Appendix D7

Noise and Vibration Supplemental Information

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Acronyms

BRT	Bus Rapid Transit
dB	decibel
dBA	A-weighted decibel
FTA	Federal Transit Administration
FTA Guidance Manual	Transit Noise and Vibration Impact Assessment
Hz	hertz
L_{dn}	day-night average sound level
L_{eq}	equivalent sound level
LRT	Light-Rail Transit
Metro	Niagara Frontier Metro Systems, Inc.
MPH	miles per hour
NYSDEC	New York State Department of Environmental Conservation
SLM	Sound Level Meter
UB	University at Buffalo
VdB	vibration decibels

Appendix D. Noise and Vibration Supplemental Information

D.1 NOISE

The following sections detail the methodology, regulatory context, and impact criteria the Niagara Frontier Metro Transit Systems, Inc. (Metro) used in the operational and construction noise analyses, as summarized in Section 4.11, "Noise" (of Chapter 4, "Environmental Considerations"), as well as elaborating on the results of the noise analysis by presenting the contribution from each individual noise source included in each Project Alternative.

D.1.1 Noise Regulatory Context

The noise analysis was conducted following procedures described in the Federal Transit Administration (FTA) *Transit Noise and Vibration Impact Assessment* (FTA Guidance Manual) (FTA Report No. 0123, September 2018) for rail and bus-related noise and vibration impacts. The FTA Guidance Manual sets forth procedures for analyzing noise and vibration resulting from non-high-speed (i.e., 90 miles per hour or below) rail projects. Guidance in the FTA Manual (section 9, Vibration Screening Procedure) indicates that other than projects that include vehicles operating within buildings or over roadway surface irregularities, projects involving rubber-tired vehicles are not expected to result in significant vibration impacts at receptors not considered highly sensitive.

Following the procedures set forth in the FTA Guidance Manual, airborne noise impacts can be analyzed using a screening procedure, a general noise assessment, and/or a detailed noise analysis. The screening procedure is performed first to determine whether any noise-sensitive receptors are within distances where impacts are likely to occur. When there are noise-sensitive receptors in locations where impacts are likely to occur, a general noise assessment is then performed to determine locations where noise impacts could occur. If this general assessment indicates that a potential for noise impact does exist, then a detailed noise analysis could be necessary. The FTA's detailed analysis methodology is used to predict impacts and evaluate the effectiveness of mitigation with greater precision than can be achieved with the general noise assessment.

The New York State Department of Environmental Conservation (NYSDEC) "Assessing and Mitigation Noise Impacts" guidance document provides general instructions for evaluation and mitigation of environmental noise for projects in New York State. However, it does not specifically address noise from transit projects, which are typically evaluated based on Federal guidance as described above. Additionally, the impact criteria in NYSDEC's guidance is comparable to that of the FTA guidance, with the FTA impact criteria generally more stringent.

As such, evaluation of the Buffalo-Amherst-Tonawanda Corridor Transit Expansion (Project) using the FTA guidance provides the most conservative method for identifying potential impacts.

The Light-Rail Transit (LRT) Build Alternative and Bus Rapid Transit (BRT) Build Alternative could result in the diversion of roadway vehicular traffic. As described in Chapter 3, "Transportation," the potential for traffic diversions due to the Build Alternatives was considered during the development of the traffic analysis methodology. A review of the Greater Buffalo Niagara Regional Transportation Council regional travel demand model and turning movement counts in the study area indicates that potential diversions would not be significant and that traffic would most likely divert to major roadways outside the study area. Metro conducted a screening analysis to determine whether traffic diverted as a result of the Build Alternatives could result in noise level increases at any noise receptors that would constitute impacts on those receptors. The FTA noise analysis procedures do not include a methodology to consider diverted vehicular traffic; however, a screening level analysis based on the expected increase in vehicular volumes was used to evaluate the potential for impacts as a result of vehicular traffic diversions.

D.1.2 Noise Fundamentals and Definitions

If sufficiently loud, noise could adversely affect people in several ways. For example, noise could interfere with human activities such as sleep, speech communication, and tasks requiring concentration or coordination. Noise could also cause annoyance, hearing damage, and other physiological problems. Several noise scales and rating methods are used to quantify the effects of noise on people. These scales and methods consider such factors as loudness, duration, time of occurrence, and changes in noise level with time.

Sound-pressure levels are measured decibels (dB). The particular character of the noise that we hear is determined by the frequency at which the air pressure fluctuates. Frequency defines the fluctuation of sound pressure in terms of cycles per second. One cycle per second is known as 1 Hertz (Hz). People can hear over a relatively limited range of sound frequencies, generally between 20 Hz and 20,000 Hz, and the human ear does not perceive all frequencies equally well. High frequencies are more easily discerned and therefore more intrusive than many of the lower frequencies.

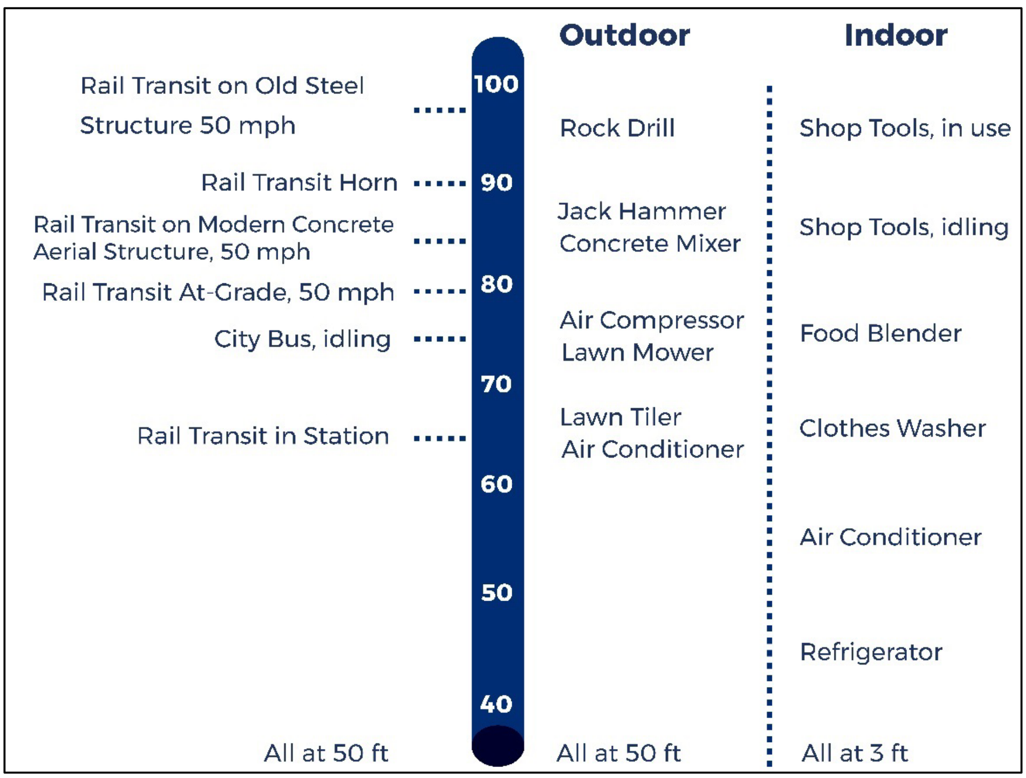
A-Weighted Sound Level

To bring a uniform noise measurement that simulates human perception of loudness and annoyance, the decibel measurement is weighted to account for those frequencies most audible to the human ear. A-weighted sound levels represent the overall noise at a receiver adjusted in frequency to approximate typical human hearing sensitivity. The A-weighted sound level is the most used descriptor of noise levels where community noise is concerned because of the weighting based on human perception. This is expressed in A-weighted decibels (dBA), which is the basic noise unit for transit noise analyses. As shown in Figure D-1, the threshold of human hearing is defined as 0 dBA; very quiet conditions (e.g., a library) are approximately 40 dBA;

levels between 50 dBA and 70 dBA define the range of normal daily activity; levels above 70 dBA are considered noisy, and then loud, intrusive, and deafening as the scale approaches 130 dBA. For most people to perceive an increase in noise, it must be at least 3 dBA. At 5 dBA, the change will be readily noticeable. An increase of 10 dBA is generally perceived as a doubling of loudness.

Combinations of different sources are not additive in an arithmetic manner due to the decibel scale's logarithmic nature. For example, two noise sources—a vacuum cleaner operating at approximately 72 dBA and a telephone ringing at approximately 58 dBA—do not combine to create a noise level of 130 dBA, the equivalent of a military jet or air raid siren. The logarithmic combination of these two noise sources would yield a noise level of 72.2 dBA.

Figure D-1. Common Noise Levels



Source: Federal Transit Administration. 2018. *Transit Noise and Vibration Impact Assessment*
Note: A 10 dBA increase in level appears to double the loudness, and a 10 dBA decrease halves the apparent loudness.

