Noise and Vibration Study
AC-500170
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Report

CAGUAS-SAN JUAN MASS TRANSIT SYSTEM

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AUTORIDAD DE CARRETERAS Y TRANSPORTACIÓN

Municipio Autónomo de Caguas

3. NOISE AND VIBRATION

This section describes the methodology used to characterize the existing noise and vibration conditions along the Caguas Rail Corridor project, and provides background information on airborne noise and ground-borne vibration issues related to the proposed transit project.

3.1 NOISE

3.1.1 Noise Basics

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 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 3.1 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 3.1, this spans the range between an “ideal” residential environment and the threshold for an unacceptable residential environment according to U.S. Federal agency criteria.

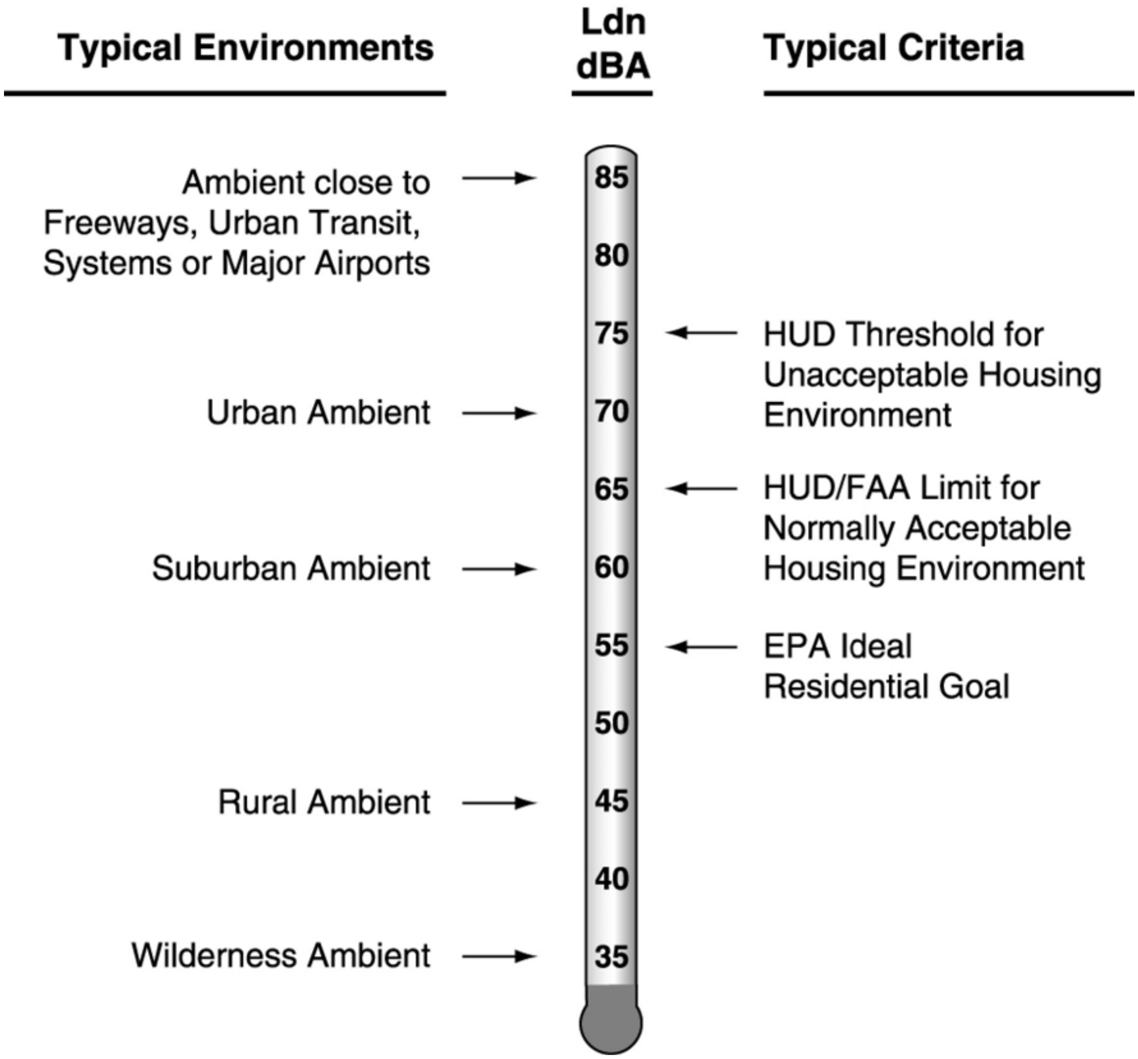

Figure 3.1 Examples of Typical Outdoor Noise Exposure

3.1.2 Transit Noise Criteria

Noise impact for this project is based on the criteria as defined in the U. S. Federal Transit Administration (FTA) guidance manual ***Transit Noise and Vibration Impact Assessment*** (FTA-VA-90-1003-06, May 2006). The FTA 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 more transit noise is allowed in neighborhoods with high levels of existing noise, smaller increases in total noise exposure are allowed with increasing levels of existing noise.

The FTA Noise Impact Criteria group noise sensitive land uses into the following three categories:

- Category 1: Buildings or parks where quiet is an essential element of their purpose.

- Category 2: Residences and buildings where people normally sleep. This includes residences, hospitals, and hotels where 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, and churches.

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 FTA criteria. The interpretation of these two levels of impact is summarized below:

- Severe: Severe noise impacts are considered "significant" as this term is used in the National Environmental Policy Act (NEPA) and implementing regulations. Noise mitigation will normally be specified for severe impact areas unless there is no practical method of mitigating the noise.

- Moderate: In this range of noise impact, other project-specific factors must be considered to determine the magnitude of the impact and the need for mitigation. These other factors can include the predicted increase over existing noise levels, the types and number of noise-sensitive land uses affected, existing outdoor-indoor sound insulation, and the cost effectiveness of mitigating noise to more acceptable levels.

The noise impact criteria are summarized in graphical form in Figure 3.2. The figure shows the existing noise exposure and the additional noise exposure from the transit project that would cause either moderate or severe impact. The future noise exposure would be the combination of the existing noise exposure and the additional noise exposure caused by the transit project. Figure 3.3 expresses the same criteria in terms of the increase in total or cumulative noise that can occur in the overall noise environment before impact occurs.

