Appendix I
Technical Report: Noise and Vibration

MBTA Draw One Bridge Replacement

Noise and Vibration Technical Report

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1 Introduction and Summary

Harris Miller Miller & Hanson Inc. (HMMH) conducted a noise and vibration impact assessment for the Massachusetts Bay Transportation Authority (MBTA) Draw One Bridge Replacement Project (Project). This assessment was carried out for MBTA under subcontract to STV Inc. (STV) in support of the National Environmental Policy Act (NEPA) Environmental Assessment (EA) for the Project. The objective of the study was to assess the potential for noise and vibration impact at sensitive locations and identify if mitigation along the Project corridor would be required.

1.1 Project Description

MBTA proposes the construction of the Draw One Bridge Replacement and associated trackwork in order to bring the crossing of the Charles River to a state of good repair and improve operation flexibility and reliability at North Station.

The project is located just north of North Station and crosses the Charles River and extends just north into Cambridge. The project area is located within the MBTA ROW except for a small acquisition required at the corner of the MGH property.

The project consists of the following elements:

- Replace the existing two bascule bridges with three vertical lift bridges
- Demolish remaining foundations from two previous bascule bridges located on the site
- Replace the north and south trestles
- Replace existing fender along a new alignment
- Raise the North Bank Bridge, relocate Piers 3 and 4, and construct a new pier 4A
- Relocate the temporary control tower
- Demolish the existing Tower A and construct the new Tower A with parking lot
- Construct a closed drainage system for the new bridge with new outfalls to the Charles River and Millers River
- Cutover signals from the existing signal houses to the new signal houses
- Connect bridge tracks to existing North Station tracks, including reconstruction of direct fixation where required
- Connect bridge tracks to mainline tracks north of the bridge

Construction will require maintenance of service into and out of the station, including a minimum of 8 active station tracks and 4 active tracks across the river during weekdays and a minimum of 5 active station tracks on weekends. This construction would impact tracks, drainage, signals, and electrical services during each stage of construction. The existing approach slab, sub-ballast slab and direct fixation slabs along with the existing seawall will all be impacted and require varying levels of modification or replacement. Construction will occur between active tracks and require equipment to operate over active tracks and will necessitate close coordination between construction and train operations for the duration of the project.

Construction is expected to last 8 years, starting spring 2026 and be completed spring of 2034.

Sequencing of activities: This work is planned to be performed as part of staged construction

- Construct the upstream temporary work trestle structures
- Construct the westerly vertical lift bridge, Tower A, and modify the North Bank Bridge
- Activate one track on the westerly bridge and construct a portion of the south trestle between the westerly bridge and center bridge.
- Construct the downstream temporary work trestle structures
- Move all train service from the center bridge to the westerly bridge and demolish the center bascule bridge and construct the center vertical lift bridge
- Activate one track on the center bridge and construct a portion of the south trestle between the center bridge and the easterly bridge.
- Demolish the upstream temporary work trestle structures
- Remove all train service from the easterly bridge, demolish the easterly bascule bridge and construct the easterly vertical lift bridge.
- Demolish the downstream temporary work trestle structures

The project is intended to improve safety and reliability and would not result in increased train activity. Therefore, the potential for effects would be limited to changes in how trains would move into and out of the existing station via the replacement bridge, as described above. Additionally, 5-mph speed increases may be possible with the new bridge structure, though such increases would remain limited by movement into and out of the station. Construction activities would be of limited durations in any particular location, and all together would be limited physically and geographically and would be limited to certain time periods.

Other planned projects in the vicinity include the following:

- MBTA proposes to perform Track and Signal Upgrades, including track realignment, installation of new special trackwork and signals and is located immediately to the north of the Draw One Replacement Project. Anticipated construction is expected to begin in Fall of 2024 and continue through Fall of 2027.
- MBTA proposes to rehabilitate and extend North Station Platform F which includes the extension of Platform F, Tracks 11 and 12 and tying Tracks 11 and 12 into the track network. The North Station Platform F work is located immediately south of the Draw One Replacement Project. Anticipated construction is expected to begin in Fall of 2024 and continue through Spring 2026.
- MBTA proposes to construct the Cross River Bridge which would be upstream of the Draw One Bridge and would provide a pedestrian connection from North Point Park across the Charles River to the Nashua Street Park. Anticipated Construction is expected to begin in Spring 2032 and continue through Fall 2034.
- DCR proposes to construct the South Bank Bridge which would cross the MBTA ROW along the bank of the Charles River from the Nashua Street Park to a new currently undeveloped park. There is no planned construction timeline for the bridge at this point.

It is expected that construction of the adjacent Track and Signal Upgrades Project and the North Station Platform F Project will be sufficiently complete when construction begins on the Draw One Project that there will be minimal impacts on the Draw One Project. The first new vertical lift bridge is not expected to be commissioned until 2029, well after completion of these two projects and allowing sufficient separation in schedule for the Draw One Project to construct additional trackwork and tie into the station and mainline tracks. The Cross River Bridge will begin construction after all construction from the upstream side of the Draw One Replacement Project is completed and will not impact construction on the downstream side of the Draw One Replacement Project. The South Bank Bridge construction has not been scheduled at this point but will be required to wait until construction of the Draw One Replacement Project is substantially complete since it will be constructed above the south trestle.

1.2 Summary of Results

A summary of the study results is described below. Section 2 provides a discussion of environmental noise and vibration basics, and Section 3 describes the criteria used to assess noise and vibration impact. Section 4 includes existing noise and vibration conditions, and Section 5 includes noise and vibration measurement results. Section 6 includes projections and impact assessment of future noise and vibration conditions, and potential mitigation measures are outlined in Section 7. Appendix A includes measurement site photographs and calibration sheets.

1.2.1 Noise and Vibration Impact Assessment

The project would not result in operational noise or vibration impacts, but it would result in temporary construction impacts. Operationally, the project enables more efficient movement of trains into and out of North Station by increasing capacity at the river crossing; however, there is no associated increase or change in operations associated with the project, other than slight speed increases of 5 miles per hour in some areas. While the tracks will be somewhat closer to some noise and vibration sensitive uses, the change in alignment is not predicted to cause exceedances of applicable impact criteria.

Construction of the project would result in noise and vibration impacts prior to mitigation. The main cause of these impacts is the use of heavy construction equipment and pile driving in relatively close proximity to various noise and vibration sensitive uses. A variety of mitigation strategies should be employed to reduce these levels where feasible to avoid damage and annoyance. Specific mitigation will be agreed to in a noise and vibration control plan prepared for the project during final design and prior to construction.

2 Environmental Noise and Vibration Basics

2.1 Noise Fundamentals and Descriptors

Noise is typically defined as unwanted or undesirable sound, where sound is characterized by small air pressure fluctuations above and below the atmospheric pressure. The basic parameters of environmental noise that affect human subjective response are (1) intensity or level, (2) frequency content and (3) variation with time. The first parameter is determined by how greatly the sound pressure fluctuates above and below the atmospheric pressure and is expressed on a compressed scale in units of decibels. By using this scale, the range of normally encountered sound can be expressed by values between 0 and 120 decibels. On a relative basis, a 3-decibel change in sound level generally represents a barely noticeable change outside the laboratory, whereas a 10-decibel change in sound level would typically be perceived as a doubling (or halving) in the loudness of a sound.

The frequency content of noise is related to the tone or pitch of the sound and is expressed based on the rate of the air pressure fluctuation in terms of cycles per second (called Hertz and abbreviated as Hz). The human ear can detect a wide range of frequencies from about 20 Hz to 17,000 Hz. However, because the sensitivity of human hearing varies with frequency, the "A-weighting system" is commonly used when measuring environmental noise to provide a single number descriptor that correlates with human subjective response. Sound levels measured using this weighting system are called "A-weighted" sound levels and are expressed in decibel notation as "dBA." The A-weighted sound level is widely accepted by acousticians as a proper unit for describing environmental noise.

Because environmental noise fluctuates from moment to moment, it is common practice to condense all this information into a single number, called the "equivalent" sound level (L_{eq}). L_{eq} can be thought of as the steady sound level that represents the same sound energy as the varying sound levels over a specified time period (typically 1 hour or 24 hours). Often the L_{eq} values over a 24-hour period are used to calculate cumulative noise exposure in terms of the Day-Night Sound Level (L_{dn}). L_{dn} is the A-weighted L_{eq} for a 24-hour period with an added 10-decibel penalty imposed on noise that occurs during the nighttime hours (between 10 P.M. and 7 A.M.). Many surveys have shown that L_{dn} is well correlated with human annoyance, and therefore this descriptor is widely used for environmental noise impact assessment. Figure 1 provides examples of typical noise environments and criteria in terms of L_{dn}. While the extremes of L_{dn} are shown to range from 35 dBA in a wilderness environment to 85 dBA in noisy urban environments, L_{dn} is generally found to range between 55 dBA and 75 dBA in most communities. As shown in Figure 1, this spans the range between an "ideal" residential environment and the threshold for an unacceptable residential environment according to some U.S. Federal agencies criteria.

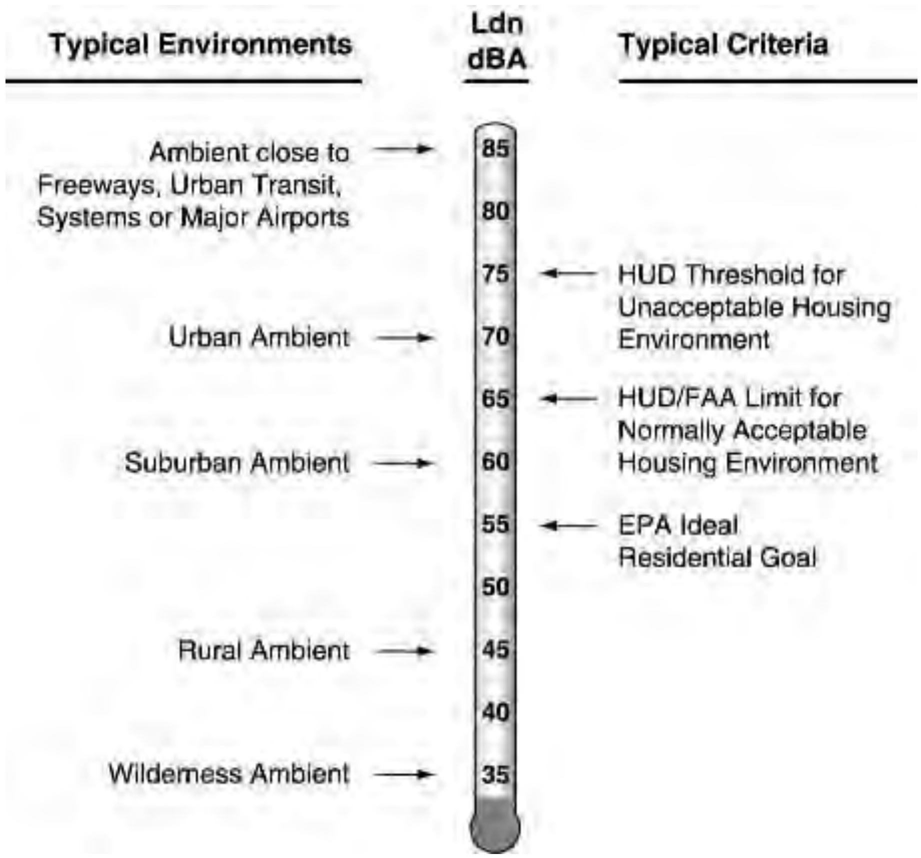

Figure 1. Examples of Outdoor Noise Exposure

2.2 Ground-Borne Noise and Vibration Fundamentals and Descriptors

Ground-borne vibration is the oscillatory motion of the ground about some equilibrium position that can be described in terms of displacement, velocity or acceleration. Because sensitivity to vibration typically corresponds to the amplitude of vibration velocity within the low-frequency range of most concern for environmental vibration (roughly four to 80 Hz), velocity is the preferred measure for evaluating ground-borne vibration from transit projects.

The most common measure used to quantify vibration amplitude is the peak particle velocity (PPV), defined as the maximum instantaneous peak of the vibratory motion. PPV is typically used in monitoring blasting and other types of construction-generated vibration, since it is related to the stresses experienced by building components. Although PPV is appropriate for evaluating building damage, it is less suitable for evaluating human response, which is better related to the average vibration amplitude. Thus, ground-borne vibration from trains is usually characterized in terms of the "smoothed" root mean square (rms) vibration velocity level, in decibels (VdB), with a reference quantity of one micro-inch per second. VdB is used in place of dB to avoid confusing vibration decibels with sound decibels.

Figure 2 illustrates typical ground-borne vibration levels for common sources as well as criteria for human and structural response to ground-borne vibration. As shown, the range of interest is from approximately 50 to 100 VdB, from imperceptible background vibration to the threshold of damage. Although the approximate threshold of human perception to vibration is 65 VdB, annoyance is usually not significant unless the vibration exceeds 70 VdB.

