



Streetcar and Track Noise – King Street East and Sumach Street

Date: June 17, 2020

To: TTC Board

From: Chief Vehicles Officer, Chief Infrastructure and Engineering Officer

Summary

The 514 Cherry Streetcar route commenced operation in June 2016. Streetcars turning at the King Street East and Sumach Street intersection generate noise and vibration. The noise is in the form of wheel squeal which is a natural by-product of rail operations in streetcar networks. Noise and vibration is also generated by trailing track switches. Trailing track switches often create a slapping of “metal on metal” noise as vehicles pass through the intersection.

The TTC is committed to mitigating track noise and vibration as much as possible. Since the introduction of service to the Distillery District (now called the 504A King), a number of initiatives have been taken at the King Street East and Sumach Street intersection to reduce the noise and vibration levels. This report provides a status update on these mitigation measures and next steps moving forward.

Financial Summary

All preliminary analyses and installations undertaken and planned in 2020 are included in the Council Approved 2020-2029 Capital Budget and Plan. The outcome of these reviews will identify future requirements that will be considered in a future year budget process.

The Interim Chief Financial Officer has reviewed this report and agrees with the financial impact information.

Equity/Accessibility Matters

The 504A King streetcar is a critical service to the Corktown community. It provides accessible transit service along King Street, and south of King Street, along Sumach and Cherry Streets into the Distillery District area.

Decision History

At its meeting on February 25, 2020, the TTC Board had before it correspondence from Ward 13 Councillor Kristyn Wong-Tam requesting that the TTC Board direct the CEO to:

1. Prioritize and expedite any and all remedial measures including the installation of dampening rings on all streetcars along the 504A route;
2. Process and test all prototypes to develop a new and improved trailing switch to reduce noise impacts from the current track switch operations; and,
3. Report back to the TTC Board by November 16, 2020 with any outcomes, status updates and timeline for any outstanding work.

[New Business – Streetcar and Track Noise at the Intersection of King Street East and Sumach Street](http://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2020/February_25/Reports/19_New_Business_Streetcar_and_Track_Noise_at_the_Intersectio.pdf)

(http://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2020/February_25/Reports/19_New_Business_Streetcar_and_Track_Noise_at_the_Intersectio.pdf)

The TTC Board referred the correspondence to staff for a report back to the June 17, 2020 meeting.

Issue Background

King Street East and Sumach Street is the newest intersection in the TTC's streetcar network. Service commenced at this intersection in June 2016. Similar to other intersections in the TTC's streetcar network, noise and vibration inherent to rail operations exists at this location. Since the commissioning of this new intersection, residents in the community have expressed concerns as to the level of noise and vibration in the area.

To address these concerns and to mitigate the amount of the noise and vibration at this location, TTC implemented a number of initiatives in 2016 and 2017 that included:

- Installation of automatic lubricators at the Distillery Loop;
- Optimization of the curved track alignment;
- Prioritizing the introduction of new LFLRVs onto the 514 Cherry route (the precursor to the 504A King route).

To gauge the effectiveness of the above initiatives and to determine next steps forward, TTC staff retained an acoustics engineering consultant to measure sound levels before and after the above mitigation measures were implemented. The results of these tests showed a reduction in the sound level being generated.

In an effort to reduce noise further, TTC staff then prototyped wheel dampening rings on several of the new LFLRVs. Additional third party noise measurements were then taken by professional engineers in August 2018 and September 2019. The results confirmed that new streetcars equipped with noise dampening rings have noticeably lower sound levels than those without. Based on these results, TTC staff plan to equip the remainder of the LFLRV fleet with wheel dampening rings.

In addition, TTC staff also continue to investigate improvements to track and switch designs to further reduce noise and vibration levels at not only King and Sumach but also at other intersections throughout the network.