Effects of Distance on Noise

Noise varies with distance. For example, highway traffic 50 feet away from a receptor (such as a person listening to the noise) typically produces sound levels of approximately 70 dBA. The same highway noise would measure 66 dBA at a distance of 100 feet, assuming soft ground conditions (such as grass). This decrease is referred to as sound propagation loss. For a line source, such as a railway, the sound level decreases approximately 4.5 dBA (for soft ground) for every doubling of distance between the noise source and receptor. For hard ground (such as concrete), the sound level decreases approximately 3 dBA for every doubling of distance between the line source and receptor. Assuming soft ground, for a point source, such as a stationary piece of construction equipment (e.g., a drill rig), the sound level decreases approximately 7.5 dBA for every doubling of distance between the noise source and receptor. For hard ground, the sound level decreases approximately 6 dBA for every doubling of distance between the point source and receptor.

Noise Descriptors Used in Impact Assessment

The sound-pressure level unit of dBA describes a noise level at just one moment, but because very few noises are constant, other ways of describing noise over more extended periods have been developed. One way of describing fluctuating sound is to describe the fluctuating noise heard over a specific period as if it were a steady, unchanging sound (i.e., as if it were averaged over that time period). For this condition, the equivalent sound level (L_{eq}) can be computed. L_{eq} is the constant sound level that, in a given situation and period, (e.g., 1 hour, denoted by $L_{eq(1hr)}$, or 24 hours, denoted as $L_{eq(24hr)}$) conveys the same sound energy as the actual time-varying sound.

A descriptor for cumulative 24-hour exposure is the day-night average sound level (L_{dn}). This is a 24-hour measurement that accounts for the moment-to-moment fluctuations in A-weighted noise levels due to all sound sources combined. Mathematically, the L_{dn} noise level is the energy average of all $L_{eq(1hr)}$ noise levels over a 24-hour period, where nighttime noise levels (10 p.m. to 7 a.m.) are increased by 10 dBA before averaging because of increased noise sensitivity during nighttime when people are typically sleeping.

Following guidance in the FTA Guidance Manual, either the maximum $L_{eq(1hr)}$ sound level or the L_{dn} sound level is used for operational noise impact assessment, depending on land use category. Also as specified in the FTA Guidance Manual, the 8-hour equivalent level (i.e., the $L_{eq(8hr)}$), and the 30-day average L_{dn} are used for construction noise impact assessment as described in the following section.

D.1.3 Operational Noise Impact Criteria

The FTA Guidance Manual defines noise criteria based on the specific type of land use that would be affected, with explicit operational noise impact criteria for three land use categories. These impact criteria are based on either peak 1-hour L_{eq} or 24-hour L_{dn} values. Table D-1 describes the land use categories defined in the FTA Guidance Manual and provides noise metrics used for determining operational noise impacts. As described in Table D-1, Categories 1 and 3. which include land uses that are noise-sensitive but where people do not sleep. require examination using the 1-hour L_{eq} descriptor for the noisiest peak hour. Category 2, which includes residences, hospitals, and other locations where nighttime sensitivity to noise is very important, requires examination using the 24-hour L_{dn} descriptor.

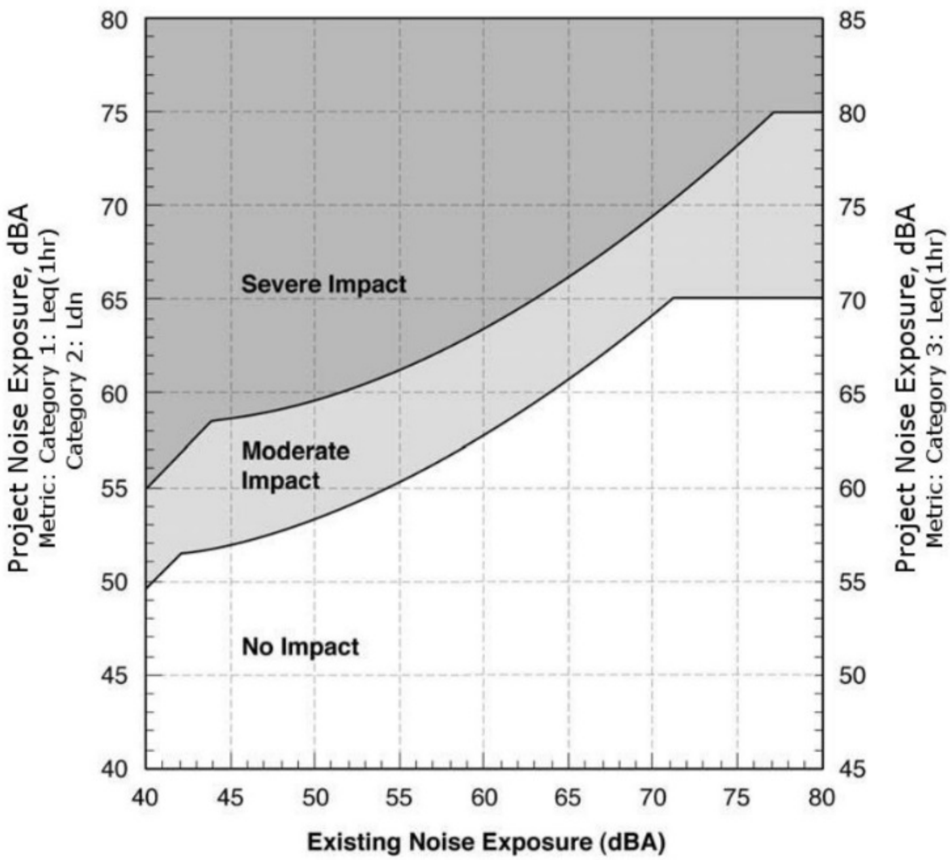
Table D-1. FTA's Land Use Category and Metrics for Transit Noise Impact Criteria

Land Use Category	Land Use Type	Noise Metric, dBA	Description of Land Use Category
1	High Sensitivity	Outdoor $L_{eq(1hr)}$*	Land where quiet is an essential element of its intended purpose. Example land uses include preserved land for serenity and quiet, outdoor amphitheaters and concert pavilions, and national historic landmarks with considerable outdoor use.
2	Residential	Outdoor L_{dn}	This category is applicable to all residential land use and buildings where people normally sleep, such as hotels and hospitals.
3	Institutional	Outdoor $L_{eq(1hr)}$*	This category is applicable to institutional land uses with primarily daytime and evening use. Example land uses include schools, libraries, theaters, and churches where it is important to avoid interference with such activities as speech, meditation, and concentration on reading material.

Source: Federal Transit Administration. 2018. *Transit Noise and Vibration Impact Assessment*
* $L_{eq(1hr)}$ for the loudest hour of project-related activity during hours of noise sensitivity.

D-2 shows the FTA's noise impact criteria for transit projects, as presented in the FTA Guidance Manual. The FTA impact criteria are keyed to the noise level generated by a project (called "project noise exposure") in locations of varying existing noise levels. Two types of impacts—moderate and severe—are defined for each land use category, depending on existing noise levels. Thus, where existing noise levels are 40 dBA, for land use Categories 1 and 2, the respective $L_{eq(1hr)}$ and L_{dn} noise exposure from a project would create moderate impacts if they were above approximately 50 dBA and would create severe impacts if they were above approximately 55 dBA. For Category 3, a project noise exposure $L_{eq(1hr)}$ above approximately 55 dBA would be considered a moderate impact, and above approximately 60 dBA would be considered a severe impact. The difference between "severe impact" and "moderate impact" is that a severe impact indicates a change in noise level that a significant percentage of people would find annoying, while a moderate impact indicates a change in noise level that is noticeable to most people but not necessarily sufficient to result in strong adverse reactions from the community. Severe impacts are generally considered to constitute adverse impacts, whereas moderate impacts require further consideration to evaluate whether they would constitute adverse impacts.

Figure D-2. FTA Noise Impact Criteria for Transit Projects



Source: Federal Transit Administration. 2018. *Transit Noise and Vibration Impact Assessment*

D.1.4 Construction Noise Impact Criteria

The local noise ordinances in Buffalo, Amherst, and Tonawanda do not provide specific criteria for evaluation of construction noise levels. The Buffalo and Amherst codes only reference construction noise in order to prohibit construction activity during nighttime hours (9:00 p.m. to 7:00 a.m.). Construction associated with the Build Alternatives would occur during daytime hours (7:00 a.m. to 9:00 p.m.), which is consistent with this prohibition. As such, the guidelines presented in the FTA Guidance Manual are used for evaluation of construction noise.

The FTA Guidance Manual provides noise impact thresholds for construction in the daytime (defined as 7 a.m. to 10 p.m.) and nighttime (defined as 10 p.m. to 7 a.m.). Separate impact thresholds are specified for various types of land use (e.g., residential, commercial, and industrial), depending on each use's sensitivity to noise, although the land use categories for the construction noise impact thresholds are not the same as the FTA land use categories for the operational noise impact criteria as described earlier. Table D-2 shows the impact thresholds for construction. Because construction of the Build Alternatives would occur during daytime hours, the daytime noise impact criteria have been used for this analysis.