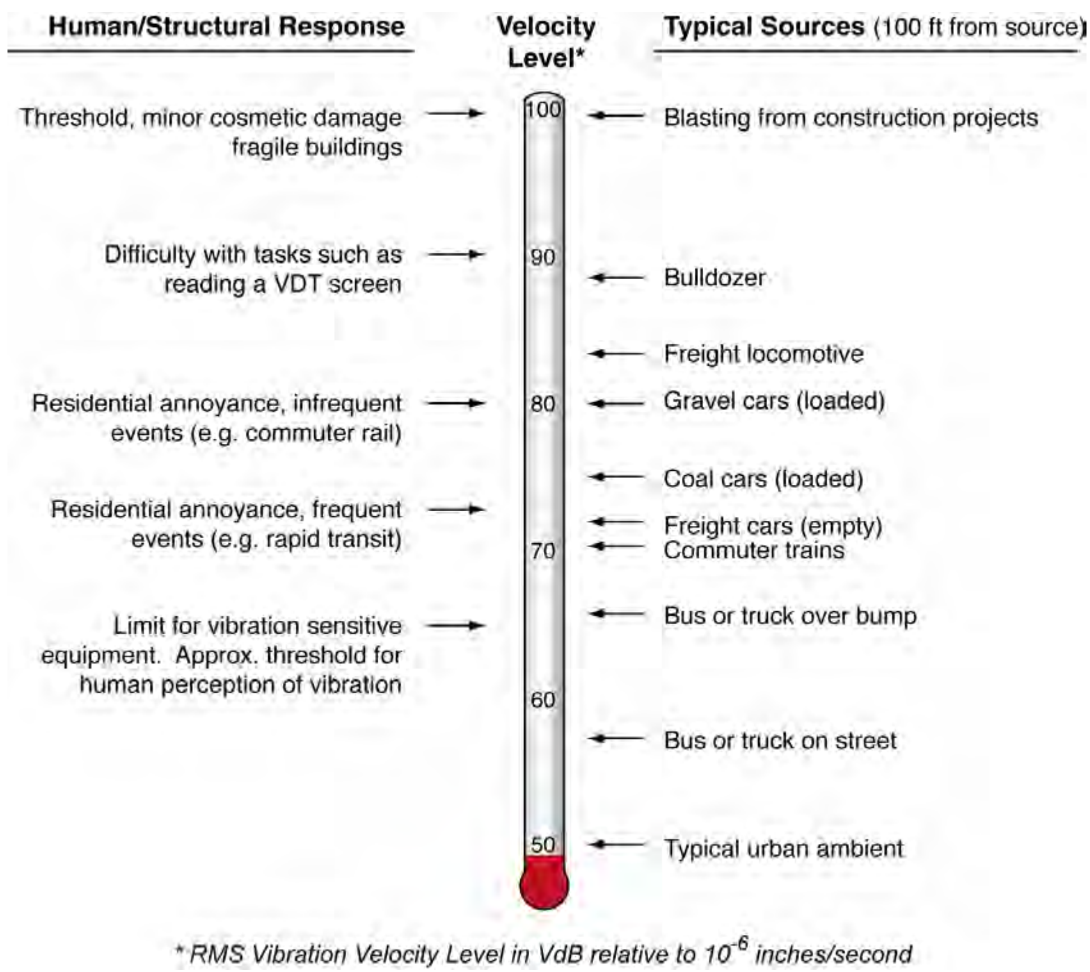

Figure 2. Typical Ground-Borne Vibration Levels

Ground-borne noise is produced when ground-borne vibration propagates into a room and radiates noise from the motion of the surfaces. The room surfaces essentially act like a giant loudspeaker from the vibration. Ground-borne noise is perceived as a low frequency rumble and is generally considered only when airborne paths are not present (e.g., train inside a tunnel or a large masonry building with no windows or other openings to the outdoors). Ground-borne noise is assessed according to the A-weighted sound level in dBA. As presented in the following section, there are separate noise criteria for potential impact from airborne noise versus ground-borne noise.

3 Noise and Vibration Impact Criteria

3.1 Noise and Vibration Sensitive Land Use Categories

The FTA classifies noise-sensitive land uses into the following three categories.

- Category 1: Tracts of land where quiet is an essential element in their intended purpose. This category includes lands set aside for serenity and quiet, and such land uses as outdoor amphitheaters and concert pavilions, as well as National Historic Landmarks with significant outdoor use. Also included are recording studios and concert halls.
- Category 2: Residences and buildings where people normally sleep. This category includes homes, hospitals, and hotels where a nighttime sensitivity is assumed to be of utmost importance.
- Category 3: Institutional land uses with primarily daytime and evening use. This category includes 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 can also be considered to be in this category. Certain historical sites and parks are also included.

The FTA classifies vibration-sensitive land uses into the same three categories as noise. Although, since vibration is only assessed inside buildings, outdoor land uses are not considered to be sensitive. In addition to the potential for human annoyance from vibration, vibration impact is also assessed for certain equipment that is sensitive to vibration and the potential for damage to building structures.

- Vibration Category 1: High Sensitivity: Included in this category are buildings where vibration would interfere with operations. Vibration levels may be well below those associated with human annoyance. These buildings include vibration-sensitive research and manufacturing facilities, hospitals with sensitive equipment and university research operations. The sensitivity to vibration is dependent on the specific equipment present. Some examples of sensitive equipment include electron-scanning microscopes, magnetic resonance imaging scanners and lithographic equipment.
- Vibration Category 2: Residential: Residences and buildings where people normally sleep. This category includes homes, hospitals, and hotels.
- Vibration Category 3: Institutional: This category includes buildings with primarily daytime and evening use. This category includes schools, libraries and churches.

There are some buildings, such as concert halls, recording studios, and theaters that can be very sensitive to noise and/or vibration but do not fit into any of the three categories. Due to the sensitivity of these buildings, they usually warrant special attention during the environmental assessment of a transit project. Potential ground-borne vibration and ground-borne noise impact is assessed at special-use buildings such as concert halls, recording studios, auditoriums and theatres.

3.2 Noise Impact Criteria

The FTA airborne noise impact criteria are founded on well-documented research on community reaction to noise and are based on the future change in noise exposure using a sliding scale. At locations with higher levels of existing noise, smaller increases in total noise exposure are allowed.

The Day-Night Sound Level (L_{dn}) is used to characterize noise exposure for locations with nighttime sensitivity (Category 2). For institutional land uses with primarily daytime use, such as parks and school buildings (Categories 1 and 3), the one-hour "equivalent" sound level (L_{eq}) during the facility's operating period is used. L_{dn} and L_{eq} are explained in Section 2.1.

There are two levels of impact included in the FTA criteria, as summarized below:

- Severe Impact: Project-generated noise in the severe impact range can be expected to cause a significant percentage of people to be highly annoyed by the new noise and represents the most compelling need for mitigation. Noise mitigation will normally be specified for severe impact areas unless there are truly extenuating circumstances that prevent it.
- Moderate Impact: In this range of noise impact, the change in the cumulative noise level is noticeable to most people but may not be sufficient to cause strong, adverse reactions from the community. In this transitional area, other project-specific factors must be considered to determine the magnitude of the impact and the need for mitigation. These factors include the existing noise level, the predicted level of increase over existing noise levels, the types and numbers of noise-sensitive land uses affected, the noise sensitivity of the properties, the effectiveness of the mitigation measures, community views and the cost of mitigating noise to more acceptable levels.

The FTA noise impact criteria used in this assessment are shown in graphical form in Figure 3. One example would be a residential use with an existing environment of 50 dBA L_{dn} would experience a moderate impact if the Project creates a noise exposure of approximately 53 dBA to 59 dBA L_{dn}. Another example would be a residence with an existing environment of 65 dBA L_{dn} would be classified as having moderate impact if the Project creates a noise exposure of 61 dBA to 66 dBA L_{dn}. Those same existing environments (50 or 65 dBA L_{dn}) would be classified as having a severe impact if the Project creates noise exposure levels greater than 59 dBA and 66 dBA L_{dn}, respectively.

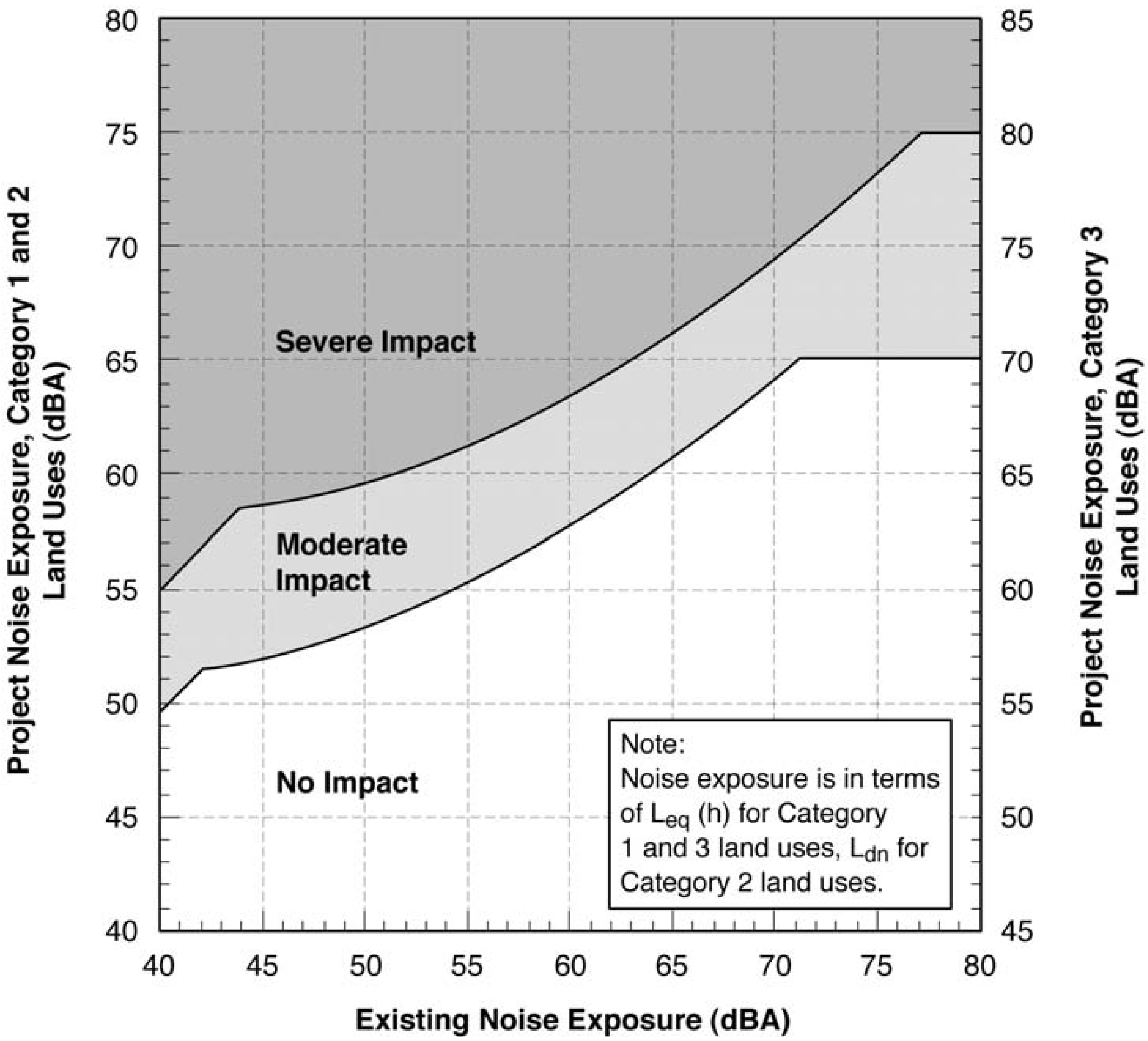

Figure 3. FTA Noise Impact Criteria

3.3 Ground-Borne Noise and Vibration Impact Criteria

The FTA vibration impact criteria are based on land use and train frequency, as shown in Table 1. There are some buildings, such as concert halls, recording studios and theaters that can be very sensitive to vibration but do not fit into any of the three categories listed in Table 1. Due to the sensitivity of these buildings, they usually warrant special attention during the environmental assessment of a transit project. Table 2 gives criteria for acceptable levels of ground-borne vibration for various types of special buildings.

It should also be noted that there are separate FTA criteria for ground-borne noise, the "rumble" that can be radiated from the motion of room surfaces in buildings due to ground-borne vibration. Such criteria are particularly important for underground transit operations. However, because airborne noise tends to mask ground-borne noise from above ground (i.e., at-grade or elevated) rail systems, ground-borne noise levels are generally only assessed in buildings without significant airborne noise paths.

Table 1. FTA Ground-Borne Noise and Vibration Impact Criteria

Land Use Category	Ground-Borne Vibration Impact Criteria (VdB re: 1 micro-inch per second)			Ground-Borne Noise Impact Criteria (dBA re: 20 mico-Pascal)		
	Frequent[1] Events	Occasional[2] Events	Infrequent[3] Events	Frequent[1] Events	Occasional[2] Events	Infrequent[3] Events
Category 1: Buildings where low ambient vibration is essential for interior operations.	65 VdB[4]	65 VdB[4]	65 VdB[4]	n/a[5]	n/a[5]	n/a[5]
Category 2: Residences and buildings where people normally sleep.	72 VdB	75 VdB	80 VdB	35 dBA	38 dBA	43 dBA
Category 3: Institutional land uses with primarily daytime use.	75 VdB	78 VdB	83 VdB	40 dBA	43 dBA	48 dBA

Notes:
1 “Frequent Events” is defined as more than 70 vibration events per day. Most rapid transit projects fall into this category.
2 “Occasional Events” is defined as between 30 and 70 vibration events of the same kind per day. Most commuter rail trunk lines have this many operations.
3 “Infrequent Events” is defined as fewer than 30 vibration events of the same kind per day. This category includes most commuter rail 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 will require detailed evaluation to define the acceptable vibration levels. Ensuring lower vibration levels in a building often requires special design of the HVAC systems and stiffened floors.
5 Vibration-sensitive equipment is generally not sensitive to ground-borne noise.

Source: FTA 2018

Table 2. FTA Gound-Borne Nosie and Vibration Impact Criteria for Special Buildings

Type of Building or Room	Ground-Borne Vibration Impact Criteria (VdB re: 1 micro-inch per second)		Ground-Borne Noise Impact Criteria (dBA re: 20 mico-Pascal)	
	Frequent Events	Occasional or Infrequent Events	Frequent Events	Occasional or Infrequent Events
Concert Halls	65 VdB	65 VdB	25 dBA	25 dBA
TV Studios	65 VdB	65 VdB	25 dBA	25 dBA
Recording Studios	65 VdB	65 VdB	25 dBA	25 dBA
Auditoriums	72 VdB	80 VdB	30 dBA	38 dBA
Theatres	72 VdB	80 VdB	35 dBA	43 dBA

Source: FTA 2018

In addition to the criteria provided in Table 1 and Table 2 for general assessment purposes, FTA has established criteria in terms of one-third octave band frequency spectra for use in detailed analyses. Table 3 and Figure 4 show the more detailed vibration criteria and the description of their use.

