL designation 1 contains two sets of criteria to manage both ground-borne noise and tactile vibration related to operational rail activities. Measurements are to be undertaken using:

- $L_{ASmax}$ in units of dBA for ground-borne (reradiated) noise (i.e. A-weighted, slow response sound pressure level).
- PPVs in units of mm/s for tactile vibration.

Designation 1 condition 63 currently reads as follows:

**Operational Vibration**

| | | |
|---|---|---|
| 63 | 1 | **Operational Rail Vibration**<br>63.1 The Requiring Authority shall confirm that operational rail vibration and reradiated noise levels comply with the following Project Criteria at any noise or vibration sensitive receiver existing at the time of lodgement of the CRL NoR: |

| Building Type | Vibration Criteria PPV (mm/s) | Reradiated Noise Criteria (dB $L_{ASmax}$ re: 20 μPa) |
|---|---|---|
| Commercial uses with primarily daytime use[1] | 0.2 | 40 |
| Residences and buildings where people normally sleep | 0.15 | 35 |
| Auditoria/Theatres[2] | 0.1 | 30 |
| TV/Recording Studios | 0.06 | 25 |

Note:

1. Such as offices, businesses, churches, schools, universities and libraries.
2. This includes Albert Street District Court.

63.2 For any noise or vibration sensitive building types that are not provided for in the table above, the upper limit for vibration and reradiated noise shall not exceed 0.3 mm/s PPV and 50 dB $L_{ASmax}$ respectively.

63.3 For the avoidance of doubt this does not apply to the North Auckland Line and Britomart Designations.

63.4 When assessing operational rail vibration and reradiated noise, compliance with Conditions 63.1 and 63.2 shall be achieved for at least 95% of any 20 consecutive train pass-by 'events'.

The operational vibration criteria (both ground-borne noise and vibration) specified in condition 63 are based on criteria in the FTA *Manual*, with modifications. The FTA *Manual* ground-borne vibration criteria are specified as maximum RMS vibration levels (given in VdB re 1 micro-inch/sec). During the original CRL NoR process the RMS vibration levels used in the FTA *Manual* were converted into "equivalent" PPVs, which was consistent with the metric used for building damage, and then reflected in condition 33. Assumptions had to be made to enable the conversion of RMS velocities to PPVs and as a result, inaccuracies affecting the derivation of the CRL project ground-borne vibration criteria in condition 63 have occurred. These inaccuracies are described in detail in the technical memorandum prepared by Pulse Acoustics Limited (Pulse), dated 19 June 2019, included as **Attachment 1**. In summary, the 2012 process of converting RMS velocities to PPVs resulted in the following:

- A theoretical sinusoidal crest factor (ratio of peak over RMS) of √2 (or 1.4) used to convert an RMS level to a PPV.
- The use of a theoretical crest factor of 1.4 to generate "equivalent" PPV project vibration criteria results in overly onerous vibration criteria. This is because the crest factor is generally significantly higher for train vibrations.

Consequently, using this theoretical crest factor to determine the CRL project criteria for ground-borne vibration, the criteria in condition 63 are over three times more onerous than what is required to achieve the human comfort criteria according to the FTA *Manual*. Pulse notes that the PPV metric is poorly suited for the assessment of human comfort and that human comfort is found to better correlate with RMS levels. This is because of the instantaneous nature of the PPV which is based on a single episode. As the human body takes time to react to a vibration inducing action, RMS levels are better suited to determining levels which adversely affect human comfort as they quantify the vibration energy rather than the maximum instantaneous vibration velocity as is done with PPVs.

The practical application of condition 63 also presents problems because the PPV criteria is so stringent that the vibration created by people walking on a suspended slab would not comply. This puts into doubt the practical application of such stringent vibration levels and would likely require measurement of train vibration at night time in empty offices – an unrealistic scenario as human comfort is meaningless without occupants.

Pulse refer to actual measurements of AT's Electric Multiple Units (EMU) conducted in 2014 and identify that the actual crest factor during a train passby is approximately 4.5 (rather than 1.4 which is the crest factor currently used to determine the criteria used in condition 63). This is consistent with Pulse's experience of many rail measurements across Australia and Asia where values in the range of 3 to 6 are typical.

As a result, the CRL designation 1 operational rail vibration levels for ground-borne vibration under condition 63 are below the threshold for annoyance and unlikely to be noticed by most humans. They are in fact more stringent than criteria applied to critical hospital areas (such as operating theatres) and metrology laboratories, microelectronics manufacturing equipment or activities using bench microscopes[1]. Given the sensitivity of the existing criteria, the measurement of vibration would need to be undertaken during evening hours when floorspaces, in any buildings subject to monitoring, are unoccupied and mechanical ventilation is turned off, in order to determine the true level of train vibration.

The flow on consequence of the existing condition 63 criteria for CRL designation 1 is that a higher level of track form attenuation (the means of reducing vibration propagation from the track to the receiver building by the rail support) is required to satisfy the vibration criteria as they specify vibration limits approximately three times below widely accepted threshold levels. This will result in unnecessary expense without any corresponding benefit and may mean that in practical terms compliance with CRL designation 1 condition 63 is not possible.

Track form design is typically not driven by ground borne (tactile) vibration, (i.e. the level at which train vibration can be felt), but rather by ground-borne noise, as the adverse impacts from underground rail tunnels almost exclusively arise from ground-borne noise. As such it is important that measurement metrics are correlated, ensuring ground-borne vibration and ground-borne noise are measured with the correct internationally recognised metric at equivalent levels. Correlation between the two operational rail vibration criteria (i.e. between ground-borne noise and ground borne (tactile) vibration as described above) is essential as otherwise the track form design for the CRL would be driven by an unnecessarily conservative PPV based criterion.

The criteria currently in existing condition 63 require mitigation beyond what is necessary to address the potential adverse effect of ground-borne vibration on receivers in CRL designation 1. This would result in a costly over design of rail infrastructure for no benefit. These matters were acknowledged and upheld with respect to the alteration to condition 63 under CRL designations 2, 4, 5 and 6 in 2018.

[1] Section 4 of Pulse Acoustic Consultancy *Proposed Change to Condition 63 – CRL 1 Portion of the CRL Designation 2500,* dated 19 June 2019

## 4 Proposed Alteration to Conditions 63

The proposed alteration to condition 63 results in the adoption of the correct FTA criteria by replacing the PPV metric with RMS velocities. The insertion of reference to the British Standard BS6472-1:2008 at condition 63.5 specifically addresses how operational rail vibration is to be measured in relation to the assessment of human comfort. The proposed alteration brings CRL designation 1 condition 63 into line with the equivalent condition (now condition 63A) of CRL designations 2, 4, 5 and 6 (altered through the NoR process described in section 2.5 above). The proposed amendments specific to 11-19 Customs Street West clarify the extent to which the amended condition is to apply.