Table D-2. FTA Construction Noise Impact Criteria

Land Use	$L_{eq.equip(1hr)}$, dBA	
	Day	Night
Residential	90	80
Commercial	100	100
Industrial	100	100

Source: Federal Transit Administration. 2018. *Transit Noise and Vibration Impact Assessment*

D.1.5 Noise Analysis Methodology

Operational Impacts

For the analysis of operational airborne noise, the following procedure was used:[1]

1. Identify noise-sensitive land uses (e.g., residential, religious, university) within the screening distance from the Project alignment and selection of representative noise receptor sites. The screening distances defined by the FTA Guidance Manual are 350 feet and 200 feet for the LRT and BRT Build Alternatives, respectively.
2. Determine existing noise levels at the selected receptor sites by performing field measurements and using acoustical fundamentals. For sites at which direct access to conduct noise level measurements was not available, noise levels were estimated in accordance with FTA procedures.
3. Determine cumulative future noise levels from sources with the Build Alternatives at each receptor site using FTA general assessment methodology and FTA noise level computation equations. The cumulative future noise levels are the sum of all individual sources, including the LRT rail vehicles or BRT buses, LRT crossings bells, LRT whistles/horns, park & ride lots, BRT storage yards, etc. The cumulative future noise levels incorporate the effects of noise reduction measures, which are included in the Build Alternatives described in the applicable Potential Mitigation Strategies sections. Table D-3 shows the inputs for the FTA general assessment of the LRT and BRT Build Alternatives.
4. Determine the Build Alternatives' noise exposure at each receptor site (i.e., noise only from Proposed Alternative-generated sources), by projecting the future noise levels for each individual source over the distance to the receptor.
5. Compare the Build Alternatives' noise exposure to the FTA criteria to identify potential impacts.
6. Consider the amount of diverted vehicular traffic associated with the Build Alternatives to determine the potential for traffic noise impacts at receptors.

[1] The noise analysis did not include charging stations in the BRT Build Alternative operational noise quantitative evaluation. It is assumed that the charging equipment would not emit noise levels greater than 55 dBA at a distance of 2 meters as indicated in the conceptual design for the basis of design equipment. Further, it is assumed that no additional exposed equipment, such as transformers or other noise-producing equipment, would be utilized.

Table D-3. Operational Noise General Assessment Procedures

	General Assessment Computation Input	Input for Build Alternative
LRT Railway	Electric or Diesel	Electric
	Average Number of Cars per Train	3
	Speed (mph)	40, 28[1] north of Ellicott Station, 10 north of I-990
	Number of Trains per Hour (Peak Hour)	15
	Average Number of Trains per Hour (Day)	12
	Average Number of Trains per Hour (Night)	4
	Number of Rows of Intervening Buildings	0 for all receptors other than 15a 1 at receptor 15a
	Rail Skirts	Yes[1] (assumption of 5 dB reduction from skirts)
	Jointed track	Yes
	Embedded Track	Yes at at-grade crossings and UB North Campus
LRT Whistles/Horns	Reference Noise Level	81 dBA at 50 ft (crossings) 83 dBA at 50 ft (warning horn at portals)[1]
	Speed (mph)	40, 28[1] north of Ellicott Station, 10 north of I-990
	Volume of Trains (7:00 a.m. – 10:00 p.m.)	172
	Volume of Trains (10:00 p.m. – 7:00 a.m.)	32
LRT Substations	Specified Noise Level	55 dBA at 15 ft
BRT Guideway	Speed (mph)	25 – 45, based on posted speed limit restrictions
	Average Events per hour (Day)	12
	Average Events per hour (Night)	4
	Number of Rows of Intervening Buildings	0 for all receptors other than 15a 1 at receptor 15a
BRT Bus Storage Lot	Peak Buses per Hour	100
LRT and BRT Park & Ride Lots	Peak Buses per Hour	0
	Peak Autos per Hour	215 at Mall property lot, 129 at I-990 lot

Source: Federal Transit Administration. 2018. Transit Noise and Vibration Impact Assessment
[1] Build Alternative-specific low-noise commitments.

Noise Measurement Locations

Metro identified 18 noise measurement locations to represent noise-sensitive locations within the screening distances that the FTA Guidance Manual specifies. These measurement locations were selected to represent the existing conditions for noise-sensitive land uses that would have the greatest potential to experience noise-level increases from the LRT Build Alternative and the BRT Build Alternative. Figure D-3 shows the measurement locations and Table D-4 presents a summary with the associated FTA land use categories and noise descriptors.

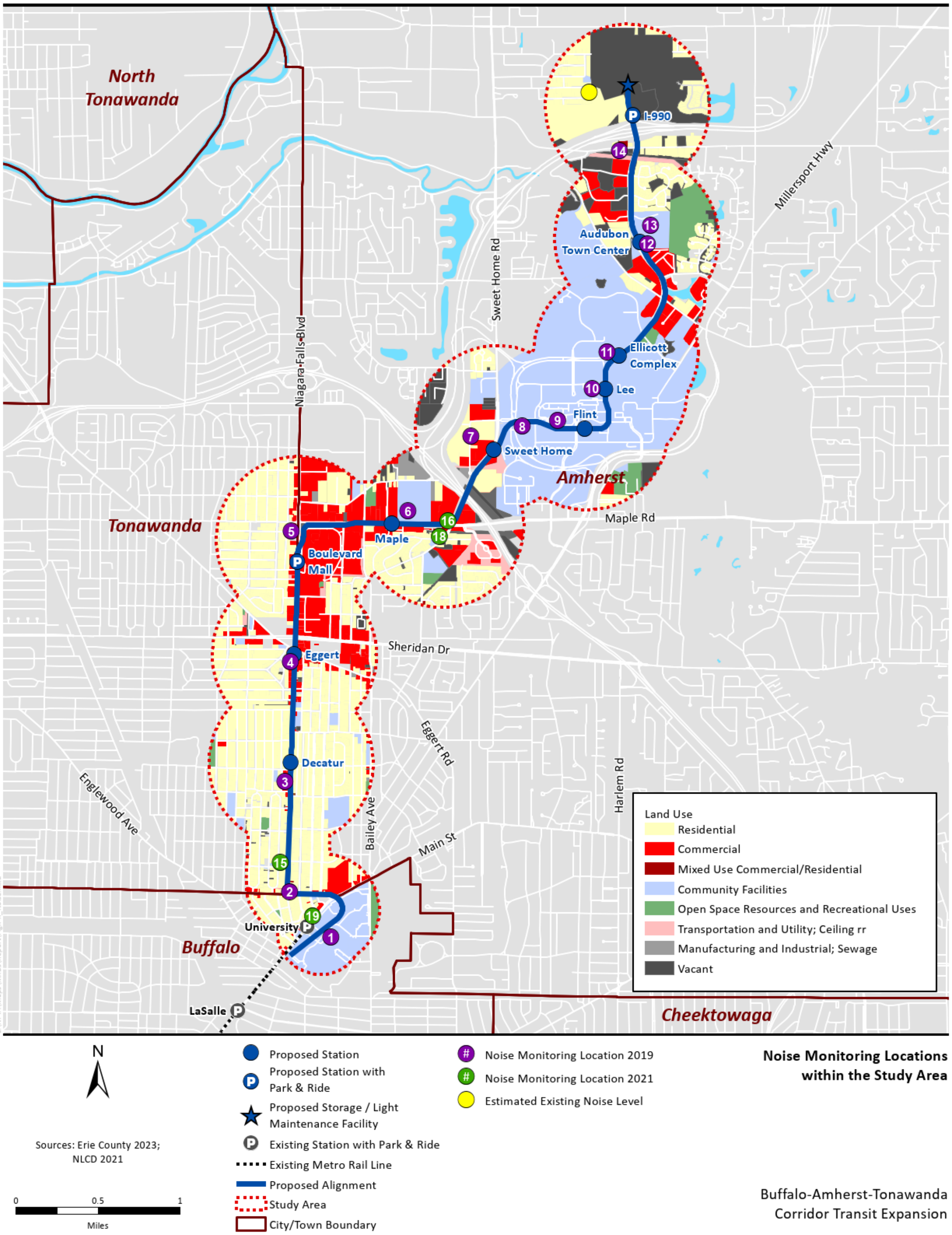
Table D-4. Noise Measurement Locations

Site #	Measurement Location	Land Use Represented	FTA Land Use Category	Noise Descriptor
1	Foster Hall	University	3	L_{eq}
19	Allenhurst Road and Main Street	Residential	2	L_{dn}
2	159 Niagara Falls Boulevard	Residential	2	L_{dn}
15	Niagara Falls Boulevard and Kenilworth Road,89 Grandview Avenue	Residential	2	L_{dn}
3	512 Niagara Falls Boulevard	Residential, Religious	2, 3	L_{dn}, L_{eq}
4	900 Niagara Falls Boulevard	Religious	3	L_{eq}
5	1328 Niagara Falls Boulevard	Residential	2	L_{dn}
18	Homecrest Drive	Residential	2	L_{dn}
16	Along Sweet Home Road near Maple Road	Residential	2	L_{dn}
6	Sweet Home Middle School, 4150 Maple Road	School	2	L_{dn}
7	100 Villas Drive East	Residential	3	L_{eq}
8	Hadley Village 110	Residential	2	L_{dn}
9	Cooke Hall, Mary Talbert Way	University	3	L_{eq}
10	Davis Hall, White Road	University	3	L_{eq}
11	Greiner Hall – UB North Campus, John James Audubon Parkway & Core Road	Residential	2	L_{dn}
12	BECPL Audubon Branch – Amherst Public Library, 350 John James Audubon Parkway	Library, Cemetery	3	L_{eq}
13	Town of Amherst Court, 400 John James Audubon Parkway	Residential	2	L_{dn}
14	Amherst Memorial Chapel, 281 Dodge Road	Residential, Religious	2, 3	L_{dn}, L_{eq}

Notes:
1. See Figure D-3 for locations.