Table 3. Vibration Criteria for Detailed Analysis

Criterion Curve	Maximum Vibration Level (VdB re: 1 micro-inch per second)	Description of Use
Workshop	90	Distinctly feelable vibration. Appropriate to workshops and non-sensitive areas
Office	84	Feelable vibration. Appropriate to offices and non-sensitive areas
Residential Day	78	Barely feelable vibration. Adequate for computer equipment and low-power optical microscopes (up to 20X)
Residential Night, Operating Rooms	72	Vibration not feelable, 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), 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 capability
VC-E	42	The most demanding criterion for extremely vibration-sensitive equipment

Source: FTA 2018

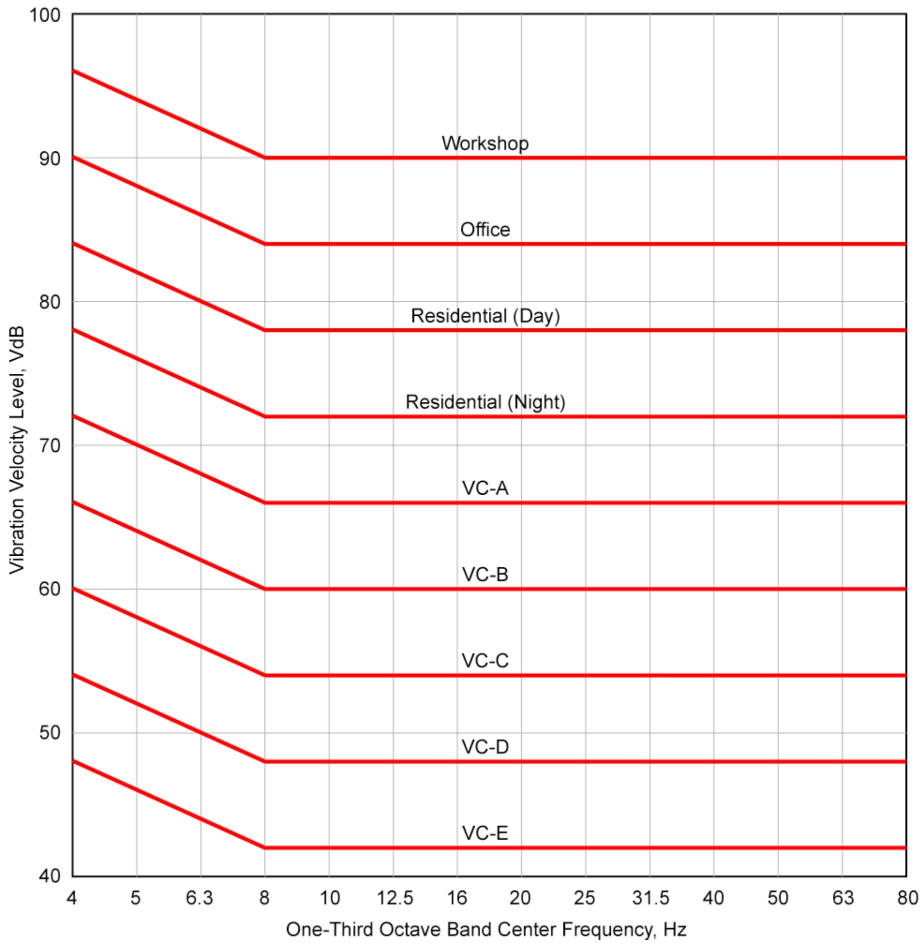

Figure 4. Criteria for Detailed Vibration Analysis

3.4 Construction Noise Criteria

Applicable construction noise criteria include those from the FTA and the cities of Boston and Cambridge, Massachusetts. The FTA construction noise guidelines are provided in Table 4 and the city Boston criteria is listed in Table 5. The City of Boston's criteria are associated with the L_{10} and L_{max} metrics. Pile driving is not regulated by the City of Boston. The L_{10} is the level exceeded 10-percent of a given period, in this case hourly, and the L_{max} is the maximum level over the same period. Boston's noise regulation indicates that an impact occurs if the background L_{10} is exceeded by 5 dB. For this analysis the background L_{10} plus 5 dB is used to assess potential impact conditions. The City of Boston, via their municipal code, also limits construction to occurring weekdays between the hours of 7:00 a.m. and 6:00 p.m. Cambridge regulates construction noise via their noise ordinance which limits construction noise to daytime periods from 7:00 a.m. to 6:00 p.m. on weekdays, 9:00 a.m. to 6:00 p.m. on Saturdays and holidays, and is not allowed on Sundays without approval from the Cambridge police department. Federal guidelines, such as those provided in Table 4 do not supersede local regulations.

Table 4. FTA Construction Noise Criteria

Land Use Category	Daytime Construction Period (dBA L_{eq})	Nighttime Construction Period (dBA L_{eq})
Residential	90	80
Commercial	100	100
Industrial	100	100

Source: FTA 2018

Table 5. City of Boston Construction Noise Limits

Land Use Category	dBA L_{10}	dBA L_{max}
Residential or Institutional	75	86
Business or Recreational	80	n/a
Industrial	85	n/a

Source: City of Boston

3.5 Construction Vibration Criteria

In addition to ground-borne vibration criteria for humans in residential, institutional, and special buildings and vibration-sensitive equipment, there are ground-borne vibration criteria for potential damage to structures. The limits of vibration that structures can withstand are substantially higher than those for humans and for sensitive equipment. Table 6 presents criteria for assessing the potential for vibration damage to structures based on the type of building construction. This table includes rms vibration levels in VdB reference to 1 micro-inch per second and peak-particle velocity levels in inches per second. A crest factor of four, representing a difference of 12 decibels between peak and rms is used in this table. It should be noted that these criteria are more conservative than other standards such as the U.S. Bureau of Mines frequency-dependent vibration criteria which is equivalent to approximately 114 VdB at 40 Hz and above.

Table 6. Construction Vibration Damage Criteria

Building Category	Ground-Borne Vibration Level (VdB) and Peak-Particle Velocity Equivalent (in/sec)
Reinforced-concrete, steel or timber	102 VdB (0.5 in/s)
Engineered concrete and masonry	98 VdB (0.3 in/s)
Non-engineered timber and masonry buildings	94 VdB (0.2 in/s)
Buildings extremely susceptible to vibration damage	90 VdB (0.12 in/s)

Source: FTA 2018

4 Existing Conditions

4.1 Noise and Vibration Sensitive Land Use

Noise and vibration-sensitive land use near the Proposed Action include institutional sites such as parks and an office. Parks that are considered to have passive recreation are sensitive to noise. Five sensitive uses are located near the project, specifically:

- North Point Park (R13 on Figure 5)
- Paul Revere Playground (N2 on Figure 5)
- Nashua Street Park (N1/R12 on Figure 5)
- Jail cells at the Suffolk County Sheriff's Department (R26 on Figure 5)
- Massachusetts General Hospital Administration Building (R27 on Figure 5; note no medical uses, only administrative offices. This will be confirmed prior to construction.)

North Point Park, Paul Revere Playground, and Nashua Street Park all have a number of passive uses, such as park benches; therefore, these uses are considered Category 3 FTA uses. Other than the North Point Park all of these Category 3 FTA uses are within the City of Boston and would be considered recreational. The jail cells at the Suffolk County Sheriff's Department are considered Category 2 FTA uses because the cells are places where people sleep. The Massachusetts General Hospital Administration Building is not considered noise sensitive; however, the office building is considered in the vibration assessment since the primary use is office space (see Table 3). For construction noise, the Massachusetts General Hospital Administration Building is considered a business for the City of Boston's construction noise criteria.

5 Noise and Vibration Measurements

Four noise and vibration measurements were conducted in the project analysis area. Figure 5 is a map of the measurement locations, sensitive land uses, and project track alignment.

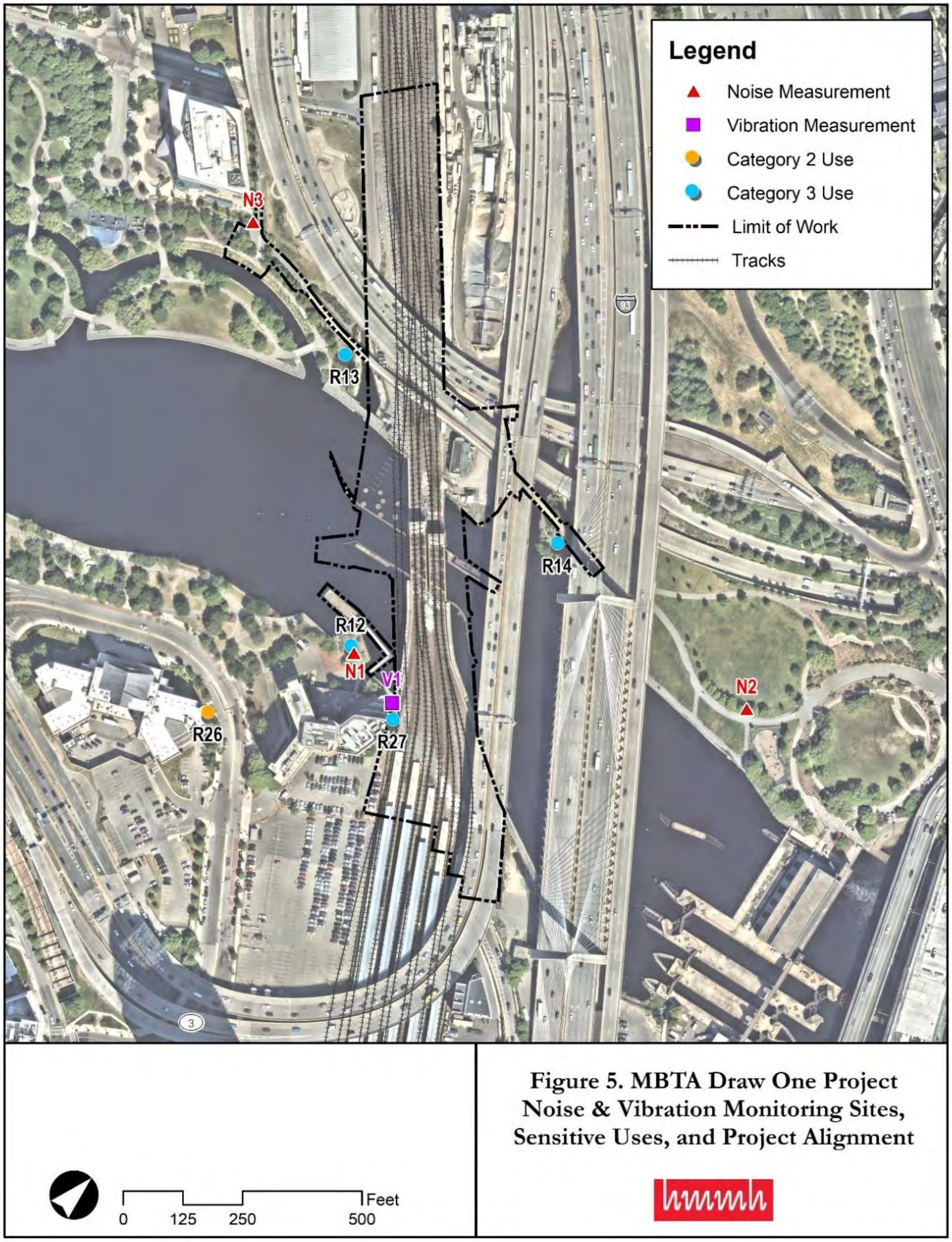

Figure 5. Noise and Vibration Measurements, Sensitive Uses, and Project Track Alignment

5.1 Noise and Vibration Measurement Equipment

All noise measurement equipment used in the study conforms to American National Standards Institute (ANSI) Standard S1.4 for Type 1 (precision) sound level meters. Calibrations traceable to the U.S. National Institute of Standards and Technology (NIST) were carried out in the field before and after each set of measurements using acoustical calibrators. Table 7 presents a list of noise and vibration measurement equipment used including manufacturer, model, and serial number. Appendix A provides the calibration certifications for each of the meters used in this analysis.

Table 7. Noise and Vibration Measurement Equipment

Equipment	Manufacturer	Model	Serial Num
Noise Meter	Bruel & Kjaer	2245	2245-100483
Vibration Meter	Bruel & Kjaer	2270	3011812

Source: HMMH 2024

5.2 Noise Measurement Methodology

Measurements to characterize the existing noise environment in the study area were conducted at three representative noise-sensitive receptors. Long-term (24-hour) measurements provide a direct measurement of both L_{dn} and peak transit-hour L_{eq}. One-second time histories of sound levels were measured along with audio recordings of events to identify noise from train activity. These measurements allowed us to separate noise generated from trains from other ambient sources.

Noise impact is assessed at outdoor land uses with frequent use such as passive park uses (i.e., benches) or at the nearest building façade. Noise measurement sites were selected based on the location of noise-sensitive land use along the project corridor, their proximity to the proposed project and the surrounding terrain. The distance from the measurement location to significant noise sources (i.e., rail line or busy streets) was chosen to be representative of typical noise-sensitive locations in each area. Furthermore, the microphone was positioned to characterize the exposure of the site to the dominant noise sources in the area, such as trains operating on the rail lines. Figure 6 through Figure 8 are photos of the noise monitoring locations.

Figure 6. Noise Measurement Location Photo at Massachusetts General Hospital Administrative Building

Figure 7. Noise Measurement Location Photo at Paul Revere Playground

Figure 8. Noise Measurement Location Photo at North Point Park

5.3 Vibration Measurements

One vibration measurement of existing commuter and Amtrak trains was conducted to provide detail on vibration generated by these sources. This information is used to characterize the levels of vibration experienced throughout the corridor at sensitive structures. The ground vibration measurement was conducted with a high-sensitivity accelerometer mounted in the vertical direction on top of steel stakes driven into soil. The acceleration signal was recorded on a Bruel and Kjaer 2270 meter and further analyzed in the HMMH lab. Figure 9 is a photo of the vibration measurement location with an MBTA train operating nearby.

Figure 9. Vibration Measurement Location Photo at Massachusetts General Hospital Administrative Building

5.4 Noise Measurement Results

To characterize the existing noise conditions throughout the Proposed Action, three long-term (24 hour) measurements were conducted. Sound levels throughout the area are consistent with an urbanized environment with dominant sources including train traffic on the existing rail alignment as well as roadway noise from busy highways such as I-93. Figure 5 shows the noise measurement site locations. Table 8 provides the existing noise measurement results including L_{dn} peak hour L_{eq}, and distance to the near track. Train pass-by events were logged while in the field and the L_{dn} as well as peak hour L_{eq} were adjusted to exclude these events to identify baseline conditions without train events as shown in Table 9. These tables show that much of the project analysis area is dominated by highway noise from the busy roadway network. The largest contribution of rail noise occurs at the receptors near Massachusetts General Hospital Administrative Building with the L_{dn} 3 dB higher with train activity than without.

