Northern Lights Express Environmental Assessment

Noise and Vibration Technical Report

HMMH Report No. 304250
April 15, 2011

Prepared for:

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1 Introduction and Summary

1.1 Background

The Northern Lights Express (NLX) is a proposed passenger rail project between the Minneapolis Transportation Interchange station in Minneapolis, Minnesota and the Cities of Superior, Wisconsin and Duluth, Minnesota. The 155 mile long rail corridor runs along Highway 65 and Interstate 35 and the existing Burlington Northern Santa Fe (BNSF) Railway tracks. Harris Miller Miller & Hanson Inc. (HMMH) has conducted a noise and vibration impact analysis for the NLX Environmental Assessment, the results of which are presented here.

1.2 Summary

This report describes the methodology used to characterize the existing noise and vibration conditions along the proposed NLX corridor, provides background information on airborne noise and ground-borne vibration issues related to the proposed rail project, discusses the criteria and models used for assessing noise and vibration impact, and presents the impact analysis results, along with mitigation recommendations, where appropriate. The methodology used to assess potential noise and vibration impacts for the project was the Federal Railroad Administration (FRA), October 2005, “High-Speed Ground Transportation Noise and Vibration Impact Assessment,” United States Department of Transportation, Office of Railroad Development.

Section 2 of this Noise and Vibration Technical Report provides an overview of noise and vibration fundamentals. Section 3 provides the applicable noise and vibration impact criteria. Section 4 describes the existing noise and vibration conditions along the project corridor. Section 5 describes the noise and vibration prediction methodology used in the assessment. Section 6 provides a summary of noise and vibration impact results. Section 7 describes recommended mitigation measures. Photographs of the noise and vibration measurement sites are included in Appendix A. Noise measurement results are included in Appendix B.

The NLX trains were assumed to be operating on the existing BNSF mainline track for much of the corridor except four locations where a new track would be installed. In the areas of new track the northbound NLX trains were assumed to be operating on the eastern-most track and the southbound NLX trains were assumed to be operating on the western-most track. Table 1 shows a summary of the noise impact results for the NLX corridor.

There are a total of 61 severe noise impacts and 289 moderate noise impacts. These noise impacts occur mostly at residential locations, but also include schools, churches, parks, and other institutional land uses as shown in Table 1. The noise impacts are caused primarily by the trains sounding the horns as they approach at-grade crossings and not the trains themselves. The proposed mitigation approach is to first establish Quiet Zones at all at-grade crossings near affected noise-sensitive areas. With the implementation of Quiet Zones all but 1 severe moderate impact at a park and 4 residential moderate noise impacts would be eliminated as shown in Table 1.

Table 1. Summary of Noise Impact Results

Alignment	Number of Moderate and Severe Residential Noise Impacts			
	Without Mitigation		With Quiet Zones	
	Moderate	Severe	Moderate	Severe
NLX Alignment	279 Residential, 4 Schools, 4 Churches, 2 Parks	43 Residential, 2 Cemeteries, 2 Schools, 9 Churches, 4 Parks, 1 Daycare	4 Residential	1 Park
Source: Harris Miller Miller & Hanson Inc., 2011				

The results of the vibration impact analysis indicate that there will be vibration impacts at four residential locations. These impacts are primarily caused by the close proximity of the residences to the NLX tracks and the high speed of the NLX trains at 90 mph to 110 mph. Vibration levels typically decrease very rapidly as the distance from the vibration source increases. Figure 8 below shows this trend. The vibration levels from high-speed trains are generally much lower in level than freight trains. One reason for this is the significantly greater weight of a freight locomotive compared to a high-speed train locomotive. Additionally the track standards for a high-speed train system are typically higher than for freight service, resulting in smoother rails with no corrugations or other defects or surface irregularities that lead to higher vibration levels.

2 Environmental Noise and Vibration Basics

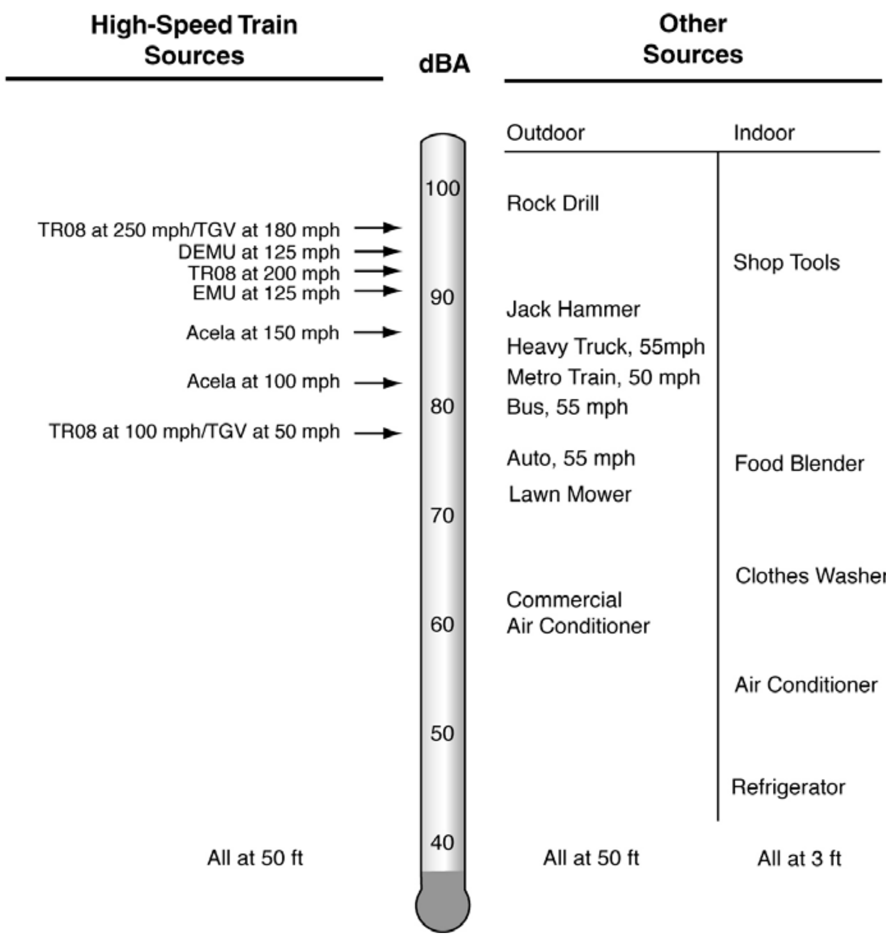
Noise and vibration are frequently among the potential impacts of most concern to residents in the vicinity of a proposed railroad project. Noise and vibration are among the most highly technical and most often misunderstood of the environmental disciplines. Consequently, this report begins with key background information to aid in the understanding of the impact assessments.

2.1 Noise Fundamentals and Descriptors

Noise from a high-speed train (HST) system is analyzed in terms of a “source-path-receiver” framework. The “source” generates noise levels which depend on the type of source (e.g., high-speed train) and its operating characteristics (e.g., speed). The “receiver” is the noise-sensitive land use (e.g., residence, hospital, or school) exposed to noise from the source. In between the source and the receiver is the “path” where the noise is reduced by distance, intervening buildings and topography. Environmental noise impacts are assessed at the receiver. Not all receivers have the same noise-sensitivity. Consequently, noise criteria are established for the various types of receivers.

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 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.

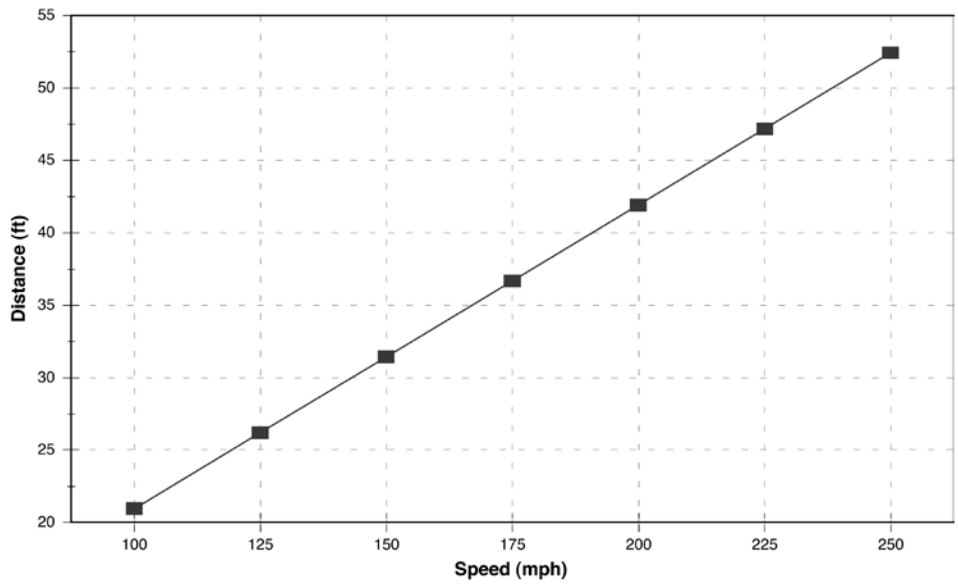
The frequency content of noise is related to the tone or pitch of the sound, and is expressed based on the rate of the air pressure fluctuation in terms of cycles per second (called Hertz and abbreviated as Hz). The human ear can detect a wide range of frequencies from about 20 Hz to 17,000 Hz. However, 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. Typical A-weighted sound levels for high-speed ground transportation and other sources are shown in Figure 1. The figure includes data for the Amtrak Acela train that operates between Boston, MA and Washington D.C. as well as the TR08 German maglev train, the TGV train in France, and electric (EMU) and diesel (DEMU) trains at various speeds.



Source: FRA (2005)

Figure 1. Typical A-Weighted Sound Levels

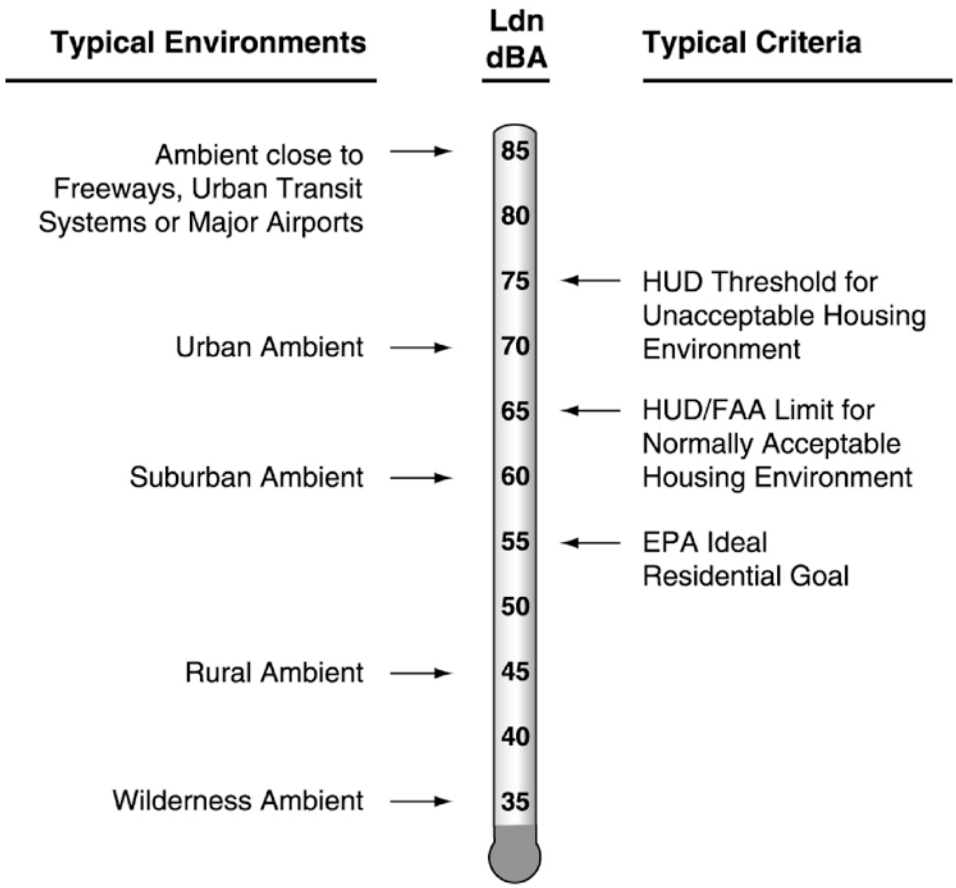
An important characteristic of the noise from high-speed rail systems is the onset rate of the sound signature. Onset rate is the average rate of change of increasing sound pressure level in decibels per second (dB/sec) during a single noise event. The rapid approach of a high-speed train is accompanied by a sudden increase in noise for a receiver near the tracks. Sounds that have faster onset rates can cause more annoyance than sounds with slower variation or steady noise with the same noise level. The relationship between speed and distance defines locations where the onset rate for high-speed train operations may cause surprise or startle. The onset rate of 30 dB/sec is used as the basis for establishing distances within which startle is likely to occur; this is shown in Figure 2 and serves as added information in the impact assessment. For the most part, the potential for increased annoyance is confined to an area very close to the tracks. For example, Figure 2 shows that for the maximum speeds along the NLX corridor of 110 mph high-speed train operations would have the potential for surprise within 22 feet of the track centerline. Any noise-sensitive land use within the distances shown in Figure 2 will be considered to have the potential for increased annoyance.



Source: FRA (2005)

Figure 2. Distance within which Surprise Can Occur for High Speed Trains

Because environmental noise fluctuates from moment to moment, it is common practice to condense all of this information into a single number, called the “equivalent” sound level (Leq). Leq 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 Leq values over a 24-hour period are used to calculate cumulative noise exposure in terms of the Day-Night Sound Level (Ldn). Ldn is the A-weighed Leq 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 Ldn is well correlated with human annoyance, and therefore this descriptor is widely used for environmental noise impact assessment. Figure 3 provides examples of typical noise environments and criteria in terms of Ldn. While the extremes of Ldn are shown to range from 35 dBA in a wilderness environment to 85 dBA in noisy urban environments, Ldn is generally found to range between 55 dBA and 75 dBA in most communities. As shown in Figure 3, this spans the range between an “ideal” residential environment and the threshold for an unacceptable residential environment according to U.S. Federal agency criteria.



Source: FRA (2005)

Figure 3. Examples of Typical Outdoor Noise Exposure

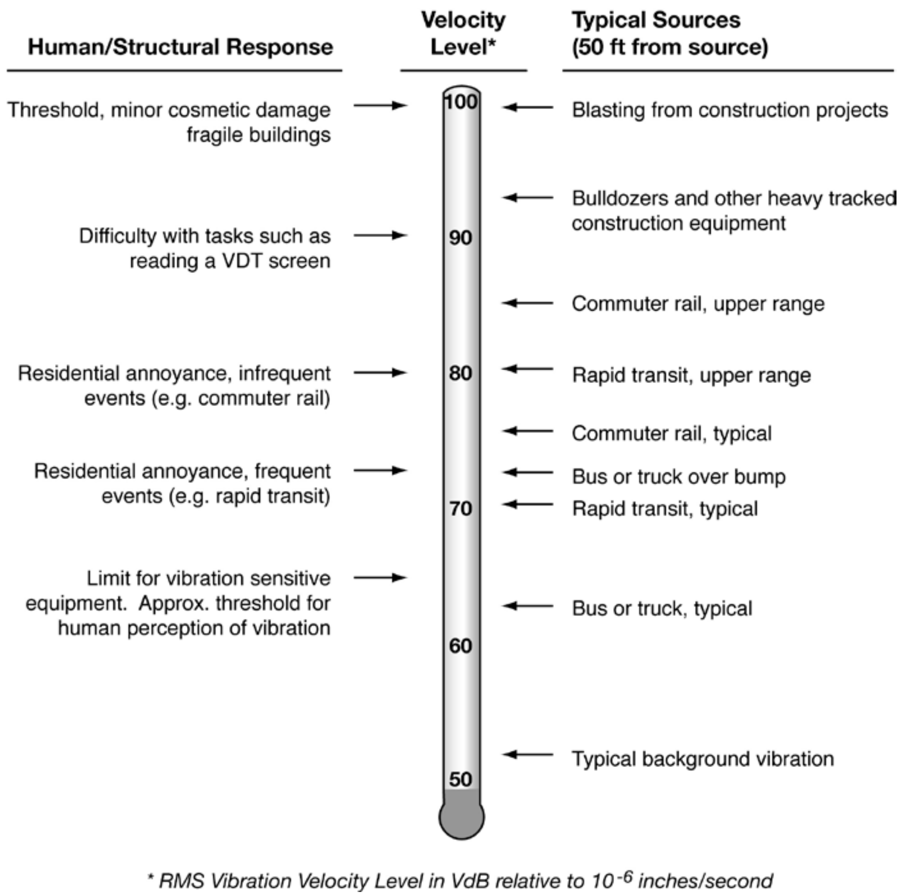
2.2 Ground-Borne Vibration Fundamentals and Descriptors

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 5-100 Hz), velocity is the preferred measure for evaluating ground-borne vibration from surface transportation projects.

Vibration from a HST system is analyzed in terms of a "source-path-receiver" framework. The "source" is the train rolling on the tracks which generates vibration energy transmitted through the supporting structure under the tracks and into the ground. Once the vibration gets into the ground, it propagates through the various soil and rock strata, the "path", to the foundations of nearby buildings, the "receivers." Ground-borne vibrations typically decrease with distance depending on the local geological conditions. A "receiver" is a vibration-sensitive building (e.g., residence, hospital, or school) where the vibrations may cause perceptible shaking of the floors, walls and ceilings and a rumbling sound inside rooms. Not all receivers have the same vibration-sensitivity. Consequently, vibration criteria are established for the various types of receivers.

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 high-speed 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 4 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.



Source: FRA (2005)

Figure 4. Typical Ground-Borne Vibration Levels and Criteria

3 Noise and Vibration Impact Criteria

3.1 Regulatory Requirements

The National Environmental Policy Act (NEPA) and related statutes, regulations and orders mandate consideration of potential impacts on the human and natural environment as part of the decision making process when Federal agencies evaluate proposals to fund or approve major actions. Minnesota and Wisconsin have similar review requirements.

Noise and vibration impact for this project is based on the criteria as defined in the FRA guidance manual (FRA, 2005). The criteria contained in this document are applicable for both NEPA and state documentation.

