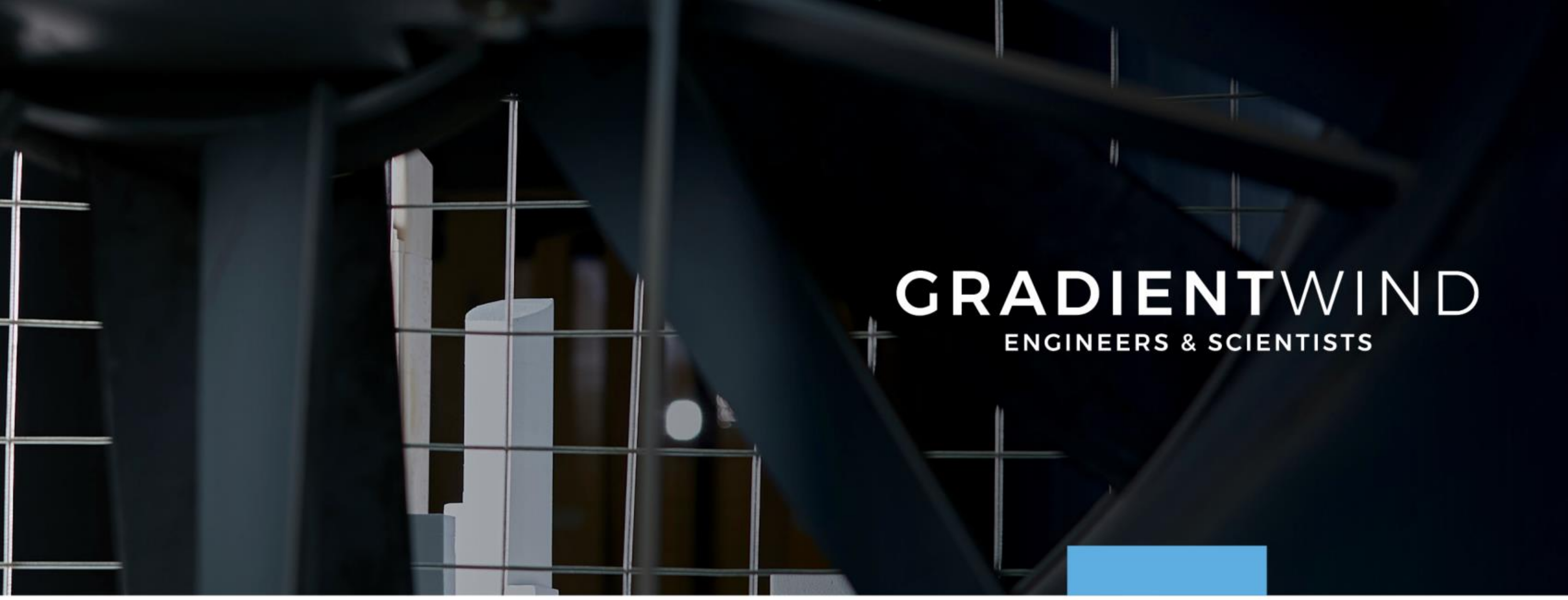
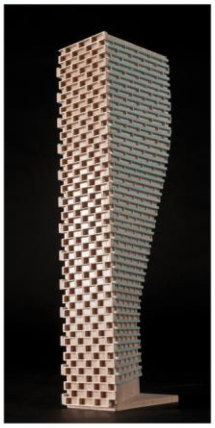
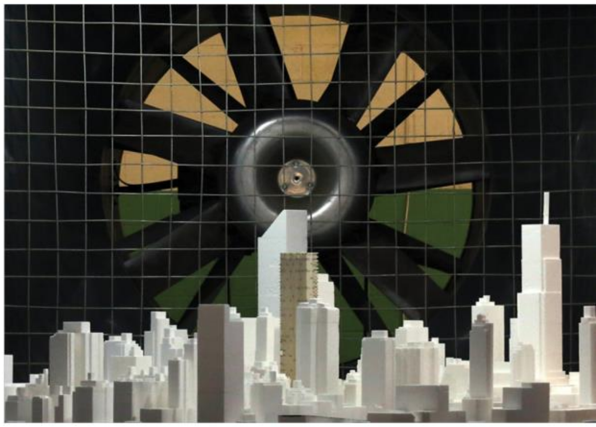


LRT NOISE & VIBRATION ASSESSMENT

New Student Residence
Carleton University
Ottawa, Ontario

GRADIENT WIND REPORT: 19-224 – Noise & Vibration





December 2, 2019

PREPARED FOR
Carleton University
1125 Colonel By Drive
Ottawa, ON K1S 5B6

Attn: Dawn Blackman, Senior Project Manager
DawnBlackman@cunet.carleton.ca

PREPARED BY
Samantha Phillips, B.Eng., Junior Environmental Scientist
Joshua Foster, P.Eng., Principal

EXECUTIVE SUMMARY

This report describes a light rail transit (LRT) noise and vibration assessment undertaken for a proposed student residence building at Carleton University located at 1125 Colonel By Drive in Ottawa, Ontario. The development is a nine-storey building with indoor amenity space at grade and residential units in the remaining floors above. At Level 2, the floorplate sets backs in all directions from the centre of the floorplan to create a central outdoor courtyard. Additionally, the floorplate sets back from the southwest corner at Level 6 and the southwest corner at Level 8 to create outdoor amenity terraces. The major source of transportation noise is the Trillium Line Light Rail Transit (LRT) to the east. Figure 1 illustrates a complete site plan with surrounding context. Colonel By Drive and Bronson Avenue are more then 100 metres from the proposed building and are therefore considered insignificant.

The assessment is based on (i) theoretical noise prediction methods that conform to the Ministry of the Environment, Conservation and Parks (MECP) and City of Ottawa requirements; (ii) noise level criteria as specified by the City of Ottawa's Environmental Noise Control Guidelines (ENCG); (iii) future Trillium Line LRT volumes and speed based on information received from the City of Ottawa for other projects; and (iv) architectural drawings provided by Diamond Schmitt Architects Inc. in November 2019.

The results of the current analysis indicate that noise levels will range between 41 and 53 dBA during the daytime period (07:00-23:00) and between 35 and 47 dBA during the nighttime period (23:00-07:00). The highest noise level (53 dBA) occurs at the east façade, which is nearest and most exposed to the LRT corridor. Noise levels at the 8th Floor Terrace (Receptor 4) are expected to approach 43 dBA during the daytime period.

Results of the calculations indicate standard building components will be sufficient to achieve the City of Ottawa's indoor sound criteria listed in Section 4.2. Additionally, there are no specific ventilation requirements or warning clauses needed.

Vibration levels due to LRT activity in the area are expected to fall below the criterion of 0.10mm/s at the nearest point of reception to the track. As a result, mitigation for vibration is not required.

TABLE OF CONTENTS

1. INTRODUCTION

Gradient Wind Engineering Inc. (Gradient Wind) was retained by Carleton University to undertake a light rail transit (LRT) noise and vibration assessment for a proposed student residence building at Carleton University located at 1125 Colonel By Drive in Ottawa, Ontario. This report summarizes the methodology, results, and recommendations related to the assessment of exterior and interior noise levels generated by the Trillium Line Light Rail Transit (LRT).

Our work is based on theoretical noise calculation methods conforming to the City of Ottawa[1] and Ministry of the Environment, Conservation and Parks (MECP)[2] guidelines. Noise calculations were based on architectural drawings provided by Diamond Schmitt Architects Inc. in November 2019, with future Trillium Line LRT volumes and speed based on information received form the City of Ottawa for other projects.