Table 8. Summary of Existing Noise Measurements with Train Events

Measurement Site	Location	Existing Day-Night Average Sound Level (L_{dn})	Existing Peak Hour Sound Level (L_{eq})	Distance to Near Track (feet)
N1	MA General Hospital Administration Building	72	69	119
N2	Paul Revere Playground	73	69	588
N3	North Point Park	71	69	299

Source: HMMH 2024

Table 9. Summary of Existing Noise Measurements without Train Events

Measurement Site	Location	Existing Day-Night Average Sound Level (L_{dn})	Existing Peak Hour Sound Level (L_{eq})	Distance to Near Track (feet)
N1	MA General Hospital Administration Building	69	66	119
N2	Paul Revere Playground	73	69	588
N3	North Point Park	70	69	299

Source: HMMH 2024

5.5 Vibration Measurement Results

Existing vibration along the project alignment varies depending on proximity to rail lines and which track vehicles are operating on. To characterize existing vibration levels, vibrations from MBTA commuter trains and Amtrak trains were measured as they operated on the existing track alignment. Measurements were made using PCB 393A accelerometers and Brüel & Kjær noise and vibration monitors (model 2270). The vibration measurement location is shown in Figure 5. Table 10 provides a summary of the vibration levels measured at the measurement location which was at Massachusetts General Hospital. The highest vibration levels were associated with trains operating on tracks closest to the measurement position, although there was some variation due to vehicle specific conditions such as differences in wheel condition.

Table 10. Summary of Existing Vibration Measurements

Train Event Track[1]	Maximum VdB	Distance to Near Track (feet)
Track 7	77.4	71.8
Track 9	85.9	45.5
Track 6	80.9	83
Track 7	80.2	71.8
Track 7	80.0	71.8
Track 7	76.2	71.8
Track 5	82.3	98.5
Track 6	80.7	83
Track 6	77.3	83
Track 2	82.5	130
Track 10	89.6	19.5
Track 7	78.0	71.8
Track 10	91.3	19.5
Track 8	79.4	54
Track 6	77.0	83

Note:
1 Track 10 is closest to the measurement position, track 9 is the next closest track, and so on.

Source: HMMH 2024

6 Noise and Vibration Impact Assessment

The steps described in FTA's Transit Noise and Vibration Impact Assessment Manual (FTA 2018) were followed to evaluate the potential noise and vibration impacts from the project. FTA methodology identifies a noise/vibration screening procedure, a general noise/vibration assessment, and a detailed noise/vibration analysis, which are outlined below. The screening procedure was used to identify what noise or vibration sensitive uses could potentially be impacted by the project and the detailed noise/vibration impact assessment procedures were used to identify potential noise and vibration impacts.

6.1 Noise Projections Methods

Existing noise levels (see Section 5) at all sensitive receptors have been estimated based on the nearest existing noise measurement location and relative distances to the dominant noise source, which is roadway noise in the vicinity of the project site. For use in the noise assessment, baseline sound levels collected were then adjusted by "removing" existing train pass activity noise to prevent operational noise from being "double-counted" as background noise when modeling the operational noise effects attributable only to the slight change in alignment that would result with the proposed project. Modeled operational sound levels were then added to this adjusted baseline logarithmically, and the impact thresholds shown in Figure 3 were used.

Noise impact is assessed at the closer location of either an outdoor area with frequent human use or the nearest building façade. The effects of terrain and intervening objects such as buildings have been included in the estimation of existing noise levels.

The contribution to future noise levels from the project is based on the distance between receptor locations and the project tracks, site-specific conditions such as the terrain, intervening objects, presence of special trackwork, presence of buildings, the train schedules and speeds.

The principal assumptions used in the analysis are summarized below:

- The track alignments used in the impact assessment were dated January 2023 based on the 75% design submittal.
- The operating periods, schedule, and consist of the commuter trains and Amtrak trains are not expected to change as part of the Project.
- The locations of the rail lines are expected to be modified as described in Section 1.1.
- The speeds of the commuter trains and Amtrak trains would increase by approximately 5 miles per hour under the new track alignment.
- Train warning horns will not be used on a routine basis.

6.1.1 Three-Dimensional Predictive Model

Operational sound levels can be assessed using spreadsheet models; however, efficiencies can be gained by implementing "off the shelf" acoustic modeling software that implements the FTA calculation methods. Additionally, analyses of complex rail operations are not easily accomplished via the spreadsheet models, such as the multiple track configurations near Boston's North Station. Therefore, for this assessment, a three dimensional off the shelf predictive model, SoundPLAN software version 8.2, was used to calculate rail noise levels implementing the FTA methods. The project received approval from the FTA to use this modeling approach via approval of the non-standard modeling request titled "MBTA Draw One Project Nosie Modeling Methodology" (HMMH 2023). The SoundPLAN model includes an array of data inputs, such as sound sources, topography, buildings, and ground characteristics, such as paved areas and vegetated areas. The following steps were taken to implement the FTA/FRA standard for rail noise sources in SoundPLAN:

- Each train configuration (i.e., MBTA commuter trains and Amtrak trains) and the number of train movements on a given track location were entered into SoundPLAN as a train noise source.
- Each source term was applied to specific rail lines based on estimates of trains with the project in place.
- Modeling included terrain along the project corridor and the sensitive uses.
- Buildings were modeled as three-dimensional shapes to capture attenuation impacts.
- Although there are small patches of grass and dirt in the Project study area, the noise predictions conservatively assume a uniformly hard and acoustically reflective surface like that of a paved area.

6.2 Vibration Projections Methods

The FTA procedures for a general operational vibration assessment were used for this analysis (FTA 2018). This FTA vibration impact assessment uses the following data:

Number of daily vibration events: The number of daily events was classified as frequent because there would be over 70 vibration events from commuter and Amtrak trains per day.

- Receiver land use designation (categories specified above): Category 2 (for the residences) or Category 3 (parks, schools, daycare) land use designations were used for all of the receivers analyzed.
- Vibration source levels: The source levels were derived from Figure 6, 4, and Table 6-10 of the FTA manual (FTA 2018) using the curve for "locomotive powered passenger or freight".
- Distance from source to receiver (building) footprints: The distance between the source (i.e., rail centerline) and the receiver was measured using a geographic information system.
- Train speed, suspension, wheel condition (worn or flat spots), and track condition: Train speeds are the same as those used for the noise impact assessment. Because the train types are regional and intercity rail the train's wheels were assumed to be well-maintained and in good condition (i.e., no flat spots).
- Soil characteristics of ground between the vibration source and receiver: Soil propagation characteristics were assumed to be normal. Typical vibration sensitive structures were assumed to be large masonry buildings based on field observations.

- Receiver construction/foundation type and description, including whether it is fragile or extremely fragile: Using the generalized ground surface vibration curve, the root mean square velocity level data at the receiver distance of interest were adjusted based on the factors affecting the source, factors affecting the vibration path, and factors affecting the receiver (FTA 2018). Structure types and associated adjustments were also obtained from the FTA manual (FTA 2018).

Following FTA methodology, the potential for vibration damage and annoyance was assessed at sensitive land uses.

6.3 Noise Impact Assessment

Changing the railroad alignment would shift the noise source, commuter trains and Amtrak trains, closer to some noise sensitive receptors which has the potential to cause impact. Predicted operational noise levels at receptors included in this analysis are provided in Table 11 with a comparison to the moderate and severe impact thresholds identified based on the existing sound level at each receptor. As these results demonstrate the project would not result in an operational noise impact.

Table 11. Summary of Operational Noise Levels

Receptor (floor)[1]	Land Use Category	Units	Existing[2] L_{dn}/L_{eq}	Impact Threshold[1]		Proposed Action[1] (L_{dn}/L_{eq})	Impact Category
				Moderate	Severe		
R12(G)	3	1	65.8	68.5	73.7	68.4	No Impact
R13(G)	3	1	70.0	69.4	74.5	67.7	No Impact
R14(G)	3	1	77.5	70.0	80.0	64.5	No Impact
R26(G)	2	1	66.2	63.8	68.9	62.8	No Impact
R26(F2)	2	1	66.2	63.8	68.9	62.8	No Impact
R26(F3)	2	1	66.2	63.8	68.9	62.8	No Impact
R26(F4)	2	1	66.2	63.8	68.9	62.8	No Impact
R26(F5)	2	1	66.2	63.8	68.9	62.8	No Impact
R26(F6)	2	1	66.2	63.8	68.9	62.8	No Impact
R26(F7)	2	1	66.2	63.8	68.9	62.8	No Impact
R26(F8)	2	1	66.2	63.8	68.9	62.8	No Impact
R26(F9)	2	1	66.2	63.8	68.9	62.8	No Impact
R26(F10)	2	1	66.2	63.8	68.9	62.8	No Impact

1 Receptor ID/location are shown on **Figure 5**.
2 Category 2 receptors are assessed using the L_{dn} metric and Category 3 are assessed using the L_{eq} metric.
Source: HMMH 2024

6.4 Vibration Impact Assessment

Like the noise impact assessment, changing the railroad alignment would shift the vibration source, commuter trains and Amtrak trains, closer to some noise sensitive receptors which has the potential to cause impact. Predicted operational vibration levels at receptors included in this analysis are provided in Table 12 with a comparison to the impact thresholds based on the use at each receptor. As these results demonstrate the project would not result in an operational vibration impact.

Table 12. Summary of Operational Vibration Levels

Receptor (floor)	FTA Category	GBV Impact Threshold (VdB)	Significant Increase Threshold (dB)	GBN Impact Threshold (dBA)	Distance to Existing Track (feet)	Distance to Project Track (feet)	Existing Speed (mph)	Future Speed (mph)	Existing VdB	Project VdB	Increase over Existing[1]	Project GBN	GBV Impact	GBN Impact
R12(G)	3	73	3.0	43	133	102	10	10	64	66	3	16	No Impact	No Impact
R13(G)	3	73	3.0	38	136	110	15	20	67	71	5	21	No Impact	No Impact
R27(F10)	3	84	3.0	43	12	12	10	10	82	83	0	33	No Impact	No Impact
R27(F11)	3	84	3.0	43	12	12	10	10	82	83	0	33	No Impact	No Impact
R27(F12)	3	84	3.0	43	12	12	10	10	82	83	0	33	No Impact	No Impact
R27(F13)	3	84	3.0	43	12	12	10	10	82	83	0	33	No Impact	No Impact
R27(F2)	3	84	3.0	43	12	12	10	10	82	83	0	33	No Impact	No Impact
R27(F3)	3	84	3.0	43	12	12	10	10	82	83	0	33	No Impact	No Impact
R27(F4)	3	84	3.0	43	12	12	10	10	82	83	0	33	No Impact	No Impact
R27(F5)	3	84	3.0	43	12	12	10	10	82	83	0	33	No Impact	No Impact
R27(F6)	3	84	3.0	43	12	12	10	10	82	83	0	33	No Impact	No Impact
R27(F7)	3	84	3.0	43	12	12	10	10	82	83	0	33	No Impact	No Impact
R27(F8)	3	84	3.0	43	12	12	10	10	82	83	0	33	No Impact	No Impact
R27(F9)	3	84	3.0	43	12	12	10	10	82	83	0	33	No Impact	No Impact
R27(G)	3	84	3.0	43	12	12	10	10	82	83	0	33	No Impact	No Impact

Note:
1 If increase over existing exceeds significant increase threshold the project VdB is compared to the GBV Impact Threshold.

Source: HMMH 2024

6.5 Temporary Construction Noise Impacts

The construction noise criteria applicable to the Proposed Action are based on the City of Boston noise limits (see Section 3.4). According to the project Construction Staging Report (MBTA June 2023) the project would be constructed via four stages listed in Table 13.

Table 13. Construction Stages

Stage	Description
Stage 1	Construction Staging Trestle Plan[1]
Stage 2	Plan and Elevation[1]
Stage 3	North Bank Bridge Over Millers River & MBTA Plan and Profile
Stage 4	North Bank Bridge Over Millers River MBTA General Plan and Elevation[1]

Notes:
1 Stage includes pile driving.
Source: MBTA 2023

Construction noise for each stage was calculated using source levels and methods provided in the Federal Highway Administration Roadway Construction Noise Model (RCNM). FTA provides prediction methods for calculating construction noise which are used in this analysis since the City of Boston does not identify specific methods to be used. The analysis conservatively assumes all construction equipment, except for pile driving, for each stage would operate simultaneously at the closest construction location to each receptor point. Pile driving is allowed as long as it occurs during weekdays between the hours of 7:00 a.m. and 6:00 p.m. Table 14 lists the construction equipment that is included in the analysis for each stage. A comparison is made to the background L_{10} plus 5 dB limits for each location to identify potential impacts in Table 15. Based on the results of the construction noise analysis, the project would result in construction noise impacts that would require mitigation.