3.2 Noise Impact Criteria

3.2.1 Operational Noise

The FRA noise impact criteria are founded on well-documented research on community reaction to noise and are based on change in noise exposure using a sliding scale. Although higher levels of train noise are allowed in neighborhoods with high levels of existing noise, smaller increases in total noise exposure are allowed with increasing levels of existing noise. The criteria apply to high-speed train operations as well as to fixed facilities such as storage and maintenance yards, passenger stations and terminals, parking facilities, and substations.

Table 2. Land Use Categories and Metrics for High Speed Train Noise Impact Criteria

Land Use Category	Noise Metric[1] (dBA)	Description of Land Use Category
1	Outdoor $L_{eq}(h)$[2]	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.
2	Outdoor L_{dn}	Residences and buildings where people normally sleep. This category includes homes, hospitals and hotels where a nighttime sensitivity to noise is assumed to be of utmost importance.
3	Outdoor $L_{eq}(h)$[2]	Institutional land uses with primarily daytime and evening use. This category includes schools, libraries and churches where it is important to avoid interference with such activities as speech, meditation and concentration on reading material. Buildings with interior spaces where quiet is important, such as medical offices, conference rooms, recording studios and concert halls fall into this category, as well as places for meditation or study associated with cemeteries, monuments and museums. Certain historical sites, parks and recreational facilities are also included.

[1] Onset-rate adjusted sound levels (L_{eq}, L_{dn}) are to be used where applicable.
[2] L_{eq} for the noisiest hour of train-related activity during hours of noise sensitivity.
Source: Federal Railroad Administration, 2005

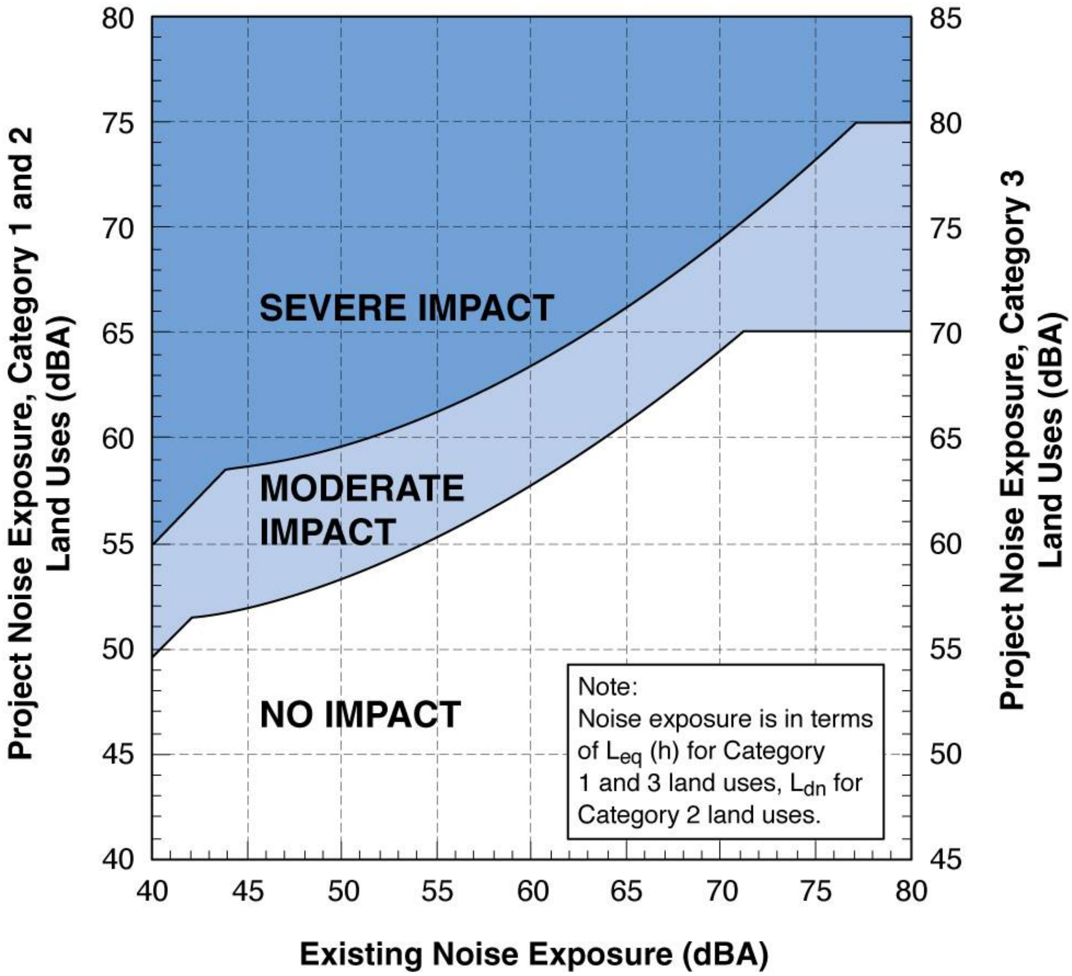
The FRA Noise Impact Criteria group noise sensitive land uses into three categories as described in Table 2. Ldn is used to characterize noise exposure for residential areas (Category 2). For other noise sensitive land uses such as parks and school buildings (Categories 1 and 3), the maximum 1-hour Leq during the facility's operating period is used.

There are two levels of impact included in the FRA criteria. The interpretation of these two levels of impact is 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 noise impact criteria are summarized in Figure 5. The plot shows the relationship between the existing noise exposure and the project noise exposure that would cause moderate impact and severe impact. FRA strongly encourages noise abatement on high-speed train projects, especially where severe noise impacts are identified.



Source: FRA (2005)

Figure 5. Noise Impact Criteria for High-Speed Rail Projects

3.2.2 Noise Effects on Wildlife and Domestic Animals

Noise effects on livestock and wildlife are also considered. Although there are no established criteria relating high-speed train noise and animal behavior, some characteristics of high-speed train noise are similar to those from aircraft overflights and researchers generally agree that such noise can have a disturbing effect on both domestic livestock and wildlife. Some animals get used to noise exposure, while some do not; documented effects range from simply taking notice and changing body position to taking flight in panic. Whether these responses represent a threat to survival of animals remains unclear, although panic flight may result in injuries to animals in rough terrain or in predation of unprotected eggs of birds.

In lieu of established criteria, a limited amount of quantitative noise data relating actual aircraft overflight noise levels to effects provides enough information to develop a screening procedure to identify areas where noise from high speed train operations could affect domestic and wild animals. While a noise descriptor for noise effects on animals has not been universally adopted, recent research indicates the sound exposure level (SEL) is the most useful predictor of responses; this metric represents the sound energy at a receiver location from a single noise event. The criteria used to screen where animals may be affected by high-speed trains are shown in Table 3.

Table 3. Interim Criteria for High-Speed Train Noise Effects on Animals

Animal Category	Class	Noise Metric	Noise Level (dBA)
Domestic	Mammals (Livestock)	SEL	100
	Birds (Poultry)	SEL	100
Wild	Mammals	SEL	100
	Birds	SEL	100
Source: Federal Railroad Administration, 2005			

3.2.3 Construction Noise

Construction noise criteria are based on the guidelines provided in the FRA guidance manual. These criteria, summarized in Table 4 below, are based on land use and time of day and are given in terms of Leq for an eight-hour work shift.

Table 4. Federal Railroad Administration Construction Noise Assessment Criteria

Land Use	8-hour L_{eq}, dBA		Noise Exposure, dBA
	Day	Night	30-day Average
Residential	80	70	75[1]
Commercial	85	85	80[2]
Industrial	90	90	85[2]

[1] In urban areas with very high ambient noise levels (L_{dn} > 65 dB), L_{dn} from construction operations should not exceed existing ambient + 10 dB.
[2] Twenty-four-hour L_{eq}, not L_{dn}.
Source: Federal Railroad Administration, 2005

3.3 Vibration Impact Criteria

3.3.1 Operational Vibration

The FRA ground-borne vibration and noise impact criteria are based on land use and train frequency, as shown in Table 5. There are some buildings, such as concert halls, recording studios and theaters that can be very sensitive to vibration and noise but do not fit into any of the three categories listed in Table 5. Due to the sensitivity of these buildings, they usually warrant special attention during the environmental assessment of a high-speed rail project. Table 6 gives criteria for acceptable levels of ground-borne vibration and noise for various types of special buildings.

It should be noted that there are separate FRA criteria for ground-borne noise: the “rumble” that can be radiated from the motion of room surfaces in buildings due to ground-borne vibration. Although expressed in dBA, which emphasizes the more audible middle and high frequencies, the criteria are set significantly lower than for airborne noise to account for the annoying low-frequency character of ground-borne noise. Because airborne noise tends to mask ground-borne noise for above ground (i.e., at-grade or elevated) rail systems, ground-borne noise criteria are primarily applied to subway operations where airborne noise is not a factor. For the above ground high-speed rail system planned along the proposed rail alignment, ground-borne noise criteria are applied only to buildings that have sensitive interior spaces that are well insulated from exterior noise.

Table 5. Ground-Borne Noise and Vibration Impact Criteria

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

[1] "Frequent Events" is defined as more than 70 vibration events per day.
[2] "Infrequent Events" is defined as fewer than 70 vibration events per day.
[3] 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.
[4] Vibration-sensitive equipment is not sensitive to ground-borne noise.
Source: Federal Railroad Administration, 2005

Table 6. Ground-Borne Noise and Vibration Impact Criteria for Special Buildings

Type of Building or Room	Ground-Borne Vibration Impact (VdB re 1 micro-inch/sec)		Ground-Borne Noise Impact (dB re 20 micro-Pascals)	
	Frequent[1] Events	Infrequent[2] Events	Frequent[1] Events	Infrequent[2] Event
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
Theaters	72 VdB	80 VdB	35 dBA	43 dBA

[1] "Frequent Events" is defined as more than 70 vibration events per day.
[2] "Infrequent Events" is defined as fewer than 70 vibration events per day.
Source: Federal Railroad Administration, 2005

3.3.2 Construction Vibration

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. The Federal Transit Administration (FTA) has established vibration damage criteria (Federal Transit Administration, May 2006, "Transit Noise and Vibration Impact Assessment", United States Department of Transportation, Office of Planning and Environment.) Table 7 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 7. Construction Vibration Damage Criteria

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

[1] RMS velocity in VdB re 1 micro-inch/second.
Source: FTA (2006).

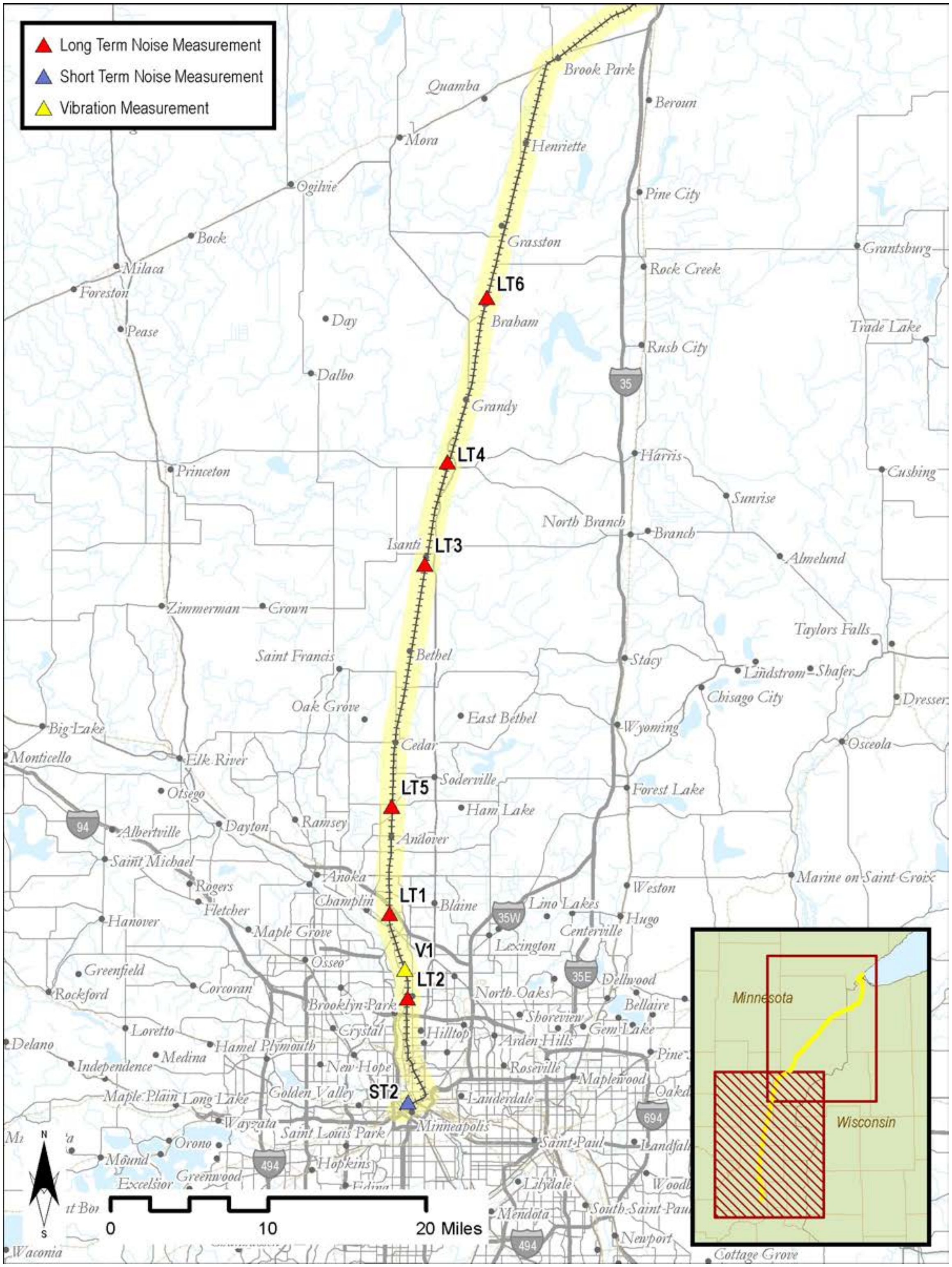
4 Existing Noise and Vibration Conditions

The Northern Lights Express corridor runs from Minneapolis to Duluth, MN. In Minneapolis and the northern suburbs, the corridor is densely populated with a mix of residential land use and some sections of commercial land use. Traveling north, the corridor becomes more rural and passes through several small towns. The corridor often runs directly through the downtown areas of these small cities and towns. At the northern end of the corridor the tracks run through the city of Superior, WI and then cross a bridge to Duluth, MN to the west. Noise-sensitive and vibration-sensitive receptors along the Northern Lights Express corridor largely consist of single-family residences, multi-family residences, schools, churches, hotels, and parks. The majority of the land use along the corridor is Category 2, as defined in section 3 above, which includes all residential land use, along with hotels and other land use with nighttime sensitivity. There are also scattered Category 3 land uses along the corridor. Additionally, the Bayfront Festival Park in Duluth, MN is the only Category 1 land use along the corridor.

The primary sources contributing to the existing noise environment at most locations on the corridor are freight train operations on the BNSF track, including horns that are sounded in the vicinity of at-grade crossings, and motor vehicle traffic on nearby roadways. The Northstar commuter rail service is also a contributing noise source on the BNSF track for locations south of the Coon Creek Junction. All of the existing at-grade crossings along the BNSF track between Minneapolis and Andover, MN are within quiet zones where the locomotive warning horns are not sounded. Other noise sources include aircraft overflights and general residential and commercial activities. BNSF freight and Northstar commuter train operations are the most significant sources of existing ground-borne vibration along the project corridor and represent the dominant sources of existing noise and vibration along the corridor between Minneapolis and Duluth.

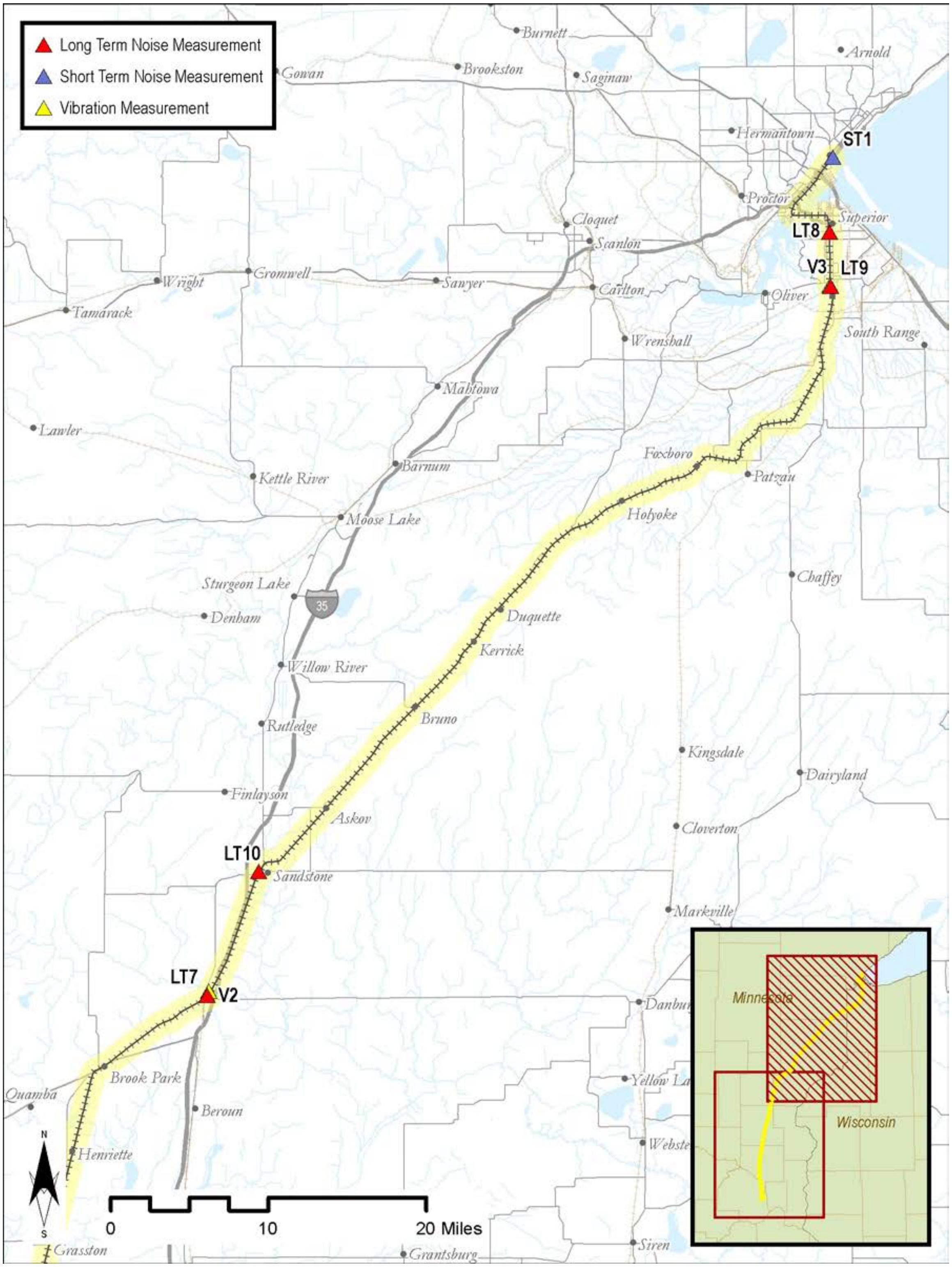
4.1 Noise

Representative sites were chosen in accordance with FRA guidelines to characterize the existing baseline noise conditions at sensitive receptors along the corridor. Noise measurements were conducted at these representative sites during the period from September 13th through September 17th, 2010. The measurement program included both long-term (24-hour) and short-term (1-hour) monitoring of the A-weighted sound level. Ten (10) sites, designated as LT-1 through LT-10, were selected for long-term monitoring and two (2) sites, designated as ST-1 and ST-2, were selected for short-term (one-hour) monitoring. The locations of the measurement sites are shown in Figures 6 and 7 and site photographs are included in Appendix A.



