global environmental solutions

Ottawa Light Rail Project
Rail Damper Assessment; Noise & Track Decay Rate

City of Ottawa

July 2020
SLR Project No.: 241.10042.00000

OTTAWA LIGHT RAIL PROJECT

RAIL DAMPER ASSESSMENT; NOISE & TRACK DECAY RATE

SLR Project No.: 241.10042.00000

Prepared by
SLR Consulting (Canada) Ltd.
200 – 1620 West 8th Avenue
Vancouver, BC V6J 1V4

for

CITY OF OTTAWA

23 July 2020

Prepared by:

Arthur Küpper, P.Eng.
Senior Acoustical Engineer

Briony Croft, Ph.D., P.Eng.
Principal

Reviewed by:

LICENSED PROFESSIONAL ENGINEER
B. E. CROFT
100547716
PROVINCE OF ONTARIO

23 Jul. 2020

Briony Croft, Ph.D., P.Eng.
Principal

CONFIDENTIAL

Distribution: Electronic to City of Ottawa

EXECUTIVE SUMMARY

In 2019 during commissioning of the City of Ottawa Light Rail Project, and following noise complaints by residents, a series of measurements were undertaken to determine if the noise levels at 215 Parkdale complied with the Project Agreement specified noise criteria, applicable at ground level in the outdoor amenity area. The 2019 investigation indicated that the noise levels during normal operations were expected to be in compliance with the PA criteria, but also recommended further measurements to quantify noise at upper levels of the building, and investigation of noise control options.

In March 2020, rail dampers were installed on the City of Ottawa LRT Confederation Line slab track areas including adjacent to the residential apartment building at 215 Parkdale Avenue. Rail dampers are a mitigation measure designed to reduce noise levels radiated from steel rails. This report describes measurements undertaken before and after the rail dampers were installed, the measurement procedures, the baseline behaviour of the track, the effect of the rail dampers on the track behaviour, and the resulting change in rail noise emissions.

The measurements described in this report were undertaken with three objectives:

1. To quantify the effect of the rail dampers.
2. To quantify OLRT noise at the upper levels of 215 Parkdale Avenue, which represent the most noise-affected residences overlooking the tracks.
3. To verify compliance with the PA noise criteria, applicable outdoors at ground level.

Covid-19 restrictions prevented immediate measurement of the noise benefit due to the rail dampers at the upper levels of 215 Parkdale, and delayed measurements to characterize the rail damper effects by two months. These delays resulted in conditions that were not directly comparable across the baseline and damped track scenarios. The data indicates that an increase in temperature may have increased noise, somewhat obscuring the rail damper effect. However, the effect of the rail dampers has been inferred by comparing and cross-referencing data from the various measurements. Differences in speed between individual train passby events depending on train mode of operation (energy saving, normal or accelerated) were also identified and are discussed in this report.

The rail dampers have had a clear effect on noise emissions, particularly at frequencies around 500 Hz and above which are most relevant to the human response to audible noise. The observed rail damper effect on the track matches expectations. The immediate effect of the rail dampers on noise was measured to be a 3 dBA reduction in overall noise levels at a location close to and overlooking the tracks, and a 4.5 dBA reduction in overall noise levels measured in the 215 Parkdale ground level out-door amenity area. It is estimated that a 5 dB reduction or possibly slightly more has been achieved at the most affected residences at the upper floors of the building.

The OLRT noise levels at the upper levels of 215 Parkdale have been quantified. The noisiest events (after installation of the rail dampers, in warmer weather) have maximum passby noise levels around 79 dBA at this location, on average the passby maximum noise level is 78 dBA.

The measured noise levels outdoors at ground level verify the conclusion of the 2019 study that the noise levels comply with the PA noise criteria, both with and without the rail dampers. With the rail dampers at this location the 16-hour daytime equivalent average noise level is 54 dBA.

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

In 2019 during commissioning of the City of Ottawa Light Rail Project (OLRT) noise complaints were made by residents. SLR Consulting (Canada) Ltd (SLR, formerly Novus) was asked to measure noise associated with operation of the system. The objective of the 2019 measurements was to determine if the noise levels at 215 Parkdale were in compliance with the noise criteria applicable to the OLRT, as described in Schedules 15 and 17 of the Project Agreement (PA). The 2019 investigation indicated that the noise levels during normal operations were expected to be in compliance with the PA criteria, applicable at ground level in the outdoor amenity area. Further investigation of noise control options was also recommended, along with additional noise monitoring during normal operations to quantify noise levels at an upper level apartment representative of the most noise-affected part of the building, overlooking the tracks.

The recommended mitigation measures were rail grinding to reduce surface roughness and hence noise, and rail dampers. Rail dampers are a noise mitigation measure designed to reduce sound levels radiated from steel rails. Rail grinding was completed later in 2019, and rail dampers were installed in March 2020.

This report describes measurements to characterize and quantify the noise benefit achieved by the rail dampers, including track decay rate and measurements of noise on an upper level balcony at 215 Parkdale. The noise levels at the balcony are included to assess the effect of the rail dampers and quantify the residual mitigated noise level. Although noise levels are higher at the upper levels of the building than at ground level, the PA criteria do not specify a noise limit applicable at the upper levels of buildings.

Measurements were undertaken both before (baseline) and after the rail dampers were installed. This report outlines the measurement procedures, the baseline dynamic behaviour of the track, the effect of the rail dampers on the track behaviour, and the resulting change in rail noise emissions.

Both noise and track decay rate measurements were affected by restrictions associated with Covid-19, which coincided with the completion of damper installation. These constraints necessitated completion of some of the post-installation measurements two months later than originally planned. The influence of the delay on measurement results is discussed in this report.

2.0 TRACK DECAY RATE

2.1 Introduction to Track Decay Rate

Track decay rate (TDR) measurements are a standardized technique used in railway acoustics to characterize the properties of a track in relation to its noise emissions. The standard describing these measurements is EN 15461:2008+A1:2010 *Railway applications – Noise emission – Characterisation of the dynamic properties of track sections for pass by noise measurements*.

The TDR is a useful measurement to quantify the effect of noise mitigation measures such as rail dampers. The vertical TDR is closely related to railway noise emissions. A low vertical TDR means that the rail is free to vibrate along its length when a train passes by, and this relatively undamped (free) vibration of the rail correlates to higher noise emissions. Increasing the TDR reduces the vibration of the rail, and hence reduces noise emissions in the frequency range in which TDR is increased.

2.2 Track Decay Rate Measurement Methodology

TDR measurements were undertaken on 16 March 2020 (baseline) and 18 May 2020 (with dampers). Track is AREMA standard 115RE rails, supported by the Delkor Alt 1 RF191 baseplate-type fasteners spaced at 0.75 m intervals. Actual spacing was measured on site with only minor variations from the nominal spacing. Air temperatures during the baseline measurements were -12°C. During the damped TDR measurements two months later, the air temperature was 13°C (25 degrees warmer) with rail temperatures expected to be similar.

Frequency Response Function (FRF) measurements were recorded in the vertical and lateral directions on one rail of each of the two tracks, for the baseline and with dampers. Identical reference response positions were used for the baseline and damped scenarios. The reference response points used on both rails were east of the Parkdale Road over-bridge (track reference 98 492A and 98 492B). The reference response points used were between representative fasteners, more than 5 m from welds and more than 40 m from joints as required by the standard.

At each response location, two accelerometers (model PCB 352C68) were attached to the rail head using magnetic mounts, with one accelerometer oriented in the vertical direction and one in the lateral direction, as illustrated in Figure 1. An instrumented hammer (model PCB 086C03) with hard stainless steel tip was used to excite the rail at the network of points recommended by the standard, reproduced in Figure 2. Impacts extended out to 78 fasteners to the east of the reference point, ie almost 60 m in both the baseline case and in the damped case.

