Austin Transit Partnership

Austin Transit Partnership

Austin Light Rail Phase 1 Project

Draft Environmental Impact Statement
Appendix I: Noise and Vibration

Austin, TX
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Acronyms and Abbreviations

Term/Acronym	Definition
ATP	Austin Transit Partnership
City	City of Austin
dB	decibel
dBA	A-weighted decibel
FTA	Federal Transit Administration
Hz	hertz
I-35	Interstate 35
Ldn	day-night sound level
Leq	equivalent sound level
Lmax	maximum noise level
mph	miles per hour
OMF	operations and maintenance facility
PPV	peak particle velocity
Project	Austin Light Rail Phase 1 Project
VdB	vibration decibel

1 Introduction

The Federal Transit Administration (FTA) and Austin Transit Partnership (ATP) are completing an environmental review of the Austin Light Rail Phase 1 Project (the Project) in Austin, Texas. The noise and vibration technical report was prepared to support the Project's Draft Environmental Impact Statement in accordance with the National Environmental Policy Act and related laws and regulations. FTA and ATP are the Lead Agencies in the National Environmental Policy Act process.

This report assesses the local and regional impacts on noise and vibration that would result from the construction and operation of the Project. The report follows the FTA guidance, *Transit Noise and Vibration Impact Assessment Manual* (2018) for evaluating impacts and potential mitigation measures. The noise and vibration Study Area extends approximately 350 feet from the proposed alignment and stations. This report describes existing noise and vibration conditions in the Study Area, the noise and vibration assessment for sensitive receptors in the Study Area, and mitigation options for potential impacts identified in this assessment.

Following a Project overview, Section 2 describes the regulatory setting, including the noise and vibration impact criteria for the Project. Section 3 discusses the methodology for the impact assessment, and Section 4 describes the existing conditions, including noise and vibration sensitive land uses and the measurements conducted to determine the existing noise and vibration conditions. Section 5 includes environmental consequences, including the results of the noise and vibration impact assessment. Section 5.2.1 describes potential mitigation measures. Section 7 includes references. **Attachment A** includes the noise fundamentals and **Attachment B** includes the vibration fundamentals. Noise and vibration fundamentals are general information regarding the noise and vibration terms and descriptors used in the assessment. **Attachment C** includes photographs of the noise measurement locations and **Attachment E** includes photographs of the vibration measurement locations. **Attachment D** shows the detailed noise data and **Attachment F** contains the vibration measurement data.

2 Regulatory Setting

This assessment was conducted in accordance with criteria in the FTA *Transit Noise and Vibration Impact Assessment Manual* (2018), for operational noise and vibration and construction noise and vibration, and City of Austin's (City) construction noise ordinance. The criteria for each are discussed below.

2.1 FTA Operational Noise Impact Criteria

The FTA operational noise impact criteria are based on well-documented research on community response to noise and are based on both the existing level of noise and the change in noise exposure due to a project. The FTA noise criteria compare the project noise with the existing noise (not the No Build Alternative noise) because comparing a noise projection with an existing noise condition is more accurate than comparing a noise projection with another noise projection. Because background noise may increase by the time a project is operational, this approach of using existing noise conditions is conservative.

The FTA noise criteria are based on the land use category of the sensitive receptor. The descriptors and criteria for assessing noise impacts vary according to land use categories adjacent to the Project. For Category 2, land uses where people live and sleep (e.g., residential neighborhoods, hospitals, and hotels), the Ldn, which is the day-night average sound level, is the assessment parameter. For other land use types (Category 1 or 3) where there are noise-sensitive uses (e.g., outdoor concert areas, schools, and libraries), the Leq, or equivalent sound level, for the loudest hour of train activity during hours of noise sensitivity is the assessment parameter. **Table 1** summarizes the three land use categories.

Table 1: Land Use Categories and Metrics for Noise Impact Criteria

Land Use Category	Land Use Type	Noise Metric (dBA)	Description of Land Use Category
1	High Sensitivity	Outdoor Leq(h)[1]	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. Recording studios and concert halls are also included in this category.
2	Residential	Outdoor Ldn	This category is applicable to all residential land use and buildings where people normally sleep, such as hotels and hospitals.
3	Institutional	Outdoor Leq(h)[1]	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. Places for meditation or study associated with cemeteries, monuments, museums, campgrounds, and recreational facilities are also included in this category.

Source: FTA 2018.

dBA = A-weighted decibel

[1] Leq (1-hour) for the loudest hour of project-related activity during hours of noise sensitivity.

Noise impact criteria are defined by the two curves shown in **Figure 1**. The criteria allow increasing project noise as existing noise levels increase, up to a point at which impact is determined based on project noise alone. The FTA noise impact criteria include three levels of impact. The three levels of impact include:

- **No Impact.** Project-generated noise is not likely to cause community annoyance. Noise projections in this range are considered acceptable by FTA and mitigation is not required.
- **Moderate Impact.** Project-generated noise in this range is considered to cause impact at the threshold of measurable annoyance. Moderate impacts serve as an alert to project planners for potential adverse impacts and complaints from the community. Mitigation should be considered at this level of impact based on project specifics and details concerning the affected properties. See Section 6.1 for more information about mitigation at the moderate impact level.
- **Severe Impact.** Project-generated noise in this range is likely to cause a high level of community annoyance. If it is not practical to avoid severe impacts by changing the location of the project, mitigation measures must be considered.

Although the curves in **Figure 1** are defined in terms of the project noise exposure and the existing noise exposure, the increase in the cumulative noise – when project-generated noise is added to existing noise levels – is the basis for the criteria. To illustrate this point, **Figure 2** shows the noise impact criteria for Category 1 and Category 2 land uses in terms of the allowable increase in the cumulative noise exposure. Because Ldn and Leq are measures of total acoustic energy, any new noise source in a community would cause an increase, even if the new source level is lower than the existing level. In **Figure 2**, the criterion for a moderate impact allows a noise exposure increase of 10 decibels (dB) if the existing noise exposure is 42 dBA (A-weighted decibel) or less, but only a 1-dB increase when the existing noise exposure is 70 dBA.

As the existing level of ambient noise increases, the allowable level of transit noise increases, but the total amount that community noise exposure is allowed to increase is reduced. This allows for situations where the project noise exposure is lower than the existing noise exposure but can still cause an effect due to the limit on overall noise exposure.

Figure 1: FTA Noise Impact Criteria

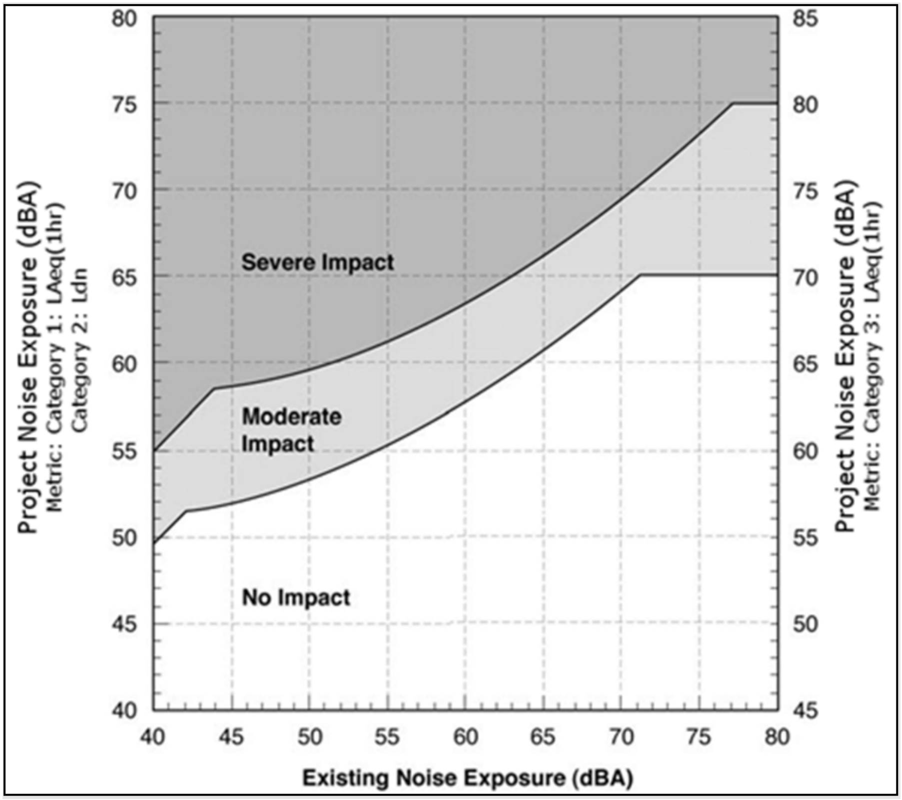
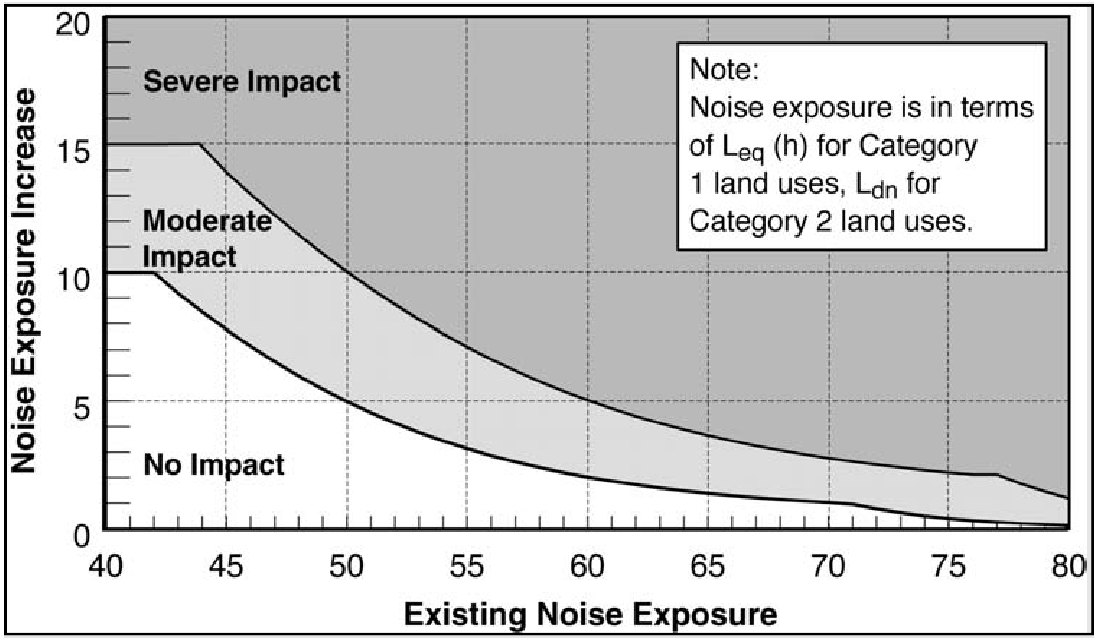


Figure 2: FTA Cumulative Noise Impact Criteria



Note:
Noise exposure is in terms of L_{eq} (h) for Category 1 land uses, L_{dn} for Category 2 land uses.

2.2 FTA Operational Vibration Impact Criteria

The operational vibration impact criteria used for this Project are based on the information contained in Section 6 of the FTA *Transit Noise and Vibration Impact Assessment Manual* (2018). The criteria for a general vibration assessment are based on land use and train frequency, as shown in **Table 2**. Some buildings, such as concert halls, recording studios, and theaters, can have a higher sensitivity to vibration (or ground-borne noise) but do not fit into the three vibration categories listed below in **Table 2**. Because of the sensitivity of these buildings, special attention is paid to these buildings during the environmental analysis of a project. **Table 3** shows the FTA criteria for acceptable levels of vibration for several types of special buildings.

Table 2 and **Table 3** also include additional criteria for ground-borne noise, which is a low-frequency noise that is radiated from the motion of room surfaces, such as walls and ceilings in buildings due to ground-borne vibration. Ground-borne noise is defined in terms of dBA, which emphasizes middle and high frequencies, which are more audible to human ears. The criteria for ground-borne noise are much lower than for airborne noise to account for the low-frequency character of ground-borne noise; however, because airborne noise typically masks ground-borne noise for above ground (at-grade or elevated) transit systems, ground-borne noise is assessed only for operations in tunnels, where airborne noise is not a factor, or at locations such as recording studios, which are well insulated from airborne noise.

Table 2: Ground-Borne Vibration and Noise Impact Criteria for General Assessment

Land Use Category	Ground-Borne Vibration Impact Levels (VdB re 1 micro-inch/sec) for Frequent Events[1]	Ground-Borne Vibration Impact Levels (VdB re 1 micro-inch/sec) for Occasional Events[2]	Ground-Borne Vibration Impact Levels (VdB re 1 micro-inch/sec) for Infrequent Events[3]	Ground-Borne Noise Impact Levels (dBA re 20 micro Pascals) for Frequent Events[1]	Ground-Borne Noise Impact Levels (dBA re 20 micro Pascals) for Occasional Events[2]	Ground-Borne Noise Impact Levels (dBA re 20 micro Pascals) for Infrequent Events[3]
Category 1: Buildings where vibration would interfere with interior operations	65[4]	65[4]	65[4]	N/A[5]	N/A[5]	N/A[5]
Category 2: Residences and buildings where people normally sleep	72	75	80	35	38	43
Category 3: Institutional land uses with primarily daytime use	75	78	83	40	43	48

Source: FTA 2018.

VdB = vibration decibel

[1] "Frequent Events" is defined as more than 70 vibration events of the same source per day. Most rapid transit projects, such as light rail, 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 level of operations.

[3] "Infrequent Events" is defined as fewer than 30 vibration events of the same kind per day. This category includes most commuter rail branch lines.

[4] This criterion limit is based on levels that are acceptable for most moderately sensitive equipment, such as optical microscopes. Vibration-sensitive manufacturing or research would require detailed evaluation to define the acceptable vibration levels. Ensuring lower vibration levels in a building often requires special design of the heating, ventilation, and air conditioning systems and stiffened floors.

[5] Vibration-sensitive equipment is generally not sensitive to ground-borne noise.

Table 3: Ground-Borne Vibration and Noise Impact Criteria for Special Buildings

Land Use Category	Ground-Borne Vibration Impact Levels (VdB re 1 micro-inch/sec) for Frequent Events[1]	Ground-Borne Vibration Impact Levels (VdB re 1 micro-inch/sec) for Infrequent Events[2]	Ground-Borne Noise Impact Levels (dBA re 20 micro-Pascals) for Frequent Events[1]	Ground-Borne Noise Impact Levels (dBA re 20 micro-Pascals) for Occasional or Infrequent Events[2]
Concert halls	65	65	25	25
TV studios	65	65	25	25
Recording studios	65	65	25	25
Auditoriums	72	80	30	38
Theaters	72	80	35	43

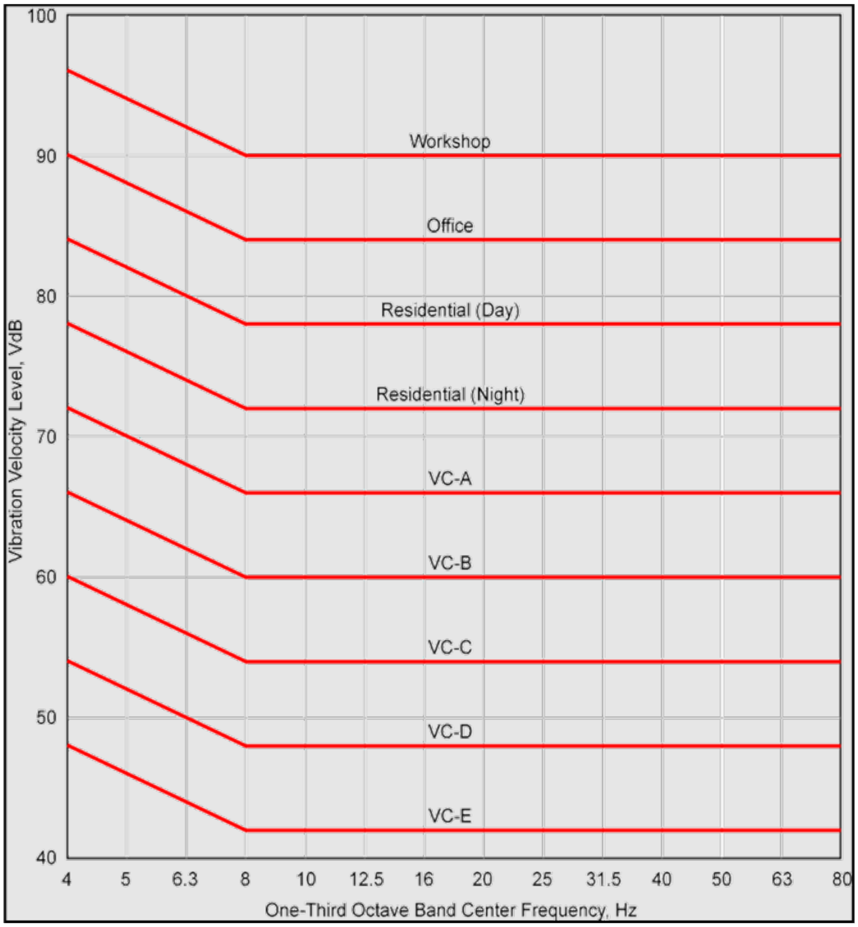
Source: FTA 2018.

[1] "Frequent Events" is defined as more than 70 vibration events of the same source per day. Most rapid transit projects, such as light rail, 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. If the building is rarely occupied when the trains are operating, there is no need to consider impact. As an example, if a commuter rail line were located next to a concert hall and no commuter trains operate after 7 p.m., it should be rare that the trains would interfere with the use of the hall.

Figure 3 shows the criteria for a detailed vibration assessment. **Table 4** provides descriptions of the curves. The curves in **Figure 3** are applied to the projected vibration spectrum for the Project. If the vibration level at any one frequency exceeds the criteria, there is an impact. Conversely, if the entire proposed vibration spectrum of the Project is below the curve, there would be no impact. For the Project, the detailed vibration assessment criteria are used to assess operational ground-borne vibration except at special buildings, where the general vibration assessment criteria are used.

Figure 3: FTA Detailed Vibration Criteria



Source: FTA 2018.

Table 4: Interpretation of Vibration Criteria for Detailed Analysis

Criterion Curve[1]	Max. Level (VdB)[2]	Description of Use
Workshop	90	Vibration that is distinctly felt. Appropriate for workshops and similar areas not as sensitive to vibration.
Office	84	Vibration that can be felt. Appropriate for offices and other areas not as sensitive to vibration.
Residential Day	78	Vibration that is barely felt. Adequate for computer equipment and low-power optical microscopes (up to 20X).
Residential Night Operating Rooms	72	Vibration is not felt, but ground-borne noise may be audible inside quiet rooms. Suitable for medium-power optical microscopes (100X) and other equipment of low sensitivity.
VC-A	66	Adequate for medium- to high-power optical microscopes (400X), microbalances, optical balances, and similar specialized equipment.
VC-B	60	Adequate for high-power optical microscopes (1000X) and inspection and lithography equipment to 3-micron line widths.
VC-C	54	Appropriate for most lithography and inspection equipment to 1-micron detail size.
VC-D	48	Suitable in most instances for the most demanding equipment, including electron microscopes operating to the limits of their capabilities.
VC-E	42	The most demanding criterion for extremely vibration-sensitive equipment.

Source: FTA 2018.

[1] See **Figure 3**.

[2] As measured in 1/3-octave bands of frequency over the frequency range 8 to 80 hertz (Hz).

2.3 FTA Construction Noise Impact Criteria

FTA has developed methods for evaluating construction noise levels. These methods do not include standardized criteria, but rather noise impact guidelines for sensitive land uses that describe levels that may result in an adverse community reaction. **Table 5** shows the FTA noise assessment criteria for construction. The last column applies to construction activities that extend over 30 days near any given receiver. The Ldn is used to assess impacts in residential areas, and 24-hour Leq is used in commercial and industrial areas. The 8-hour Leq and the 30-day average Ldn noise exposure from construction noise calculations use the noise emission levels of the construction equipment, their location, and operating hours. The construction noise limits are normally assessed at the noise-sensitive receiver property line.

Table 5: FTA Construction Noise Criteria

Land Use	8-Hour Leq, dBA	8-Hour Leq, dBA Night	Noise Exposure Leq, dBA
Residential	80	70	75
Commercial	85	85	80
Industrial	90	90	85

Source: FTA 2018.

2.4 FTA Construction Vibration Impact Criteria

In addition to the vibration criteria for human annoyance and interference with equipment and spaces described above, there are also vibration criteria for damage from construction activities. Typical transit operations do not have the potential for damage, so only certain construction activities are assessed for generating vibration with the potential for building damage.

The thresholds for damage to structures are typically several orders of magnitude above the thresholds for human response to vibration. **Table 6** shows the FTA criteria for vibration damage to structures. This is based on the structure and construction type (and not a designation as historic). **Table 6** includes criteria in both vibration decibel (VdB) and peak particle velocity (PPV).

Table 6: FTA Construction Vibration Damage Criteria

Building Category	PPV (inches/second)	Appropriate Level[1] (VdB)
I. Reinforced-concrete, steel, or timber (no plaster)	0.5	102
II. Engineered concrete and masonry (no plaster)	0.3	98
III. Non-engineered timber and masonry buildings	0.2	94
IV. Buildings extremely susceptible to vibration damage	0.12	90

Source: FTA 2018.

[1] Root mean square velocity in VdB re 1 micro-inch/second.

2.5 City's Construction Noise Ordinance

While the City's Code of Ordinances Chapter 9-2 regulates construction noise, the City has passed an ordinance regarding construction limits and construction noise specifically for transit system projects. This ordinance provides greater flexibility for construction noise and requires submission of a construction noise mitigation and monitoring plan, project noise requirements for construction contractors, and a public communications plan (City of Austin 2022). If there is a conflict with Chapter 9-2, the approved noise mitigation plan will supersede Chapter 9-2.

3 Methodology

ATP modeled noise and vibration from light rail operations using the methods described in the FTA *Transit Noise and Vibration Impact Assessment Manual* (2018). Noise-generating activities from light rail operations on the guideway include rail noise, bells and activities around stations, parking facilities, traction power substations, and the operations and maintenance facility (OMF). The activity that would generate substantial vibration would be light rail operations on the guideway.

ATP performed detailed noise and vibration impact assessments based on the criteria discussed in Section 2 and the prediction methodology described below. The noise and vibration impact assessment included the following steps:

1. ATP identified noise- and vibration-sensitive land uses using aerial photography, geographic information system data, and field surveys. See Section 4.1.
2. ATP measured existing noise levels in the Study Area at sensitive receptors. See Section 4.2.
3. ATP measured vibration-propagation characteristics of the soil in the Study Area near representative sensitive receptors. See Section 4.3.
4. ATP predicted the Project noise and vibration levels from transit operations using Build Alternative plan and profile maps (dated January 24, 2024) and information on speeds, headways, track type, and vehicle type for the Build Alternative.
5. ATP assessed the potential noise impact from transit operations by comparing the noise from the Build Alternative with the existing noise (not the No Build Alternative noise) using the FTA noise impact criteria. See **Figure 1** above.
6. ATP assessed the potential vibration impact from transit operations by comparing the Build Alternative vibration levels with the FTA vibration impact criteria in **Figure 3** above.
7. ATP recommended mitigation at locations where noise or vibration levels would exceed the impact criteria.

3.1 Operational Noise Assessment Methodology

3.1.1 Light Rail Noise Assessment Methodology

ATP determined the projection of wayside noise levels from light rail operations at sensitive receptors, using the model specified in the FTA *Transit Noise and Vibration Impact Assessment Manual* (2018) along with current design data for the Build Alternative, with the following assumptions:

- Light rail train speeds range from 20 miles per hour (mph) to 35 mph for revenue operations. Light rail train speeds are based on modeled speeds that reflect train operating characteristics, track geometry, and passenger station locations.
- The weekday operating hours and headways for the Build Alternative are:
    - For trunk routes:

        - Early-morning operations (5 a.m. to 6:30 a.m.): 7.5-minute headways
        - Midday operations (6:30 a.m. to 7:30 p.m.): 5-minute headways
        - Nighttime operations (7:30 p.m. to 12:30 a.m.): 7.5-minute headways
    - For branch routes:
        - Early-morning operations (5 a.m. to 6:30 a.m.): 15-minute headways
        - Midday operations (6:30 a.m. to 7:30 p.m.): 10-minute headways
        - Nighttime operations (7:30 p.m. to 12:30 a.m.): 15-minute headways
- The sound exposure level at 50 feet for a one-car light rail train operating on ballast and tie track at 50 mph is assumed to be 82 dBA.
- The sound exposure level at 50 feet for a light rail train operating on embedded tracks is increased by 3 dB relative to ballast and tie tracks.
- The sound exposure level at 50 feet for a light rail train operating on direct fixation tracks on an elevated structure is increased by 4 dB relative to ballast and tie tracks.
- ATP identified locations of elevated structures, crossovers, and embedded track based on plan and profile maps (dated January 24, 2024) provided by ATP.
- ATP wheel impacts at crossovers and turnouts are assumed to cause localized noise increases of 5 dB up to a distance of 300 feet and no increase beyond 200 feet.
- ATP would limit sounding of bells or horns at any at-grade crossings.
- ATP included all noise-sensitive receptors located within the FTA guidance manual screening distance of 200 feet for stations in the assessment of station noise, including warning bells on light rail vehicles.
- The OMF located off Airport Commerce Drive was assessed with the following preliminary planning level assumptions:
    - The light rail speeds in the yard and on the lead track do not exceed 15 mph.
    - The track in the yard is ballast and tie.
    - The trains enter and exit the OMF on the following schedule:
        - 6 trains enter at 7:30 p.m.
        - 11 trains enter at 12:30 a.m.
        - 11 trains exit at 5:00 a.m.
        - 6 trains exit at 6:30 a.m.

3.1.2 Noise Measurement Procedures and Equipment Methodology

ATP conducted the noise measurement program in April 2021, February 2024, and May 2024. The noise measurement program consisted of long-term (24-hour) and short-term (1-hour) monitoring of the A-weighted sound level. ATP placed all the measurement locations in or near noise-sensitive areas. ATP selected locations to represent a range of existing noise conditions near the Build Alternative. ATP conducted long-term noise measurements at 13 locations, and short-term noise measurements at 7 locations near the Build Alternative. In Section 4.2, **Figure 6** shows the noise measurement locations, and **Attachment C** provides photographs of the measurement locations. **Attachment D** presents detailed noise measurement data. Section 4.2 presents summary information regarding the noise measurements for the Project.

At each of the measurement locations, ATP continuously monitored A-weighted sound levels during the measurement periods. ATP performed noise measurements with NTi Audio Model XL2 noise monitors that conform to American National Standards Institute (ANSI) Standard S1.4 for Type 1 (Precision) sound level meters. ATP carried out calibrations, traceable to the U.S. National Institute of Standards and Technology (NIST), in the field before and after each set of measurements using an acoustical calibrator.

In all cases, ATP protected the measurement microphone by a windscreen and supported on a tripod at a height of 4 to 6 feet above the ground. ATP positioned the measurement microphone to characterize the exposure of the location to the dominant noise sources in the Study Area. For example, ATP located microphones at the approximate setback lines of the receptors from adjacent roads and positioned them to avoid acoustic shielding by landscaping, fences, or other obstructions.

3.1.3 KUT Radio Station and Jesse H. Jones Communications Center – Building B

ATP also conducted outdoor-to-indoor noise measurements at two locations highly sensitive to noise: KUT 90.5 FM NPR Austin and the Jesse H. Jones Communication Center – Building B. The measurements were used to determine the noise reduction provided by each building's exterior walls and windows. To determine noise measurements, a loudspeaker is located outside a building and generates high levels of pink noise with two microphones measuring the noise levels at the building's outdoor façade and in the interior spaces. The calculated difference in the outdoor and indoor measured noise levels provides the reduction that can be expected from the exterior wall and windows.

The measurement followed the procedure from ASTM standard E966 "Standard Guide for Field Measurements of Airborne Sound Attenuation of Building Façade and Façade Elements." As a part of the noise measurements at KUT and the Jesse H. Jones Communications Center – Building B, noise measurements of existing interior sensitive spaces were conducted. The locations of these measurements are shown in **Figure 7**.

3.2 Operational Vibration Assessment Methodology

3.2.1 Light Rail Vibration Assessment Methodology

ATP carried out the projection of ground-borne vibration from train operations using the model specified in the FTA *Transit Noise and Vibration Impact Assessment Manual* (2018), with the following assumptions:

- Light rail train speeds range from 20 mph to 35 mph for revenue operations;

- Light rail train speeds are based on modeled speeds that reflect train operating characteristics, track geometry, and passenger station locations;
- ATP identified locations of elevated structures, crossovers, and embedded track based on plan and profile maps (dated January 24, 2024) provided by ATP;
- ATP assumed wheel impacts at track crossovers and turnouts to cause localized vibration increases of 10 VdB for nearby sensitive receptors within 100 feet and 5 VdB for receivers within 200 feet of the crossover, due to the gaps in the track rails at these locations;
- Elevated structures reduce the ground-borne vibration levels by 10 VdB at nearby sensitive receptors compared with at-grade track;
- ATP based vibration source (force density) levels on reference test data from a typical light rail vehicle for both ballast and tie tracks and direct fixation tracks. The vehicle force density includes a 3 VdB safety factor; and
- ATP conducted vibration propagation tests at representative locations in the Study Area near sensitive receptors, as described in Section 4.3. ATP combined the results of these tests with the light rail vehicle vibration source level measurement data to provide projections of vibration levels from the Build Alternative.