Source: HMMH (2011)

Figure 6. Existing Field Noise and Vibration Measurement Locations



Source: HMMH (2011)

Figure 7. Existing Field Noise and Vibration Measurement Locations

At each of the long-term sites, unattended Larson Davis model 870 or 820 portable, automatic noise monitors were used to continuously sample the A-weighted sound level (with slow response), over one 24-hour period. The noise monitors gathered hourly results, including the maximum sound level (Lmax), the equivalent sound level (Leq) and the statistical percentile sound levels (Ln, denoting the sound level exceeded n-percent of the time). The day-night equivalent sound level (Ldn) was subsequently computed from the hourly Leq data. In addition, the noise monitors at the long-term sites were programmed to collect single-event noise data for train operations, where applicable. At the short-term sites, an attended Larson Davis model 870 or 820 noise monitor was used to obtain the equivalent, A-weighted sound level for 1-minute intervals over one-hour periods. The one-minute Leq data were then combined to obtain the Leq for the 60-minute periods. From the measured hourly Leq data the Ldn values were estimated following procedures in the FRA guidance manual (FRA, 2005).

All the noise measurement equipment described above conforms to 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. In all cases, the measurement microphone was protected by a windscreen, and supported on a tripod at a height of 4 to 6 feet above the ground. Furthermore, the microphone was positioned to characterize the exposure of the site to the dominant noise sources in the area. For example, microphones were located at the approximate setback lines of the receptors from adjacent roads or rail lines and were positioned to avoid acoustic shielding by landscaping, fences or other obstructions.

The results of the existing ambient noise measurements are summarized in Table 8. These results serve as the basis for determining the existing noise conditions at all noise-sensitive receptors along the proposed Northern Lights Express corridor. The results at each long-term and short-term monitoring site are also described below.

Table 8. Summary of Existing Noise Measurements

Measurement Site	Measurement Location Description	Start of Measurement		Meas. Duration (hrs)	Outdoor Noise Exposure	
		Date	Time		Ldn (dBA)	Leq (dBA)
LT-1	1040 105th Avenue - Coon Rapids, MN	09/13/10	11:00	24	62	47
LT-2	6324 Starlite Boulevard - Fridley, MN	09/13/10	13:00	24	67	61
LT-3	902 3rd Avenue SW - Isanti, MN	09/13/10	15:00	24	75	45
LT-4	412 4th Avenue NE - Cambridge, MN	09/13/10	16:00	24	70	45
LT-5	15969 Vale Street - Andover, MN	09/14/10	16:00	24	70	48
LT-6	312 Beechwood Avenue N - Braham, MN	09/14/10	17:00	24	78	49
LT-7	203 3rd Street SE - Hinckley, MN	09/16/10	14:00	24	83	46
LT-8	2309 Butler Avenue - Superior, WI	09/16/10	9:00	24	63	45
LT-9	6425 Butler Avenue - Superior, WI	09/16/10	10:00	24	62	45
LT-10	32 Bush Street - Sandstone, MN	09/16/10	12:00	24	71	44
ST-1	Playfront Park / Bayfront Festival Park - Duluth, MN	09/17/10	12:36	1	61[1]	63
ST-2	Renaissance on the River Apartments - Minneapolis, MN	09/17/10	17:08	1	55[1]	57

[1] Ldn values estimated from 1-hour Leq measurements as per FRA guidance manual (2005).
Source: Harris Miller Miller & Hanson Inc., 2011

Site LT-1: 1040 105th Avenue - Coon Rapids, MN. This site was located in the back yard of a single-family residence north of Coon Creek Junction. The Ldn measured over a 24-hour period at this residence was 62 dBA. The dominant source of noise at this site was freight operations on the BNSF track, as well as noise from community roads and activities.

Site LT-2: 6324 Starlite Boulevard - Fridley, MN. This site was located in the back yard of a single-family residence located south of Coon Creek Junction. The Ldn measured over a 24-hour period at this residence was 67 dBA. Noise was dominated by both freight and passenger train operations on the BNSF track, as well as noise from community roads and activities.

Site LT-3: 902 3rd Avenue SW - Isanti, MN. This site was located in the back yard of a single-family residence located in a residential development. The Ldn measured over a 24-hour period at this residence was 75 dBA. Noise was dominated by freight operations on the BNSF track, as well as noise from community roads and activities.

Site LT-4: 412 4th Avenue NE - Cambridge, MN. This site was located in the back yard of a single-family residence and daycare. The Ldn measured over a 24-hour period at this residence was 70 dBA. Noise was dominated by freight operations on the BNSF track, as well as noise from community roads and activities.

Site LT-5: 15969 Vale Street - Andover, MN. This site was located in the back yard of a multi-family residence located in a residential development consisting of mostly duplex homes. The Ldn measured over a 24-hour period at this residence was 70 dBA. Noise was dominated by freight operations on the BNSF track, as well as noise from community roads and activities.

Site LT-6: 312 Beechwood Avenue N - Braham, MN. This site was located in the back yard of a single family residence. The Ldn measured over a 24-hour period at this residence was 78 dBA. Noise was dominated by freight operations on the BNSF track, as well as noise from community roads and activities.

Site LT-7: 203 3rd Street SE - Hinckley, MN. This site was located in the back yard of a single family residence. The Ldn measured over a 24-hour period at this residence was 83 dBA. Noise was dominated by freight operations on the BNSF track, as well as noise from community roads and activities.

Site LT-8: 2309 Butler Avenue - Superior, WI. This site was located in the back yard of a single family residence. The Ldn measured over a 24-hour period at this residence was 63 dBA. Noise was dominated by freight operations on the BNSF track and railroad yard, as well as noise from community roads and activities.

Site LT-9: 6425 Butler Avenue - Superior, WI. This site was located in the back yard of a single family residence. The Ldn measured over a 24-hour period at this residence was 62 dBA. Noise was dominated by freight operations on the BNSF track and railroad yard, as well as noise from community roads and activities.

Site LT-10: 32 Bush Street - Sandstone, MN. This site was located in the back yard of a single family residence. The Ldn measured over a 24-hour period at this residence was 71 dBA. Noise was dominated by freight operations on the BNSF track, as well as noise from community roads and activities.

Site ST-1: Playfront Park / Bayfront Festival Park - Duluth, MN. This site was at the northwest edge of Playfront Park located on W Railroad Street near Bayfront Festival Park. The Leq measured over a one-hour period at this park was 63 dBA. The dominant sources of noise at this site were from traffic on Interstate 35 and local roadways. Noise from tourist passenger train operations and playground and community activities also contributed to the nose environment at this site.

Site ST-2: Renaissance on the River Apartments - Minneapolis, MN. This site was at the southeast side of a multi-family residential building located in the Renaissance on the River Apartments complex at 21 4th Avenue N. The Leq measured over a one-hour period at this residence was 57 dBA. Passenger train operations, as well as noise from aircraft over flights and local roadways and other community activities contributed to the noise environment at this site.

4.2 Vibration

To characterize the existing baseline vibration conditions at sensitive receptors along the corridor, direct field measurements were conducted during the period from September 13th through September 17th, 2010. The measurement program consisted of measurements of vibration levels during train operations in representative areas along the project corridor. Three sites were selected to represent the existing vibration conditions generated by train operations along the alignment. At each site vibration levels were measured at six different distances from the track simultaneously in order to establish the decrease in vibration level with distance. The locations of these vibration measurement sites are shown in Figures 6 and 7 above and site photographs are included in Appendix A. Table 9 summarizes the existing vibration measurement sites and is followed by further description of the sites.

Table 9. Summary of Existing Vibration Measurements

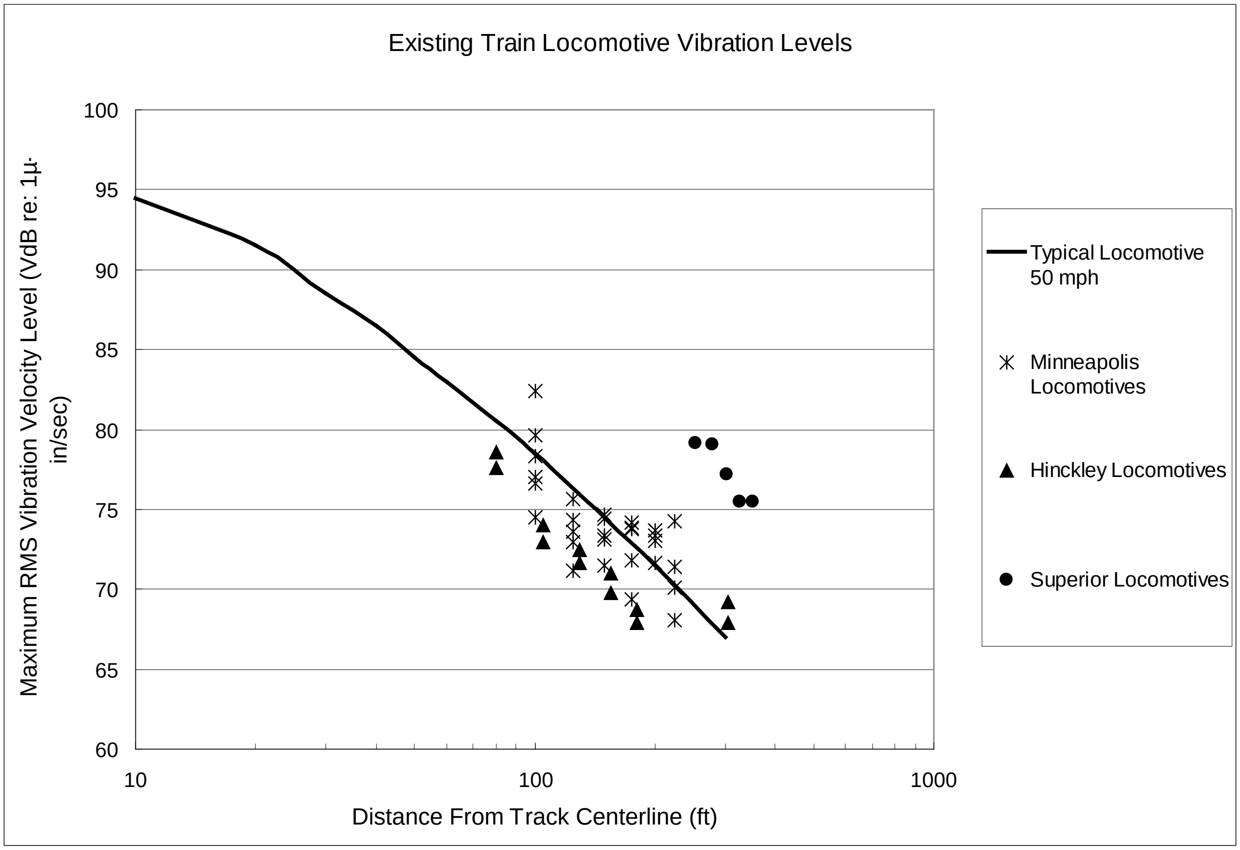
Measurement Site	Measurement Location Description	Date	Event Type	Number of Events
V-1	78th Way NE and Hickory Street NE - Fridley, MN	09/14/10	Freight	5
V-2	1st Street NE and Power Avenue N - Hinckley, MN	09/16/10	Freight	2
V-3	64th Street and Butler Avenue - Superior, WI	09/17/10	Freight	2
Source: Harris Miller Miller & Hanson Inc., 2011				

Site V-1: Fridley, MN. This site was located at the corner of 78th Way NE and Hickory Street NE near commercial/industrial buildings south of Coon Creek Junction. Freight and passenger operations occur on this section of the track, but only freight operation vibration levels were measured at this site. The distance from the first accelerometer to the track centerline was 100 feet.

Site V-2: Hinckley, MN. This site was at the corner of 1st Street NE and Power Avenue N located near a church and high school. Freight operation vibration levels were measured at this site. The distance from the first accelerometer to the track centerline was 80 feet.

Site V-3: Superior, WI. This site was at the corner of 64th Street and Butler Avenue located in a residential area. Freight operation vibration levels were measured at this site. The distance from the first accelerometer to the track centerline was 250 feet.

The ground vibration measurements at the above sites were made with high-sensitivity accelerometers mounted in the vertical direction on either paved surfaces, or on top of steel stakes driven into soil. The acceleration signals were measured using PCB model 393A and 393C accelerometers and recorded on a TEAC model LX-110 16-channel digital recorder. The results of the measurements are shown in Figure 8 where ground vibrations from locomotives measured along the corridor are compared with the generalized vibration curve in Figure 10-1 of the FTA guidance manual (FTA, 2006). Each data point identifies the vibration level measured at a specific distance from the track centerline. The measured vibration levels were adjusted to 50 mph for a site-to-site comparison. The overall vibration levels of locomotives measured in Minneapolis and Hinckley are very near the typical FTA locomotive curve. Some data points in Hinckley fall 2 to 3 dB below the typical curve. The vibration levels in Superior all fall approximately 10 dB above the curve. This was due to the presence of a turnout in the vicinity of the accelerometers. The FTA guidance manual states that vibration levels nearby a crossover or turnout may be increased by up to 10 dB, which agrees with the measurement data. The vibration data found from locomotives measured along the corridor support the general trend of typical locomotives in the FTA guidance manual shown as a bold line in Figure 8. The results indicate that the FTA curve does represent an average of the data, thereby validating the use of it for estimating the existing impact conditions.



Source: HMMH (2011)

Figure 8. Measured Ground-Borne Vibration Levels

5 Methodology for Assessment of Noise and Vibration Impacts

This section summarizes the models used to project future noise and vibration levels for potential sources of community impact related to the Northern Lights Express rail project. The projection models for both noise and vibration are described below.

5.1 Rail Noise

The primary components of wayside noise from train operations on the NLX corridor are locomotive warning horns sounding as trains approach at-grade crossings, wheel/rail noise, which results from the steel wheels rolling on steel rails, and power car (locomotive) noise, which results from the diesel engine. The projection of wayside noise from train operations was carried out using the models specified in the FRA guidance manual and the FTA guidance manual, with the following assumptions:

- The predictions assumed that NLX trains would consist of one locomotive and 3 passenger cars.

- The lengths of the locomotive and passenger cars respectively were assumed to be 68-feet and 85 feet. Because a specific vehicle technology has not been determined at this time, these typical lengths were assumed for the noise modeling analysis. For reference these lengths are the same as the Northstar Commuter Rail vehicles.

- The operating times for the proposed service would include the first northbound train leaving Minneapolis at 7:05 AM and the last train arriving in Duluth at 12:29 AM. Southbound trains would begin departing from Duluth at 5:10 AM and the last train would arrive in Minneapolis at 11:55 PM. There would be a total of eight trains traveling in each direction per day. The same consists of one locomotive and three-cars would operate throughout the day.

- The analysis assumed that the NLX trains follow the speed profile provided in the report: NLX Technical Memorandum: Functional Analysis of Routes 9, 11 and 11A (December, 2010), prepared by Transportation Economics & Management Systems, Inc. NLX train speed profile data from Exhibit 6-4 of that document was used in this analysis. Speeds were interpolated every 1/10 mile to provide more accurate results. The maximum speed along the corridor is 110 mph.

- The noise analysis included noise from locomotive warning horns at grade crossings without quiet zones. Locomotive warning horns were assumed to generate a maximum sound level of 110 dBA at 50 feet to the side of the tracks and would be sounded starting no further than ¼ mile from any crossing. Crossing bells were assumed be sounded at all gated crossings and to generate a sound level of 73 dBA at 50 feet and would be sounded before and after each train pass-by for a total duration of 30 seconds.

- The noise analysis followed the general noise assessment procedures outlined in the FRA guidance manual (FRA, 2005).