Figure 1 Accelerometers attached to rail at response location

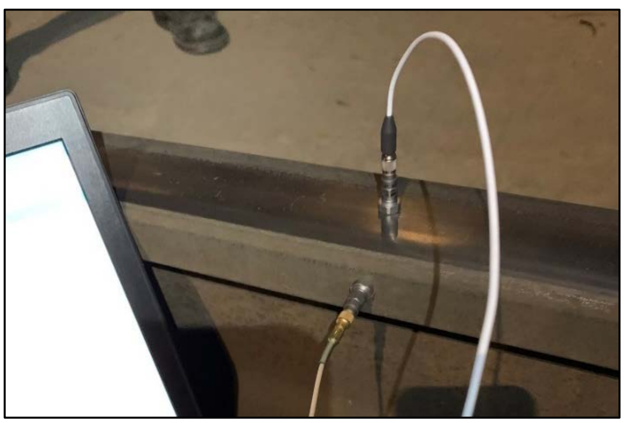
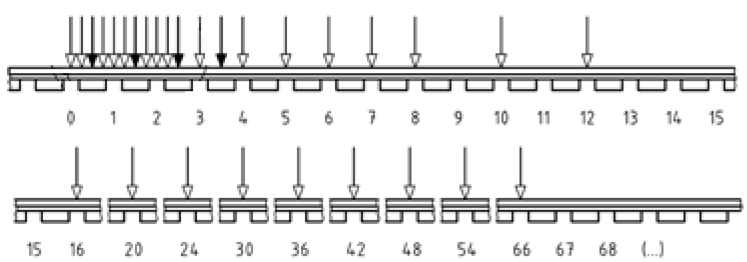


Figure 2 Standard hammer impact locations



SLR utilised LMS SCADAS data acquisition equipment and Test.Xpress analysis software to record the time domain force and acceleration data, as well as calculate accelerances and coherence for review on site. The sampling frequency was 20.48 kHz. 10 impacts (excluding any double-hits) were identified from the peaks in the hammer trace. These peaks and the associated decay were then extracted for analysis following the method described in the standard.

2.3 TDR Results

Table 1 provides the numerical values of TDR as calculated using the approach defined in the standard. The measured vertical TDRs for the baseline and damped scenarios are shown in Figure 3. The measured lateral TDRs for the baseline situation are shown in Figure 4.

Table 1 TDR results (dB/m)

1/3 Octave Band Centre Freq. (Hz)	100	125	160	200	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
VERTICAL TDRs																		
Rail 1 Baseline	1.5	2.7	1.5	1.2	1.0	0.7	0.6	1.0	1.4	1.2	0.4	0.5	0.7	3.2	2.9	7.5	3.6	22.7
Rail 2 Baseline	6.6	3.8	2.1	2.0	0.7	0.5	0.7	1.0	1.4	0.9	0.4	0.8	1.3	3.7	2.2	5.7	3.4	14.2
Rail 1 Damped	1.6	0.6	0.5	0.6	0.5	0.5	0.7	1.6	4.6	2.4	3.9	4.2	6.4	7.9	5.3	13.9	17.1	23.3
Rail 2 Damped	3.9	0.9	0.8	0.4	0.4	0.5	0.9	2.5	5.2	2.6	3.4	5.7	5.8	8.1	3.6	6.9	12.4	20.5
Average Baseline	4.1	3.2	1.8	1.6	0.8	0.6	0.7	1.0	1.4	1.0	0.4	0.7	1.0	3.4	2.6	6.6	3.5	18.4
Average Damped	2.7	0.8	0.7	0.5	0.4	0.5	0.8	2.1	4.9	2.5	3.7	4.9	6.1	8.0	4.5	10.4	14.8	21.9
LATERAL TDRs																		
Rail 1 Baseline	2.4	1.6	1.3	1.2	1.6	1.1	1.3	1.5	5.6	2.6	1.4	0.5	0.5	1.3	2.4	2.9	5.1	3.8
Rail 2 Baseline	3.1	1.7	1.1	1.7	1.9	0.9	1.2	3.6	3.5	2.1	1.5	0.6	0.4	1.5	2.5	3.3	6.1	3.7
Rail 1 Damped	0.6	0.5	0.4	1.2	1.6	1.9	3.6	6.4	9.9	3.6	4.3	4.2	3.7	6.8	8.3	6.6	9.5	6.0
Rail 2 Damped	0.7	0.3	0.7	1.9	1.4	1.2	6.6	14.3	4.9	3.2	4.4	4.2	3.7	7.6	9.9	6.5	10.6	8.1
Average Baseline	2.7	1.7	1.2	1.4	1.7	1.0	1.2	2.5	4.5	2.3	1.5	0.5	0.5	1.4	2.4	3.1	5.6	3.8
Average Damped	0.7	0.4	0.6	1.5	1.5	1.6	5.1	10.3	7.4	3.4	4.3	4.2	3.7	7.2	9.1	6.6	10.0	7.1

Figure 3 Vertical TDRs

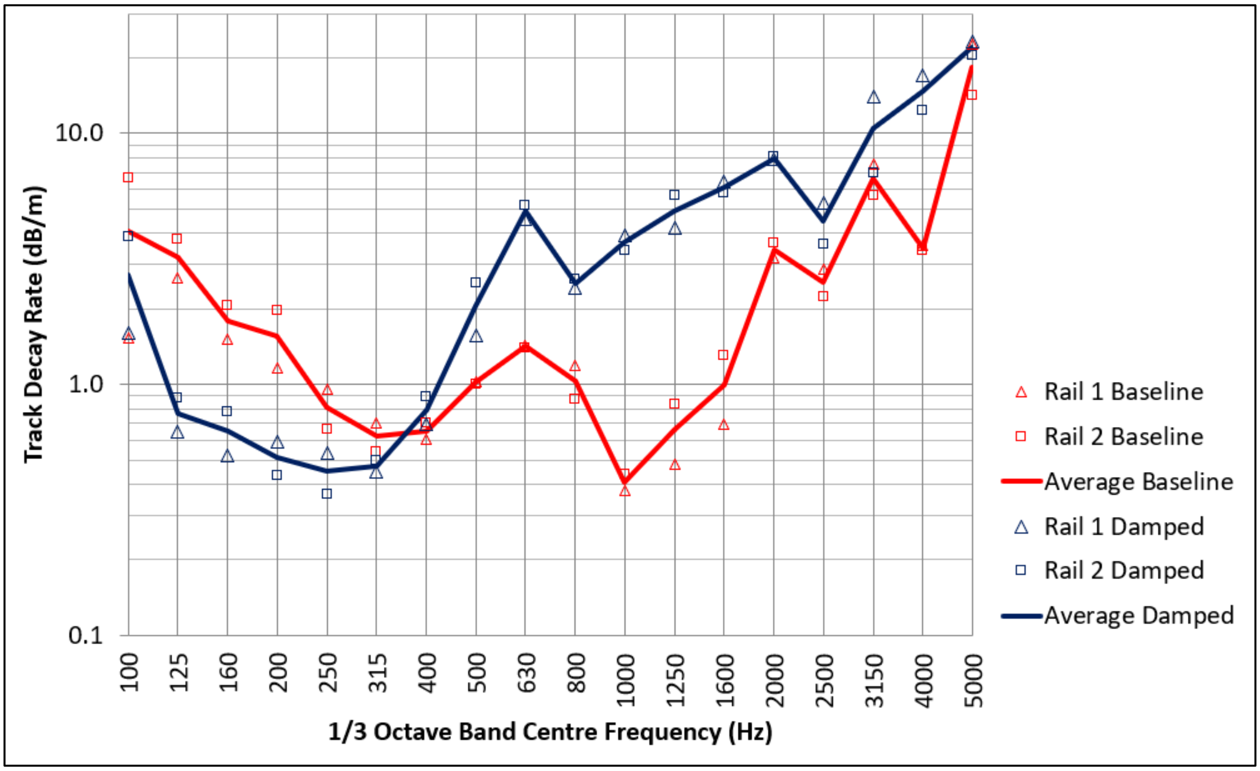
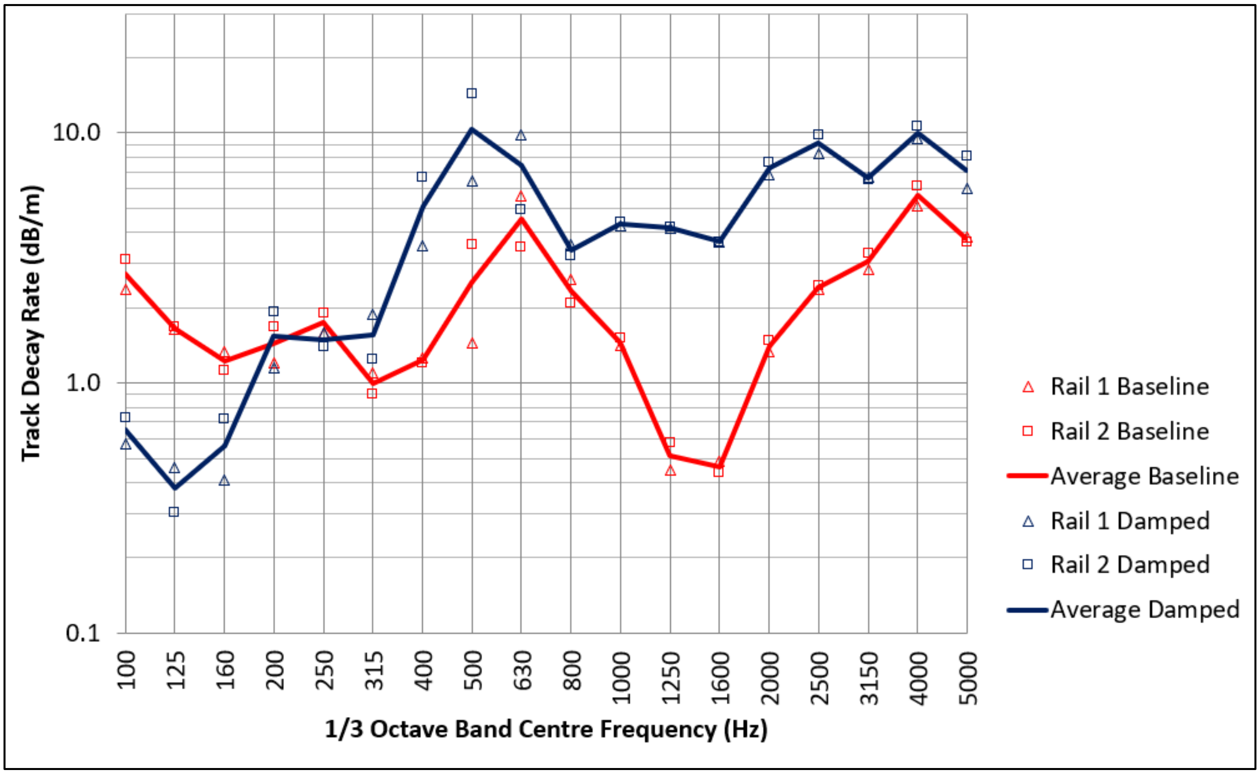