Table 14. Construction Equipment by Stage

Stage 1	Stage 2	Stage 3	Stage 4
Compressor	Compressor	Compressor	Compressor
Crane	Backhoe	Backhoe	Backhoe
Generator	Paving - Asphalt (Paver + Dump Truck)	Concrete Mixer Truck	Concrete Mixer Truck
Impact Wrench	Compactor (Plate)	Concrete Pump Truck	Concrete Pump Truck
Chipping Gun	Concrete Mixer Truck	Vibratory Concrete Consolidator	Vibratory Concrete Consolidator
Circular Saw	Concrete Pump Truck	Crane	Crane
	Vibratory Concrete Consolidator	Generator	Generator
	Crane	Impact Wrench	Impact Wrench
	Generator	Jackhammer	Front End Loader (Passby)
	Power Tools - Impact Wrench	Front End Loader (Passby)	Paving - Asphalt (Paver + Dump Truck)
	Jackhammer	Paving - Asphalt (Paver + Dump Truck)	Chipping Gun
	Front End Loader (Cyclical)	Chipping Gun	Compactor (Roller)
	Paving - Asphalt (Paver + Dump Truck)	Compactor (Roller)	Flatbed Truck
	Chipping Gun	Circular Saw	Pile Driver (Impact)
	Circular Saw	Flatbed Truck	
	Compactor (Roller)		
	Circular Saw		
	Power Tools - Jackhammer		
	Circular Saw		
	Excavator		
	Flatbed Truck		
	Pile Driver (Impact)		

Source: MBTA 2023

Table 15. Summary of Construction Noise Levels

Receptor (floor)	Land Use	Background dBA L_{10} plus 5 dB	Stage 1 dBA L_{10}	Stage 2 dBA L_{10}	Stage 3 dBA L_{10}	Stage 4 dBA L_{10}
R12(G)	Institutional	75	97	91	78	92
R13(G)	Institutional	76	84	79	90	88
R14(G)	Institutional	83	84	84	106	78
R26(F10)	Institutional	72	78	81	74	81
R26(F2)	Institutional	72	79	81	74	81
R26(F3)	Institutional	72	79	81	74	81
R26(F4)	Institutional	72	78	81	74	81
R26(F5)	Institutional	72	78	81	74	81
R26(F6)	Institutional	72	78	81	74	81
R26(F7)	Institutional	72	78	81	74	81
R26(F8)	Institutional	72	78	81	74	81
R26(F9)	Institutional	72	78	81	74	81
R26(G)	Institutional	72	79	81	74	81
R27(F10)	Institutional	77	87	93	77	82
R27(F11)	Institutional	77	86	92	77	82
R27(F12)	Institutional	77	86	91	77	81
R27(F13)	Institutional	77	85	91	77	81
R27(F2)	Institutional	77	89	103	77	82
R27(F3)	Institutional	77	89	101	77	82
R27(F4)	Institutional	77	89	100	77	82
R27(F5)	Institutional	77	89	98	77	82
R27(F6)	Institutional	77	88	97	77	82
R27(F7)	Institutional	77	88	96	77	82
R27(F8)	Institutional	77	88	95	77	82
R27(F9)	Institutional	77	87	94	77	82
R27(G)	Institutional	77	89	104	77	82

Source: HMMH 2024

6.6 Temporary Construction Vibration Impacts

Temporary construction vibration levels were predicted for the most vibration intensive pieces of equipment that would be used in each project stage, such as pile driving. The analysis conservatively assumes that all buildings are Category III for the damage assessment, see Section 3.5. Annoyance thresholds are 80 VdB for places where people sleep, 83 VdB for institutional uses, and 84 VdB for offices. Construction vibration predictions are provided in Table 16 through Table 21 shows that impacts would occur under all stages and would require mitigation.

Table 16. Stage 1 Heavy Equipment Construction Vibration Levels

Receptor (floor)	Distance (ft)	Pile Driver Construction PPV	Pile Driver Construction VdB	Jackhammer Construction PPV	Jackhammer Construction VdB	Damage Threshold PPV	Annoyance Threshold VdB	Pile Driver Construction Damage	Jackhammer Construction Damage	Pile Driver Construction Annoyance	Jackhammer Construction Annoyance
R12(G)	44.5	0.6382	104.5	0.0147	71.5	0.2	83	IMPACT	None	IMPACT	None
R13(G)	182.7	0.0768	86.1	0.0018	53.1	0.2	83	None	None	IMPACT	None
R14(G)	187.1	0.0742	85.8	0.0017	52.8	0.2	83	None	None	IMPACT	None
R26(F10)	366.6	0.0270	77.0	0.0006	44.0	0.2	80	None	None	None	None
R26(F2)	354.4	0.0284	77.5	0.0007	44.5	0.2	80	None	None	None	None
R26(F3)	355.0	0.0284	77.4	0.0007	44.4	0.2	80	None	None	None	None
R26(F4)	355.8	0.0283	77.4	0.0007	44.4	0.2	80	None	None	None	None
R26(F5)	356.9	0.0281	77.4	0.0006	44.4	0.2	80	None	None	None	None
R26(F6)	358.3	0.0280	77.3	0.0006	44.3	0.2	80	None	None	None	None
R26(F7)	360.0	0.0278	77.2	0.0006	44.2	0.2	80	None	None	None	None
R26(F8)	362.0	0.0276	77.2	0.0006	44.2	0.2	80	None	None	None	None
R26(F9)	364.2	0.0273	77.1	0.0006	44.1	0.2	80	None	None	None	None
R26(G)	354.1	0.0285	77.5	0.0007	44.5	0.2	80	None	None	None	None
R27(F10)	138.2	0.1167	89.7	0.0027	56.7	0.2	84	None	None	IMPACT	None
R27(F11)	145.3	0.1083	89.1	0.0025	56.1	0.2	84	None	None	IMPACT	None
R27(F12)	152.7	0.1006	88.4	0.0023	55.4	0.2	84	None	None	IMPACT	None
R27(F13)	160.3	0.0935	87.8	0.0022	54.8	0.2	84	None	None	IMPACT	None
R27(F2)	101.5	0.1855	93.7	0.0043	60.7	0.2	84	None	None	IMPACT	None
R27(F3)	103.5	0.1802	93.5	0.0042	60.5	0.2	84	None	None	IMPACT	None
R27(F4)	106.3	0.1730	93.1	0.0040	60.1	0.2	84	None	None	IMPACT	None
R27(F5)	110.0	0.1644	92.7	0.0038	59.7	0.2	84	None	None	IMPACT	None
R27(F6)	114.5	0.1549	92.2	0.0036	59.2	0.2	84	None	None	IMPACT	None
R27(F7)	119.6	0.1450	91.6	0.0033	58.6	0.2	84	None	None	IMPACT	None
R27(F8)	125.3	0.1352	91.0	0.0031	58.0	0.2	84	None	None	IMPACT	None
R27(F9)	131.6	0.1257	90.4	0.0029	57.4	0.2	84	None	None	IMPACT	None
R27(G)	100.5	0.1882	93.9	0.0043	60.9	0.2	84	None	None	IMPACT	None

Source: HMMH 2024

Table 17. Stage 2 Construction Vibration Levels

Receptor (floor)	Distance (ft)	Vibratory Roller Construction PPV	Vibratory Roller Construction VdB	Loaded Trucks Construction PPV	Loaded Trucks Construction VdB	Jackhammer Construction PPV	Jackhammer Construction VdB	Damage Threshold PPV	Annoyance Threshold VdB	Vibratory Roller Construction Damage	Loaded Trucks Construction Damage	Jackhammer Construction Damage	Vibratory Roller Construction Annoyance	Loaded Trucks Construction Annoyance	Jackhammer Construction Annoyance
R12(G)	121	0.0198	73.5	0.0072	65.5	0.0033	58.5	0.2	83	None	None	None	None	None	None
R13(G)	493	0.0024	55.1	0.0009	47.1	0.0004	40.1	0.2	83	None	None	None	None	None	None
R14(G)	264	0.0061	63.3	0.0022	55.3	0.0010	48.3	0.2	83	None	None	None	None	None	None
R26(F10)	406	0.0032	57.7	0.0012	49.7	0.0005	42.7	0.2	80	None	None	None	None	None	None
R26(F2)	395	0.0033	58.0	0.0012	50.0	0.0006	43.0	0.2	80	None	None	None	None	None	None
R26(F3)	396	0.0033	58.0	0.0012	50.0	0.0006	43.0	0.2	80	None	None	None	None	None	None
R26(F4)	397	0.0033	58.0	0.0012	50.0	0.0006	43.0	0.2	80	None	None	None	None	None	None
R26(F5)	398	0.0033	58.0	0.0012	50.0	0.0006	43.0	0.2	80	None	None	None	None	None	None
R26(F6)	399	0.0033	57.9	0.0012	49.9	0.0005	42.9	0.2	80	None	None	None	None	None	None
R26(F7)	400	0.0033	57.9	0.0012	49.9	0.0005	42.9	0.2	80	None	None	None	None	None	None
R26(F8)	402	0.0033	57.8	0.0012	49.8	0.0005	42.8	0.2	80	None	None	None	None	None	None
R26(F9)	404	0.0032	57.7	0.0012	49.7	0.0005	42.7	0.2	80	None	None	None	None	None	None
R26(G)	395	0.0033	58.0	0.0012	50.0	0.0006	43.0	0.2	80	None	None	None	None	None	None
R27(F10)	99	0.0266	76.1	0.0096	68.1	0.0044	61.1	0.2	84	None	None	None	None	None	None
R27(F11)	109	0.0232	74.9	0.0084	66.9	0.0039	59.9	0.2	84	None	None	None	None	None	None
R27(F12)	118	0.0204	73.7	0.0074	65.7	0.0034	58.7	0.2	84	None	None	None	None	None	None
R27(F13)	128	0.0181	72.7	0.0066	64.7	0.0030	57.7	0.2	84	None	None	None	None	None	None
R27(F2)	32	0.1465	90.9	0.0530	82.9	0.0244	75.9	0.2	84	None	None	None	IMPACT	None	None
R27(F3)	38	0.1141	88.7	0.0413	80.7	0.0190	73.7	0.2	84	None	None	None	IMPACT	None	None
R27(F4)	45	0.0874	86.4	0.0316	78.4	0.0146	71.4	0.2	84	None	None	None	IMPACT	None	None
R27(F5)	53	0.0680	84.2	0.0246	76.2	0.0113	69.2	0.2	84	None	None	None	IMPACT	None	None
R27(F6)	62	0.0541	82.2	0.0196	74.2	0.0090	67.2	0.2	84	None	None	None	None	None	None
R27(F7)	71	0.0441	80.4	0.0160	72.4	0.0073	65.4	0.2	84	None	None	None	None	None	None
R27(F8)	80	0.0366	78.8	0.0133	70.8	0.0061	63.8	0.2	84	None	None	None	None	None	None
R27(F9)	90	0.0310	77.4	0.0112	69.4	0.0052	62.4	0.2	84	None	None	None	None	None	None
R27(G)	28	0.1728	92.3	0.0625	84.3	0.0288	77.3	0.2	84	None	None	None	IMPACT	IMPACT	None

Source: HMMH 2024

Table 18. Stage 2 Pile Driver Construction Vibration Levels

Receptor (floor)	Distance (ft)	Pile Driver Construction PPV	Pile Driver Construction VdB	Damage Threshold PPV	Annoyance Threshold VdB	Pile Driver Construction Damage	Pile Driver Construction Annoyance
R12(G)	103	0.1808	93.5	0.2	83	None	IMPACT
R13(G)	241	0.0507	82.5	0.2	83	None	None
R14(G)	158	0.0954	88.0	0.2	83	None	IMPACT
R26(F10)	412	0.0227	75.5	0.2	80	None	None
R26(F2)	402	0.0236	75.8	0.2	80	None	None
R26(F3)	402	0.0235	75.8	0.2	80	None	None
R26(F4)	403	0.0235	75.8	0.2	80	None	None
R26(F5)	404	0.0234	75.7	0.2	80	None	None
R26(F6)	405	0.0233	75.7	0.2	80	None	None
R26(F7)	407	0.0231	75.7	0.2	80	None	None
R26(F8)	408	0.0230	75.6	0.2	80	None	None
R26(F9)	410	0.0228	75.5	0.2	80	None	None
R26(G)	401	0.0236	75.8	0.2	80	None	None
R27(F10)	122	0.1400	91.3	0.2	84	None	IMPACT
R27(F11)	130	0.1275	90.5	0.2	84	None	IMPACT
R27(F12)	139	0.1163	89.7	0.2	84	None	IMPACT
R27(F13)	147	0.1065	88.9	0.2	84	None	IMPACT
R27(F2)	79	0.2717	97.1	0.2	84	IMPACT	IMPACT
R27(F3)	81	0.2592	96.6	0.2	84	IMPACT	IMPACT
R27(F4)	85	0.2428	96.1	0.2	84	IMPACT	IMPACT
R27(F5)	89	0.2244	95.4	0.2	84	IMPACT	IMPACT
R27(F6)	95	0.2054	94.6	0.2	84	IMPACT	IMPACT
R27(F7)	101	0.1870	93.8	0.2	84	None	IMPACT
R27(F8)	108	0.1698	93.0	0.2	84	None	IMPACT
R27(F9)	115	0.1541	92.1	0.2	84	None	IMPACT
R27(G)	77	0.2785	97.3	0.2	84	IMPACT	IMPACT

Source: HMMH 2024

Table 19. Stage 3 Construction Vibration Levels

Receptor (floor)	Distance (ft)	Vibratory Roller Construction PPV	Vibratory Roller Construction VdB	Loaded Trucks Construction PPV	Loaded Trucks Construction VdB	Jackhammer Construction PPV	Jackhammer Construction VdB	Damage Threshold PPV	Annoyance Threshold VdB	Vibratory Roller Construction Damage	Loaded Trucks Construction Damage	Jackhammer Construction Damage	Vibratory Roller Construction Annoyance	LOADED TRUCKS Construction ANNOYANCE	JACKHAMMER Construction ANNOYANCE
R12(G)	493	0.0024	55.2	0.0009	47.2	0.0004	40.2	0.2	83	None	None	None	None	None	None
R13(G)	117	0.0207	73.9	0.0075	65.9	0.0035	58.9	0.2	83	None	None	None	None	None	None
R14(G)	20	0.2901	96.8	0.1050	88.8	0.0484	81.8	0.2	83	IMPACT	None	None	IMPACT	IMPACT	None
R26(F10)	791	0.0012	49.0	0.0004	41.0	0.0002	34.0	0.2	80	None	None	None	None	None	None
R26(F2)	785	0.0012	49.1	0.0004	41.1	0.0002	34.1	0.2	80	None	None	None	None	None	None
R26(F3)	785	0.0012	49.1	0.0004	41.1	0.0002	34.1	0.2	80	None	None	None	None	None	None
R26(F4)	786	0.0012	49.1	0.0004	41.1	0.0002	34.1	0.2	80	None	None	None	None	None	None
R26(F5)	786	0.0012	49.1	0.0004	41.1	0.0002	34.1	0.2	80	None	None	None	None	None	None
R26(F6)	787	0.0012	49.1	0.0004	41.1	0.0002	34.1	0.2	80	None	None	None	None	None	None
R26(F7)	788	0.0012	49.0	0.0004	41.0	0.0002	34.0	0.2	80	None	None	None	None	None	None
R26(F8)	788	0.0012	49.0	0.0004	41.0	0.0002	34.0	0.2	80	None	None	None	None	None	None
R26(F9)	789	0.0012	49.0	0.0004	41.0	0.0002	34.0	0.2	80	None	None	None	None	None	None
R26(G)	785	0.0012	49.1	0.0004	41.1	0.0002	34.1	0.2	80	None	None	None	None	None	None
R27(F10)	531	0.0021	54.2	0.0008	46.2	0.0004	39.2	0.2	84	None	None	None	None	None	None
R27(F11)	533	0.0021	54.1	0.0008	46.1	0.0004	39.1	0.2	84	None	None	None	None	None	None
R27(F12)	535	0.0021	54.1	0.0008	46.1	0.0004	39.1	0.2	84	None	None	None	None	None	None
R27(F13)	537	0.0021	54.0	0.0008	46.0	0.0004	39.0	0.2	84	None	None	None	None	None	None
R27(F2)	523	0.0022	54.4	0.0008	46.4	0.0004	39.4	0.2	84	None	None	None	None	None	None
R27(F3)	523	0.0022	54.4	0.0008	46.4	0.0004	39.4	0.2	84	None	None	None	None	None	None
R27(F4)	523	0.0022	54.4	0.0008	46.4	0.0004	39.4	0.2	84	None	None	None	None	None	None
R27(F5)	524	0.0022	54.4	0.0008	46.4	0.0004	39.4	0.2	84	None	None	None	None	None	None
R27(F6)	525	0.0022	54.3	0.0008	46.3	0.0004	39.3	0.2	84	None	None	None	None	None	None
R27(F7)	526	0.0022	54.3	0.0008	46.3	0.0004	39.3	0.2	84	None	None	None	None	None	None
R27(F8)	528	0.0022	54.3	0.0008	46.3	0.0004	39.3	0.2	84	None	None	None	None	None	None
R27(F9)	529	0.0022	54.2	0.0008	46.2	0.0004	39.2	0.2	84	None	None	None	None	None	None
R27(G)	522	0.0022	54.4	0.0008	46.4	0.0004	39.4	0.2	84	None	None	None	None	None	None