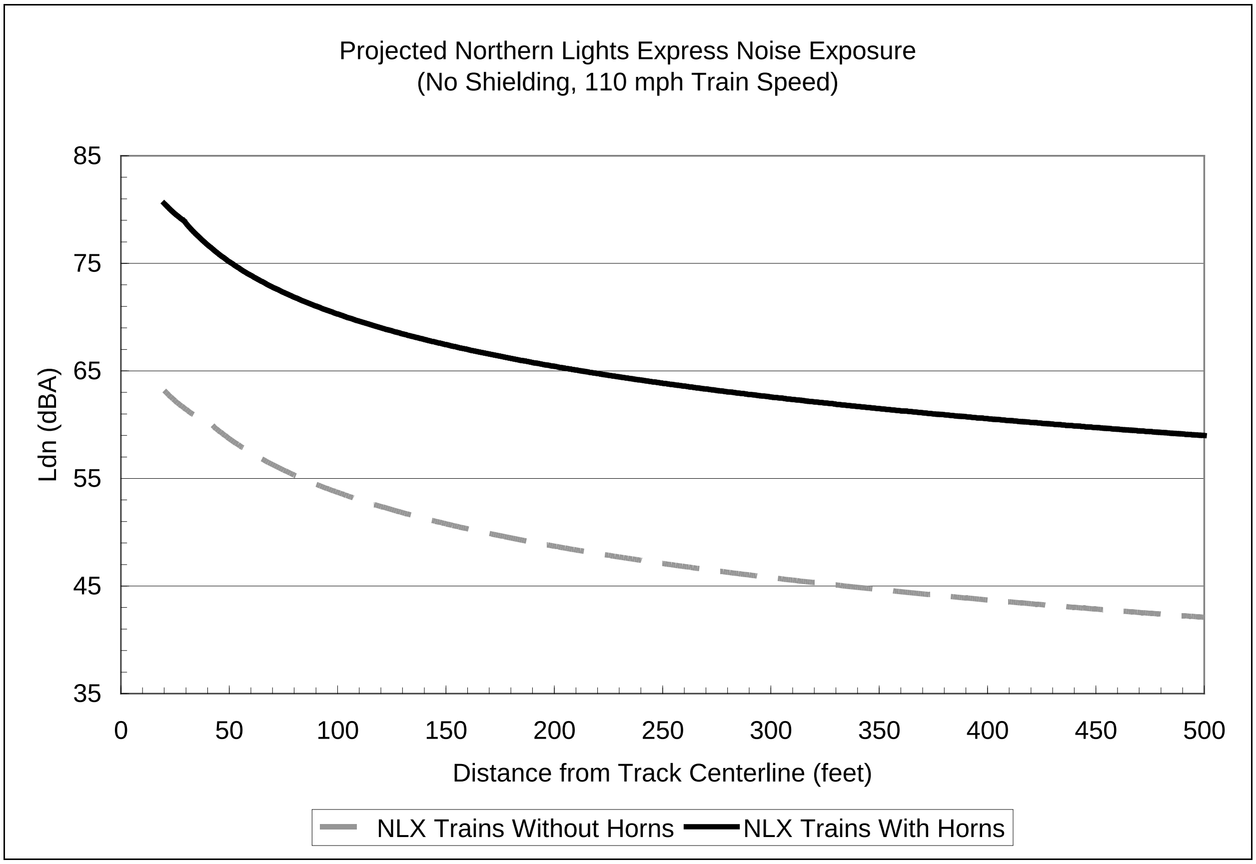
- The noise analysis was based on the reference parameters for a steel-wheeled fossil fuel vehicle as defined in Table 4-3 in the FRA guidance manual (FRA, 2005).

- Wheel impacts at turnouts at the four locations where new track will be installed are assumed to cause localized increases in noise of 6 dBA. In further stages of design when all turnout and crossover locations have been determined the localized increase in noise will be applied throughout the corridor.

- The noise analysis assumed that there will be no change to the existing freight train operations along the corridor.

- The noise analysis assumed that all existing quiet zones throughout the corridor will remain in place and that NLX trains will not sound horns at crossings where the freight trains currently do not sound horns. All at-grade crossings between Minneapolis, MN and Andover, MN are currently in quiet zones.

The projected noise exposure in terms of Ldn at unshielded community locations from NLX operations are shown in Figure 9 as a function of distance for the maximum train speed of 110 mph. These results show that the highest noise levels occur when train horns are sounded.



Source: HMMH (2011)

Figure 9. Projected NLX Noise Exposure vs. Distance

5.2 Ground-borne Vibration

The potential vibration impact from high-speed rail operations was assessed on an absolute basis using the FRA criteria. The following factors were used in determining potential vibration impacts along the proposed rail alignment:

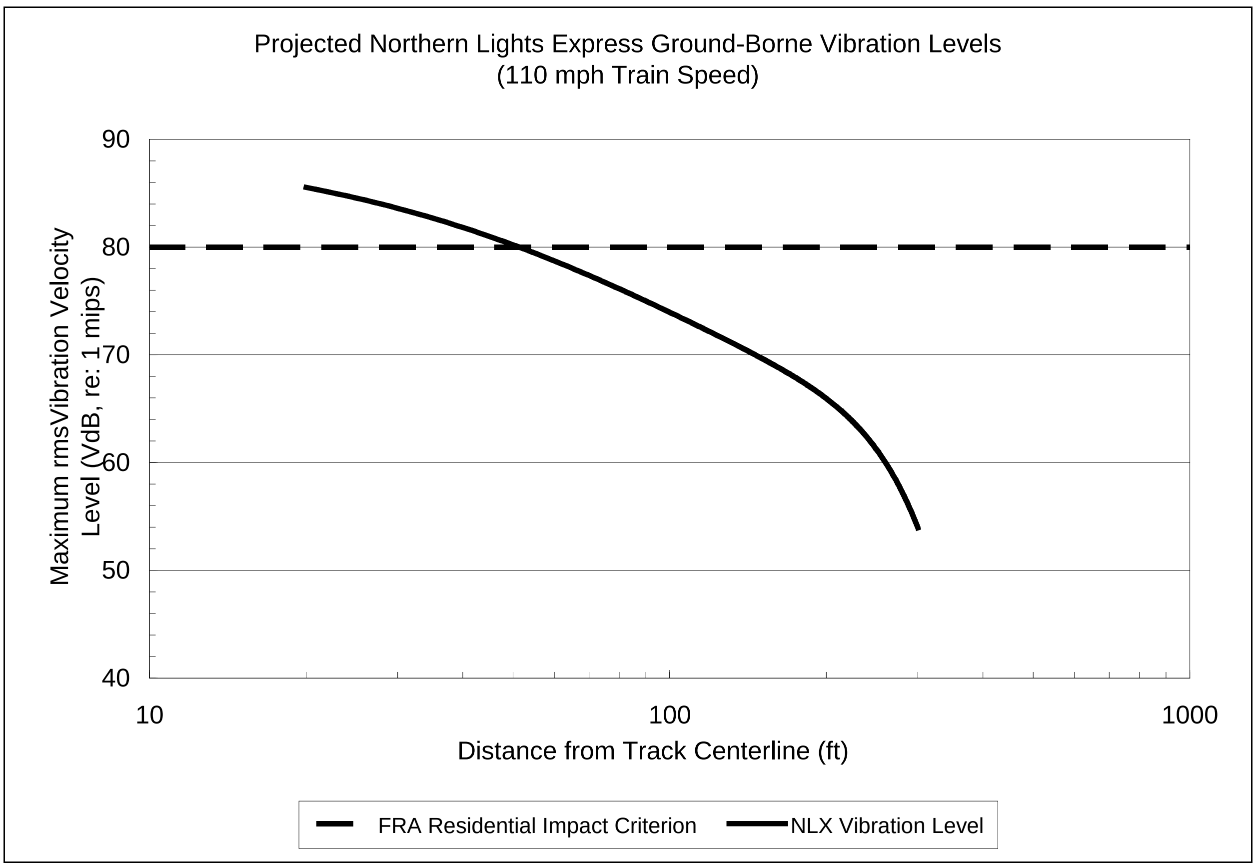
- Existing ground-borne vibration measurements were conducted at three sites along the corridor near sensitive receptors. These measurement results were compared with the typical locomotive curve in the FTA guidance manual as discussed in section 4. From this curve existing overall vibration levels were modeled at all sensitive receptor locations along the corridor for comparison with projected NLX vibration levels.

- The existing vibration conditions in the corridor south of Coon Creek Junction were assumed to be in the category of a “Moderately Used Rail Corridor”, and north of that location were assumed to be in the category of an “Infrequently Used Rail Corridor”, as defined in the FRA guidance manual.

- The vibration analysis followed the general vibration assessment procedures outlined in the FRA guidance manual. The projected vibration levels were assumed to follow the generalized ground-borne vibration curve for steel-wheeled vehicle at grade in Figure 8-1 of the FRA guidance manual.

- The number of daily NLX vibration events is fewer than 70 and falls into the category of “Infrequent Events” as defined by the FRA guidance manual in Table 5 above.
- The analysis assumed that the NLX trains follow the speed profile provided in the report: NLX Technical Memorandum: Functional Analysis of Routes 9, 11 and 11A (December, 2010), prepared by Transportation Economics & Management Systems, Inc. NLX train speed profile data from Exhibit 6-4 of that document was used in this analysis. Speeds were interpolated every 1/10 mile to provide more accurate results. The maximum speed along the corridor is 110 mph.
- Wheel impacts at turnouts at the four locations where new track will be installed are assumed to cause a localized increase in vibration of 10 dBA. In further stages of design when all turnout and crossover locations have been determined the localized increase in vibration will be applied throughout the corridor.
- The vibration analysis assumes that there will be no change to the existing freight train operations along the corridor.

The projected maximum ground-borne vibration levels from NLX operations are provided in Figure 10 as a function of distance for the maximum train speed of 110 mph.



Source: HMMH (2011)

Figure 10. Projected NLX Vibration Level vs. Distance

5.3 Construction Noise

Construction noise varies greatly depending on the construction process, type and condition of equipment used, and layout of the construction site. Many of these factors are traditionally left to the contractor's discretion, which makes it difficult to accurately estimate levels of construction noise. Overall, construction noise levels are governed primarily by the noisiest pieces of equipment. For most construction equipment, the engine, which is usually diesel, is the dominant noise source. This is particularly true of engines without sufficient muffling. For special activities such as impact pile driving and pavement breaking, noise generated by the actual process dominates.

Projecting construction noise requires a construction scenario of the equipment likely to be used and the average utilization factors or duty cycles (i.e., the percentage of time during operating hours that the equipment operates under full power during each phase). Using the typical sound emission characteristics, it is then possible to estimate Leq or Ldn at various distances from the construction site. The noise impact assessment for a construction site is based on:

- An estimate of the type of equipment that will be used during each phase of the construction and the average daily duty cycle for each category of equipment,
- Typical noise emission levels for each category of equipment, and
- An estimate of noise attenuation as a function of distance from the construction site.

Construction noise estimates are always approximate because of the lack of specific information available at the time of the environmental assessment. Decisions about the procedures and equipment to be used are made by the contractor. Project designers usually try to minimize constraints on how the construction will be performed and what equipment will be used so that contractors can perform construction in the most cost effective manner.

Based on a typical construction scenario for ballast-and-tie track construction, an 8-hour Leq of 88 dBA should be expected at a distance of 50 feet from the geometric center of the work site. With at-grade track construction, the duration of the activities at a specific location along the alignment will be relatively limited, usually a matter of several weeks. As a result, even when there may be noise impacts, the limited duration of the construction can mean that mitigation is not cost effective.

6 Noise and Vibration Impact Assessment

A noise and vibration impact assessment was conducted based on the criteria discussed in section 3 and the methodology, data, and assumptions discussed in section 5 above. The results of the project impacts are discussed below.

The NLX trains were assumed to be operating on the existing BNSF mainline track for much of the corridor from Minneapolis to Duluth except four locations where a new track would be installed. In the areas of new track the northbound NLX trains were assumed to be operating on the eastern-most track and the southbound NLX trains were assumed to be operating on the western-most track. The locations of new track include a new double track section through the Minneapolis Junction, a new third main track approximately 30 feet to 50 feet to the west of the existing main from Minnesota State Highway 610 to Coon Rapids, MN, a new second track 15 feet to 30 feet to the west of the existing main from Isanti, MN to Hinckley, MN, and a new second track 15 feet to the east of the existing track in Superior, WI. Additionally, multiple siding tracks along the corridor would be extended; however, no NLX trains were assumed to operate on any sidings. The noise analysis assumed there would be no changes in operations or shifts in the location of any existing freight traffic.

6.1 Operational Noise Impact

The results of the noise analysis indicate that there would be 43 residential (Category 2), and 18 institutional (Category 3) severe noise impacts in addition to 279 residential, and 10 institutional moderate noise impacts from the NLX trains. There is no noise impact projected at Bayfront Festival Park in Duluth, MN, the only Category 1 land use along the corridor. Table 10 provides detailed results within separate communities for the impacted receivers. For impacted receivers the table provides the location by mile post along the alignment (mile post 0 corresponds to Minneapolis), range of train speeds, distance from the NLX track centerline, existing noise level and noise impact criteria, predicted NLX sound level as well as total future noise level and increase above existing, and the number of noise impacts. The results for Category 2 and 3 receptors are listed separately in the table. For communities with no noise impacts the projected levels and other information are provided for the closest residential receptor to the NLX track. Figures 11 through 15 below show the locations of the noise impacts along the corridor.

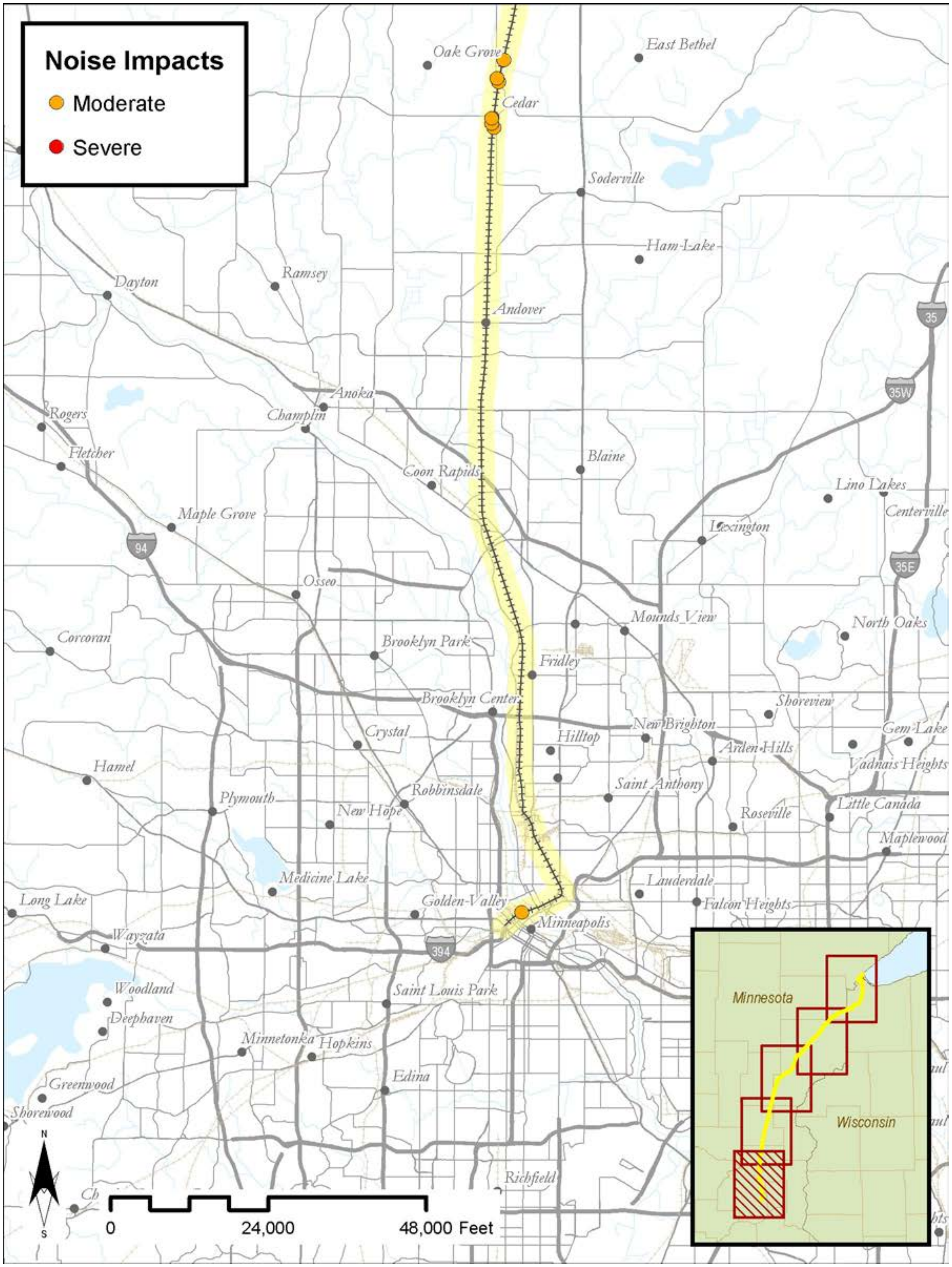
In Minneapolis between mile posts 0-5 there is one multi-family residential building, consisting of 4 residences, predicted to have moderate noise impact. These noise impacts are due to the close proximity of the proposed alignment to the buildings, approximately 30 feet away. Trains currently do not sound their horns in this area. In Braham, MN there is one park with severe noise impact due to the proximity of the proposed alignment. All of the other noise impacts along the NLX corridor are caused primarily by the sounding of locomotive warning horns as trains approach at-grade crossings.