Figure 4 Lateral TDRs



2.4 TDR Discussion

A 25 degree temperature difference between the baseline and damped cases is significant in relation to TDR measurements since it changes the behaviour of rubber elements of the rail fasteners. In a study on the effect of temperature on railway noise from ballasted track with natural rubber rail pads[1], a 3-4 dB increase in noise was observed as temperatures increased from 0°C up to 35°C, with corresponding temperature effects in the TDR across a broad frequency range. The increase in noise was attributed to reductions in stiffness and loss factor of the natural rubber. The Ottawa track-form at this location is slab track rather than ballasted, and uses HDPE rail pads which are expected to be less sensitive to temperature than natural rubber pads. However, the Delkor Alt 1 fastening system does incorporate a rubber baseplate pad so some effects of a 25° change in temperature are expected, especially at frequencies below 400 Hz where the baseplate pad stiffness effects dominate the TDR.

For this project, the baseline TDR measurements were taken in cold conditions (-12°C) whereas the damped track measurements were taken in milder conditions (13°C). When measurements of the effect of rail dampers are collected without a change in temperature, it is normal to see the effects of rail dampers increasing the TDR at frequencies of around 400 Hz and above, while there is no change at lower frequencies where the rail dampers do not have an effect. In this case, both vertical and lateral results show a decrease in TDR at frequencies below 400 Hz in the damped track measurements. Since there is no mechanism for the addition of a rail damper to reduce the TDR, this reduction in TDR at low frequency is attributed to temperature effects. By delaying the damped TDR measurements to a warmer time, some of the increase in TDR due to the dampers is likely to have been masked by the reduction in TDR due to increasing temperature.

Notwithstanding these temperature effects, the TDR measurements do show that rail dampers have increased the TDR in the target frequency range, above 400 Hz, and the resulting damped TDR results are representative of the track at milder temperatures. The damped TDR results indicate that the rail dampers are performing as intended.

3.0 NOISE EMISSIONS

3.1 Introduction to Noise Measurements

The noise measurements undertaken have three objectives:

1. To quantify the effect of the rail dampers on OLRT noise levels.
2. To quantify noise at the upper levels of 215 Parkdale Avenue, which represent the most noise-affected residences overlooking the tracks.
3. To verify compliance of noise levels with the PA criteria, applicable at ground level in the outdoor amenity area.

In relation to the third objective above, the 2019 measurements undertaken during commissioning of the system indicated compliance with the PA criteria was likely. Since during the commissioning period there was some variation in LRT speeds and lengths, this additional check is included to verify the 2019 findings still apply with normal operations.

[1] Squicciarini, G., Thompson, D.J., Toward, M.G.R., and Cottrell, R.A. The effect of temperature on railway rolling noise. Proc. IMechE Part F: J Rail and Rapid Transit 2016, Vol. 230(8) 1777-1789.

3.2 Noise Evaluation Parameters

This assessment uses two A-weighted parameters to quantify the sound levels during an LRV passby for the purpose of assessing the effect of the rail dampers:

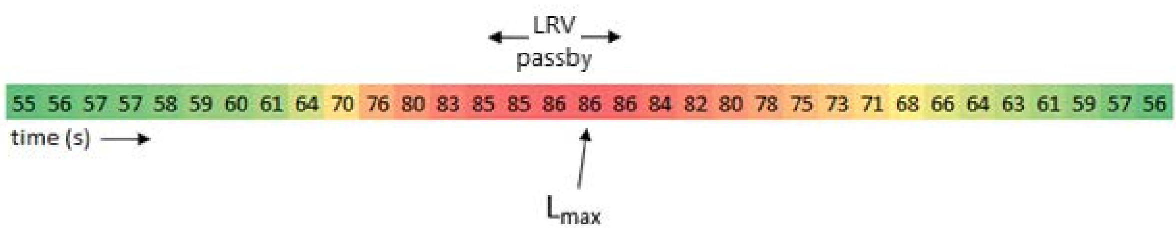
Sound Exposure Level (SEL) - the total acoustic energy contained during an individual train passby event, normalized to a 1-second period.

Maximum Sound Level (L_{Amax}) - the maximum 1 second sound level during a passby event.

The A-weighted SEL is used to calculate overall energy equivalent noise levels (L_{Aeq} noise levels) due to all train traffic in a particular time period, such as the 16 hour day ($L_{Aeq16hr}$). The $L_{Aeq16hr}$ is the noise parameter used to assess compliance with Project Agreement (PA) noise criteria.

The L_{Amax} correlates well to the loudness of noise perceived by people from an intermittent source. It identifies LRV sound levels independent of background noise sources. Figure 5 below shows the changing sound levels as an LRV approaches and passes by a microphone located on the edge of the cutting (location 1). The values represent the maximum sound level measured each second in decibels (dBA) with the maximum sound level for the entire passby identified. Each LRV is typically directly opposite the microphone for about 5 seconds (the noisiest part of the event), with build-up and decay of noise on either side.

Figure 5 Sound Level Time History for a Typical LRV Passby (dBA)



3.3 Noise Measurement Methodology

SLR performed sound level measurements both before and after rail damper installation in accordance with ISO 1996-2:2007 *Acoustics – Description, measurement and assessment of environmental noise; Part 2 – Determination of environmental noise levels.*

The sound level meters used were Larson Davis model 824 and 831 meters which comply with the Class 1 specification outlined in IEC 61672-1:2002. The meters were calibrated both before and after each measurement period with a Larson Davis CAL150 calibrator and have current laboratory certification. The microphones were positioned at a height of 1.5 m above the ground or floor and a microphone windscreen was used to reduce the effects of wind-induced noise.

Measurements were conducted at four positions at the 215 Parkdale Avenue apartment building as shown below in Figure 6 and detailed in Table 2 including photos of the instrumentation setup. Both the baseline measurements and post-installation measurements were conducted at the same locations to ensure a direct comparison of results.

Figure 6 Sound Level Measurement Positions - Overview

Table 2 Sound Level Measurement Positions - Details

Position 1: Between train line and footpath. 	**Position 2:** Inside the courtyard of 215 Parkdale Ave., at ground level. 
Position 3: Upper level of the parking structure 	**Position 4**: On the balcony of a 9th floor apartment facing the train line. 