2. TERMS OF REFERENCE

The focus of this LRT noise and vibration assessment is a proposed student residence building at Carleton University in Ottawa, Ontario. The study site is located at the north side of campus, bounded by Leeds House to the west, Dundas House to the south, Campus Avenue to the east, and a parking lot to the north. The proposed development is a nine-storey residential building. Indoor amenity areas occupy grade level, followed by residential units for remaining floors above. At Level 2, the floorplate sets backs in all directions from the center of the floorplan to create a central outdoor courtyard. Additionally, the floorplate sets back from the southwest corner at Level 6 and the southwest corner at Level 8 to create outdoor amenity terraces.

The site is surrounded by low and mid-rise student residence buildings to the south, a parking garage to the northeast, low-rise recreational facilities to the southeast, a paved lot followed by Dow's Lake to the north, and the Rideau Canal followed by green space to the west. The major source of transportation noise is the Trillium Line LRT to the east. Colonel By Drive and Bronson Avenue are more then 100 metres

[1] City of Ottawa Environmental Noise Control Guidelines, January 2016
[2] Ontario Ministry of the Environment and Climate Change – Environmental Noise Guidelines, Publication NPC-300, Queens Printer for Ontario, Toronto, 2013

from the proposed building and are therefore considered insignificant. Figure 1 illustrates a complete site plan with surrounding context.

3. OBJECTIVES

The principal objectives of this study are to (i) calculate the future noise levels on the study buildings produced by the Trillium Line LRT, and (ii) ensure that interior and exterior noise levels do not exceed the allowable limits specified by the City of Ottawa's Environmental Noise Control Guidelines as outlined in Section 4.2 of this report.

4. METHODOLOGY

4.1 Background

Noise can be defined as any obtrusive sound. It is created at a source, transmitted through a medium, such as air, and intercepted by a receiver. Noise may be characterized in terms of the power of the source or the sound pressure at a specific distance. While the power of a source is characteristic of that particular source, the sound pressure depends on the location of the receiver and the path that the noise takes to reach the receiver. Measurement of noise is based on the decibel unit, dBA, which is a logarithmic ratio referenced to a standard noise level (2×10^{-5} Pascals). The 'A' suffix refers to a weighting scale, which better represents how the noise is perceived by the human ear. With this scale, a doubling of power results in a 3 dBA increase in measured noise levels and is just perceptible to most people. An increase of 10 dBA is often perceived to be twice as loud.

4.2 LRT Traffic Noise

4.2.1 Criteria for LRT Traffic Noise

For roadway and railway traffic noise, the equivalent sound energy level, L_{eq}, provides a measure of the time varying noise levels, which is well correlated with the annoyance of sound. It is defined as the continuous sound level, which has the same energy as a time varying noise level over a period of time. For roadways and light rail transit corridors, the L_{eq} is commonly calculated on the basis of a 16-hour (L_{eq16}) daytime (07:00-23:00) / 8-hour (L_{eq8}) nighttime (23:00-07:00) split to assess its impact on residential buildings. The City of Ottawa's Environmental Noise Control Guidelines (ENCG) specifies that the recommended indoor noise limit range (that is relevant to this study) is 40 and 35 dBA for living areas and sleeping quarters respectively for railways (LRT) as listed in Table 1.

TABLE 1: INDOOR SOUND LEVEL CRITERIA (RAIL) [3]

Type of Space	Time Period	Leq (dBA)
General offices, reception areas, retail stores, etc.	07:00 – 23:00	45
Living/dining/den areas of **residences**, hospitals, schools, nursing/retirement homes, day-care centres, theatres, places of worship, libraries, individual or semi-private offices, conference rooms, etc.	07:00 – 23:00	40
Sleeping quarters of hotels/motels	23:00 – 07:00	40
Sleeping quarters of **residences**, hospitals, nursing/retirement homes, etc.	23:00 – 07:00	35

Predicted noise levels at the plane of window (POW) dictate the action required to achieve the recommended sound levels. An open window is considered to provide a 10 dBA reduction in noise, while a standard closed window is capable of providing a minimum 20 dBA noise reduction[4]. A closed window due to a ventilation requirement will bring noise levels down to achieve an acceptable indoor environment[5]. Therefore, where noise levels exceed 55 dBA daytime and 50 dBA nighttime, the ventilation for the building should consider the need for having windows and doors closed, which triggers the need for forced air heating with provision for central air conditioning. Where noise levels exceed 60 dBA daytime and 55 dBA nighttime, air conditioning will be required and building components will require higher levels of sound attenuation[6].

The sound level criterion for outdoor living areas is 55 dBA, which applies during the daytime (07:00 to 23:00). When noise levels exceed 55 dBA, mitigation must be provided to reduce noise levels where technically and administratively feasible to acceptable levels at or below the criterion.

[3] Adapted from ENCG 2016 – Tables 2.2b and 2.2c
[4] Burberry, P.B. (2014). Mitchell's Environment and Services. Routledge, Page 125
[5] MOECP, Environmental Noise Guidelines, NPC 300 – Part C, Section 7.8
[6] MOECP, Environmental Noise Guidelines, NPC 300 – Part C, Section 7.1.3

4.2.2 Theoretical LRT Noise Predictions

Noise predictions were performed with the aid of the MECP computerized noise assessment program, STAMSON 5.04, for road and rail analysis. Appendix A includes the STAMSON 5.04 input and output data.

In addition to the LRT traffic volumes summarized in Table 2, theoretical noise predictions were based on the following parameters:

- The Trillium LRT line has been modelled using 4-car Scarborough Rapid Transit (SRT) vehicle in STAMSON.
- Ground surfaces were taken to be reflective due to the presence of hard (paved) ground.
- Topography was assumed to be a flat/gentle slope surrounding the study building. As the LRT corridor is situated approximately 7 metres below grade with sloping topography to the east and west, a barrier with a height of 7 metres was assumed along the west side of the corridor.
- Receptor height was taken to be 16.5 metres at Level 5 for the centre of the window (height to 5th floor slab + 1.5 metres) for Receptors 1-3, and 25.5 m for rooftop Receptor 4.
- The parking garage to the northeast was assumed to block all noise, as the LRT travels below the structure.
- Noise receptors were strategically placed at 4 locations around the study area (see Figure 2).
- Receptor distances and exposure angles are illustrated in Figures 3-4.

4.2.1 LRT Traffic Volumes

Future Trillium Line LRT volumes and speed are based on information received from the City of Ottawa. Table 2 (below) summarizes the daytime and nighttime LRT traffic volumes included in this assessment.

TABLE 2: LRT TRAFFIC DATA

Segment	Traffic Data	Speed Limit (km/h)	Traffic Volumes
Trillium Line	LRT	70	**192/24***

* Daytime/nighttime period

4.3 Ground Vibration & Ground-borne Noise

Transit systems and heavy vehicles on roadways can produce perceptible levels of ground vibrations, especially when they are in close proximity to residential neighbourhoods or vibration-sensitive buildings. Similar to sound waves in air, vibrations in solids are generated at a source, propagated through a medium, and intercepted by a receiver. In the case of ground vibrations, the medium can be uniform, or more often, a complex layering of soils and rock strata. Also, similar to sound waves in air, ground vibrations produce perceptible motions and regenerated noise known as 'ground-borne noise' when the vibrations encounter a hollow structure such as a building. Ground-borne noise and vibrations are generated when there is excitation of the ground, such as from a train. Repetitive motion of the wheels on the track or rubber tires passing over an uneven surface causes vibrations to propagate through the soil. When they encounter a building, vibrations pass along the structure of the building beginning at the foundation and propagating to all floors. Air inside the building excited by the vibrating walls and floors represents regenerated airborne noise. Characteristics of the soil and the building are imparted to the noise, thereby creating a unique noise signature.