Key:
BECPL = Buffalo & Erie County Public Library
FTA = Federal Transit Administration
L_{dn} = day-night average sound level
L_{eq} = equivalent sound level

Figure D-3. Noise Monitoring Locations



Construction Impacts

Metro analyzed the airborne noise associated with construction of the Build Alternatives using the general assessment procedures described in the FTA Guidance Manual to the extent possible based on the conceptual construction information available. A quantified general assessment was conducted to evaluate the potential for construction-related (e.g., tunnel and shaft construction, track construction, station construction, and construction of the storage facility north of I-990) noise impacts at sensitive receptors near areas of construction for the Build Alternatives. Construction-related noise was calculated by assuming that the two loudest pieces of construction equipment would operate simultaneously and continuously for one hour during the daytime period (7:00 a.m. to 10:00 p.m.) at the center of the construction site or centerline of the alignment. Table D-5. lists the equipment that could be used for construction of the Build Alternatives, along with associated noise emission levels at a distance of 50 feet. The emission levels for the two noisiest pieces of equipment (see Table D-5. for list of equipment assumptions for each construction work area and time period) were then projected to the distance at which the construction noise level would exceed the construction noise impact thresholds described in Table D-2. The projected distance at which construction noise levels would exceed FTA construction noise impact criteria shown in Table D-2 were mapped and receptors within the potential impact zone identified to determine the potential for construction noise impacts. This methodology provides a conservative estimate of potential impacts.

Table D-5. Construction Equipment Noise Emission Levels

Equipment	L_{max}, dBA
Air Compressor	80
Backhoe	80
Ballast Equalizer	82
Ballast Tamper	83
Compactor	82
Concrete Mixer	85
Concrete Pump	82
Concrete Vibrator	76
Crane	80[1]
Dozer	85
Generator	82
Grader	85
Impact Wrench	85
Loader	80
Paver	85
Pneumatic Tool	85
Pump	77
Rock Drill	80[1]
Roller	85
Saw	76
Scarifier	83

Equipment	L_{max}, dBA
Scraper	85
Shovel	82
Spike Driver	77
Tie Cutter	84
Tie Handler	80
Tie Inserter	85
Truck	84

Source: Federal Transit Administration. 2018. *Transit Noise and Vibration Impact Assessment*
[1] Build Alternative-specific low-noise commitments.

Table D-6. Construction General noise Analysis Equipment Assumptions

Work Area	Time	Equipment Assumption
Tunnel Sequential Excavation Method	Daytime (7AM to 10PM)	2 Trucks
Tunnel Cut and Cover	Daytime (7AM to 10PM)	2 Concrete Mixers
	Nighttime (10PM to 7AM)	2 Rock Drills
Shaft at Main Street	Daytime (7AM to 10PM)	2 Trucks
Kenmore Avenue at Niagara Falls Boulevard	Daytime (7AM to 10PM)	2 Concrete Mixers
Typical At-Grade Track Work	Daytime (7AM to 10PM)	2 Dozers
Typical Station Construction	Daytime (7AM to 10PM)	1 Dozer, 1 Truck
Typical Substation Construction	Daytime (7AM to 10PM)	2 Concrete Mixers
Route 990 Storage Yard Construction	Daytime (7AM to 10PM)	2 Dozers
Typical Truck Route	Daytime (7AM to 10PM)	2 Trucks
	Nighttime (10PM to 7AM)	2 Trucks

D.1.6 Noise Existing Conditions

Table D-7 identifies the locations where Metro conducted noise measurements. Data from the surveys were used to determine existing noise levels according to the FTA Guidance Manual, using the noise level descriptor for each receptor's land use category.

Table D-7 shows the existing noise levels for each measurement location. These values were calculated following the procedures described previously. Existing noise levels at all locations include noise generated by vehicular traffic including trucks and buses on adjacent roadways and aircraft overflights. Additional noise sources that contributed to existing noise levels included UB bus traffic at Locations 1, 10, and 11; pedestrian foot traffic at Locations 1, 6, 7, 8, 9, 10, 11, 12, and 13; and nearby mechanical equipment at Locations 3, 5, and 10.

The noise levels measured at each location were used to represent multiple nearby noise-sensitive receptors within the same noise environment. For example, noise levels measured at Location 3 were used in the noise analysis to represent nearby receptors 3a, 3b, etc. A total of 29 analysis receptor sites were identified to represent noise-sensitive receptors that could experience noise-level increases resulting from the LRT Build Alternative and the BRT Build Alternative. The receptors are representative of existing land uses in the study area and were chosen to provide geographic coverage of the areas where noise impacts could occur. The 29 analysis receptor locations were selected at the closest developed land uses to the alignment of the LRT Build Alternative and the BRT Build Alternative and each of the construction work areas. For this reason, each studied receptor would be more likely to experience noise impacts from the activities of the LRT Build Alternative and the BRT Build Alternative than other nearby noise-sensitive uses along the Project corridor. Table D-8 lists the locations of the analysis receptor sites.

Table D-7. Existing Noise Levels

Site #	Measurement Location	Measurement Type	FTA Land Use Category	Noise Descriptor	Existing Noise Level (dBA) AM Peak L_{eq}	Existing Noise Level (dBA) L_{dn}
1	Foster Hall	1 hour AM Peak	3	L_{eq}	56	N/A
19	Allenhurst Road and Main Street	24 hours	2	L_{dn}	N/A	60
2	159 Niagara Falls Boulevard	24 hours	2	L_{dn}	N/A	61
15	Niagara Falls and Kenilworth Road,89 Grandview Avenue	24 hours	2	L_{dn}	N/A	61
3	512 Niagara Falls Boulevard	24 hours	2, 3	L_{dn}, L_{eq}	70[1]	70
4	900 Niagara Falls Boulevard	1 hour AM, MD, LN Peak	2	L_{dn}	61	58[3]
5	1328 Niagara Falls Boulevard	24 hours	2	L_{dn}	59[1]	59[2]
6	Sweet Home Middle School, 4150 Maple Rd	1 hour AM Peak	2, 3	L_{dn}, L_{eq}	62	60[3]
18	Homecrest Drive	24 hours	2	L_{dn}	N/A	62
16	Along Sweet Home Road near Maple Road	24 hours	2	L_{dn}	N/A	69
7	100 Villas Drive East	24 hours	2	L_{dn}	58[1]	60
8	Hadley Village 110	24 hours	2	L_{dn}	58[1]	60[2]
9	Cooke Hall, Mary Talbert Way	1 hour AM Peak	3	L_{eq}	56	N/A
10	Davis Hall, White Rd	1 hour AM Peak	3	L_{eq}	56	N/A
11	Greiner Hall - UB North Campus, John James Audubon Parkway & Core Road	24 hours	2	L_{dn}	54[1]	56
12	BECPL Audubon Branch - Amherst Public Library, 350 John James Audubon Parkway	1 hour AM Peak	3	L_{eq}	54	N/A
13	Town of Amherst Court, 400 John James Audubon Parkway	1 hour AM, MD, LN Peak	3	L_{dn}	N/A	53[3]
14	Amherst Memorial Chapel, 281 Dodge Rd	24 hours	2, 3	L_{dn}, L_{eq}	60[1]	60

Notes: Field measurements were conducted March 25–28, 2019 and April 6-8, 2021.

1 Where 24-hour measurements were conducted, the minimum 1-hour L_{eq} during the AM peak time period (7:00 AM-10:00 AM) was conservatively utilized as the AM peak L_{eq}

2 Use of noisy landscaping equipment near this location during the noise measurement contaminated a portion of the measurement time. Audio recordings were utilized to exclude contaminated hours, noise levels during which were estimated based on data measured in the preceding or following hours to calculate the Ldn.