Sound level measurements summarized in this report were conducted over four separate survey periods; two of which occurred before the damper installation (June 2019 and March 2020) and two after the damper installation (March and May 2020) as detailed below in Table 3.

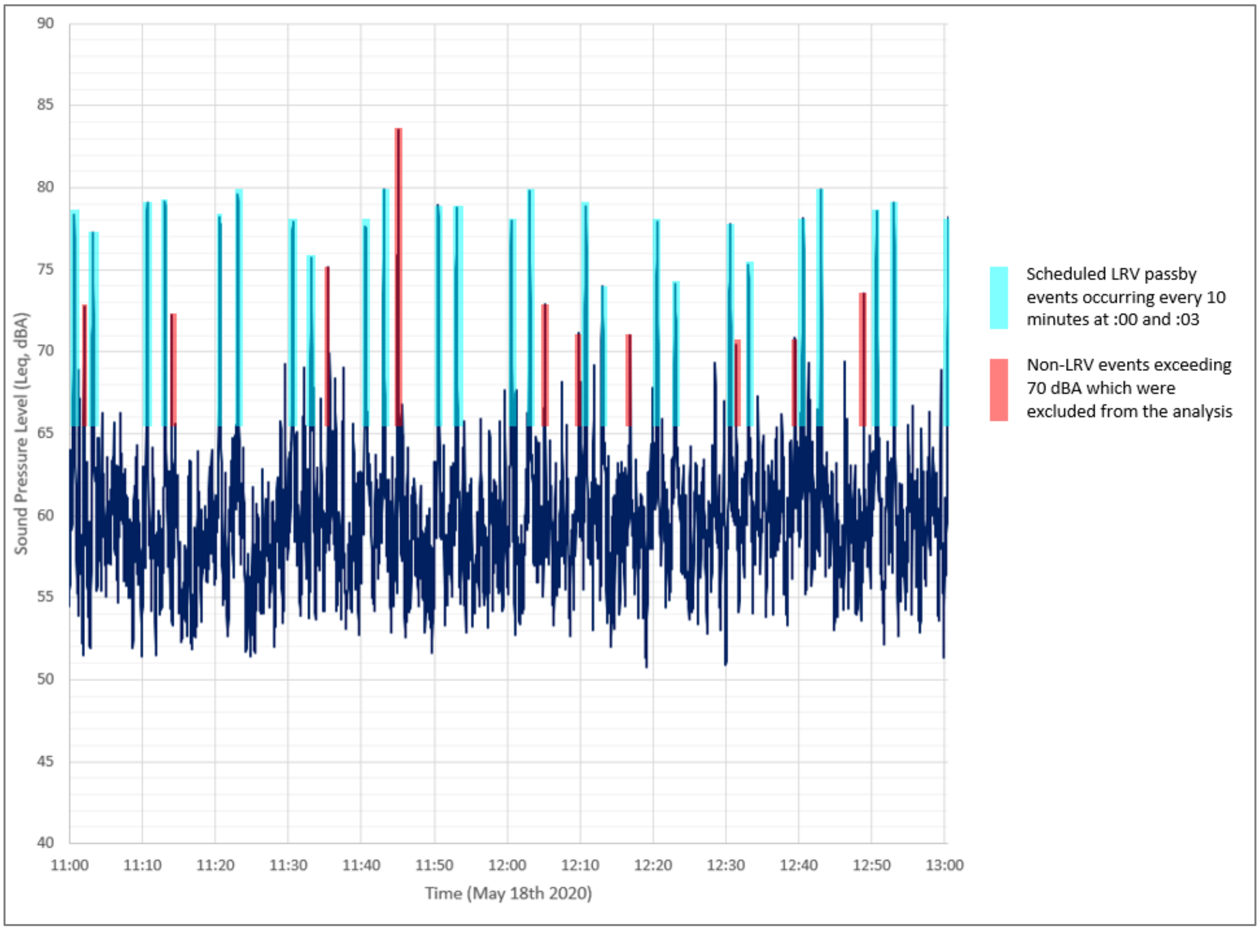
Table 3 Sound Level Survey Details

Survey Dates	Damper Condition	Measurement Positions	Survey Notes
June 3-4, 2019	Baseline – 9 months before damper installation	3	• Un-attended logging conducted over 19 hours beginning at 5 pm on June 3rd. • Measurements during OLRT commissioning, some vehicles were shorter trains than typical 2020 operations.
March 18-19, 2020	Baseline – immediately before damper installation	1, 2, 3, & 4	• Attended measurements at positions 1, 2, & 3 conducted on March 18th for 1-2 hours at each location. • At position 3 trains from both directions were passing at or near the same time, for this location data from 2019 measurements was used as the baseline. • Un-attended logging conducted at position 4 over 20 hours beginning at 6 pm on March 18th.
March 24, 2020	Immediately after damper installation	1, 2, & 3	• Attended measurements at positions 1, 2, & 3 for 1-2 hours at each location. • As a Covid-19 precaution, measurements were not conducted at position 4 (private balcony) during this survey.
May 17-18, 2020	Two months after damper installation	1, 4	• Attended measurements at position 1 for around 3 hours, as a check on any changes in the two months since damper installation. • Unattended logging conducted at position 4. 24 hours of data collected commencing 5 pm on May 17th.

The attended measurements of LRV passbys at positions 1, 2, & 3 were analyzed based on field notes. The time, direction and duration of LRV passbys were noted along with any extraneous events (not OLRT passbys). Events with extraneous noise sources were excluded from the analysis and results. Similarly, passby events were excluded from analysis if two trains were present at the same time.

For the unattended measurements at positions 3 and 4, events were identified based on the regular pattern of noise rising above the background level for the duration of LRV passbys. Identified events were cross-referenced with the OLRT schedules and compared with the typical time history of a passby event to ensure that only LRV passby events were assessed. An example of this event analysis is presented below in Figure 7. The figure shows a two-hour window of the time history recorded at position 4 (balcony) on May 18th, 2020. LRV passby events are highlighted in blue and non-LRV events which have been excluded are highlighted in red. In addition to the excluded events, this figure also shows the normal variability in the LRV event sound levels, due to differences in speed and potentially in some cases differences in vehicle wheel condition.

Figure 7 Time History Window at Position 4 Highlighting LRV and Excluded Events



3.4 Discussion of Speed Variation

Some speed variation between different train events was evident in the data collected. The City of Ottawa has indicated that the system has three modes of operation which can result in differences in train speed at 215 Parkdale Avenue. These modes are not scheduled, they relate to headways. For example, the accelerated mode may used at any time on any day if needed to recover from a delay to meet the timetable. The three speed modes and resulting maximum speeds past 215 Parkdale Avenue are as follows:

- Energy Saving Mode – maximum speed 72 km/h
- Normal Mode – maximum speed 81 km/h
- Accelerated Mode – maximum speed 86 km/h

This range of top speeds from 72 to 86 km/h results in approximately 2 dB variation in noise levels. Some trains were also observed operating at slower speeds (measured by timing passby events with a stopwatch). In order to remove speed effects as much as possible from the analysis of the rail damper effects, the analysis of data collected using the balcony noise logger at Location 4 considers the twenty highest speed (noisiest) events in each scenario, in addition to reviewing all events. SLR has verified with the City of Ottawa that the data collected before and after rail damper installation at this location includes trains operating in accelerated mode.

3.5 Noise Emission Results – Overall Passby Noise Levels

A summary of the noise emission results before and after rail damper installation are presented in Table 4 below. At each location, all results shown in Table 4 include train events in both directions. Data was reviewed for each direction separately for the operator-attended measurements. For operator-attended measurements, train speeds were also checked by timing the duration of each passby event. At all locations, the average speeds and noise levels were very similar from trains in both directions and there was no clear trend of higher noise levels for trains on one track over the other track. Therefore, results have been combined in this summary.