Human response to ground vibrations is dependent on the magnitude of the vibrations, which is measured by the root mean square (RMS) of the movement of a particle on a surface. Typical units of ground vibration measures are millimeters per second (mm/s), or inch per second (in/s). Since vibrations can vary over a wide range, it is also convenient to represent them in decibel units, or dBV. In North America, it is common practice to use the reference value of one micro-inch per second (μin/s) to represent vibration levels for this purpose. The threshold level of human perception to vibrations is about 0.10 mm/s RMS or about 72 dBV. Although somewhat variable, the threshold of annoyance for continuous vibrations is 1.0 mm/s RMS (or 92 dBV), ten times higher than the perception threshold, whereas the threshold for significant structural damage is 10 mm/s RMS (or 112 dBV), at least one hundred times higher than the perception threshold level.

4.3.1 Ground Vibration Criteria

In the United States, the Federal Transportation Authority (FTA) has set vibration criteria for sensitive land uses next to transit corridors. Similar standards have been developed by a partnership between the MECP and the Toronto Transit Commission[7]. These standards indicate that the appropriate criteria for residential buildings is 0.1 mm/s RMS for vibrations. For main line railways, a document titled Guidelines for New Development in Proximity to Railway Operations[8], indicates that vibration conditions should not exceed 0.14 mm/s RMS averaged over a one second time-period at the first floor and above of the proposed building. As the main vibration source is due to the LRT system, the 0.10 mm/s RMS (72 dBV) vibration criteria and 35 dBA ground borne noise criteria were adopted for this study.

4.3.2 Theoretical Ground Vibration Prediction Procedure

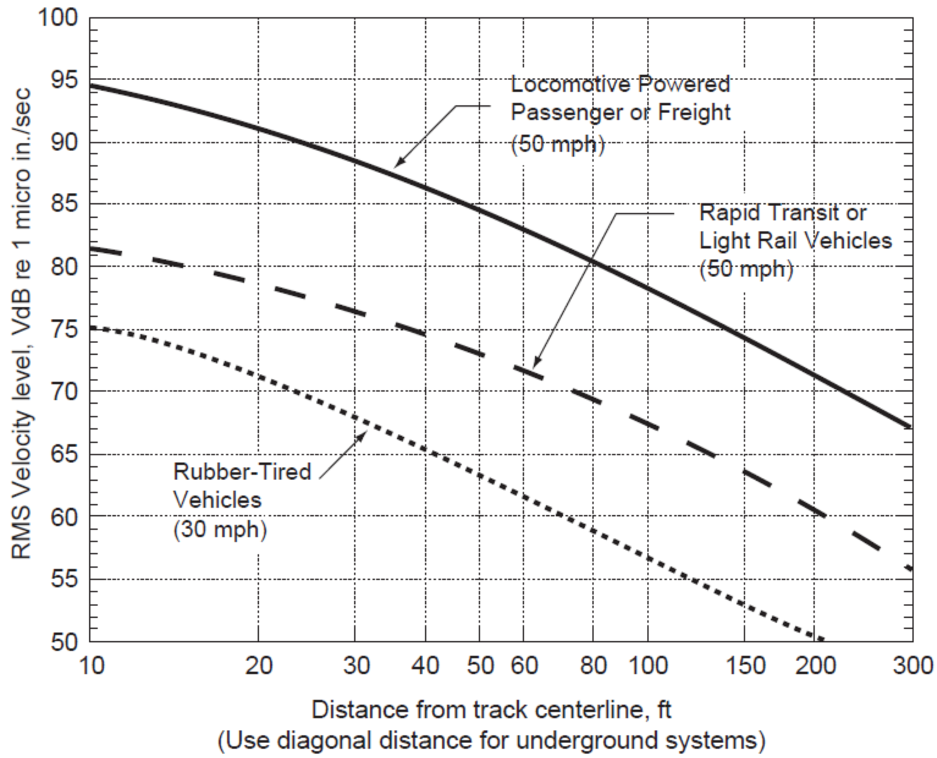
Potential vibration impacts of the existing Trillium Line LRT were predicted using the FTA's Transit Noise and Vibration Impact Assessment[9] protocol. The FTA general vibration assessment is based on an upper bound generic set of curves that show vibration level attenuation with distance. These curves, illustrated in the figure below, are based on ground vibration measurements at various transit systems throughout North America. Vibration levels at points of reception are adjusted by various factors to incorporate known characteristics of the system being analyzed, such as operating speed of vehicle, conditions of the track, construction of the track and geology, as well as the structural type of the impacted building structures. Based on the setback distance of the closest building, initial vibration levels were deduced from a curve for light rail trains at 50 miles per hour (mph) and applying an adjustment factor of -1 dBV to account for an operational speed of 70 km/h (43.4 mph). Other factors considered; the track was assumed to have welded joints. Details of the vibration calculations are presented in Appendix B.

---

[7] MOECP/TTC Protocol for Noise and Vibration Assessment for the Proposed Yonge-Spadina Subway Loop, June 16, 1993

[8] Dialog and J.E. Coulter Associates Limited, prepared for The Federation of Canadian Municipalities and The Railway Association of Canada, May 2013

[9] C. E. Hanson; D. A. Towers; and L. D. Meister, Transit Noise and Vibration Impact Assessment, Federal Transit Administration, May 2006.



FTA GENERALIZED CURVES OF VIBRATION LEVELS VERSUS DISTANCE (ADOPTED FROM FIGURE 10-1, FTA TRANSIT NOISE AND VIBRATION IMPACT ASSESSMENT)

5. RESULTS AND DISCUSSION

5.1 LRT Noise Levels

The results of the LRT traffic noise calculations are summarized in Table 3 below. A complete set of input and output data from all STAMSON 5.04 calculations are available in Appendix A.

TABLE 3: EXTERIOR NOISE LEVELS DUE TO ROAD TRAFFIC

Receptor Number	Receptor Height Above Grade (m)	Receptor Location	STAMSON 5.04 Noise Level (dBA)	
			Day	Night
1	16.5	POW – 5th Floor – East Façade	53	47
2	16.5	POW – 5th Floor – North Façade	41	35
3	16.5	POW – 5th Floor – South Façade	50	44
5	25.5	OLA – Rooftop Outdoor Amenity Area	43	-

The results of the current analysis indicate that noise levels will range between 41 and 53 dBA during the daytime period (07:00-23:00) and between 35 and 47 dBA during the nighttime period (23:00-07:00). The highest noise level (53 dBA) occurs at the east façade, which is nearest and most exposed to the LRT corridor.

5.2 Noise Control Measures

The noise levels predicted due to LRT traffic do not exceed the criteria in Section 4.2 for building components. Therefore, standard building components will be sufficient to attenuating indoor sound levels to meet the ENCG criteria as listed in Table 1. Additionally, there are no specific ventilation requirements or warning clauses needed.

5.3 Ground Vibrations & Ground-borne Noise Levels

Based on an offset distance of 46 metres between the LRT centreline and the nearest foundation, the estimated vibration level at the nearest point of reception is expected to be 0.052 mm/s RMS (66.29 dBV) based on the FTA protocol. Details of the calculation are provided in Appendix B. Since predicted vibration levels are below the criterion of 0.10 mm/s RMS, no mitigation will be required.