Source: HMMH 2024

Table 20. Stage 4 Construction Vibration Levels

Receptor (floor)	Distance (ft)	Vibratory Roller Construction PPV	Vibratory Roller Construction VdB	Loaded Trucks Construction PPV	Loaded Trucks Construction VdB	Jackhammer (Pneumatic Tool) PPV	Jackhammer (Pneumatic Tool) VdB	Damage Threshold PPV	Annoyance Threshold VdB	Vibratory Roller Construction Damage	Loaded Trucks Construction Damage	Jackhammer Construction Damage	Vibratory Roller Construction Annoyance	LOADED TRUCKS Construction ANNOYANCE	JACKHAMMER (Pneumatic Tool) ANNOYANCE
R12(G)	83	0.0346	78.3	0.0125	70.3	0.0058	63.3	0.2	83	None	None	None	None	None	None
R13(G)	137	0.0164	71.9	0.0059	63.9	0.0027	56.9	0.2	83	None	None	None	None	None	None
R14(G)	399	0.0033	57.9	0.0012	49.9	0.0005	42.9	0.2	83	None	None	None	None	None	None
R26(F10)	306	0.0049	61.4	0.0018	53.4	0.0008	46.4	0.2	80	None	None	None	None	None	None
R26(F2)	291	0.0053	62.0	0.0019	54.0	0.0009	47.0	0.2	80	None	None	None	None	None	None
R26(F3)	291	0.0053	62.0	0.0019	54.0	0.0009	47.0	0.2	80	None	None	None	None	None	None
R26(F4)	292	0.0052	62.0	0.0019	54.0	0.0009	47.0	0.2	80	None	None	None	None	None	None
R26(F5)	294	0.0052	61.9	0.0019	53.9	0.0009	46.9	0.2	80	None	None	None	None	None	None
R26(F6)	296	0.0052	61.8	0.0019	53.8	0.0009	46.8	0.2	80	None	None	None	None	None	None
R26(F7)	298	0.0051	61.7	0.0019	53.7	0.0009	46.7	0.2	80	None	None	None	None	None	None
R26(F8)	300	0.0051	61.6	0.0018	53.6	0.0008	46.6	0.2	80	None	None	None	None	None	None
R26(F9)	303	0.0050	61.5	0.0018	53.5	0.0008	46.5	0.2	80	None	None	None	None	None	None
R26(G)	290	0.0053	62.0	0.0019	54.0	0.0009	47.0	0.2	80	None	None	None	None	None	None
R27(F10)	274	0.0058	62.8	0.0021	54.8	0.0010	47.8	0.2	84	None	None	None	None	None	None
R27(F11)	278	0.0057	62.6	0.0021	54.6	0.0009	47.6	0.2	84	None	None	None	None	None	None
R27(F12)	282	0.0055	62.4	0.0020	54.4	0.0009	47.4	0.2	84	None	None	None	None	None	None
R27(F13)	286	0.0054	62.2	0.0020	54.2	0.0009	47.2	0.2	84	None	None	None	None	None	None
R27(F2)	258	0.0063	63.6	0.0023	55.6	0.0011	48.6	0.2	84	None	None	None	None	None	None
R27(F3)	259	0.0063	63.6	0.0023	55.6	0.0011	48.6	0.2	84	None	None	None	None	None	None
R27(F4)	260	0.0063	63.5	0.0023	55.5	0.0010	48.5	0.2	84	None	None	None	None	None	None
R27(F5)	261	0.0062	63.4	0.0022	55.4	0.0010	48.4	0.2	84	None	None	None	None	None	None
R27(F6)	263	0.0061	63.3	0.0022	55.3	0.0010	48.3	0.2	84	None	None	None	None	None	None
R27(F7)	265	0.0061	63.2	0.0022	55.2	0.0010	48.2	0.2	84	None	None	None	None	None	None
R27(F8)	268	0.0060	63.1	0.0022	55.1	0.0010	48.1	0.2	84	None	None	None	None	None	None
R27(F9)	271	0.0059	62.9	0.0021	54.9	0.0010	47.9	0.2	84	None	None	None	None	None	None
R27(G)	257	0.0064	63.6	0.0023	55.6	0.0011	48.6	0.2	84	None	None	None	None	None	None

Source: HMMH 2024

Table 21. Stage 4 Pile Driver Construction Vibration Levels

Receptor (floor)	Distance (ft)	Pile Driver Construction PPV	Pile Driver Construction VdB	Damage Threshold PPV	Annoyance Threshold VdB	Pile Driver Construction Damage	Pile Driver Construction Annoyance
R12(G)	86	0.2375	96	0.2	83	IMPACT	IMPACT
R13(G)	558	0.0144	72	0.2	83	None	None
R14(G)	533	0.0154	72	0.2	83	None	None
R26(F2)	146	0.1072	89	0.2	80	None	IMPACT
R26(F3)	148	0.1057	89	0.2	80	None	IMPACT
R26(F4)	150	0.1036	89	0.2	80	None	IMPACT
R26(F5)	152	0.1009	88	0.2	80	None	IMPACT
R26(F6)	156	0.0978	88	0.2	80	None	IMPACT
R26(F7)	159	0.0943	88	0.2	80	None	IMPACT
R26(F8)	164	0.0906	88	0.2	80	None	IMPACT
R26(F9)	169	0.0867	87	0.2	80	None	IMPACT
R26(G)	146	0.1080	89	0.2	80	None	IMPACT
R27(F10)	274	0.0418	81	0.2	80	None	IMPACT
R27(F11)	278	0.0410	81	0.2	84	None	None
R27(F12)	282	0.0401	80	0.2	84	None	None
R27(F13)	286	0.0392	80	0.2	84	None	None
R27(F2)	258	0.0459	82	0.2	84	None	None
R27(F3)	258	0.0457	82	0.2	84	None	None
R27(F4)	260	0.0454	82	0.2	84	None	None
R27(F5)	261	0.0450	81	0.2	84	None	None
R27(F6)	263	0.0445	81	0.2	84	None	None
R27(F7)	265	0.0439	81	0.2	84	None	None
R27(F8)	268	0.0433	81	0.2	84	None	None
R27(F9)	271	0.0425	81	0.2	84	None	None
R27(G)	257	0.0460	82	0.2	84	None	None

Source: HMMH 2024

7 Mitigation of Noise and Vibration Impacts

The project is predicted to cause construction noise and vibration impacts requiring mitigation. There are no noise or vibration operational impacts predicted from the project. The following sections summarize strategies to address construction noise and vibration impacts from the project.

7.1 Construction Noise Mitigation

Construction noise mitigation includes the preparation of a Noise Control Plan in conjunction with the contractor’s specific equipment, schedule and methods of construction, maximum noise limits for each piece of equipment, prohibition on certain types of equipment during the nighttime hours and engineering noise control measures. An Acoustical Engineer will prepare a Noise Control Plan in conjunction with the contractor’s specific equipment and methods of construction. Key elements to the Plan include:

- Identification of specific sensitive sites where noise monitoring will occur
- Background noise monitoring prior to and during construction
- Construction equipment noise certification testing
- Prohibition of impact pile-drivers during evening and nighttime hours (i.e., 6:00 PM to 10:00 PM and 10:00 PM to 7:00 AM)
- Prohibition of vibratory sheet pile driving and all impact devices including hoe rams, jackhammers and pavement breakers during nighttime hours
- Requirement for ambient-adjusting or manually adjusted backup alarms set to 5 dBA over background levels
- Truck idling limited to five minutes
- Acoustic shield requirement for jackhammers, chainsaws and pavement breakers
- Methods for projecting construction noise levels
- Detailed engineering noise control measures
- Methods for responding to community complaints
- Reporting of noise monitoring results, noise reduction measures used and responses to the community

Noise control measures will be used to reduce noise emissions and potential impact to sensitive receptors where feasible. Many types of construction equipment include diesel engines which can be the most significant noise source. Therefore, reducing engine noise is often a key element to mitigating potential impact. Examples of such noise control measures include:

- Shields, shrouds or intake and exhaust mufflers
- Noise deadening materials adhered to chutes or storage bins
- Temporary noise barriers
- Acoustic enclosures
- Specialized back-up alarms

- Limiting the size of generators and the duration of their use
- Truck routes that minimize exposure to sensitive receptors

7.2 Construction Vibration Mitigation

To mitigate potential vibration impact from construction activities, the following measures will be applied where feasible:

- Using alternative construction methods to minimize the use of impact and vibratory equipment (e.g., pile drivers and compactors)
- Truck routes that minimize exposure to sensitive receptors and maintaining smooth roadway surfaces
- Avoiding nighttime construction in residential neighborhoods
- Continuously monitor construction vibration to identify any vibration levels that may approach damage thresholds and report the levels to the construction contractor and other stakeholders so they can be addressed before damage occurs.

8 References

FTA (Federal Transit Administration). 2018. Transit Noise and Vibration Impact Assessment. https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/118131/transit-noise-and-vibration-impact-assessment-manual-fta-report-no-0123_0.pdf.

HMMH. 2023. MBTA Draw One Noise Modeling Methodology.

MBTA. 2023. North Station Draw One Bridge Replacement Construction Staging Report.

Appendix A Equipment Calibration Sheets

HBK
HOTTINGER BRÜEL & KJÆR

The Hottinger Bruel & Kjaer Calibration Laboratory
3079 Premiere Parkway Suite 120
Duluth, GA 30097
Telephone: 770/209-6907
Fax: 770/447-4033
Web site address: http://www.hbkworld.com

Calibration Certificate Number 1568.01

CERTIFICATE OF CALIBRATION

Certificate No: CAS-616748-H1Q2T7-101

Page 1 of 10

CALIBRATION OF:

Sound Level Meter:	Brüel & Kjær	2245	Serial No: 2245-100483
Microphone:	Brüel & Kjær	4966	Serial No: 3236855
Supplied Calibrator:	Brüel & Kjær	4231	Serial No: 3025161
Software version:	1.1.2.386		

CLIENT:

Harris Miller Miller & Hanson Inc.
700 District Avenue Suite 800
Burlington, MA 01803

CALIBRATION CONDITIONS:

Preconditioning:	4 hours at 23 ± 3 °C
Environment conditions	See actual values in Environmental Condition sections

SPECIFICATIONS:

This document certifies that the instrument as listed under "Model/Serial Number" has been calibrated and unless otherwise indicated under "Final Data", meets acceptance criteria as prescribed by the referenced Procedure. The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95%. Statements of compliance, where applicable, are based on calibration results falling within specified criteria with no reduction by the uncertainty of the measurement. The calibration of the listed instrumentation, was accomplished using a test system which conforms with the requirements of ISO/IEC 17025, ANSI/NCSL Z540-1, and ISO 10012-1. For "as received" and/or "final" data, see the attached page(s). Items marked with one asterisk (*) are not covered by the scope of the current A2LA accreditation This Certificate and attached data pages shall not be reproduced, except in full, without the written approval of the Hottinger Brüel & Kjær Calibration Laboratory-Duluth, GA. Results relate only to the items tested. This instrument has been calibrated using Measurement Standards with values traceable to the National Institute of Standards and Technology, National Measurement Institutes or derived from natural physical constants.

PROCEDURE:

Hottinger Brüel & Kjær Model 3630 Sound Level Meter Calibration System Software 7763 Version 8.6 - DB: 8.60 Test Collection 2245-E, 4966 (BZ-7301).