Table 4 OLRT Passby noise level results

Scenario	No. of Assessed Passbys	Logarithmic Average SEL (dBA)	Average Lmax (dBA)
LOCATION 1			
Baseline (March 2020)	41	94.0	85.8
After damper installation (March 2020)	56	91.0	83.0
After damper installation (May 2020)	33	92.5	84.6
Rail damper reduction (based on March data)	-	-3.0	-2.8
Change in noise level March to May	-	+1.5	+1.6
LOCATION 2			
Baseline (March 2020)	20	79.7	70.6
After Damper Installation (March 2020)	29	75.5	66.0
Rail damper reduction	-	-4.3	-4.6
LOCATION 3			
Baseline before grinding (June 2019)	110	88.5*	80.8
After grinding and damper installation (March 2020)	25	85.2	76.5
Change in noise level 2019 to 2020	-	-3.3*	-4.3
LOCATION 4 – All Events, Variable Speeds			
Baseline (March 2020)	304	89.5	80.5
After damper installation (May)	166	86.6	77.6
Change in noise level	-	-2.9	-2.9
LOCATION 4 – Noisiest 20 Events, Consistent Highest Speeds			
Baseline (March 2020)	20	92.2	83.5
After damper installation (May)	20	87.6	79.2
Change in noise level	-	-4.6	-4.3

* The vehicle length affects the SEL parameter (double length vehicle increases SEL by 3 dB). In June 2019 a mix of single and double length LRTs were operating. Since the length of vehicles in 2020 was consistently double length LRTs, the change in SEL levels is not solely due to rail damper effects. At this location the damper effects can be better seen in the passby maximum noise level parameter which is not affected by train length.

3.6 Noise Emission Results – Noise Time History on Balcony

Time history plots of the recorded sound levels at position 4 on the 9th floor balcony are shown below in Figure 8 and Figure 9. These plots represent the raw data including noise from all sources. In relation to these measurements and figures note that:

- Baseline measurements were collected mid-week whereas damped measurements were completed on a weekend, with resulting differences in OLRT frequency and hours of operation, reflected in the overall number of events analyzed.
- While extraneous events have not been excluded in these figures, most noise events are due to OLRT passbys. The influence of noise from other sources was minimal partly due to reduced road traffic due to Covid-19.
- In the baseline measurements in March, the majority of OLRT noise events appear to become quieter after 9 pm, and increase after 7 am the next day with only a few higher noise events observed. This variation is attributed to train speeds. SLR has verified that the difference in speeds is not timetabled, and both the baseline and damped measurements included trains operating in accelerated mode.
- Temperatures ranged from -3°C up to 5°C during the baseline measurement period.
- During the damped measurements in May, temperatures ranged from around 12-20°C.

Figure 8 Time History Plot of Baseline Survey at Position 4

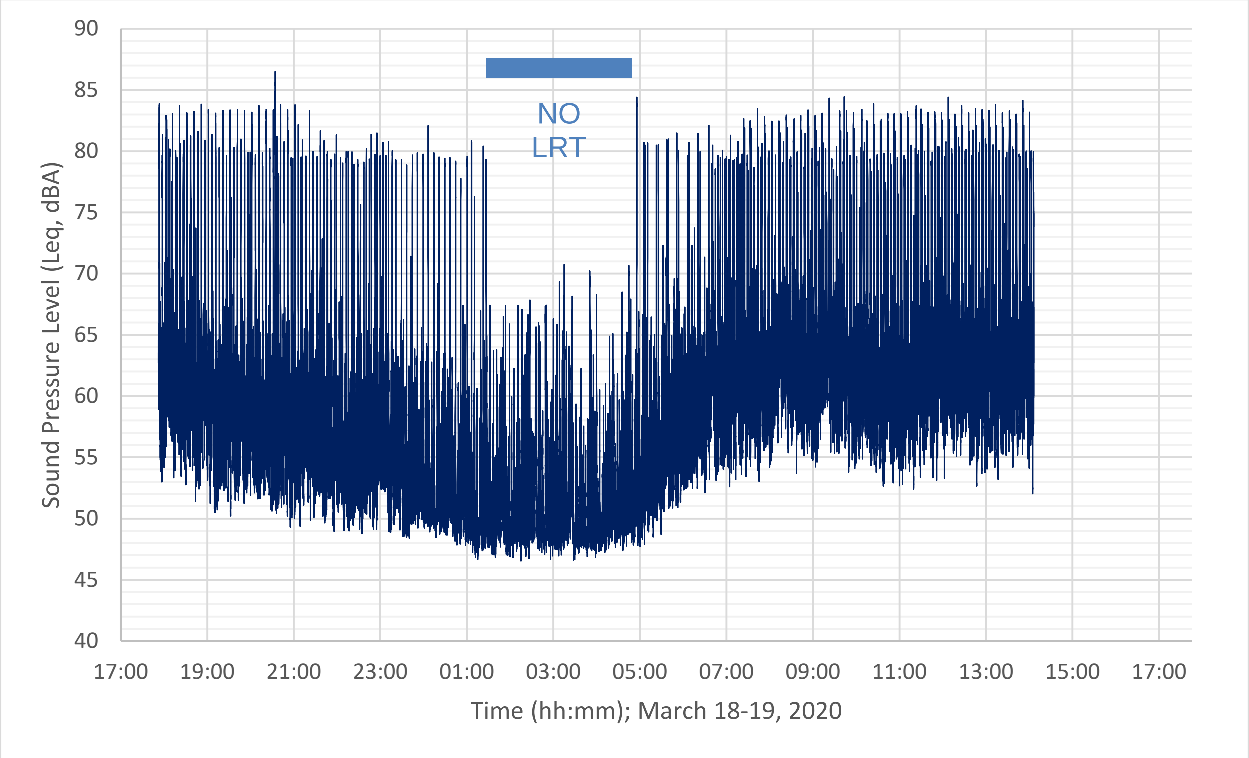
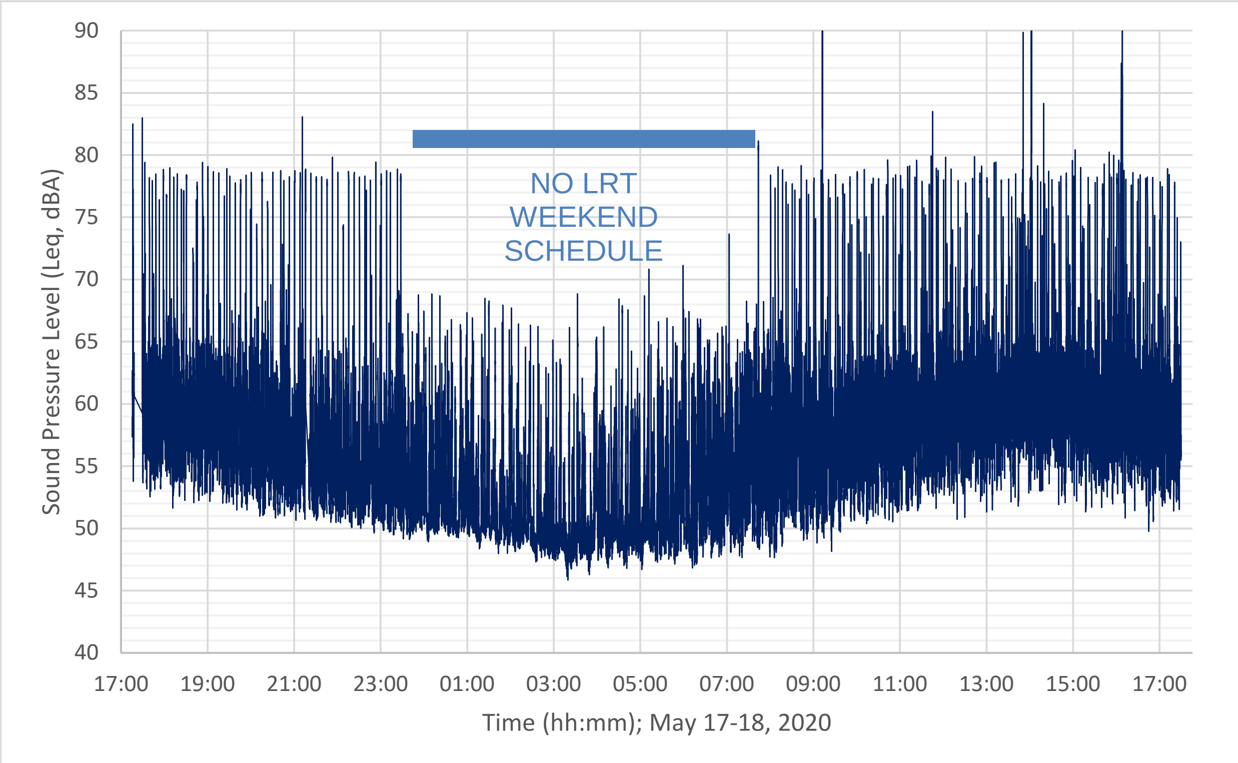


