SNOLAVALIN	VIBRATION CONTROL PLAN	Rev.	Date	Page
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Title : Vibration Control Plan

Client : **City of Ottawa**

Project : **Trillium Line Extension Project**

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Revision				Notes
Rev.	By	Appr.	Date	
00	JT	IS	April 9, 2019	Issued for City submission
01	JT		June 3, 2019	Address City comments
02	JT		November 17, 2020	For internal review
03	JT		2020-12-08	For city review.

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1.0 Introduction

Schedule 17 of the Trillium Line Extension (TLE) Project Agreement (PA), in regards with Environmental obligations, requires that a Vibration Control Plan (NVCP) is developed and submitted to the City Representative.

The present document forms part of this VCP. It is supplemented by the document titled: "DST ENVIRONMENTAL - NOISE AND VIBRATION CONTROL PLAN - PART A - CONSTRUCTION - OCTOBER 27, 2020. This document concerns utility monitoring, baseline monitoring, and monitoring during the operations period.

2.0 Vibration during Design Period

2.1 OBJECTIVE

The objectives of this portion are to control vibration that may be predicted to occur during operations. This document will discuss the prediction and mitigation of noise and vibration levels to the extent reasonably possible and at least to meet the Applicable Vibration Requirements, as defined in PA, Schedule 17, Part 8.

This activity will be performed by identifying representative sensitive receivers (RSRs), creating baseline monitoring, Analyzing the data to determine the source vibration, the ground attenuation of that source, and effect on the receiver. Mitigation will then be designed for areas that are determined to breach the applicable noise and vibration requirements.

2.2 APPLICABLE NOISE AND VIBRATION REQUIREMENTS

2.2.1 Reference Documents

In regards with noise and vibration produced during Construction period, the Project shall comply with the documents as outlined in the PA, Schedule 17, Part 8 "**Noise and Vibration Guidance Documents**" as applicable. The exceedance standards for construction vibration are outlined in Table 8.2 of the PA, Schedule 17, and are replicated below. The applicable performance limit is the corresponding entry in Table 8.2 or a level 5 dB below the mitigated air borne sound level, whichever is higher.

Noise and Vibration Performance Limits			
Source	**Receiver**	**Descriptor**	**Limit Requiring Mitigation**
Construction Equipment	Ground outside any building or adjacent to any structure	Peak Particle Velocity	Refer to construction vibration damage criteria in the Federal Transit Administration's Transit Noise and Vibration Impact Assessment, Report FTA VA 90 1003 06, Federal Transit Administration, U.S. Department of Transportation, 2006, as amended.
Revenue Vehicle passby vibration	Inside highly sensitive buildings (e.g. concert halls, television studios, recording studios, vibration-sensitive research and manufacturing facilities, hospitals with vibration- sensitive equipment, some university research facilities)	Vertical vibration velocity passby rms	Not to exceed 65 VdB re: 1 microinch/sec (0.045 mm/sec)
	Inside residences and buildings where people normally sleep (e.g. residential buildings, hotels, hospitals); or theatres and auditoriums	Vertical vibration velocity passby rms	Not to exceed 72 VdB re: 1 microinch/sec (0.1 mm/sec)
	Inside sensitive institutional buildings and office buildings (e.g. schools, churches and quiet/commercial offices)	Vertical vibration velocity passby rms	Not to exceed 75 VdB re: 1 microinch/sec (0.14 mm/sec rms)
Revenue Vehicle passby ground borne noise measured as maximum passby sound pressure level	Inside concert halls, television studios, recording studios	Ground-borne passby Leq or Lmax,S	Not to exceed 25dBA re: 20 micropascals
	Inside theatres and	Ground-borne passby Leq or	Not to exceed 30dBA re: 20

Noise and Vibration Performance Limits			
Source	**Receiver**	**Descriptor**	**Limit Requiring Mitigation**
using slow response	auditoriums	Lmax, S	micropascals
	Inside residences and buildings where people normally sleep (e.g. residential buildings, hotels, hospitals)	Ground-borne passby Leq or Lmax, S	Not to exceed 35dBA re: 20 micropascals
		Ground-borne passby Leq or Lmax, S	Not to exceed 35dBA re: 20 micropascals

Table 1: Ground-borne Noise and Vibration Performance Limits (PA, Schedule 17)

The reference for vibration criteria during construction to US FTA Transit Noise and Vibration Impact Assessment Manual (FTA) (2006). This reference notes that the general criteria presented above act as limits on operational values.

2.3 PREDICTION PROCEDURE

2.3.1 Vehicle Operation

2.3.1.1 Vibration Criterion

FTA defines the sound level criteria as well as the assessment methodology to be applied to the Project.

The vibration criterion is based on the peak vertical acceleration, or the equivalent RMS, experienced on a subject site, and is shown in Table 1 above. Peak values may be monitored but will be converted to RMS values using a calibrated Crest Factor. This will be determined using train data calculate that factor. A crest factor of 1.414 represents a pure sine wave. For rail vibrations, a crest factor of 2.2 to 3.6 may be measured, depending on the specific physical system creating the vibration.

2.3.1.2 Assessment Method

FTA suggests that assessment of rail traffic vibration impact should be conducted using a screening distance from the proposed railway development and then performing an analytical prediction on any sensitive receivers within that screening distance. The screening distances will be established based on the line speeds, track configurations, and train operations at which the predicted vibration will be higher than permitted levels in the PA. A screening distance of 100 m provides an adequate zone to allow vibrations to abate naturally from the anticipated train vibrations.