Figure 4 represents the assumed vehicle vibration characteristics by the force density levels spectra at 25 mph for both ballast and tie tracks and direct fixation tracks. The force density is the vehicle input force, by frequency, which is measured for vehicles operating on different track structures. ATP combined the results with the ground vibration propagation test results (represented by transfer mobility spectra shown in **Attachment F**) to Build Alternative vibration levels as a function of distance. The formula for calculating the future vibration levels at the outdoor edge of a building is as follows:

$$Lv = FDL + LSTM$$

where:

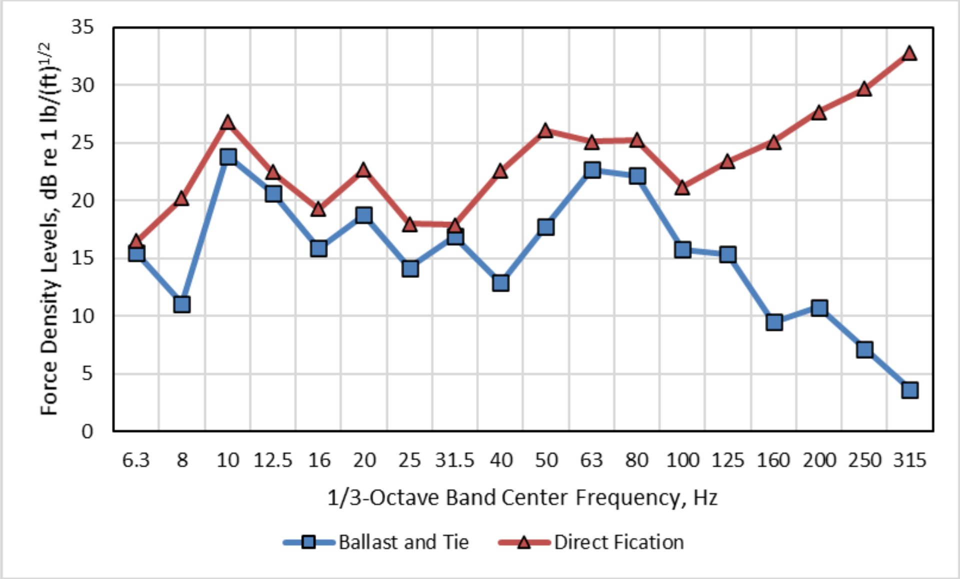
Lv = projected train vibration level;

FDL = vehicle force density; and

LSTM = line source transfer mobility at a given location.

Because each building is unique, it is difficult to estimate the effects of foundations and building response on vibration levels. While FTA does provide some guidance for this, the approach taken here is to estimate vibration levels outside of buildings except in special situations, such as the KUT radio station, which are extremely sensitive, and the building foundation response is measured directly.

Figure 4: Force Density Levels



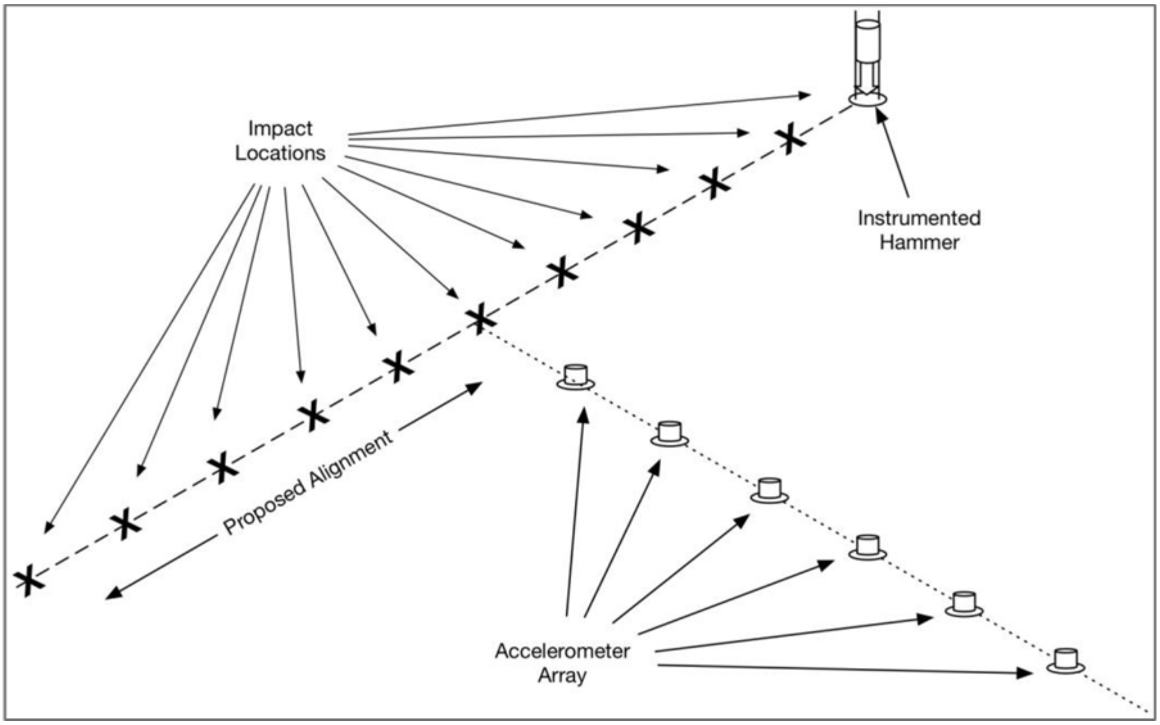
Source: Cross-Spectrum Acoustics 2024.

3.2.2 Vibration Measurement Procedures Methodology

ATP conducted vibration propagation measurements during April 2021 and February 2024 to determine the vibration response characteristics of the ground near vibration-sensitive locations located near the proposed track. ATP used a custom-built instrumented hammer to impart an impulsive force to the ground to determine the ground response. ATP measured the impact force using a load cell mounted below the falling hammer. ATP measured the resulting vibration signals using high-sensitivity accelerometers (PCB Model 393B05) mounted in a vertical direction (i.e., perpendicular to the ground, on pavement or on steel spikes driven into the ground). ATP recorded signals from the hammer and accelerometers using Data Translation DT9837A digital acquisition hardware. ATP used Data Translation’s QuickDAQ software, running on a laptop computer, to review the measurement data.

Figure 5 shows the vibration propagation test procedure. ATP used an instrumented hammer to generate impulses at specific locations, spaced 15 feet apart along a line on or parallel to the proposed alignment. ATP placed a line of accelerometers perpendicular to the line of impacts as shown in **Figure 5**. ATP calculated the relationship between the input force and the resulting vibration measured by the accelerometers, called the transfer mobility, using proprietary software in the Cross-Spectrum Acoustics laboratory. The transfer mobility represents the vibration propagation characteristics of the ground at the measurement location and along the track.

Figure 5: Vibration Propagation Measurement Schematic



Source: Cross-Spectrum Acoustics 2024.

3.2.3 KUT Radio Station and Jesse H. Jones Communication Center – Building B

ATP also conducted outdoor-to-indoor vibration propagation measurements at two locations highly sensitive to vibration: KUT 90.5 FM NPR Austin and the Jesse H. Jones Communication Center – Building B. The measurements are used to evaluate how the foundation and building will interact with the vibration generated by the Project. This measurement is similar to the measurements conducted for noise, but the vibration measurements include one or more accelerometers placed inside the building in addition to those outside the building. The instrumentation is the same as for noise measurements. The location of the measurements is shown in **Figure 8**.

3.3 Construction Noise Impact Assessment Methodology

ATP assessed construction noise and impacts using a combination of the methods and construction source data contained in the FTA *Transit Noise and Vibration Impact Assessment Manual* (218) and the Federal Highway Administration Roadway Construction Noise Model from the *FHWA Construction Noise Handbook* (2006). **Table 7** lists the typical noise levels generated by representative pieces of equipment. The noise exposure at a receiver location may be calculated using decibel addition of all operating construction equipment using the following equation:

$$Leq(n) = L_{max} + 10\times Log(UF) - 20\times Log(D/50) - Ashielding$$

where:

Leq(n) = noise exposure at a receiver resulting from the operation of a single piece of equipment over n hours;

Lmax = noise emission level of the particular piece of equipment at the reference distance of 50 feet (taken from **Table 7**);

Ashielding = shielding provided by barriers, building, or terrain;

D = distance from the receiver to the piece of equipment in feet; and

UF = usage factor that accounts for the fraction of time that the equipment is in use over the specified time period. For Leq (1-hour) assume a UF equal to 100 percent, and for 8 hours or more use the values in **Table 7**.

The combination of noise from several pieces of equipment operating during the same time period is obtained from decibel addition of the Leq of each single piece of equipment calculated using the above equations.

Table 7: Construction Equipment Noise Emission Levels at 50 Feet

Equipment	Typical Noise Level (dBA)	Equipment Usage Factor
Air compressor	80	40
Backhoe	80	40
Ballast equalizer	82	50
Ballast tamper	83	50
Compactor	82	20
Concrete mixer	85	40
Concrete pump	82	20
Crane, derrick	88	16
Crane, mobile	83	16
Dozer	85	16
Generator	82	50
Grader	85	40
Impact wrench	85	50
Jackhammer	88	20
Loader	80	40
Paver	85	50
Pile driver (impact)	101	20

Equipment	Typical Noise Level (dBA)	Equipment Usage Factor
Pile driver (vibratory)	95	20
Pneumatic tool	85	50
Pump	77	50
Rail saw	90	20
Rock drill	85	20
Roller	85	20
Saw	76	20
Scarifier	83	20
Scraper	85	40
Shovel	82	40
Spike driver	77	20
Tie cutter	84	20
Tie handler	80	20
Tie inserter	85	20
Truck	84	40

Sources: FTA 2018; Federal Highway Administration 2006.

3.4 Construction Vibration Assessment Methodology

Construction vibration is assessed for areas where there is potential for impact from construction activities. Such activities include blasting, pile driving, demolition, and drilling or excavation in proximity to sensitive structures. **Table 8** lists typical vibration levels generated by representative pieces of equipment. For damage assessment, the following equation is used:

$$PPV_{equip} = PPV_{ref} \times [(25/D)]^{1.5}$$

where:

PPVequip = the peak particle velocity in inches/second of the equipment adjusted for distance;

PPVref = the reference vibration level in inches/second at 25 feet from **Table 8**; and

D = the distance from the equipment to the receiver in feet.

For annoyance assessment, the following equation is used:

$$Lv(D) = Lv(25\ ft) - 30 \times \log(D/25)$$

where:

Lv(D) = Root mean square vibration level at distance D;

Lv(25 ft) = Root mean square vibration level at 25 feet from **Table 8**; and

D = the distance from the equipment to the receiver in feet.

Table 8: Construction Equipment Vibration Levels at 50 Feet

Equipment		PPV at 25 Feet (inches/second)	Approximate Level[1] at 25 Feet (VdB)
Pile driver (impact)	Upper range	1.518	112
	Typical	0.644	104
Pile driver (vibratory)	Upper range	0.734	105
	Typical	0.170	93
Clam shovel drop (slurry wall)		0.202	94
Hydromill (slurry wall)	In soil	0.008	66
	In rock	0.017	75
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: FTA 2018.

[1] Root mean square velocity in decibels (VdB) re 1 micro-inch/second

4 Affected Environment

The affected noise and vibration environment in the Study Area for the Project was investigated based on a review of current project and land use information, geographic information system data, a windshield survey, and measurements conducted during April 2021 (for the previous Blue Line project) and February 2024 and May 2024 (for the areas outside the previous Blue Line project area). Land use in the Study Area, which is within approximately 350 feet of the proposed alignment and station, includes a combination of residential, institutional, commercial, and industrial zones. Sensitive receptors located in the Study Area include single-family and multifamily residences, hotels, places of worship, schools, and the NPR radio station on the University of Texas at Austin campus. A summary of noise- and vibration-sensitive land uses in the Study Area is provided below, followed by descriptions of the existing noise and vibration conditions in the Study Area.

4.1 Noise and Vibration Sensitive Land Use

4.1.1 North of the University of Texas

The land uses in the north of the University of Texas at Austin section of the Study Area are a mixture of commercial and residential properties. The noise- and vibration-sensitive land uses are a mix of single- and multifamily homes and Austin Fire Station 5. There are no institutional or highly sensitive noise- or vibration-sensitive land uses adjacent to this section.

4.1.2 The University of Texas

The land uses in the University of Texas at Austin section of the Study Area are a mixture of commercial, institutional and residential properties. The noise- and vibration-sensitive land uses are a mix of dormitories, classroom buildings, a hotel, the University United Methodist Church, University Baptist Church, the Harry Ransom Center (library), the Jesse H. Jones Communication Center – Building B, and the KUT radio station.

4.1.3 Downtown Austin

The land uses in the Downtown Austin section of the Study Area are a mixture of commercial, institutional, and residential properties. The noise- and vibration-sensitive land uses are a mix of multifamily homes, hotels, the History of Medicine Gallery, the First Church of Christ, the Central Christian Church, the Austin History Center/Austin Public Library, and Rowling Hall (the University of Texas at Austin).

4.1.4 South Congress

The land uses in the South Congress section of the Study Area are a mixture of commercial, institutional, and residential properties. The noise- and vibration-sensitive land uses are a mix of single- and multifamily homes, hotels, Austin Fire Station 6, and The Church on Congress Avenue.

4.1.5 Riverside Drive

The land uses in the East Austin section of the Study Area are a mixture of commercial, institutional, and residential properties. The noise- and vibration-sensitive land uses are a mix of single- and multifamily homes, hotels, East Riverside Emergency Room, Austin Fire Station 22, and Onion Creek Baptist Church.

4.2 Existing Noise Conditions

Existing noise sources in the Study Area include traffic on East Riverside Drive, South Congress Avenue, Guadalupe Street, other major roadways, local roadway traffic, aircraft overflights, and local community activities. The existing ambient sound levels vary by location, depending on the proximity to major roadways, and are generally typical of a suburban environment near busy arterial roadways.

Table 9 summarizes the results of the existing noise measurement program for the Project, and **Figure 6** shows the locations of the noise measurements for the Project. ATP used the results of the existing noise long-term (LT) and short-term (ST) measurements to characterize the existing noise levels at all noise-sensitive locations in the Study Area. The locations are further described below:

- **LT-1: 3200 Guadalupe Street.** The Ldn calculated at this location was 71 dBA, and the measured peak hour Leq was 73 dBA. This location is representative of the single- and multifamily homes along Guadalupe Street north of 29th Street. Traffic on Guadalupe Street and 33rd Street dominated the ambient noise levels.
- **LT-2: Villas on Guadalupe – 2810 Hemphill Park.** The Ldn measured at this location was 72 dBA and the measured peak hour Leq was 70 dBA. This location is representative of the multifamily, hotels, and dorms along Guadalupe Street between West Dean Keeton Street and 29th Street. Traffic on Guadalupe Street dominated the ambient noise levels.
- **LT-3: AMLI Downtown – 201 Lavaca Street.** The Ldn measured at this location was 68 dBA and the measured peak hour Leq was 65 dBA. This location is representative of the multifamily homes and hotels in Downtown Austin from 7th Street to Lady Bird Lake. Local traffic on 2nd Street and Guadalupe Street dominated the ambient noise levels.
- **LT-5: Muse at SoCo – 1007 South Congress Avenue.** The Ldn measured at this location was 61 dBA and the measured peak hour Leq was 60 dBA. This location is representative of the multifamily homes and hotels between East Riverside Drive and Gibson Street. Traffic on South Congress Avenue and traffic coming into and out of the apartment parking garage dominated the ambient noise levels.
- **LT-6: 107 W Monroe Street.** The Ldn measured at this location was 61 dBA and the measured peak hour Leq was 53 dBA. This location is representative of the single- and multifamily homes along South Congress Avenue between Gibson Street to Mary Street, the South Congress Hotel, and Austin Fire Station 6. Traffic on South Congress Avenue and local traffic dominated the ambient noise levels.
- **LT-7: 2107 Eva Street.** The Ldn measured at this location was 55 dBA and the measured peak hour Leq was 54 dBA. This location is representative of the single- and multifamily homes along South Congress Avenue between Mary Street and Oltorf Street and the Colton House Hotel. Traffic on South Congress Avenue and local traffic dominated the ambient noise levels.

- **LT-8: 807 Edgecliff Terrace.** The Ldn measured at this location was 67 dBA and the measured peak hour Leq was 65 dBA. This location is representative of the single-family homes between Academy Drive and Interstate 35 (I-35). The ambient noise levels were dominated by traffic on East Riverside Drive.
- **LT-9: AMLI South Store.** The Ldn measured at this location was 70 dBA and the measured peak hour Leq was 66 dBA. This location is representative of the single- and multifamily homes between I-35 and South Lakeshore Boulevard. Traffic dominated the ambient noise levels on East Riverside Drive and South Lakeshore Boulevard.
- **LT-10: Tempo at Riverside.** The Ldn measured at this location was 69 dBA and the measured peak hour Leq was 65 dBA. This location is representative of the single- and multifamily homes between Wikersham Lane and River Crossing Circle. Traffic dominated the ambient noise levels on East Riverside Drive and community noise.
- **LT-11: Austin Fire Station 22.** The Ldn measured at this location was 69 dBA and the measured peak hour Leq was 66 dBA. This location is representative of the single- and multifamily homes between River Crossing Circle and Grove Boulevard. Traffic dominated the ambient noise levels on East Riverside Drive.
- **LT-12: Riverside Nursing and Rehab.** The Ldn measured at this location was 65 dBA and the measured peak hour Leq was 63 dBA. This location is representative of the single- and multifamily homes between Grove Boulevard and Coriander Drive. Traffic dominated the ambient noise levels on East Riverside Drive.
- **LT-13: Home2Suites – 1705 Airport Commerce Drive.** The Ldn measured at this location was 62 dBA and the measured peak hour Leq was 60 dBA. This location is representative of the multifamily homes and hotels along Airport Commerce Drive. Traffic on Airport Commerce Drive and air traffic from Austin-Bergstrom International Airport dominated the ambient noise levels.
- **LT-14: 1340 Airport Commerce Drive.** The Ldn calculated at this location was 57 dBA and the measured peak hour Leq was 61 dBA. This location is representative of the single-family homes close to the proposed OMF. Traffic around the Airport Commerce Park and air traffic from Austin-Bergstrom International Airport dominated the ambient noise levels.
- **ST-1: Guadalupe Street and West Dean Keeton Street.** The Leq measured at this location was 66 dBA and the estimated Ldn, using the methods described in the FTA guidance manual, was 64 dBA. This location is representative of the University of Texas at Austin school buildings along Guadalupe Street between 24th Street and 27th Street, the KUT radio station, and University United Methodist Church. Traffic on Guadalupe Street and West Dean Keeton Street dominated the ambient noise levels.

- **ST-2: Guadalupe Street and 22nd Street.** The Leq measured at this location was 67 dBA and the estimated Ldn, using the methods described in the FTA guidance manual, was 65 dBA. This location is representative of the University of Texas at Austin school buildings along Guadalupe Street between MLK Boulevard and 24th Steet, the University Baptist Church, and the Church of Scientology of Texas. Foot and vehicle traffic on Guadalupe Street and 22nd Street dominated the ambient noise levels.
- **ST-3: 10th Street and Guadalupe Street.** The Leq measured at this location was 64 dBA and the estimated Ldn, using the methods described in the FTA guidance manual, was 62 dBA. This location is representative of multifamily homes and hotels along Guadalupe Street between 8th Street and MLK Boulevard, the History of Medicine Gallery, the First Church of Christ, Scientist, the Central Christian Church, and the Austin History Center and Austin Public Library. Traffic on Guadalupe Street, air traffic, and pedestrian traffic dominated the ambient noise levels.
- **ST-4: 1503 South Congress Avenue.** The Leq measured at this location was 68 dBA and the estimated Ldn, using the methods described in the FTA guidance manual, was 66 dBA. This location is representative of The Church on Congress Avenue. Traffic on South Congress and pedestrian traffic dominated the ambient noise levels.
- **ST-5: 500 Sunny Lane.** The Leq measured at this location was 53 dBA and the estimated Ldn, using the methods described in the FTA guidance manual, was 51 dBA. This location is representative of the single-family homes with shielding between Academy Drive and I-35. The ambient noise levels were dominated by local traffic and distant traffic on East Riverside Drive.
- **ST-6: Austin Emergency Center – 2020 East Riverside Drive.** The Leq measured at this location was 65 dBA and the estimated Ldn, using the methods described in the FTA guidance manual, was 63 dBA. This location is representative of the Austin Emergency Center at 2020 East Riverside Drive. Traffic dominated the ambient noise levels on East Riverside Drive.
- **ST-7: 222 East Riverside Drive.** The Leq measured at this location was 54 dBA and the estimated Ldn, using the methods described in the FTA guidance manual, was 52 dBA. This location is representative of the three multifamily buildings south of Lady Bird Lake. Local foot traffic and distant traffic dominated the ambient noise levels on East Riverside Drive.

Table 9: Summary of Existing Ambient Noise Measurements Results

Location No. [1]	Measurement Location Description	Start Date	Start Time	Meas. Duration (hours)	Noise Exposure (dBA) Ldn	Noise Exposure (dBA) 1-hour Leq
LT-1	3200 Guadalupe Street	5/8/2024	0:00	3 [2]	71	73
LT-2	Villas on Guadalupe -- 2810 Hemphill Park	2/26/2024	15:00	24	72	70
LT-3	AMLI Downtown -- 201 Lavaca Street	2/27/2024	11:00	24	68	65
LT-5	Muse at SoCo -- 1007 South Congress Avenue	2/27/2024	11:00	24	61	60
LT-6	107 W Monroe Street	2/28/2024	15:00	24	61	53
LT-7	2107 Eva Street	2/28/2024	9:00	24	55	54
LT-8	807 Edgecliff Terrace	4/27/21	17:00	24	67	65
LT-9	AMLI South Store	4/27/21	15:00	24	70	66
LT-10	Tempo at Riverside	4/27/21	14:00	24	69	65
LT-11	Austin Fire Station 22	4/27/21	15:00	24	69	66
LT-12	Riverside Nursing and Rehab	4/26/21	15:00	24	65	63
LT-13	Home2Suites -- 1705 Airport Commerce Dr	2/28/2024	16:00	24	62	60
LT-14	1340 Airport Commerce Dr	2/29/2024	14:00	3 [2]	57	61
ST-1	Guadalupe St and W Dean Keaton St	2/27/2024	8:21	1	64 [3]	66
ST-2	Guadalupe St and 22nd St	2/27/2024	11:53	1	65 [3]	67
ST-3	10th St and Guadalupe St	2/29/2024	9:23	1	62 [3]	64
ST-4	1503 South Congress Ave	2/29/2024	11:33	1	66 [3]	68
ST-5	500 Sunny Lane	4/28/21	10:52	1	51 [3]	53
ST-6	Austin Emergency Center – 2020 Riverside Drive	4/27/21	12:07	1	63 [3]	65
ST-7	222 East Riverside Drive	4/26/21	16:30	1	52 [3]	54

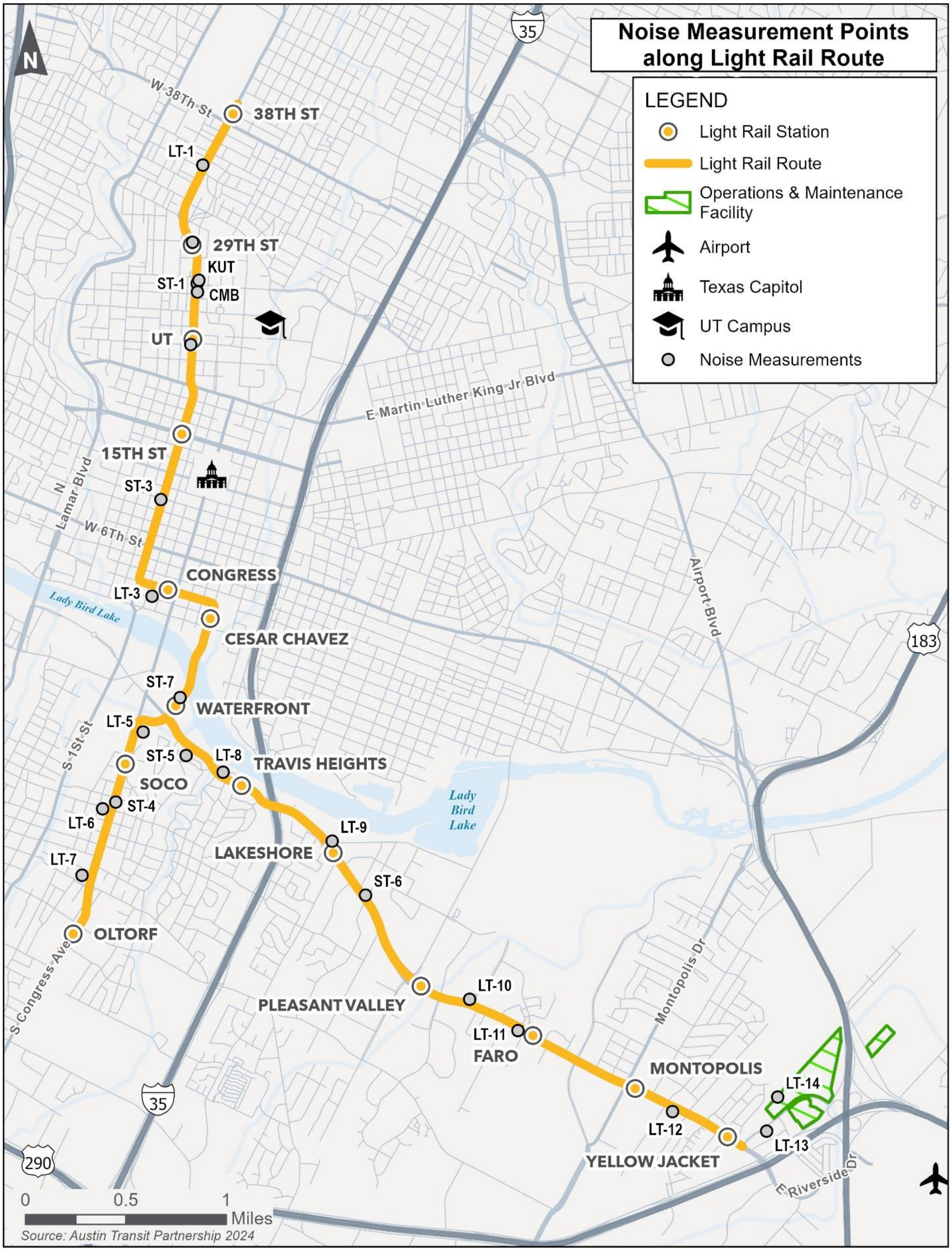
Source: Cross-Spectrum Acoustics 2024.

[1] LT = long-term (24 hours); ST = short-term (1 hour).

[2] Due to limitations of access, ATP used three 1-hour short-term noise measurements to estimate an Ldn using FTA guidance.

[3] The Ldn at these locations was estimated from the Leq using the methods described in the FTA guidance.

Figure 6: Noise Measurement Locations



Source: Austin Transit Partnership 2024

4.3 Existing Vibration Conditions

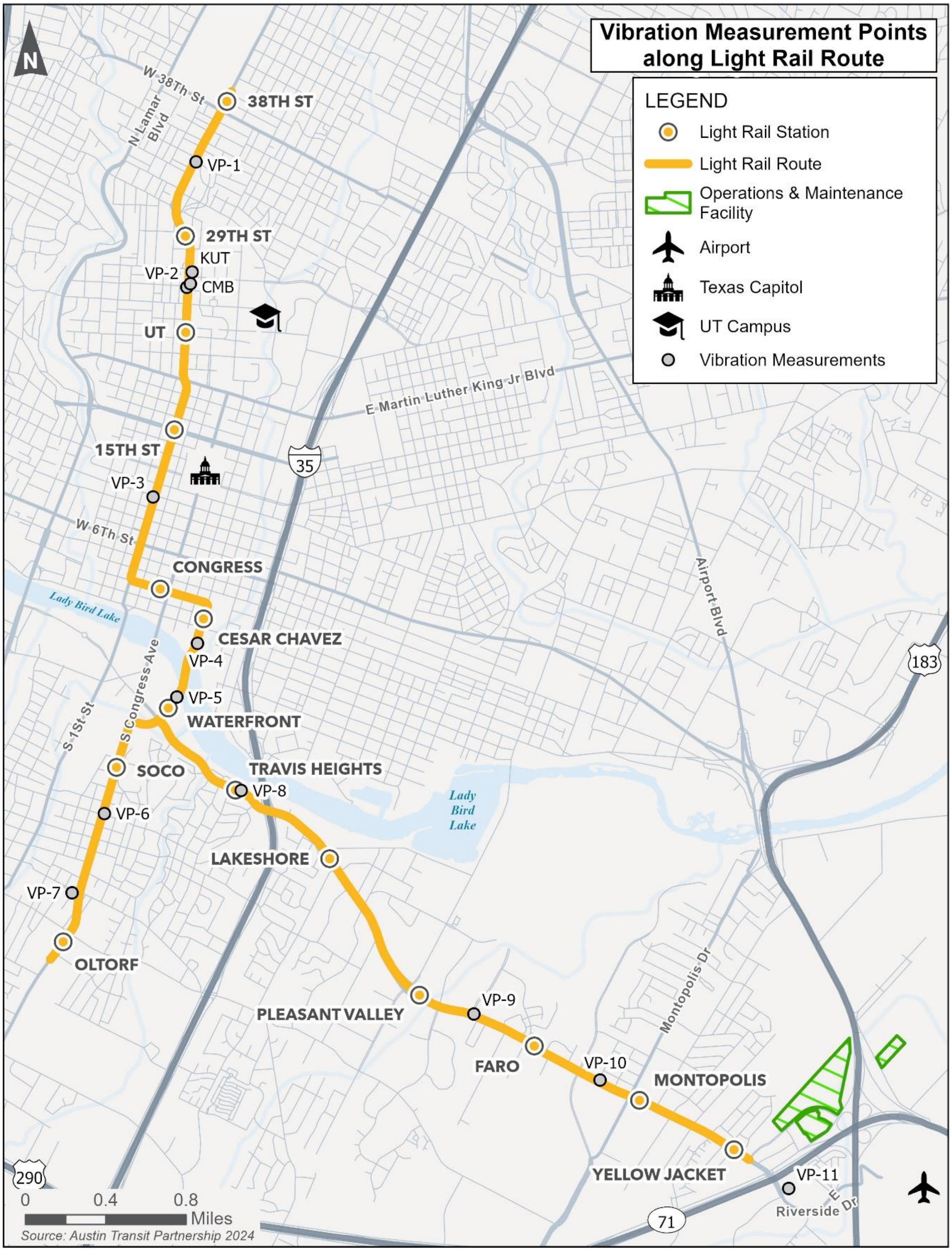
Vibration-sensitive land use for the Project is the same as the noise-sensitive land use described in Section 4.1. Existing vibration sources in the Study Area include auto, bus, and truck traffic on local streets. However, vibration from street traffic is not generally perceptible at receivers in the Study Area unless streets have substantial bumps, potholes, or other uneven surfaces. Furthermore, the FTA vibration impact criteria are not ambient based; that is, future Project vibrations are not compared with existing vibrations to assess impact. Therefore, the vibration measurements for the Project focused on characterizing the vibration propagation through various soil conditions along the track rather than on characterizing the existing vibration levels, as described below.