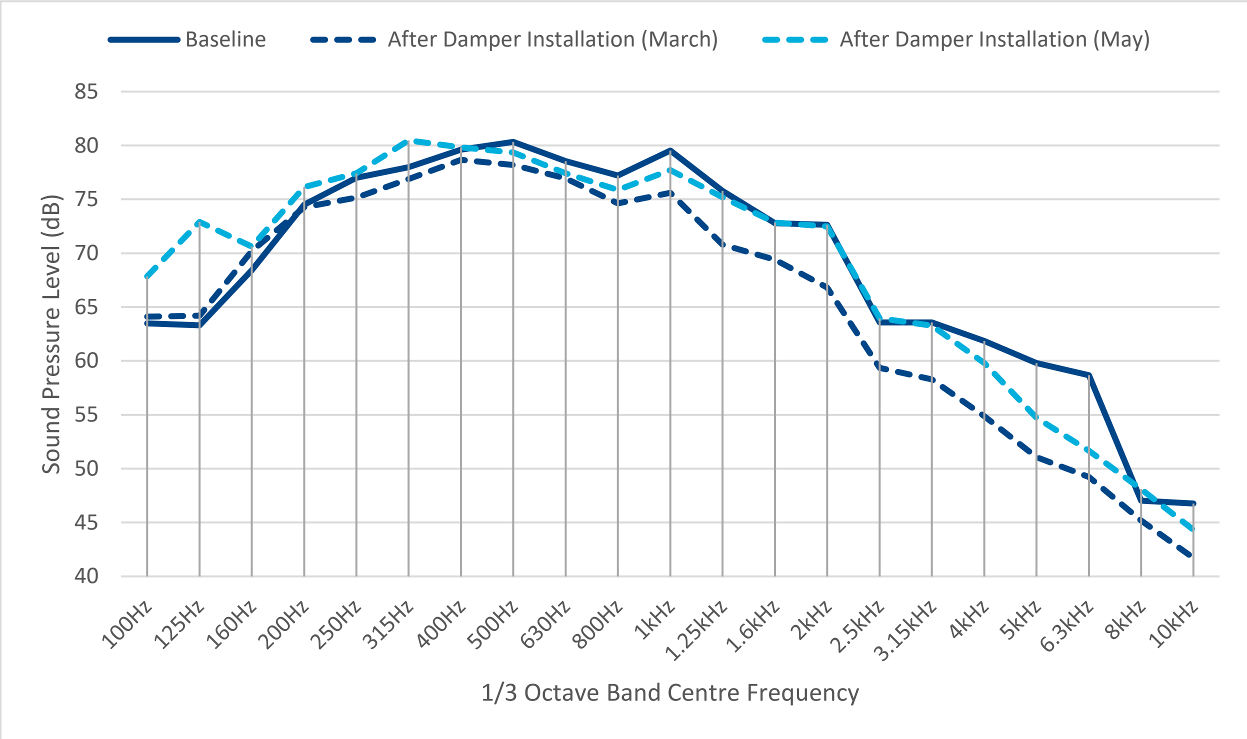
Figure 9 Time History Plot of Post-Damper Survey at Position 4



3.7 Noise Emission Results – Example Spectra

The logarithmically averaged unweighted passby noise spectra from all train events at positions 1 and 4 are presented in Figure 10 and Figure 11 respectively. These locations have direct line of sight to the rails enabling direct assessment of the rail damper effects.

Figure 10 Train Passby Sound Level Spectrums – Location 1



In Figure 10, the effect of the rail dampers is best seen immediately after installation. This shows minimal changes at frequencies less than 200 Hz, where rail dampers are not expected to make a difference since there is no increase in the TDR. There is a small 1-3 dB reduction at frequencies up to 800 Hz, a 5 dB reduction at 1 kHz, and increasing damper effectiveness at higher frequencies. Temperatures were similar for the March baseline and damped measurements, around 2°C during the day.

In the data collected 2 months later, the shape of the spectrum is similar, but noise levels have increased in all frequency bands. Consistent speeds on average are indicated by the consistent spectral shape, since a change in train speed would shift the peaks in the spectrum (eg at 1 kHz) to higher or lower frequencies. The 1.5 dB increase in overall A-weighted noise level at this location from March to May is possibly due to temperature effects[2]. In March the daytime temperature during measurements was around 2°C, this increased to 18°C in May.

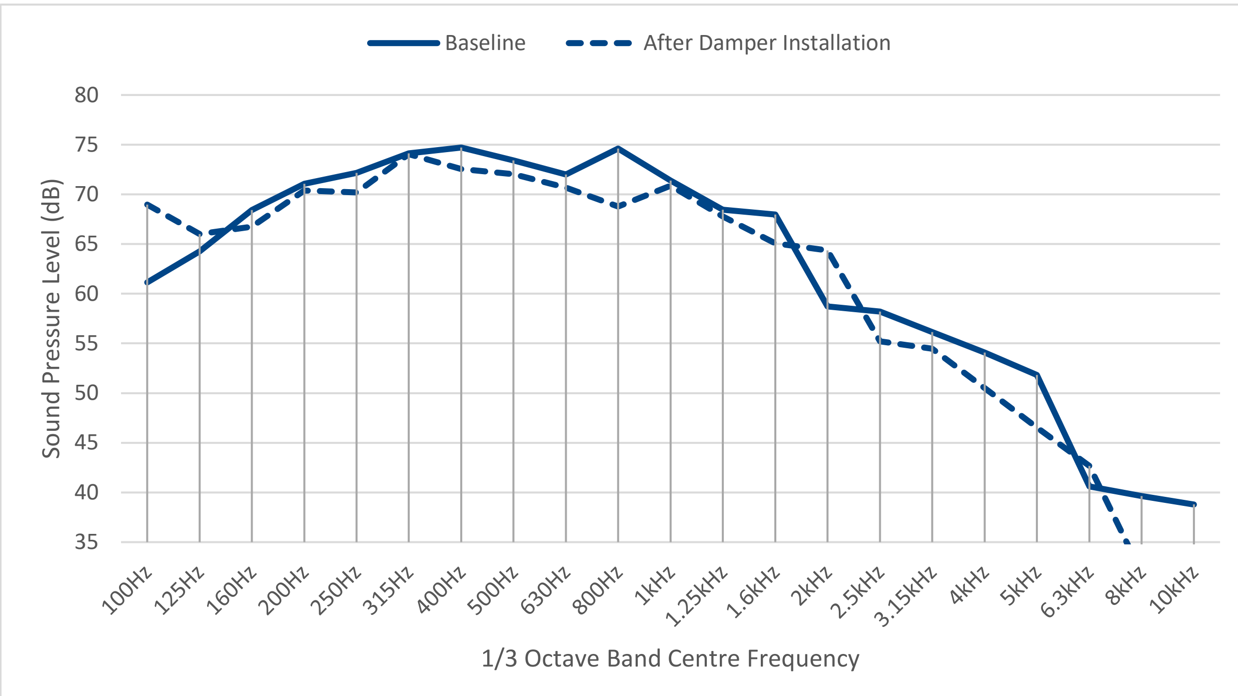
The other potential reason for the increase in noise levels from March to May is increasing rail roughness, if the rails are wearing over time. This cannot definitively be ruled out since rail roughness was not measured (at the time of the baseline the delay in completing the damped measurements was not anticipated). However, based on experience from other rail systems a change in rail roughness is considered less likely to be the cause of the observed OLRT noise increase between March and May than temperature effects. The rail steel used by OLRT is relatively hard and expected to be slow-wearing. A rapidly increasing roughness (within 2 months) is normally associated with changes in noise in specific frequency bands, which was not seen

[2] Squicciarini, G., Thompson, D.J., Toward, M.G.R., and Cottrell, R.A. The effect of temperature on railway rolling noise. Proc. IMechE Part F: J Rail and Rapid Transit 2016, Vol. 230(8) 1777-1789.

here. Instead the increase in noise was observed across a wide range of frequencies and for this reason temperature effects are considered a more likely explanation than a change in rail roughness.