The analysis procedure is outlined in FTA; however, the prediction of ground borne vibration is complex and requires site measurement to determine the vibration propagation properties. The vibration characteristics of the revenue vehicle will be generated by measuring the vibration of the existing vehicles operating on the existent Segment 2. This input will be scaled for the length and weight of the anticipated Revenue Vehicle. The characteristics of the ground will be measured from existent inputs, where they exist, or modeled based on the ground characteristics of other sites with similar geotechnical characteristics. These predictions will be used to assist in the assessment of sensitive receivers. Site measurement will also be required to verify the effectiveness of vibration mitigation during the operation period. In general; the procedure is to create a ground model for each RSR based on background readings. Data collected prior to construction will be used to calibrate the ground model. The input vibration energy from the RSR is measured or calculated from the design of that vehicle and input into the ground model. The ground model then outputs a vibration level at the RSR. This output serves as a prediction of the expected vibration at the RSR and can be confirmed during commissioning. Should the output vibration be above the receiver limit the track design around the RSR will have to be modified using expected reduction values for mitigation solutions. These values are generally provided by the manufacturer.

3.3.1.3 Possible Mitigation Measures

Mitigation measures which are generally observed in surface transportation projects include:

- Selection or alteration of a horizontal alignment;
- Depressed or elevated corridor profiles;
- Earth berms;
- Geocellular matting or ballast matting under the rail line;
- Rail stiffening/softening (i.e. high compliance fasteners, tie spacing, etc.)
- Traffic management;
- Reduction or establishment of suitable vehicle speed limits;

However, at this stage of advancement of the Project, it is highly probable that the most acceptable mitigation measures consist of Ballast mats, with geocellular matting at the problematic locations. The geocellular mattress absorbs vibration and energy by reducing the amplitude and frequency at the track bed and distributing energy along the geocellular mattress. A much larger mass of material is mobilized by vehicle passage when a mattress is used. This reduces the maximum value of the RMS as the vibration propagates past the mattress. In some cases, other mitigations may be used such as high compliance fasteners or rail stiffening measures. These are less effective than geocellular mattresses as they mobilize less mass but may still be appropriate in some circumstance.

2.4 VIBRATION ASSESSMENT

Construction activities that are likely to generate vibration in exceedance to the applicable limits (5 mm/s peak), per the PA, will undergo a vibration assessment. This assessment will identify the construction activity as well as details such as when and where the activity will take place. An estimate of the vibration caused by the activity will be predicted using applicable references.

3.0 Vibration Monitoring During Construction

Vibration monitoring during construction is being performed as two separate activities. Monitoring of RSRs is being performed under a control plan titled, “DST ENVIRONMENTAL - NOISE AND VIBRATION CONTROL PLAN - PART A - CONSTRUCTION - OCTOBER 27, 2020.”

3.1 VIBRATION MONITORING OF UTILITES

Vibration monitoring for utilities is ongoing. Utilities which may require monitoring are identified in the CIAR/GIMP process. Those utilities are then assessed for vibration impact using the FTA assessment method, taking into account the distance between the activities and the vibration of the construction activity. The applicable limits are outlined in SP-F-1201 and OPSS 120, and while those specifications are for blasting activities, their applicable limits are being extended to general construction activities. Any non-city utilities are assessed against the utility owner's vibration limits for nearby construction activities.

The assessment is used to guide construction on the acceptability of activities, and also will propose a monitoring plan to record the vibration which reaches the utility location. Due to the constraints of working construction sites, monitoring locations cannot be pre-prescribed. This monitoring will be released to the city weekly in a Utility Vibration Monitoring Report.

4.0 Vibration During Operation Period

4.1 OBJECTIVE

The objective of this section is to monitor vibration during the operational period to confirm compliance with the applicable vibration specifications during the operation of the line.

4.2 APPLICABLE REQUIREMENTS

4.2.1 Reference Documents

In regards with noise produced during Operation period, the Project shall comply with the following documents.

- PA, Schedule 17, Part 8
- US FTA Transit Noise and Vibration Impact Assessment Manual (USFTA-TNVIAM)(2006)

4.2.2 Applicable Limits

Depending on the vibration source, the following limits apply (excerpted from PA, Schedule 17, Part 8, Table 8.2):

Applicable Limits		
Type of noise and vibration source	Receiver	Applicable Limit
Revenue Vehicle passby vibration	Vertical vibration not to exceed 65 VdB re: 1 microinch/sec (0.045 mm/sec)	Vertical vibration not to exceed 65 VdB re: 1 microinch/sec (0.045 mm/sec)
Revenue Vehicle passby vibration	Inside residences and buildings where people normally sleep (e.g. residential buildings, hotels, hospitals); or theatres and auditoriums	Vertical vibration not to exceed 72 VdB re: 1 microinch/sec (0.1 mm/sec)
Revenue Vehicle passby vibration	Inside sensitive institutional buildings and office buildings (e.g. schools, churches and quiet/commercial offices)	Vertical vibration not to exceed 75 VdB re: 1 microinch/sec (0.14 mm/sec rms)

Table 2: Applicable vibration restrictions during operations

5.0 Representative Sensitive Receivers and Baseline

RSR selection and baseline recordings are outlined in “DST ENVIRONMENTAL - NOISE AND VIBRATION CONTROL PLAN - PART A - CONSTRUCTION - OCTOBER 27, 2020.”