Table 10. Noise Impact Summary

Receptor Location	Land Use Category	Distance to NLX Track (ft)	Mile Post	NLX Train Speed (mph)	Existing Noise Level[1]	NLX Project Noise Level[1]			Total Noise Level[1]	Noise Level Increase[1]	Number of Impacts[3]	
						Predicted[2]	Impact Criteria: Moderate	Impact Criteria: Severe			Moderate	Severe
Minneapolis	Cat. 2	29	0-5	60	55	57	55	61	59	4	4	0
Fridley	Cat. 2	61[4]	5-11	79[4]	67[4]	54[4]	62[4]	68[4]	67[4]	0[4]	0	0
Coon Rapids	Cat. 2	95[4]	11-16	71[4]	62[4]	51[4]	59[4]	64[4]	62[4]	0[4]	0	0
Andover	Cat. 2	133-221	16-30	90	75	65-67	65	73	75-76	0-1	7	0
	Cat. 3	237	16-30	90	45	63	57	64	63	18	1 School	0
Bethel	Cat. 2	116-215	30-35	90	75	66-70	65	73	75-76	1	7	0
	Cat. 3	473	30-35	90	45	61	57	64	61	16	1 Church	0
Isanti	Cat. 2	98-119	35-37	108-110	75	65-68	65	73	75-76	1	22	0
	Cat. 3	288	35-37	110	45	63	57	64	63	19	1 Church	0
Cambridge	Cat. 2	82-396	37-46	20-107	70	64-69	64	69	71-73	1-3	53	0
	Cat. 3	80-441	37-46	20-34	45	64-74	57	64	64-74	19-29	0	2 Churches 1 Cemetery, 1 Daycare
Stanchfield	Cat. 2	85-146	46-53	109-110	70-78	66-67	64-65	69-75	72-78	0-2	11	0
	Cat. 3	101-127	46-53	110	45-49	65-68	57-58	64	65-68	17-23	0	1 Cemetery, 2 Churches
Braham	Cat. 2	96	53-54	110	78	67	65	75	78	0	12	0
	Cat. 3	10-146	53-54	110	49	64-82	58	64	64-82	16-33	1 Park	1 Park
Grasston	Cat. 2	98-116	54-60	110	78	66	65	75	78	0	2	0
Henriette	Cat. 2	86-146	60-65	110	78	67-71	65	75	78-79	0-1	11	0
Brook Park	Cat. 2	52-73	65-73	87-105	83	66-74	65	75	83-84	0-1	4	0
Hinckley	Cat. 2	59-383	73-79	20-109	83	66-81	65	75	83-85	0-2	36	10
	Cat. 3	52-250	73-79	20	46	72-83	57	64	72-83	26-37	0	1 School, 3 Churches
Sandstone	Cat. 3	79-375	79-88	75-90	45	59-71	57	64	59-71	15-26	1 School, 1 Church	2 Parks

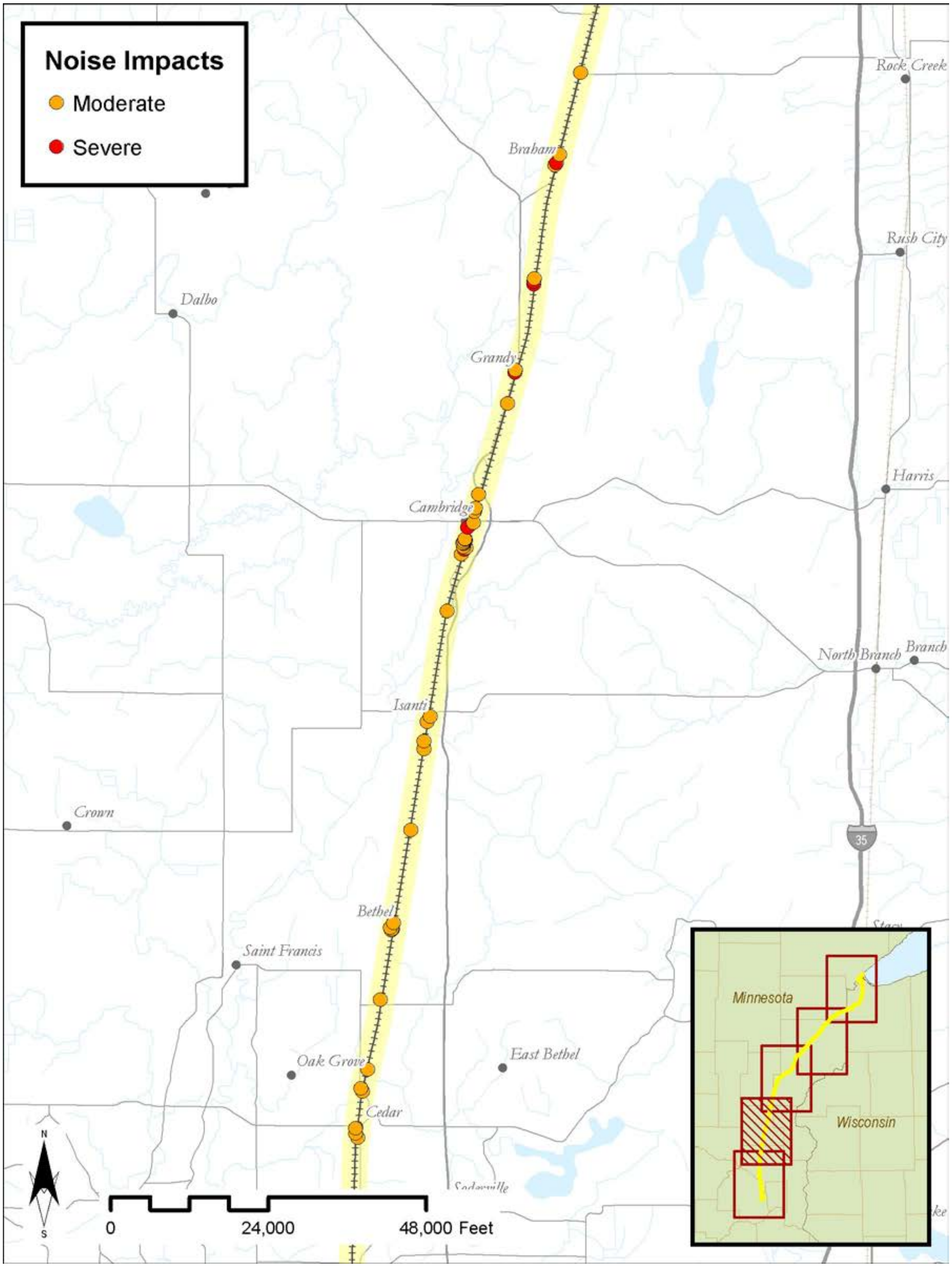
Receptor Location	Land Use Category	Distance to NLX Track (ft)	Mile Post	NLX Train Speed (mph)	Existing Noise Level[1]	NLX Project Noise Level[1]			Total Noise Level[1]	Noise Level Increase[1]	Number of Impacts[3]	
						Predicted[2]	Impact Criteria					
							Moderate	Severe			Moderate	Severe
Askov	Cat. 2	93-197	88-99	90	72	65-68	65	71	72-73	1-2	16	0
	Cat. 3	194-363	88-99	90	45	60-64	57	64	60-64	15-20	1 School, 1 Church, 1 Park	1 Church
Bruno	Cat. 3	296-459	99-105	90	45	58-64	57	64	58-64	14-20	1 School	1 Church
Kerrick	Cat. 2	153-224	105-113	90	72	65-66	65	71	72-73	1	2	0
	Cat. 3	196	105-113	90	45	64	57	64	64	19	0	1 Park
Holyoke	Cat. 2	142-317	113-124	90	62	59-67	59	64	64-68	2-6	9	2
Superior	Cat. 2	104-410	124-146	73-90	62-63	59-69	59	64-65	64-70	2-8	83	31
	Cat. 3	135	124-146	89	45	67	57	64	67	22	0	1 School
Duluth	Cat. 2	474[4]	146-154	45[4]	61[4]	38[4]	59[4]	64[4]	61[4]	0[4]	0	0
Total NLX Alignment Noise Impacts											**279 Residential, 4 Schools, 4 Churches, 2 Parks**	**43 Residential, 2 Cemeteries, 2 Schools, 9 Churches, 4 Parks, 1 Daycare**

[1] Noise levels for land use category 2 are based on Ldn and measured in dBA. Noise levels for land use category 3 are based on Leq and measured in dBA.
[2] Predicted levels include horn and bell noise, where applicable (rounded to the nearest decibel).
[3] All impacts are residential unless otherwise noted.
[4] Data are for the closest non-impacted residential receptor in this location. There are no noise impacts in this section.
Source: Harris Miller Miller & Hanson Inc., 2011



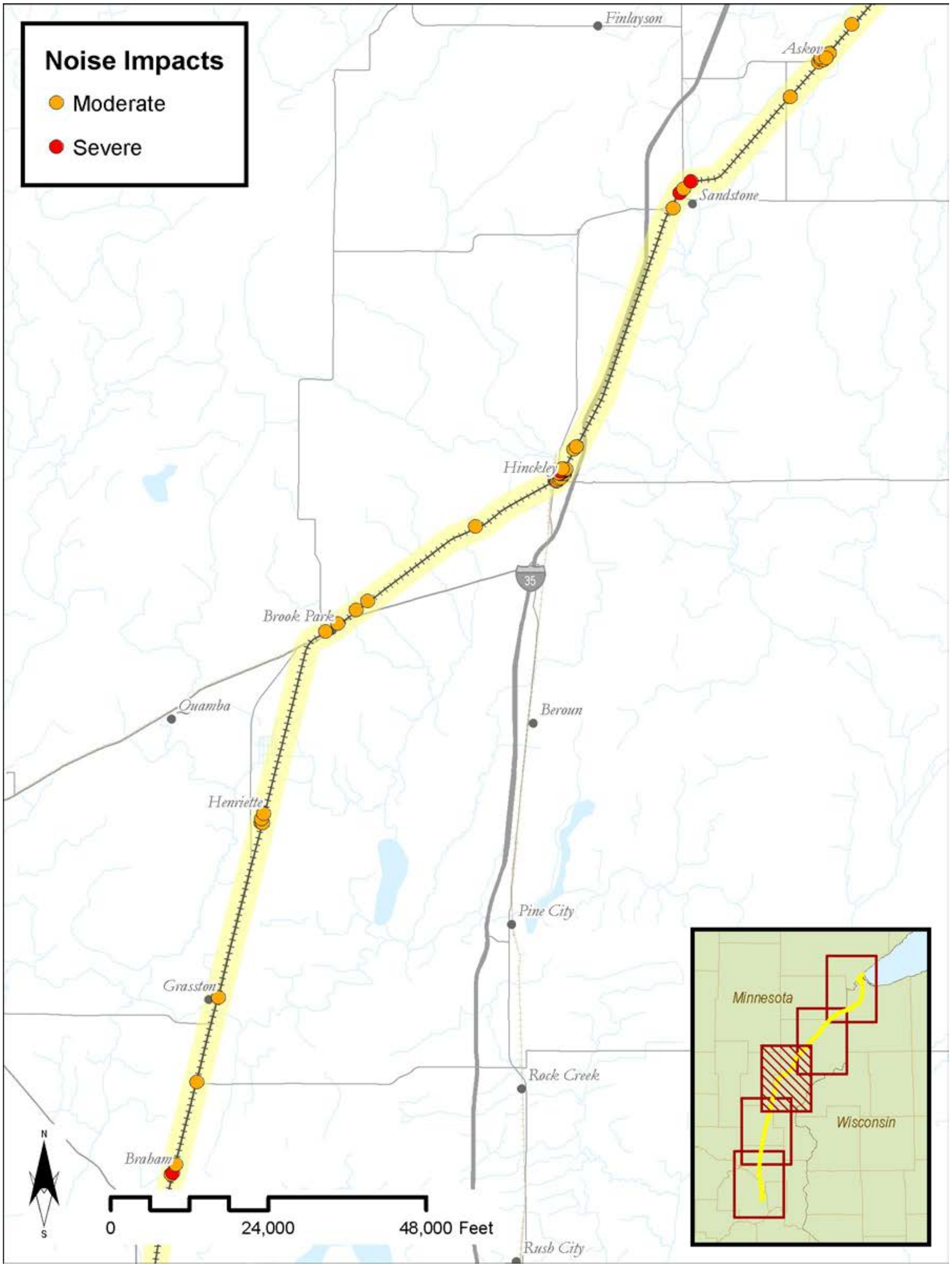
Source: HMMH (2011)

Figure 11. Noise Impact Locations



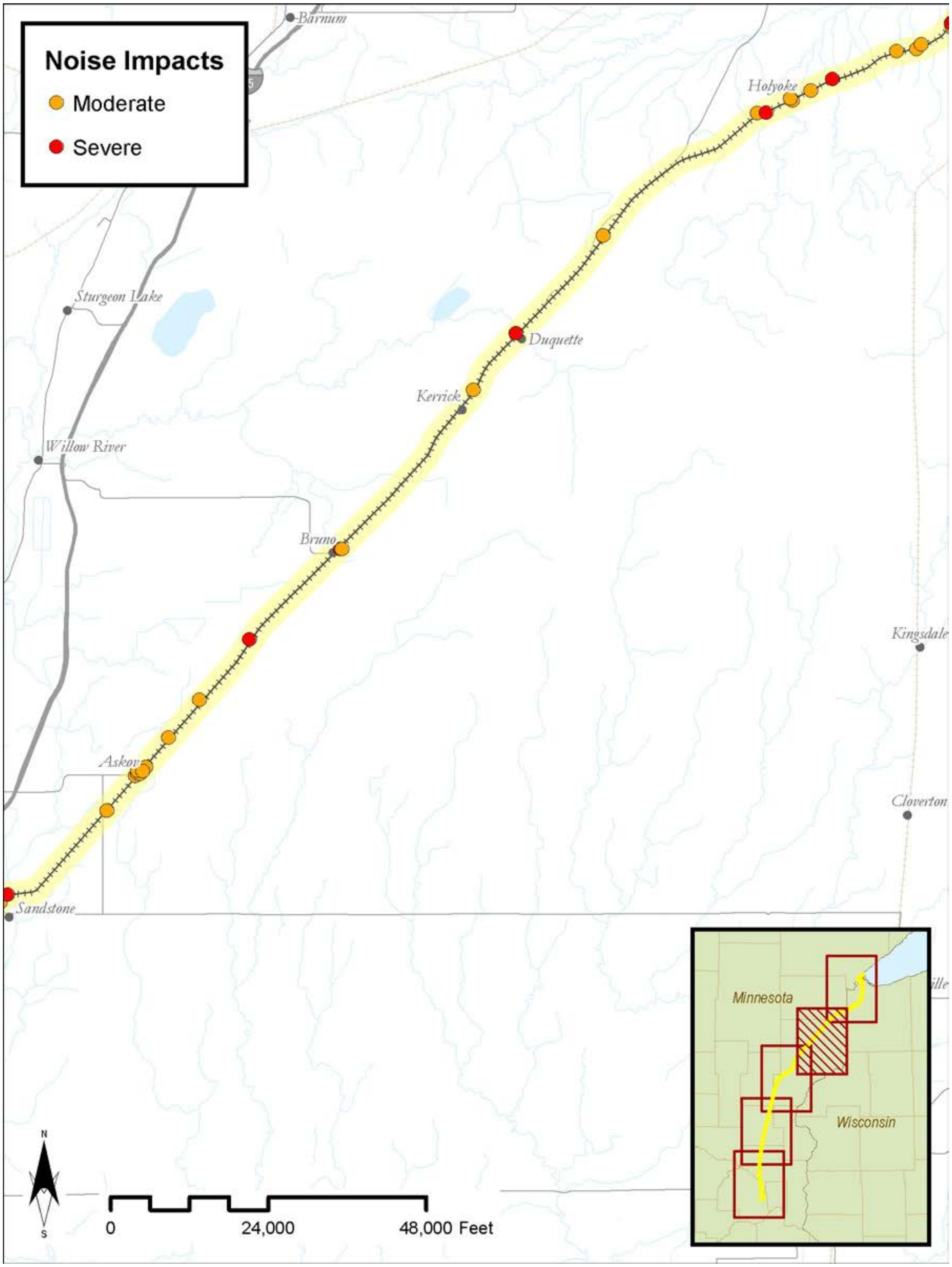
Source: HMMH (2011)

Figure 12. Noise Impact Locations



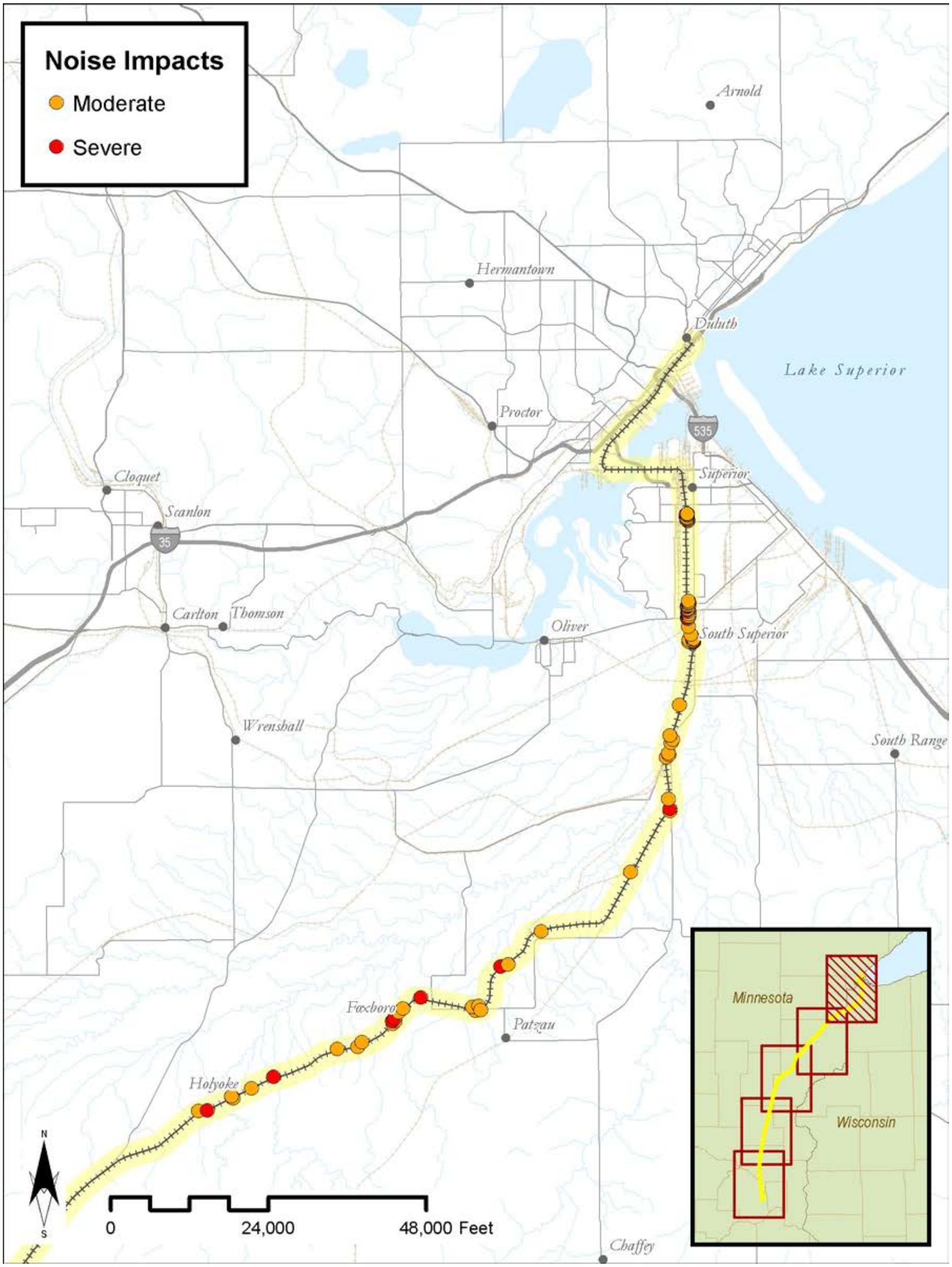
Source: HMMH (2011)

Figure 13. Noise Impact Locations



Source: HMMH (2011)

Figure 14. Noise Impact Locations



Source: HMMH (2011)

Figure 15. Noise Impact Locations

6.2 Noise Effects on Wildlife and Domestic Animals

FRA also addresses impacts to wildlife (mammals and birds) and domestic animals (livestock and poultry). The noise exposure limit for each is an SEL of 100 dBA from train pass-bys. A screening assessment was conducted to determine typical and maximum distances from the NLX tracks at which this limit may be exceeded. Train passby SELs were calculated for the maximum train speed along the corridor. To provide a conservative estimate, no shielding due to intervening structures or terrain was assumed.