Therefore, it is proposed to amend condition 63 of CRL designation 1 as follows (changes denoted as strikethroughs, underlying and bold. A copy of the amended condition is contained in **Attachment 3**):

**Operational Vibration**

| | | |
|---|---|---|
| 63 | 1 | **Operational Rail Vibration**<br>63.1 The Requiring Authority shall confirm that operational rail vibration and reradiated noise levels comply with the following Project Criteria at:<br>(a) any noise or vibration sensitive receiver existing at the time of lodgement of the CRL NoR; **and**<br>**(b) the Commercial Bay office tower[4] at 11-19 Customs Street West (Lot 2 DP 69547)** |

| Building Type | Vibration Criteria **Velocity[3]** ~~PPV~~ **(mm/s)** | Reradiated Noise Criteria (dB $L_{ASmax}$ re: 20 μPa) |
|---|---|---|
| Commercial uses with primarily daytime use[1] | ~~0.2~~ **0.14** | 40 |
| Residences and buildings where people normally sleep | ~~0.15~~ **0.1** | 35 |
| Auditoria/Theatres[2] | 0.1 | 30 |
| TV/Recording Studios | ~~0.06~~ **0.045** | 25 |

Note:

1. Such as offices, businesses, churches, schools, universities and libraries.
2. This includes Albert Street District Court.
3. **Maximum one-second root-mean-square (RMS) value with an upper frequency limit of 80 Hz.**
4. **Commercial Bay office tower means that part of the building commencing at level 4 above ground level.**

63.2 For any noise or vibration sensitive building types that are not provided for in the table above, the upper limit for vibration and reradiated noise shall not exceed **a RMS level (1s, maximum) of 0.21 mm/s and 50 dB $L_{ASmax}$** ~~0.3 mm/s PPV and 50 dB $L_{ASmax}$~~ respectively.

63.3 For the avoidance of doubt **the Project Criteria in Conditions 63.1 and 63.2 do** ~~this does~~ not apply to the North Auckland Line and Britomart Designations.

63.4 When assessing operational rail vibration and reradiated noise, compliance with Conditions 63.1 and 63.2 shall be achieved for at least 95% of any 20 consecutive train pass-by 'events'. **The events shall be representative of the rolling stock fleet operating on the line and shall include maintenance activities, unless such maintenance activities are undertaken after 11.30pm or before 6.00am.**

**63.5 Subject to Condition 66.4 in the case of MediaWorks, when assessing operational rail vibration measurement shall be made in accordance with Section 5.2.3 of BS6472-1:2008 *Guide to evaluation of human exposure to vibration in buildings.***

# 5 Assessment of Effects

## 5.1 Positive Effects

The positive outcomes of the alteration are:

- It results in the management of the actual and potential effects of operational rail vibration arising from the CRL project in accordance with internationally recognised and accepted standards.
- It will provide certainty for receivers by ensuring the potential adverse effect of operational rail vibration resulting from the CRL project is managed consistently.
- The avoidance of a considerable design risk in that track form design will not be required to a level that serves no benefit in the management of actual effects associated with ground borne (tactile) vibration from trains.
- A more efficient outcome for Auckland ratepayers and an effective, efficient, and safe Auckland land transport system, which is being developed in the public interest.

## 5.2 Potential Adverse Effects of Altered Condition 63

The proposed alteration to condition 63 of CRL designation 1 will allow for slightly higher levels of ground-borne vibration from operational rail activities than currently permitted under the existing condition. While a slightly greater number of people may be able to perceive train vibration where a building is directly located over the CRL tunnels, the threshold of annoyance (as determined by the FTA *Manual*) will not be exceeded and the slight increase in vibration will not adversely impact upon the amenity of receivers, being occupants of buildings located directly over the CRL tunnels. Pulse note that train vibration levels up to 0.14mm/s RMS (as proposed for this alteration in respect of buildings with commercial uses) are unlikely to be felt where an occupied building has higher ambient vibration levels. In an unoccupied building vibration at this level would be generally unnoticeable.

By default, the potential adverse effects of ground borne vibration resulting from this NoR, based on the supporting technical assessment by Pulse, for occupants of buildings on sites adjacent to CRL designation 1, is considered to be even less.

It is acknowledged that buildings on the following sites will be located directly above CRL designation 1 and where the CRL rail alignment and station infrastructure will operate:

- 11-19 Customs Street West (Lot 2 DP 69547)
- 32-42 Wellesley Street West (Lot 19 DP 21520)
- 8-10 Mayoral Drive (Pt Lot 21, Lots 15, 18, 23, 24, 25 DP 21520)
- 24 Wellesley Street West (Lots 1 and 2 DP 200295, Lots 16 and 17 DP 21520)

Except for 11-19 Customs Street West, CRLL hold an interest in the remaining above listed sites where CRL rail alignment and station infrastructure will operate. These sites are currently vacant in anticipation of the construction of the new CRL Aotea Station.

CRL designation 1 covers the following additional sites; however, these areas serve to enable the construction of the CRL only and have no corresponding strata designation (CRL designation 2500 2) via which the CRL tunnels can be constructed and operate:

- 87-89 Albert Street (Lot 1 DP 104578)
- 99 Albert Street (Lot DP 116925)
- 103, 1C-11F/105, 107 Albert Street (Lot 1 DP 73175)
- 109-125 Albert Street (Lot 2, DP28234, Lot 1 DP 1753, Pt Allotment 6 SECT 22 Auckland City, Lot 2 DP52242)

- 120-130 Albert Street (Lot 1 110543)
- 135 Albert Street (Lot 1 DP 123332)
- 62A-D Victoria Street West (Lot 2 DP 450454
- 62 Victoria Street West (Lot 1 DP 450454)

Pulse state in their technical memorandum:

*"The change in the vibration criterion, therefore, will not result in a material loss of amenity relative to a standard office building designed to well established vibration criteria…"* In other words, building occupants will be no worse off as a result of the altered condition 63 with respect to operational rail vibration. The most common adverse impact from underground rail tunnels comes from ground borne noise. The ground borne noise criteria for condition 63 remain unchanged.

Regarding the effect of the altered condition on sensitive activities, the changed condition remains specific to activities carried out within a defined building type and any ground borne noise or vibration sensitive receiver existing at the time of lodgement of the original CRL NoR. Condition 63.2 provides for any building types not provided for in condition 63.1 and specifies upper limits for ground borne vibration and noise.

Overall, the potential adverse effects resulting from this NoR are considered to be less than minor.

## 6 Section 181 Alteration of Designation

Section 181 of the RMA provides for the alteration of existing designations, requested by the Requiring Authority responsible for the designation. Subsection (2) states that subject to subsection (3), sections 168 to 179 and 198AA and 198AD shall, with all necessary modifications, apply to a requirement for an alteration under subsection (1) as if the requirement were for a new designation.

### 6.1 Section 168 Notice of Requirement to Territorial Authority

Section 168(2) of the RMA states:

*"A requiring authority for the purposes approved under section 167 may at any time give notice in the prescribed form to a territorial authority of its requirement for a designation—*

*(a) for a project or work; or…"*

### 6.2 Section 169 Further information, notification, submissions, and hearing for notice of requirement to territorial authority

In accordance with section 169 the territorial authority must decide whether to notify the NoR under sections 169(1A) or sections 149ZCB(1) to (4), 149ZCC(1) to (4), 149ZCE, and 149ZCF .

#### *6.2.1 Section 149 notification assessment*

Section 149ZCB states:

*(1) The Minister may, in his or her discretion, decide whether to require the EPA to publicly notify an application or a notice.*
*(2) Despite subsection (1), the EPA must publicly notify an application or a notice if—*
*(a) the Minister decides (under section 149ZCE) that the activity that is the subject of the application or notice will have, or is likely to have, adverse effects on the environment that are more than minor; or*
*(b) the applicant requests public notification of the application or notice; or*

*(c) a rule or national environmental standard requires public notification of the application or notice.*

*(3) Despite subsections (1) and (2)(a), the EPA must not publicly notify the application or notice if—*

*(a) a rule or national environmental standard precludes public notification of the application or notice; and*

*(b) subsection (2)(b) does not apply.*

*(4) Despite subsection (3), the EPA may publicly notify an application or a notice if the Minister decides that special circumstances exist in relation to the application or notice.*

*(5) …*

Public notification of the NoR is not required for the following reasons:

- Based on the assessment in section 5 previous the potential adverse effects are considered to be less than minor.
- The applicant does not request public notification.
- No rule or national environmental standard requires public notification of the NoR.
- No special circumstances requiring public notification exist.