ATP selected six vibration propagation test locations for the 2021 measurements for the Project and five vibration propagation test locations for the 2024 measurements for the Project. **Figure 7** shows the vibration measurement locations. **Attachment C** includes location photographs, and **Attachments D and E** includes detailed propagation information. **Figure 8** and **Figure 9** show the results of the vibration propagation tests at 100 feet for each of the test locations for the Project. The vibration measurement locations are described below.

- **VP-1: 32nd Street and Guadalupe Street.** ATP conducted the vibration propagation measurement on the southeast corner of 32nd Street and Guadalupe Street. The location is used to represent the vibration from 29th Street to 38th Street.
- **VP-2: 25th Street and Guadalupe Street.** ATP conducted the vibration propagation measurement on the southwest corner of 25th Street and Guadalupe Street. The location is used to represent the vibration from West 15th Street to 29th Street.
- **VP-3: 10th Street and Guadalupe Street.** ATP conducted the vibration propagation measurement on the southwest corner of 10th Street and Guadalupe Street. The location is used to represent the vibration from Trinity Street to West 15th Street.
- **VP-4: Willow Street.** ATP conducted the vibration propagation measurement at this location in Willow Street Park off Trinity Street. This location is used to represent the vibration in Downtown Austin north of Lady Bird Lake.
- **VP-5: 222 East Riverside Drive.** ATP conducted the vibration propagation measurement in the parking lot adjacent to the *Austin American-Statesman*. This location is used to represent the vibration south of Lady Bird Lake before the Project turns onto East Riverside Drive.
- **VP-6: Monroe Street and South Congress Avenue.** ATP conducted the vibration propagation measurement on the northeast corner of Monroe Street and South Congress Avenue. The location is used to represent the vibration from Mary Street to the tracks turn off South Congress Avenue.
- **VP-7: Lindell Avenue and Bartlett Street.** ATP conducted the vibration propagation measurement on the southwest corner of Lindell Avenue and Bartlett Street. The location is used to represent the vibration from Long Bow Lane to Mary Street.

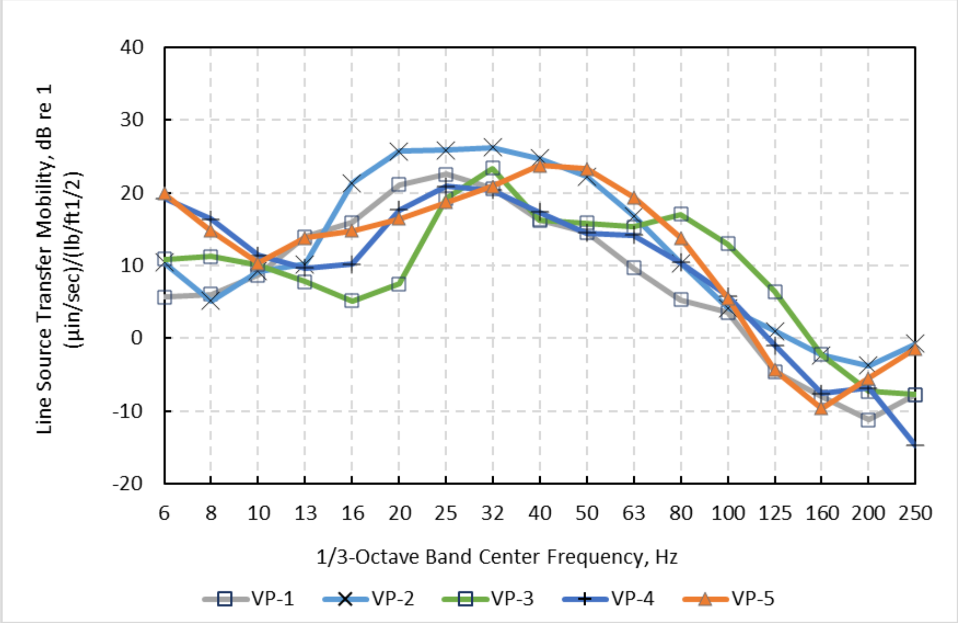
- **VP-8: Norwood Tract in Town Lake Metropolitan Park.** ATP conducted the vibration propagation measurement in the Norwood Tract in Town Lake Metropolitan Park between Edgecliff Terrace and East Riverside Drive. This location is used to represent the vibration from where the Project turns onto East Riverside Drive to Lakeshore Boulevard.
- **VP-9: East Riverside Drive and Crossing Place.** ATP conducted the vibration propagation measurement on the northeast corner of East Riverside Drive and Crossing Place. The location is used to represent the vibration from Lakeshore Boulevard to River Crossing Circle.
- **VP-10: East Riverside Drive and Clubview Avenue.** ATP conducted the vibration propagation measurement on the northeast corner of East Riverside Drive and Clubview Avenue. The location is used to represent the vibration from River Crossing Circle to Montague Street.
- **VP-11: Hampton Inn and Suites Austin-Airport.** ATP conducted the vibration propagation measurement in the grass field north of the Hampton Inn and Suites Austin-Airport. The location is used to represent the vibration from Montague Street to the airport.

Figure 7: Vibration Measurement Locations



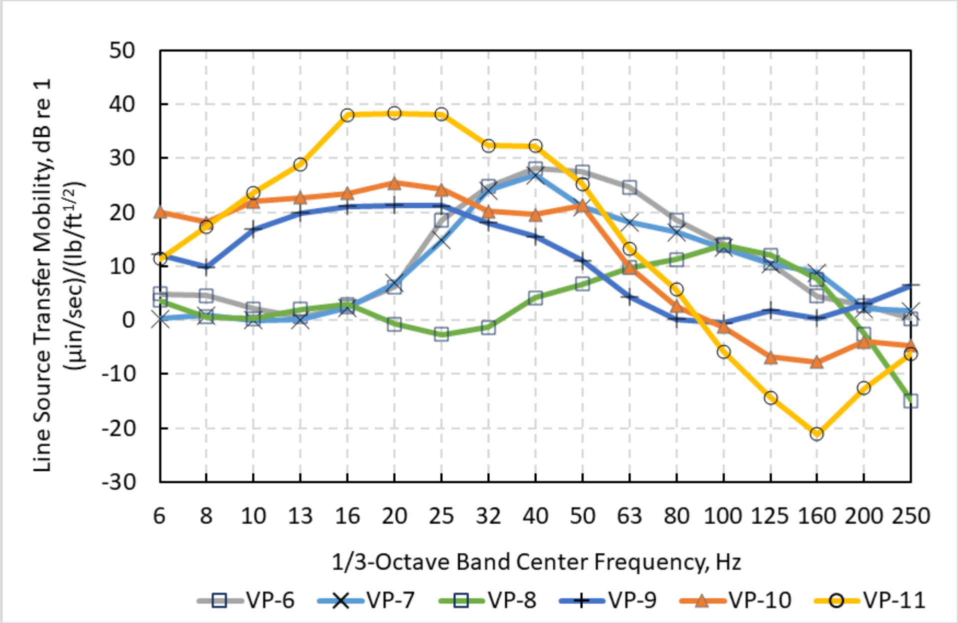
Source: Austin Transit Partnership 2024

Figure 8: LSTM at 100 Feet for Vibration Propagation Measurement Locations VP-1 through VP-5



Source: Cross-Spectrum Acoustics 2024.

Figure 9: LSTM at 100 Feet for Vibration Propagation Measurement Locations VP-6 through VP-11



Source: Cross-Spectrum Acoustics 2024.

5 Environmental Consequences

This section presents the noise and vibration impact assessment results for the No Build Alternative, the Build Alternative, and the Design Options.

5.1 No Build Alternative

The No-Build Alternative would not result in any transit noise or vibration impacts. There would likely be increases in highway and local roadway noise due to increased traffic volumes. There would be no changes in vibration levels under the No Build Alternative. The potential impacts of other projects would be evaluated separately by project sponsors.

5.2 Build Alternative

5.2.1 Operational (Long-Term) Noise Impacts

FTA's methodology for identifying noise impacts is conservative, and the predicted increases in noise due to the Project would be barely perceptible or not noticeable in most locations. The Project noise levels include noise from the light rail vehicles, traction power substations, park-and-rides, special track (i.e., crossovers), stations, and any grade crossing warning signals. **Table 10** includes the results for FTA Category 2 (residential) receptors (single-family homes or dwelling units within multifamily buildings) with both daytime and nighttime sensitivity to noise for the Build Alternative. **Table 11** includes the results for FTA Category 3 (institutional) receptors for the Build Alternative.

In addition to the distances to the nearest track, **Table 10** and **Table 11** include the existing noise levels, the projected noise levels from light rail operations, and the FTA noise impact criteria. Based on a comparison of the predicted Build Alternative noise levels with the impact criteria, the tables also include an inventory of the moderate and severe noise impacts for the Build Alternative.

Table 10: Summary of FTA Category 2 Noise Impacts for Build Alternative

Location	Side of Track	Distance to Near Track (feet)	Existing Noise Level (Ldn, dBA)	Project Noise Level (Ldn, dBA)	Moderate Noise Criteria (Ldn, dBA)	Severe Noise Criteria (Ldn, dBA)	# of Moderate Impacts	# of Severe Impacts
38th St to 30th St	NB	45	71	62	65	70	0	0
38th St to 30th St	SB	43	71	63	65	70	0	0
30th St to 27th St	NB	36	72	67	65	71	144 (1)	0
30th St to 27th St	SB	108	72	53	65	71	0	0
27th St to 24th St	NB	58	72	56	65	71	0	0
27th St to 24th St	SB	37	72	59	65	71	0	0
24th St to MLK Jr Blvd	NB	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*
24th St to MLK Jr Blvd	SB	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*
MLK Jr Blvd to 15th St	NB	28	62	62	59	64	79 (1)	0
MLK Jr Blvd to 15th St	SB	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*
15th St to 9th St	NB	98	62	58	59	64	0	0
15th St to 9th St	SB	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*
9th St to 3rd St	NB	36	68	61	63	68	0	0
9th St to 3rd St	SB	37	68	61	63	68	0	0
Guadalupe St to Trinity St	NB	46	68	64	63	68	1 (1)	0
Guadalupe St to Trinity St	SB	25	68	68	63	68	1 (1)	308 (1)
3rd St to Lady Bird Lake	NB	56	68	58	63	68	0	0
3rd St to Lady Bird Lake	SB	42	68	66	63	68	1 (1)	0
Lady Bird Lake to East Riverside Dr	NB	53	52	65	54	60	27 (2)	36 (1)

Location	Side of Track	Distance to Near Track (feet)	Existing Noise Level (Ldn, dBA)	Project Noise Level (Ldn, dBA)	Moderate Noise Criteria (Ldn, dBA)	Severe Noise Criteria (Ldn, dBA)	# of Moderate Impacts	# of Severe Impacts
Lady Bird Lake to East Riverside Dr	SB	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*
East Riverside Dr to Elizabeth St	NB	84	61	55	58	64	0	0
East Riverside Dr to Elizabeth St	SB	59	61	57	58	64	0	0
Elizabeth St to Mary St	NB	219	61	58	58	64	0	0
Elizabeth St to Mary St	SB	211	61	45	58	64	0	0
Mary St to Oltorf St	NB	50	55	59	55	61	40 (1)	0
Mary St to Oltorf St	SB	86	55	60	55	61	107 (5)	0
Newning Ave to Academy Dr	NB	46	67	59	62	68	0	0
Newning Ave to Academy Dr	SB	72	67	57	62	68	0	0
Academy Dr to I-35	NB	87	67	57	62	68	0	0
Academy Dr to I-35	SB	77	67	58	62	68	0	0
I-35 to S Lakeshore Blvd	NB	91	70	55	65	70	0	0
I-35 to S Lakeshore Blvd	SB	97	70	54	65	70	0	0
S Lakeshore Blvd to Tinnin Ford Rd	NB	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*
S Lakeshore Blvd to Tinnin Ford Rd	SB	114	63	53	59	65	0	0
Tinnin Ford Rd to S Pleasant Valley Rd	NB	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*
Tinnin Ford Rd to S Pleasant Valley Rd	SB	132	69	52	63	68	0	0

Location	Side of Track	Distance to Near Track (feet)	Existing Noise Level (Ldn, dBA)	Project Noise Level (Ldn, dBA)	Moderate Noise Criteria (Ldn, dBA)	Severe Noise Criteria (Ldn, dBA)	# of Moderate Impacts	# of Severe Impacts
S Pleasant Valley Rd to Crossing Pl	NB	103	69	54	63	68	0	0
S Pleasant Valley Rd to Crossing Pl	SB	91	69	55	63	68	0	0
Crossing Pl to Faro Dr	NB	85	69	55	63	69	0	0
Crossing Pl to Faro Dr	SB	73	69	56	63	68	0	0
Faro Dr to Grove Blvd	NB	198	69	59	63	69	0	0
Faro Dr to Grove Blvd	SB	71	69	59	63	69	0	0
Grove Blvd to Lawrence St	NB	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*
Grove Blvd to Lawrence St	SB	62	65	62	61	66	80 (1)	0
Lawrence St to Coriander Dr	NB	77	65	61	61	66	6 (1)	0
Lawrence St to Coriander Dr	SB	80	65	61	61	66	1 (1)	0
						Total	487 (16)	344 (2)

Source: Cross-Spectrum Acoustics 2024.

Note: (N/A*) There are no residential noise sensitive receivers in this location.
Numbers in parentheses represent the number of buildings with noise impact.

Table 11: Summary of FTA Category 3 Noise Impacts for Build Alternative

Name	Side of Track	Distance to Near Track (feet)	Existing Noise Level (Ldn, dBA)	Project Noise Level (Ldn, dBA)	Moderate Noise Criteria (Ldn, dBA)	Severe Noise Criteria (Ldn, dBA)	# of Moderate Impacts	# of Severe Impacts
Cedar Street Courtyard	NB	402	65	42	65	71	0	0
Moody College of Communication	NB	71	66	52	67	72	0	0
William Randolph Hearst Building	NB	160	66	42	67	72	0	0
University United Methodist Church	NB	46	66	54	67	72	0	0
Goldsmith Hall	NB	100	67	54	67	73	0	0
University Baptist Church	SB	49	67	54	67	73	0	0
Harry Ransom Center	NB	109	67	48	67	73	0	0
Rowling Hall	NB	61	67	55	67	73	0	0
History Of Medicine Gallery	SB	33	64	65	65	71	0	0
First Church of Christ, Scientist	NB	32	64	59	65	71	0	0
Central Christian Church	SB	43	64	57	65	71	0	0
Austin History Center | Austin Public Library	SB	80	64	53	65	71	0	0
Church of Scientology of Texas	SB	28	67	66	67	73	0	0
East Riverside Emergency Room (CT Scanner)	NB	121	64.50	55	65	71	0	0
Onion Creek Baptist Church	NB	211	63	46	64	70	0	0
The Church on Congress Avenue	NB	57	68	55	67	73	0	0
						Total	0	0

Source: Cross-Spectrum Acoustics 2024.

5.2.1.1 North of the University of Texas

Figure 10The Build Alternative would result in 144 moderate noise impacts at one multifamily building along Guadalupe Street between 30th Street and 27th Street. The impacts are due to the bells as trains approach a nearby station and proximity of the tracks. The locations of the impacted receivers are shown in **Figure 10**.

5.2.1.2 The University of Texas

There are no noise impacts in the University of Texas at Austin area.

5.2.1.3 Downtown Austin

The Build Alternative would result in 79 moderate noise impacts at one multifamily building along Guadalupe Street between MLK Boulevard and 15th Street. The impacts are due to the proximity of the tracks. The location of the impacted receiver is shown in **Figure 11**.

The Build Alternative would result in 2 moderate and 308 severe noise impacts at one multifamily building, the JW Marriott Austin hotel, and the Kasa Lady Bird Lake Austin hotel along 3rd Street between Guadalupe Street and Trinity Street. The impacts are due to the nearby crossover. The locations of the impacted receivers are shown in **Figure 11**.

The Build Alternative would result in one moderate noise impact at the Austin Marriot Downtown along Trinity Street between 3rd Street and Lady Bird Lake. The impacts are due to the nearby station and proximity of the tracks. The location of the impacted receiver is shown in **Figure 11**.

The Build Alternative would result in 27 moderate noise impacts at 2 multifamily buildings and 36 severe noise impacts at one multifamily building south of Lady Bird Lake before the turn onto East Riverside Drive. The impacts are due to the low existing noise levels, bells as trains approach a nearby station, a nearby traction power substation, and the proximity of the tracks. The locations of the impacted receivers are shown in **Figure 11**.

5.2.1.4 South Congress

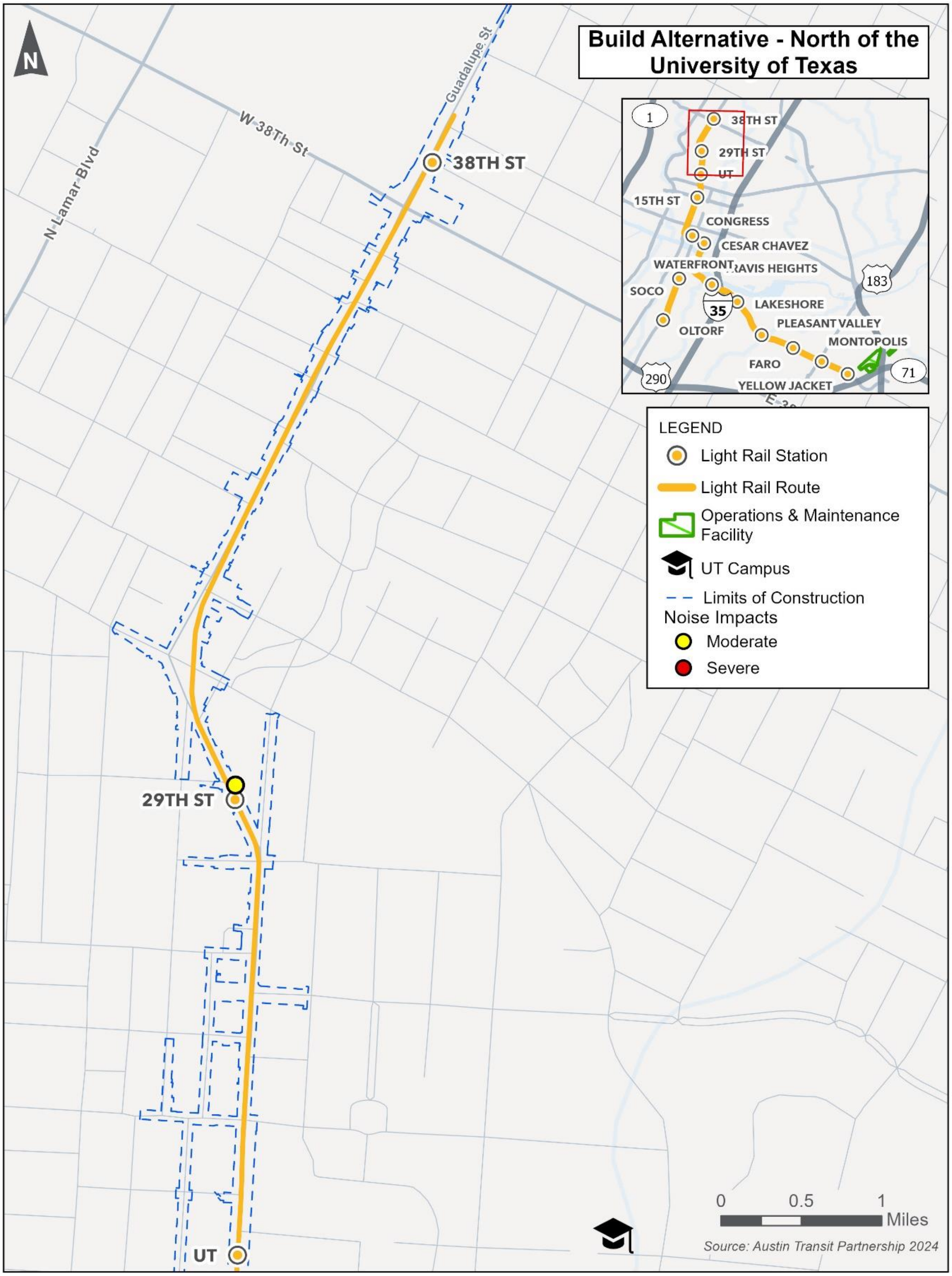
The Build Alternative would result in 149 moderate noise impacts at four single-family homes and two multifamily buildings along South Congress Avenue between Mary Street and Oltorf Street. The impacts are due to the proximity of the tracks and a nearby crossover. The locations of the impacted receivers are shown in **Figure 12**.

5.2.1.5 Riverside Drive

The Build Alternative would result in 80 moderate noise impacts at one multifamily building along East Riverside Drive between Grove Boulevard and Lawrence Street. The impacts are due to the proximity of the tracks and a nearby crossover. The locations of the impacted receivers are shown in **Figure 13**.

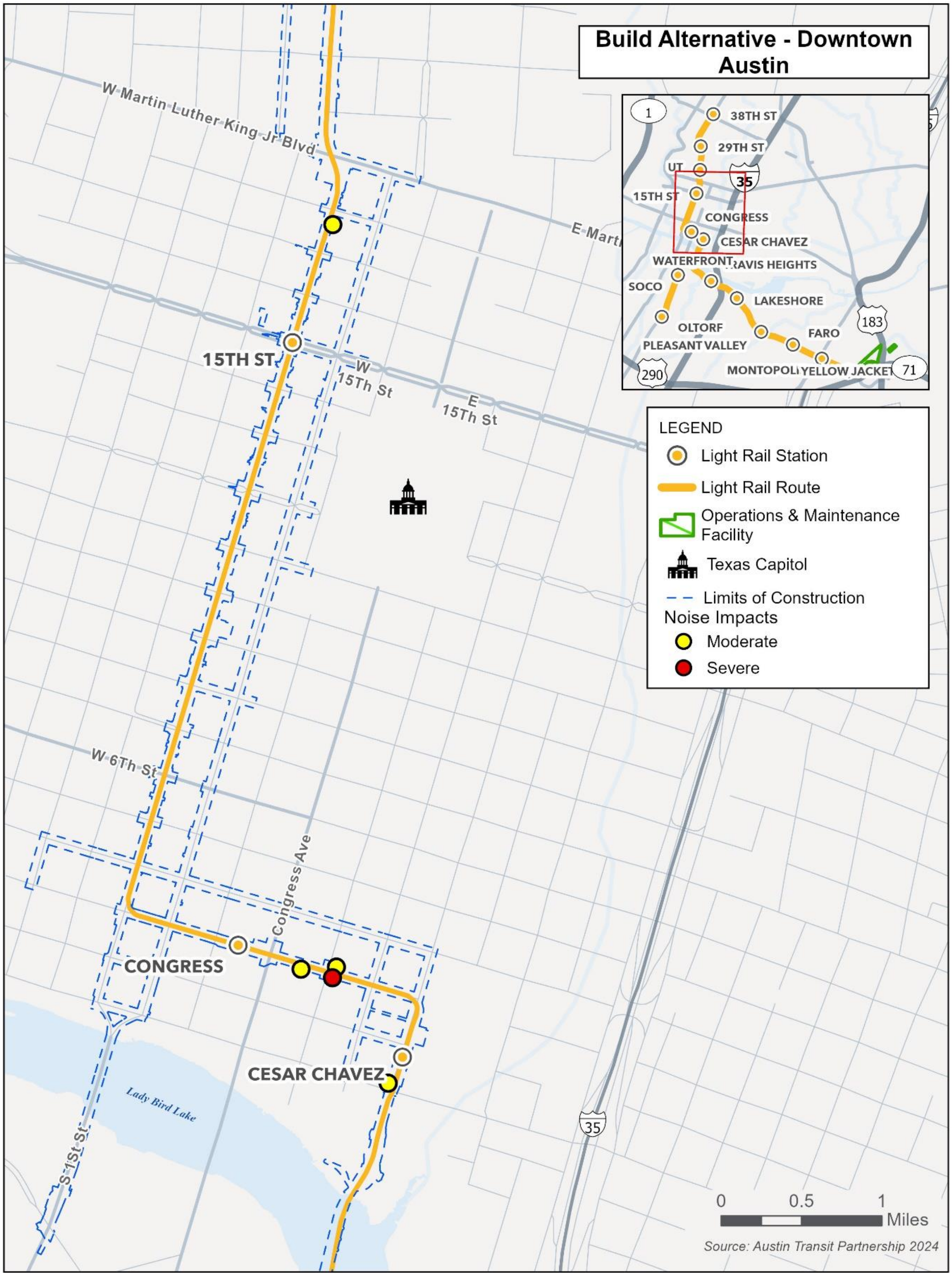
The Build Alternative would result in seven moderate noise impacts at one single-family home and one multifamily building along East Riverside Drive between Lawrence Street and Coriander Drive. The impacts are due to the proximity of the tracks and two nearby crossovers. The locations of the impacted receivers are shown in **Figure 13**.