Where NLX trains would not sound locomotive warning horns approaching at-grade crossings, the screening distance for a single-train passby SEL of 100 dBA would be approximately 10 feet from the track centerline. Near at-grade crossings where NLX trains would sound locomotive warning horns, the screening distance for a single-train passby SEL of 100 dBA would be approximately 170 feet from the track centerline.

6.3 Operational Vibration Impact

The results of the vibration analysis indicate that there will be four residential ground-borne vibration impacts from NLX trains. Table 11 provides detailed information for sensitive vibration receivers within separate communities including the distance of the closest receiver from the NLX track centerline, location by mile post along the alignment, range of train speeds, existing vibration level, projected vibration level, vibration impact criterion, and number of vibration impacts. All the data in Table 11 are for residential locations with the exception of the Duluth Depot Museum.

The ground-borne vibration and ground-borne noise impact criteria for special buildings from Table 6 above were applied to the Duluth Depot Great Hall auditorium. For the ground-borne noise assessment, the ground-borne noise levels were estimated using the methods recommended in the preliminary vibration assessment methodology provided in Chapter 8 of the FRA guidance manual (FRA, 2005). Even with a conservative assessment of the ground-borne vibration and ground-borne noise in the auditorium, the levels were substantially below the impact criteria, and no ground-borne noise or vibration impact is projected at the Duluth Depot Great Hall.

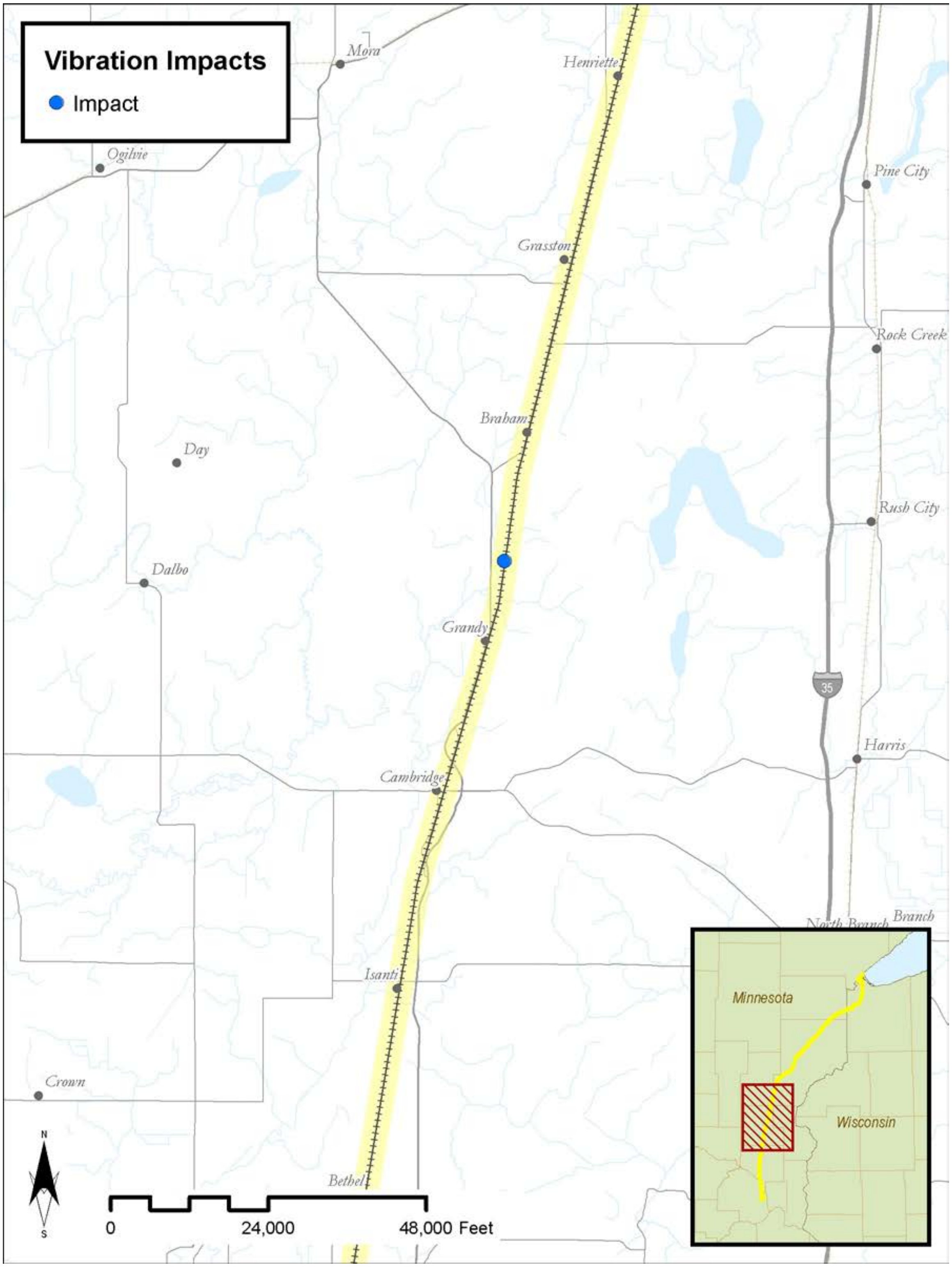
Figures 16 and 17 show the locations of the vibration impacts along the NLX corridor. There are three projected vibration impacts at single-family residences in Stanchfield, MN near mile post 49. These impacts are caused by the close proximity of these residences to the NLX track, approximately 50 feet, and the speed of the passing NLX trains at 110 mph. There is also one projected vibration impact at a single-family residence in Kerrick, MN near mile post 113. This vibration impact is caused by the close proximity of the residence to the NLX track, approximately 35 feet, and the speed of the passing NLX trains at 90 mph.

Vibration levels typically decrease very rapidly as the distance from the vibration source increases. The vibration levels from high-speed trains are generally much lower in level than freight trains. One reason for this is the significantly greater weight of a freight locomotive compared to a high-speed train locomotive. Additionally, the track standards for a high-speed train system are typically higher than for freight service, resulting in smoother rails with no corrugations or other defects or surface irregularities that lead to higher vibration levels.

Table 11. Vibration Impact Summary

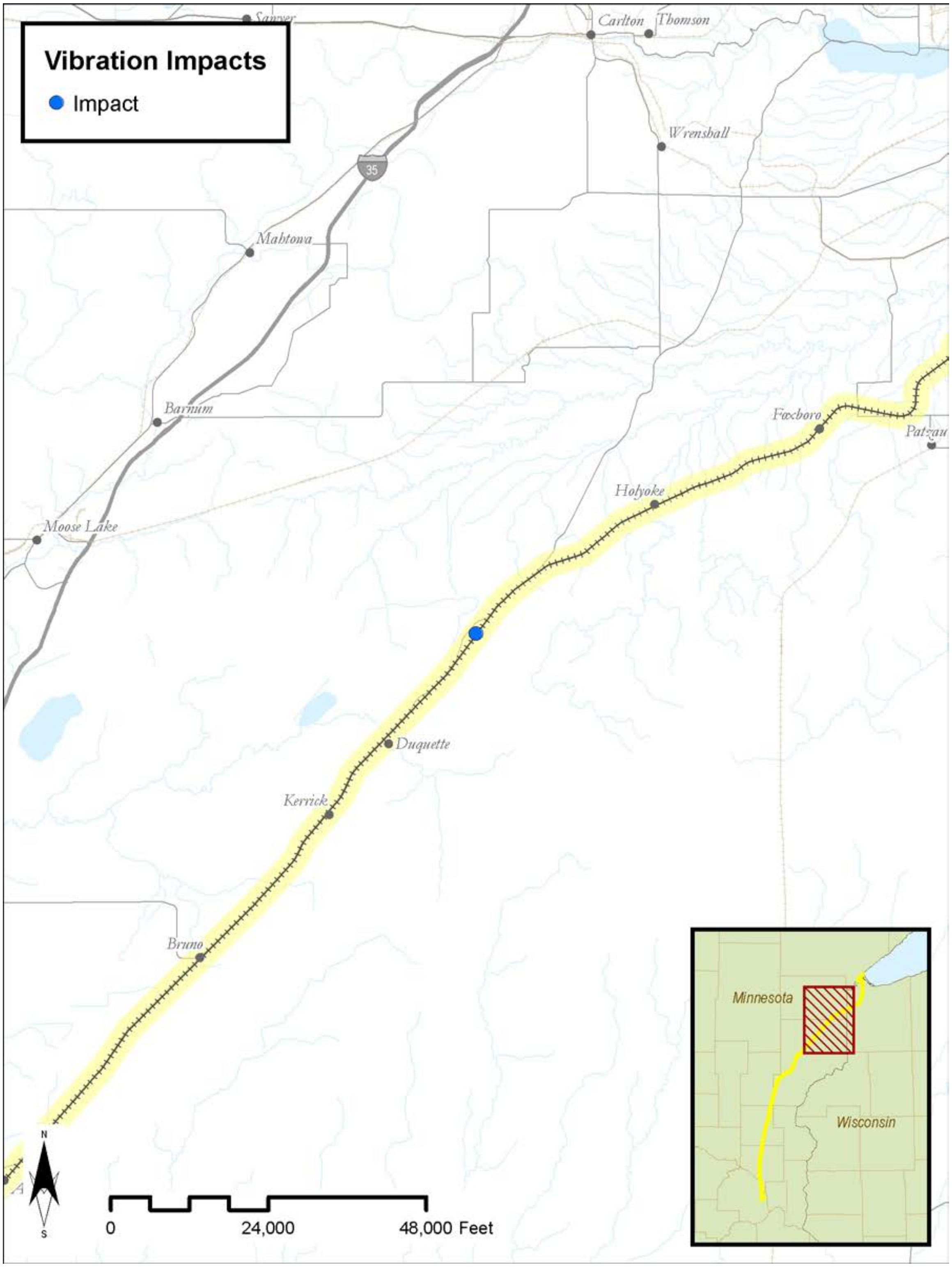
Receptor Location	Dist. To NLX Track (ft)	Mile Post	NLX Train Speed (mph)	Existing Freight Vibration Level[1]	Projected NLX Vibration Level[1]	Vibration Impact Criterion[1]	Number of Vibration Impacts[2]
Minneapolis	29	0-5	60-79	86	79	80	0
Fridley	61	5-11	79	78	76	80	0
Coon Rapids	159	11-16	46-90	74	73	80	0
Andover	86	16-30	90	78	74	80	0
Bethel	116	30-35	90-103	76	71	80	0
Isanti	98	35-37	108- 110	77	74	80	0
Cambridge	121	37-46	109-110	73	72	80	0
Stanchfield	51	46-53	110	81	80	80	3
Braham	126	53-54	110	79	74	80	0
Grasston	128	54-60	110	78	74	80	0
Henriette	86	60-65	110	75	75	80	0
Brook Park	58	65-73	101-110	77	78	80	0
Hinckley	64	73-79	65-110	82	74	80	0
Sandstone	159	79-88	76-90	73	67	80	0
Askov	93	88-99	90	76	73	80	0
Bruno	206	99-105	90	70	64	80	0
Kerrick	31	105-113	90	85	82	80	1
Holyoke	142	113-124	90	74	69	80	0
Superior	141	124-146	89-90	74	79	80	0
Duluth	178	146-154	45	73	60	80[3]	0
Total NLX Alignment Vibration Impacts							**4**

[1]Vibration levels are measured in VdB referenced to 1 µ-inch/second.
[2]All impacts are residential unless otherwise noted.
[3]Special building vibration impact criteria from Table 6 applied to Duluth Depot Great Hall auditorium.
Source: Harris Miller Miller & Hanson Inc., 2011



Source: HMMH (2011)

Figure 16. Vibration Impact Locations



Source: HMMH (2011)

Figure 17. Vibration Impact Locations

6.4 Construction Noise and Vibration Impacts

Temporary noise and vibration impacts could result from activities associated with the construction of new tracks and stations, utility relocation, grading, excavation, track work, demolition, and installation of systems components. Such impacts may occur in residential areas and at other noise-sensitive land uses located within several hundred feet of the alignment. The potential for noise impact would be greatest at locations near pile-driving operations for bridges and other structures, and at locations close to any nighttime construction work. The potential for vibration impact would be greatest at locations near pile-driving for bridges and other structures, and at locations close to vibratory compactor operations.

7 Mitigation of Noise and Vibration Impacts

7.1 Operational Noise Mitigation Measures

Potential mitigation measures for reducing noise impacts from high-speed train system sources are described below:

- **Noise Barriers**: Installation of noise barriers beside the tracks is commonly used to reduce noise from surface transportation sources. Depending on the height and location relative to the tracks noise barriers can achieve between 5 and 15 dB of noise reduction. The primary requirements for an effective noise barrier are that (1) the barrier must be high enough and long enough to break the line-of-sight between the sound source and the receiver, (2) the barrier must be of an impervious material with a minimum surface density of 4 lb/sq. ft., and (3) the barrier must not have any gaps or holes between the panels or at the bottom. Because many materials meet these requirements, the selection of materials for noise barriers is usually dictated by aesthetics, durability, cost, and maintenance considerations. Noise barriers typically range in height from twelve to fifteen feet for diesel locomotive-hauled trains, eight to ten feet for electric trains.

- **Establishment of Quiet Zones**: An effective option for mitigating noise impacts along the alignment would be to establish “quiet zones” near grade crossings in accordance with FRA regulations. In quiet zones, because of safety improvements at the at-grade crossings, train operators would sound horns only in emergency situations rather than as a standard operating procedure. Establishing quiet zones would require cooperative action among the municipalities along the corridor, Minnesota DOT, Wisconsin DOT, FRA, the freight railroads and the passenger rail authority. The municipalities are key participants in the process as they must initiate the request to establish the zones through application to the FRA. To meet safety criteria, the municipalities may also be required to provide improvements at grade crossings such as modifications to the streets, raised medians, warning lights, and other devices. The FRA regulation also authorizes the use of automated wayside horns at crossings along with flashing lights and gates as a substitute for the train horn. While activated by the approach of trains, these devices are pole-mounted at the grade crossing, thereby limiting the horn noise exposure area to the immediate vicinity of the crossing. There are 18 at-grade crossings along the corridor between Minneapolis and Andover, MN that are currently “quiet zones” where the train horns are not regularly sounded.

- **Vehicle noise specification**: In the procurement of vehicle technology performance limits can be set for noise levels in order to reduce community noise impacts throughout the corridor. Depending on the available technology this could reduce the number of impacts throughout the corridor.

- **Building Sound Insulation**: Sound insulation of residences and institutional buildings to improve the outdoor-to-indoor noise reduction has been widely applied around airports and has seen limited application for rail and transit projects. Although this approach has no effect on noise in exterior areas, it may be the best choice for sites where noise barriers are not feasible or desirable and for buildings where indoor sensitivity is of most concern. Substantial improvements in building sound insulation (on the order of 5 to 10 dBA) can often be achieved by adding an extra layer of glazing to the windows, by sealing holes in exterior surfaces that act as sound leaks, and by providing forced ventilation and air-conditioning so that windows do not need to be opened.

- **Special Trackwork at Crossovers and Turnouts**: Because the impacts of wheels over rail gaps at track crossover locations, or turn-outs for passing tracks, increases noise by about 6 dBA, crossovers are a major source of noise impact when they are located in sensitive areas. If crossovers cannot be relocated away from residential areas, another approach is to use spring-rail or moveable point frogs in place of standard rigid frogs at turnouts. These devices allow the flangeway gap to remain closed in the main traffic direction for revenue service trains.

- **Property Acquisitions or Easements**: Additional options for avoiding noise impacts are for the agency to purchase residences likely to be impacted by train operations or to acquire easements for such residences by paying the homeowners to accept the future train noise conditions. These approaches are usually taken only in isolated cases where other mitigation options are infeasible, impractical, or too costly.

The projected NLX noise impacts are primarily due to the sounding of horns near at-grade crossings. Therefore, the most feasible way to mitigate the noise impacts is with the establishment of quiet zones for all at-grade crossings near noise-sensitive receivers. The establishment of quiet zones would eliminate all but 4 moderate noise impacts at one multi-family residential building in Minneapolis, MN near mile post 1 and one severe noise impact at Freedom Park in Braham, MN near mile post 53. Table 12 summarizes the noise impacts by community, without mitigation and with the implementation of quiet zones along the corridor. Figures 18 and 19 show the locations of the residual noise impacts with the implementation of quiet zones.

The implementation of quiet zones in the NLX corridor would have the additional benefit of reducing the existing noise from freight train locomotive horns. This would be expected to decrease the Ldn at sensitive locations along the corridor by up to 5 dBA to 15 dBA compared to existing levels.

The implementation of noise barriers would not be an effective mitigation option for the NLX corridor where noise impacts are caused by locomotive horn noise. Noise barriers would need to be approximately 15 feet high in order to provide noise reduction from the locomotive horns. Additionally noise barriers would be ineffective at locations near at-grade crossings because they could not extend across roadways.