Section 149ZCC states:

*(1) If the Minister decides not to require the EPA to publicly notify an application or a notice, the Minister must, in relation to the activity,—*

*(a) decide if there is any affected person (under section 149ZCF); and*

*(b) identify any affected protected customary rights group or affected customary marine title group.*

*(2) The EPA must give limited notification of the application or notice to any affected person unless a rule or national environmental standard precludes limited notification of the application or notice.*

*(3) The EPA must give limited notification of the application or notice to an affected protected customary rights group or affected customary marine title group even if a rule or national environmental standard precludes public or limited notification of the application or notice.*

*(4) In subsections (1) and (3), the requirements relating to an affected customary marine title group apply only in the case of applications for accommodated activities.*

*(5) …*

Section 149ZCF states a person is an affected person, in relation to an activity, if the adverse effects of the activity on the person are minor or more than minor (but are not less than minor). Based on the assessment undertaken at section 5 the potential adverse effects of the NoR are considered to be less than minor.

Limited notification of the NoR is not required for the following reasons:

- Based on the assessment in section 5 previous the potential adverse effects are considered to be less than minor. As such, in accordance with section 149ZCF there are no adversely affected parties.
- There are no affected protected customary rights groups or affected customary marine title groups.

Notwithstanding the conclusions regarding limited notification, CRLL request limited notification of the NoR to the owner of the site at 11-19 Customs Street West (Lot 2 DP 69547).

## 6.3 Section 171 Recommendation by Territorial Authority

When considering a requirement and any submissions received, a territorial authority must, subject to Part 2, consider the effects on the environment of allowing the requirement, having particular regard to the following matters.

### *6.3.1 Section 171(1)(a)*

*(a) any relevant provisions of—*
*(i) a national policy statement:*
*(ii) a New Zealand coastal policy statement:*
*(iii) a regional policy statement or proposed regional policy statement:*
*(iv) a plan or proposed plan; and…*

An assessment of the above matters was undertaken for CRL designations 1 to 6 in 2012 and remains relevant to this NoR. The proposed alteration supports the construction, operation and maintenance of the CRL designation and does not alter the former assessment of relevant statutory documents. The proposed alteration to condition 63 of CRL designation 1 is not inconsistent with any of the above documents.

### *6.3.2 Section 171(1)(b)*

*(b) whether adequate consideration has been given to alternative sites, routes, or methods of undertaking the work if—*
*(i) the requiring authority does not have an interest in the land sufficient for undertaking the work; or*
*(ii) it is likely that the work will have a significant adverse effect on the environment; and…*

The NoR to alter condition 63 of CRL designation 1 does not impact on the land requirements for the CRL.

The actual and potential effects of the NoR to alter condition 63 are identified and described in section 5 above where it is concluded the effects of the proposed alteration will result in actual and potential effects that will be less than minor.

The proposed alterations to conditions 63 are required to address a technical error in the existing condition by correctly applying a recognised international guideline (the FTA *Manual*) and to bring the condition into line with what has previous been approved for the AT BTC designation 314[2], CRLL BTC designation 2501[3] and CRL designations 2, 4, 5 and 6[4]. Based on the foregoing commentary, no alternative methodology to the assessment of operational rail vibration is considered necessary in this instance.

### *6.3.3 Section 171(1)(c)*

*(c) whether the work and designation are reasonably necessary for achieving the objectives of the requiring authority for which the designation is sought; and…*

This NoR to alter condition 63 of CRL designation 1 is necessary to correct a technical error in the existing condition and ensure consistency in the mitigation of operational vibration effects is achieved between the CRL designations and CRLL BTC Designation 2501. In order that the designation can operate in accordance with the intention of the condition (which is to mitigate the actual and potential

[2] AT Britomart designation 314 NoR alteration confirmed 4 April 2016 (now referred to in the Auckland Unitary Plan (Operative in Part) as *Britomart Transport Centre designation 1556)*
[3] CRLL designation 2501 confirmed 18 June 2018
[4] CRLL designation 2500-2, 4, 5 and 6 alteration confirmed 24 July 2018

effects of operational rail vibration) this error requires correction. As such it is concluded that the NoR is reasonably necessary.

### *6.3.4 Section 171(1)(d)*

*(d) any other matter the territorial authority considers reasonably necessary in order to make a recommendation on the requirement.*

It is considered there are no other matters the Council is required to consider in order to make a recommendation on the proposed alteration to condition 63 of CRL designation 1.

## 7 Consultation and Engagement

During the course of the statutory processes for the BTC designation 314 NoR and the NoR for CRL designations 2, 4, 5 and 6, AT (and then CRLL) engaged with Auckland Council to discuss the effects of noise and vibration associated with the construction and operation of the CRL. It was acknowledged by Auckland Council at the hearing for the BTC designation 314 NoR that use of RMS in that designation, was the appropriate form of measurement of tactile vibration resulting from the CRL[5].

This approach was re-confirmed in 2018 when the Council recommended condition 63 of CRL designations 2, 4, 5 and 6 be altered to reflect the use of RMS to measure CRL operational rail vibration[6].

## 8 Conclusion

The proposal to alter condition 63 of CRL designation 1 is considered necessary for the appropriate management of the potential adverse effect of ground borne (tactile) vibration resulting from operational rail activities. While the change to the ground borne (tactile) vibration criteria will result in a slight increase in the allowable vibration levels and a greater number of people may be able to perceive train vibration where a building sits directly above the CRL tunnels, the proposed criterion will ensure that the threshold of annoyance for occupants of those buildings is not exceeded. For occupants of buildings adjacent to the CRL designation 1 the potential effect will be even less given those building are not located over the CRL tunnels. The recommended criteria have been successfully used in the design and operation of train systems worldwide and as such ensure that vibration will not adversely impact on the amenity of receivers.

In addition to the above the proposed alteration will avoid a considerable design risk in that track form design will not be required to a level (and associated cost) that serves no benefit in the management of actual effects associated with ground borne (tactile vibration) from trains.

It is noted the reradiated noise criteria contained within condition 63.1 are not changing under this NoR.

Overall, the proposed alteration is considered appropriate and necessary. It will result in the management of the actual and potential effects of operational rail vibration arising from the CRL in accordance with accepted internationally recognised standards.

[5] AT BTC designation 314 NoR confirmed 4 April 2016 (now referred to in the Auckland Unitary Plan (Operative in Part) as *Britomart Transport Centre designation 1556)*
[6] CRLL designation 2500 2, 4, 5 and 6 alteration confirmed 24 July 2018

Yours faithfully

Helen McLean
Associate

Enc:
**Attachment 1** – Proposed Change to Condition 63 of CRL Designation 2500-1, prepared by Pulse Acoustic Consultancy, dated 19 June 2019
**Attachment 2** – CRL project objectives
**Attachment 3** – Proposed amendments to condition 63

Attachment 1

# Proposed Change to Condition 63 of CRL Designation

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2019-04-10 Change to Condition 63 for CRL 2500 -1

19 June 2019

Version: Final

# Proposed Change to Condition 63 of CRL Designation

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| 2019-04-10 Change to Condition 63 for CRL 2500-1 | Final | 10th April, 2019 | Matthew Harrison | Renzo Arango | Matthew Harrison |

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## FIGURES

# 1 INTRODUCTION

This report provides technical support to the proposal to change Condition 63 of City Rail Link (CRL) Designation 1 (Auckland Unitary Plan reference 2500-1). CRL Designation 1 includes lower Queen Street, the Precinct Properties "Commercial Bay" development site at 5-7 Queen Street, Albert Street and the new CRL Aotea Station at 24 and 32-42 Wellesley Street West, 4-8, 10 and 10A Mayoral Drive.