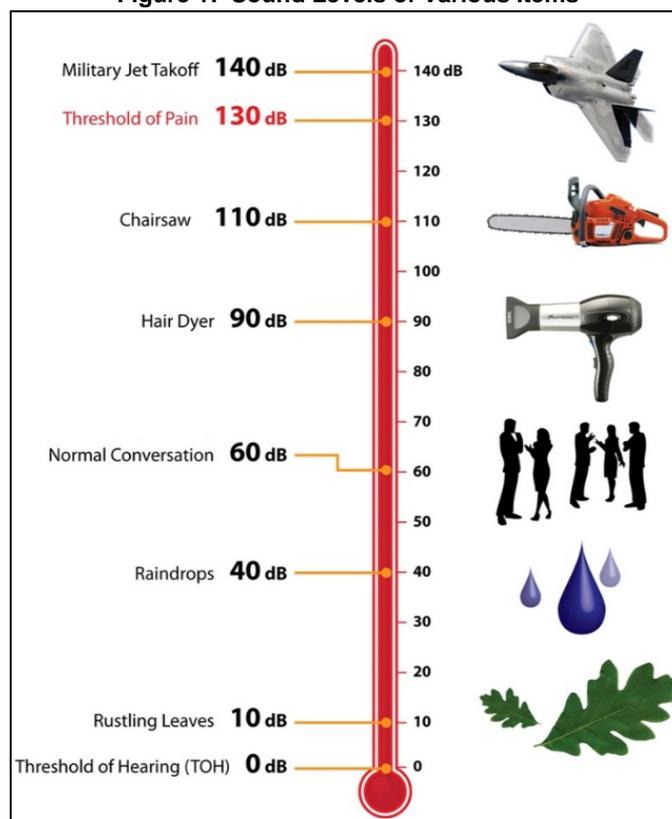
This report is to provide follow-up information to the request made by Ward 13 Councilor Kristyn Wong-Tam at the February 25, 2020 Board Meeting.

Discussion

Characteristics of Sound (Noise)

The level of sound (or noise) is measured in decibels (dB). Generally, the higher the sound level, the more disturbing it can be to the human ear. Figure 1 provides examples of different activities/items and their sound levels:

Figure 1: Sound Levels of Various Items



Equally important when considering sound is the frequency at which it is transmitted. When sound travels, it creates vibrations through the air (or medium). The size and speed of these vibrations is called frequency and is measured in Hertz (Hz). Humans are receptive to a range of frequencies where a high frequency measurement produces a high pitch sound and a low frequency measurement produces a low rumble. Noises that are annoying to the human ear typically have frequencies that fall in the range of 1000 Hz to 5000 Hz.

When referencing noise, it is therefore important to take into consideration both decibels and frequency

Noise in a Rail Network

Noise and vibration in light rail networks typically comes in the form of one or both of the following:

- **Wheel Squeal**
A high pitched noise generated by steel “wheel to rail” interaction in curves which produces micro-vibrations of the wheels resulting in a high pitched ringing.
- **Audible Track Switch Noise (Switch Point Slapping)**
A ‘slapping’ metal on metal noise generated every time a streetcar traverses the switch causing the switch parts to rock and unintentionally contact each other.

Mitigation Measures

Lubricators and Track Geometry Improvements (2016-2017)