Figure 10: Build Alternative Noise Impacts – North of the University of Texas at Austin



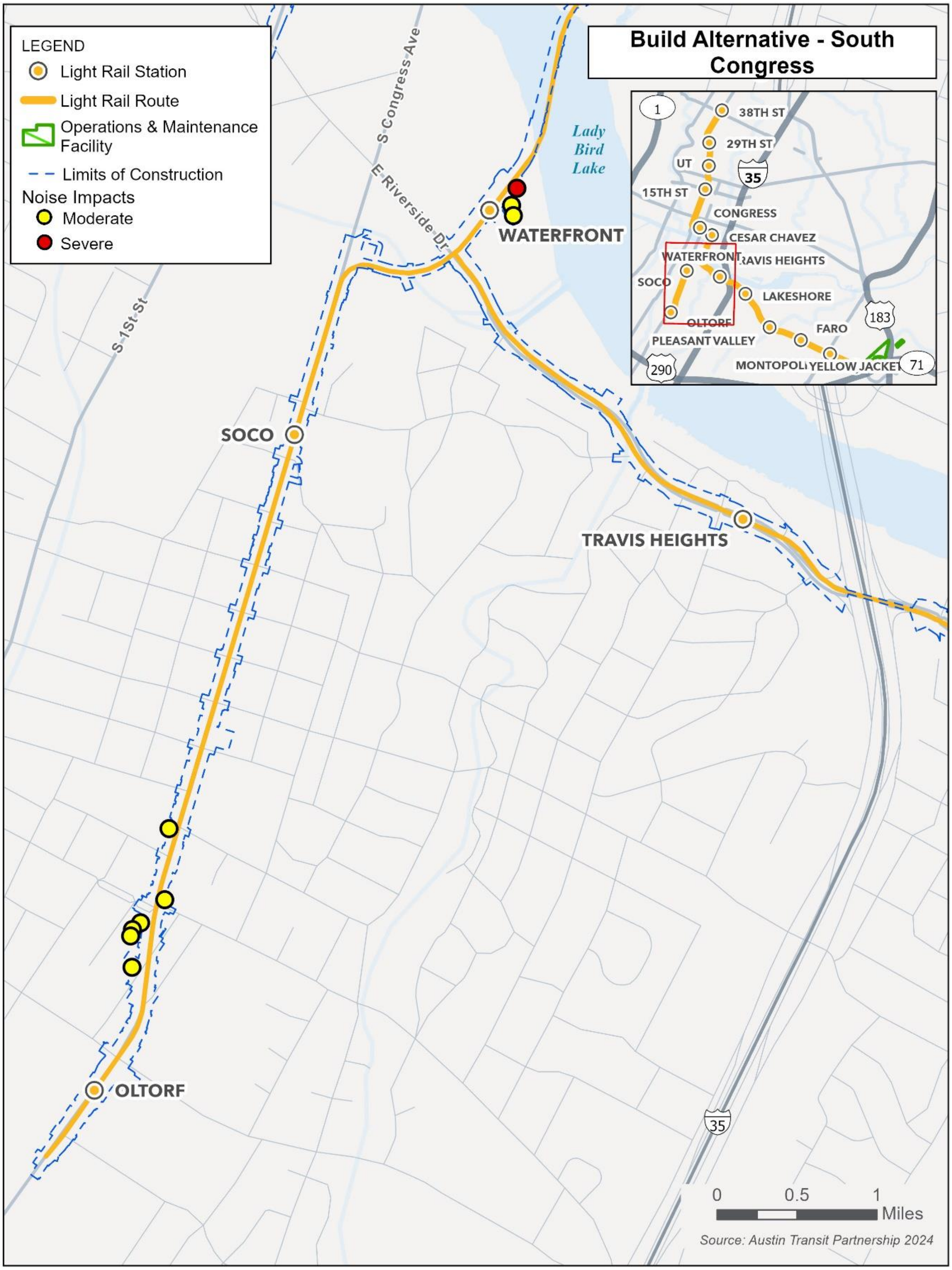
Source: Austin Transit Partnership 2024

Figure 11: Build Alternative Noise Impacts – Downtown Austin



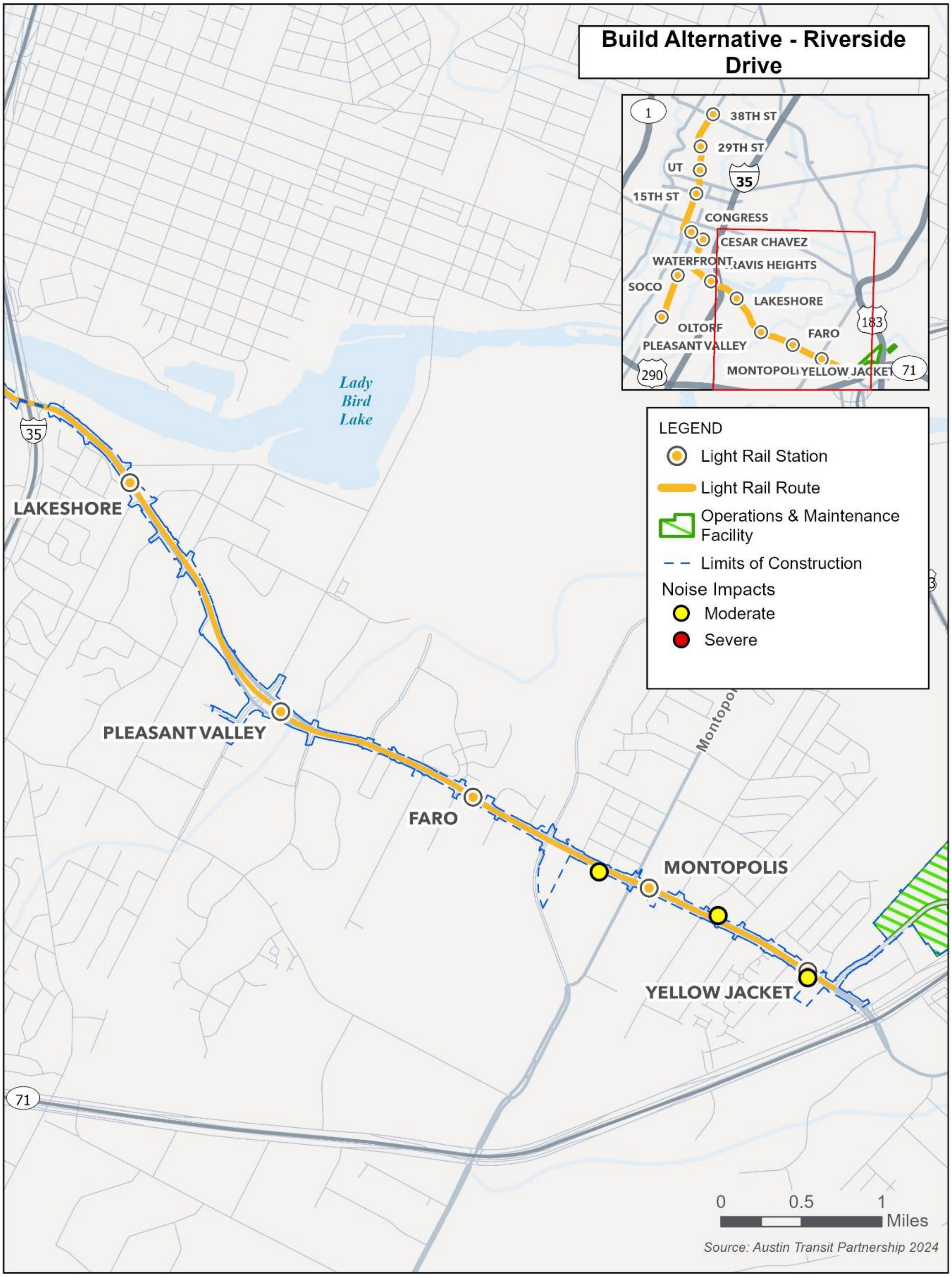
Source: Austin Transit Partnership 2024

Figure 12: Build Alternative Noise Impacts – South Congress



Source: Austin Transit Partnership 2024

Figure 13: Build Alternative Noise Impacts – Riverside Drive



Source: Austin Transit Partnership 2024

5.2.2 Operations and Maintenance Facility Noise Impacts

Table 12 compares the existing and Project noise levels for the OMF operations and includes the results for FTA Category 2 (residential) receptors with both daytime and nighttime sensitivity to noise for the Design Option. There are no FTA Category 3 (institutional) receptors located near the OMF.

Table 12: Summary of FTA Category 2 Noise Impacts for the OMF

Location	Side of Track	Distance to Near Track (feet)	Existing Noise Level (Ldn, dBA)	Project Noise Level (Ldn, dBA)	Moderate Noise Criteria (Ldn, dBA)	Severe Noise Criteria (Ldn, dBA)	# of Moderate Impacts	# of Severe Impacts
Lead Track	South	19	65	61	61	66	1	0
Lead Track	North	56	62	55	59	65	0	0
Coriander Drive	--	173	57	45	56	62	0	0

Source: Cross-Spectrum Acoustics 2024.

The OMF operations would result in one moderate noise impact at the Motel 6 Austin, TX - Airport along the lead track. The impact is due to the nearby turnout and proximity of the tracks. The location of the impacted receiver is shown in **Figure 18**.

5.2.3 Design Option Noise Impacts

5.2.3.1 Wooldridge Square Station Design Option

The only noise sensitive receiver in the area of the Wooldridge Square Station Design Option is the Austin History Center and Ausitn Public Library, and there are no changes to the noise impact assessment at this receiver due to the Design Option.

5.2.3.2 Cesar Chavez Station Design Option

Table 13 provides comparisons of the existing and Project noise levels for the Cesar Chavez Station Design Option and includes the results for FTA Category 2 (residential) receptors with both daytime and nighttime sensitivity to noise for the Design Option. There are no Category 3 (institutional) receptors in this area.

Table 13: Summary of FTA Category 2 Noise Impacts for Cesar Chavez Station Design Option

Location	Side of Track	Distance to Near Track (feet)	Existing Noise Level (Ldn, dBA)	Project Noise Level (Ldn, dBA)	Moderate Noise Criteria (Ldn, dBA)	Severe Noise Criteria (Ldn, dBA)	# of Moderate Impacts	# of Severe Impacts
Guadalupe St to Trinity St	NB	46	68	61	63	68	0	0
Guadalupe St to Trinity St	SB	25	68	65	63	68	309 (2)	0
3rd St to Lady Bird Lake	NB	56	68	55	63	68	0	0
3rd St to Lady Bird Lake	SB	22	73	61	65	71	0	0

Source: Cross-Spectrum Acoustics 2024.

Note: Numbers in parentheses represents the number of buildings with noise impact.

The Cesar Chavez Station Design Option would result in 309 moderate noise impacts at one multifamily building and the JW Marriott Austin hotel along 3rd Street between Guadalupe Street and Trinity Street. The impacts are due to the proximity of the tracks and the nearby station. With the Build Alternative, there would be 2 moderate and 308 severe noise impacts in this location. The locations of the impacted receivers are shown in **Figure 14**.

Figure 14: Cesar Chavez Station Design Option Noise Impacts

Source: Austin Transit Partnership 2024

5.2.3.3 Lady Bird Lake Bridge Extension Design Option

Table 14 compares the existing and Project noise levels for the Design Option that extends the light rail bridge south of Lady Bird Lake and includes the results for FTA Category 2 (residential) receptors with both daytime and nighttime sensitivity to noise for the Design Option. There are no Category 3 (institutional) receptors in this area.

Table 14: Summary of FTA Category 2 Noise Impacts for Lady Bird Lake Bridge Extension Design Option

Location	Side of Track	Distance to Near Track (feet)	Existing Noise Level (Ldn, dBA)	Project Noise Level (Ldn, dBA)	Moderate Noise Criteria (Ldn, dBA)	Severe Noise Criteria (Ldn, dBA)	# of Moderate Impacts	# of Severe Impacts
Lady Bird Lake to East Riverside Dr	NB	53	52	65	54	60	9 (1)	54 (2)
Lady Bird Lake to East Riverside Dr	SB	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*
Newning Ave to Academy Dr	NB	59	67	59	62	68	0	0
Newning Ave to Academy Dr	SB	61	67	59	62	68	0	0
Academy Dr to I-35	NB	87	67	58	62	68	0	0
Academy Dr to I-35	SB	77	67	57	62	68	0	0

Source: Cross-Spectrum Acoustics 2024.

Notes: (*) There are no residential noise sensitive receivers in this location.
Numbers in parentheses represent the number of buildings with noise impact.

The Lady Bird Lake Bridge Extension Design Option would result in 9 moderate noise impacts at 1 multifamily building and 54 severe noise impacts at 2 multifamily buildings south of Lady Bird Lake before the turn onto East Riverside Drive. The impacts would be due to the low existing noise levels, bells as trains approach a nearby station, a nearby traction power substation, and the proximity of the tracks. With the Build Alternative, there would be 27 moderate noise impacts at 2 multifamily buildings and 36 severe noise impacts at 1 multifamily building in this location. The locations of the impacted receivers are shown in **Figure 15**.

Figure 15: Lady Bird Lake Bridge Extension Design Option Noise Impacts

Source: Austin Transit Partnership 2024

5.2.3.4 Travis Heights Station Design Option

Table 15 compares the existing and Project noise levels for the Travis Heights Station Design Option and includes the results for FTA Category 2 (residential) receptors with both daytime and nighttime sensitivity to noise for the Design Option. There are no Category 3 (Institutional) receivers in this area. There are no noise impacts due to the Design Option. With the Build Alternative, there would be no impacts in this location.

Table 15: Summary of FTA Category 2 Noise Impacts for Travis Heights Station Design Option

Location	Side of Track	Distance to Near Track (feet)	Existing Noise Level (Ldn, dBA)	Project Noise Level (Ldn, dBA)	Moderate Noise Criteria (Ldn, dBA)	Severe Noise Criteria (Ldn, dBA)	# of Moderate Impacts	# of Severe Impacts
Academy Dr to I-35	NB	99	67	53	62	68	0	0
Academy Dr to I-35	SB	67	67	56	62	68	0	0

Source: Cross-Spectrum Acoustics 2024.

5.2.3.5 Center-Running Bike/Pedestrian and Shade Tree Facilities on East Riverside Design Option

Table 16 compares the existing and Project noise levels for the center-running bike and pedestrian facilities on East Riverside Drive east of I-35 and includes the results for FTA Category 2 (residential) receptors with both daytime and nighttime sensitivity to noise for the Design Option. **Table 17** includes the results for FTA Category 3 (institutional) receptors for this Design Option. There are no noise impacts to due to the Design Option. With the Build Alternative, there would be no impacts in this location.

Table 16: Summary of FTA Category 2 Noise Impacts for Center-Running Bike/Pedestrian and Shade Tree Facilities on East Riverside Design Option

Location	Side of Track	Distance to Near Track (feet)	Existing Noise Level (Ldn, dBA)	Project Noise Level (Ldn, dBA)	Moderate Noise Criteria (Ldn, dBA)	Severe Noise Criteria (Ldn, dBA)	# of Moderate Impacts	# of Severe Impacts
I-35 to S Lakeshore Blvd	NB	91	70	55	65	70	0	0
I-35 to S Lakeshore Blvd	SB	97	70	54	65	70	0	0
S Lakeshore Blvd to Tinnin Ford Rd	NB	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*
S Lakeshore Blvd to Tinnin Ford Rd	SB	96	63	59	59	65	0	0
Tinnin Ford Rd to S Pleasant Valley Rd	NB	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*
Tinnin Ford Rd to S Pleasant Valley Rd	SB	132	69	52	63	68	0	0

Source: Cross-Spectrum Acoustics 2024.
Note: (*) There are no residential noise sensitive receivers in this location.

Table 17: Summary of FTA Category 3 Noise Impacts for Center-Running Bike/Pedestrian and Shade Tree Facilities on East Riverside Design Option

Name	Side of Track	Distance to Near Track (feet)	Existing Noise Level (Ldn, dBA)	Project Noise Level (Ldn, dBA)	Moderate Noise Criteria (Ldn, dBA)	Severe Noise Criteria (Ldn, dBA)	# of Moderate Impacts	# of Severe Impacts
East Riverside Emergency Room (CT Scanner)	NB	121	65	54	65	71	0	0

Source: Cross-Spectrum Acoustics 2024.

5.2.3.6 Grove Station Design Option

Table 18 compares the existing and Project noise levels for the Grove Station Design Option and includes the results for FTA Category 2 (residential) receptors with both daytime and nighttime sensitivity to noise for the Design Option. There are no Category 3 (institutional) receptors for this Design Option.

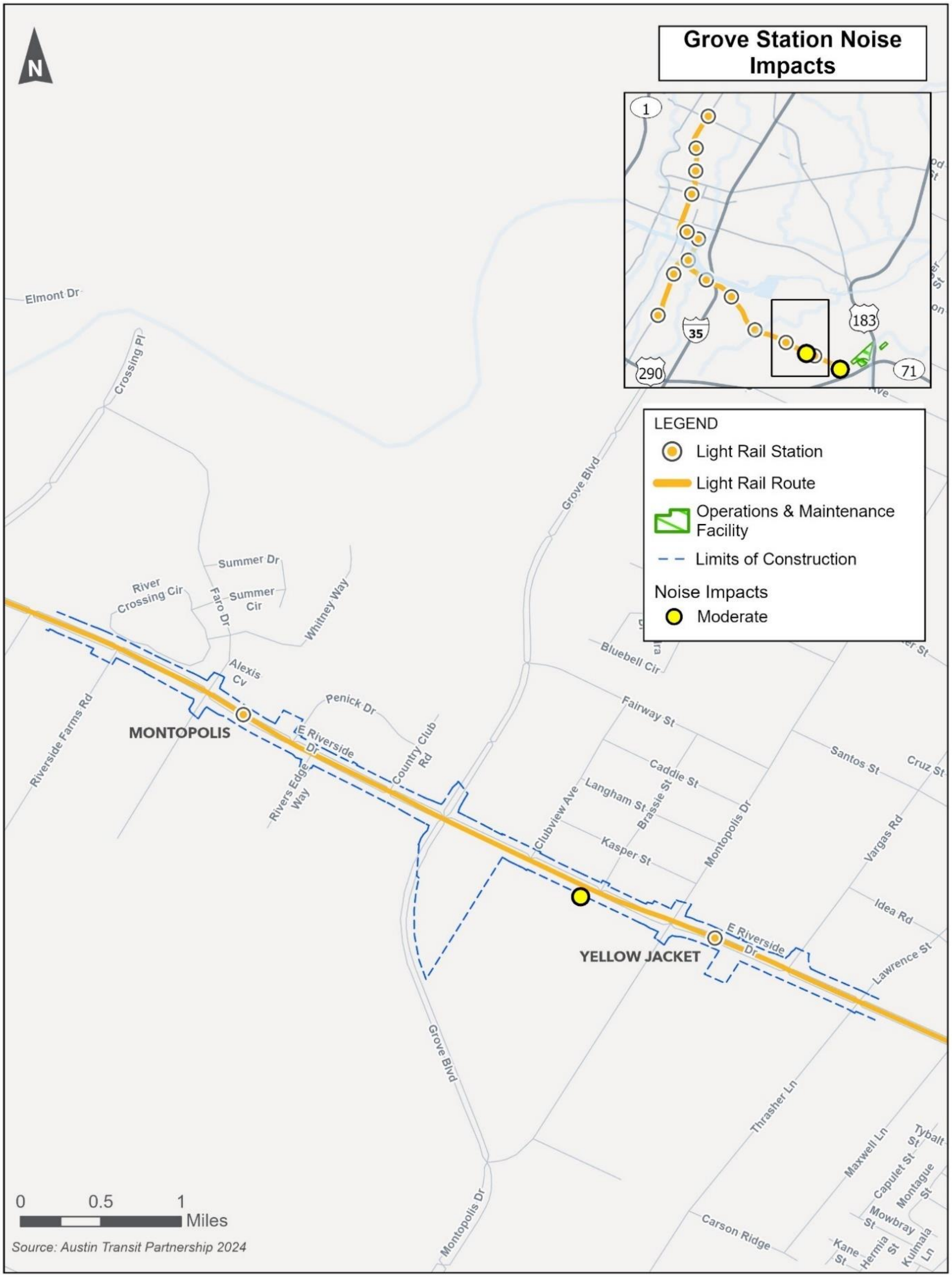
Table 18: Summary of FTA Category 2 Noise Impacts for Grove Station Design Option

Location	Side of Track	Distance to Near Track (feet)	Existing Noise Level (Ldn, dBA)	Project Noise Level (Ldn, dBA)	Moderate Noise Criteria (Ldn, dBA)	Severe Noise Criteria (Ldn, dBA)	# of Moderate Impacts	# of Severe Impacts
Crossing Pl to Faro Dr	NB	85	69	55	63	69	0	0
Crossing Pl to Faro Dr	SB	73	69	56	63	68	0	0
Faro Dr to Grove Blvd	NB	210	69	59	63	69	0	0
Faro Dr to Grove Blvd	SB	67	69	57	63	69	0	0
Grove Blvd to Lawrence St	NB	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*	N/A*
Grove Blvd to Lawrence St	SB	71	65	65	61	66	80 (1)	0
Lawrence St to Coriander Dr	NB	80	65	55	61	66	0	0
Lawrence St to Coriander Dr	SB	80	65	61	61	66	1 (1)	0

Source: Cross-Spectrum Acoustics 2024.
Notes: (*) There are no residential noise sensitive receivers in this location.
The number in parentheses is the number of buildings impacted.

The Grove Station Design Option would result in 81 moderate noise impacts at 1 multifamily building and 1 single-family home. These noise impacts would be due to nearby crossovers. With the Build Alternative, there would be 87 moderate noise impacts in this location at 2 multifamily buildings and 1 single-family home. The locations of the impacts are shown in **Figure 16**.

Figure 16: Grove Station Design Option Noise Impacts



Source: Austin Transit Partnership 2024

5.2.4 Operational (Long-Term) Vibration Impacts

Table 19 includes the results of the vibration assessment for FTA Category 2 (residential) receptors (single-family homes or dwelling units within multifamily buildings) with both daytime and nighttime sensitivity to vibration. **Table 20** includes the results of the vibration assessment for FTA Category 3 (institutional) receptors for the Build Alternative. The results include a tabulation of location information for each sensitive receptor group, the projections of future vibration levels, the impact criteria, and the total number of vibration impacts for each location. There are no operational vibration impacts associated with the Build Alternative. There are vibration impacts associated with the OMF, which is discussed below.

Table 19: Summary of FTA Category 2 Vibration Impacts for the Build Alternative

Location	Side of Track	Distance to Near Track (feet)	Project 1/3 Octave Band Maximum Vibration Level (VdB)	Project Vibration 1/3 Octave Band Frequency (Hz)	FTA Vibration Criterion (VdB)	# of Impacts
38th St to 30th St	NB	45	50	65	72	0
38th St to 30th St	SB	58	50	65	72	0
30th St to 27th St	NB	30	80	70	72	0
30th St to 27th St	SB	108	20	48	72	0
27th St to 24th St	NB	58	50	58	72	0
27th St to 24th St	SB	37	50	66	72	0
24th St to MLK Jr Blvd	NB	N/A*	N/A*	N/A*	N/A*	N/A*
24th St to MLK Jr Blvd	SB	N/A*	N/A*	N/A*	N/A*	N/A*
MLK Jr Blvd to 15th St	NB	28	40	62	72	0
MLK Jr Blvd to 15th St	SB	N/A*	N/A*	N/A*	N/A*	N/A*
15th St to 9th St	NB	98	80	43	72	0
15th St to 9th St	SB	N/A*	N/A*	N/A*	N/A*	N/A*
9th St to 3rd St	NB	36	50	57	72	0
9th St to 3rd St	SB	37	50	57	72	0
Guadalupe St to Trinity St	NB	46	50	54	72	0
Guadalupe St to Trinity St	SB	31	40	70	72	0
3rd St to Lady Bird Lake	NB	56	50	50	72	0
3rd St to Lady Bird Lake	SB	45	50	53	72	0
Lady Bird Lake to East Riverside Dr	NB	53	50	66	72	0
Lady Bird Lake to East Riverside Dr	SB	N/A*	N/A*	N/A*	N/A*	N/A*
East Riverside Dr to Elizabeth St	NB	N/A*	N/A*	N/A*	N/A*	N/A*

Location	Side of Track	Distance to Near Track (feet)	Project 1/3 Octave Band Maximum Vibration Level (VdB)	Project Vibration 1/3 Octave Band Frequency (Hz)	FTA Vibration Criterion (VdB)	# of Impacts
East Riverside Dr to Elizabeth St	SB	59	50	69	72	0
Elizabeth St to Mary St	NB	57	50	69	72	0
Elizabeth St to Mary St	SB	N/A*	N/A*	N/A*	N/A*	N/A*
Mary St to Oltorf St	NB	50	50	67	72	0
Mary St to Oltorf St	SB	56	50	65	72	0
Newning Ave to Academy Dr	NB	46	63	50	72	0
Newning Ave to Academy Dr	SB	68	63	44	72	0
Academy Dr to I-35	NB	87	63	50	72	0
Academy Dr to I-35	SB	68	63	43	72	0
I-35 to S Lakeshore Blvd	NB	91	63	41	72	0
I-35 to S Lakeshore Blvd	SB	97	63	50	72	0
S Lakeshore Blvd to Tinnin Ford Rd	NB	N/A*	N/A*	N/A*	N/A*	N/A*
S Lakeshore Blvd to Tinnin Ford Rd	SB	114	10	46	72	0
Tinnin Ford Rd to S Pleasant Valley Rd	NB	N/A*	N/A*	N/A*	N/A*	N/A*
Tinnin Ford Rd to S Pleasant Valley Rd	SB	132	10	46	72	0
S Pleasant Valley Rd to Crossing Pl	NB	103	10	46	72	0
S Pleasant Valley Rd to Crossing Pl	SB	91	40	47	72	0
Crossing Pl to Faro Dr	NB	84	50	56	72	0
Crossing Pl to Faro Dr	SB	112	50	53	72	0
Faro Dr to Grove Blvd	NB	82	50	57	72	0
Faro Dr to Grove Blvd	SB	85	50	60	72	0
Grove Blvd to Lawrence St	NB	N/A*	N/A*	N/A*	N/A*	N/A*
Grove Blvd to Lawrence St	SB	62	50	65	72	0
Lawrence St to Coriander Dr	NB	77	50	68	72	0
Lawrence St to Coriander Dr	SB	80	50	66	72	0
					Total	0

Source: Cross-Spectrum Acoustics 2024.

Note: (*) There are no vibration sensitive residential receivers in this area.

Table 20: Summary of FTA Category 3 Vibration Impacts for Build Alternative

Name	Side of Track	Distance to Near Track (feet)	Project 1/3 Octave Band Maximum Vibration Level (VdB)	Project Vibration 1/3 Octave Band Frequency (Hz)	FTA Vibration Criterion (VdB)	# of Impacts
Cedar Street Courtyard	NB	402	10	36	75	0
Moody College of Communication	NB	71	50	55	75	0
William Randolph Hearst Building	NB	160	20	46	75	0
University United Methodist Church	NB	46	50	63	75	0
Goldsmith Hall	NB	100	20	48	75	0
University Baptist Church	SB	49	50	61	75	0
Harry Ransom Center	NB	109	20	48	75	0
Rowling Hall	NB	61	50	57	75	0
History Of Medicine Gallery	SB	33	40	60	75	0
First Church of Christ, Scientist	NB	32	40	60	75	0
Central Christian Church	SB	43	50	55	75	0
Austin History Center | Austin Public Library	SB	80	50	46	75	0
Church of Scientology of Texas	SB	28	80	72	75	0
East Riverside Emergency Room (CT Scanner)	NB	121	10	51	75	0
Onion Creek Baptist Church	NB	211	20	53	75	0
The Church on Congress Avenue	NB	57	50	69	75	0
					Total	0

Source: Cross-Spectrum Acoustics 2024.

5.2.5 Operations and Maintenance Facility Vibration Impacts

Table 21 includes the results of the vibration assessment for FTA Category 2 (residential) receptors with both daytime and nighttime sensitivity to vibration. There are no FTA Category 3 (institutional) receptors located near the OMF. The results include a tabulation of location information for each sensitive receptor group, the projections of future vibration levels, the impact criteria, and the total number of vibration impacts for each location.

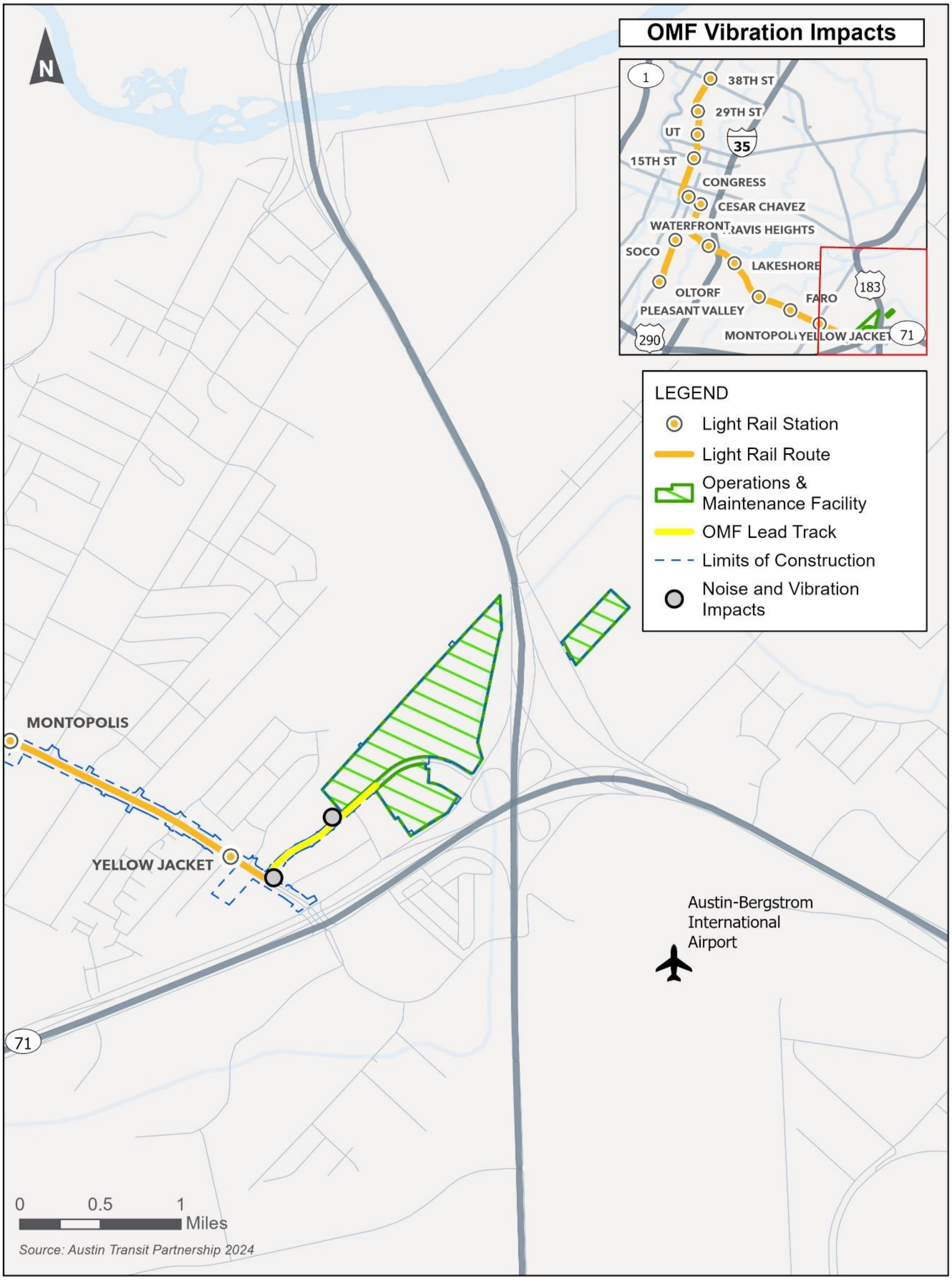
Table 21: Summary of FTA Category 2 Vibration Impacts for the OMF

Location	Side of Track	Distance to Near Track (feet)	Project 1/3 Octave Band Maximum Vibration Level (VdB)	Project Vibration 1/3 Octave Band Frequency (Hz)	FTA Vibration Criterion (VdB)	# of Impacts
Lead Track	South	19	63	85	72	1
Lead Track	North	56	20	73	72	135
Coriander Drive	--	173	20	47	72	0
					Total	136

Source: Cross-Spectrum Acoustics 2024.

The OMF operations would result in 135 vibration impacts at 1 multifamily building and 1 vibration impact at the Motel 6 Austin, TX - Airport along the lead track. The impact is due to the nearby turnouts and proximity of the tracks. The location of the impacted receiver is shown in **Figure 17**.

Figure 17: Operations and Maintenance Facility Noise and Vibration Impacts



Source: Austin Transit Partnership 2024

5.2.6 Design Option Vibration Impacts

5.2.6.1 Wooldridge Square Station Design Option

The only receiver in the area of the Wooldridge Square Station Design Option is the Austin History Center and Ausitn Public Library. There are no vibration impacts for the Design Option at this location.

5.2.6.2 Cesar Chavez Station Design Option

Table 19 includes the results of the vibration assessment for FTA Category 2 (residential) receptors with both daytime and nighttime sensitivity to vibration. There are no FTA Category 3 (institutional) receptors in this area. There are no vibration impacts with the Cesar Chavez Station Design Option.

Table 22: Summary of FTA Category 2 Vibration Impacts for the Cesar Chavez Station Design Option

Location	Side of Track	Distance to Near Track (feet)	Project 1/3 Octave Band Maximum Vibration Level (VdB)	Project Vibration 1/3 Octave Band Frequency (Hz)	FTA Vibration Criterion (VdB)	# of Impacts
Guadalupe St to Trinity St	NB	46	50	54	72	0
Guadalupe St to Trinity St	SB	25	40	70	72	0
3rd St to Lady Bird Lake	NB	56	50	50	72	0
3rd St to Lady Bird Lake	SB	22	50	64	72	0
					Total	0

Source: Cross-Spectrum Acoustics 2024.