Currently CRL Designation 1 is subject to Condition 63, which uses peak particle velocity (PPV) as the basis for specifying operational rail vibration criteria. In contrast, the vibration criteria for CRL Designations 2, 4, 5 and 6 have had their tactile vibration[i] criteria changed to a more technically correct maximum one-second root-mean-square (RMS) velocity level, with an upper frequency limit of 80 Hz.

The purpose of changing Condition 63 of CRL Designation 1 is to achieve consistency with the amended tactile vibration condition now adopted for the other CRL designations. The proposed change to Condition 63 will ensure the track design for CRL incorporates appropriate mitigation measures that are best suited to efficiently achieve appropriate noise and vibration levels in buildings overlaying or adjoining the railway.

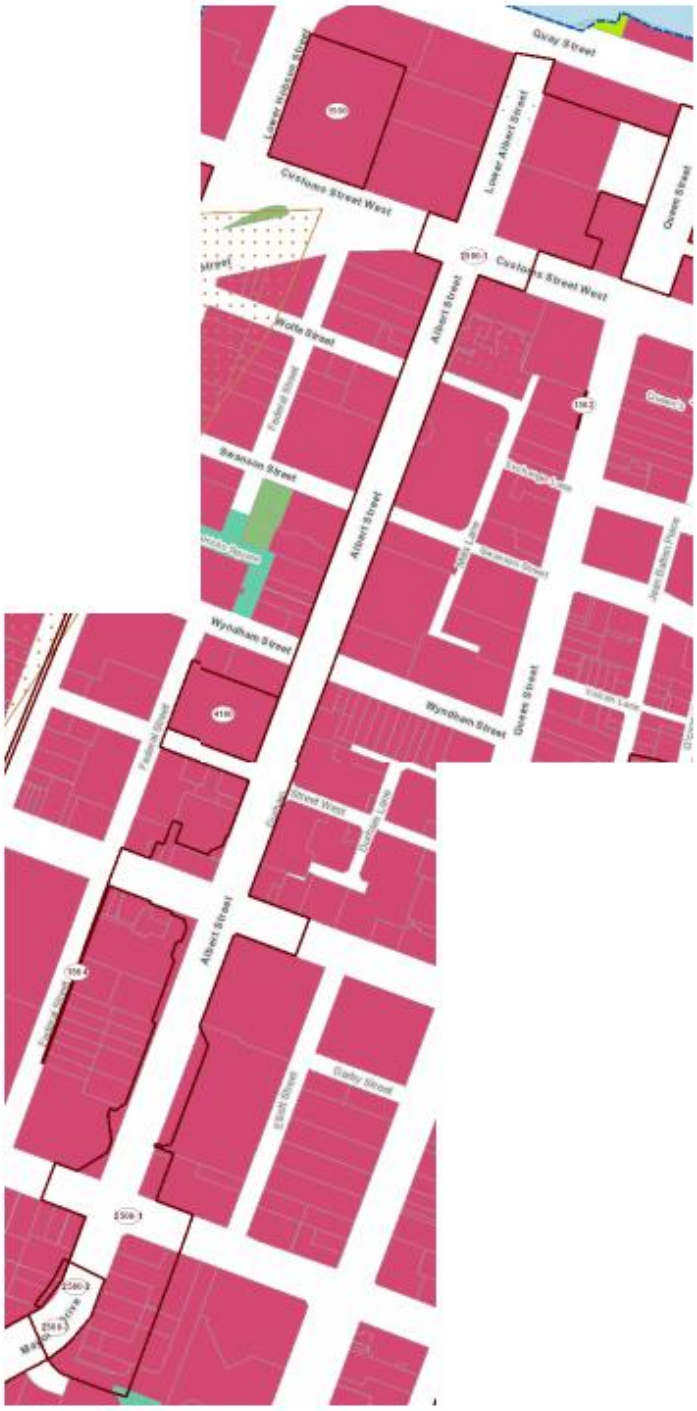
In this report we provide the following:

1. Technical assessment of the proposed change in tactile vibration criteria (based on previous work);
2. Comment on the acceptability of a change from a PPV limit to a maximum one-second RMS velocity level (with an upper frequency limit of 80 Hz); and
3. An explanation of what this change means in terms of actual and potential effects from operational vibration from the CRL 2500-1 portion of the CRL designation to receiver locations in the CRL Designation 1.

A series of changes to Condition 63 have been proposed over time by various parties, dating from December 2016 through to today. These proposed changes are shown in Appendix A to this memo in a marked-up version of Condition 63. These changes in the tactile vibration criteria have already been made for CRL Designations 2, 4, 5 and 6

The location of the CRL Designation 1 is shown in Figure 1 below.

**Figure 1 CRL Designation 2500-1** ***Source: Auckland Unitary Plan (Operative in Part)***



# 2 CONDITIONS 63 AND 63A

Condition 63 provides the operational vibration and reradiated noise[ii] criteria for that part of the CRL located within Designation 1. The existing Condition 63 for Designation 1 is reproduced in Section 2.1 below.

## 2.1 Existing Condition 63 for CRL Designation 1

**OPERATIONAL CONDITIONS**

| | | |
|---|---|---|
| 63 | 1 | **Operational Rail Vibration**<br>63.1 The Requiring Authority shall confirm that operational rail vibration and reradiated noise levels comply with the following Project Criteria at any noise or vibration sensitive receiver existing at the time of lodgement of the CRL NoR: |

| Building Type | **Vibration Criteria** PPV **(mm/s)** | Reradiated Noise Criteria (dB $L_{ASmax}$ re: 20 µPa) |
|---|---|---|
| Commercial uses with primarily daytime use[1] | 0.2 | 40 |
| Residences and buildings where people normally sleep | 0.15 | 35 |
| Auditoria/Theatres[2] | 0.1 | 30 |
| TV/Recording Studios | 0.06 | 25 |

Note:

1. Such as offices, businesses, churches, schools, universities and libraries.
2. This includes Albert Street District Court.

63.2 For any noise or vibration sensitive building types that are not provided for in the table above, the upper limit for vibration and reradiated noise shall not exceed 0.3 mm/s PPV and 50 dB $L_{ASmax}$ respectively.

63.3 For the avoidance of doubt this does not apply to the North Auckland Line and Britomart Designations.

63.4 When assessing operational rail vibration and reradiated noise, compliance with Conditions 63.1 and 63.2 shall be achieved for at least 95% of any 20 consecutive train pass-by 'events'.

The altered condition now applying to CRL Designations 2, 4, 5 and 6, renumbered as Condition 63A, is reproduced in Section 2.2 below.

## 2.2 Condition 63A for CRL Designations 2, 4, 5 and 6

**OPERATIONAL CONDITIONS**

63A | 2 4 5 6

**Operational Rail Vibration**

63A.1 The Requiring Authority shall confirm that operational rail vibration and reradiated noise levels comply with the following Project Criteria at any noise or vibration sensitive receiver existing at the time of lodgement of the CRL NoR:

| Building Type | **Vibration Criteria Velocity[3] (mm/s)** | Reradiated Noise Criteria (dB LASmax re: 20 μPa) |
|---|---|---|
| Commercial uses with primarily daytime use[1] | 0.14 | 40 |
| Residences and buildings where people normally sleep | 0.1 | 35 |
| Auditoria/Theatres[2] | 0.1 | 30 |
| TV/Recording Studios | 0.045 | 25 |

Note:

1. Such as offices, businesses, churches, schools, universities and libraries.
2. This includes Albert Street District Court.
3. Maximum one-second root-mean-square (RMS) value with an upper frequency limit of 80 Hz.