3 L_{dn} estimated using FTA's *Transit Noise and Vibration Impact Assessment Manual*, Table 4-17 and Appendix E.

Key:
BECPL = Buffalo & Erie County Public Library
dBA = A-weighted decibels
FTA = Federal Transit Administration
L_{dn} = day-night average sound level
L_{eq} = equivalent sound level
N/A = not applicable

Table D-8. Noise Analysis Receptor Locations

Receptor Site		Land Use Represented	FTA Land Use Category	Noise Descriptor	Distance to Project (feet)
1[1]	UB Foster Hall	University	3	L_{eq}	160
19a[1]	3442 Main Street (University Court Apartments)	Residential	2	L_{dn}	23
2a[1]	135 Kenmore Ave	Residential	2	L_{dn}	30
2b[1]	171 Niagara Falls Boulevard	Residential	2	L_{dn}	25
15a	Niagara Falls Boulevard and Kenilworth Road (89 Grandview Avenue)	Residential	2	L_{dn}	138
3a	345 Niagara Falls Boulevard	Residential	2	L_{dn}	40
3f	248 Niagara Falls Boulevard	Residential	2	L_{dn}	45
3i	Trinity United Methodist Church	Religious	3	L_{eq}	37
3t	316 Niagara Falls Boulevard	Residential	2	L_{dn}	50
4a	315 Curtis Parkway	Residential	2	L_{dn}	209
5a	51 Wrexham Court North	Residential	2	L_{dn}	287
5h	1343 Brighton Road	Residential	2	L_{dn}	461
18a	324 Homecrest Drive	Residential	2	L_{dn}	313
18f	344 Homecrest Drive	Residential	2	L_{dn}	272
16b	1185 Sweet Home Road (The Station at Buffalo)	Residential	2	L_{dn}	96
6	Sweet Home Middle School	School	3	L_{eq}	224
7a	100 Villas Drive	Residential	2	L_{dn}	274
8a	Hadley Village 112	Residential	2	L_{dn}	113
9a	Park Hall, UB North Campus	University	3	L_{eq}	131
10	Davis Hall, UB North Campus	University	3	L_{eq}	281
10c	Lockwood Memorial Library, UB North Campus	University	3	L_{eq}	85
11a	Greiner Hall, UB North Campus	Residential	2	L_{dn}	256
12	Audubon Branch Amherst Public Library	Library	3	L_{eq}	122
12a	Skinnersville Cemetery, Frontier Road	Cemetery	3	L_{eq}	58
13a	2 Partridge Run	Residential	2	L_{dn}	70
14	Amherst Chapel/Funeral Home	Religious	3	L_{eq}	418
14a	300 Dodge Road	Residential	2	L_{dn}	90
14h	Muir Woods Future Residential Development	Future Residential	2	L_{dn}	107
14k	Muir Woods Future Residential Development	Future Residential	2	L_{dn}	137

Note:
[1] Receptors used for BRT Build Alternative analysis only

Key:
BRT = Bust Rapid Transit
dBA = A-weighted decibels
FTA = Federal Transit Administration
L_{dn} = day-night average sound level
L_{eq} = equivalent sound level
N/A = not applicable

D.1.7 Noise Analysis Results

Existing Noise Survey

Following the categories and descriptors outlined above, 1-hour peak equivalent sound level (L_{eq}) noise levels were collected for Category 1 and Category 3 receptors. The operation schedule for the LRT Build Alternative and the BRT Build Alternative would be comparable to the current Metro Rail operation schedule for the existing system. Based on the existing Metro Rail operation schedule, the peak hours for the operations of the LRT Build Alternative and the BRT Build Alternative would be between 7:00 a.m. and 10:00 a.m. Therefore, for Category 1 and Category 3 receptors, noise measurements were collected over a 1-hour time period between 7:00 a.m. and 10:00 a.m. and the 1-hour peak L_{eq} noise levels from this hour were utilized in the analysis. For Category 2 receptors, where examination of the 24-hour day-night average sound level (L_{dn}) descriptor is required, 24-hour continuous measurements were collected where site access could be obtained for the full 24-hour survey. At Category 2 receptors with limited site access, 1-hour measurements were collected during the AM, midday (between the morning and afternoon roadway-traffic peak hours), and late-night (between midnight and 5:00 a.m.) time periods to calculate the existing L_{dn} based on Equation E-1 provided in Appendix E of the FTA Guidance Manual and shown below.

$$L_{dn} \approx 10\log(3 \times 10^{\frac{L_{eq.peakhour}-2}{10}} + 12 \times 10^{\frac{L_{eq.midday}-2}{10}} + 9 \times 10^{\frac{L_{eq.latenight}+8}{10}}) - 13.8 \qquad \textbf{Eq. E-1}$$

Noise measurements were taken using Brüel & Kjær Type 2250, 2250L, 2260, and 2270 Noise Level Meters; Brüel & Kjær Sound Level Calibrators Type 4231; and Brüel & Kjær Type 4189 1/2-inch microphones. Instruments were mounted at a height of approximately 5 feet above the ground. The meters were calibrated before and after readings using Brüel & Kjær Type 4231 sound level calibrators using the appropriate adaptors. The sound meters digitally recorded the data and displayed the data at the end of the measurement period in units of A-weighted decibels (dBA). Measured quantities included L_{eq}, L_1, L_{10}, L_{50}, and L_{90}.[2, 3] Windscreens were used during all sound measurements except for calibration. The measurement procedures conformed to the requirements of American National Standards Institute Standard S1.13-2005.

At Locations 2, 3, 5, 7, 8, 11, 14, 15, 16, 18, and 19, 24-hour continuous noise-level measurements were conducted. At Locations 1, 6, 9, 10, and 12, 1-hour duration measurements were conducted during the AM peak time period, which represents the peak period of operations and peak (*i.e.*, worst-case) period of noise production for the LRT Build Alternative and the BRT Build Alternative, because this is when highest hourly volume of vehicles would be expected to occur. At Locations 4 and 13, 1-hour duration noise measurements were conducted during the AM, midday, and late-nighttime periods, as per the FTA Guidance Manual. Noise levels from

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2 L_1 = noise level exceeded for 1 percent of the time of the measurement duration; L_{10} = 10 percent of the time; L_{50} = 50 percent of the time.

3 L_{90} is taken to be the ambient or background noise level.

these three measurements were combined to estimate the existing L_{dn} values using Equation E-1 shown above. Noise level measurements were conducted from March 25 through 28, 2019, and April 6 through 8, 2021.

LRT Alternative

Table 4.12-4 summarizes the results of the operational noise analysis for the LRT Build Alternative. Table D-9 below shows the project noise exposure broken down by each noise source included in the LRT Build Alternative.

Table D-9. Noise Exposure by Noise Source with the LRT Build Alternative (in dBA)

Receptor Site #	Receptor Site	Rail Cars	Crossing Signals	Whistle at At-Grade Crossing	Horn at Portal	Substation	Park & Ride Lots	LRT Build Alternative Total Noise Exposure
15a	89 Grandview Avenue	54	0	0	53	37	0	56
3a	339 Niagara Falls Boulevard	64	56	59	0	24	0	66
3t	297 Niagara Falls Boulevard	61	0	0	0	29	0	61
3f	249 Niagara Falls Boulevard	61	0	0	60	43	0	64
3i	Trinity United Methodist Church	61	39	51	0	0	0	61
4a	315 Curtis Parkway	56	43	53	0	0	0	58
5a	51 Wrexham Court North	54	40	52	0	24	38	56
5h	1343 Brighton Road	48	0	0	0	28	0	48
6	Sweet Home Middle School	54	41	51	49	0	0	57
18a	324 Homecrest Drive	53	39	51	0	0	0	56
18f	344 Homecrest Drive	54	40	52	50	0	0	57
16b	1185 Sweet Home Road	61	52	57	0	0	0	63
7a	100 Villas Drive	54	39	52	0	39	0	56
8a	Hadley Village 112	55	43	55	0	24	0	58
9a	Park Hall, UB North Campus	55	40	53	0	23	0	57
10	Davis Hall, UB North Campus	50	38	52	0	18	0	54
10c	Lockwood Memorial Library, UB North Campus	57	52	57	0	42	0	61
11a	Greiner Hall, UB North Campus	52	0	0	0	0	0	52
12	Audubon Branch Amherst Public Library	55	0	0	0	19	0	55
12a	Skinnersville Cemetery, Frontier Road	56	0	0	0	22	0	56
13a	2 Partridge Run	59	0	0	0	27	0	59
14	Amherst Chapel and Funeral Home	47	0	0	0	0	0	47
14a	300 Dodge Road	58	0	0	0	0	0	58
14h	Muir Woods Future Residential Development	48	0	0	0	39	47	51
14k	Muir Woods Future Residential Development	44	0	0	0	57	37	58

Key:
dBA = A-weighted decibels; FTA = Federal Transit Administration; LRT = Light-Rail Transit

BRT Alternative

Table D-10 shows the project noise exposure broken down by each noise source included in the BRT Alternative.