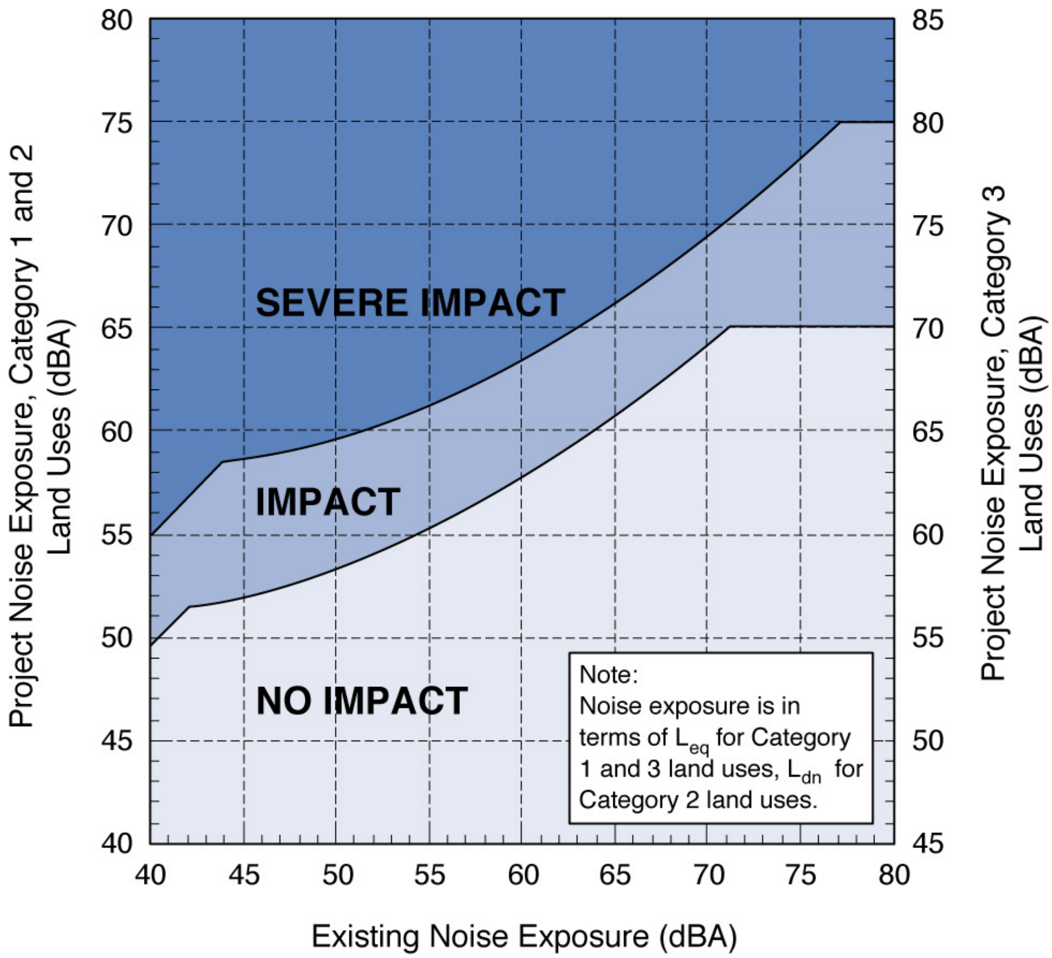

Figure 3.2. FTA Project Noise Impact Criteria

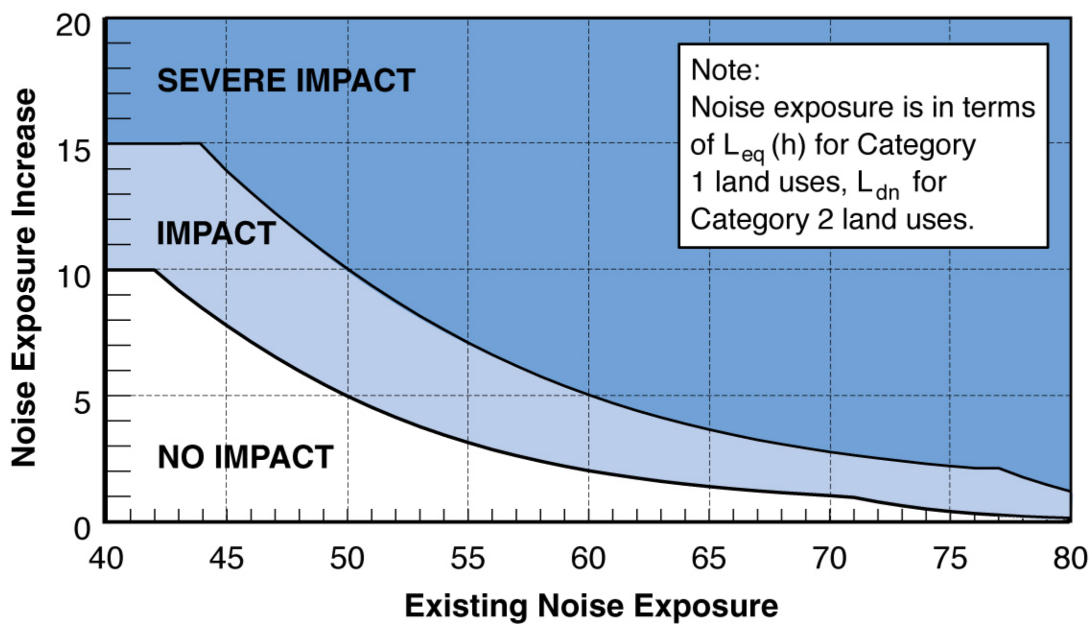

Figure 3.3. Increase in Cumulative Noise Exposure Allowed by FTA Criteria

3.1.3 Existing Noise Conditions

Noise-sensitive land use along the project corridor was identified based on preliminary alignment drawings, aerial photographs, and visual surveys. Areas adjacent to the proposed corridor include primarily single-family residences, along with some multi-family residences, non-residential (commercial) and a few institutional land uses.

Existing ambient noise levels in the above areas were characterized through direct measurements at eight sites along the proposed alignment during the period from November 14 through November 17, 2006, May 7 through 8, 2007 and February 4 through 5, 2008. Estimating existing noise exposure is an important step in the noise impact assessment since the thresholds for noise impact are based on the existing levels of noise exposure. The measurements included long-term (24-hour) monitoring of the A-weighted sound level at representative noise-sensitive locations. All of the measurement sites were located in noise-sensitive areas, and were selected to represent a range of existing noise conditions along the corridor.

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 (1.5 meters) 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, summarized in Table 3.1, serve as the basis for determining the existing noise conditions at all noise-sensitive receptors along the Caguas Rail Corridor project. The results at each site are described below.