Figure 11 shows the logarithmic average spectral information from all passby events measured on the 9th floor balcony. These data sets were collected around 2 months apart. The time history data indicates that speeds were slower for part of the baseline monitoring period (see Figure 9), but more consistent during the later measurements (Figure 9). The average spectral results show a shift in frequency of peaks in the noise for example from the 800 Hz band up to the 1 kHz band. This indicates somewhat higher average speed in the damped scenario, but this is not possible to quantify without information on the speed of every event.

Figure 11 Train Passby Sound Level Spectrums – Location 4



3.8 Discussion of Rail Damper Effect

At Location 1 on the edge of the cutting overlooking the tracks, measurements undertaken in comparable conditions immediately before and after rail damper installation indicated a noise reduction of around 3 dB.

Location 2 in the outdoor space at 215 Parkdale is set back further from the tracks than Location 1, and does not have direct line of sight to the rails due to the shielding provided by the cutting. At this location measurements undertaken in comparable conditions immediately before and after rail damper installation indicated a noise reduction of around 4.5 dB.

Location 3 on the top of the car park is again set back further from the tracks relative to Location 1, but with a clearer line of sight than Location 2. At this location noise data indicated a 4.3 dB reduction in maximum noise levels from June 2019 to March 2020, this time period included rail grinding, installation of the rail dampers and any temperature effects.

At Location 4 on the balcony, a reduction of 2.9 dB was measured as the average of all events following a 2 month delay, with some indication the average speeds may not be comparable. With reference to measurements at location 1, it is likely that the rail damper reduction immediately after installation was greater than 2.9 dB, with the rail damper effects obscured by increasing temperature and potentially higher average speeds.

An estimate of the rail damper effect on the balcony for comparable speeds has been obtained from examining only the noisiest twenty train events in each data set, assuming these are all accelerated mode trains at the highest speeds. This dataset indicates a passby noise reduction due to the rail dampers of at least 4.3 dB at Location 4 on the balcony, neglecting temperature effects which counteract the damper benefit.

Overall, the delays in completing the damped measurement and varying speed of every individual passby event means that the current calculated reduction contains uncertainty. However, it is estimated the rail dampers have reduced noise levels from the highest speed events by approximately 5 dBA at the upper levels of the building, or possibly a little more when temperature effects are considered.

The observed rail damper effect appears to be greater at the measurement locations further away from the tracks (3 dB effect at location 1, compared to 4-5 dB or a little more at other locations). It is hypothesized that this may be due to the relative noise contributions generated from the rails and from the baseplate rail fasteners. The attenuation of noise over distance is different for point and line sources, with noise from point sources attenuating more rapidly (6 dB with doubling of distance) than from line sources (3 dB with doubling of distance). The baseplate fasteners might be represented by point sources, whereas the rails are line sources. It is possible that noise from the baseplates has a stronger influence on the overall measured levels closer to the tracks, while at the upper levels of the building the rail noise dominates. The rail dampers primary effect is to reduce the rail noise component which is the main source of the noise at the residential facades.

Recent work by Hima et al[3] investigating noise from similar slab track types supports the hypothesis of baseplate noise contributing to the overall level close to the source. They identify that the source sound power level of the baseplate fastener components can be comparable to or higher in overall level than the source sound power level of the rail. The baseplate fasteners particularly contribute to radiated noise at lower frequencies, less than 500 Hz, while noise from the rail dominates at higher frequencies.

In this situation, modifications to the baseplate fastener components might reduce the noise from this component and the overall noise measured closest to the tracks, but the benefit at the upper levels of the building would be minimal. For this reason, changes to the baseplate fasteners are not recommended.

[3] Hima, B.S., Thompson, D.J., Squicciarini, G., Ntotsios, E. and Herron, D. Estimation of track decay rates from laboratory measurements on a baseplate fastening system. Proceedings of 13th International Workshop on Railway Noise, 16th-20th September 2019, Ghent, Belgium.

3.9 Verification of Compliance with PA Noise Criteria

The 2019 SLR noise investigations identified that compliance with the PA noise criteria was likely. This conclusion was reached by calculation of an overall daytime outdoor noise level ($L_{Aeq16hr}$) due to normal train operations for the outdoor amenity area of 215 Parkdale Avenue, for comparison with the project criteria. The $L_{Aeq16hr}$ noise level was calculated by:

- Determining the average sound energy (SEL) for a single train passby event, then
- Calculating the overall daytime train noise contribution based on the maximum number of trains between 7:00 am and 11:00 pm (up to 431 per day, with less trains on weekends).

On the basis of the 2019 commissioning measurements, the 16 hour daytime equivalent average noise levels ($L_{Aeq16hr}$) in the ground level outdoor amenity area was calculated to be 59 dBA, or up to 61 dBA in a worst case scenario calculated from the single noisiest event observed. Repeating this calculation using the same number of trains with the 2020 measured SEL results in $L_{Aeq16hr}$ of 58 dBA in the baseline situation (before installation of the rail dampers), and $L_{Aeq16hr}$ of 54 dBA in the mitigated scenario. This confirms the conclusion that the noise levels in the ground level outdoor area of 215 Parkdale Avenue comply with the PA noise criteria.

The PA noise criteria are not applicable to the noise at upper levels of the building, however the 16 hour daytime equivalent average noise levels ($L_{Aeq16hr}$) on the balcony can be calculated in the same way. At this location the $L_{Aeq16hr}$ noise level in the mitigated “with damper” scenario is 65 dBA.

4.0 CONCLUSIONS

The measurements described in this report were undertaken with three objectives:

1. To quantify the effect of the rail dampers.
2. To quantify OLRT noise at the upper levels of 215 Parkdale Avenue, which represent the most noise-affected residences overlooking the tracks.
3. To verify compliance of noise levels with the PA criteria, applicable outdoors at ground level.

Covid-19 restrictions prevented immediate measurement of the noise benefit due to the rail dampers at the upper levels of 215 Parkdale, and delayed the damped track TDR measurements. These delays resulted in significant differences in temperature which affected the noise and TDR results. Notwithstanding that temperature effects counteract the damper effects (increasing temperature increases noise), the effect of the rail dampers has been inferred by comparing and cross-referencing data from the various measurements.

The rail dampers have had a clear effect on the TDR and noise emissions, particularly at frequencies around 500 Hz and above which are most relevant to the human response to audible noise. The observed rail damper effect on TDR matches expectations. In relation to noise emissions, the immediate effect of the rail dampers was measured to be a 3 dB reduction in overall noise levels at a location close to and overlooking the tracks, and a 4.5 dB reduction in overall noise levels measured in the 215 Parkdale ground level out-door amenity area. The delays in measurement, temperature effects and some observed differences in speed mean the results are less conclusive for the effect of the rail dampers on the upper levels of 215 Parkdale, but it is estimated that at least a 5 dB reduction was achieved.

The maximum noise levels during OLRT passbys at the upper levels of 215 Parkdale have been measured. The noisiest events (after installation of the rail dampers, in warmer weather) have maximum noise levels around 79 dBA at this location, on average the passby maximum noise level is 78 dBA.

The measured noise levels outdoors at ground level verify the conclusion of the 2019 study that the noise levels comply with the PA noise criteria.

5.0 STATEMENT OF LIMITATIONS

This report has been prepared and the work referred to in this report has been undertaken by SLR Consulting (Canada) Ltd. (SLR) for the City of Ottawa, hereafter referred to as the “Client”. It is intended for the sole and exclusive use of the Client. The report has been prepared in accordance with the Scope of Work and agreement between SLR and the Client. Other than by the Client and as set out herein, copying or distribution of this report or use of or reliance on the information contained herein, in whole or in part, is not permitted unless payment for the work has been made in full and express written permission has been obtained from SLR.

This report has been prepared in a manner generally accepted by professional consulting principles and practices for the same locality and under similar conditions. No other representations or warranties, expressed or implied, are made.

Opinions and recommendations contained in this report are based on conditions that existed at the time the services were performed and are intended only for the client, purposes, locations, time frames and project parameters as outlined in the Scope or Work and agreement between SLR and the Client. The data reported, findings, observations and conclusions expressed are limited by the Scope of Work. SLR is not responsible for the impacts of any changes in environmental standards, practices, or regulations subsequent to performance of services. SLR does not warranty the accuracy of information provided by third party sources.