According to the United States Federal Transit Authority's vibration assessment protocol, ground borne noise can be estimated by subtracting 35 dB from the velocity vibration level in dBV. Since measured vibration levels were found to be less than 0.10 mm/s peak partial velocity (ppv), ground borne noise levels are also expected to be below the ground borne noise criteria of 35 dB.

6. CONCLUSIONS AND RECOMMENDATIONS

The results of the current analysis indicate that noise levels will range between 41 and 53 dBA during the daytime period (07:00-23:00) and between 35 and 47 dBA during the nighttime period (23:00-07:00). The highest noise level (53 dBA) occurs at the east façade, which is nearest and most exposed to the LRT corridor. Noise levels at the 8th Floor Terrace (Receptor 4) are expected to approach 43 dBA during the daytime period.

Results of the calculations indicate standard building components will be sufficient to achieve the City of Ottawa's indoor sound criteria listed in Section 4.2. Additionally, there are no specific ventilation requirements or warning clauses needed.

Vibration levels due to LRT activity in the area are expected to fall below the criterion of 0.10mm/s at the nearest point of reception to the track. As a result, mitigation for vibration is not required.

This concludes our LRT noise and vibration assessment and report. If you have any questions or wish to discuss our findings, please advise us. In the interim, we thank you for the opportunity to be of service.

Sincerely,

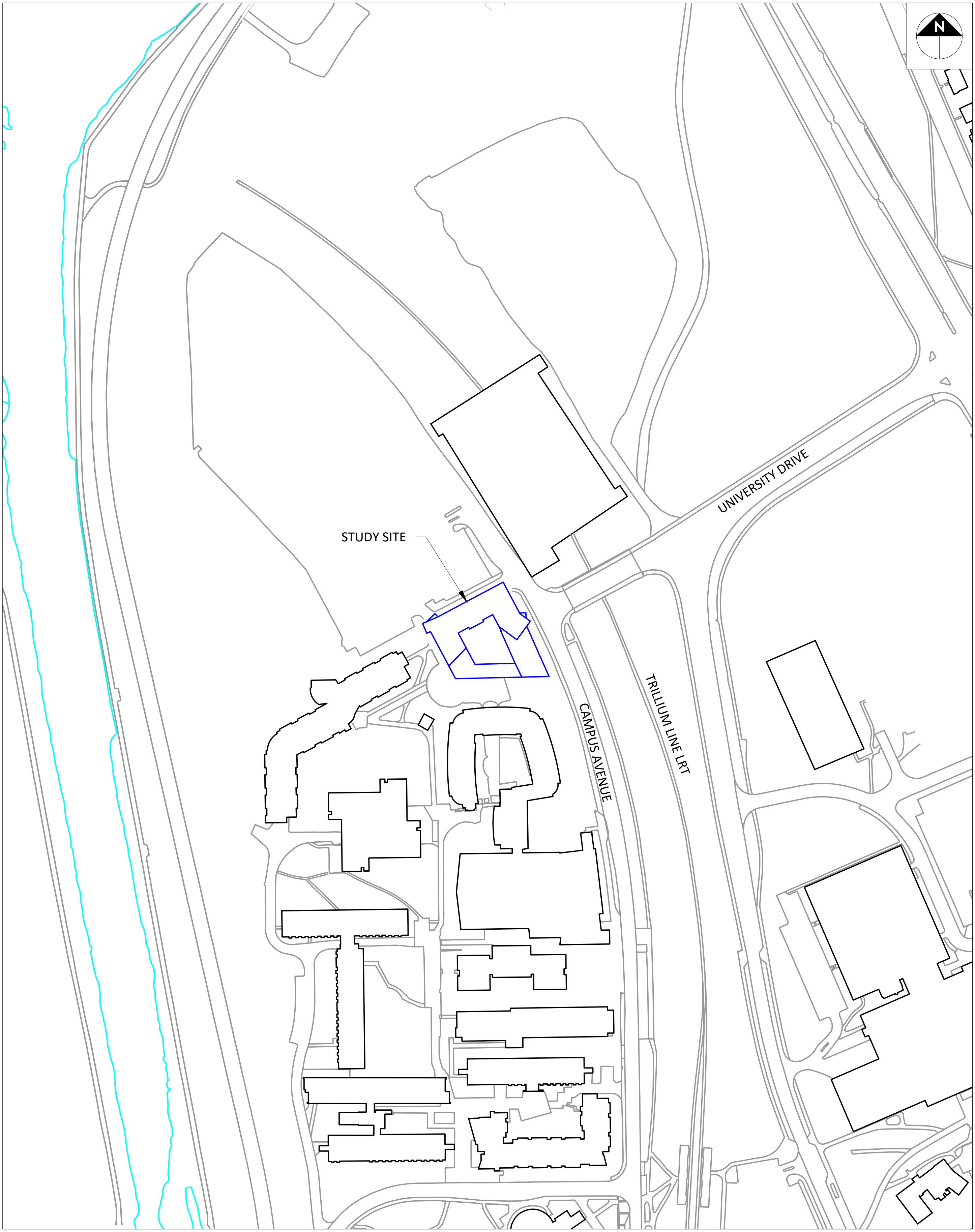
Gradient Wind Engineering Inc.