Table 3.1 Summary of Existing Noise Measurement Results

Site No.	Measurement Location Description	Start of Measurement		Meas. Time (hrs)	Noise Exposure (Ldn, dBA)
		Date	Time		
LT-1	G5 Alborlada, Caguas	11-14-06	10:00	24	72
LT-2	Cazabe CL 4, Caguas	11-14-06	11:00	24	73
LT-3	11 Dali St, Caguas	11-14-06	12:00	24	73
LT-4	PR 175 Ramal 739, San Juan	11-14-06	12:00	24	69
LT-5	133 Guaraguo St, San Juan	11-14-06	15:00	24	70
LT-6	Rose LL14, San Juan	11-15-06	14:00	24	73
LT-7	Calle 3 S-4-13 Urbanizacion Parana, San Juan	11-15-06	14:00	24	70
LT-8	Calle Calve, PRHTA Building, Urbanizacion Antosanti, San Juan	11-16-06	10:00	24	66
LT-9	1649 Alda Ponce del Leon, El Cerezal, San Juan	5-7-07	15:00	24	69
LT-10	Calle 3, Santa Juana, Caguas	2-4-08	08:00	24	58

(to be added)
Figure 3.4 Ambient Noise Monitoring Locations

Site LT-1: Single-family residence at G5 Alborlada, Caguas. The measured Ldn at this location was 72 dBA. The microphone was located in the backyard of the home, adjacent to the proposed alignment and PR 52. The dominant noise source was traffic on PR 52.

Site LT-2: Single-family residence at Cazabe CL 4, Caguas. The measured Ldn at this location was 73 dBA. The microphone was located in the front yard of the home inside the fence adjacent to the proposed alignment and PR 52. The dominant noise source was traffic on PR 52.

Site LT-3: 11 Dali St, Caguas. The measured Ldn at this location was 73 dBA. The microphone was located in the backyard of the home, adjacent to the proposed alignment and PR 52. The dominant noise source was traffic on PR 52.

Site LT-4: PR 175 Ramal 739, San Juan. The measured Ldn at this location was 69 dBA. The microphone was located in the front yard of the home, next to the driveway. The dominant noise source was traffic on PR 52. Other noise sources included local activities and traffic on PR 175.

Site LT-5: 133 Guaraguo St, San Juan. The measured Ldn at this location was 70 dBA. The microphone was located in the backyard of the home, adjacent to the proposed alignment and PR 52 and behind the existing noise barrier. The dominant noise source was traffic on PR 52.

Site LT-6: Rose LL14, San Juan. The measured Ldn at this location was 73 dBA. The microphone was located in the front yard of the home, adjacent to the proposed alignment and PR 52 and behind the existing noise barrier. The dominant noise source was traffic on PR 52.

Site LT-7: Calle 3 S-4-13 Urbanazacion Parana, San Juan. The measured Ldn at this location was 70 dBA. The microphone was located in the backyard of the home, adjacent to the proposed alignment and PR 52. The dominant noise source was traffic on PR 52.

Site LT-8: Calle Calve, PRHTA Building, Urbanizacion Antosanti, San Juan. The measured Ldn at this location was 73 dBA. The microphone was located in the yard of the PRHTA building, near the existing Tren Urbano elevated structure. The dominant noise sources at this location were Tren Urbano operations and traffic on local roads.

Site LT-9: 1649 Alda Ponce del Leon, El Cerezal, San Juan. The measured Ldn at this location was 69 dBA. The microphone was located in the front yard of the home, adjacent to the proposed alignment and PR-1. The dominant noise source at this location was traffic on PR-1.

Site LT-10: Calle 3, Santa Juana, Caguas. The measured Ldn at this location was 58 dBA. The microphone was located in the front yard of a home, behind the highway noise barrier, adjacent to the proposed alignment and PR-30. The dominant noise source at this location was traffic on PR-30.

3.2 VIBRATION

3.2.1 Vibration Basics

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 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 transit 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 3.5 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.

Harris Miller Miller & Hanson Inc. (2008) Noise and Vibration Study.

Figure 3.4

Ambient Noise Monitoring Locations

Fuente: USGS. (2004). Fotografías Aéreas.