RESULTS:

As Received Condition	As Received Data	Final Data
_X_ Received in good condition	_X_ Within acceptance criteria	_X_ Within acceptance criteria
___ Damaged - See attached report	___ Outside acceptance criteria	___ Limited test - See attached details
	___ Inoperative	
	___ Data not taken	

Date of Calibration: Jan. 09. 2023

Certificate issued: Jan. 09. 2023

John Avitabile
Calibration Technician

Grant Kennedy
Quality Representative

HBK HOTTINGER BRÜEL & KJÆR
The Hottinger Brüel & Kjær Inc. Calibration Laboratory
3079 Premiere Parkway Suite 120
Duluth, GA 30097
Telephone: 770-209-6907
Fax: 770-447-4033
Web site address: http://www.hbkworld.com

ACCREDITED
Calibration Certificate # 1568.01

CERTIFICATE OF CALIBRATION No.: CAS-616748-H1Q2T7-402 Page 1 of 4

CALIBRATION OF:

Microphone: Brüel & Kjær Type 4966 Serial No. 3236855

CUSTOMER:

Harris Miller Miller & Hanson, Inc
700 District Ave, Ste 800
Burlington, MA 01803

CALIBRATION CONDITIONS:

Environment conditions:	Air temperature:	23.1	°C
	Air pressure:	98.027	kPa
	Relative Humidity:	30	%RH
Applied polarization voltage:	0 Vdc		

SPECIFICATIONS:

This document certifies that the instrument as listed under "Type" has been calibrated and unless otherwise indicated under "Final Data", meets acceptance criteria as prescribed by the referenced Procedure. Statements of compliance, where applicable, are based on calibration results falling within specified criteria with no reduction by the uncertainty of the measurements. The calibration of the listed transducer was accomplished using a test system which conforms to the requirements of ISO/IEC 17025, ANSI/NCSL Z540-1, and guidelines of ISO 10012-1. For "as received" and "final" data, see the attached page(s). Items marked with one asterisk (*) are not covered by the scope of the current A2LA accreditation. This Certificate and attached data pages shall not be reproduced, except in full, without written approval of the Hottinger Brüel & Kjær Calibration Laboratory-Duluth, GA. Results relate only to the items tested. The transducer has been calibrated using Measurement Standards with values traceable to the National Institute of Standards and Technology, National Measurement Institutes or derived from natural physical constants.

PROCEDURE:

The measurements have been performed with the assistance of the Hottinger Brüel & Kjær Inc. Microphone Calibration System B&K 9721 with application software WT9649 and WT9650 version 5.3.0.10 using calibration procedure: 4966 S251-FR01

RESULTS:

- [X] "As Received" Data: Within Acceptance Criteria
- [ ] "As Received" Data: Outside Acceptance Criteria
- [X] "Final" Data : Within Acceptance Criteria
- [ ] "Final" Data : Outside Acceptance Criteria

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k=2$ providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from standards, calibration method, effect of environmental conditions and any short term contribution from the device under calibration.

Date of Calibration: January 11, 2023

Certificate issued: January 11, 2023

Meshaun Hobbs
Calibration Technician

John Avitabile
Quality Representative

HBK HOTTINGER BRÜEL & KJÆR

The Hottinger Brüel & Kjær Inc. Calibration Laboratory
3079 Premiere Parkway Suite 120
Duluth, GA 30097
Telephone: 770-209-6907
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ACCREDITED

Calibration Certificate # 1568.01

CERTIFICATE OF CALIBRATION No.: CAS-616748-H1Q2T7-401 Page 1 of 2

CALIBRATION OF:

Calibrator:	Brüel & Kjær	Type 4231 IEC Class: 1	Serial No.: 3025161

CUSTOMER:

Harris Miller Miller & Hanson, Inc
700 District Ave, Ste 800
Burlington, MA 01803

CALIBRATION CONDITIONS:

Environment conditions:	Air temperature:	24.1	°C
	Air pressure:	98.18	kPa
	Relative Humidity:	31.1	%RH

SPECIFICATIONS:

This document certifies that the acoustic calibrator as listed under "Type" has been calibrated and unless otherwise indicated under "Final Data", meets acceptance criteria as prescribed by the referenced Procedure. Statements of compliance, where applicable, are based on calibration results falling within specified criteria with no reduction by the uncertainty of the measurements. The calibration of the listed transducer was accomplished using a test system which conforms to the requirements of ISO/IEC 17025, ANSI/NCSL Z540-1, and guidelines of ISO 10012-1. For "as received" and "final" data, see the attached page(s). Items marked with one asterisk (*) are not covered by the scope of the current A2LA accreditation. This Certificate and attached data pages shall not be reproduced, except in full, without written approval of the Hottinger Brüel & Kjær Inc. Calibration Laboratory-Duluth, GA. Results relate only to the items tested. The transducer has been calibrated using Measurement Standards with values traceable to the National Institute of Standards and Technology, National Measurement Institutes or derived from natural physical constants. The acoustic calibrator has been calibrated in accordance with the requirements as specified in IEC60942.

PROCEDURE:

The measurements have been performed with the assistance of Hottinger Brüel & Kjær Inc. acoustic calibrator calibration application
Software version 2.3.4 Type 7794 using calibration procedure4231 Complete

RESULTS:

[X] "As Received" Data: Within Acceptance Criteria	[ ] "As Received" Data: Outside Acceptance Criteria
[X] "Final" Data : Within Acceptance Criteria	[ ] "Final" Data : Outside Acceptance Criteria

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$, providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with EA-4/02from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the calibrator under calibration.

Date of Calibration: January 11, 2023

Certificate issued: January 11, 2023

Meshaun Hobbs

Calibration Technician

John Astilik

Grant Kennedy
Quality Representative

HBK
HOTTINGER BRÜEL & KJÆR

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3079 Premiere Parkway Suite 120
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Web site address: http://www.hbkworld.com

ACCREDITED
Calibration Certificate Number 1568.01

CERTIFICATE OF CALIBRATION

Certificate No: CAS-627959-W7J9D6-103

Page 1 of 10

CALIBRATION OF:

Sound Level Meter:	Brüel & Kjær	2270	Serial No: 3011812
Microphone:	Brüel & Kjær	4189	Serial No: 2578555
Preamplifier:	Brüel & Kjær	ZC-0032	Serial No: 6182
Supplied Calibrator:	Brüel & Kjær	4231	Serial No: 3025680
Software version:	BZ7222 Version 4.7.7		

CLIENT:

Harris Miller Miller & Hanson Inc.
700 District Avenue Suite 800
Burlington, MA 01803

CALIBRATION CONDITIONS:

Preconditioning: 4 hours at 23 ± 3 °C

Environment conditions: See actual values in Environmental Condition sections

SPECIFICATIONS:

This document certifies that the instrument as listed under "Model/Serial Number" has been calibrated and unless otherwise indicated under "Final Data", meets acceptance criteria as prescribed by the referenced Procedure. The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95%. Statements of compliance, where applicable, are based on calibration results falling within specified criteria with no reduction by the uncertainty of the measurement. The calibration of the listed instrumentation, was accomplished using a test system which conforms with the requirements of ISO/IEC 17025, ANSI/NCSL Z540-1, and ISO 10012-1. For "as received" and/or "final" data, see the attached page(s). Items marked with one asterisk (*) are not covered by the scope of the current A2LA accreditation This Certificate and attached data pages shall not be reproduced, except in full, without the written approval of the Hottinger Brüel & Kjær Calibration Laboratory-Duluth, GA. Results relate only to the items tested. This instrument has been calibrated using Measurement Standards with values traceable to the National Institute of Standards and Technology, National Measurement Institutes or derived from natural physical constants.

PROCEDURE:

Hottinger Brüel & Kjær Model 3630 Sound Level Meter Calibration System Software 7763 Version 8.6 - DB: 8.60 Test Collection 2270-4189.

RESULTS:

As Received Condition	As Received Data	Final Data
_X_ Received in good condition	_X_ Within acceptance criteria	_X_ Within acceptance criteria
___ Damaged - See attached report	___ Outside acceptance criteria	___ Limited test - See attached details
	___ Inoperative	
	___ Data not taken	

Date of Calibration: 08 Mar. 2023

Certificate issued: 10 Mar. 2023

John Avitabile
Calibration Technician

Grant Kennedy
Quality Representative

HBK
HOTTINGER BRÜEL & KJÆR

The Hottinger Bruel & Kjaer Calibration Laboratory
3079 Premiere Parkway Suite 120
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Web site address: http://www.hbkworld.com

ACCREDITED
Calibration Certificate Number 1568.01

CERTIFICATE OF CALIBRATION

Certificate No: CAS-627959-W7J9D6-104

Page 1 of 10

CALIBRATION OF:

Sound Level Meter:	Brüel & Kjær	2270	Serial No: 3011812
Microphone:	Brüel & Kjær	4189	Serial No: 2009039
Preamplifier:	Brüel & Kjær	ZC-0032	Serial No: 28389
Supplied Calibrator:	Brüel & Kjær	4231	Serial No: 3025680
Software version:	BZ7222 Version 4.7.7		

CLIENT:

Harris Miller Miller & Hanson Inc.
700 District Avenue Suite 800
Burlington, MA 01803

CALIBRATION CONDITIONS:

Preconditioning:	4 hours at 23 ± 3 °C
Environment conditions	See actual values in Environmental Condition sections

SPECIFICATIONS:

This document certifies that the instrument as listed under "Model/Serial Number" has been calibrated and unless otherwise indicated under "Final Data", meets acceptance criteria as prescribed by the referenced Procedure. The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor k = 2 providing a level of confidence of approximately 95%. Statements of compliance, where applicable, are based on calibration results falling within specified criteria with no reduction by the uncertainty of the measurement. The calibration of the listed instrumentation, was accomplished using a test system which conforms with the requirements of ISO/IEC 17025, ANSI/NCSL Z540-1, and ISO 10012-1. For "as received" and/or "final" data, see the attached page(s). Items marked with one asterisk (*) are not covered by the scope of the current A2LA accreditation This Certificate and attached data pages shall not be reproduced, except in full, without the written approval of the Hottinger Brüel & Kjær Calibration Laboratory-Duluth, GA. Results relate only to the items tested. This instrument has been calibrated using Measurement Standards with values traceable to the National Institute of Standards and Technology, National Measurement Institutes or derived from natural physical constants.

PROCEDURE:

Hottinger Brüel & Kjær Model 3630 Sound Level Meter Calibration System Software 7763 Version 8.6 - DB: 8.60 Test Collection 2270-4189.

RESULTS:

As Received Condition	As Received Data	Final Data
_X_ Received in good condition	_X_ Within acceptance criteria	_X_ Within acceptance criteria
___ Damaged - See attached report	___ Outside acceptance criteria	___ Limited test - See attached details
	___ Inoperative	
	___ Data not taken	

Date of Calibration: 08 Mar. 2023

Certificate issued: 10 Mar. 2023

John Avitabile
Calibration Technician

Grant Kennedy
Quality Representative

HBK HOTTINGER BRÜEL & KJÆR
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ACCREDITED
Calibration Certificate # 1568.01

CERTIFICATE OF CALIBRATION No.: CAS-627959-W7J9D6-506 Page 1 of 4

CALIBRATION OF:

Microphone: Brüel & Kjær Type 4189 Serial No. 2578555

CUSTOMER:

Harris Miller Miller & Hanson, Inc
700 District Ave, Ste 800
Burlington, MA 01803

CALIBRATION CONDITIONS:

Environment conditions:	Air temperature:	22.7	°C
	Air pressure:	97.601	kPa
	Relative Humidity:	39	%RH
Applied polarization voltage:	0 Vdc		

SPECIFICATIONS:

This document certifies that the instrument as listed under "Type" has been calibrated and unless otherwise indicated under "Final Data", meets acceptance criteria as prescribed by the referenced Procedure. Statements of compliance, where applicable, are based on calibration results falling within specified criteria with no reduction by the uncertainty of the measurements. The calibration of the listed transducer was accomplished using a test system which conforms to the requirements of ISO/IEC 17025, ANSI/NCSL Z540-1, and guidelines of ISO 10012-1. For "as received" and "final" data, see the attached page(s). Items marked with one asterisk (*) are not covered by the scope of the current A2LA accreditation. This Certificate and attached data pages shall not be reproduced, except in full, without written approval of the Hottinger Brüel & Kjær Calibration Laboratory-Duluth, GA. Results relate only to the items tested. The transducer has been calibrated using Measurement Standards with values traceable to the National Institute of Standards and Technology, National Measurement Institutes or derived from natural physical constants.

PROCEDURE:

The measurements have been performed with the assistance of the Hottinger Brüel & Kjær Inc. Microphone Calibration System B&K 9721 with application software WT9649 and WT9650 version 5.3.0.10 using calibration procedure: 4189-S251-FF-01

RESULTS:

[X] "As Received" Data: Within Acceptance Criteria
[ ] "As Received" Data: Outside Acceptance Criteria
[X] "Final" Data : Within Acceptance Criteria
[ ] "Final" Data : Outside Acceptance Criteria

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k=2$ providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from standards, calibration method, effect of environmental conditions and any short term contribution from the device under calibration.

Date of Calibration: March 10, 2023

Certificate issued: March 10, 2023

Jimmy Smith
Calibration Technician

John Avitabile
Quality Representative

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A2LA ACCREDITED
Calibration Certificate # 1568.01

CERTIFICATE OF CALIBRATION

No.: CAS-627959-W7J9D6-501

Page 1 of 4

CALIBRATION OF:

Microphone: Brüel & Kjær Type 4189 Serial No. 2009039

CUSTOMER:

Harris Miller Miller & Hanson, Inc
700 District Ave, Ste 800
Burlington, MA 01803

CALIBRATION CONDITIONS:

Environment conditions:	Air temperature:	22.7	°C
	Air pressure:	97.601	kPa
	Relative Humidity:	39	%RH
Applied polarization voltage:	0 Vdc		

SPECIFICATIONS:

This document certifies that the instrument as listed under "Type" has been calibrated and unless otherwise indicated under "Final Data", meets acceptance criteria as prescribed by the referenced Procedure. Statements of compliance, where applicable, are based on calibration results falling within specified criteria with no reduction by the uncertainty of the measurements. The calibration of the listed transducer was accomplished using a test system which conforms to the requirements of ISO/IEC 17025, ANSI/NCSL Z540-1, and guidelines of ISO 10012-1. For "as received" and "final" data, see the attached page(s). Items marked with one asterisk (*) are not covered by the scope of the current A2LA accreditation. This Certificate and attached data pages shall not be reproduced, except in full, without written approval of the Hottinger Brüel & Kjær Calibration Laboratory-Duluth, GA. Results relate only to the items tested. The transducer has been calibrated using Measurement Standards with values traceable to the National Institute of Standards and Technology, National Measurement Institutes or derived from natural physical constants.