N:\Guelph\Jobs\2010\10-0042 City Of Ottawa Light Rail Program\Reports And Deliverables\
20200528 Rail Damper TDR And Noise\215 Parkdale Damper Results 2020-07-23.Docx

Appendix A

Relevant Project Agreement Noise Criteria

RELEVANT PROJECT AGREEMENT NOISE CRITERIA

The noise criteria applicable to the OLRT are described in Schedules 15 and 17 of the Project Agreement (PA) with reference to current guidelines and project impact assessments.

Airborne noise criteria

The airborne noise criteria applicable to the OLRT as it passes the apartments at 215 Parkdale Avenue can be found in Novus report entitled *City of Ottawa Light Rail Project, University of Ottawa Campus and Parkdale Avenue / Merton Street Sections, Noise and Vibration Impact Assessment,* dated September 23, 2011 (the “2011 Novus Report”). This report and the City of Ottawa’s Environmental Noise Control Guidelines are specifically referenced in the PA. The following text describing the airborne noise criteria from the City of Ottawa noise guidelines is reproduced from the 2011 Novus Report:

> In evaluating potential noise impacts the applicable criteria are the City of Ottawa’s *Environmental Noise Control Guidelines*, dated 2006. Section 2.0 of the guidelines deals with noise impacts from capital works projects, including surface transportation projects such as the OLRT.
>
> The guidelines apply to receptors within 250 m of the corridor. The applicable sound level criteria (quoted from the Guideline) are:
>
> a) *The guideline applies to outdoor levels in the outdoor living area only.*
>
> b) *The applicable sound level descriptor is the A-Weighted Equivalent Sound Pressure Level, L_{eq} in dBA established for the daytime period from 07:00 to 23:00; also referred to as L_{eq} 16hr, dBA.*
>
> c) *The objective for outdoor sound levels is the higher of the L_{eq} 16hr 55 dBA or the L_{eq} 16hr ambient sound level that may prevail at the start of project construction (referred to as the "established ambient").*
>
> d) *The significance of a noise impact, also referred to as the 'excess' or 'change', will be quantified by comparing the future sound levels with the higher of L_{eq} 16hr 55 dBA and/or the established ambient sound level.*
>
> e) *Mitigation will attempt to achieve sound levels as close to the objective level as is technically, economically and administratively feasible.*
>
> f) *The acoustic impact rating, the degree of effort applied and action for mitigation of the noise impact should conform to Table 2.1* (**Table A1** of this appendix).
>
> g) *Where the future sound level exceeds L_{eq} 16hr 55 dBA and the increase in the sound levels above the established ambient exceeds 5 dBA, the City of Ottawa will investigate the feasibility of noise control measures within the right-of-way and introduce appropriate measures such that, where feasible, a minimum attenuation (averaged over the first row of receivers) of 6 dBA can be achieved.*
>
> h) *If the future sound level is greater than L_{eq} 16hr 55 dBA and less than or equal to L_{eq} 16hr 60 dBA and the excess or change in sound level above the established ambient is either:*
>
> - *less than 5 dBA, then no mitigation is required; or,*
> - *exceeds 5 dBA, then the sound level criteria in Clauses a) to f) above will apply at the sole cost of the City and within the City of Ottawa r.o.w.*

i) If the future sound level is greater than L_{eq} 16hr 60 dBA and the excess or change in sound level above the established ambient is less than 5 dBA, the feasibility of noise control measures within the right-of-way will be investigated under the City of Ottawa's Local Improvements policy and guidelines. The barrier(s) will be maintained within the City's r.o.w. The City prefers retrofit sound barrier walls at the flanking ends to be on City owned lands, however if required, property owners at the termination points of the noise abatement wall will be asked to register an easement to the City of Ottawa for the construction and maintenance of a noise wall along a side lot line. The side lot line noise wall will provide protection for the rear yard area of the adjacent property. If the landowner refuses to transfer the easement, the City will not attempt to purchase or expropriate the easement but will delete this section of wall from the noise abatement construction project.

j) Where the dominant noise source is due to transit activities within:

[1] *an LRT or a Transitway terminal,*
[2] *a rail yard facility to accommodate the LRT service yard,*
[3] *or a terminal building containing mechanical systems*

then the City of Ottawa will use the "Stationary Sources" criteria.

k) Alternative noise control measures shall be considered prior to making the decision to use barriers.

Table A1: Table 2.1 of Environmental Noise Control Guidelines

Future Sound Level, L_{eq} 16 hr	Change Above Ambient, dBA	Impact Rating	Mitigation
Greater than 55 dBA and less than or equal to 60 dBA	0-3	Insignificant	None
	3-5	Noticeable	None
	5-10	Significant	Investigate noise control measures and mitigate to achieve retrofit criteria (minimum attenuation is 6 dBA)
	10+	Very Significant	
Greater than 60 dBA	0-3	Insignificant	Investigate noise control measures and mitigate to achieve retrofit criteria (minimum attenuation is 6 dBA)
	3-5	Noticeable	
	5-10	Significant	
	10+	Very Significant	

Established ambient noise level

The established ambient noise level for the outdoor living area of 215 Parkdale Avenue is included in the 2011 Novus Report. The established ambient noise level due to the existing noise sources, including noise from road traffic and the then operational BRT, was L_{eq}16h 70 dBA.

Discussion of criteria as applicable to 215 Parkdale Avenue

In accordance with the PA and current guidelines from the City of Ottawa, airborne noise criteria are only applicable to outdoor living areas. The definition of outdoor living areas in the City of Ottawa guidelines specifically excludes balconies and elevated terraces. Therefore, at 215 Parkdale Avenue the criteria are applied to the ground level outdoor amenity area only.

global environmental solutions

Calgary, AB
200 - 708 11th Avenue SW
Calgary, AB T2R 0E4
Canada
Tel: (403) 266-2030
Fax: (403) 263-7906

Edmonton, AB
6940 Roper Road NW
Edmonton, AB T6B 3H9
Canada
Tel: (780) 490-7893
Fax: (780) 490-7819

Grande Prairie, AB
9905 97 Avenue
Grande Prairie, AB T8V 0N2
Canada
Tel: (780) 513-6819
Fax: (780) 513-6821

Guelph, ON
105 - 150 Research Lane
Guelph, ON N1G 4T2
Canada
Tel: (226) 706-8080
Fax: (226) 706-8081

Kamloops, BC
8 St. Paul Street West
Kamloops, BC V2C 1G1
Canada
Tel: (250) 374-8749
Fax: (250) 374-8656

Kelowna, BC
107 - 1726 Dolphin Avenue
Kelowna, BC V1Y 9R9
Canada
Tel: (250) 762-7202
Fax: (250) 763-7303

Markham, ON
200 - 300 Town Centre Blvd
Markham, ON L3R 5Z6
Canada
Tel: (905) 415-7248
Fax: (905) 415-1019

Nanaimo, BC
9 - 6421 Applecross Road
Nanaimo, BC V9V 1N1
Canada
Tel: (250) 390-5050
Fax: (250) 390-5042

Ottawa, ON
400 - 2301 St. Laurent Blvd.
Ottawa, ON K1G 4J7
Canada
Tel: (613) 725-1777

Prince George, BC
1586 Ogilvie Street S.
Prince George, BC V2N 1W9
Canada
Tel: (250) 562-4452

Regina, SK
1048 Winnipeg Street
Regina, SK S4R 8P8
Canada
Tel: (306) 525-4690

Saskatoon, SK
620 - 3530 Millar Avenue
Saskatoon, SK S7P 0B6
Canada
Tel: (306) 374-6800

Toronto, ON
4th Floor, 36 King Street E.
Toronto, ON M5C 1E5
Canada
Tel: (905) 415-7248
Fax: (905) 415-1019

Vancouver, BC (Head Office)
200 - 1620 West 8th Avenue
Vancouver, BC V6J 1V4
Canada
Tel: (604) 738-2500
Fax: (604) 738-2508

Victoria, BC
303 - 3960 Quadra Street
Victoria, BC V8X 4A3
Canada
Tel: (250) 475-9595
Fax: (250) 475-9596

Whitehorse, YT
6131 6th Avenue
Whitehorse, YT Y1A 1N2
Canada
Tel: (867) 689-8957

Winnipeg, MB
1353 Kenaston Boulevard
Winnipeg, MB R3P 2P2
Canada
Tel: (204) 477-1848

Yellowknife, NT
1B Coronation Drive
Yellowknife, NT X1A 0G5
Canada
Tel: (867) 689-8957