Trains do not currently sound horns in the area of the multi-family residential building with residual moderate impact in Minneapolis, so the noise impacts are caused by the NLX trains and not horn noise. The impacted multi-family building is elevated above the alignment in this location. A noise barrier could potentially mitigate this noise impact if located near the track, but it would need to be approximately 12 feet to 15 feet high in order to provide noise reduction from the locomotive noise source. Providing sound insulation for this building is another potential mitigation option. Before any final decision is made regarding noise mitigation at this building, a site specific long-term existing noise measurement should be conducted during the design phase of the project. The existing Ldn at this location was estimated from a one-hour noise measurement. A 24-hour noise measurement at this site would refine the results and may indicate no noise impact.

The residual severe noise impact at Freedom Park in Braham, MN could potentially be mitigated with a noise barrier, but may not be feasible due to its location approximately 10 feet from the NLX track.

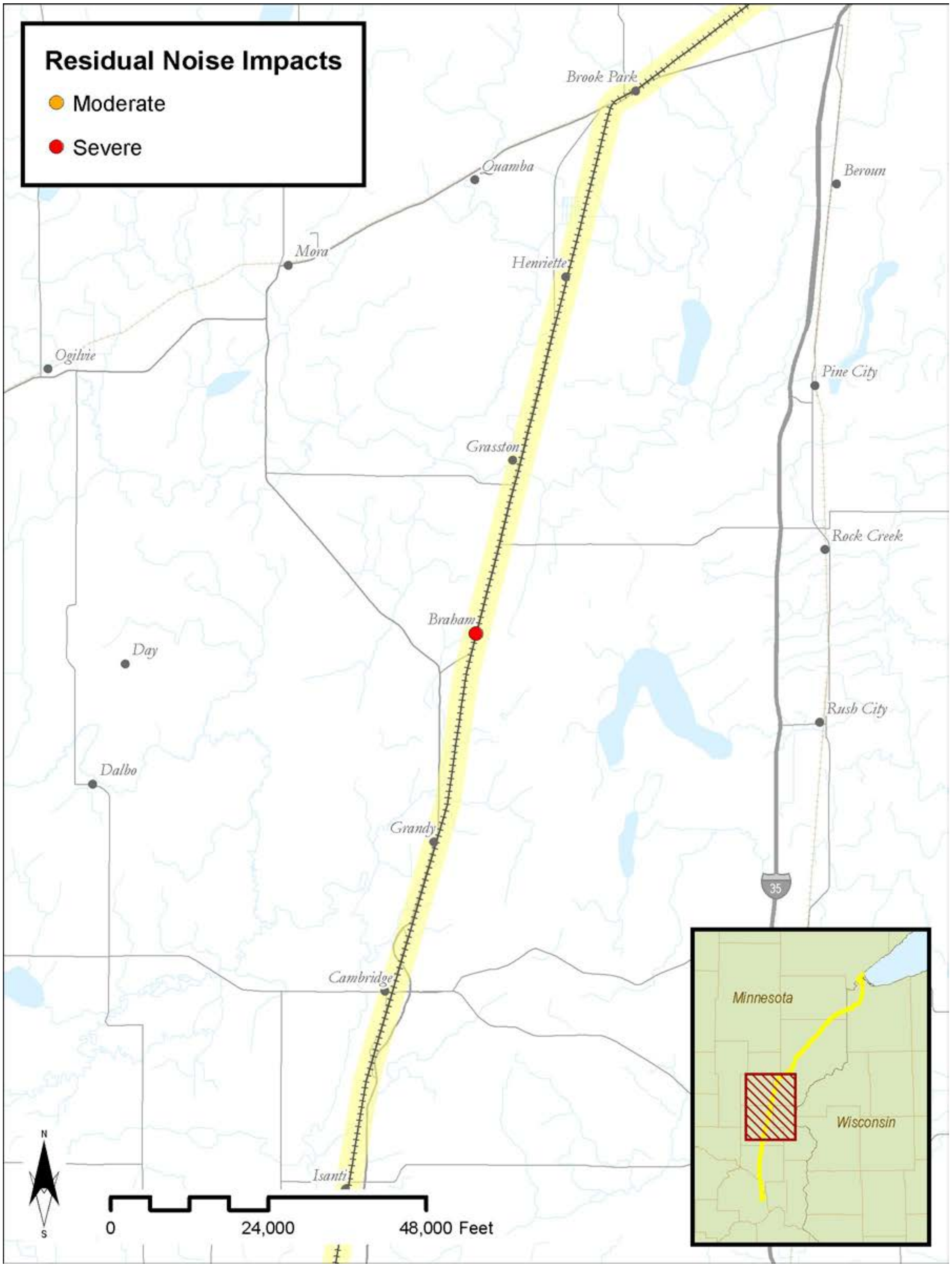
Table 12. Summary of Noise Mitigation Effectiveness

Receptor Location	Number of Moderate and Severe Residential Noise Impacts[1]			
	Without Mitigation		With Quiet Zones	
	Moderate	Severe	Moderate	Severe
Minneapolis	4	0	4	0
Fridley	0	0	0	0
Coon Rapids	0	0	0	0
Andover	7	0	0	0
Bethel	1 School	0	0	0
Isanti	7	0	0	0
Cambridge	1 Church	0	0	0
Stanchfield	22	0	0	0
Braham	1 Church	0	0	1 Park
Grasston	53	0	0	0
Henriette	0	2 Churches 1 Cemetery, 1 Daycare	0	0
Brook Park	11	0	0	0
Hinckley	0	1 Cemetery, 2 Churches	0	0
Sandstone	12	0	0	0
Askov	1 Park	1 Park	0	0
Bruno	2	0	0	0
Kerrick	11	0	0	0
Holyoke	4	0	0	0
Superior	36	10	0	0
Duluth	0	1 School, 3 Churches	0	0
TOTAL	**279 Residential, 4 Schools, 4 Churches, 2 Parks**	**43 Residential, 2 Cemeteries, 2 Schools, 9 Churches, 4 Parks, 1 Daycare**	**4 Residential**	**1 Park**

[1] All impacts are residential unless otherwise noted.
Source: Harris Miller Miller & Hanson Inc., 2011

Source: HMMH (2011)

Figure 18. Residual Noise Impact Locations with Quiet Zones



Source: HMMH (2011)

Figure 19. Residual Noise Impact Locations with Quiet Zones

7.2 Operational Vibration Mitigation Measures

The assessment assumes that the vehicle wheels and track are maintained in good condition with regular wheel truing and rail grinding. Beyond this, there are several approaches to reduce ground-borne vibration from high-speed rail operations, as described below.

- **Ballast Mats**: A ballast mat consists of a pad made of rubber or rubber-like material placed on an asphalt or concrete base with the normal ballast, ties, and rail on top. The reduction in ground-borne vibration provided by a ballast mat is strongly dependent on the frequency content of the vibration and design and support of the mat.

- **Tire Derived Aggregate (TDA)**: Also known as shredded tires, a typical TDA installation consists of an underlayment of 12 inches of nominally 3-inch size tire shreds or chips wrapped with filter fabric, covered with 12 inches of sub-ballast and 12 inches of ballast above that to the base of the ties. Tests suggest that the vibration attenuation properties of this treatment are midway between that of ballast mats and floating slab track. While this is a low-cost option, it has only recently been installed on two U.S. light rail transit systems (San Jose and Denver) and its long-term performance is unknown.

- **Floating Slabs**: Floating slabs consist of thick concrete slabs supported by resilient pads on a concrete foundation; the tracks are mounted on top of the floating slab. Most successful floating slab installations are in subways; their use for at-grade track is less common because they are only used where there is a concrete base such as the subway tunnel invert or a slab track. Floating slabs are designed to provide vibration reduction at lower frequencies than other treatments like resilient rail fasteners but they are extremely expensive.

- **Resilient Rail Fasteners**: Resilient fasteners can be used to provide vibration isolation between rails and concrete slabs for direct fixation track on aerial structures or in tunnels. These fasteners include a soft, resilient element to provide greater vibration isolation than standard rail fasteners in the vertical direction.

- **Special Trackwork at Crossovers and Turnouts**: Because the impacts of wheels over rail gaps at track crossover locations, or turn-outs for passing tracks, increases vibration by about 10 dBA, crossovers are a major source of vibration impact when they are located in sensitive areas. If crossovers cannot be relocated away from residential areas, another approach is to use spring-rail or moveable point frogs in place of standard rigid frogs at turnouts. These devices allow the flangeway gap to remain closed in the main traffic direction for revenue service trains.

- **Property Acquisitions or Easements**: Additional options for avoiding vibration impacts are for the agency to purchase residences likely to be impacted by train operations or to acquire easements for such residences by paying the homeowners to accept the future train noise conditions. These approaches are usually taken only in isolated cases where other mitigation options are infeasible, impractical, or too costly.

The NLX alignment is projected to cause four vibration impacts at residential buildings. Specific vibration mitigation measures will be recommended in preliminary design when more specific characteristics of the vehicle are known. Additionally, site specific ground-borne vibration propagation testing may be conducted during design to provide less conservative results that may indicate no vibration impact.

7.3 Construction Noise and Vibration Mitigation Measures

Construction activities will be carried out in compliance with all applicable local noise regulations. In addition, the following mitigation measures will be applied as needed to minimize temporary construction noise and vibration impacts:

- Avoiding nighttime construction in residential neighborhoods.
- Locating stationary construction equipment as far as possible from noise-sensitive sites.
- Constructing noise barriers, such as temporary walls or piles of excavated material, between noisy activities and noise-sensitive receivers.
- Routing construction-related truck traffic to roadways that will cause the least disturbance to residents.
- Using alternative construction methods to minimize the use of impact and vibratory equipment (e.g., pile-drivers and compactors).

Appendix A Measurement Site Photographs

A.1 Noise Measurement Locations

Figure A-1. Site LT-1: 1040 105th Avenue, Coon Rapids, MN

Figure A-2. Site LT-2: 6324 Starlite Boulevard, Fridley, MN

Figure A-3. Site LT-3: 902 3rd Avenue SW, Isanti, MN

Figure A-4. Site LT-4: 412 4th Avenue NE, Cambridge, MN

Figure A-5. Site LT-5: 15969 Vale Street, Andover, MN

Figure A-6. Site LT-6: 312 Beechwood Avenue N, Braham MN

Figure A-7. Site LT-7: 203 3rd Street SE, Hinckley, MN

Figure A-8. Site LT-8: 2309 Butler Avenue, Superior, WI

Figure A-9. Site LT-9: 6425 Butler Avenue, Superior, WI

Figure A-10. Site LT-10: 32 Bush Street, Sandstone, MN

Figure A-11. Site ST-1: Playfront Park / Bayfront Festival Park

Figure A-12. Site ST-2: Renaissance on the River Apartments, Minnesota, MN

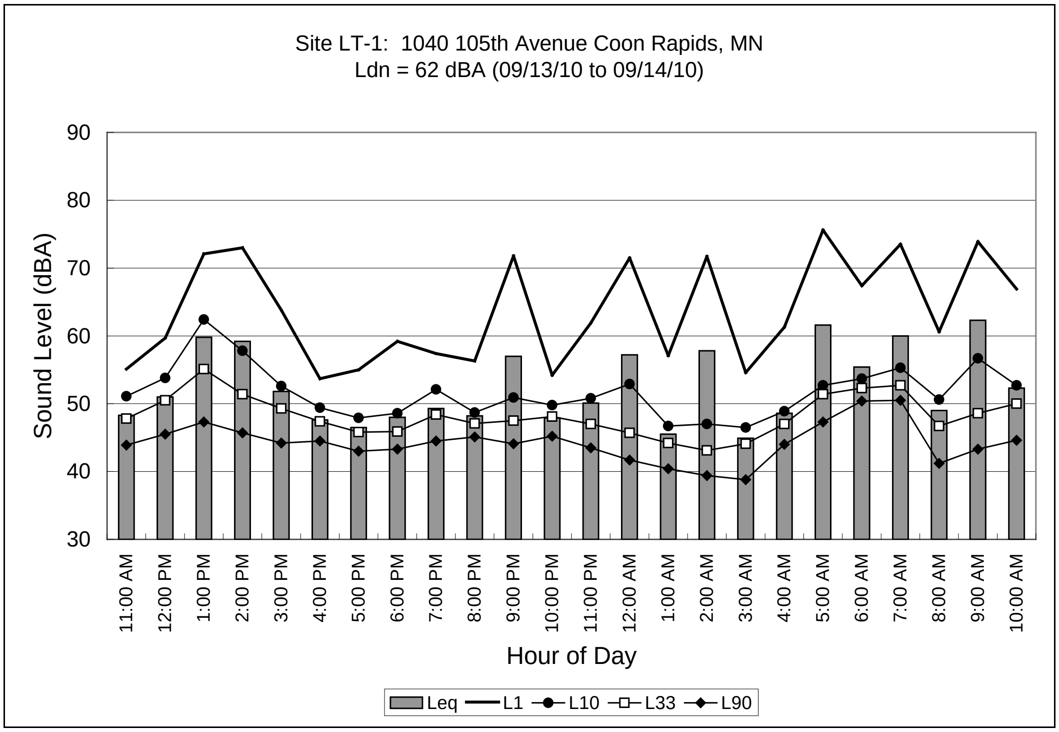
A.2 Vibration Measurement Locations

Figure A-13. Site V-1: 78th Way NE and Hickory Street NE, Fridley, MN

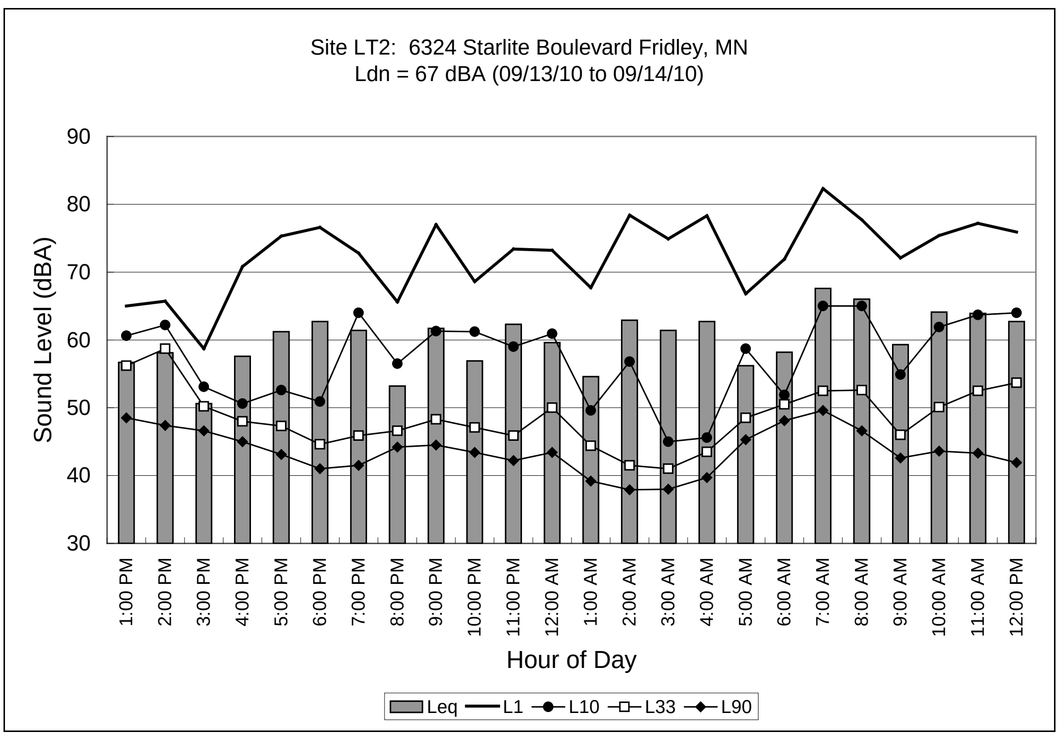
Figure A-14. Site V-2: 1st Street NE and Power Avenue N, Hinckley, MN

Figure A-15. Site V-3: 64th Street and Butler Avenue, Superior, WI

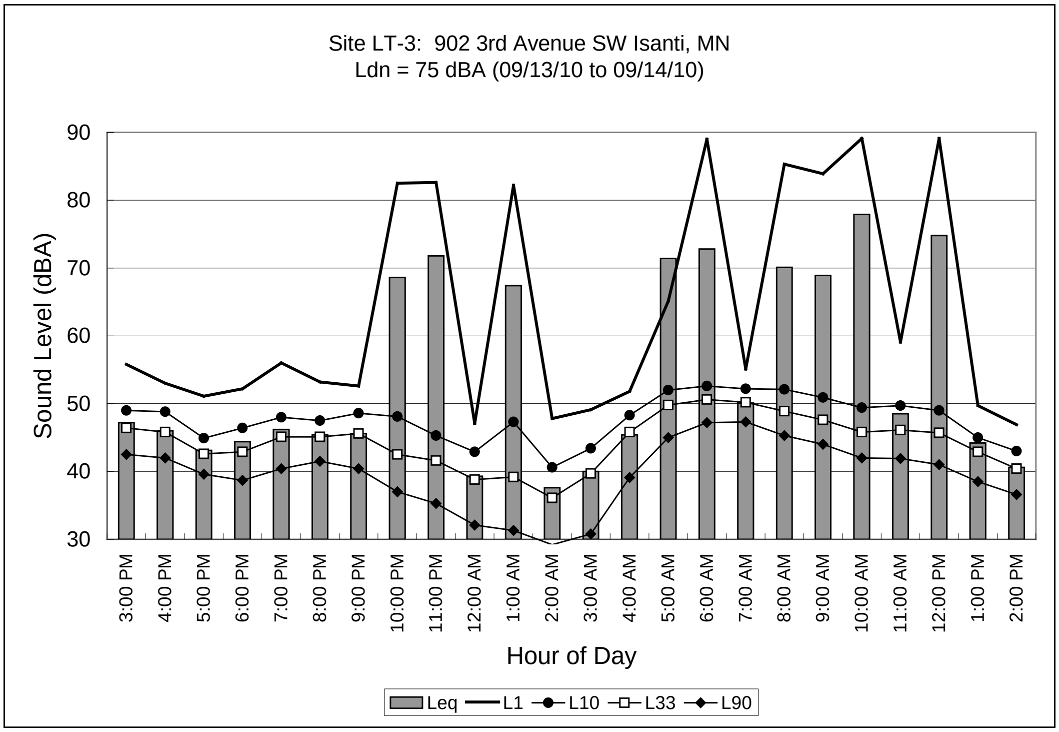
Appendix B Long-Term Noise Measurement Data