LICENSED PROFESSIONAL ENGINEER
J. R. FOSTER
100155655
Dec 2, 2019
PROVINCE OF ONTARIO

Samantha Phillips, B.Eng.
Junior Environmental Scientist

Joshua Foster, P.Eng.
Principal

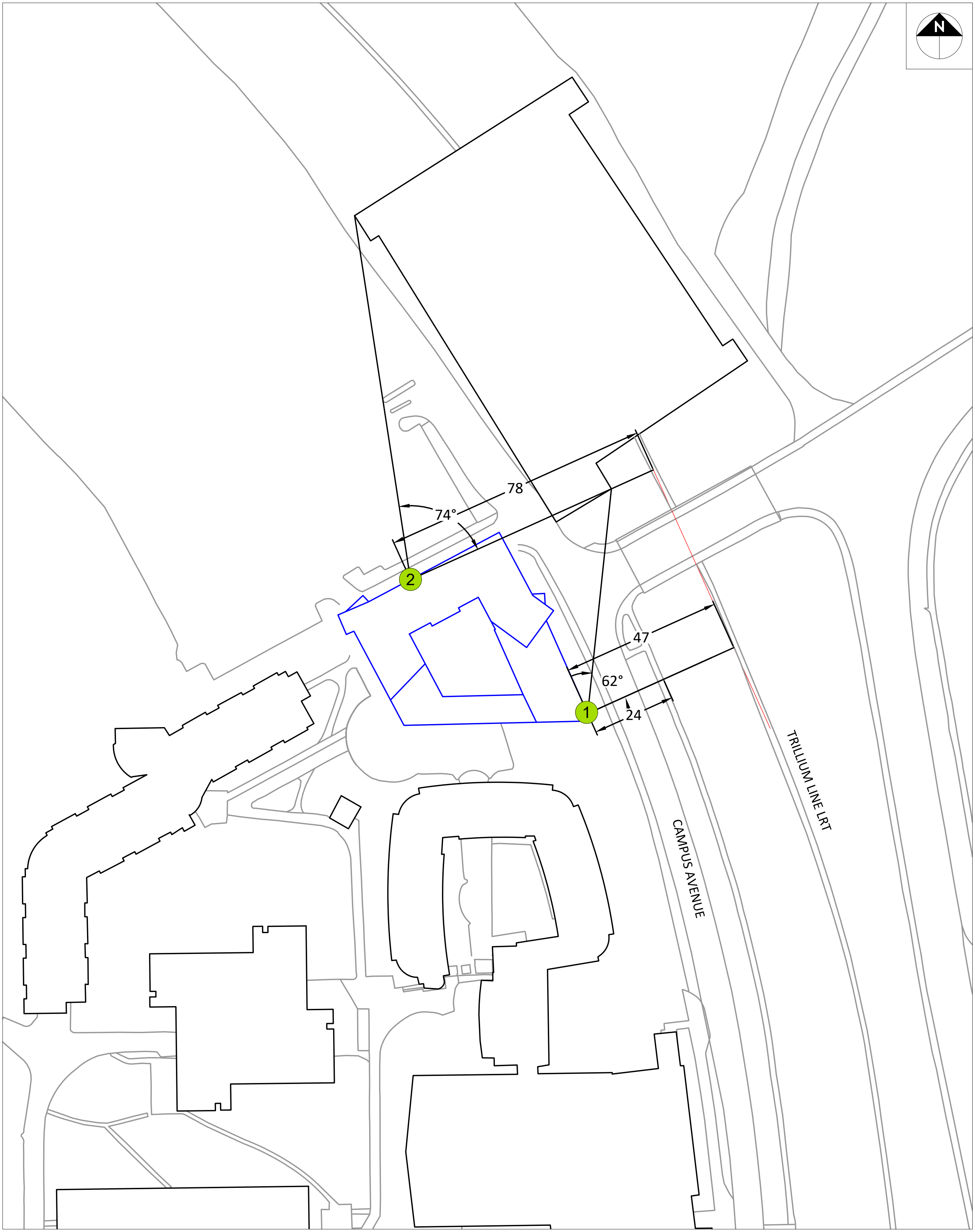
Gradient Wind File #19-224-Noise & Vibration



GRADIENTWIND
ENGINEERS & SCIENTISTS
127 WALGREEN ROAD , OTTAWA, ON
613 836 0934 • GRADIENTWIND.COM

PROJECT: NEW STUDENT RESIDENCE - CARLETON UNIVERSITY LRT NOISE AND VIBRATION ASSESSMENT		DESCRIPTION: FIGURE 1: SITE PLAN AND SURROUNDING CONTEXT
SCALE: 1:3000 (APPROX.)	DRAWING NO.: GW19-224-1	
DATE: NOVEMBER 26, 2019	DRAWN BY: S.P.	

GRADIENTWIND ENGINEERS & SCIENTISTS 127 WALGREEN ROAD , OTTAWA, ON 613 836 0934 • GRADIENTWIND.COM	PROJECT: NEW STUDENT RESIDENCE - CARLETON UNIVERSITY LRT NOISE AND VIBRATION ASSESSMENT		DESCRIPTION
	SCALE: 1:500 (APPROX.)	DRAWING NO.: GW19-224-2	FIGURE 2: RECEPTOR LOCATIONS
	DATE: NOVEMBER 26, 2019	DRAWN BY: S.P.	



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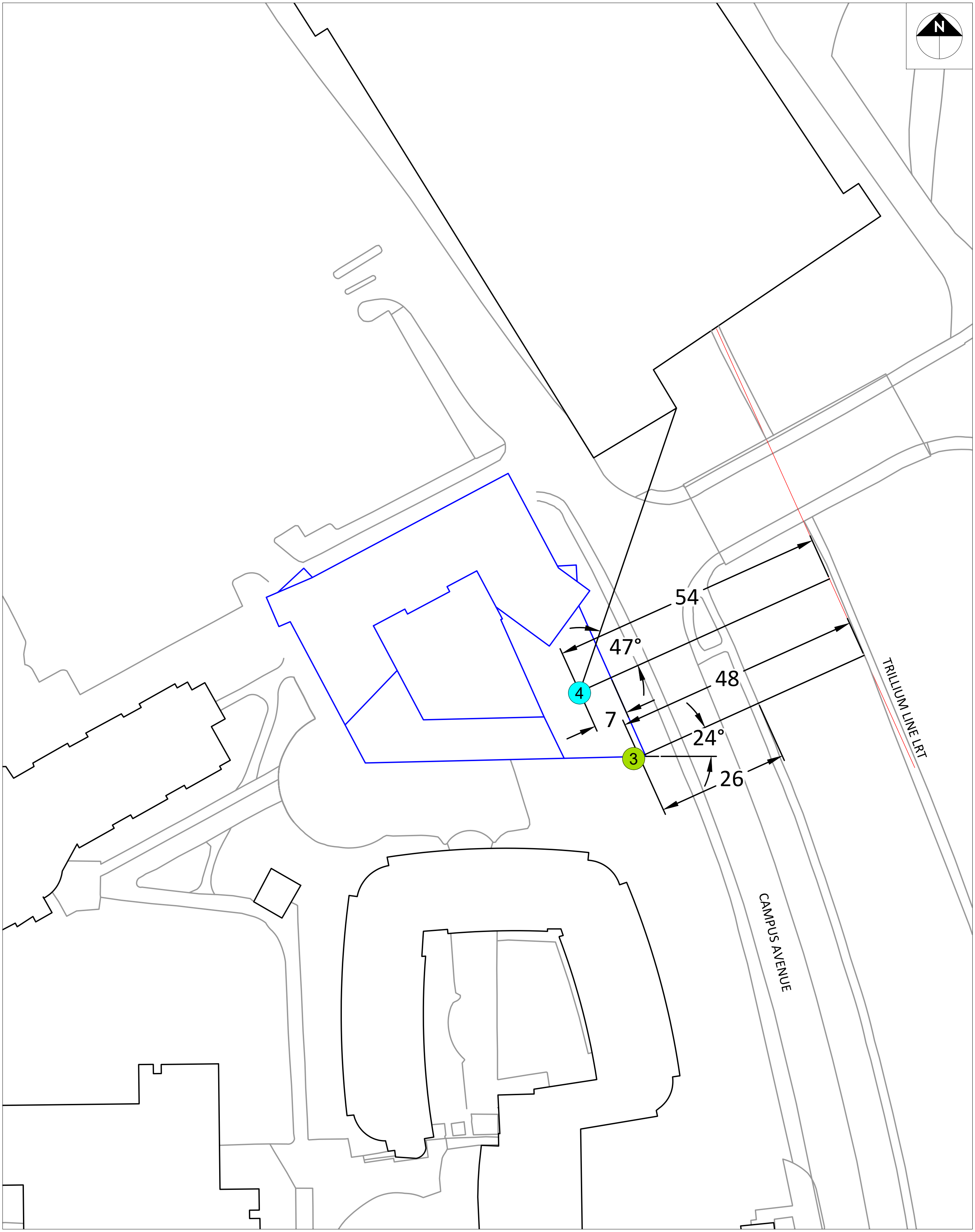
PROJECT	NEW STUDENT RESIDENCE - CARLETON UNIVERSITY LRT NOISE AND VIBRATION ASSESSMENT		DESCRIPTION
SCALE	1:1500 (APPROX.)	DRAWING NO. GW19-224-3	FIGURE 3: STAMSON INPUT PARAMETERS - RECEPTOR 1 & 2
DATE	NOVEMBER 26, 2019	DRAWN BY S.P.	