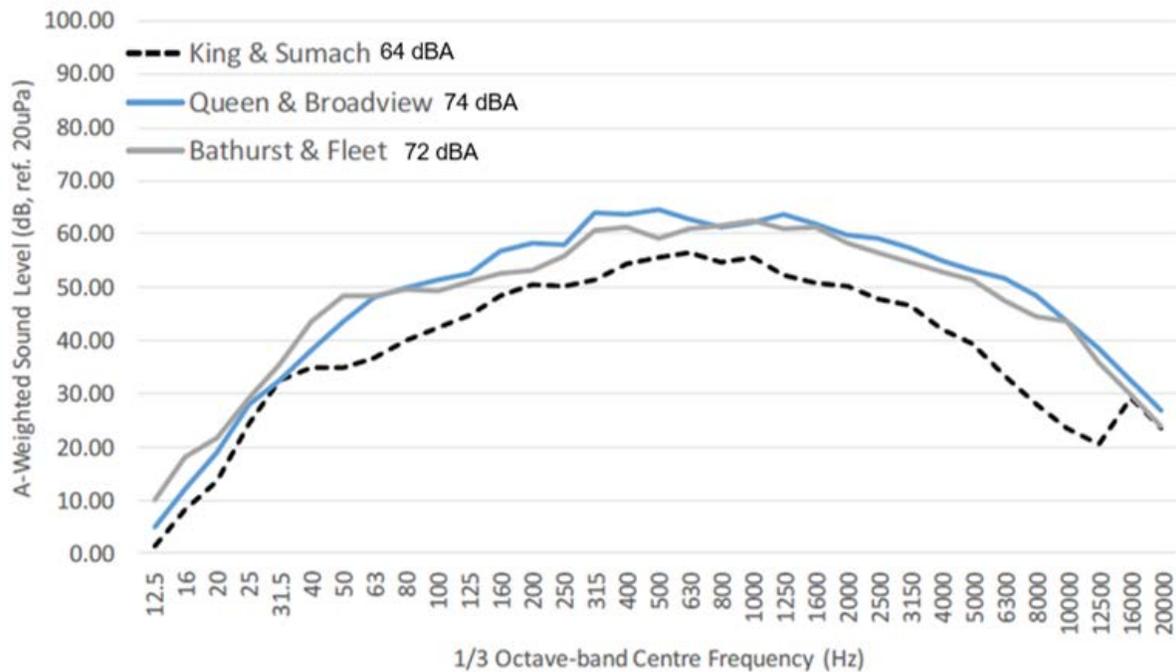
A number of mitigation measures have been taken to date to reduce noise at the King-Sumach intersection. Starting in 2016, improvements to the track geometry were made to help reduce the amount of noise and vibration. In addition, the installation of automatic track lubricators at the Distillery Loop and the introduction of the new LFLRV streetcars along the 514 Cherry route also contributed to a reduction in noise levels.

The new LFLRV are equipped with on-board wheel flange lubricators (WFL). WFL are similar to track lubricators. Lubricators, in general, apply lubricant to the interface between wheel and rail. This lubricant reduces the amount of friction between the wheel and rail contact surfaces which in turn reduces wheel squeal.

Measurements taken before and after these initiatives were implemented, showed a noticeable reduction in both decibels and frequency of the noise generated through the King-Sumach intersection. This reduction was in the order of 5dB – 15dB throughout the frequency range of 300 Hz and higher. Reference Graph 1 and 2 in the Appendix.

By way of comparison, sound measurements were also taken at the Queen-Broadview and the Bathurst-Fleet intersections. These intersections have similar track geometry and layouts to the King-Sumach intersection. The results of this comparative study is shown in the graph below:

Sound Measurements at Comparable Intersections on May 4, 2017- Average Leq
Measurement Location: Inside of Track Curve



Currently, 102 LFLRVs, or 50% of the streetcar fleet, is equipped with the WFL system. The quantity of vehicles equipped with WFL on TTC’s LFLRV fleet was based on OEM recommendations and industry experience from Europe at the time of procurement. Staff will review potential benefits of equipping a larger percentage (up to 100%) of the fleet in future years. Funding requirements for additional WFL will be included in the 2021 budget. Increasing the number of vehicles that have WFL will increase the coverage of vehicles across the network and may help to further reduce noise in other areas of the City, including at Bathurst-Fleet, Queen-Broadview and King-Sumach

Wheel Dampeners (2018 – 2019)

To reduce noise through the King-Sumach intersection further, staff began an investigation into wheel dampener technology. Wheel dampeners are rings that are added to the steel wheel. These rings react to various frequencies and are designed to absorb energy (noise). While wheel dampeners do not eliminate wheel squeal, they are designed to reduce or dampen the noise emitted from the steel wheel on steel rail interface.

Wheel dampeners were first prototyped on a LFLRV streetcar in 2018. Preliminary results from this first prototype were favourable. To increase the sample size, wheel dampeners were then installed onto another nine LFLRV in 2019.

In total 10 streetcars were equipped with the wheel dampener technology and are prioritized and deployed onto the 504A route, which represents almost 50% of the cars servicing the King-Sumach intersection.

To evaluate the performance of the wheel dampeners in reducing noise, testing was conducted on vehicles with and without dampeners in a controlled environment. To simulate the conditions (track geometry and radius) of the King Street East and Sumach Street intersection, Track 18 SE of Russell Carhouse Yard was selected as the test location. Testing was conducted by specialized third party consulting firms in August 2018 and September 2019 respectively. A summary of the results is listed in Table 1 below.