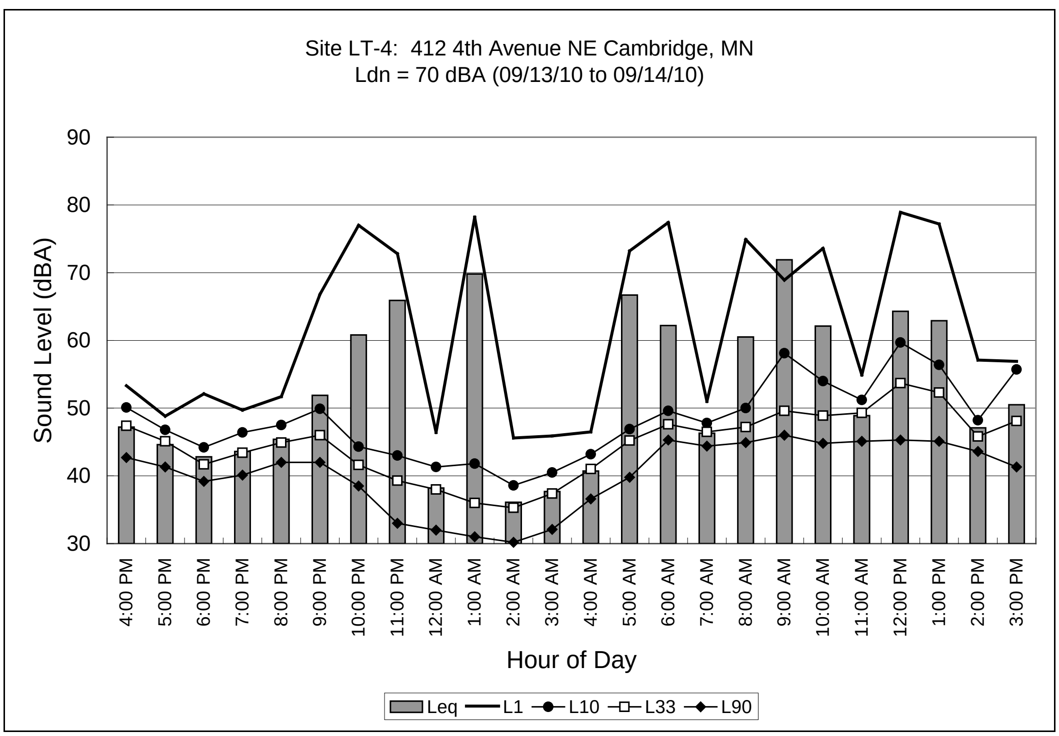
B- 1. Site LT-1: Noise Measurement Results



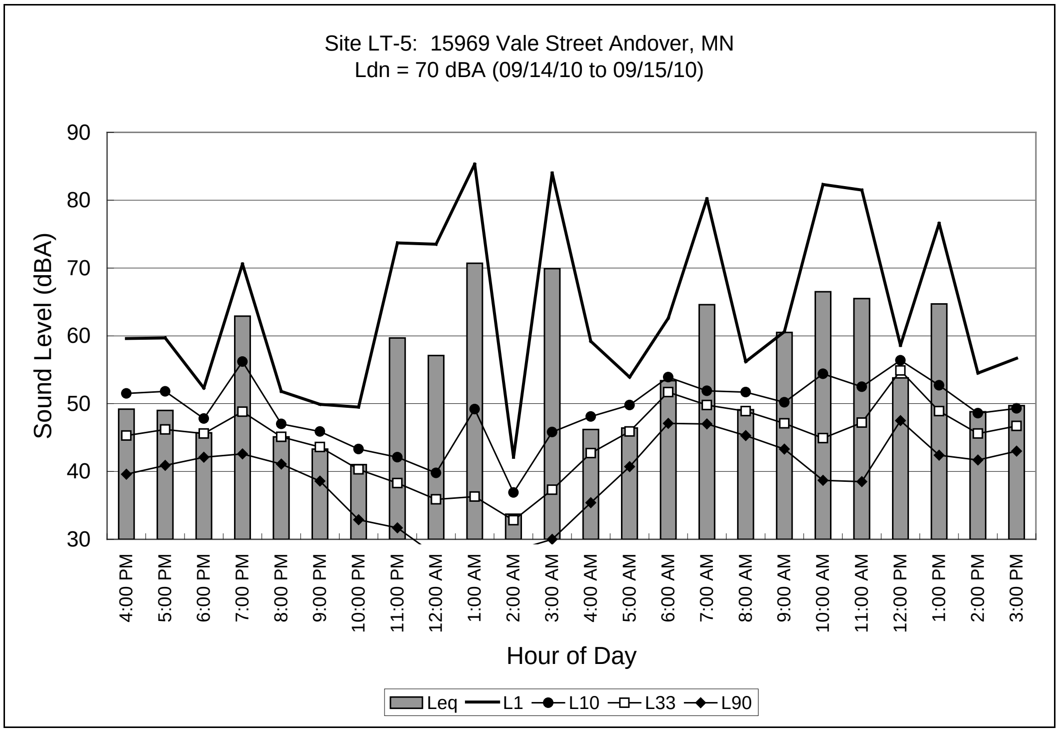
B- 2. Site LT-2: Noise Measurement Results



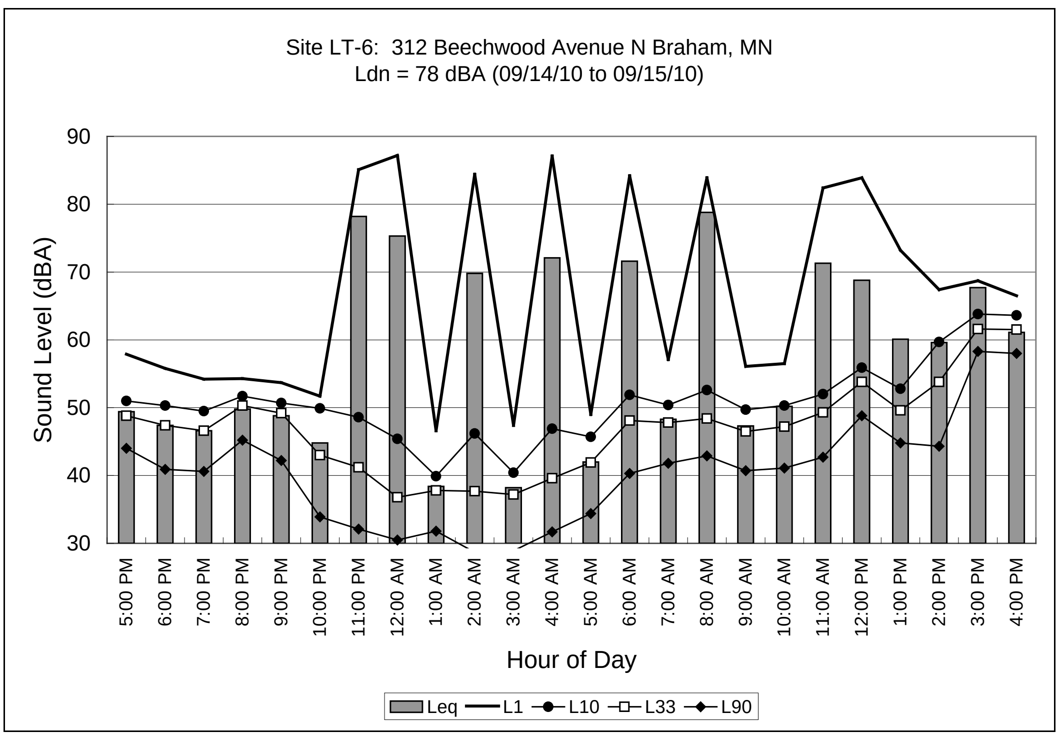
B- 3. Site LT-3: Noise Measurement Results



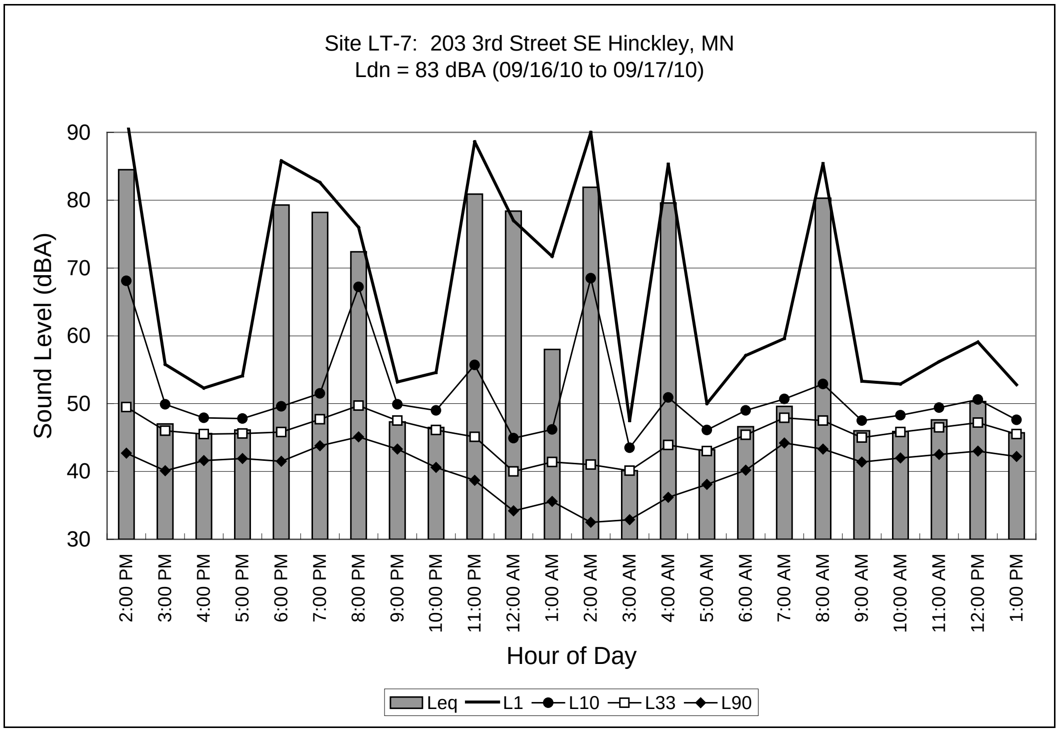
B- 4. Site LT-4: Noise Measurement Results



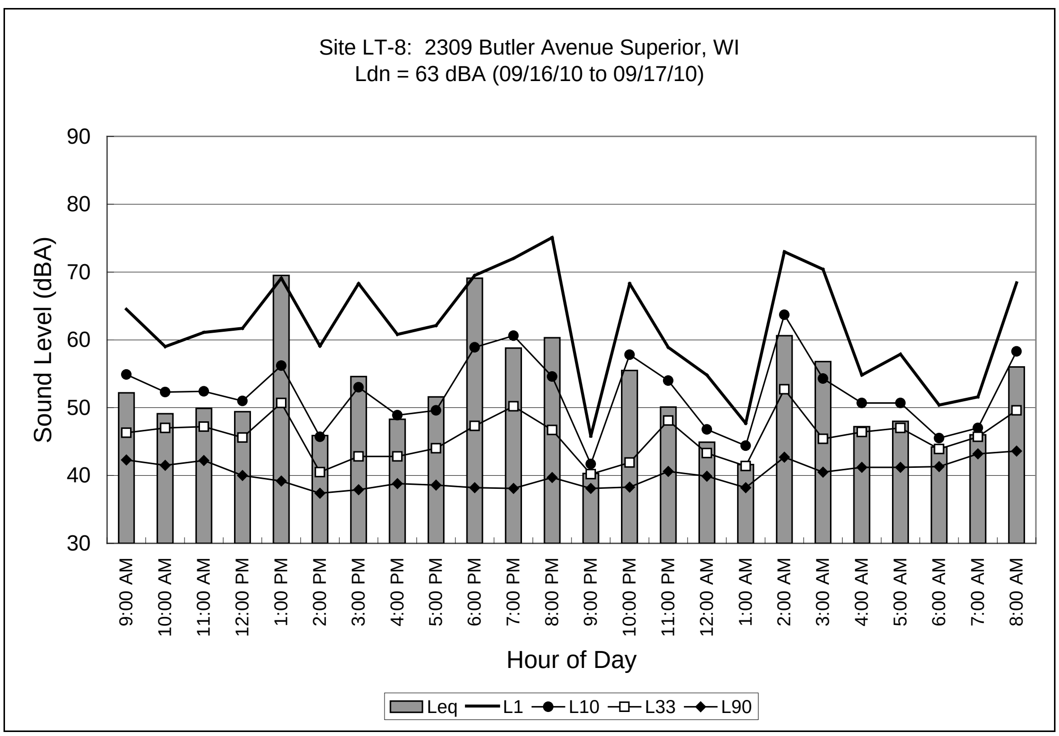
B- 5. Site LT-5: Noise Measurement Results



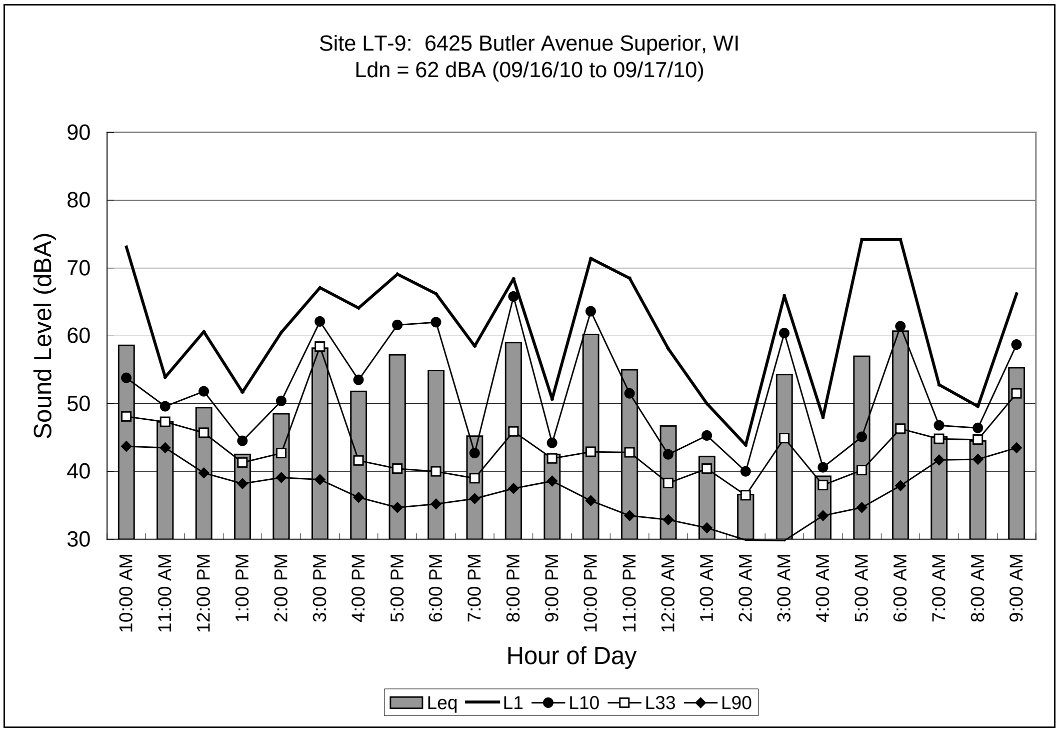
B- 6. Site LT-6: Noise Measurement Results



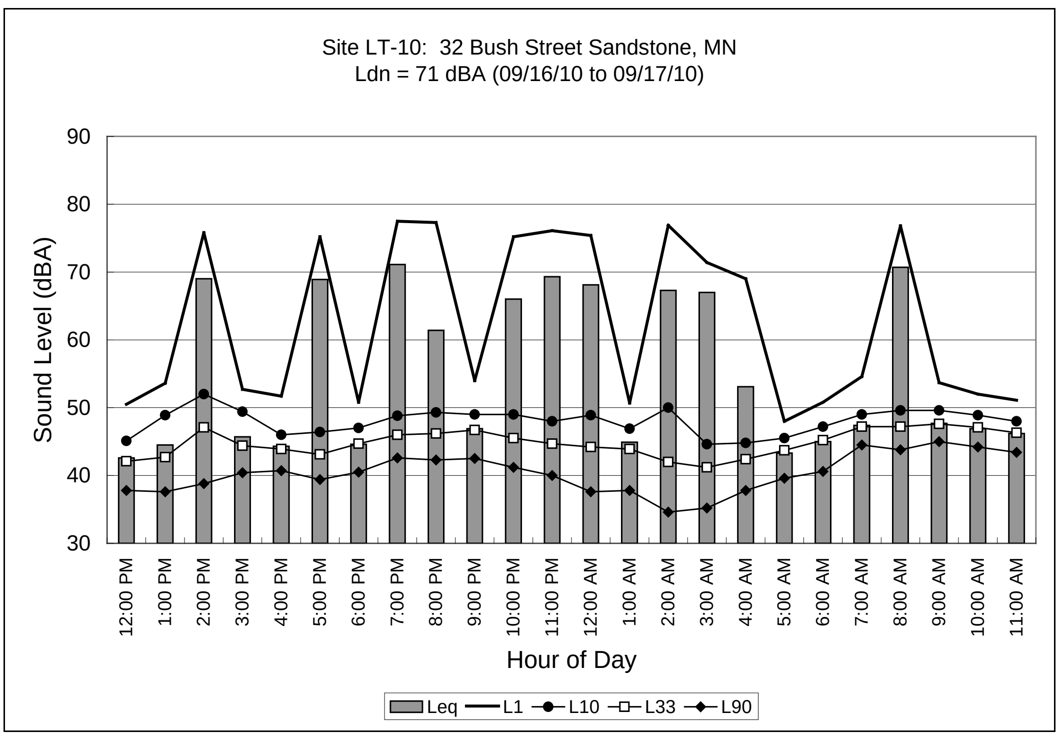
B- 7. Site LT-7: Noise Measurement Results



B- 8. Site LT8: Noise Measurement Results



B- 9. Site LT-9: Noise Measurement Results



B- 10. Site LT-10: Noise Measurement Results