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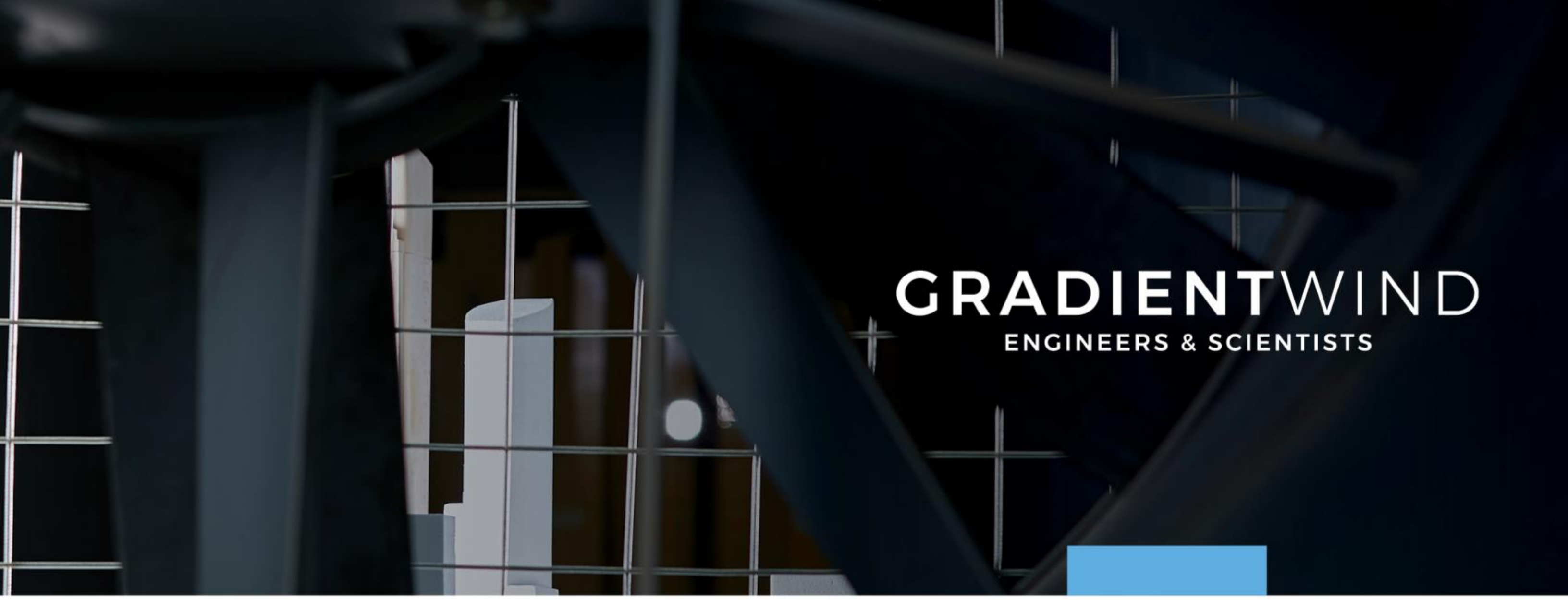
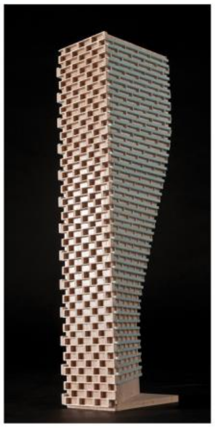
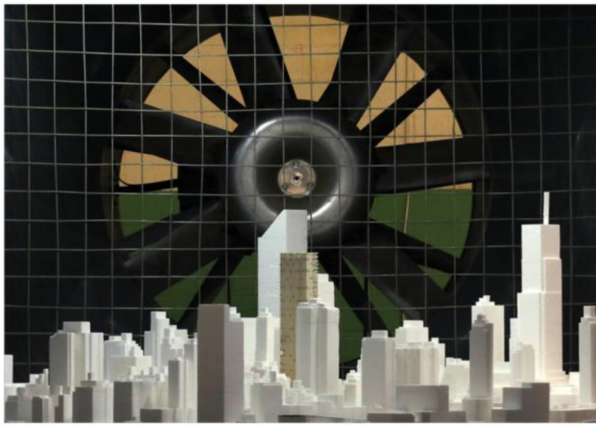
PROJECT	NEW STUDENT RESIDENCE - CARLETON UNIVERSITY LRT NOISE AND VIBRATION ASSESSMENT		
SCALE	1:1000 (APPROX.)	DRAWING NO.	GW19-224-4
DATE	NOVEMBER 26, 2019	DRAWN BY	S.P.