Table 1: Controlled Test Results - Russell Carhouse Yard, Track 18 SE Curve

Tests	Measurement Vehicle	Quantitative Sound Level Change (dBA)
Date: August 15, 2018 Performed by: Aercoustics	With Dampener	-7
Date: September 10, 2019 Performed by: Frontop Engineering Limited	With Dampener	-5

The test results indicated a sound level reduction of about 5-7 dBA after the installation of the dampening rings.

The reduction in emitted noise levels by using wheel dampeners therefore has the potential to reduce the noise impact throughout the streetcar network. As a result, staff are planning to equip the remainder of the fleet with wheel dampening rings.

Currently on order are wheel dampeners for 60 additional car sets at a cost of \$965K with an expected delivery date of January 2021. Table 2 provides a preliminary schedule for the installation of dampening rings for the next 60 vehicles in 2021. Through the 2021 Capital Budget submission, staff will plan to equip the remainder of the fleet (134 LFLRV) with the wheel dampening rings

Table 2: Dampener Installation Schedule

Year		Number of Vehicles Planned for Dampener Installation	Cumulative Number of Vehicles with Dampeners Installed
2020		-	10
2021	Q1	10	20
	Q2	14	34
	Q3	18	52
	Q4	18	70

Note. Based on the modification schedule, the 504A route will be fully serviced with cars with the wheel dampeners installed by Q2 2021.

Track & Switch Design Analysis (2019)

Track Geometry Condition Improvements

In 2019, detailed track measurements were taken at the intersection of King Street East and Sumach Street to verify the current state of the super-elevation (the difference in height between inner and outer rail) and track gauge in the curves. Based on these baseline measurements, TTC staff are developing state of good repair preventative maintenance programs to ensure that the track geometry at the intersection remains in optimal condition.

Additional Track Maintenance

The metal on metal noise can be further mitigated through additional track maintenance initiatives. In 2019, TTC staff completed an analysis of the converging switch (trailing switch) on the east side of the intersection. A review of this switch revealed that the mating components of the switch were not perfectly flat. Given that these components are manufactured using a casting process, it is not practical to produce a fine flatness tolerance. This variance contributed to uneven seating of the components and increased rocking of the parts. Based on this analysis, in April 2020, additional track maintenance at the south east side of King Street East and Sumach Street was conducted. This included grinding and increased maintenance to the switch point and its mating surface to re-establish the desired flatness of components in an effort to reduce the magnitude of the metal on metal noise.

Preliminary sound level measurements by the TTC indicate approximately a 6 dBA improvement. The absolute noise levels in this test cannot be correlated to the previous measurements of the acoustic consultants due to the fact that these measurements were taken from a hand held unit in closer proximity to the switch. It should also be noted that only the before and after switch noise was the subject of these measurements. Test results can be found in Table 3 below.

Table 3: Test Results - Track Switch Noise (South-East Side)

Quantitative Noise Measurement (dBA)		Quantitative Sound Level Change (dBA)
Before Maintenance Correction	After Maintenance Correction of Switch Flatness	
77	71	-6