5.2.6.3 Lady Bird Lake Bridge Extension Design Option

Table 23 includes the results for FTA Category 2 (residential) receptors with both daytime and nighttime sensitivity to vibration for the Design Option. There are no Category 3 (institutional) receptors in this area. There are no vibration impacts with the Lady Bird Lake Bridge Extension Design Option.

Table 23: Summary of FTA Category 2 Vibration Impacts for Lady Bird Lake Bridge Extension Design Option

Location	Side of Track	Distance to Near Track (feet)	Project 1/3 Octave Band Maximum Vibration Level (VdB)	Project Vibration 1/3 Octave Band Frequency (Hz)	FTA Vibration Criterion (VdB)	# of Impacts
Lady Bird Lake to East Riverside Dr	NB	53	63	49	72	0
Lady Bird Lake to East Riverside Dr	SB	N/A*	N/A*	N/A*	N/A*	N/A*
Newning Ave to Academy Dr	NB	59	63	39	72	0
Newning Ave to Academy Dr	SB	55	63	35	72	0
Academy Dr to I-35	NB	87	63	40	72	0
Academy Dr to I-35	SB	68	63	41	72	0
					Total	0

Source: Cross-Spectrum Acoustics 2024.
Note: (*) There are no vibration sensitive residential receivers in this area.

5.2.6.4 Travis Heights Station Design Option

Table 24: includes the results for FTA Category 2 (residential) receptors with both daytime and nighttime sensitivity to vibration for the Design Option. There are no Category 3 (institutional) receptors in this area. There are no vibration impacts with the Travis Heights Station Design Option.

Table 24: Summary of FTA Category 2 Vibration Impacts for Travis Heights Station Design Option

Location	Side of Track	Distance to Near Track (feet)	Project 1/3 Octave Band Maximum Vibration Level (VdB)	Project Vibration 1/3 Octave Band Frequency (Hz)	FTA Vibration Criterion (VdB)	# of Impacts
Academy Dr to I-35	NB	99	63	41	72	0
Academy Dr to I-35	SB	67	63	50	72	0
					Total	0

Source: Cross-Spectrum Acoustics 2024.
Note: (*) There are no vibration sensitive residential receivers in this area.

5.2.6.5 Center-Running Bike/Pedestrian and Shade Tree Facilities on East Riverside Design Option

Table 23 includes the results for FTA Category 2 (residential) receptors with both daytime and nighttime sensitivity to vibration for the Design Option. **Table** 26: includes the results for FTA Category 3 (institutional) receptors. There are no vibration impacts with the center-running bike and pedestrian facilities east of I-35.

Table 25: Summary of FTA Category 2 Vibration Impacts for Center-Running Bike/Pedestrian and Shade Tree Facilities on East Riverside Design Option

Location	Side of Track	Distance to Near Track (feet)	Project 1/3 Octave Band Maximum Vibration Level (VdB)	Project Vibration 1/3 Octave Band Frequency (Hz)	FTA Vibration Criterion (VdB)	# of Impacts
I-35 to S Lakeshore Blvd	NB	91	63	43	72	0
I-35 to S Lakeshore Blvd	SB	97	63	41	72	0
S Lakeshore Blvd to Tinnin Ford Rd	NB	N/A*	N/A*	N/A*	N/A*	N/A*
S Lakeshore Blvd to Tinnin Ford Rd	SB	96	10	56	72	0
Tinnin Ford Rd to S Pleasant Valley Rd	NB	N/A*	N/A*	N/A*	N/A*	N/A*
Tinnin Ford Rd to S Pleasant Valley Rd	SB	132	10	46	72	0
					Total	0

Source: Cross-Spectrum Acoustics 2024.
Note: (*) There are no vibration sensitive residential receivers in this area.

Table 26: Summary of FTA Category 3 Vibration Impacts for Center-Running Bike/Pedestrian and Shade Tree Facilities on East Riverside Design Option

Name	Side of Track	Distance to Near Track (feet)	Project 1/3 Octave Band Maximum Vibration Level (VdB)	Project Vibration 1/3 Octave Band Frequency (Hz)	FTA Vibration Criterion (VdB)	# of Impacts
East Riverside Emergency Room (CT Scanner)	NB	121	10	46	75	0
					Total	0

Source: Cross-Spectrum Acoustics 2024.

5.2.6.6 Grove Station Design Option

Table 27 includes the results for FTA Category 2 (residential) receptors with both daytime and nighttime sensitivity to vibration for the Design Option. There are no Category 3 (institutional) receptors in this area. There are no vibration impacts with the Grove Station Design Option.

Table 27: Summary of FTA Category 2 Vibration Impacts for Grove Station Design Option

Location	Side of Track	Distance to Near Track (feet)	Project 1/3 Octave Band Maximum Vibration Level (VdB)	Project Vibration 1/3 Octave Band Frequency (Hz)	FTA Vibration Criterion (VdB)	# of Impacts
Crossing Pl to Faro Dr	NB	97	50	55	72	0
Crossing Pl to Faro Dr	SB	110	50	53	72	0
Faro Dr to Grove Blvd	NB	89	50	56	72	0
Faro Dr to Grove Blvd	SB	67	50	59	72	0
Grove Blvd to Lawrence St	NB	N/A*	N/A*	N/A*	N/A*	N/A*
Grove Blvd to Lawrence St	SB	71	50	64	72	0
Lawrence St to Coriander Dr	NB	80	50	57	72	0
Lawrence St to Coriander Dr	SB	86	50	66	72	0
					Total	0

Source: Cross-Spectrum Acoustics 2024.
Note: (*) There are no vibration sensitive residential receivers in this area.

5.2.7 KUT Radio Station and Jesse H. Jones Communication Center – Building B

There are two special buildings along the proposed alignment that require a more detailed assessment: the KUT Radio station inside the GB Dealey Center for New Media and the Jesse H. Jones Communication Center – Building B. Both buildings have facilities that are more sensitive to noise and vibration than residential or institutional receivers. FTA has stricter criteria for assessing these types of buildings and their uses.

Table 28 provides the results of the noise assessment at KUT Radio and the Jesse H. Jones Communication Center – Building B. The results show that the Project noise inside the buildings would be more than 20 dB below the existing interior noise levels and would not impact either facility. The FTA criteria do not have specific interior noise level limits for spaces like KUT Radio or the Jesse H. Jones Communication Center – Building B. However, project noise levels are below the ground-borne noise thresholds for impact as well as being substantially below the measured existing interior noise levels.

Table 29 provides the results of the vibration and ground-borne noise assessment at KUT Radio and the Jesse H. Jones Communication Center – Building B. The results show that the Project would not have a vibration or ground-borne noise impact at either building.

Table 28: Summary of Noise Impacts at KUT Radio and Jesse H. Jones Communication Center – Building B

Name	Side of Track	Distance to Near Track (feet)	Existing Interior Background Noise Level (Leq, dBA)	Interior Project Noise Level (Leq, dBA)	Impact
KUT 90.5 FM (NPR Austin)	NB	66	34	6	None
Jesse H. Jones Communication Center – Building B 3rd Floor	NB	52	42	20	None
Jesse H. Jones Communication Center – Building B 4th Floor	NB	52	34	1	None

Source: Cross-Spectrum Acoustics 2024.

Table 29: Summary of Vibration and Ground-Borne Noise at KUT Radio and Jesse H. Jones Communication Center– Building B

Name	Side of Track	Distance to Near Track (feet)	Project 1/3 Octave Band Maximum Vibration Level (VdB)	Project Vibration 1/3 Octave Band Frequency (Hz)	FTA Vibration Criterion (VdB)	# of Impacts	Project Ground Borne Noise Levels (dBA)	FTA Ground Borne Noise Criterion (dBA)	# of Impacts
KUT 90.5 FM (NPR Austin)	NB	66	47	63	65	0	19	25	0
Jesse H. Jones Communication Center – Building B 4th Floor*	NB	52	51	20	65	0	19	25	0
					Total	0		**Total**	0

Source: Cross-Spectrum Acoustics 2024.
Note: (*) The 3rd floor of the communication building is not sensitive to vibration or ground-borne noise.

5.2.1 Construction-Related (Short-Term) Impacts

5.2.1.1 Construction Noise

Elevated noise levels from construction activities are, to a degree, unavoidable for this type of project. For most construction equipment, diesel engines are typically the dominant noise source. For other activities, such as impact pile driving and jackhammering, noise generated by the actual process dominates. Haul trucks transporting materials to and from the construction sites are an additional source of temporary noise, which would be most prominent during material loading and unloading or when trucks are accelerating or braking. Short-term noise during construction can be intrusive to residents near the construction sites or along designated haul routes. Most of the construction would consist of site preparation, constructing the light rail guideway, and laying new tracks and should occur primarily during daytime hours. At some locations, more extensive work would occur, such as pile driving for elevated structures and retaining walls. Nighttime work may be required in some locations or for specific activities. While the City's Code of Ordinances Chapter 9-2 regulates construction noise, the City has passed an ordinance regarding construction limits and construction noise specifically for transit system projects. This ordinance provides greater flexibility for construction noise and requires submission of a construction noise mitigation and monitoring plan, project noise requirements for construction contractors, and a public communications plan (City of Austin 2022). If there is a conflict with Chapter 9-2, the approved noise and mitigation plan will supersede Chapter 9-2.

Table 5 shows noise levels of typical construction equipment from the FTA *Transit Noise and Vibration Impact Assessment Manual* in terms of the maximum levels at 50 feet. Construction noise predictions at noise-sensitive locations depend on the amount of noise during each construction phase, the duration of the noise, and the distance from the construction activities to the sensitive receptor.

Table 30 provides an example of a construction noise projection for typical at-grade track construction. Construction noise projections for other Project features, such as station or parking facilities, would have similar results. Specific construction scenarios would be developed during the preparation of the construction noise and vibration plan, when more information on methods, equipment, and durations is available. Using these assumptions, an 8-hour Leq of 88 dBA would be projected at a distance of 50 feet from the construction site.

Using the criteria in Section 2.3 and the example for at-grade construction in Table 30, the potential noise impacts on nearby sensitive receptors, including residential areas, have been assessed in accordance with FTA standards. For residential land use, the FTA noise impact criteria of 80 dBA Leq (8-hour) for daytime construction and 70 dBA Leq (8-hour) for nighttime construction are applicable. Based on these criteria, short-term noise impacts from at-grade track construction during the daytime are projected to extend up to 120 feet from the Project centerline, where noise levels may reach or exceed 80 dBA, potentially affecting nearby residences. For nighttime construction, when the lower 70 dBA threshold applies, noise impacts could extend to approximately 380 feet from the Project centerline, increasing the likelihood of disruption to sensitive land uses.

For elevated structure construction or other locations where pile driving may occur, daytime noise impacts may exceed FTA's residential threshold of 80 dBA at up to approximately 250 feet assuming a usage factor of 20 percent. If alternative methods of piling are used, the distance to impact could be less. When a specific piling method is determined, a screening distance could be calculated. The Project's construction noise and vibration plan would further refine these assessments based on finalized construction methods to minimize potential disruptions to sensitive receptors as feasible.

Table 30: Typical Construction Scenario, At-Grade Track

Equipment Type	Typical Noise Level at 50 feet (dBA)	Equipment Utilization Factor (%)	Leq (dBA)
Grader	85	50	82
Backhoe	80	40	76
Compactor	82	20	75
Loader	85	20	78
Roller	74	20	67
Truck	88	40	84
Crane, mobile	83	20	76
		Total 8-hour workday Leq at 50 feet	88

Source: FTA 2018

5.2.1.2 Construction Vibration

Unlike typical light rail operations, construction activities, such as pile driving, hoe rams, vibratory compaction, and loaded trucks, have the potential to generate vibration levels that may damage nearby structures at close distances. Most limits on construction vibration are established to reduce the risk of damage to nearby structures. Although construction vibrations are only temporary, the potential for human annoyance and damage is assessed. Unlike noise, construction vibration is not assessed cumulatively; instead, the individual types of construction equipment are assessed for their specific potential to cause damage or annoyance. **Table 31** identifies the types of construction equipment that generate substantial levels of vibration. Other types of construction equipment do not generate vibration levels high enough to assess for annoyance or damage.

As a conservative approach, the analysis uses the non-engineered timber and masonry construction category (Category 3) to assess the potential for construction vibration impacts. A vibration criterion of 94 VdB has been used to assess potential damage impact, and 72 VdB has been used to assess potential vibration annoyance from construction activities. **Table 31** presents vibration source levels at 25 feet and shows the distances at which residential damage or annoyance could occur. Except for impact pile driving, the potential for damage is limited to within 25 feet of construction activities. For impact pile driving, the distance for the potential for damage increases up to 55 feet depending on the piling method used.

Because the exact location of construction equipment significantly affects vibration levels, a more detailed assessment of potential vibration damage would be performed during final design when more accurate equipment locations are known.

Table 31: Summary of Potential Construction Vibration Impacts

Equipment Type	Typical Vibration Level at 25 feet (dBA)	Distance for Potential Damage (feet)	Distance for Potential Annoyance (feet)
Impact pile driving	104	55	290
Push piling	84	25	125
Hoe ram	87	15	80
Caisson drilling	87	15	80
Loaded trucks	86	15	75
Clam shovel	94	25	135
Vibratory roller	94	25	135

Source: FTA 2018.

6 Mitigation

As described in Section 5.2, the Build Alternative would have noise and vibration impacts. During subsequent design, ATP will examine opportunities to further minimize and mitigate noise and vibration impacts and incorporate feasible and reasonable measures into the construction and operations plans for the Project. Noise and vibration minimization and mitigation measures are summarized below.

6.1 Operational Noise

FTA states that, in determining the need for noise mitigation, severe impacts should be mitigated unless there are no practical means to do so. At the moderate impact level, more discretion should be used, and other Project-specific factors should be included in the consideration of mitigation. These other factors can include the predicted increase over existing noise levels, the types and number of noise-sensitive land uses affected, existing outdoor-to-indoor sound insulation, and the cost-effectiveness of mitigating noise to more acceptable levels. For operational noise, there are two locations with moderate noise impacts where ATP would consider mitigation. Potential mitigation measures for reducing noise impacts are described below:

- **Noise barriers.** Installation of noise barriers beside the tracks is commonly used to reduce noise from surface transportation sources. Depending on the height and location relative to the tracks, noise barriers can achieve between 5 and 15 dB of noise reduction. The primary requirements for an effective noise barrier are that (1) the barrier must be high enough and long enough to break the line of sight between the sound source and the receiver, (2) the barrier must be of an impervious material with a minimum surface density of 4 pounds per square foot, and (3) the barrier must not have any gaps or holes between the panels or at the bottom. Because many materials meet these requirements, the selection of materials for noise barriers is usually dictated by aesthetics, durability, cost, and maintenance considerations. Noise barriers for transit projects typically range in height from 8 to 12 feet for at-grade track and 4 to 6 feet in height on elevated structures.

- **Building sound insulation.** Although sound insulation of buildings has no effect on noise in exterior areas, it may be the best choice for sites where noise barriers are not feasible or desirable and for buildings where indoor sensitivity is of most concern. Substantial improvements in building sound insulation (on the order of 5 to 10 dBA) can often be achieved by adding an extra layer of glazing to the windows, by sealing holes in exterior surfaces that act as sound leaks, and by providing forced ventilation and air-conditioning so that windows do not need to be opened.
- **Special trackwork.** Because the impacts of rail vehicle wheels over rail gaps at track turnout locations (which are used to allow trains to move from one track to another) increase airborne noise by about 6 dB close to the track, crossovers and turnouts are a major source of noise impact when they are located in sensitive areas. If turnouts cannot be relocated away from sensitive areas, other noise control measures can be used such as the use of spring-rail, flange-bearing, or moveable-point turnouts in place of standard rigid turnouts. These devices allow the flangeway gap to remain closed in the main traffic direction for revenue service trains.

There are four locations on the Build Alternative with noise impacts where mitigation to be considered would involve using one of the types of special trackwork described above to eliminate the impacts.

1. **Guadalupe Street and Trinity Street.** The first location is at an apartment building (reduced from a severe noise impact to a moderate noise impact) and two hotels along 3rd Street between Guadalupe Street and Trinity Street where a crossover is located.
2. **Mary Street and Oltorf Street.** The second location is at three single-family homes along South Congress Avenue between Mary Street and Oltorf Street where a crossover is located.
3. **Grove Boulevard and Lawrence Street.** The third location is at one multifamily building along East Riverside Drive between Grove Boulevard and Lawrence Street where a crossover is located.
4. **Lawrence Street and Coriander Drive.** The fourth location is at one multifamily building and one single-family home along East Riverside Drive between Lawrence Street and Coriander Drive where a crossover is located.

The crossover located at Grove Boulevard and Lawrence Street in the Grove Station Design Option would also be a candidate for using one of the types of special trackwork described above to eliminate the impact at one multifamily building along East Riverside Drive.

All the other noise impacts associated with the Build Alternative and the Design Options are not due to crossover noise and most are also not in locations where noise barriers would be feasible. At these locations, sound insulation would need to be assessed for potential noise mitigation. For the noise impacts associated with the extended elevated structure south of Lady Bird Lake, a noise barrier on the northbound side on the elevated structure could be feasible to mitigate the noise impacts. If other mitigation measures are identified as the Project progresses, these could be incorporated with approval by FTA.

6.2 Operational Vibration

Several different approaches have been used by rail transit systems to reduce ground-borne vibration and ground-borne noise. The most common vibration mitigation measures used on light rail systems consist of placing a resilient layer between the track and the soil. Some standard approaches for vibration mitigation are described below:

- **Ballast mats.** A ballast mat is a pad made of rubber or other material placed underneath the ballast and mounted on top of an asphalt or concrete base. Ballast mats provide a modest reduction in vibration levels at frequencies above 40 Hz.
- **Tire-derived aggregate.** Tire-derived aggregate, or shredded tires, consist of a layer of tire shreds wrapped in geotechnical fabric placed underneath the ballast and placed on hard packed ground. This is a low-cost mitigation option that provides a reduction in vibration levels at frequencies above 25 Hz.
- **Resilient fasteners.** Direct-fixation track fasteners are used to attach the rail to the concrete track slab in a tunnel or on an elevated structure. Resilient fasteners include a soft, resilient element to provide greater vibration isolation than standard rail fasteners in the vertical direction.
- **Floating slabs.** Floating slabs consist of a concrete slab supported by elastomer springs on a concrete foundation. The frequency range at which a floating slab is effective depends on the thickness of the slab and the stiffness of the springs. Floating slabs are very effective at reducing vibration levels, particularly at low frequencies. However, they are also very expensive.
- **Low-impact special trackwork.** The impacts of vehicle wheels over rail gaps at special trackwork locations such as turnouts and switches can increase vibration levels by up to 10 dB. If special trackwork cannot be located away from vibration-sensitive receivers, another approach is to use low-impact frogs. Spring-rail and moveable point frogs allow the flangeway gap to remain closed in the main traffic direction for revenue service trains and can almost completely reduce the vibration increase caused by special trackwork. Monoblock frogs are milled out of a single block of steel and their tolerances can be tighter than a traditional frog, which reduces the vibration increase. Flange-bearing frogs include a ramp to support the flange of the wheel to minimize banging. Well-designed monoblock and flange-bearing frogs can reduce the vibration level increase by about half compared to a standard frog.
- **Alternative approaches.** There are alternative vibration mitigation approaches that may be applied under specific circumstances. Examples include increasing the thickness of the concrete under the track, specifying straighter rails, and building the track on top of pile foundation systems when the track would traverse very soft sections of soil.

There are two locations that would need to be considered for vibration mitigation. The Motel 6 Austin, TX - Airport and a multifamily building along the lead track for the OMF are vibration impacts due to the proximity of the rail and the turnouts associated with the lead tracks. Specific mitigation options at these locations will be examined during the design phase of the project and could include special types of turnouts or vibration isolation systems.

6.3 Construction Noise and Vibration

ATP would carry out construction activities in compliance with all applicable local noise regulations. ATP would refine specific construction noise and vibration avoidance, minimization, and mitigation measures during the design phase of the Project when more detailed construction information is available. ATP may apply the following measures, as needed, to minimize temporary construction noise and vibration impacts:

- Limiting nighttime construction in residential areas;
- Locating stationary construction equipment as far as possible from noise-sensitive sites;
- Constructing noise barriers, such as temporary walls or piles of excavated material, between noisy activities and noise-sensitive receptors;
- Routing construction-related truck traffic to roadways that would cause the least disturbance to residents; and
- Using alternative construction methods to minimize the use of impact and vibratory equipment (e.g., pile drivers and compactors). If use of this equipment is necessary, limit the time of day the activity can occur.

In addition to the measures above, ATP will prepare a noise control plan in accordance with Ordinance No. 20221115-048 (City of Austin 2022). A noise control engineer or acoustician would work with the contractor to prepare a Noise Control Plan in conjunction with the contractor's specific equipment and methods of construction. Key elements of a Noise Control Plan include:

- contractor's specific equipment types;
- schedule (dates and times of day) and methods of construction;
- maximum noise limits for each piece of equipment with certification testing;
- prohibitions on certain types of equipment and processes during the night or daytime hours per local agency coordination and approved variances;
- identification of specific sensitive locations near construction sites;
- design-designated haul routes to avoid noise-sensitive areas when possible;
- methods for projecting construction noise levels;
- implementation of noise and vibration control measures where appropriate; and
- methods for responding to community complaints.

7 References

City of Austin. 2022. Ordinance No. 20221115-048. An Ordinance Amending City Code Title 25 and Chapter 9-2 to Allow Construction of Certain Transit System Projects and Related Transportation Infrastructure. Approved November 15, 2022. Accessed July 21, 2024. https://services.austintexas.gov/edims/document.cfm?id=399272.

Federal Highway Administration. 2006. *FHWA Construction Noise Handbook*. Final Report FHWA-HEP-06-015.

FTA. 2018. *Transit Noise and Vibration Impact Assessment Manual*. FTA Report No. 0123. Federal Transit Administration, John A. Volpe National Transportation System Center and Cross-Spectrum Acoustics, Inc.

Attachment A. Noise Fundamentals

Noise Fundamentals

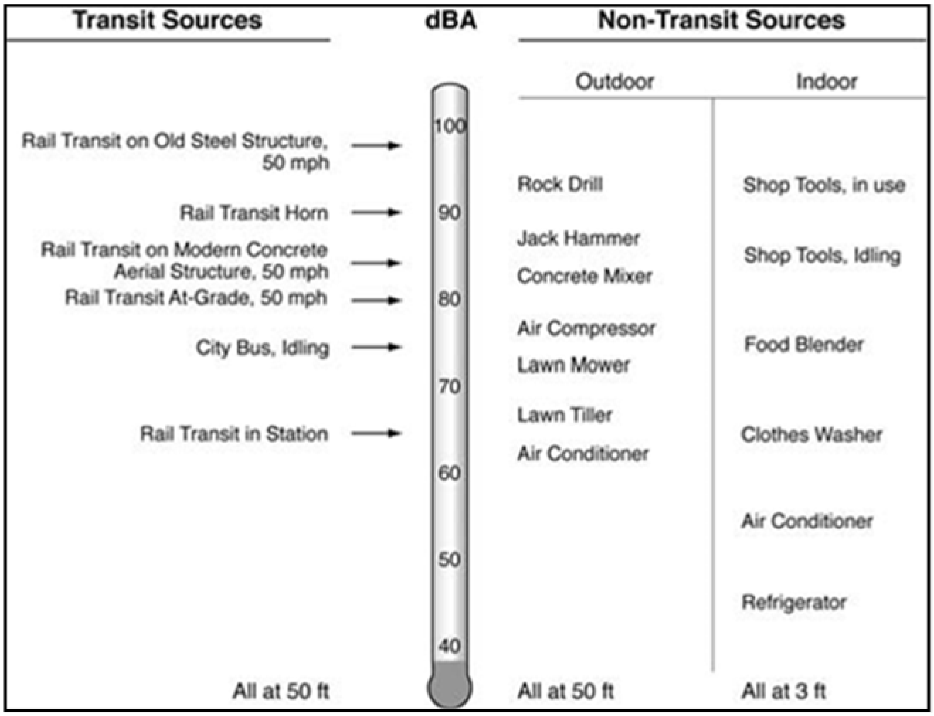
Sound is defined as small changes in air pressure above and below the standard atmospheric pressure, and noise is usually considered to be unwanted sound. The three parameters that define noise include:

- **Level.** The level of sound is the magnitude of air pressure change above and below atmospheric pressure and is expressed in decibels (dB). Typical sounds fall within a range between 0 dB (the approximate lower limit of human hearing) and 120 dB (the highest sound level generally experienced in the environment). A 3-dB change in sound level is perceived as a barely noticeable change outdoors, and a 10-dB change in sound level is perceived as a doubling (or halving) of loudness.
- **Frequency.** The frequency (pitch or tone) of sound is the rate of air pressure change and is expressed in cycles per second, or Hertz (Hz). Human ears can detect a wide range of frequencies from around 20 Hz to 20,000 Hz; however, human hearing is not as sensitive at high and low frequencies, and the A-weighting system, which measures what humans hear in a more meaningful way by reducing the sound levels of higher and lower frequency sounds, is used to provide a measure (dBA) that correlates with human response to noise. **Figure A-1** shows typical maximum A-weighted sound levels for transit and non-transit sources. The A-weighted sound level has been widely adopted by acousticians as the most appropriate descriptor for environmental noise.
- **Time Pattern.** Because environmental noise is constantly changing, it is common to condense all this information into a single number, called the “equivalent” sound level (Leq). The Leq represents the changing sound level over a period of time, typically 1 hour or 24 hours in transit noise assessments. For assessing the noise impact of rail projects at residential land uses, the day-night sound level (Ldn) is the noise descriptor commonly used, and it has been adopted by many agencies as the best way to describe how people respond to noise in their environment. Ldn is a 24-hour cumulative A weighted noise level that includes all noises that occur during a day, with a 10-dB penalty for nighttime noise (10 p.m. to 7 a.m.). This nighttime penalty means that any noise events at night are equivalent to 10 similar events during the day.

Typical Ldn values for various transit operations and environments are shown on **Figure A-2**.

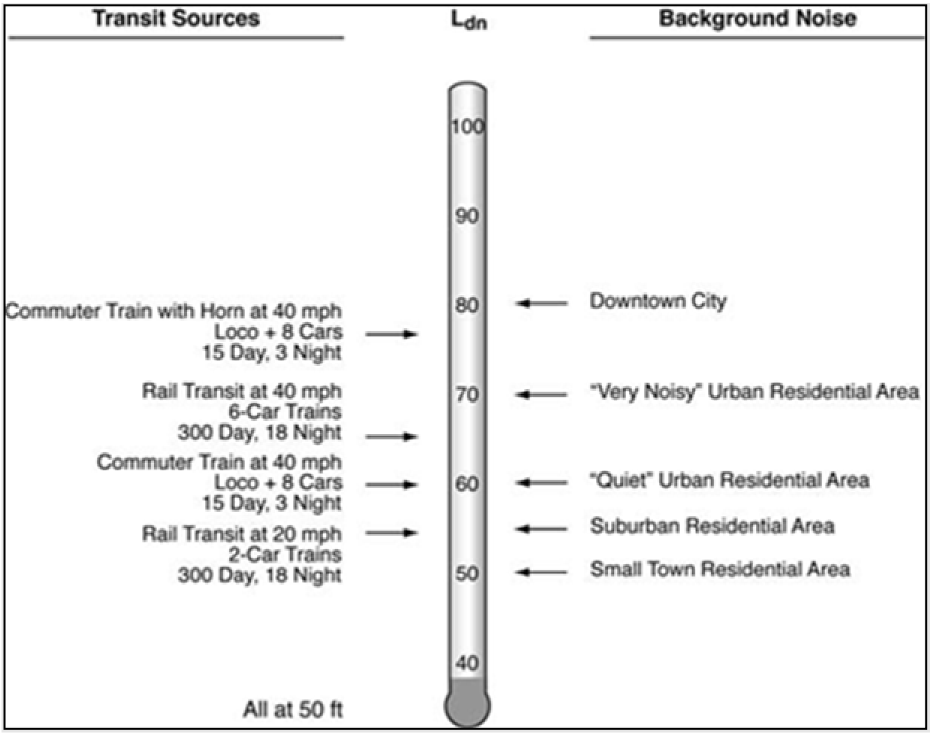
In addition to the Leq and Ldn, there are other metrics used to describe noise. The loudest 1 second of noise over a measurement period, or maximum A-weighted sound level (Lmax), is used in many local and state ordinances for noise emitted from private land uses and for construction noise impact evaluations. Environmental noise can also be viewed on a statistical basis using percentile sound levels (Ln), which refers to the sound level exceeded n-percent of the time.

Figure A-1: Typical A-Weighted Sound Levels



Source: FTA 2018.

Figure A-2: Typical Ldn Noise Exposure Levels



Source: FTA 2018.