Table D-10. Noise Exposure by Noise Source with the BRT Build Alternative (in dBA)

Receptor Site #	Receptor Site	BRT Roadway	Park & Ride Lot	Storage Yard	BRT Build Alternative Total Noise Exposure
1	UB Foster Hall	41	0	0	41
19a	3442 Route 5 (University Court Apartments)	57	0	0	57
2a	135 Kenmore Ave	55	0	0	55
2b	171 Niagara Falls Boulevard	60	0	0	60
15a	89 Grandview Avenue	46[1]	0	0	46
3a	339 Niagara Falls Boulevard	57	0	0	57
3f	249 Niagara Falls Boulevard	56	0	0	56
3i	Trinity United Methodist Church	54	0	0	54
3t	297 Niagara Falls Boulevard	55	0	0	55
16b	1185 Sweet Home Road	51	0	0	51
7a	100 Villas Drive	44	0	0	44
8a	Hadley Village 112	46	0	0	46
9a	Park Hall, UB North Campus	45	0	0	45
10c	Lockwood Memorial Library, UB North Campus	51	0	0	51
11a	Greiner Hall, UB North Campus	45	0	0	45
12	Audubon Branch Amherst Public Library	47	0	0	47
12a	Skinnersville Cemetery, Frontier Road	52	0	0	52
13a	2 Partridge Run	53	0	0	53
14	Amherst Chapel and Funeral Home	40	0	0	40
14a	300 Dodge Road	51	0	0	51
14h	Muir Woods Future Residential Development	50	47	56	57

Notes:
[1] Includes adjustment for one row of intervening buildings
Key: dBA = A-weighted decibels; FTA = Federal Transit Administration; BRT = Bus Rapid Transit

D.2 VIBRATION

The following sections detail vibration fundamentals, the methodology, and the impact criteria Metro used in the operational and construction vibration analyses as summarized in Section 4.12, “Vibration.”

D.2.1 Vibration Fundamentals and Definitions

Fixed-railway operations can produce high vibration levels because railway vehicles contact a rigid steel rail with steel wheels. Train wheels rolling on the steel rails create vibration energy that is transmitted into the track support system. The amount of vibrational energy strongly depends on such factors as wheel and rail smoothness and the vehicle suspension system. The vibration of the track structure “excites” the adjacent ground, creating vibration waves that propagate through the various soil and rock strata to the foundations of nearby buildings. As the vibration propagates from the foundation through the remaining building structure, certain resonant, or natural, frequencies of various components of the building could be excited. Guidance in the FTA Manual indicates that other than projects that include vehicles operating within buildings or over roadway surface irregularities, projects involving rubber-tired vehicles are not expected to result in significant vibration impacts at receptors not considered highly sensitive.

The effects of ground-borne vibration could include discernable movement of building floors, rattling of windows, and shaking of items on shelves or hanging on walls. In extreme cases, the vibration can cause damage to buildings. The vibration of floors and walls could cause perceptible vibration, rattling such items as windows or dishes on shelves. The movement of building surfaces and objects within the building can also result in a low-frequency rumble noise. The rumble is the noise radiated from the motion of the room surfaces, even when the motion itself cannot be felt. This is called ground-borne noise.

Vibration decibels (VdB) are used to distinguish from noise decibels. All vibration levels are referenced to $1x10^{-6}$ inches per second, as recommended in the FTA Guidance Manual.

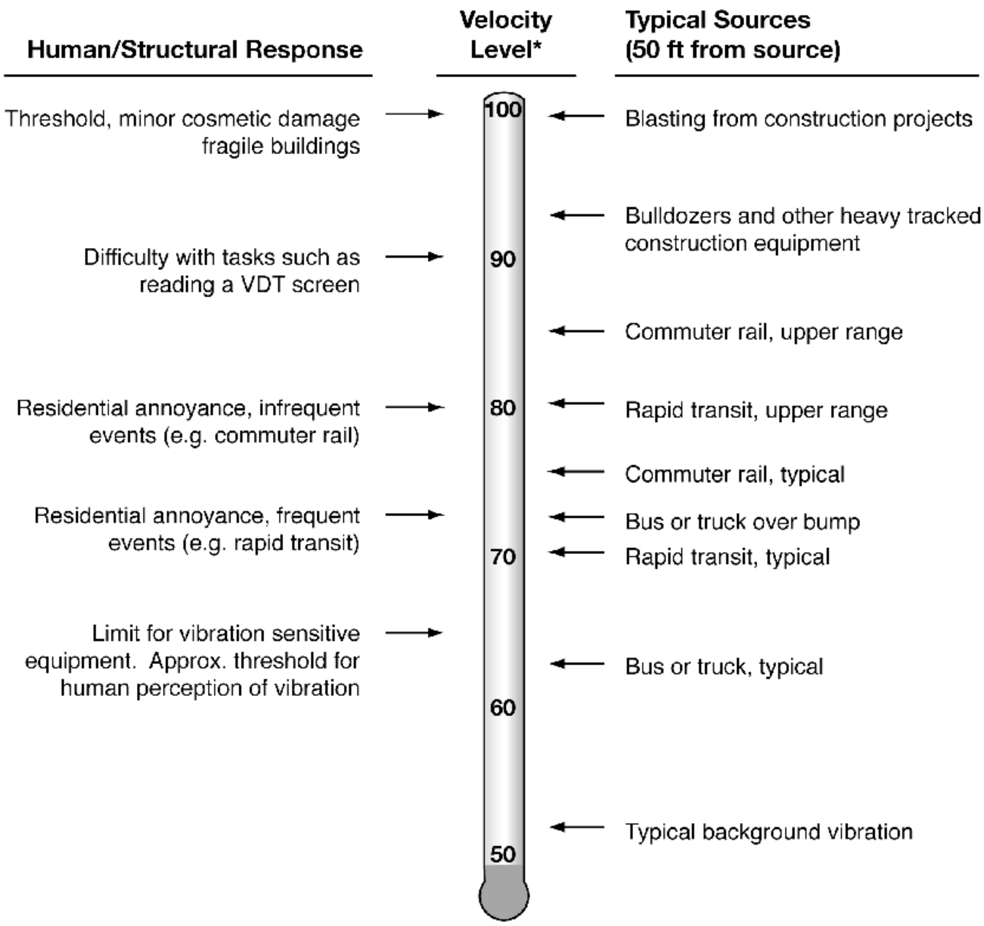
Effect of Propagation Path

Vibration is transmitted from the source to the ground and propagates through the ground to the receptor. Soil conditions have a strong influence on the levels of ground-borne vibration. Stiff soils, such as some clay and rock, can transmit vibrations over substantial distances. Sandy soils, wetlands, and groundwater tend to absorb movement and thus reduce vibration transmission. Because subsurface conditions vary widely, measurement of actual vibration conditions (defined as transfer mobility) at the site can be the most practical way to address the variability of propagation conditions**.**

Human Response to Vibration Levels

In accordance with the FTA Guidance Manual, the perceptibility threshold is approximately 65 VdB. However, human response to vibration is not usually substantial unless the vibration exceeds 70 VdB. For example, buses and trucks rarely create vibration that exceeds 72 VdB unless there are significant bumps in the road and these vehicles are operating at moderate speeds. Figure D-4 shows a range of vibration levels with typical human and structural responses, as well as typical vibration sources.

Figure D-4. Typical Levels of Ground-Borne Vibration



* *RMS Vibration Velocity Level in VdB relative to 10^{-6} inches/second*

Source: U.S. Department of Transportation, FTA, *Transit Noise and Vibration Impact Assessment,* September 2018.

D.2.2 Vibration Standards and Impact Criteria

Operational

To examine potential impacts during operation, the FTA Guidance Manual outlines a three-step approach (similar to the approach for assessing airborne noise described in Section 4.11, “Noise”) to analyze vibration and ground-borne noise:

- A screening procedure determines whether any vibration-sensitive receptors are within distances where impacts are likely to occur.
- A general assessment methodology determines locations or rail segments where there is potential for impacts.
- A detailed analysis methodology predicts impacts and evaluates the effectiveness of mitigation with greater precision than can be achieved with the general assessment.

The FTA criteria for environmental impact from ground-borne vibration and noise are based on the land use category and maximum levels for a single event. Table D-11 shows the land use categories as defined in the FTA Guidance Manual.

Table D-11. FTA's Land Use Categories for General Vibration Assessment Impact Criteria

Land Use Category	Land Use Type	Description of Land Use Category
—	Special Buildings	This category includes special-use facilities that are very sensitive to vibration and noise that are not included in the categories below and require special consideration. However, if the building will rarely be occupied when the source of the vibration (e.g., a transit system) is operating, there is no need to evaluate for impact. Examples of these facilities include concert halls, TV and recording studios, and theaters.
1	High Sensitivity	This category includes buildings where vibration levels, including those below the threshold of human annoyance, would interfere with operations within the building. Examples include buildings where vibration-sensitive research and manufacturing* is conducted, hospitals with vibration-sensitive equipment, and universities conducting physical research operations. The building's degree of sensitivity to vibration is dependent on the specific equipment that will be affected by the vibration. Equipment moderately sensitive to vibration, such as high resolution lithographic equipment, optical microscopes, and electron microscopes with vibration isolation systems are included in this category.** For equipment that is more sensitive, a Detailed Vibration Analysis must be conducted.
2	Residential	This category includes all residential land use and buildings where people normally sleep, such as hotels and hospitals. Transit-generated ground-borne vibration and noise are considered to have a similar effect on receivers.***
3	Institutional	This category includes institutions and offices that have vibration-sensitive equipment and have the potential for activity interference such as schools, churches, doctors' offices. Commercial or industrial locations including office buildings are not included in this category unless there is vibration-sensitive activity or equipment within the building. As with noise, the use of the building determines the vibration sensitivity.