Alternative Switch Designs Improvement

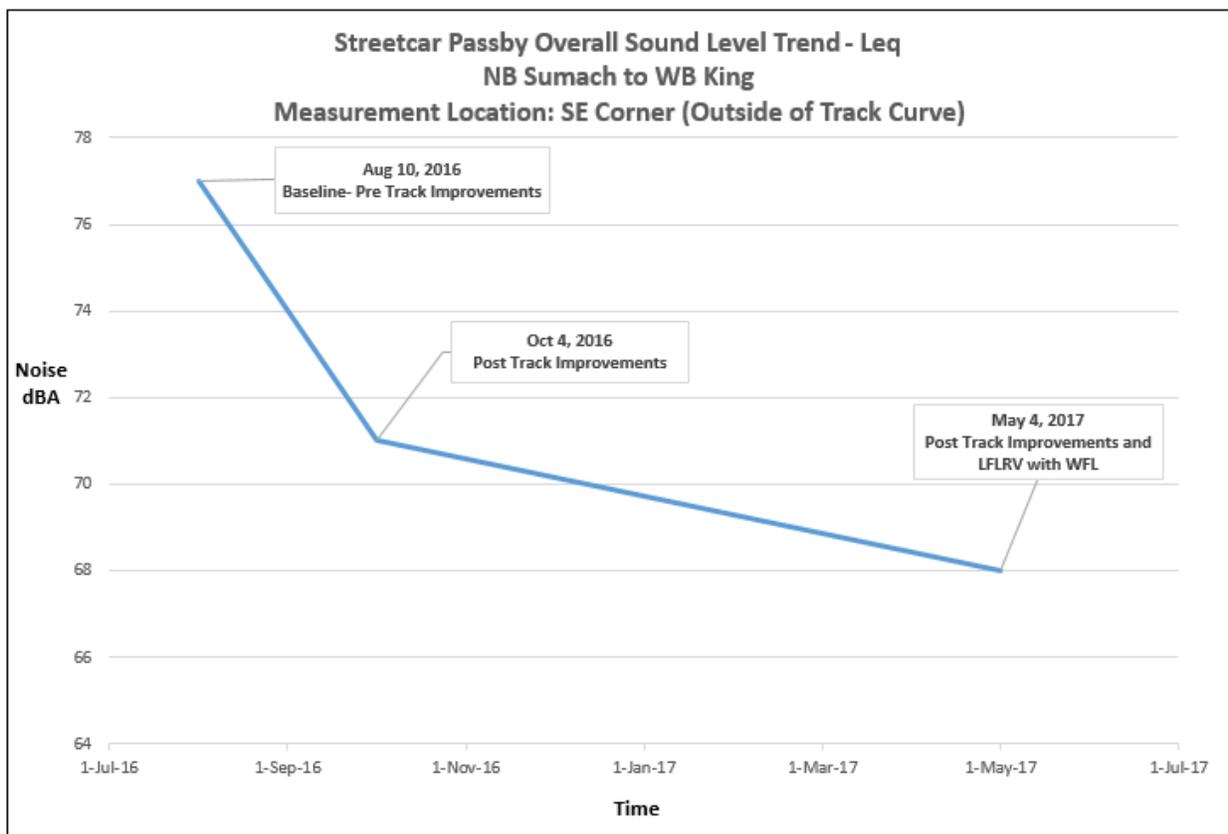
Alternative switch designs (North to East trailing switch) are being investigated in an effort to mitigate the switch point rocking movement. Two switch designs were taken into consideration, 'double mate' and 'flex tongue/point'; installed at the CNE Loop and College and Lansdowne intersection in 2016 respectively. These switch designs have their operational and safety advantages and disadvantages. The alternative under immediate consideration is the adoption of a 'flex tongue/point' switch to replace TTC's cast switch tongue to potentially reduce noise during streetcar operations. The flex tongue features improved manufacturing tolerances and positive mechanical fastening that keep components securely assembled between regular service and maintenance intervals.

Streetcar track engineering plans to complete the flex tongue switch design package for King and Sumach trailing switches in Q3 2020.