DESCRIPTION

FIGURE 4:
STAMSON INPUT PARAMETERS - RECEPTOR 3 & 4







APPENDIX A

STAMSON 5.04 – INPUT AND OUTPUT DATA

127 WALGREEN ROAD, OTTAWA, ON, CANADA K0A 1L0 | 613 836 0934
GRADIENTWIND.COM

```
STAMSON 5.0         NORMAL REPORT        Date: 22-11-2019 11:46:38
MINISTRY OF ENVIRONMENT AND ENERGY / NOISE ASSESSMENT

Filename: r1.te                 Time Period: Day/Night 16/8 hours
Description:


RT/Custom data, segment # 1: LRT (day/night)
--------------------------------------------
1 - 4-car SRT:
Traffic volume     :   192/24    veh/TimePeriod
Speed              :    70 km/h

Data for Segment # 1: LRT (day/night)
-------------------------------------
Angle1   Angle2           : -62.00 deg   90.00 deg
Wood depth                :      0       (No woods.)
No of house rows          :      0 / 0
Surface                   :      2       (Reflective ground surface)
Receiver source distance  :  47.00 / 47.00  m
Receiver height           :  16.50 / 16.50  m
Topography                :      2       (Flat/gentle slope; with barrier)
Barrier angle1            : -62.00 deg   Angle2 : 90.00 deg
Barrier height            :   7.00 m
Barrier receiver distance :  24.00 / 24.00  m
Source elevation          :  -7.00 m
Receiver elevation        :   0.00 m
Barrier elevation         :  -7.00 m
Reference angle           :   0.00
```

```
Results segment # 1: LRT (day)
------------------------------

Source height = 0.50 m

Barrier height for grazing incidence
------------------------------------
Source      ! Receiver    ! Barrier     ! Elevation of
Height  (m) ! Height  (m) ! Height  (m) ! Barrier Top  (m)
------------+-------------+-------------+---------------
       0.50 !       16.50 !       11.76 !          4.76

RT/Custom (0.00 + 53.25 + 0.00) = 53.25 dBA
Angle1 Angle2  Alpha RefLeq  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------
   -62     90   0.00  58.95  -4.96  -0.73   0.00   0.00  -0.07  53.18*
   -62     90   0.00  58.95  -4.96  -0.73   0.00   0.00   0.00  53.25
----------------------------------------------------------------------

 * Bright Zone !

Segment Leq : 53.25 dBA

Total Leq All Segments: 53.25 dBA
```

```
Results segment # 1: LRT (night)
--------------------------------

Source height = 0.50 m

Barrier height for grazing incidence
------------------------------------
Source      ! Receiver    ! Barrier     ! Elevation of
Height  (m) ! Height  (m) ! Height  (m) ! Barrier Top  (m)
------------+-------------+-------------+---------------
       0.50 !       16.50 !       11.76 !          4.76

RT/Custom (0.00 + 47.23 + 0.00) = 47.23 dBA
Angle1 Angle2  Alpha RefLeq  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------
   -62     90   0.00  52.93  -4.96  -0.73   0.00   0.00  -0.07  47.16*
   -62     90   0.00  52.93  -4.96  -0.73   0.00   0.00   0.00  47.23
----------------------------------------------------------------------

 * Bright Zone !

Segment Leq : 47.23 dBA

Total Leq All Segments: 47.23 dBA



TOTAL Leq FROM ALL SOURCES (DAY): 53.25
                         (NIGHT): 47.23
```

```
STAMSON 5.0        NORMAL REPORT        Date: 22-11-2019 11:51:08
MINISTRY OF ENVIRONMENT AND ENERGY / NOISE ASSESSMENT

Filename: r2.te                Time Period: Day/Night 16/8 hours
Description:


RT/Custom data, segment # 1: LRT (day/night)
--------------------------------------------
1 - 4-car SRT:
Traffic volume    :   192/24    veh/TimePeriod
Speed             :    70  km/h

Data for Segment # 1: LRT (day/night)
-------------------------------------
Angle1   Angle2           : -90.00 deg   -74.00 deg
Wood depth                :      0       (No woods.)
No of house rows          :      0 / 0
Surface                   :      2       (Reflective ground surface)
Receiver source distance  :  78.00 / 78.00  m
Receiver height           :  16.50 / 16.50  m
Topography                :      1       (Flat/gentle slope; no barrier)
Reference angle           :   0.00


Results segment # 1: LRT (day)
------------------------------

Source height = 0.50 m

RT/Custom (0.00 + 41.27 + 0.00) = 41.27 dBA
Angle1 Angle2  Alpha RefLeq  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------
   -90    -74   0.00  58.95  -7.16 -10.51   0.00   0.00   0.00  41.27
----------------------------------------------------------------------

Segment Leq : 41.27 dBA

Total Leq All Segments: 41.27 dBA
```

```
Results segment # 1: LRT (night)
--------------------------------

Source height = 0.50 m

RT/Custom (0.00 + 35.25 + 0.00) = 35.25 dBA
Angle1 Angle2  Alpha RefLeq  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------
   -90    -74   0.00  52.93  -7.16 -10.51   0.00   0.00   0.00  35.25
----------------------------------------------------------------------

Segment Leq : 35.25 dBA

Total Leq All Segments: 35.25 dBA



TOTAL Leq FROM ALL SOURCES (DAY): 41.27
                         (NIGHT): 35.25
```

```
STAMSON 5.0        NORMAL REPORT        Date: 22-11-2019 11:53:25
MINISTRY OF ENVIRONMENT AND ENERGY / NOISE ASSESSMENT

Filename: r3.te                Time Period: Day/Night 16/8 hours
Description:


RT/Custom data, segment # 1: LRT (day/night)
--------------------------------------------
1 - 4-car SRT:
Traffic volume    :   192/24    veh/TimePeriod
Speed             :    70 km/h

Data for Segment # 1: LRT (day/night)
-------------------------------------
Angle1   Angle2           :  24.00 deg   90.00 deg
Wood depth                :      0       (No woods.)
No of house rows          :      0 / 0
Surface                   :      2       (Reflective ground surface)
Receiver source distance  :  48.00 / 48.00  m
Receiver height           :  16.50 / 16.50  m
Topography                :      2       (Flat/gentle slope; with barrier)
Barrier angle1            :  24.00 deg   Angle2 : 90.00 deg
Barrier height            :   7.00 m
Barrier receiver distance :  26.00 / 26.00  m
Source elevation          :  -7.00 m
Receiver elevation        :   0.00 m
Barrier elevation         :  -7.00 m
Reference angle           :   0.00
```

```
Results segment # 1: LRT (day)
------------------------------

Source height = 0.50 m

Barrier height for grazing incidence
------------------------------------
Source      ! Receiver     ! Barrier      ! Elevation of
Height  (m) ! Height   (m) ! Height   (m) ! Barrier Top  (m)
------------+--------------+--------------+---------------
       0.50 !        16.50 !        11.04 !          4.04

RT/Custom (0.00 + 49.54 + 0.00) = 49.54 dBA
Angle1 Angle2  Alpha RefLeq  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------
    24     90   0.00  58.95  -5.05  -4.36   0.00   0.00  -0.22  49.31*
    24     90   0.00  58.95  -5.05  -4.36   0.00   0.00   0.00  49.54
----------------------------------------------------------------------

 * Bright Zone !

Segment Leq : 49.54 dBA

Total Leq All Segments: 49.54 dBA
```

```
Results segment # 1: LRT (night)
--------------------------------

Source height = 0.50 m

Barrier height for grazing incidence
------------------------------------
Source      ! Receiver    ! Barrier     ! Elevation of
Height  (m) ! Height  (m) ! Height  (m) ! Barrier Top  (m)
------------+-------------+-------------+--------------
       0.50 !       16.50 !       11.04 !          4.04

RT/Custom (0.00 + 43.52 + 0.00) = 43.52 dBA
Angle1 Angle2  Alpha RefLeq  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
----------------------------------------------------------------------
    24     90   0.00  52.93  -5.05  -4.36   0.00   0.00  -0.22  43.29*
    24     90   0.00  52.93  -5.05  -4.36   0.00   0.00   0.00  43.52
----------------------------------------------------------------------

 * Bright Zone !

Segment Leq : 43.52 dBA

Total Leq All Segments: 43.52 dBA


TOTAL Leq FROM ALL SOURCES (DAY): 49.54
                         (NIGHT): 43.52
```

```
STAMSON 5.0        NORMAL REPORT        Date: 22-11-2019 11:55:26
MINISTRY OF ENVIRONMENT AND ENERGY / NOISE ASSESSMENT

Filename: r4.te                Time Period: Day/Night 16/8 hours
Description:


RT/Custom data, segment # 1: LRT (day/night)
--------------------------------------------
1 - 4-car SRT:
Traffic volume    :   192/24    veh/TimePeriod
Speed             :    70 km/h

Data for Segment # 1: LRT (day/night)
-------------------------------------
Angle1   Angle2           : -47.00 deg   90.00 deg
Wood depth                :      0       (No woods.)
No of house rows          :      0 / 0
Surface                   :      2       (Reflective ground surface)
Receiver source distance  :  54.00 / 54.00  m
Receiver height           :  25.50 / 25.50  m
Topography                :      2       (Flat/gentle slope; with barrier)
Barrier angle1            : -47.00 deg   Angle2 : 90.00 deg
Barrier height            :  24.00 m
Barrier receiver distance :   7.00 / 7.00   m
Source elevation          :   0.00 m
Receiver elevation        :   0.00 m
Barrier elevation         :   0.00 m
Reference angle           :   0.00
```

```
Results segment # 1: LRT (day)
------------------------------

Source height = 0.50 m

Barrier height for grazing incidence
------------------------------------
Source      ! Receiver    ! Barrier     ! Elevation of
Height  (m) ! Height  (m) ! Height  (m) ! Barrier Top  (m)
------------+-------------+-------------+---------------
       0.50 !       25.50 !       22.26 !        22.26

RT/Custom (0.00 + 42.80 + 0.00) = 42.80 dBA
Angle1 Angle2  Alpha RefLeq  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
-----------------------------------------------------------------------
   -47     90   0.00  58.95  -5.56  -1.19   0.00   0.00  -9.40  42.80
-----------------------------------------------------------------------

Segment Leq : 42.80 dBA

Total Leq All Segments: 42.80 dBA


Results segment # 1: LRT (night)
--------------------------------

Source height = 0.50 m

Barrier height for grazing incidence
------------------------------------
Source      ! Receiver    ! Barrier     ! Elevation of
Height  (m) ! Height  (m) ! Height  (m) ! Barrier Top  (m)
------------+-------------+-------------+---------------
       0.50 !       25.50 !       22.26 !        22.26

RT/Custom (0.00 + 36.78 + 0.00) = 36.78 dBA
Angle1 Angle2  Alpha RefLeq  D.Adj  F.Adj  W.Adj  H.Adj  B.Adj SubLeq
-----------------------------------------------------------------------
   -47     90   0.00  52.93  -5.56  -1.19   0.00   0.00  -9.40  36.78
-----------------------------------------------------------------------

Segment Leq : 36.78 dBA

Total Leq All Segments: 36.78 dBA


TOTAL Leq FROM ALL SOURCES (DAY): 42.80
                          (NIGHT): 36.78
```