Source: U.S. Department of Transportation, FTA, *Transit Noise and Vibration Impact Assessment,* September 2018.

* Manufacturing of computer chips is an example of a vibration-sensitive process.

** Standard optical microscopes can be impacted at vibration levels below the threshold of human annoyance.

*** Even in noisy urban areas, the bedrooms will often be in quiet buildings with effective noise insulation. However, ground-borne vibration and noise are experienced indoors, and building occupants have practically no means to reduce their exposure. Therefore, occupants in noisy urban areas are just as likely to be exposed to ground-borne vibration and noise as those in quiet suburban areas.

Table D-11 **s**hows the vibration impact criteria for land use Categories 1 through 3, as defined in the FTA Guidance Manual. Table D-13 shows the impact criteria for ground-borne noise due to vibration. The criteria for acceptable ground-borne vibration are expressed in terms of Root Mean Square velocity levels in decibels and the criteria for acceptable ground-borne noise are expressed in terms of A-weighted sound level. As shown in the tables, the FTA methodology provides three different impact criteria:

- One for "infrequent" events, when there are fewer than 30 vibration events per day
- One for "occasional" events, when there are between 30 and 70 vibration events per day
- One for "frequent" events, when there are more than 70 vibration events per day

Table D-12. Ground-Borne Vibration Impact Criteria for General Assessment

Land Use Category	Ground-Borne Vibration Impact Levels (VdB re 1 micro-inch/sec)		
	Frequent Events[1]	Occasional Events[2]	Infrequent Events[3]
Category 1: Buildings where vibration would interfere with interior operations	65 VdB[4]	65 VdB[4]	65 VdB[4]
Category 2: Residences and buildings where people normally sleep	72 VdB	75 VdB	80 VdB
Category 3: Institutional land uses with primarily daytime use	75 VdB	78 VdB	83 VdB

Source: U.S. Department of Transportation, FTA, *Transit Noise and Vibration Impact Assessment,* September 2018.
Notes:
1 "Frequent Events" is defined as more than 70 vibration events of the same source per day. Most rapid transit projects fall into this category.
2 "Occasional Events" is defined as between 30 and 70 vibration events of the same source per day. Most commuter trunk lines have this many operations.
3 "Infrequent Events" is defined as fewer than 30 vibration events of the same kind per day. This category includes most commuter rail systems.
4 This criterion limit is based on levels that are acceptable for most moderately sensitive equipment such as optical microscopes. For equipment that is more sensitive, a detailed vibration analysis must be performed.

Table D-13. Ground-Borne Noise Impact Criteria for General Assessment

Land Use Category	Ground-Borne Noise Impact Levels (dB re 20 micro Pascals)		
	Frequent Events[1]	Occasional Events[2]	Infrequent Events[3]
Category 1: Buildings where vibration would interfere with interior operations	N/A[4]	N/A[4]	N/A[4]
Category 2: Residences and buildings where people normally sleep	35 dBA	38 dBA	43 dBA
Category 3: Institutional land uses with primarily daytime use	40 dBA	43 dBA	48 dBA

Source: U.S. Department of Transportation, FTA, *Transit Noise and Vibration Impact Assessment,* September 2018.
Notes:
1 "Frequent Events" is defined as more than 70 vibration events of the same source per day. Most rapid transit projects fall into this category.
2 "Occasional Events" is defined as between 30 and 70 vibration events of the same source per day. Most commuter trunk lines have this many operations.
3 "Infrequent Events" is defined as fewer than 30 vibration events of the same kind per day. This category includes most commuter rail systems.
4 Vibration-sensitive equipment is generally not sensitive to ground-borne noise; however, the manufacturer's specifications should be reviewed for acoustic and vibration sensitivity.

These impacts occur only if a project causes ground-borne noise or vibration levels that are higher than existing vibration levels. Thus, if the vibration level for a building in Category 1 is already 70 VdB (5 VdB above the 65 VdB threshold listed in Table D-14) but a hypothetical project would not increase that level, then the project would not be considered to have an impact.

Special vibration level thresholds, shown in Table D-14 and Table D-15, are defined in the FTA Guidance Manual for land uses that have special sensitivity to ground-borne vibration and ground-borne noise.

Table D-14. Ground-Borne Vibration Impact Criteria for Special Buildings

Type of Building or Room	Ground-Borne Vibration Impact Levels (VdB re 1 micro-inch/sec)	
	Frequent Events[1]	Occasional or Infrequent Events[2]
Concert Halls	65 VdB	65 VdB
TV Studios	65 VdB	65 VdB
Recording Studios	65 VdB	65 VdB
Auditoriums	72 VdB	80 VdB
Theaters	72 VdB	80 VdB

Source: U.S. Department of Transportation, FTA, *Transit Noise and Vibration Impact Assessment,* September 2018.
1 "Frequent Events" is defined as more than 70 vibration events of the same source per day. Most rapid transit projects fall into this category.
2 "Occasional or Infrequent Events" is defined as fewer than 70 vibration events per day. This category includes most commuter rail systems.
3 If the building will rarely be occupied when the trains are operating, there is no need to consider impact.

Table D-15. Ground-Borne Noise Impact Criteria for Special Buildings

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

Source: U.S. Department of Transportation, FTA, *Transit Noise and Vibration Impact Assessment,* September 2018.
1 "Frequent Events" is defined as more than 70 vibration events of the same source per day. Most rapid transit projects fall into this category.
2 "Occasional or Infrequent Events" is defined as fewer than 70 vibration events per day. This category includes most commuter rail systems.
3 If the building will rarely be occupied when the trains are operating, there is no need to consider impact.

Construction

The FTA provides architectural and structural damage risk and perceptibility thresholds (Table D-16) for residential and historic structures in proximity to the types of construction activities (Table D-17) that would occur during construction of the Build Alternatives. Architectural damage includes cosmetic damage, such as cracked plaster, etc., and is not considered potentially dangerous. As shown in Table D-16, pile driving has the greatest potential to result in architectural damage to most building types. Most other construction activities require very small distances (i.e., less than 25 feet) between the structure and the construction equipment or the presence of highly fragile buildings for impacts to occur. For fragile and highly fragile buildings, the FTA recommends a limit of peak particle velocities of 0.2 and 0.12 inches per second or 94 and 90 VdB, respectively.

Table D-16. Vibration Source Levels for Construction Equipment

Equipment	PPV at 25 ft (in/sec)	Approximate L_v[1] at 25 ft
Pile Driver (impact)	0.644 – 1.518	104 – 112
Pile Driver (sonic)	0.170 – 0.734	93 - 105
Clam Shovel drop (slurry wall)	0.202	94
Hydromill (slurry wall in soil)	0.008	66
Hydromill (slurry wall in rock)	0.017	75

Equipment	PPV at 25 ft (in/sec)	Approximate L_v[1] at 25 ft
Vibratory Roller	0.210	94
Hoe Ram	0.089	87
Large bulldozer	0.089	87
Caisson drilling	0.089	87
Loaded trucks	0.076	86
Jackhammer	0.035	79
Small bulldozer	0.003	58

Source: U.S. Department of Transportation, FTA, *Transit Noise and Vibration Impact Assessment,* September 2018.
Key: PPV = peak particle velocity
Notes:
1 Root Mean Square velocity in decibels (VdB) re 1 micro-inch/second.

Table D-17. Construction Vibration Damage Criteria

Building Category	PPV (in/sec)	Approximate Lv
I. Reinforced-concrete, steel or timber (no plaster)	0.50	102
II. Engineered concrete and masonry (no plaster)	0.30	98
III. Non-engineered timber and masonry buildings	0.20	94
IV. Buildings extremely susceptible to vibration damage	0.12	90

Source: U.S. Department of Transportation, FTA, *Transit Noise and Vibration Impact Assessment,* September 2018.
Key: PPV = peak particle velocity

D.2.3 Vibration Analysis Methodology

Metro conducted the vibration analysis following procedures described in the FTA *Transit Noise and Vibration Impact Assessment Manual* (FTA Guidance Manual).[4] The FTA Guidance Manual outlines the procedures to (1) identify vibration-sensitive receptors and their land use category and (2) determine vibration levels associated with the LRT Build Alternative and the BRT Build Alternative for comparison to the FTA impact criteria. Vibration impacts were assessed for the LRT Build Alternative and the BRT Build Alternative using FTA assessment methodology.