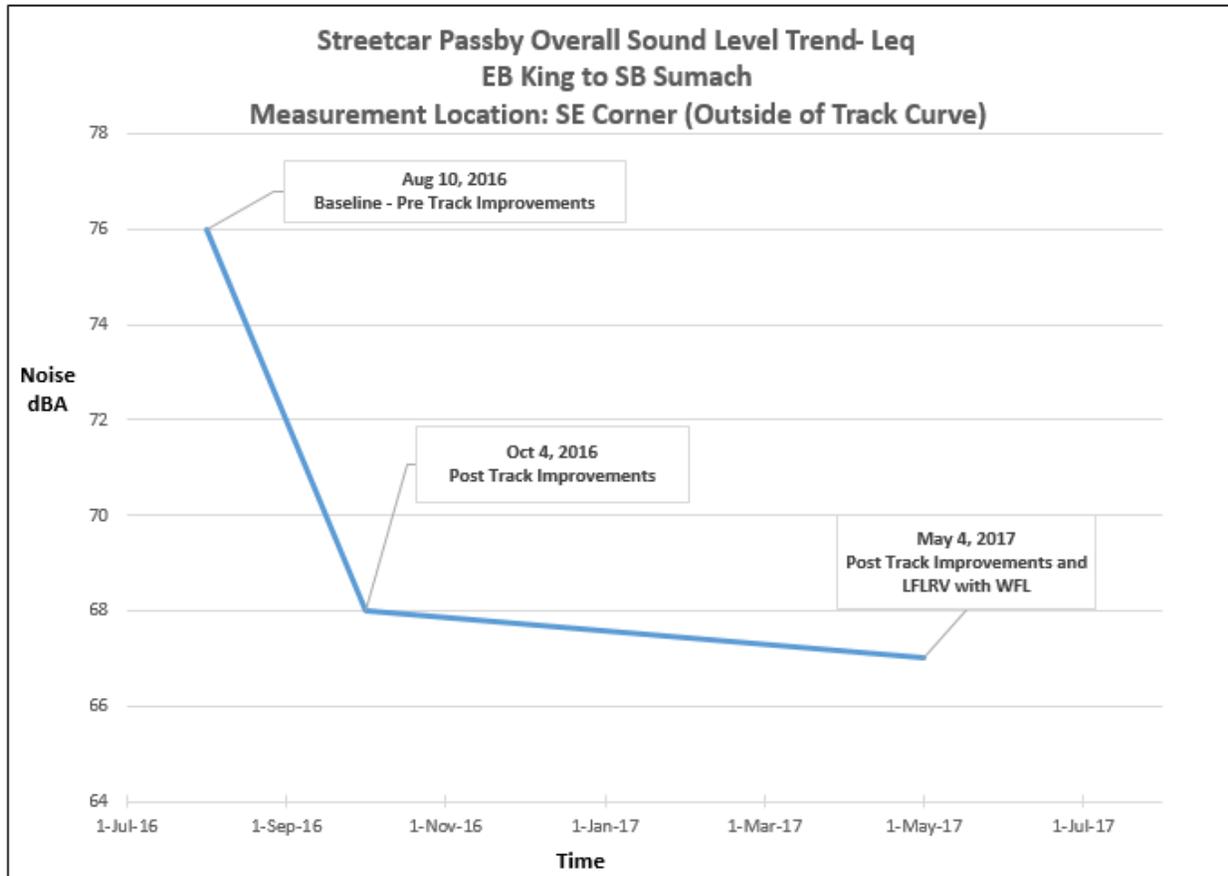
Next Steps

Staff remains committed to reducing noise and vibration along the streetcar network wherever possible. Based on efforts to date at the King and Sumach intersection, incremental improvements are being made. The following graphs illustrates measurable reductions in the sound level at the King-Sumach intersections from the various initiatives.

Noise Measurements with Track Improvements (NB Sumach to WB King)



Noise Measurements with Track Improvements (EB King to SB Sumach)



To continue these efforts, the following action items are identified as next steps:

1. Receive and install wheel dampeners onto an additional 60 LFLRVs in 2021;
2. Budget for the purchase and installation of wheel dampeners on the remainder of the LFLRV fleet in the 2021 Capital Budget submission;
3. Budget for purchase and installation of wheel flange lubricators on 51 additional cars in the 2021 Capital Budget submission;
4. Finalize the optimized curved track geometry design through the King and Sumach intersection and request funding approval as part of the 2021 Capital Budget submission.
5. Finalize the flex tongue switch design package for King and Sumach in Q3 of 2020. Develop cost estimate for replacing the existing track switches with the new design and include in 2021 Capital Budget submissions for approval.

In addition to the above action items, staff plan to conduct another round of acoustic testing in August 2020 to identify if there have been any changes to the noise and vibration levels at the intersection of King Street East and Sumach Street.