63A.2 For any noise or vibration sensitive building types that are not provided for in the table above, the upper limit for vibration and reradiated noise shall not exceed a RMS level (1s, maximum) of 0.21 mm/s and 50 dB LASmax respectively.

63A.3 For the avoidance of doubt, the Project Criteria in Conditions 63A.1 and 63A.2 do not apply to the North Auckland Line and Britomart Designations.

63A.4 When assessing operational rail vibration and reradiated noise, compliance with Conditions 63A.1 and 63A.2 shall be achieved for at least 95% of any 20 consecutive train pass-by 'events'. The events shall be representative of the rolling stock fleet operating on the line and shall include maintenance activities, unless such maintenance activities are undertaken after 11.30pm or before 6.00am.

63A.5 Subject to Condition 66.4 in the case of MediaWorks, when assessing operational rail vibration measurement shall be made in accordance with Section 5.2.3 of BS6472-1:2008 Guide to evaluation of human exposure to vibration in buildings.

## 2.3 Summary of the proposed changes to existing Condition 63 for CRL Designation 1

The proposed changes to Condition 63 of CRL Designation 1 are shown as a mark-up in the table below.

The criteria for re-radiated noise remain unchanged in the amended condition. In particular, it is noted that the re-radiated noise criterion remains unchanged at $L_{ASmax}$ of 40 dBA for commercial spaces and 50 dBA for retail spaces.

**OPERATIONAL CONDITIONS**

| | | |
|---|---|---|
| 63 | 1 | **Operational Rail Vibration**<br>63.1 The Requiring Authority shall confirm that operational rail vibration and reradiated noise levels comply with the following Project Criteria at any noise or vibration sensitive receiver existing at the time of lodgement of the CRL NoR: |

| Building Type | Vibration Criteria ~~PPV~~ **Velocity[3]** (mm/s) | Reradiated Noise Criteria (dB $L_{ASmax}$ re: 20 μPa) |
|---|---|---|
| Commercial uses with primarily daytime use[1] | ~~0.2~~ **0.14** | 40 |
| Residences and buildings where people normally sleep | ~~0.15~~ **0.1** | 35 |
| Auditoria/Theatres[2] | ~~0.1~~ **0.1** | 30 |
| TV/Recording Studios | ~~0.06~~ **0.045** | 25 |

Note:

1. Such as offices, businesses, churches, schools, universities and libraries.
2. This includes Albert Street District Court.
3. **Maximum one-second root-mean-square (RMS) value with an upper frequency limit of 80 Hz**

63.2 For any noise or vibration sensitive building types that are not provided for in the table above, the upper limit for vibration and reradiated noise shall not exceed ~~0.3 mm/s PPV~~ **an RMS level (1s, maximum) of 0.21 mm/s** and 50 dB $L_{ASmax}$ respectively.

63.3 For the avoidance of doubt this does not apply to the North Auckland Line and Britomart Designations.

63.4 When assessing operational rail vibration and reradiated noise, compliance with Conditions 63.1 and 63.2 shall be achieved for at least 95% of any 20 consecutive train pass-by 'events'. **The events shall be representative of the rolling stock fleet operating on the line and shall include maintenance activities, unless such maintenance activities are undertaken after 11.30pm or before 6.00am.**

63.5 **When assessing operational rail vibration, measurement shall be made in accordance with Section 5.2.3 of BS6472-1:2008 with respect to measurement locations.**

# 3 BACKGROUND FOR THE PROPOSED CHANGES TO CONDITION 63

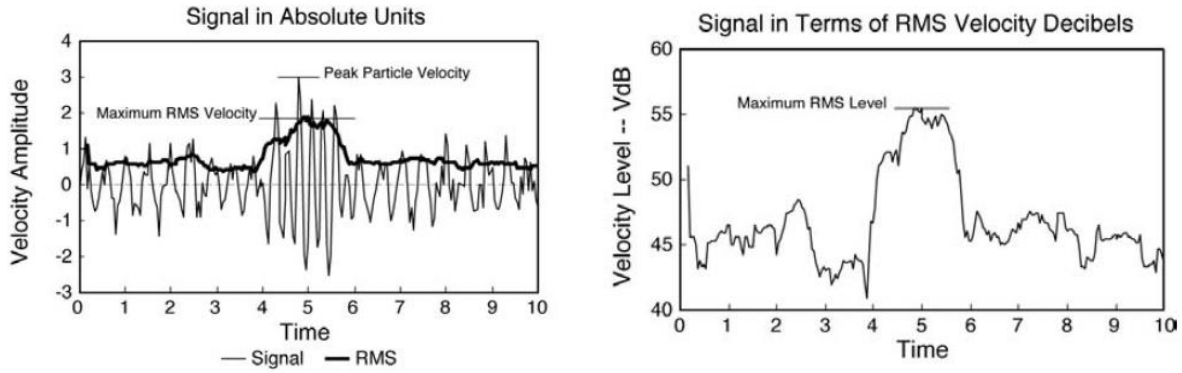
In proposing these changes to Condition 63 of CRL Designation 1, it is useful to outline the history of how the Operational Vibration Assessment for the 2012 CRL Notice of Requirement (NoR) was originally undertaken.

Marshall Day Acoustics (MDA) provided a report (City Rail Link Noise and Vibration Assessment Report No.: 001 R07 2012068A, dated 13 August 2012) in support of the NoR.

Operational vibration was assessed in the MDA NoR report using the United States' Federal Transit Administration (FTA) General Vibration Assessment method, as detailed in Chapter 10 of the FTA document FTA-VA-90-1003-06 *Transit Noise and Vibration Impact Assessment* (Ref. [**1**]). The performance criteria contained in Chapter 8 of this document were adopted as the CRL Operational Vibration Criteria. In the MDA report, the vibration criteria were also expressed as PPV values (unlike in the FTA document where the criteria are given in terms of RMS velocity) and these were then carried through to the CRL designation conditions.

Figure 2 below shows the PPV and RMS descriptors as they can be used to quantify vibration. The PPV is the maximum instantaneous vibration velocity. It is not well suited for evaluating human response as it takes some time for the human body to respond to vibration. Additionally, annoyance is more strongly linked to exposure level (which includes both duration and level) than vibration amplitude only. The FTA manual states that '*the human body responds to an average vibration amplitude*'. Therefore the RMS amplitude, evaluated over a one second period (or often longer time periods), is the preferred metric used in many standards to measure vibration.

**Figure 2 Different methods of describing a vibration signal (from Section 7.1.2 of Ref. [1])**




PPV is defined as the maximum instantaneous positive or negative peak of the vibration signal. PPV is often used in monitoring of blasting vibration since it is related to the stresses that are experienced by buildings. Although PPV is appropriate for evaluating the potential of building damage, it is not suitable for evaluating human response. Because the net average of a vibration signal is zero, the RMS amplitude is used to describe the "smoothed" vibration amplitude. The RMS of a signal is the square root of the average of the squared amplitude of the signal. The average is typically calculated over a one-second or longer period.

Vibration velocities can also be given in terms of decibels. A decibel is a logarithmic unit used to express an amplitude relative to a reference amplitude. In this memo all reference velocities are relative to the International Standard reference velocity of 1 nm/s (contrary to the FTA manual which uses $10^{-6}$ inches/s, as indicated above). A RMS vibration level of 0.14 mm/s equals 103 dB (often written as VdB or dBV to indicate that it is vibration and not noise).