Attachment B. Vibration Fundamentals

Vibration Fundamentals

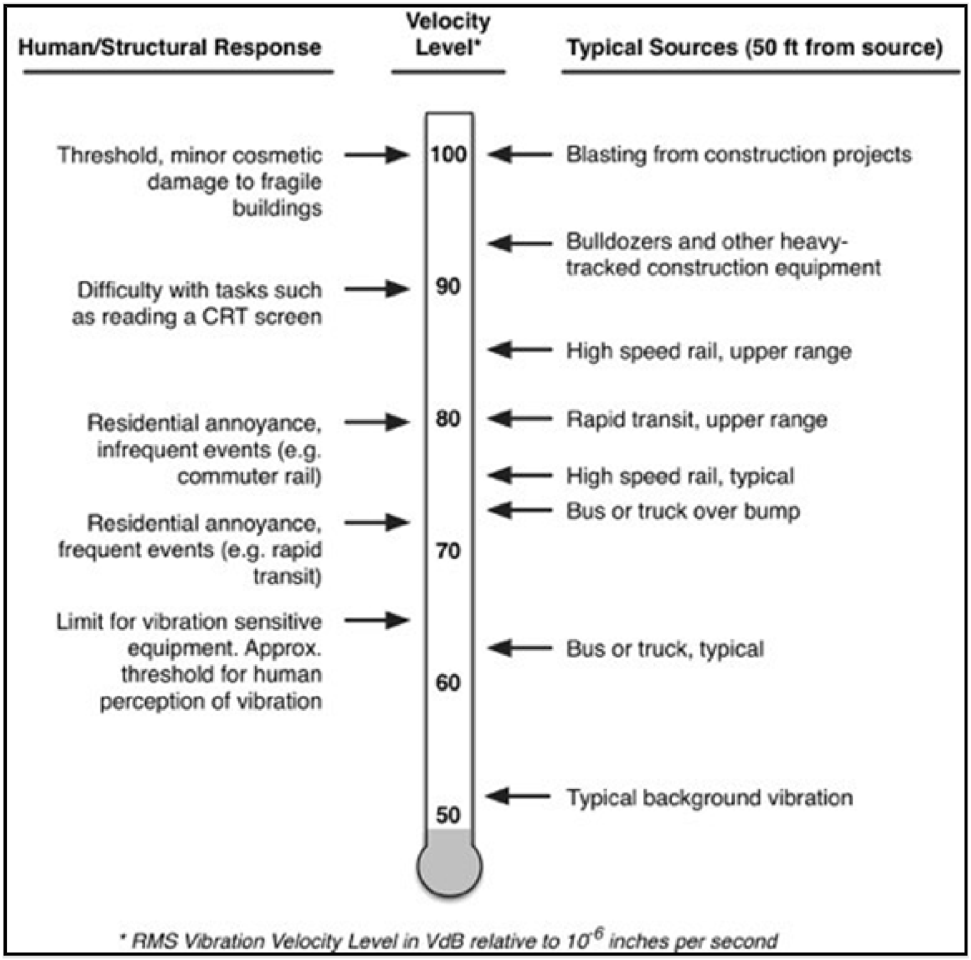
Ground-borne vibration from trains refers to the fluctuating or oscillatory motion experienced by persons on the ground and in buildings near railroad tracks. Vibration can be described in terms of displacement, velocity, or acceleration. Displacement is the simplest descriptor to perceive. For a vibrating floor, the displacement is simply the distance that a point on the floor moves away from its static position. Velocity represents the instantaneous speed of the floor movement, and acceleration is the rate of change of the speed. Although displacement may be simpler to perceive, the response of humans, buildings, and equipment to vibration is more accurately described using velocity or acceleration.

Two methods are used for quantifying vibration. The peak particle velocity (PPV) is defined as the maximum instantaneous positive or negative peak of the vibration signal. PPV often is used in monitoring of blasting vibration, since it is related to the stresses experienced by buildings. Although PPV is appropriate for evaluating the potential for building damage, it is not suitable for evaluating human response. It takes some time for the human body to respond to vibration impulses. In a sense, the human body responds to an average of the vibration amplitude. Because the net average of a vibration signal is zero, the root mean square amplitude is used to describe the “smoothed” vibration amplitude.

PPV and root mean square velocities are normally described in inches per second. Decibel notation is in common use for vibration and has been adopted by the FTA in their guidance. Decibel notation compresses the range of numbers required to describe vibration. Vibration levels in this report are referenced to 1 x 10-6 inches per second. The abbreviation “VdB” is used in this document for vibration decibels to reduce the potential for confusion with sound decibels. Common vibration sources and human and structural response to ground-borne vibration are illustrated in **Figure B-1**. Typical vibration levels can range from below 50 VdB to 100 VdB (0.000316 inch/second to 0.1 inch/second). The human threshold of perception is approximately 65 VdB.

Ground-borne vibration can lead to ground-borne noise, which is a low-volume, low-frequency rumble inside buildings that occurs when ground vibration causes the flexible walls of the buildings to resonate and generate noise. Ground-borne noise is normally not a consideration when trains are elevated or at grade. In these situations, the airborne noise usually overwhelms ground-borne noise, so the airborne noise level is the major consideration. However, ground-borne noise becomes an important consideration where there are sections of the alignment in a tunnel or where sensitive interior spaces are well isolated from the airborne noise. In these situations, the airborne noise path is impeded and ground-borne noise dominates inside buildings. In rare situations, ground-borne noise may also need to be considered where the airborne noise from a project is substantially mitigated by a sound wall.

Figure B-1: Typical Levels of Ground-Borne Vibration



Source: FTA 2018.

Attachment C. Noise Measurement Location Photographs

Figure C-1: Long-Term Noise Measurement Location LT-1, 3200 Guadalupe Street

Figure C-2: Long-Term Noise Measurement Location LT-2, Villas on Gudalupe – 2810 Hemphill Park

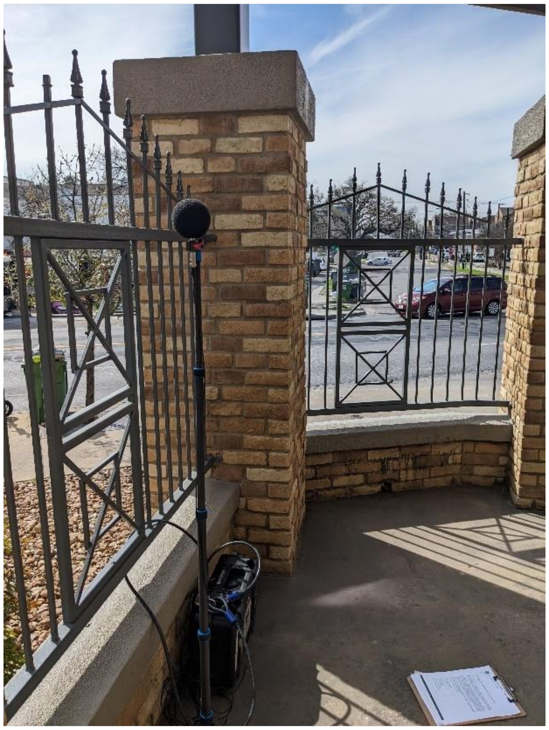


Figure C-3: Long-Term Noise Measurement Location LT-3, AMLI Downtown – 201 Lavaca Street

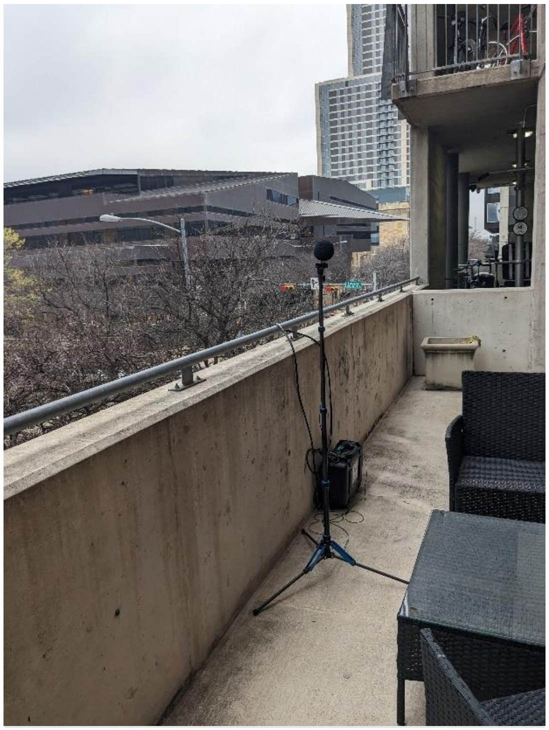


Figure C-4: Long-Term Noise Measurement Location LT-5, Muse at SoCo – 1007 South Congress Avenue

Figure C-5: Long-Term Noise Measurement Location LT-6, 107 W Monroe Street

Figure C-6: Long-Term Noise Measurement Location LT-7, 2107 Eva Street

Figure C-7: Long-Term Noise Measurement Location LT-8, 807 Edgecliff Terrace

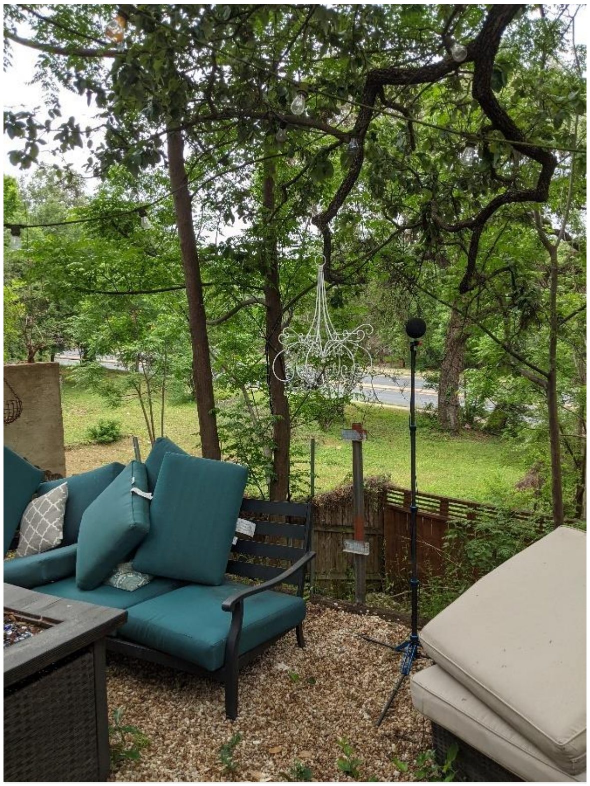


Figure C-8: Long-Term Noise Measurement Location LT-9, AMLI South Store

Figure C-9: Long-Term Noise Measurement Location LT-10, Tempo at Riverside

Figure C-10: Long-Term Noise Measurement Location LT-11, Austin Fire Station 22

Figure C-11: Long-Term Noise Measurement Location LT-12, Riverside Nursing and Rehab

Figure C-12: Long-Term Noise Measurement Location LT-13, Home2Suites – 1705 Airport Commerce Dr

Figure C-13: Long-Term Noise Measurement Location LT-14, 1340 Airport Commerce Drive

Figure C-14: Short-Term Noise Measurement Location ST-1, Guadalupe Street and W Dean Keaton Street

Figure C-15: Short-Term Noise Measurement Location ST-2, Guadalupe Street and 22nd Street

Figure C-16: Short-Term Noise Measurement Location ST-3, 10th Street and Guadalupe Street

Figure C-17: Short-Term Noise Measurement Location ST-4, 1503 South Congress Avenue

Figure C-18: Short-Term Noise Measurement Location ST-5, 500 Sunny Lane

Figure C-19: Short-Term Noise Measurement Location ST-6, Austin Emergency Center

Figure C-20: Short-Term Noise Measurement Location ST-7, 222 East Riverside Drive

Attachment D. Noise Measurement Data

Figure D-1: Long-Term Noise Measurement Location LT-2, Villas on Gudalupe – 2810 Hemphill Park

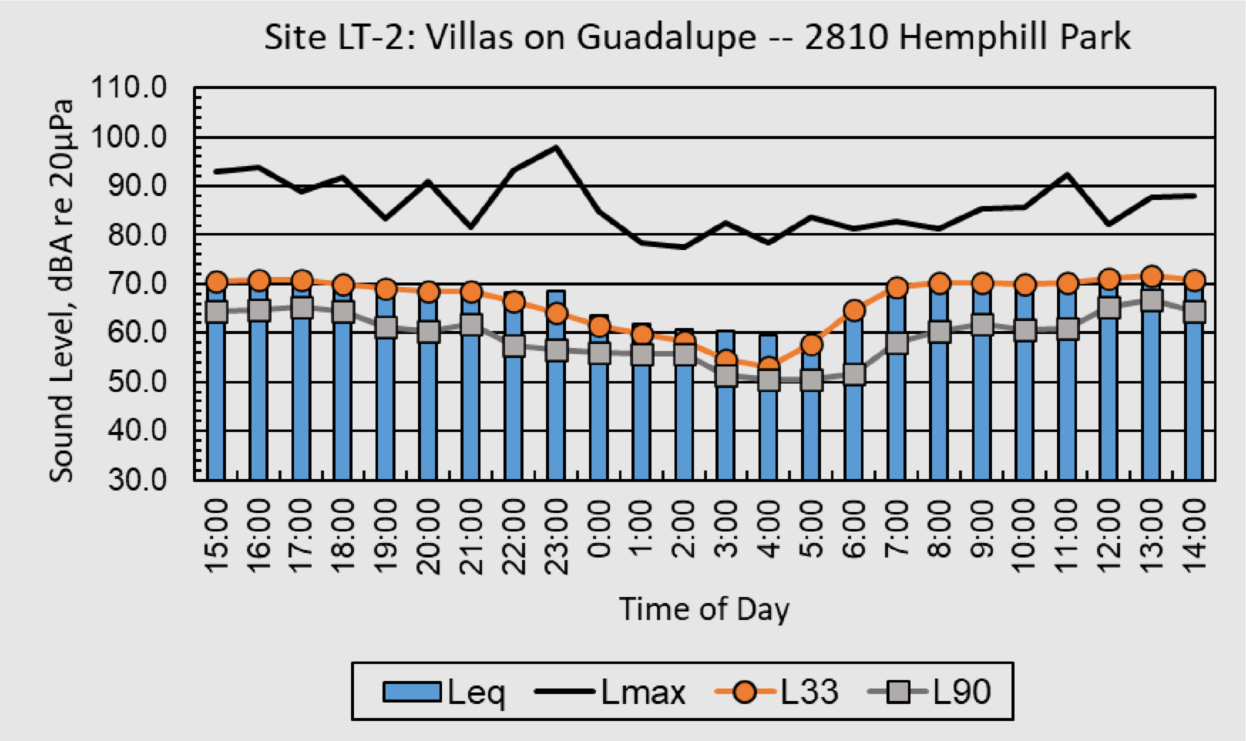


Figure D-2: Long-Term Noise Measurement Location LT-3, AMLI Downtown – 201 Lavaca Street

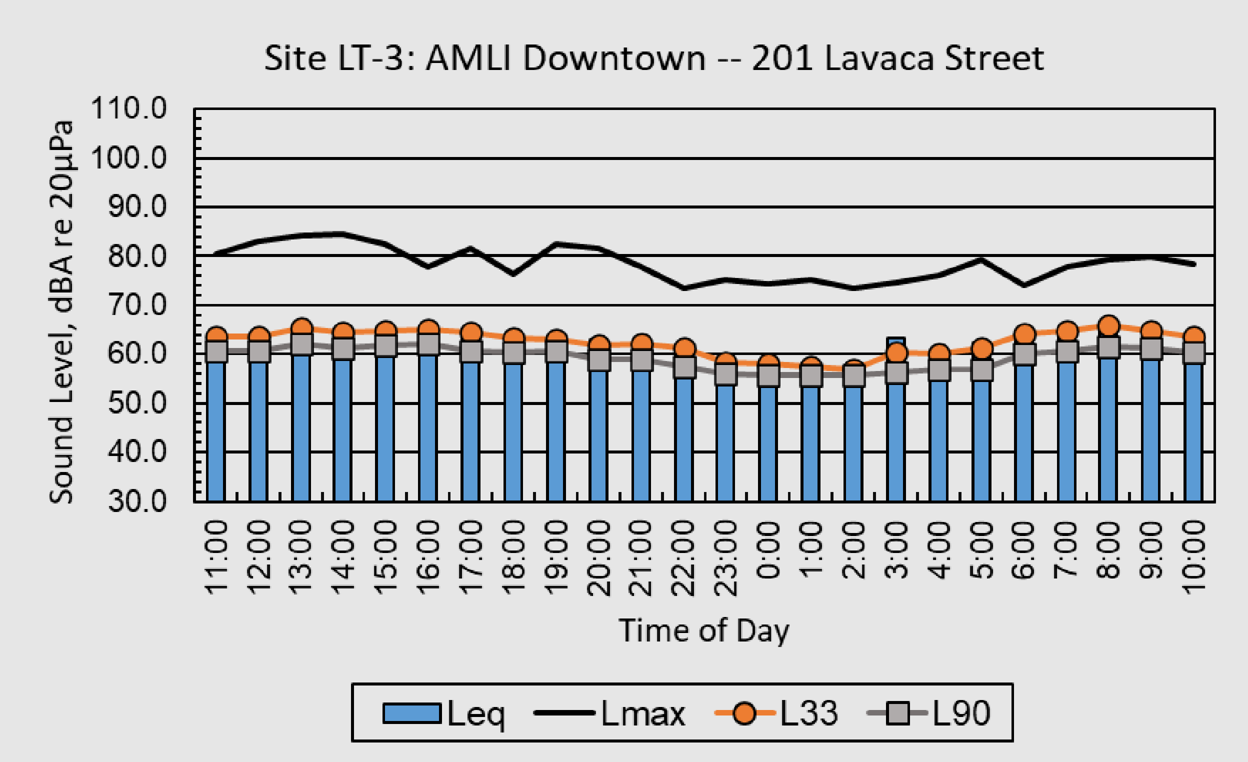


Figure D-3 Long-Term Noise Measurement Location LT-5, Muse at SoCo – 1007 South Congress Avenue