Contact

Peter Hrovat, Head of Streetcar Infrastructure
416 393-4299
peter.hrovat@ttc.ca

Roy Park, Senior Project Manager
416 393-6977
roy.park@ttc.ca

Signature

Rich Wong
Chief Vehicles Officer

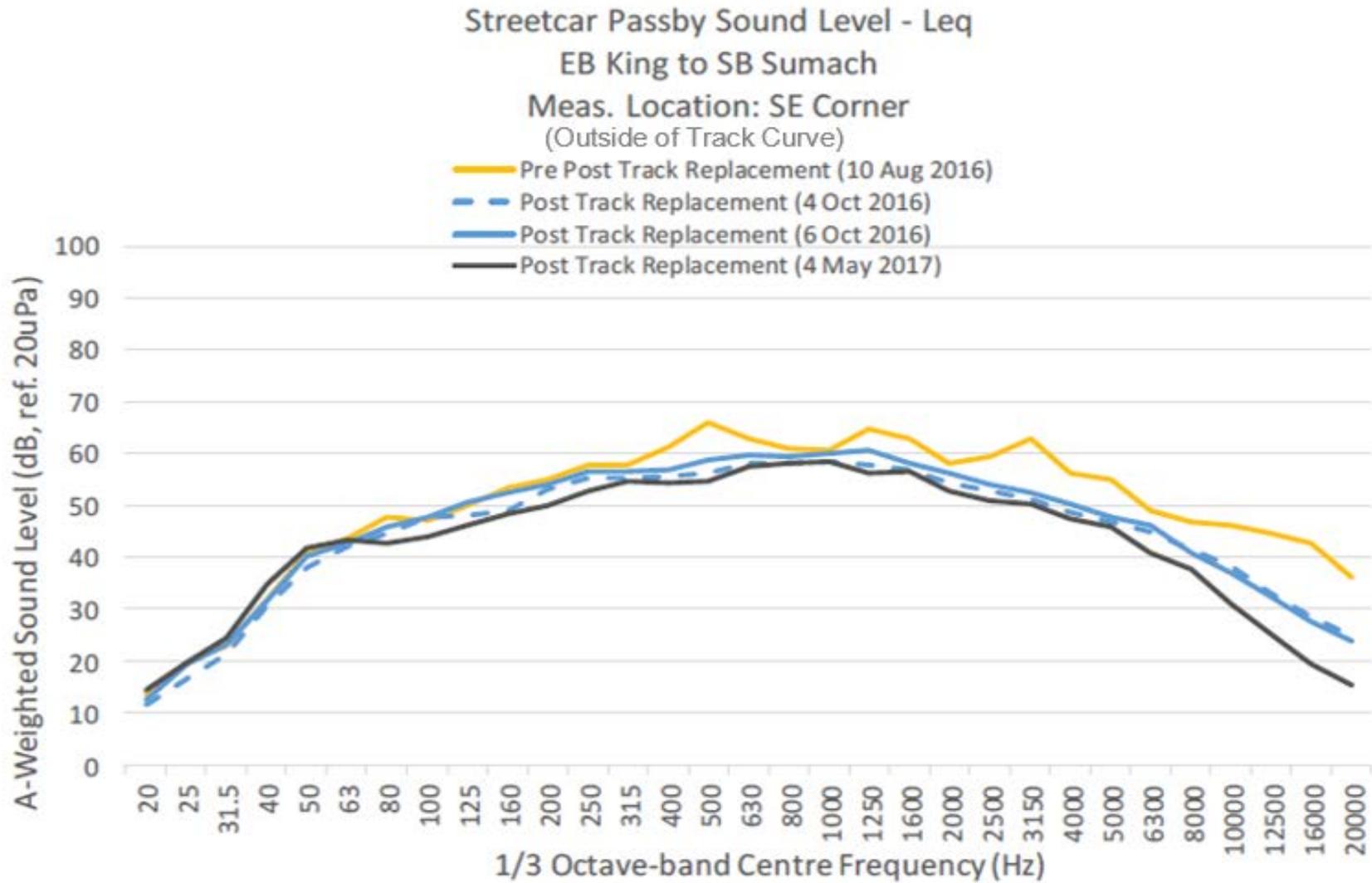
Fortunato Monaco
Chief Infrastructure and Engineering Officer

Attachments

APPENDIX A – Graph 1 Noise Measurements with Track Improvements
(EB King to SB Sumach)

APPENDIX B – Graph 2 Noise Measurements with Track Improvements
(NB Sumach to WB King)

APPENDIX A
 Graph 1: Noise Measurements with Track Improvements
 (EB King to SB Sumach)



APPENDIX B
 Graph 2: Noise Measurements with Track Improvements
 (NB Sumach to WB King)