APPENDIX B

FTA VIBRATION CALCULATIONS

127 WALGREEN ROAD, OTTAWA, ON, CANADA K0A 1L0 | 613 836 0934
GRADIENTWIND.COM

GW19-224 25-Nov-19

Possible Vibration Impacts on the New Student Residence at Carleton University
Perdicted using FTA General Assesment

Train Speed 70 km/h 43.5 mph

	Distance from C/L	
	(m)	(ft)
LRT	46.0	150.9

		Vibration		
From FTA Manual Fig 10-1				
	Vibration Levels at distance from track	73.5	dBV re 1 micro in/sec	
Adjustment Factors FTA Table 10-1				
	Speed reference 50 mph	-1	Speed Limit of 70 km/h (43.5 mph)	
	Vehicle Parameters	0	Assume Soft primary suspension, Weels run true	
	Track Condition	0	None	
	Track Treatments	0	None	
	Type of Transit Structure	0	Open Cut	
	Efficient vibration Propagation	0	None	
	Vibration Levels at Fdn	72		0.105
	Coupling to Building Foundation	-10	Large Massonry on Piles	
	Floor to Floor Attenuation	-2.0	Ground Floor Occupied	
	Amplification of Floor and Walls	6		
	Total Vibration Level	66.29039	dBV or	0.052 mm/s
	Noise Level in dBA	31.29039	dBA	

Table 10-1. Adjustment Factors for Generalized Predictions of Ground-Borne Vibration and Noise				
Factors Affecting Vibration Source				
Source Factor	**Adjustment to Propagation Curve**			**Comment**
		Reference Speed		
Speed	Vehicle Speed	50 mph	30 mph	Vibration level is approximately proportional to 20*log(speed/speed$_{ref}$). Sometimes the variation with speed has been observed to be as low as 10 to 15 log(speed/speed$_{ref}$).
	60 mph	+1.6 dB	+6.0 dB	
	50 mph	0.0 dB	+4.4 dB	
	40 mph	-1.9 dB	+2.5 dB	
	30 mph	-4.4 dB	0.0 dB	
	20 mph	-8.0 dB	-3.5 dB	
Vehicle Parameters (not additive, apply greatest value only)				
Vehicle with stiff primary suspension	+8 dB			Transit vehicles with stiff primary suspensions have been shown to create high vibration levels. Include this adjustment when the primary suspension has a vertical resonance frequency greater than 15 Hz.
Resilient Wheels	0 dB			Resilient wheels do not generally affect ground-borne vibration except at frequencies greater than about 80 Hz.
Worn Wheels or Wheels with Flats	+10 dB			Wheel flats or wheels that are unevenly worn can cause high vibration levels. This can be prevented with wheel truing and slip-slide detectors to prevent the wheels from sliding on the track.
Track Conditions (not additive, apply greatest value only)				
Worn or Corrugated Track	+10 dB			If both the wheels and the track are worn, only one adjustment should be used. Corrugated track is a common problem. Mill scale on new rail can cause higher vibration levels until the rail has been in use for some time.
Special Trackwork	+10 dB			Wheel impacts at special trackwork will significantly increase vibration levels. The increase will be less at greater distances from the track.
Jointed Track or Uneven Road Surfaces	+5 dB			Jointed track can cause higher vibration levels than welded track. Rough roads or expansion joints are sources of increased vibration for rubber-tire transit.
Track Treatments (not additive, apply greatest value only)				
Floating Slab Trackbed	-15 dB			The reduction achieved with a floating slab trackbed is strongly dependent on the frequency characteristics of the vibration.
Ballast Mats	-10 dB			Actual reduction is strongly dependent on frequency of vibration.
High-Resilience Fasteners	-5 dB			Slab track with track fasteners that are very compliant in the vertical direction can reduce vibration at frequencies greater than 40 Hz.

Table 10-1. Adjustment Factors for Generalized Predictions of Ground-Borne Vibration and Noise (Continued)

Factors Affecting Vibration Path		
Path Factor	**Adjustment to Propagation Curve**	**Comment**
Resiliently Supported Ties	-10 dB	Resiliently supported tie systems have been found to provide very effective control of low-frequency vibration.
Track Configuration (not additive, apply greatest value only)		
Type of Transit Structure	Relative to at-grade tie & ballast: Elevated structure -10 dB Open cut 0 dB	The general rule is the heavier the structure, the lower the vibration levels. Putting the track in cut may reduce the vibration levels slightly. Rock-based subways generate higher-frequency vibration.
	Relative to bored subway tunnel in soil: Station -5 dB Cut and cover -3 dB Rock-based - 15 dB	
Ground-borne Propagation Effects		
Geologic conditions that promote efficient vibration propagation	Efficient propagation in soil +10 dB	Refer to the text for guidance on identifying areas where efficient propagation is possible.
	Propagation in rock layer — **Dist.** / **Adjust.**: 50 ft +2 dB 100 ft +4 dB 150 ft +6 dB 200 ft +9 dB	The positive adjustment accounts for the lower attenuation of vibration in rock compared to soil. It is generally more difficult to excite vibrations in rock than in soil at the source.
Coupling to building foundation	Wood Frame Houses -5 dB 1-2 Story Masonry -7 dB 3-4 Story Masonry -10 dB Large Masonry on Piles -10 dB Large Masonry on Spread Footings -13 dB Foundation in Rock 0 dB	The general rule is the heavier the building construction, the greater the coupling loss.
Factors Affecting Vibration Receiver		
Receiver Factor	**Adjustment to Propagation Curve**	**Comment**
Floor-to-floor attenuation	1 to 5 floors above grade: -2 dB/floor 5 to 10 floors above grade: -1 dB/floor	This factor accounts for dispersion and attenuation of the vibration energy as it propagates through a building.
Amplification due to resonances of floors, walls, and ceilings	+6 dB	The actual amplification will vary greatly depending on the type of construction. The amplification is lower near the wall/floor and wall/ceiling intersections.
Conversion to Ground-borne Noise		
Noise Level in dBA	Peak frequency of ground vibration: Low frequency (<30 Hz): -50 dB Typical (peak 30 to 60 Hz): -35 dB High frequency (>60 Hz): -20 dB	Use these adjustments to estimate the A-weighted sound level given the average vibration velocity level of the room surfaces. See text for guidelines for selecting low, typical or high frequency characteristics. Use the high-frequency adjustment for subway tunnels in rock or if the dominant frequencies of the vibration spectrum are known to be 60 Hz or greater.