The FTA Guidance Manual sets forth procedures for analyzing noise and vibration resulting from non-high-speed (*i.e.*, 90 miles per hour or below) rail projects. Guidance in the FTA Manual indicates that other than projects that include vehicles operating within buildings or over roadway surface irregularities, projects involving rubber-tired vehicles are not expected to result in significant vibration impacts at receptors not considered highly sensitive. There are no State regulatory requirements for vibration from transit projects.

The study area for the operational and construction vibration and ground-borne noise studies includes receptors within the FTA Guidance Manual screening distances, as well as those locations chosen based on input from UB where research buildings contain vibration-sensitive equipment or involve vibration-sensitive research procedures. Unlike the noise analysis presented in Section 4.11, "Noise," predicted construction and operational vibration levels were

4 *Transit Noise and Vibration Impact Assessment Manual.* 2018. Prepared by John A. *https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/118131/transit-noise-and-vibration-impact-assessment-manual-fta-report-no-0123_0.pdf.*

compared directly to vibration criteria. Therefore, existing ambient vibration measurements were not required as part of the FTA Guidance Manual procedures, and existing vibration levels were measured only in buildings on the UB North Campus where vibration-sensitive research may occur.

Existing Vibration Survey

A Bruel and Kjaer 2250 Sound Level Meter (SLM) was used to measure low-frequency vertical-direction acceleration in the basement slabs of Cooke Hall (C-16), Park Hall (B-12) and Davis Hall (SB01) during no-traffic (ambient) conditions on nearby roadways. Specifically, a Wilcoxon Research Model 793L low-frequency high-sensitivity accelerometer was used in conjunction with the SLM through appropriate adapters and cabling. The 793L accelerometer has a nominal sensitivity of 500 mV/g over a frequency range of 0.02 Hz to 2,300 Hz and is capable of accurate vibration measurements below 10 µg. The high-sensitivity accelerometer calibration was field checked before and after measurements using a hand-held Meggit Reference Mate Type REF2510 vibration calibrator.

Operational Impacts

Guidance in the FTA Manual indicates that other than projects that include vehicles operating within buildings or over roadway surface irregularities, projects involving rubber-tired vehicles are not expected to result in significant vibration impacts at receptors not considered highly sensitive. Consequently, the operational vibration analysis is focused on the LRT Build Alternative.

The FTA vibration analysis methodology begins with a vibration screening to determine whether any vibration-sensitive receptors are within a distance where an impact is likely to occur. According to the FTA screening methodology, the potential for vibration impacts should be examined if high-sensitivity receptors are located within 450 feet of the centerline of a light rail transit system, residential receptors within 150 feet from the track centerline, or institutional/office receptors within 100 feet from the track centerline. Residential land uses and high-sensitivity UB buildings with vibration-sensitive research are within the screening distances of the Project alignment. Therefore, a general assessment of operational vibration was conducted.

For each receptor identified within the screening distances, Metro calculated future rail vibration levels with the LRT Build Alternative using the FTA Guidance Manual's general assessment methodology. According to the FTA Guidance Manual methodology, maximum predicted vibration levels are calculated based on a variety of parameters for the rail system, including the rail vehicle and wheel configuration, track construction, soil conditions, and building construction for each receptor (Table D-18). Maximum predicted vibration levels are projected to each receptor using the distance between the LRT Build Alternative alignment and the receptor. The predicted vibration levels were compared to the FTA vibration criteria (Table

D-18) to identify potential operational vibration or ground-borne noise impacts associated with the LRT Build Alternative.

Construction Impacts

Following the general assessment procedures described in the FTA Guidance Manual, for each construction work area, vibration levels were projected to nearby receptors and compared to FTA vibration damage criteria (Table D-17). For the quantitative construction vibration assessment, the vibration level for the piece of equipment anticipated to produce the most vibration was used to determine the vibration levels at each receptor. Section 4.17, "Construction Effects" of this Draft presents the construction-related Project vibration impacts and proposed mitigation.

Table D-18. LRT - Operational Vibration General Assessment Procedures

	General Assessment Computation Input	Input for Build Alternative
Source (LRT)	Daily Frequency of Trains	Frequent (greater than 70)
	Speed (mph)	40, 28[1] north of Ellicott Station, 10 north of I-990
	Vehicle Parameters	Vehicle with stiff primary suspension[2]
	Track Conditions	Jointed Track
	Track Treatment	High Resilience Fasteners[1]
	Track Ties	Resiliently Supported Ties (Low Vibration Track, LVT)[1]
	Type of Transit Structure	Rock-based (bored tunnel) between University of Buffalo South campus and Kenmore Avenue Cut & Cover (underground) on Kenmore Avenue Open (at-grade) from Niagara Falls Blvd to I-990
Path	Geological/Soil conditions between source and receptor	Efficient propagation in soil[3]
	Ground-borne noise adjustment	High-Frequency selected where alignment is underground Mid-frequency adjustment conservatively selected for the remainder of the alignment
Receptor	Coupling to Building Foundation (based on building's construction)	Varies by receptor. Wood-frame, 1-2 story masonry, or 3-4 story masonry adjustment selected conservatively based on field observations.
	Project Specific Receiver Conditions	Varies by receptor. Light-weight, wood frame 2-3 story buildings, light-weight, wood frame construction 1 story buildings, small masonry buildings, or large buildings adjustment selected conservatively based on field observations.

Source: Federal Transit Administration. 2018. Transit Noise and Vibration Impact Assessment

1 Build Alternative-specific low-noise commitments.
2 This is a conservative assumption based on Build Alternative-specific commitment to utilize all new fleet of vehicles (no wheel flats).
3 This is the most conservative assumption based on unknown geological conditions.

D.2.4 Existing Conditions

Although not required as part of the FTA Guidance Manual procedures, Metro selected three locations on the UB North Campus for vibration measurements for the purposes of quantifying existing ambient vibration levels without the operation of the LRT Build Alternative and the BRT Build Alternative. These locations have vibration-sensitive equipment used for research and are near the Project alignment. Vibration measurements were collected for 5 minutes in the lower levels of the selected buildings away from activities that would be expected to result in increased vibration levels such as mechanical equipment, pedestrian hallways, etc. Table D-19 lists these receptors and the measured ambient vibration levels.

Table D-19. Existing Vibration Measurement Locations

Receptor[1]	Location	Approximate Distance to Project Alignment (feet)	Measured Ambient Vibration Level (VdB)
1	Cooke Hall, Basement Room C-16	95	39
2	Park Hall, Basement Room B-12	125	20

Receptor[1]	Location	Approximate Distance to Project Alignment (feet)	Measured Ambient Vibration Level (VdB)
3	Davis Hall, Basement near SB01 stairwell	195	45

[1] Ambient vibration levels collected on March 26, 2019.

Existing condition vibration levels measured in all three locations on the UB North Campus are below the ground-borne vibration criteria for buildings.

In addition, Metro identified receptors that fall within the FTA Guidance Manual vibration analysis screening distance from the LRT Build Alternative and the BRT Build Alternative. Table D-20 lists the receptors used in the vibration analysis with corresponding FTA Land Use Categories.

Table D-20. Vibration Analysis Receptor Locations

Receptor	Location	Distance to Vibration Source (Feet)	FTA Land Use Category[1]
1	Department of Oral Biology, UB South Campus	311	1
2[2]	School of Dental Medicine, UB South Campus	327	1
3[2]	Allen Hall, UB South Campus	87	1
4[2]	Cornerstone Community Church	93	3
5	Residences on Kenmore Avenue at Niagara Falls Boulevard	63	2
6[2]	252 Niagara Falls Boulevard	52	2
7	Trinity United Methodist Church	60	3
8[2]	Christian Fellowship Baptist Church	60	3
9[2]	800 Niagara Falls Boulevard	65	3
10[2]	839 Niagara Falls Boulevard	89	3
11[2]	885 Niagara Falls Boulevard	113	3
12[2]	1280 Sweet Home Road	142	2
13[2]	Hadley Village 110	100	2
14[2]	Cook Hall, UB North Campus	100	1
15	Park Hall, UB North Campus	100	1
16	Lockwood Memorial Library, UB North Campus	43	3
17[2]	Baird Hall, UB North Campus	122	1
18[2]	Slee Hall, UB North Campus	292	1
19[2]	Center for the Arts, UB North Campus	440	1
20	Davis Hall, UB North Campus	204	1
21	Greiner Hall, UB North Campus	161	2
22[2]	Mechanical and Astrospace Engineering, UB North Campus	200	1
23[2]	25 Bluebird Lane	90	2
24	Muir Woods Future Residential Development	90	2
25	Residences along Homecrest Drive	267	2
27	1185 Sweet Home Road	96	2

[1] FTA Land Use Categories as described in Table D-1.
[2] Receptor represents a vibration sensitive use such as residential, doctors' office, religious center, research facility, or school. However,

these receptors are not included in the airborne noise analysis Table 4.12-1 because the represented land use would not be noise-sensitive according to the FTA Guidance Manual or it was not the worst-case noise receptor based on proximity to additional noise sources such as rail crossings

Note: Receptor 26 represented a potential future receptor that was removed from the analysis.