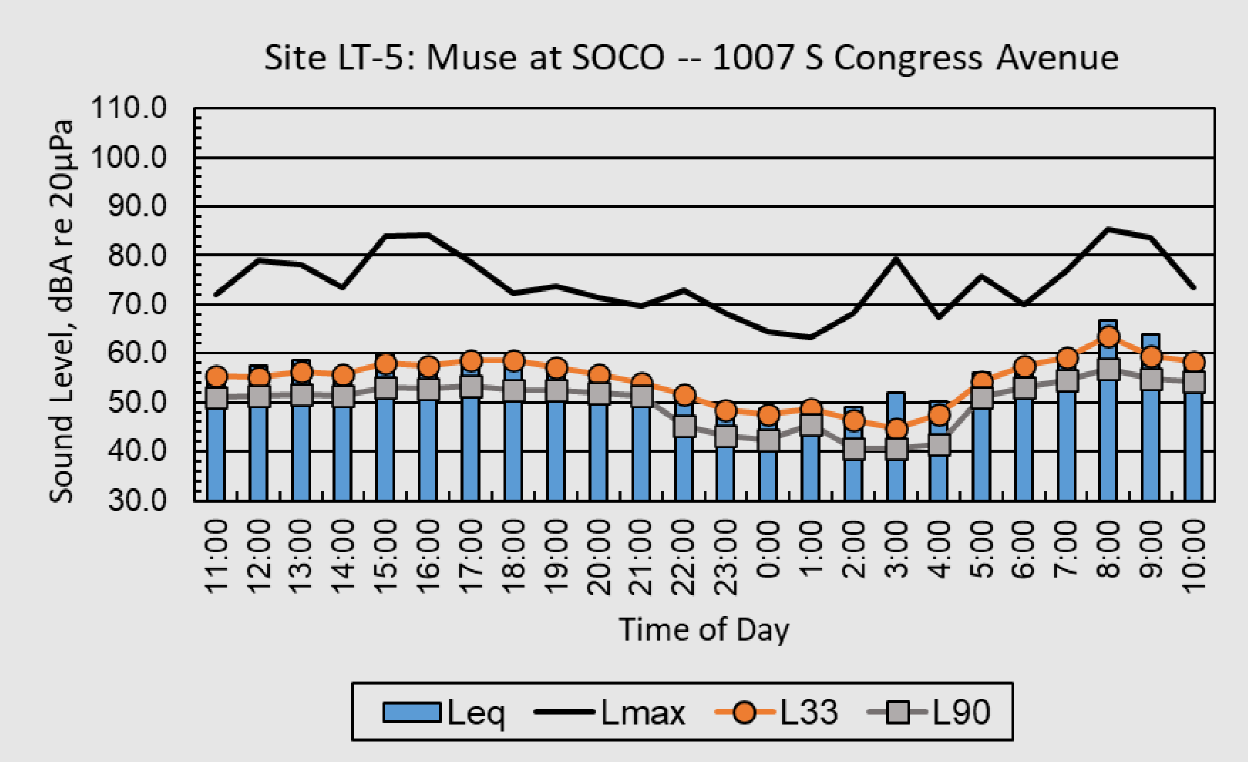


Figure D-4: Long-Term Noise Measurement Location LT-6, 107 W Monroe Street

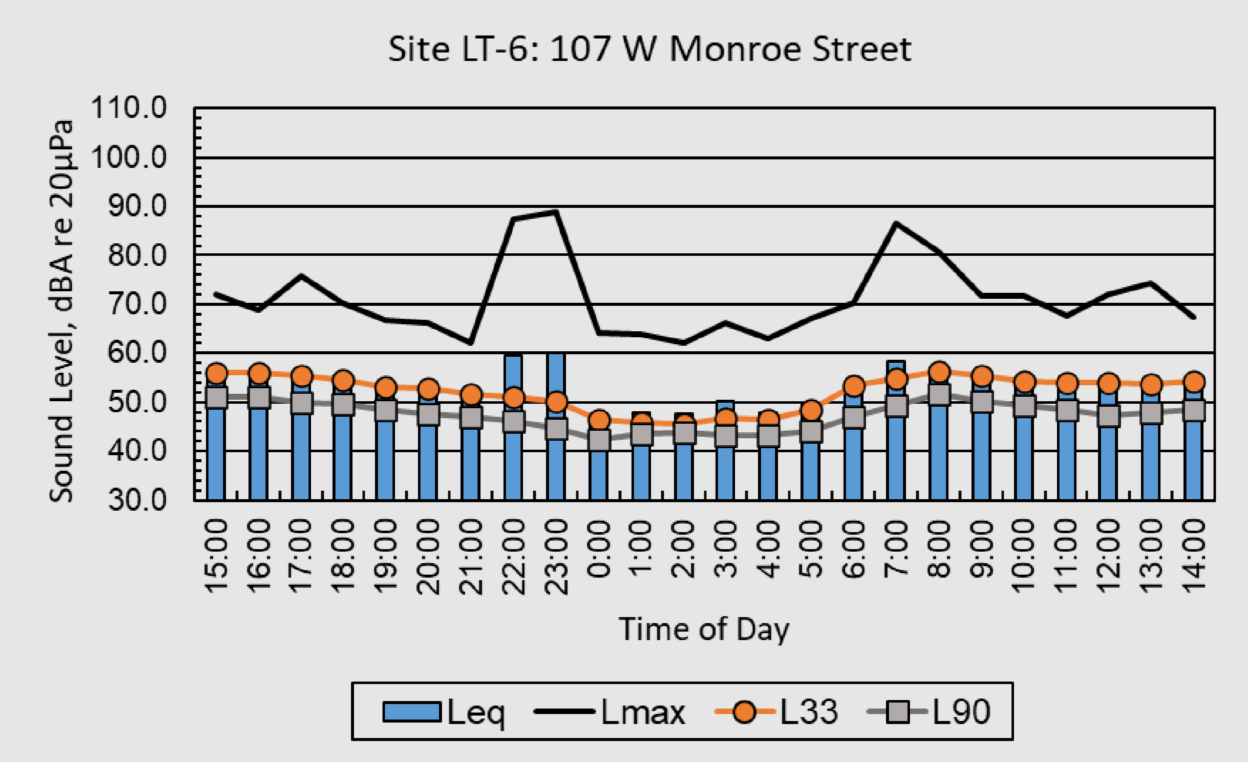


Figure D-5: Long-Term Noise Measurement Location LT-7, 2107 Eva Street

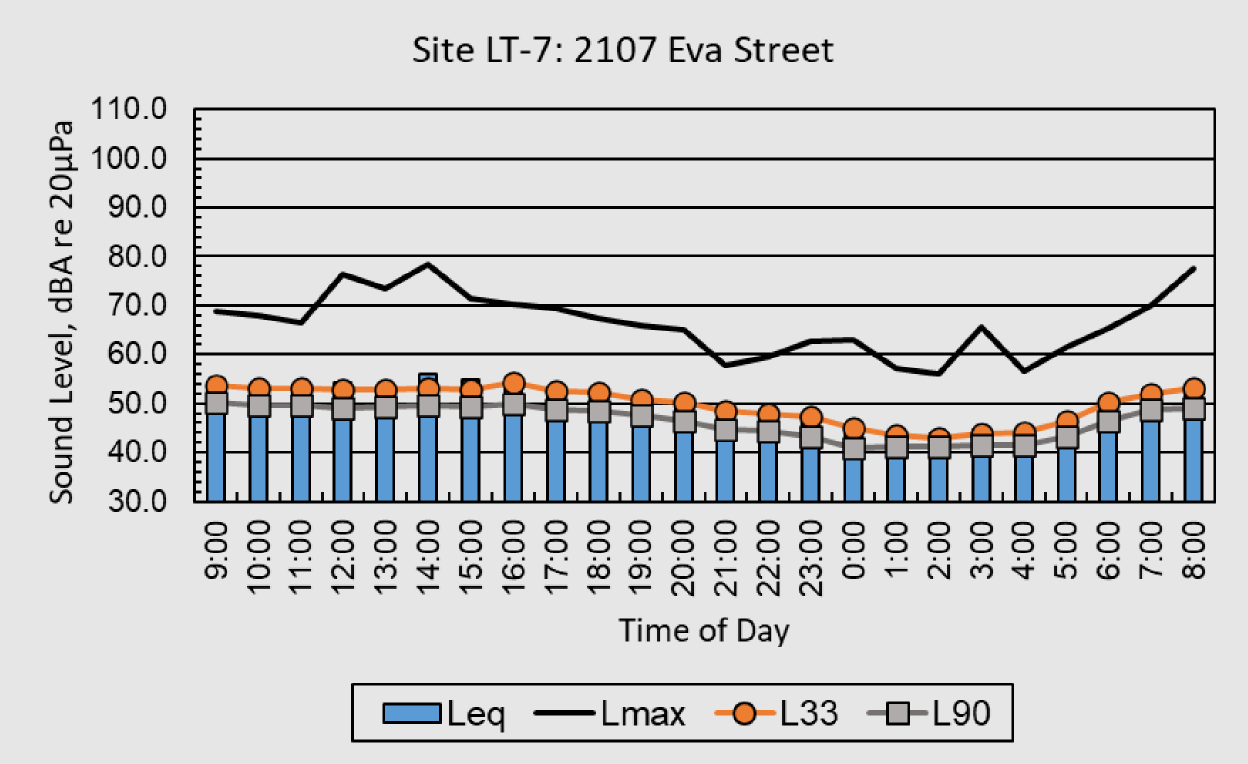


Figure D-6: Long-Term Noise Measurement Location LT-8, 807 Edgecliff Terrace

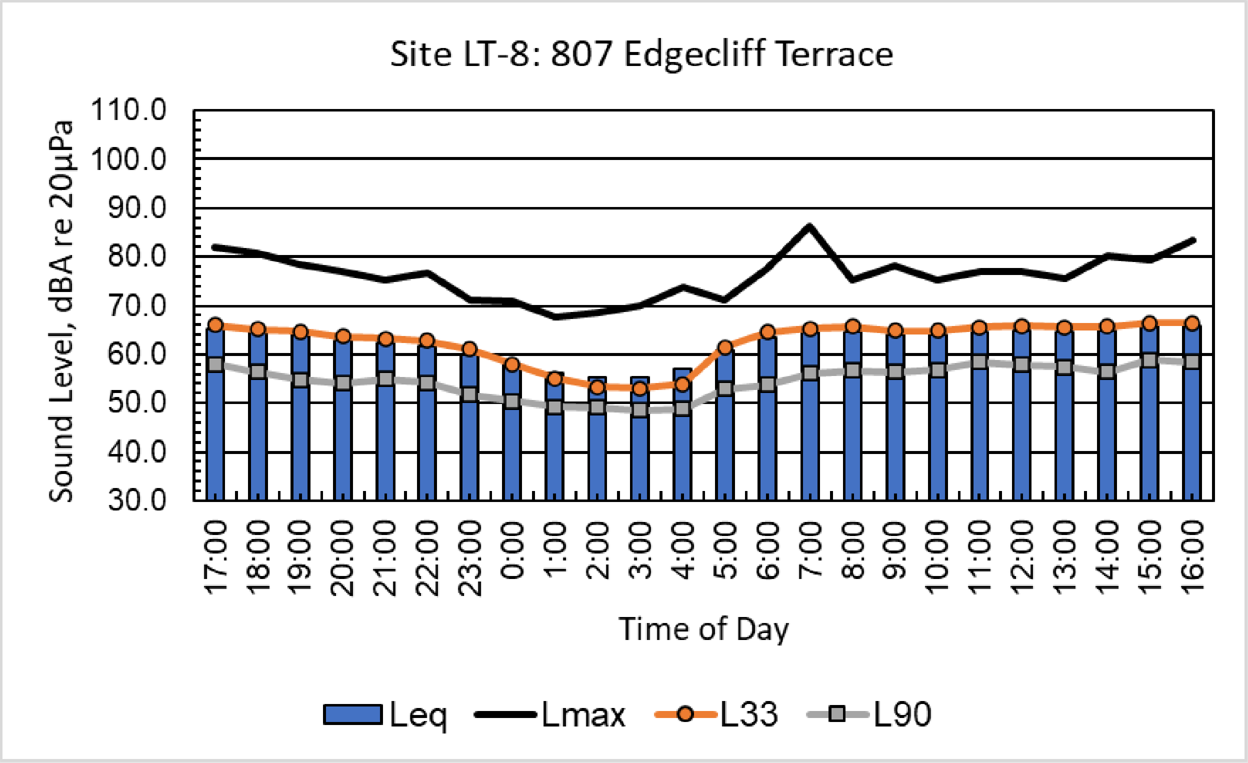


Figure D-7: Long-Term Noise Measurement Location LT-9, AMLI South Store

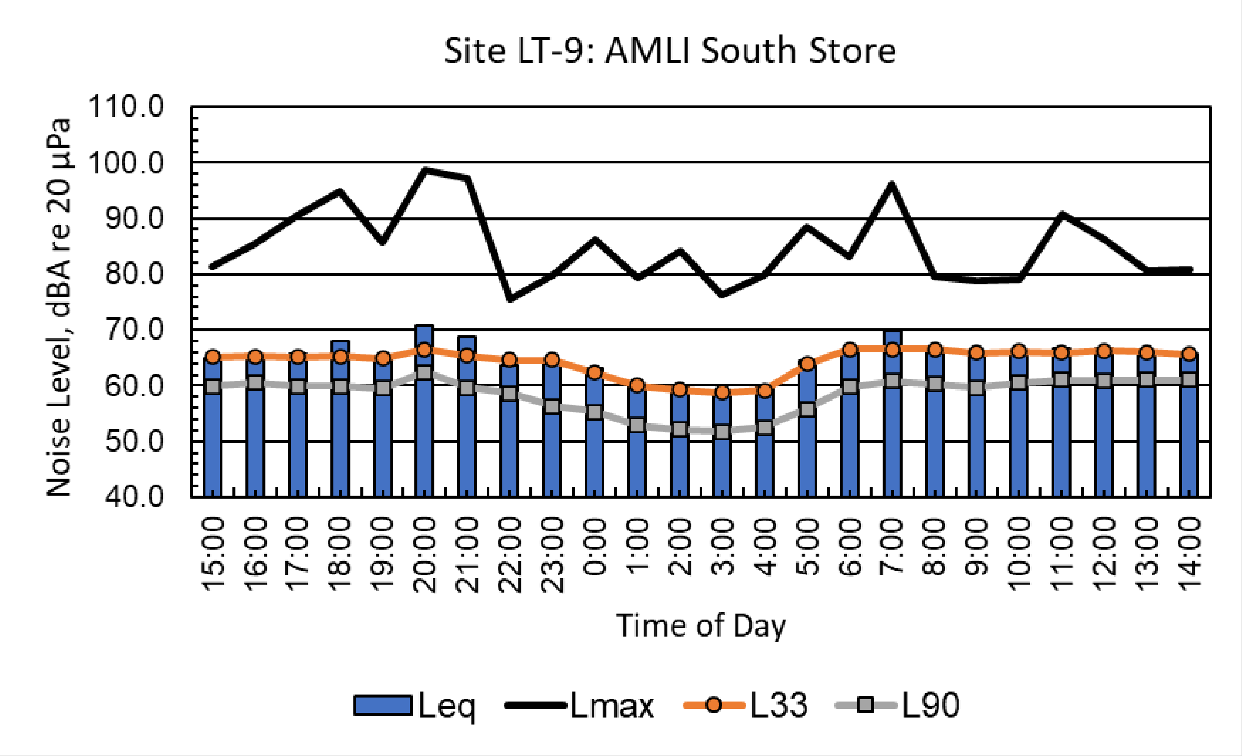


Figure D-8: Long-Term Noise Measurement Location LT-10, Tempo at Riverside

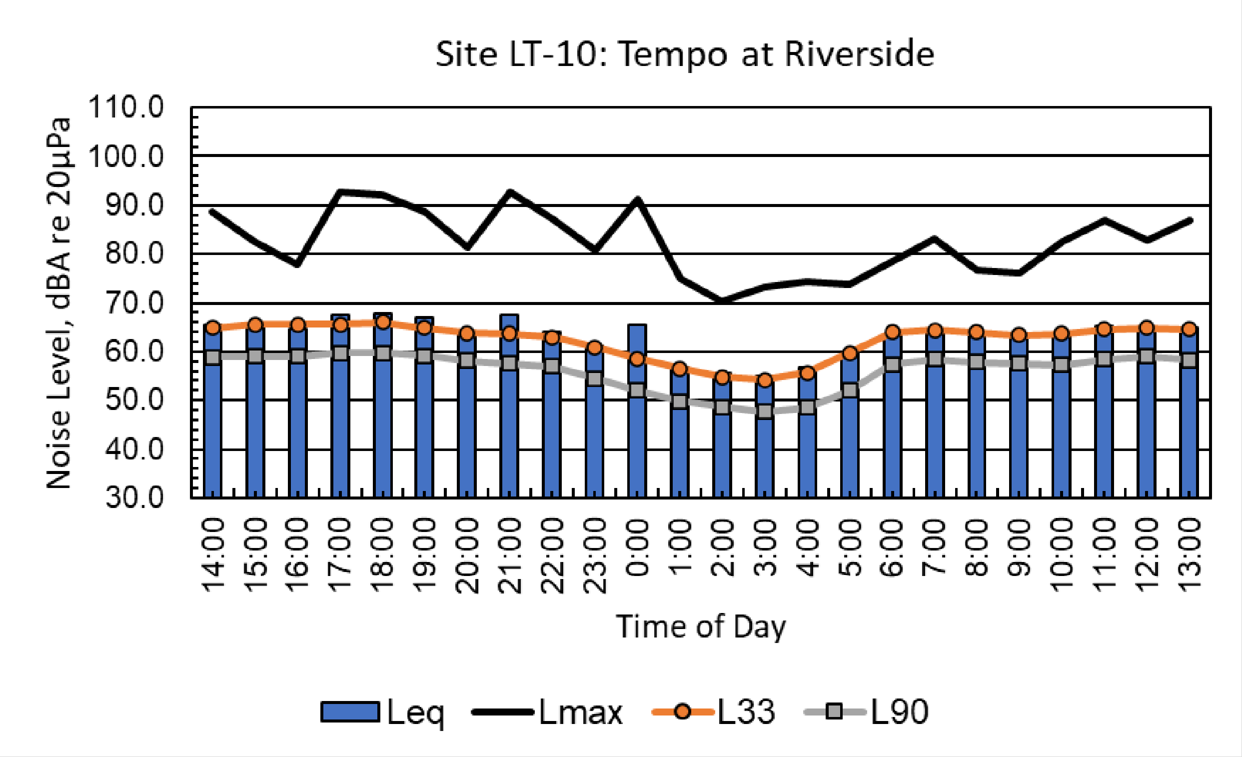


Figure D-9: Long-Term Noise Measurement Location LT-11, Austin Fire Station 22

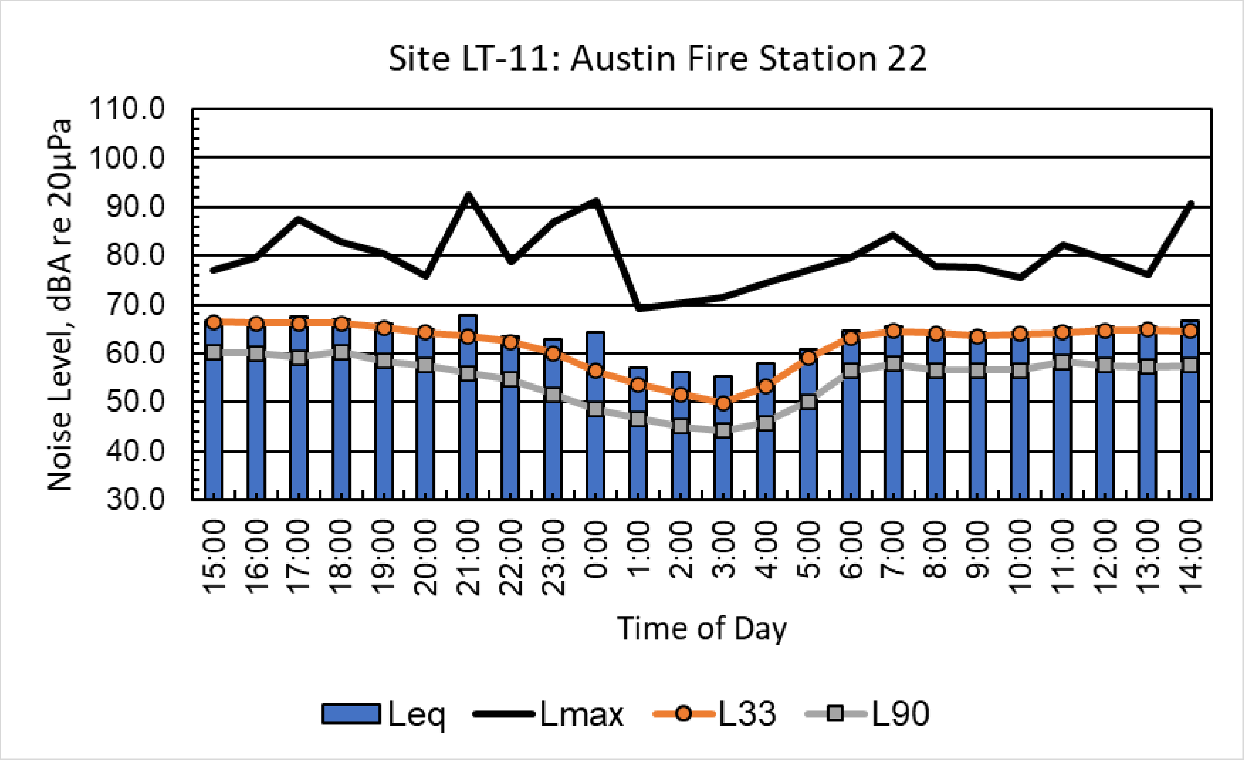


Figure D-10: Long-Term Noise Measurement Location LT-12, Riverside Nursing and Rehab

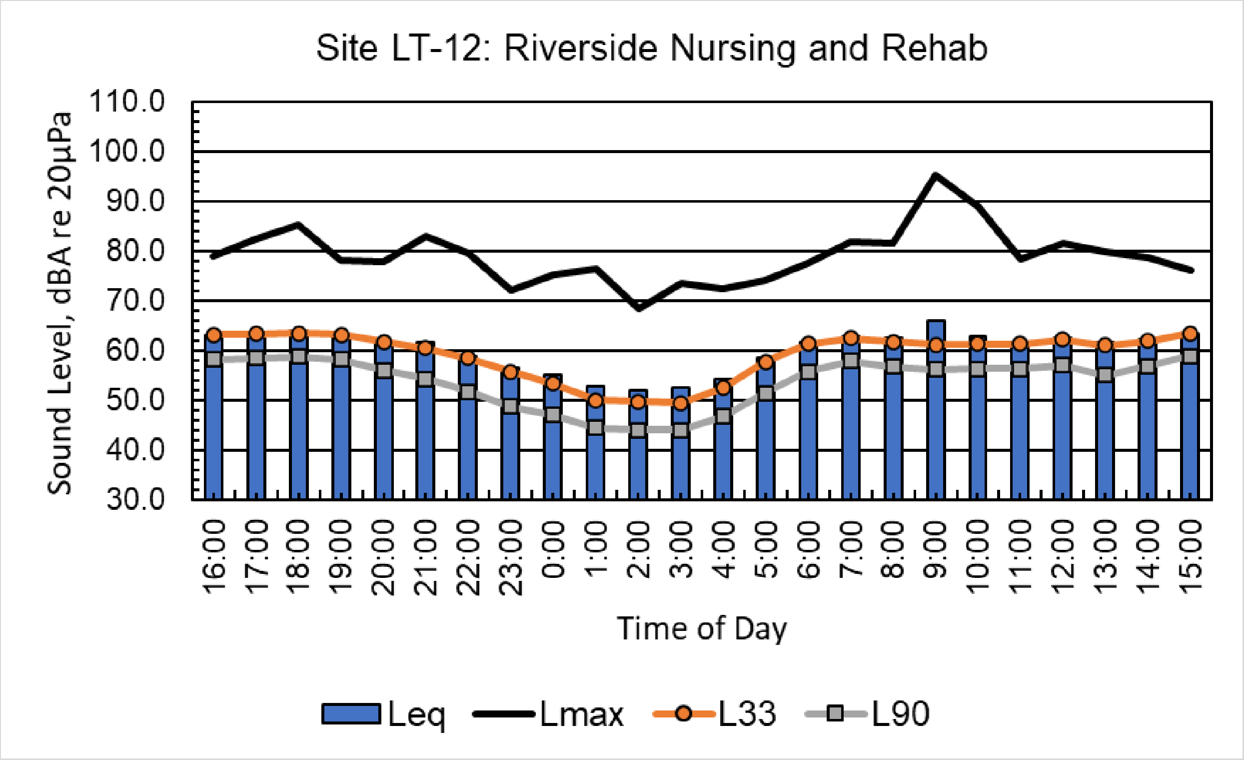
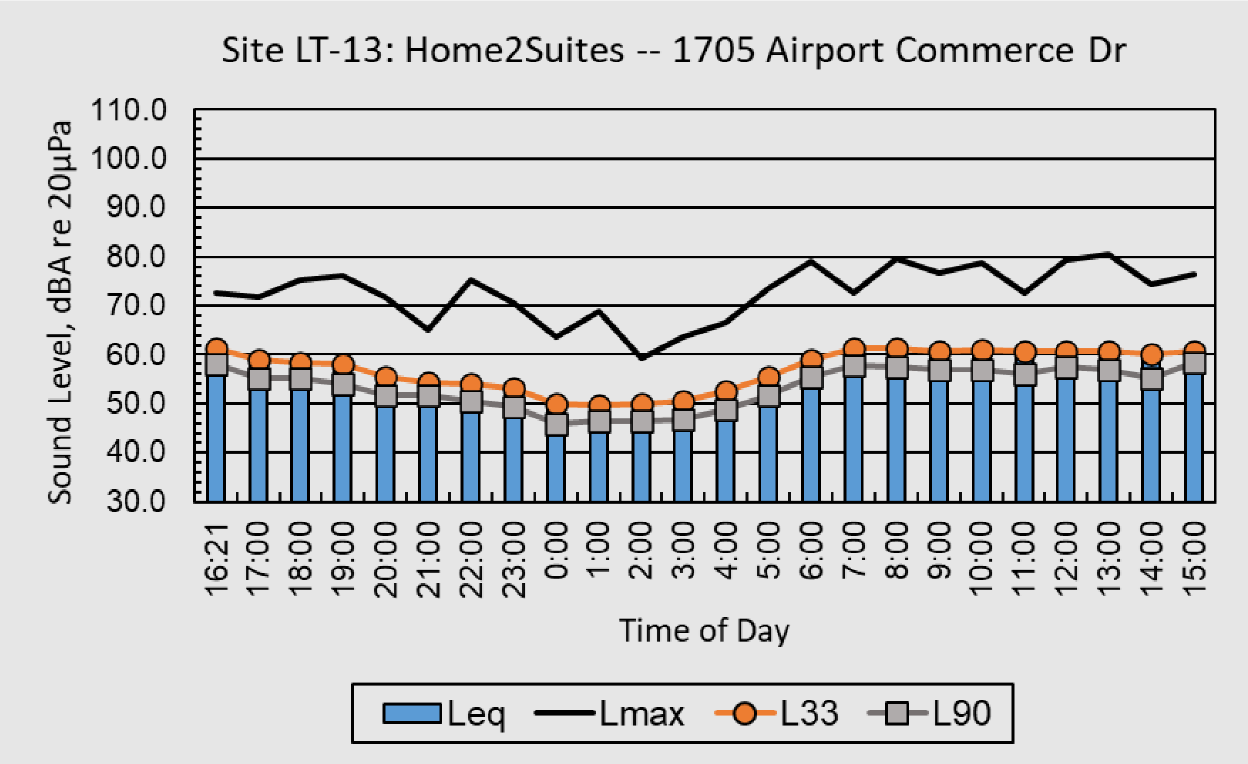


Figure D-11: Long-Term Noise Measurement Location LT-13, Home 2 Suites – 1705 Airport Commerce Drive



Attachment E. Vibration Measurement Location Photographs

Figure E-1: Vibration Propagation Mitigation Location VP-1, 32nd Street and Guadalupe Street

Figure E-2: Vibration Propagation Mitigation Location VP-2, 25th Street and Guadalupe Street

Figure E-3: Vibration Propagation Mitigation Location VP-3, 10th Street and Guadalupe Street

Figure E-4: Vibration Propagation Mitigation Location VP-4, Willow Street (Park)

Figure E-5: Vibration Propagation Mitigation Location VP-5, 222 East Riverside Drive

Figure E-6: Vibration Propagation Mitigation Location VP-6, Monroe Street and South Congress Avenue

Figure E-7: Vibration Propagation Mitigation Location VP-7, Lindell Avenue and Bartlett Street

Figure E-8: Vibration Propagation Mitigation Location VP-8, Norwood Tract in Town Lake Metropolitan Park

Figure E-9: Vibration Propagation Mitigation Location VP-9, East Riverside Drive and Crossing Place

Figure E-10: Vibration Propagation Mitigation Location VP-10, East Riverside Drive and Clubview Avenue

Figure E-11: Vibration Propagation Mitigation Location VP-11, Hampton Inn and Suites Austin-Airport Hotel

Attachment F. Vibration Measurement Data

Table F-1: Vibration Propagation Mitigation Location VP-1, 32nd Street and Guadalupe Street 1/3-Octave Band Transfer Mobility Coefficients

Coeff.	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz	200 Hz
A	39.8	24.3	29.7	44.8	95.7	115.4	119.7	115.0	116.0	109.8	109.5	107.5	93.1	96.3	71.3	76.4
B	-17.1	-9.1	-10.5	-15.4	-39.9	-47.2	-48.6	-47.2	-49.9	-47.6	-49.9	-51.1	-44.8	-50.4	-39.7	-43.8
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

$$LSTM = A + B * \log(dist) + C * \log(dist)^2$$

Figure F-1: Vibration Propagation Mitigation Location VP-1, 32nd Street and Guadalupe Street

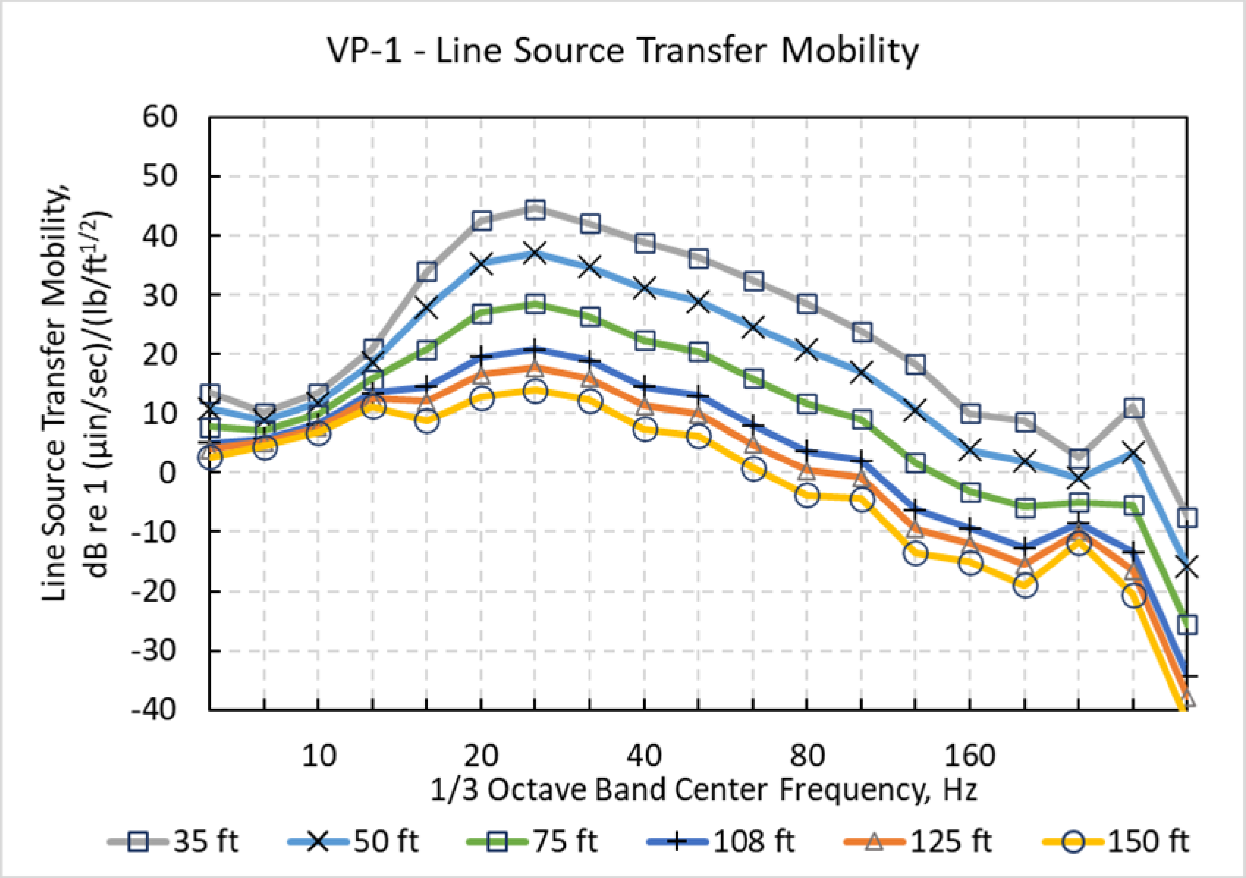


Table F-2: Vibration Propagation Mitigation Location VP-2, 25th Street and Guadalupe Street 1/3-Octave Band Transfer Mobility Coefficients

Coeff.	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz	200 Hz
A	15.7	18.4	22.9	14.4	34.1	49.9	49.3	56.2	79.7	104.0	118.3	141.6	113.2	74.0	83.2	59.5
B	-2.7	-6.6	-6.9	-2.1	-6.4	-12.1	-11.7	-15.0	-27.5	-40.9	-50.7	-65.6	-54.5	-36.5	-42.8	-31.6
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

$$LSTM = A + B * \log(dist) + C * \log{(dist)}^2$$

Figure F-2: Vibration Propagation Mitigation Location VP-2, 25th Street and Guadalupe Street

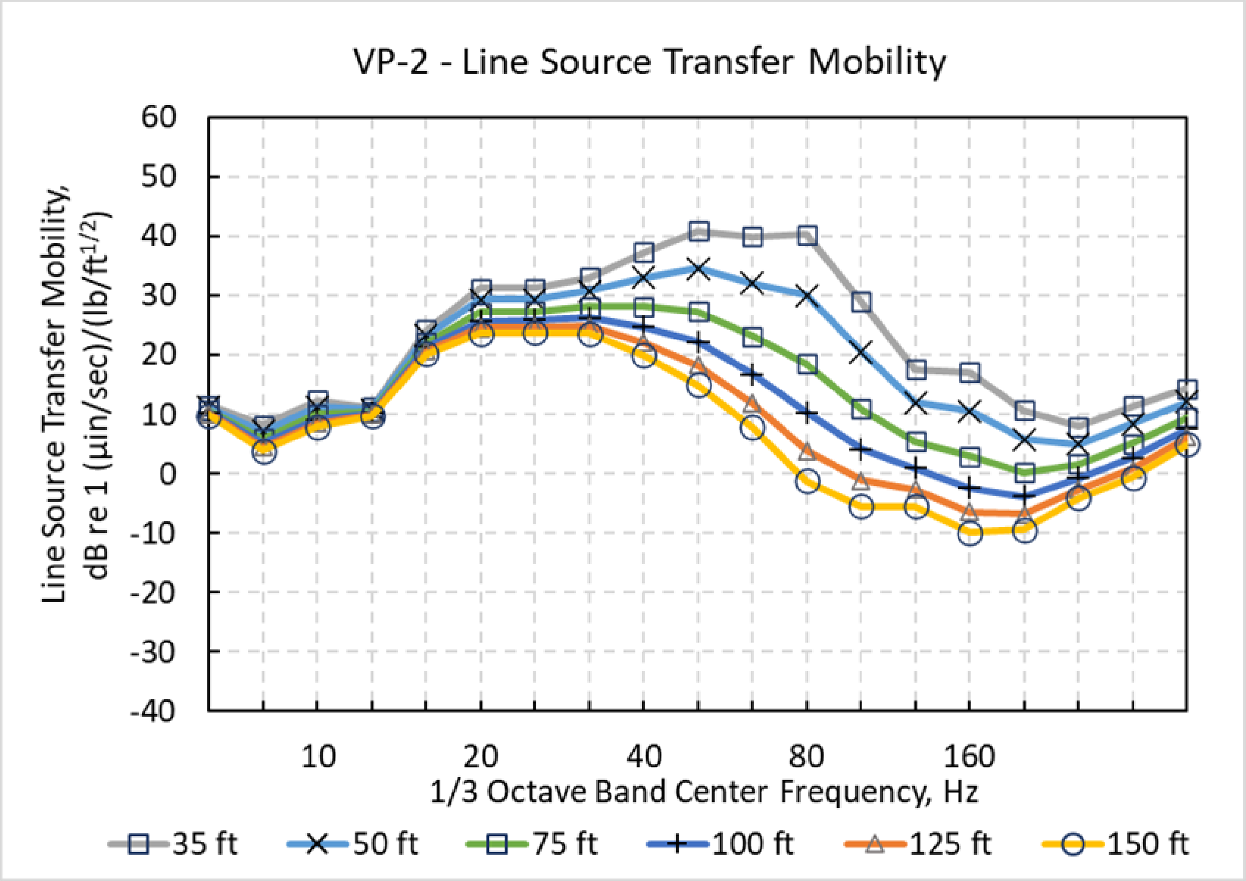


Table F-3: Vibration Propagation Mitigation Location VP-3, 10th Street and Guadalupe Street 1/3-Octave Band Transfer Mobility Coefficients

Coeff.	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz	200 Hz
A	12.0	14.2	14.2	12.1	11.8	39.8	40.9	68.0	99.9	85.8	76.9	68.2	76.5	64.5	56.1	58.3
B	-0.6	-1.5	-2.0	-2.2	-3.3	-16.2	-10.8	-22.3	-41.8	-35.0	-30.8	-25.6	-31.8	-29.1	-29.2	-32.8
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

$$LSTM = A + B * \log(dist) + C * \log(dist)^2$$

Figure F-3: Vibration Propagation Mitigation Location VP-3, 10th Street and Guadalupe Street

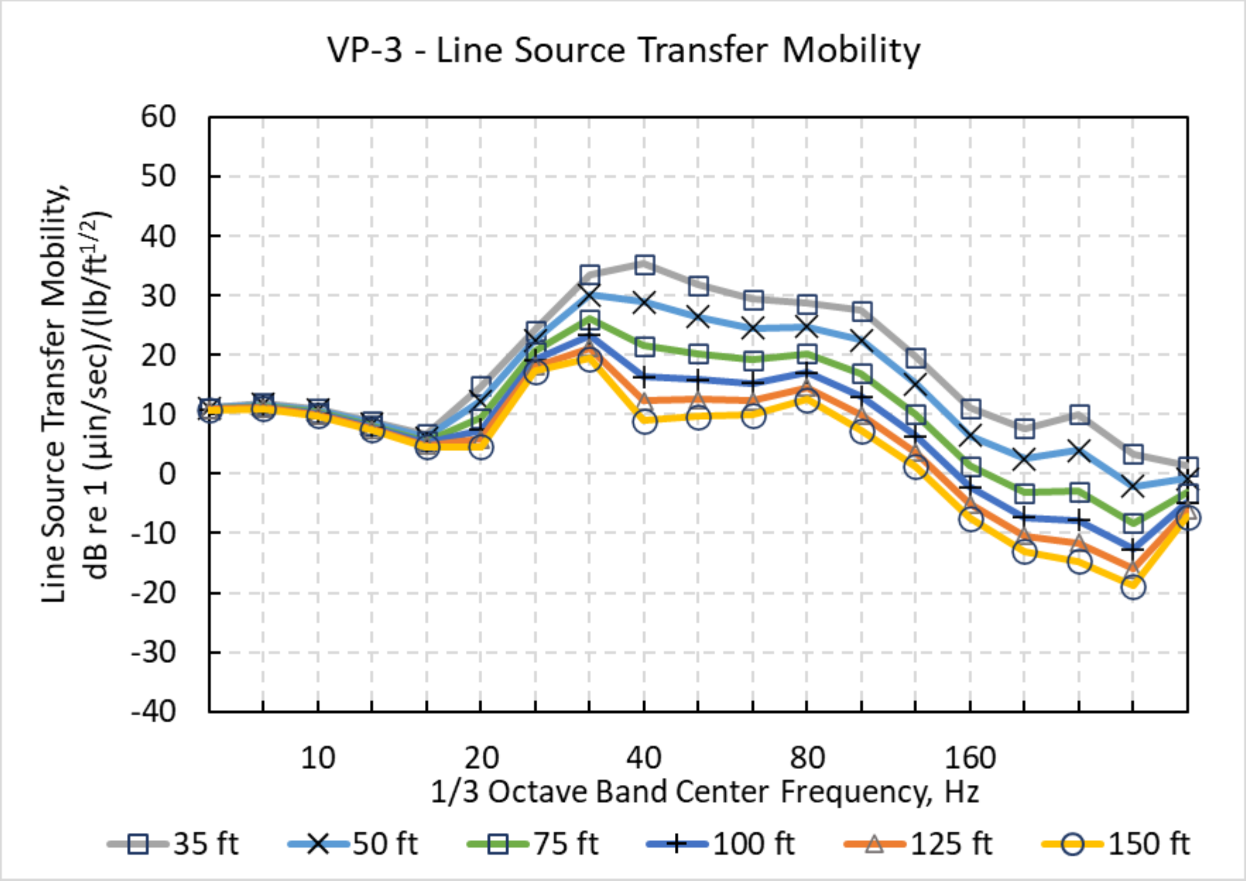


Table F-4: Vibration Propagation Mitigation Location VP-4, Willow Street (Park) 1/3-Octave Band Transfer Mobility Coefficients

Coeff.	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz	200 Hz
A	35.9	36.1	32.4	28.9	36.9	46.9	54.7	69.0	86.1	85.2	84.4	90.4	89.8	109.9	111.0	90.4
B	-8.4	-9.9	-10.5	-9.6	-13.3	-14.7	-16.9	-24.3	-34.4	-35.4	-35.1	-40.0	-42.0	-55.5	-59.3	-48.7
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

$$LSTM = A + B * \log(dist) + C * \log(dist)^2$$

Figure F-4: Vibration Propagation Mitigation Location VP-4, Willow Street (Park)