The Operational Vibration Criteria specified by MDA are shown in Table 1 below. MDA notes that a vibration level of 100 dB corresponds to approximately 0.15 mm/s PPV, which is close to the limit of perception. Annex B to British Standard 5228-2:2009 notes that the threshold of perception is typically in the PPV range of 0.14 mm/s to 0.3 mm/s. This means that the CRL criterion originally proposed by MDA for dwellings is imperceptibility. MDA also state that the limit for auditoria/theatres is even lower than imperceptibility, and the limit for TV/Recording Studios is lower again.

**Table 1 Operation Vibration Criteria from MDA report "City Rail Link Noise and Vibration Assessment Report No.: 001 R07 2012068A, dated 13 August 2012"**

**Table 6.3.2: Project Criteria – Operation Vibration**

| Building Type | Vibration Criteria | | Reradiated Noise Criteria (dB re: 20 µPa) |
|---|---|---|---|
| | (dB re: 1 nm/s) | PPV (mm/s) | |
| Commercial and Industrial Buildings | 103 | 0.2 | 40 |
| Dwellings | 100 | 0.15 | 35 |
| Auditoria/Theatres | 97 | 0.1 | 30 |
| TV/Recording Studios | 93 | 0.06 | 25 |

Although the MDA table above includes the metric versions of the FTA document FTA-VA-90-1003-06 *Transit Noise and Vibration Impact Assessment* (FTA guideline) criteria table, the actual guideline recommends vibration and re-radiated noise criteria for different receivers, depending on the number of train pass-bys per day, as can be seen in Table 8-1 of the FTA guideline (see Table 2 below).

For frequent events (as is appropriate for Metro type rail developments), the corresponding RMS vibration velocities in SI units have been overlaid, shown in red.

**Table 2 Ground-borne vibration (GBV) and ground-borne noise (GBN) impact criteria for general assessment (Table 8.1 from Federal Transit Administration document FTA-VA-90-1003-06 Transit Noise and Vibration Impact Assessment).**

| Land Use Category | GBV Impact Levels (VdB re 1 micro-inch /sec) | | | GBN Impact Levels (dB re 20 micro Pascals) | | |
|---|---|---|---|---|---|---|
| | Frequent Events[1] | Occasional Events[2] | Infrequent Events[3] | Frequent Events[1] | Occasional Events[2] | Infrequent Events[3] |
| **Category 1**: Buildings where vibration would interfere with interior operations. | 65 VdB[4] **0.045 mm/s RMS** | 65 VdB[4] | 65 VdB[4] | N/A[4] | N/A[4] | N/A[4] |
| **Category 2**: Residences and buildings where people normally sleep. | 72 VdB **0.101 mm/s RMS** | 75 VdB | 80 VdB | 35 dBA | 38 dBA | 43 dBA |
| **Category 3**: Institutional land uses with primarily daytime use. | 75 VdB **0.142 mm/s RMS** | 78 VdB | 83 VdB | 40 dBA | 43 dBA | 48 dBA |

**Notes:**

1. "Frequent Events" is defined as more than 70 vibration events of the same source per day. Most rapid transit projects fall into this category.
2. "Occasional Events" is defined as between 30 and 70 vibration events of the same source per day. Most commuter trunk lines have this many operations.
3. "Infrequent Events" is defined as fewer than 30 vibration events of the same kind per day. This category includes most commuter rail branch lines.
4. This criterion limit is based on levels that are acceptable for most moderately sensitive equipment such as optical microscopes. Vibration-sensitive manufacturing or research will require detailed evaluation to define the acceptable vibration levels. Ensuring lower vibration levels in a building often requires special design of the HVAC systems and stiffened floors.
5. Vibration-sensitive equipment is generally not sensitive to ground-borne noise.

The FTA 'Category 3 – institutional land uses with primarily daytime use' recommends a 1s RMS velocity of 75 VdB (re: 1 micro-inch/s).

This is equivalent to:

- 0.142 mm/s RMS (i.e. $10^{\frac{75VdB}{20}} \times 10^{-6} \times 25.4mm/in = 0.142mm/s$); or
- 103 dB re: 1 nm/s ( i.e. $20\log\frac{0.142\times10^{-3}}{10-9} = 103dBV$)

It is also worth pointing out that the chosen office criterion for the CRL Operational Vibration Criteria has been based on Category 3 receivers "Institutional land uses with primarily daytime use". This Category is appropriate for "*quiet offices that do not have vibration-sensitive equipment, but still have the potential for activity interference*".

The vibration criteria in Condition 63.1 for critical spaces such as theatres and studio spaces were derived from Table 8-2 of the FTA guideline.

The FTA criteria for critical spaces are shown Table 3 below.

**Table 3 Table 8.2 from Federal Transit Administration document FTA-VA-90-1003-06 Transit Noise and Vibration Impact Assessment**

**Table 8-2. Ground-Borne Vibration and Noise Impact Criteria for Special Buildings**

| Type of Building or Room | Ground-Borne Vibration Impact Levels (VdB re 1 micro-inch/sec) | | Ground-Borne Noise Impact Levels (dB re 20 micro-Pascals) | |
|---|---|---|---|---|
| | Frequent [1] Events | Occasional or Infrequent[2] Events | Frequent[1] Events | Occasional or Infrequent[2] Events |
| Concert Halls | 65 VdB | 65 VdB | 25 dBA | 25 dBA |
| TV Studios | 65 VdB | 65 VdB | 25 dBA | 25 dBA |
| Recording Studios | 65 VdB | 65 VdB | 25 dBA | 25 dBA |
| Auditoriums | 72 VdB | 80 VdB | 30 dBA | 38 dBA |
| Theaters | 72 VdB | 80 VdB | 35 dBA | 43 dBA |

Notes:
1."Frequent Events" is defined as more than 70 vibration events per day. Most rapid transit projects fall into this category.
2."Occasional or Infrequent Events" is defined as fewer than 70 vibration events per day. This category includes most commuter rail systems.
3.If the building will rarely be occupied when the trains are operating, there is no need to consider impact. As an example, consider locating a commuter rail line next to a concert hall. If no commuter trains will operate after 7 pm, it should be rare that the trains interfere with the use of the hall.

The vibration limits given in Table 3 above are maximum RMS vibration levels for repeated events of the same source given in terms of VdB re 1 micro-inch/s.

In the MDA 2012 CRL operational vibration criteria table the RMS criteria stipulated in the FTA manual were converted to PPV criteria by multiplying by a crest factor of 1.4 (i.e. multiplying by $\sqrt{2}$, assuming the vibrations from rail movements are sinusoidal). This conversion factor, however, is wrong in the context of train vibration.

Measurements of train pass-bys in Auckland during November 2014 showed that vibration from the new EMU's actually has a multiplication factor (crest factor) of approximately 4.5. This agrees with our experience of many rail measurements across Australia and Asia where values in the range of 3 to 6 are typical. The conversion to PPV should have been made by multiplying the RMS level by 4.5 and not 1.4. For construction equipment, the crest factor is regularly 10 or more. **As a consequence, the 2012 CRL Designation Condition 63 criteria for vibration were approximately three-times more stringent than recommended in the FTA manual.**

In summary, the alterations to CRL Designation 2500 - 1, 2, 4, 5 and 6 address the following:

- Vibration criteria derived from using an incorrect conversion factor when converting RMS values to PPV; and

- The application of the RMS metric as a more appropriate means of assessing human response to vibration.