PROCEDURE:

The measurements have been performed with the assistance of the Hottinger Brüel & Kjær Inc. Microphone Calibration System B&K 9721 with application software WT9649 and WT9650 version 5.3.0.10 using calibration procedure: 4189-S251-FF-01

RESULTS:

- [X] "As Received" Data: Within Acceptance Criteria
- [ ] "As Received" Data: Outside Acceptance Criteria
- [X] "Final" Data : Within Acceptance Criteria
- [ ] "Final" Data : Outside Acceptance Criteria

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k=2$ providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from standards, calibration method, effect of environmental conditions and any short term contribution from the device under calibration.

Date of Calibration: March 10, 2023

Certificate issued: March 10, 2023

Jimmy Smith
Calibration Technician

John Avitabile
Quality Representative

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Calibration Certificate # 1568.01

CERTIFICATE OF CALIBRATION No.: CAS-627959-W7J9D6-106 Page 1 of 2

CALIBRATION OF:

Calibrator: Brüel & Kjær Type 4231 IEC Class: 1 Serial No.: 3025680

CUSTOMER:

Harris Miller Miller & Hanson, Inc
700 District Ave, Ste 800
Burlington, MA 01803

CALIBRATION CONDITIONS:

Environment conditions:

Air temperature:	23	°C
Air pressure:	98.391	kPa
Relative Humidity:	33	%RH

SPECIFICATIONS:

This document certifies that the acoustic calibrator as listed under "Type" has been calibrated and unless otherwise indicated under "Final Data", meets acceptance criteria as prescribed by the referenced Procedure. Statements of compliance, where applicable, are based on calibration results falling within specified criteria with no reduction by the uncertainty of the measurements. The calibration of the listed transducer was accomplished using a test system which conforms to the requirements of ISO/IEC 17025, ANSI/NCSL Z540-1, and guidelines of ISO 10012-1. For "as received" and "final" data, see the attached page(s). Items marked with one asterisk (*) are not covered by the scope of the current A2LA accreditation. This Certificate and attached data pages shall not be reproduced, except in full, without written approval of the Hottinger Brüel & Kjær Inc. Calibration Laboratory-Duluth, GA. Results relate only to the items tested. The transducer has been calibrated using Measurement Standards with values traceable to the National Institute of Standards and Technology, National Measurement Institutes or derived from natural physical constants. The acoustic calibrator has been calibrated in accordance with the requirements as specified in IEC60942.

PROCEDURE:

The measurements have been performed with the assistance of Hottinger Brüel & Kjær Inc. acoustic calibrator calibration application
Software version 2.3.4 Type 7794 using calibration procedure4231 Complete

RESULTS:

[X] "As Received" Data: Within Acceptance Criteria
[X] "Final" Data : Within Acceptance Criteria
[ ] "As Received" Data: Outside Acceptance Criteria
[ ] "Final" Data : Outside Acceptance Criteria

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$, providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with EA-4/02from elements originating from the standards, calibration method, effect of environmental conditions and any short time contribution from the calibrator under calibration.

Date of Calibration: March 9, 2023

Certificate issued: March 9, 2023

John Avitabile
Calibration Technician

Jimmy Smith
Quality Representative

HBK HOTTINGER BRÜEL & KJÆR

The Hottinger Brüel & Kjær Inc. Calibration Laboratory
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ACCREDITED

Calibration Certificate # 1568.01

CERTIFICATE OF CALIBRATION

No.: CAS-627959-W7J9D6-608A

Page 1 of 3

CALIBRATION OF:

Vibration Meter:	B&K	Type	2270/393A03	Serial No.	3011812/65285
Channel 1					

CUSTOMER:

Harris Miller Miller & Hanson, Inc
700 District Avenue
Burlington, MA 01803

CALIBRATION CONDITIONS:

Environment conditions:	Air temperature:	23	°C
	Air pressure:	976	mBars
	Relative Humidity:	33	%RH

SPECIFICATIONS:

This document certifies that the instrument as listed under "Type" has been calibrated and unless otherwise indicated under "Final Data", meets acceptance criteria as prescribed by the referenced Procedure. Statements of compliance, where applicable, are based on calibration results falling within specified criteria with no reduction by the uncertainty of the measurements. The calibration of the listed transducer was accomplished using a test system which conforms with the requirements of ISO/IEC 17025, ANSI/NCSL Z540-1, and guidelines of ISO 10012-1. For "as received" and "final" data, see the attached page(s). Items marked with one asterisk (*) are not covered by the scope of the current A2LA accreditation. This Certificate and attached data pages shall not be reproduced, except in full, without written approval of the Hottinger Brüel & Kjær Inc. Calibration Laboratory-Duluth, GA. Results relate only to the items tested. The transducer has been calibrated using Measurement Standards with values traceable to the National Institute of Standards and Technology, National Measurement Institutes or derived from natural physical constants.

PROCEDURE:

The calibrations were performed according to procedure: 2270/393A03 10Hz-3kHz

RESULTS:

- [X] "As Received" Data: Within Acceptance Criteria
- [ ] "As Received" Data: Outside Acceptance Criteria
- [X] "Final" Data : Within Acceptance Criteria
- [ ] "Final" Data : Outside Acceptance Criteria

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k=2$ providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from standards, calibration method, effect of environmental conditions and any short term contribution from the device under calibration.

Date of Calibration: 3/13/2023

Certificate issued: 3/13/2023

Aundra Welch

Calibration Technician

John Avitabile

Quality Representative

HBK HOTTINGER BRÜEL & KJÆR

The Hottinger Brüel & Kjær Inc. Calibration Laboratory
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ACCREDITED
Calibration Certificate # 1568.01

CERTIFICATE OF CALIBRATION No.: CAS-627959-W7J9D6-608B Page 1 of 3

CALIBRATION OF:

Vibration Meter:	B&K	Type	2270/393A03	Serial No.	3011812/65286
Channel 2					

CUSTOMER:

Harris Miller Miller & Hanson, Inc
700 District Avenue
Burlington, MA 01803

CALIBRATION CONDITIONS:

Environment conditions:	Air temperature:	23	°C
	Air pressure:	976	mBars
	Relative Humidity:	33	%RH

SPECIFICATIONS:

This document certifies that the instrument as listed under "Type" has been calibrated and unless otherwise indicated under "Final Data", meets acceptance criteria as prescribed by the referenced Procedure. Statements of compliance, where applicable, are based on calibration results falling within specified criteria with no reduction by the uncertainty of the measurements. The calibration of the listed transducer was accomplished using a test system which conforms with the requirements of ISO/IEC 17025, ANSI/NCSL Z540-1, and guidelines of ISO 10012-1. For "as received" and "final" data, see the attached page(s). Items marked with one asterisk (*) are not covered by the scope of the current A2LA accreditation. This Certificate and attached data pages shall not be reproduced, except in full, without written approval of the Hottinger Brüel & Kjær Inc. Calibration Laboratory-Duluth, GA. Results relate only to the items tested. The transducer has been calibrated using Measurement Standards with values traceable to the National Institute of Standards and Technology, National Measurement Institutes or derived from natural physical constants.

PROCEDURE:

The calibrations were performed according to procedure: 2270/393A03 10Hz-3kHz

RESULTS:

- [X] "As Received" Data: Within Acceptance Criteria
- [ ] "As Received" Data: Outside Acceptance Criteria
- [X] "Final" Data : Within Acceptance Criteria
- [ ] "Final" Data : Outside Acceptance Criteria

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k=2$ providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from standards, calibration method, effect of environmental conditions and any short term contribution from the device under calibration.

Date of Calibration: 3/13/2023

Certificate issued: 3/13/2023

Aundra Welch

Calibration Technician

John Avitabile

Quality Representative

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Calibration Certificate # 1568.01

CERTIFICATE OF CALIBRATION No.: CAS-627959-W7J9D6-604 Page 1 of 4

CALIBRATION OF:

Accelerometer:	PCB	Type	393A03	Serial No.	65285

CUSTOMER:

Harris Miller Miller & Hanson, Inc
700 District Avenue
Burlington, MA 01803

CALIBRATION CONDITIONS:

Environment conditions:	Air temperature:	21.9	°C
	Air pressure:	980.6	mBars
	Relative Humidity:	40	%RH

SPECIFICATIONS:

This document certifies that the instrument as listed under "Type" has been calibrated and unless otherwise indicated under "Final Data", meets acceptance criteria as prescribed by the referenced Procedure. Statements of compliance, where applicable, are based on calibration results falling within specified criteria with no reduction by the uncertainty of the measurements. The calibration of the listed transducer was accomplished using a test system which conforms with the requirements of ISO/IEC 17025, ANSI/NCSL Z540-1, and guidelines of ISO 10012-1. For "as received" and "final" data, see the attached page(s). Items marked with one asterisk (*) are not covered by the scope of the current A2LA accreditation. This Certificate and attached data pages shall not be reproduced, except in full, without written approval of the Hottinger Bruel & Kjaer Calibration Laboratory-Duluth, GA. Results relate only to the items tested. The transducer has been calibrated using Measurement Standards with values traceable to the National Institute of Standards and Technology, National Measurement Institutes or derived from natural physical constants.

PROCEDURE:

The measurements have been performed with the assistance of Hottinger Brüel & Kjær Accelerometer Calibration System B&K 3629 with application software 5308 version 3.0.1.230 using calibration procedure: 393A03 10Hz-2kHz

RESULTS:

[X] "As Received" Data: Within Acceptance Criteria
[ ] "As Received" Data: Outside Acceptance Criteria
[X] "Final" Data : Within Acceptance Criteria
[ ] "Final" Data : Outside Acceptance Criteria

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from standards, calibration method, effect of environmental conditions and any short term contribution from the device under calibration.

Date of Calibration: 3/9/2023

Certificate issued: 3/10/2023

Aundra Welch

Calibration Technician

Grant Kennedy
Quality Representative

HBK HOTTINGER BRÜEL & KJÆR

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Calibration Certificate # 1568.01

CERTIFICATE OF CALIBRATION

No.: CAS-627959-W7J9D6-606

Page 1 of 4

CALIBRATION OF:

Accelerometer:	PCB	Type	393A03	Serial No.	65286

CUSTOMER:

Harris Miller Miller & Hanson, Inc
700 District Avenue
Burlington, MA 01803

CALIBRATION CONDITIONS:

Environment conditions:	Air temperature:	21.9	°C
	Air pressure:	980.6	mBars
	Relative Humidity:	40	%RH

SPECIFICATIONS:

This document certifies that the instrument as listed under "Type" has been calibrated and unless otherwise indicated under "Final Data", meets acceptance criteria as prescribed by the referenced Procedure. Statements of compliance, where applicable, are based on calibration results falling within specified criteria with no reduction by the uncertainty of the measurements. The calibration of the listed transducer was accomplished using a test system which conforms with the requirements of ISO/IEC 17025, ANSI/NCSL Z540-1, and guidelines of ISO 10012-1. For "as received" and "final" data, see the attached page(s). Items marked with one asterisk (*) are not covered by the scope of the current A2LA accreditation. This Certificate and attached data pages shall not be reproduced, except in full, without written approval of the Hottinger Bruel & Kjaer Calibration Laboratory-Duluth, GA. Results relate only to the items tested. The transducer has been calibrated using Measurement Standards with values traceable to the National Institute of Standards and Technology, National Measurement Institutes or derived from natural physical constants.

PROCEDURE:

The measurements have been performed with the assistance of Hottinger Brüel & Kjær Accelerometer Calibration System B&K 3629 with application software 5308 version 3.0.1.230 using calibration procedure: 393A03 10Hz-2kHz

RESULTS:

[X] "As Received" Data: Within Acceptance Criteria
[X] "Final" Data : Within Acceptance Criteria
[ ] "As Received" Data: Outside Acceptance Criteria
[ ] "Final" Data : Outside Acceptance Criteria

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor *k* =2 providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from standards, calibration method, effect of environmental conditions and any short term contribution from the device under calibration.

Date of Calibration: 3/9/2023

Certificate issued: 3/10/2023

Aundra Welch

Calibration Technician

Grant Kennedy

Quality Representative

HBK HOTTINGER BRÜEL & KJÆR

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3079 Premiere Parkway Suite 120
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ACCREDITED Calibration Certificate # 1568.01

CERTIFICATE OF CALIBRATION No.: CAS-627959-W7J9D6-802 Page 1 of 3

CALIBRATION OF:

Calibration Exiter:	IMI	Type	699B02	Serial No.	2771

CUSTOMER:

Harris Miller Miller & Hanson, Inc
700 District Avenue
Burlington, MA 01803

CALIBRATION CONDITIONS:

Environment conditions:	Air temperature:	22.4	°C
	Air pressure:	980	mBars
	Relative Humidity:	37	%RH

SPECIFICATIONS:

This document certifies that the instrument as listed under "Type" has been calibrated and unless otherwise indicated under "Final Data", meets acceptance criteria as prescribed by the referenced Procedure. Statements of compliance, where applicable, are based on calibration results falling within specified criteria with no reduction by the uncertainty of the measurements. The calibration of the listed transducer was accomplished using a test system which conforms with the requirements of ISO/IEC 17025, ANSI/NCSL Z540-1, and guidelines of ISO 10012-1. For "as received" and "final" data, see the attached page(s). Items marked with one asterisk (*) are not covered by the scope of the current A2LA accreditation. This Certificate and attached data pages shall not be reproduced, except in full, without written approval of the Hottinger Brüel & Kjær Calibration Laboratory-Duluth, GA. Results relate only to the items tested. The transducer has been calibrated using Measurement Standards with values traceable to the National Institute of Standards and Technology, National Measurement Institutes or derived from natural physical constants.

PROCEDURE:

The measurements have been performed with the assistance of Hottinger Brüel & Kjær Accelerometer Calibration System B&K 3629 with application software 5308 version 3.0.1.230 using calibration procedure: 699B02

RESULTS:

- [X] "As Received" Data: Within Acceptance Criteria
- [ ] "As Received" Data: Outside Acceptance Criteria
- [X] "Final" Data : Within Acceptance Criteria
- [ ] "Final" Data : Outside Acceptance Criteria

The reported expanded uncertainty is based on the standard uncertainty multiplied by a coverage factor $k = 2$ providing a level of confidence of approximately 95%. The uncertainty evaluation has been carried out in accordance with EA-4/02 from elements originating from standards, calibration method, effect of environmental conditions and any short term contribution from the device under calibration.

Date of Calibration: 3/7/2023

Certificate issued: 3/8/2023

Grant Kennedy

Calibration Technician

Meshaun Hobbs
Quality Representative