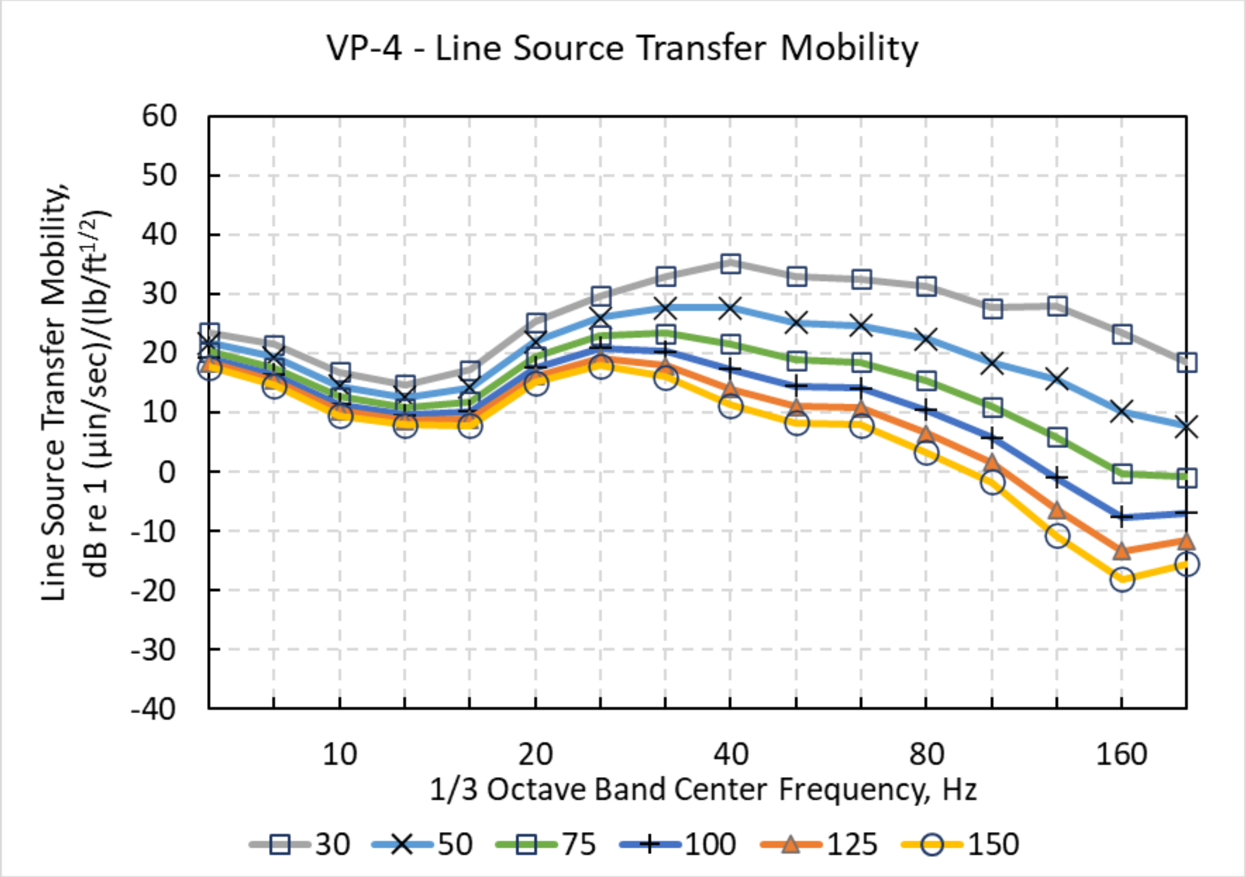


Table F-5: Vibration Propagation Mitigation Location VP-5, 222 East Riverside Drive 1/3-Octave Band Transfer Mobility Coefficients

Coeff.	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz	200 Hz
A	-86.2	-74.2	18.7	-4.4	-65.1	-87.9	-114.5	-92.1	-119.2	-126.6	-163.3	-94.4	-28.6	136.7	133.3	106.7
B	125.6	111.4	4.2	40.7	111.9	137.9	168.2	145.7	186.3	203.4	250.9	175.7	110.8	-70.5	-71.5	-56.1
C	-36.3	-33.5	-4.2	-15.8	-36.0	-42.9	-50.8	-44.6	-57.4	-64.2	-79.8	-60.8	-46.9	0.0	0.0	0.0

$$LSTM = A + B * \log(dist) + C * \log(dist)^2$$

Figure F-5: Vibration Propagation Mitigation Location VP-5, 222 East Riverside Drive

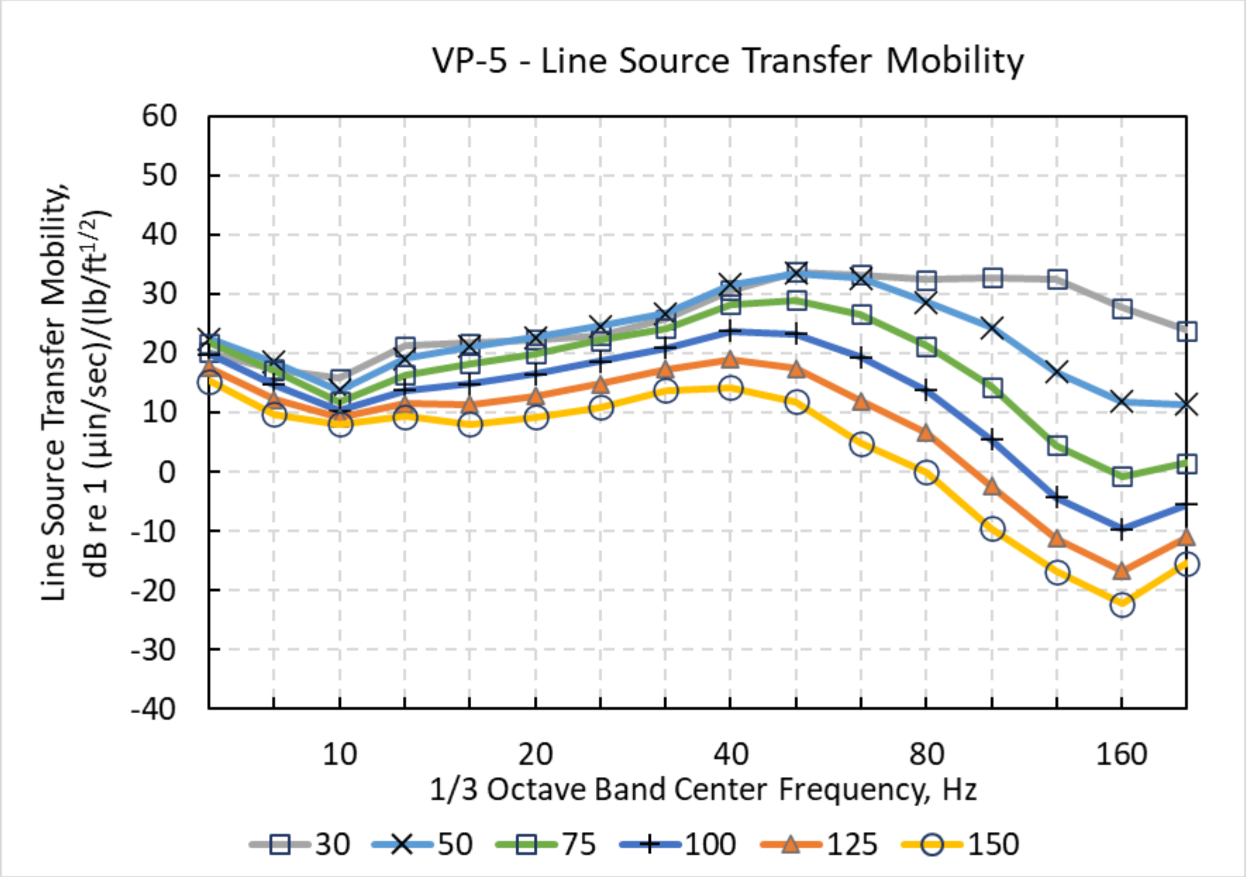


Table F-6: Vibration Propagation Mitigation Location VP-6, Monroe Street and South Congress Avenue 1/3-Octave Band Transfer Mobility Coefficients

Coeff.	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz	200 Hz
A	62.5	55.8	56.1	51.5	50.1	47.9	43.2	58.8	73.7	97.9	107.3	90.6	93.5	100.0	106.6	122.2
B	-28.8	-25.7	-27.0	-25.4	-23.8	-20.9	-12.3	-17.0	-22.8	-35.2	-41.4	-36.0	-39.7	-44.8	-51.1	-59.7
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

$$LSTM = A + B * \log(dist) + C * \log(dist)^2$$

Figure F-6: Vibration Propagation Mitigation Location VP-6, Monroe Street and South Congress Avenue

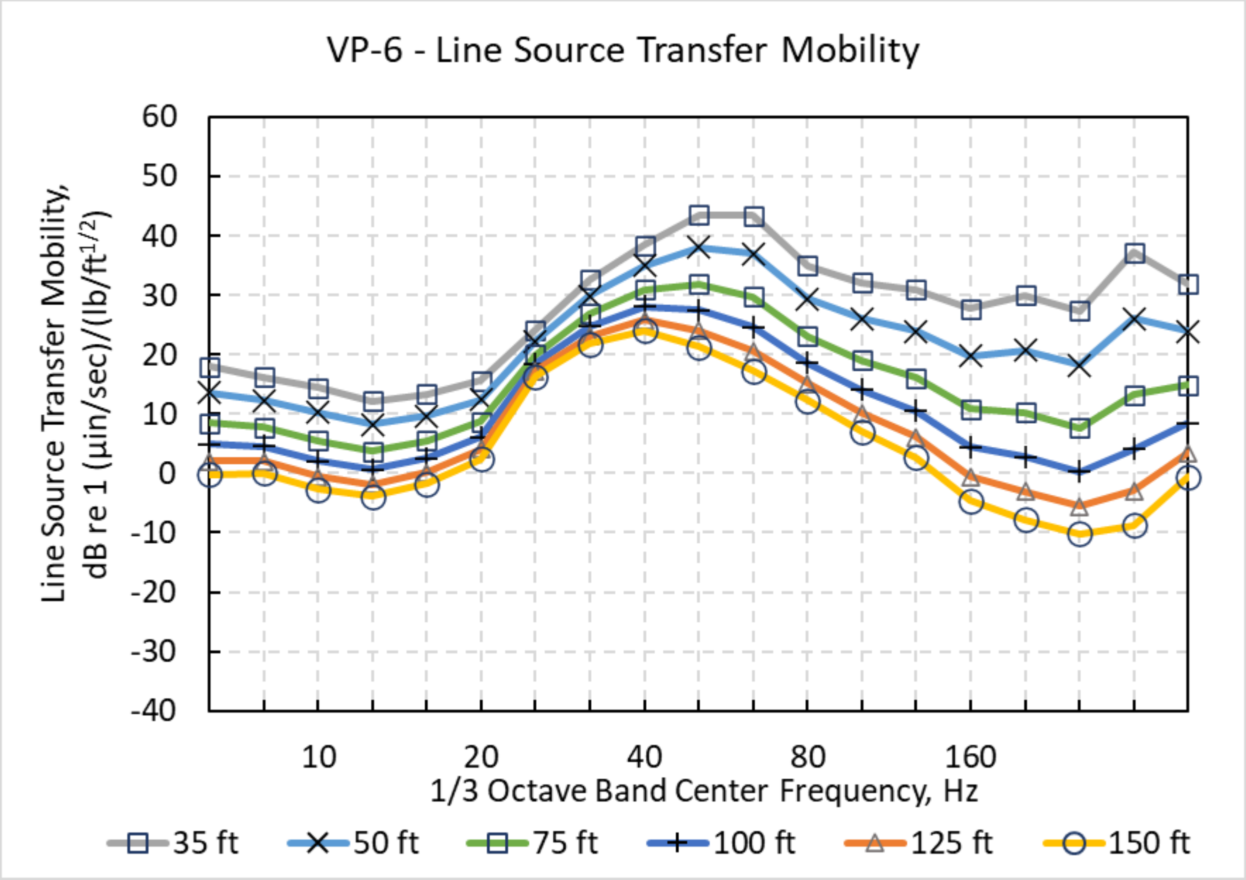


Table F-7: Vibration Propagation Mitigation Location VP-7, Lindell Avenue and Bartlett Street 1/3-Octave Band Transfer Mobility Coefficients

Coeff.	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz	200 Hz
A	11.8	7.1	4.9	5.9	17.2	30.5	31.6	41.8	75.1	106.5	78.1	74.6	95.8	105.5	94.2	99.5
B	-5.8	-3.1	-2.5	-2.9	-7.5	-11.8	-8.4	-8.9	-24.1	-42.7	-30.0	-29.2	-41.2	-47.5	-42.7	-48.7
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

$$LSTM = A + B * \log(dist) + C * \log(dist)^2$$

Figure F-7: Vibration Propagation Mitigation Location VP-7, Lindell Avenue and Bartlett Street

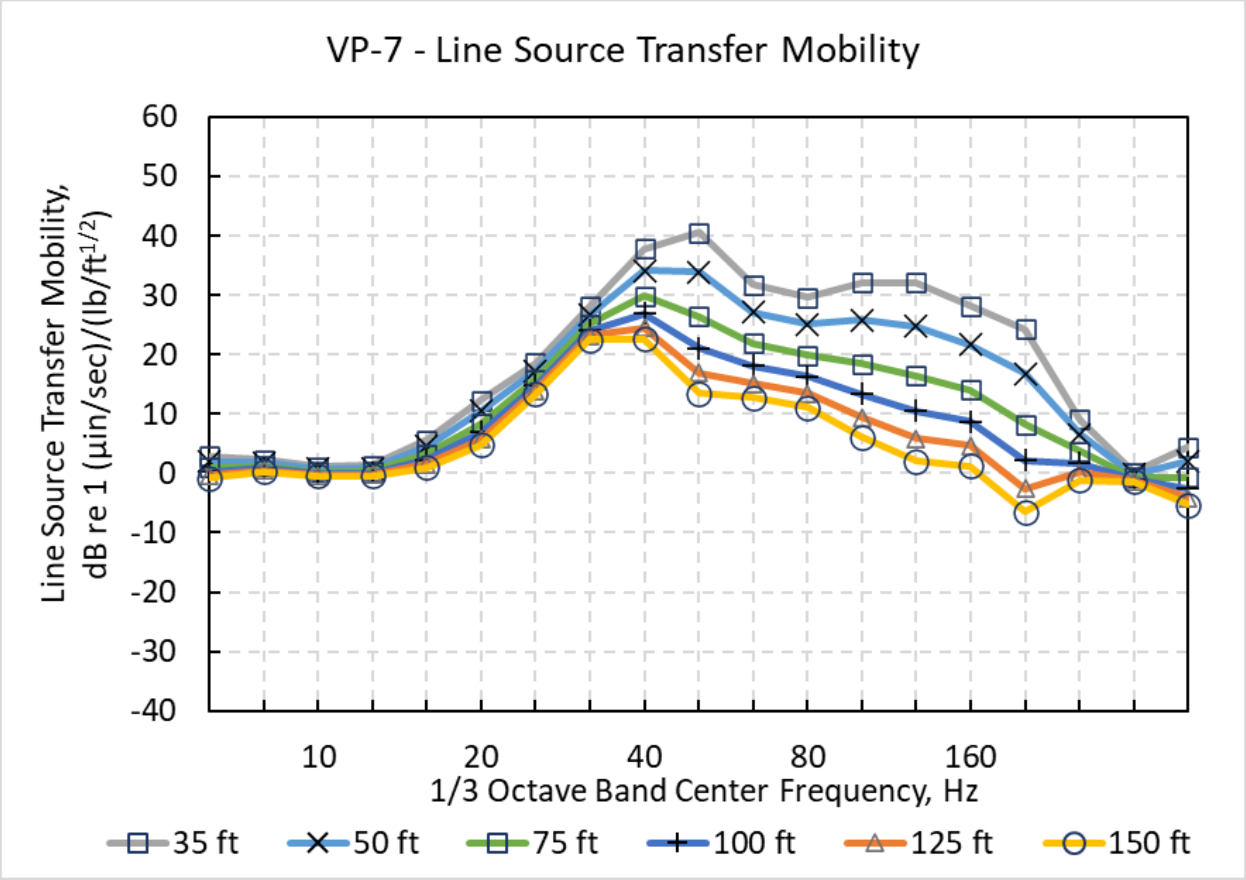


Table F-8: Vibration Propagation Mitigation Location VP-8, Norwood Tract in Town Lake Metropolitan Park 1/3-Octave Band Transfer Mobility Coefficients

Coeff.	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz	200 Hz
A	12.0	12.1	17.3	23.8	25.5	30.6	43.2	72.3	106.5	116.5	125.8	107.4	56.9	23.4	43.4	60.1
B	-4.2	-5.8	-8.5	-10.9	-11.3	-15.7	-22.9	-36.9	-51.2	-54.9	-58.1	-48.1	-21.5	-5.7	-17.9	-31.3
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

$$STM = A + B * \log(dist) + C * \log{(dist)}^2$$

Figure F-8: Vibration Propagation Mitigation Location VP-8, Norwood Tract in Town Lake Metropolitan Park

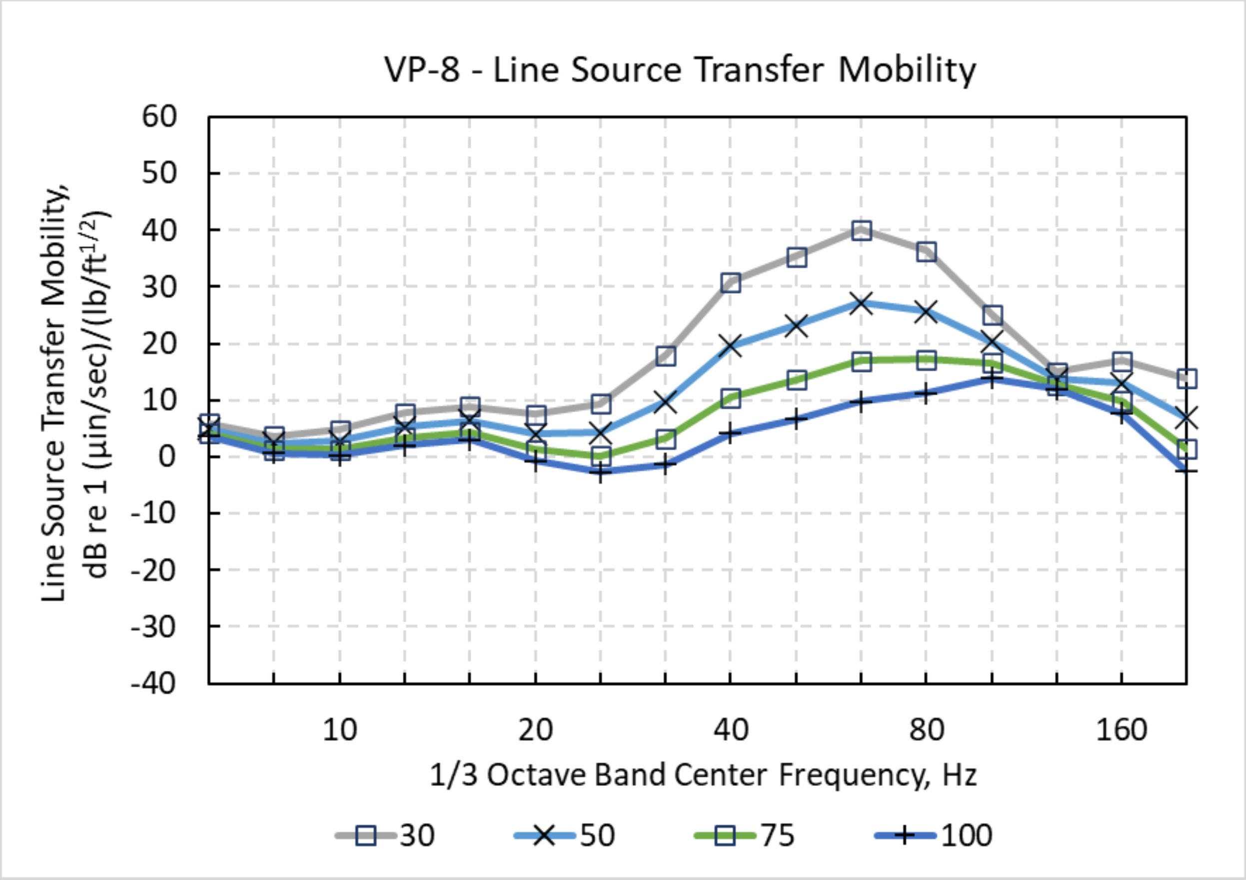


Table F-9: Vibration Propagation Mitigation Location VP-9, East Riverside Drive and Crossing Place 1/3-Octave Band Transfer Mobility Coefficients

Coeff.	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz	200 Hz
A	18.1	19.2	21.0	40.5	65.1	72.4	81.2	92.0	102.0	100.9	121.9	99.4	80.7	89.6	88.2	97.1
B	-2.9	-4.7	-2.1	-10.3	-22.0	-25.6	-30.0	-37.0	-43.3	-44.9	-58.8	-49.6	-40.6	-43.9	-43.9	-47.0
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

$$LSTM = A + B * \log(dist) + C * \log{(dist)}^2$$

Figure F-9: Vibration Propagation Mitigation Location VP-9, East Riverside Drive and Crossing Place

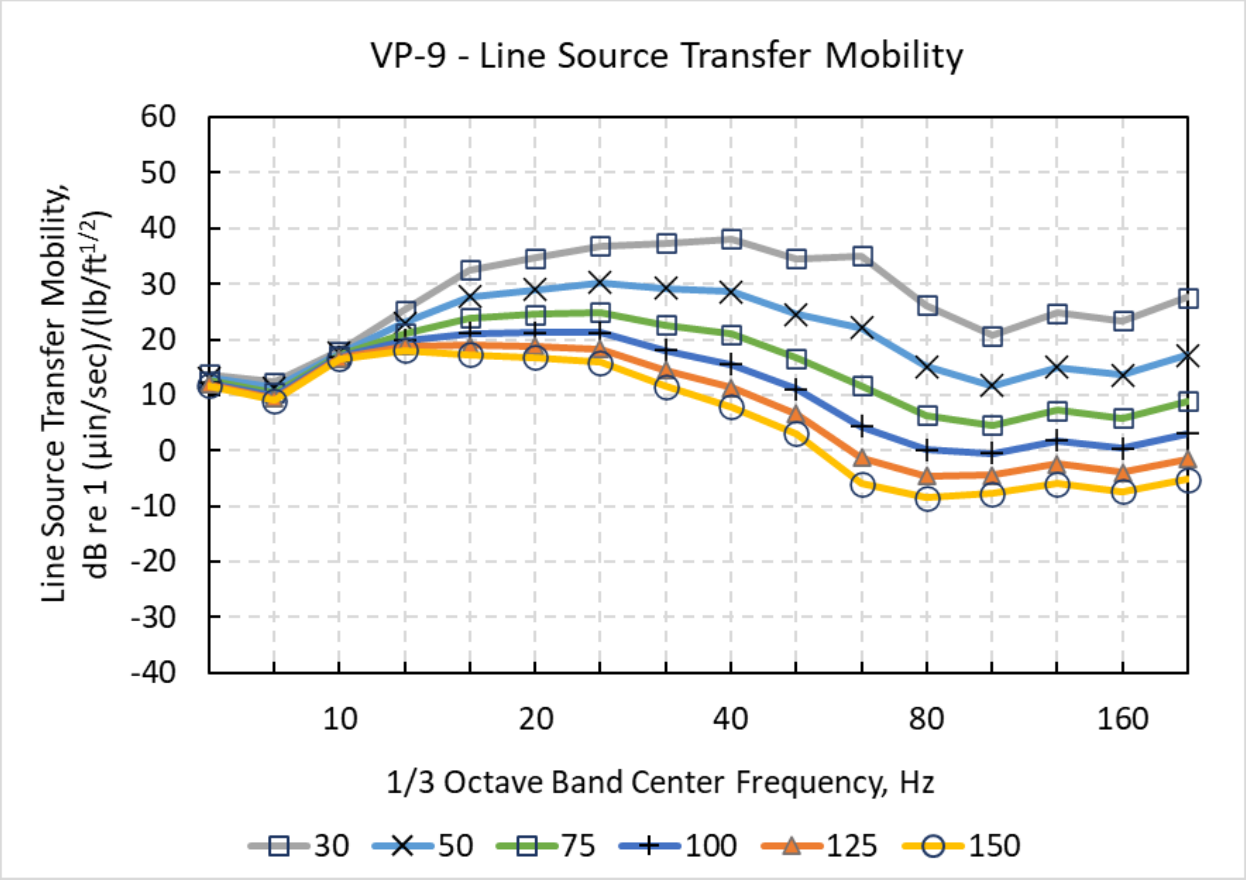


Table F-10: Vibration Propagation Mitigation Location VP-10, East Riverside Drive and Clubview Avenue 1/3-Octave Band Transfer Mobility Coefficients

Coeff.	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz	200 Hz
A	24.0	27.9	34.0	47.0	48.2	56.1	81.1	96.3	93.4	76.8	88.3	89.1	71.6	72.2	77.2	44.1
B	-1.9	-4.9	-6.0	-12.2	-12.3	-15.3	-28.4	-38.1	-36.9	-27.7	-39.2	-43.2	-36.4	-39.5	-42.4	-24.0
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

$$LSTM = A + B * \log(dist) + C * \log(dist)^2$$

Figure F-10: Vibration Propagation Mitigation Location VP-10, East Riverside Drive and Clubview Avenue

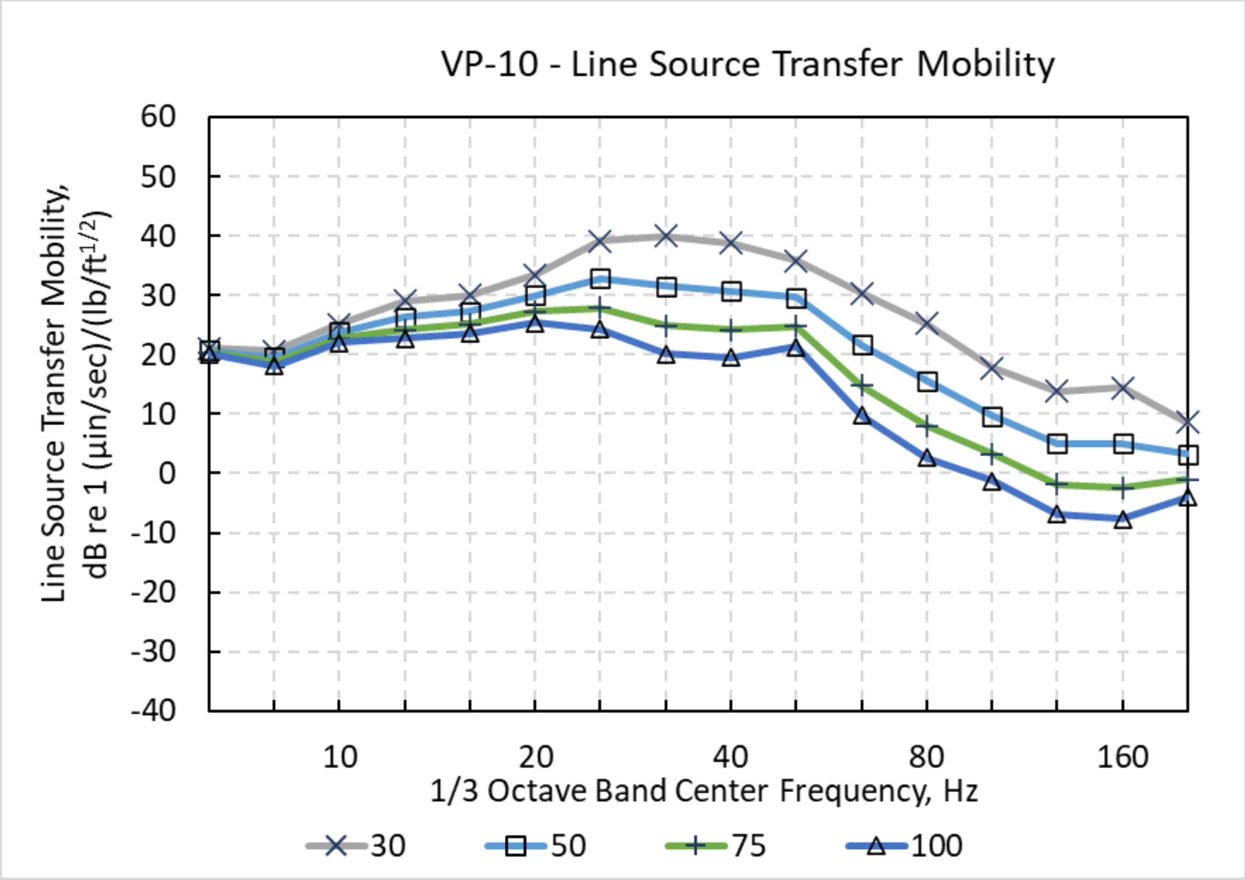


Table F-11: Vibration Propagation Mitigation Location VP-11, Hampton Inn and Suites Austin-Airport Hotel 1/3-Octave Band Transfer Mobility Coefficients

Coeff.	6.3 Hz	8 Hz	10 Hz	12.5 Hz	16 Hz	20 Hz	25 Hz	31.5 Hz	40 Hz	50 Hz	63 Hz	80 Hz	100 Hz	125 Hz	160 Hz	200 Hz
A	31.4	55.3	84.6	81.7	80.9	85.0	90.5	118.7	108.6	117.7	145.0	143.1	140.2	117.2	110.5	76.4
B	-10.0	-19.0	-30.5	-26.4	-21.4	-23.4	-26.2	-43.2	-38.2	-46.2	-65.9	-68.7	-73.0	-65.8	-65.8	-44.5
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

$$LSTM = A + B * \log(dist) + C * \log{(dist)}^2$$

Figure F-11: Vibration Propagation Mitigation Location VP-11, Hampton Inn and Suites Austin-Airport Hotel