# 4 RELEVANCE OF THE PROPOSED CHANGES TO CONDITION 63 FOR THE COMMERCIAL RECIEVERS IN CRL DESIGNATION 1

Human response to floor vibration is a complex phenomenon. Acceptable values of human exposure to vibration are primarily dependent on the use of the space (e.g. office, residence, etc) and the character of the vibration (e.g. continuous or intermittent, frequency content, etc). In addition, specific responses are dependent upon social and cultural factors, psychological attitudes, expected interference with privacy, and ultimately the individual's perceptibility (which will also depend of whether the receiver is standing, seated or prone). Expectation of tactile vibration and predictability is also a key aspect in response determination. Griffin (Ref. [**2**]) further states that the building occupants' responses also depend on '*whether they believe anything could be done to reduce the vibration and whether they anticipated that expressing their dissatisfaction would be likely to produce any improvement in the conditions or some financial compensation*'.

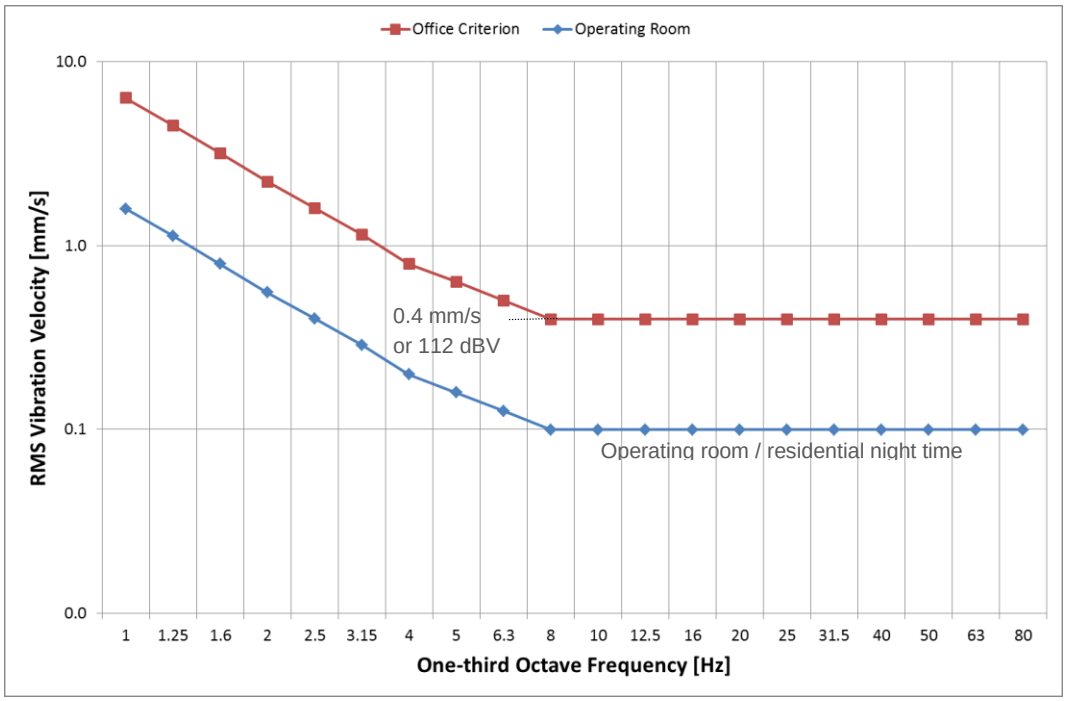
Notwithstanding these considerations, tactile vibration criteria for train vibration can be stipulated meaningfully. Present day criteria have been calibrated and adjusted over time and build on extensive surveys.

One criteria framework that has been historically used is that of baseline curves or base-curves. Base-curves are one-third octave vibration levels of roughly equal annoyance or equal perception. The blue line in Figure 3 to follow shows an operating room curve (e.g. surgical operating theatres). For the assessment of human comfort, this curve is shifted up depending on the receiver environment and the type of vibration. The FTA recommended multiplier for offices is 4 (identical to the recommendations of ISO 2631-2:1989 *"Evaluation of human exposure to whole-body vibration – Part 2: Continuous and shock-induced vibration in buildings (1 to 80 Hz)"* (Ref. [**3**])) and the resulting office curve criterion is the red line in Figure 3. This curve has actually been derived for ***continuous*** vibration (such as from stationary mechanical plant such as a pump or motor) and using it for transient train vibration is very conservative as higher vibration levels are acceptable for shorter exposure durations.

Fundamentally a base-curve approach (as adopted by the FTA) is poorly suited for assessing transient vibration events because of the difficulties associated in estimating adequate multipliers. Most standards only provide multipliers for continuous vibration and for events that occur up to 3 times per day – clearly trains fall in between these limits. This is the main reason why many international standards have now shifted towards assessments based on vibration dose values (VDVs). VDVs assess the combined effects of vibration magnitude and exposure duration and as such inherently capture the trade-off between the two critical elements of magnitude and exposure duration (it is true however that vibration dose is more strongly influenced by magnitude to the extent that a doubling in magnitude is equivalent to an increase in exposure duration by a factor of 16).

Willford and Young (Ref. [4]) state that a base-curve multiplier of 8 "is almost always satisfactory for commercial buildings such as offices, retail, restaurants, airports and the like where some people are seated". This statement is consistent with the recommendations provided in the sources cited in Ref. [4].

**Figure 3 Office criterion (red) and operating room criterion (blue).**




It is important to remember that the base-curve criteria provide limits for individual one-third octave bands, and is different to the overall vibration limit given in Condition 63 (which is effectively the sum of all the vibration levels measured in one-third octave bands).

For example, a train pass-by with a PPV of 0.15 mm/s, as currently specified in Condition 63 in relation to residences, would have corresponding maximum one-third octave vibration velocities of approx. 0.04 mm/s. A maximum third-octave vibration velocity of 0.04 mm/s is below the operating theatre curve which applies in critical hospital areas. In fact 0.04 mm/s is below the Vibration Criteria Curve A (VC-A) criterion which applies for metrology laboratories, microelectronics manufacturing equipment or bench microscopes up to 400X magnification (Ref. [**5**]).

For commercial development located in CRL Designation 1 (including the Commercial Bay development at 5-7 Queen Street) the relevant criterion is mainly that for offices. The original and amended vibration criteria are:

Existing CRL Designation 1 Condition 63:

- **Offices:** Maximum Peak Particle Velocities (PPV) of 0.2 mm/s. PPVs are maximum instantaneous vibration velocities.

Note: this condition, if correctly derived, would have been a PPV of 0.64mm/s when converted from the FTA RMS based criterion of 75 VdB re 1 micro-inch/sec.

Proposed CRL Designation 1 Condition 63:

- **Offices**: Maximum 1 second root-mean-square (RMS) vibration velocities of 0.14 mm/s and limiting the maximum frequency to 80 Hz.

This amended criterion remains a very conservative criterion for the following reasons:

- It is 35% of the allowable vibration level (i.e. 0.45mm/s) recommended for offices in the FTA's detailed assessment procedure (see Section 8.2.1 of the FTA manual).

- The overall level of 0.14 mm/s (maximum 1 second RMS) is likely to have most or even all the individual one-third octave levels below the operating room and residential night time criteria of 0.1 mm/s.
- The underlying base-curve is for continuous vibration. Higher allowable levels are recommended for transient events in the source ISO standards, but this has not been adopted in the FTA.

# 5 CONSEQUENCES OF THE CURRENT VIBRATION CONDITION 63 FOR CRL DESIGNATION 1

Griffin (Ref. [2]) states that “comfort, or ‘a conscious wellbeing’, within a building merely requires the absence of ‘perceptible’ vibration for most of the time. Thresholds for the perception of vibration therefore provide the lower limits for unacceptable vibration in most buildings. The upper limit for acceptable vibration may be expected to vary from around the perception threshold to many times greater, depending on the building, the area, the activities of persons in the building, their knowledge of the vibration and the duration and other characteristics of the motion”.

Train pass-bys with vibration levels up to 0.14mm/s RMS are unlikely to be noticeable in an occupied building with higher “ambient” vibration levels. Vibrations at this level will be generally unnoticeable in an otherwise unoccupied building (although the re-radiated noise from these pass-bys is likely to be audible when the air conditioning is off and the building is generally unoccupied).

The change in the vibration criterion, therefore, will not result in a material loss of amenity relative to a standard office building designed to well established vibration criteria. The altered criteria are generally aligned with the operating room criteria curve, which is described as being: “vibration not feelable, but ground–borne noise may be audible inside quiet rooms. Suitable for medium-power optical microscopes (100x) and other equipment of low sensitivity”.

In conclusion, the proposed change in vibration criteria, which is required to correct an historical technical error, will result in no material loss of amenity to buildings located above or adjacent to the CRL rail alignment. The resultant effect can be accurately classified as being “less than minor’.

## REFERENCES

1. Federal Transit Administration's "Transit Noise and Vibration Impact Assessment" FTA-VA-90-1003-06, May 2006.
2. Griffin "Handbook of Human Vibration" ISBN 0-12-303040-4.
3. ISO 2631-2:1989 "Evaluation of human exposure to whole-body vibration – Part 2: Continuous and shock-induced vibration in buildings (1 to 80 Hz)". SUPERSEDED.
4. Willford and Young "A design guide for footfall induced vibration of structures", CCIP-016 published November 2006, ISBN 1-904482-29-5.
5. Institute of Environmental Sciences and Technology, "Considerations in Clean Room Design," RR-CC012.1, 1993.

## APPENDIX A

The below table shows re the proposed changes to the operational vibration criteria, the original FTA criteria (in original VdB re: micro-inch/s format plus their equivalent metric values), the MDA derived PPV criteria levels (that incorrectly assumes a crest factor of √2) as well a PPV limit using the more correct crest factor of 4.5. Note: the FTA criteria for auditoria is indicated in red because the criteria for this building type is not actually listed and has reasonably been inferred as being somewhere between FTA building Categories 1 and 2.

63.1

| Building Type | FTA criteria | | | MDA PPV mm/s (crest factor of 1.4) | PPV mm/s (crest factor of 4.5) | **Vibration Criteria ~~PPV~~ Velocity[3] (mm/s)** | **Reradiated Noise Criteria (dB $L_{ASmax}$ re: 20 µPa)** |
|---|---|---|---|---|---|---|---|
| | (re 1 µ-inch/s) | (re 1nm/s) | (mm/s RMS) | | | | |
| Commercial uses with primarily daytime use[1] | 75 VdB | 103 dBV | 0.143 | 0.20 | 0.64 | ~~0.2~~ 0.14 | **40** |
| Residences and buildings where people normally sleep | 72 VdB | 100 dBV | 0.101 | 0.14 | 0.46 | ~~0.15~~ 0.1 | **35** |
| Auditoria / Theatres[2] | 69 VdB | 97 dBV | 0.072 | 0.10 | 0.32 | ~~0.1~~ ~~0.07~~ 0.1 | **30** |
| TV/Recording Studios | 65 Vdb | 93 dBV | 0.045 | 0.06 | 0.20 | ~~0.06~~ ~~0.25~~ 0.045 | **25** |

Notes:

1. Such as offices, businesses, churches, schools, universities and libraries.
2. This includes Albert Street District Court
3. **Maximum one-second root-mean-square (RMS) value with an upper frequency limit of 80 Hz**

[i] Tactile vibration is vibration that may be felt by a building occupant. The range of frequencies usually associated with the effects of whole body vibration on comfort is between 0.5 Hz and 80 Hz. Magnitudes of acceleration below about 0.01 $ms^{-2}$ will rarely be felt and frequencies below 4 Hz and above 8 Hz require higher magnitudes (in the z-axis direction) for equal response.

[ii] Reradiated noise is noise that is generated by vibration in the building structure rather than by airborne transmission from the source to the receiver. It is most often experienced in buildings as impact noise (commonly from footfall impacts or construction activity, such as the use of impact drills) or as a "rumble" from underground rail lines.

**ATTACHMENT 2**
CRL Project Objectives

| Objective Number | Provision |
|---|---|
| 1 | Improve transport access into and around the city centre for a rapidly growing Auckland<br>(a) Future proof for expected growth |
| 2 | Improve the efficiency and resilience of the transport network of urban Auckland<br>(a) Improve journey time, frequency and reliability of all transport modes<br>(b) Maximise the benefits of existing and proposed investment in transport<br>(c) Release the rail capacity constraint at Britomart |
| 3 | Significantly contribute to lifting and shaping Auckland's economic growth<br>(a) Support economic development opportunities<br>(b) Provide the greatest amount of benefit for cost<br>(c) Enable a more productive and efficient city |
| 4 | Provide a sustainable transport solution that minimises environmental impacts<br>(a) Limit visual, air quality and noise effects<br>(b) Contribute to the country's carbon emission targets |
| 5 | Contribute positively to a liveable, vibrant and safe city<br>(a) Enhance the attractiveness of the city as a place to live, work and visit<br>(b) Protect our cultural and historic heritage for future generations<br>(c) Help safeguard the city and community against rising transport costs |

**ATACHMENT 3**

**Operational Vibration**

| | | |
|---|---|---|
| 63 | 1 | **Operational Rail Vibration**<br>63.1 The Requiring Authority shall confirm that operational rail vibration and reradiated noise levels comply with the following Project Criteria at:<br>(a) any noise or vibration sensitive receiver existing at the time of lodgement of the CRL NoR; **and**<br>**(b) the Commercial Bay office tower[4] at 11-19 Custom Street West (Lot 2 DP 69547)** |

| Building Type | Vibration Criteria **Velocity[3]** ~~PPV~~ **(mm/s)** | Reradiated Noise Criteria (dB $L_{ASmax}$ re: 20 μPa) |
|---|---|---|
| Commercial uses with primarily daytime use[1] | ~~0.2~~ **0.14** | 40 |
| Residences and buildings where people normally sleep | ~~0.15~~ **0.1** | 35 |
| Auditoria/Theatres[1] | 0.1 | 30 |
| TV/Recording Studios | ~~0.06~~ **0.045** | 25 |

Note:

1. Such as offices, businesses, churches, schools, universities and libraries.
2. This includes Albert Street District Court.
3. **Maximum one-second root-mean-square (RMS) value with an upper frequency limit of 80 Hz.**
4. **Commercial Bay office tower means that part of the building commencing at level 4 above ground level.**

63.2 For any noise or vibration sensitive building types that are not provided for in the table above, the upper limit for vibration and reradiated noise shall not exceed **a RMS level (1s, maximum) of 0.21 mm/s and 50 dB $L_{ASmax}$** ~~0.3 mm/s PPV and 50 dB $L_{ASmax}$~~ respectively.

63.3 For the avoidance of doubt **the Project Criteria in Conditions 63.1 and 63.2 do** ~~this does~~ not apply to the North Auckland Line and Britomart Designations.

63.4 When assessing operational rail vibration and reradiated noise, compliance with Conditions 63.1 and 63.2 shall be achieved for at least 95% of any 20 consecutive train pass-by 'events'. **The events shall be representative of the rolling stock fleet operating on the line and shall include maintenance activities, unless such maintenance activities are undertaken after 11.30pm or before 6.00am.**

**63.5 Subject to Condition 66.4 in the case of MediaWorks, when assessing operational rail vibration measurement shall be made in accordance with Section 5.2.3 of BS6472-1:2008 *Guide to evaluation of human exposure to vibration in buildings.***