LEGEND

Caguas - San Juan Aligment

Stations

Noise Monitoring Locations

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Preparado por: *María López Maldonado*

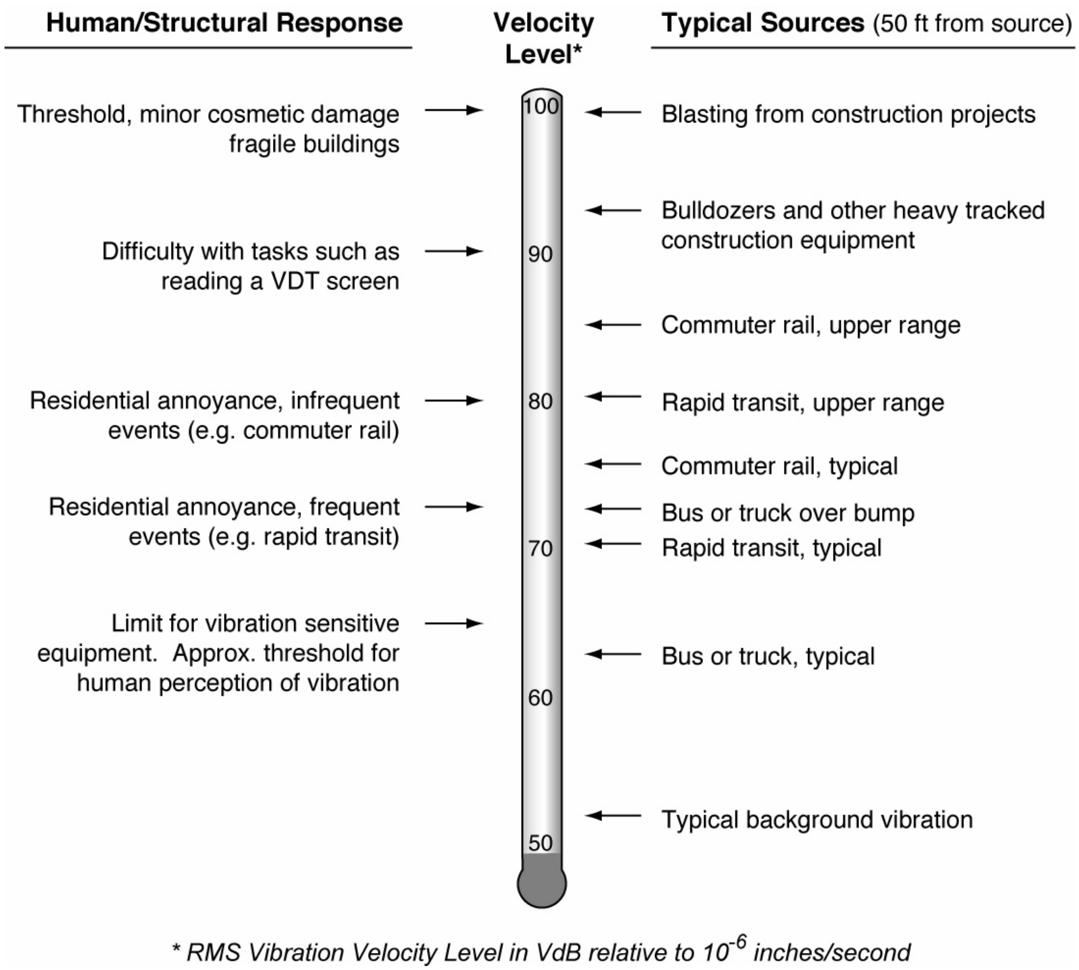


Figure 3.5 Typical Ground-Borne Vibration Levels and Criteria

3.2.2 Ground-Borne Vibration Criteria

The FTA ground-borne vibration impact criteria are based on land use and train frequency, as shown in Table 3.2. 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 3.2. Due to the sensitivity of these buildings, they usually warrant special attention during the environmental assessment of a transit project. Table 3.3 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 for above ground (i.e. at-grade or elevated) rail systems, ground-borne noise criteria are not applied to this project.

Table 3.2 Ground-Borne Vibration Impact Criteria

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

[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 source per day. Most commuter trunk lines have this many operations.
[3] "Infrequent Events" is defined as fewer than 70 vibration events per day. This category includes most commuter rail systems.
[4] This criterion limit is based on levels that are acceptable for most moderately sensitive equipment such as optical microscopes. 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.

Source: Federal Transit Administration, May 2006

Table 3.3 Ground-Borne Vibration Impact Criteria for Special Buildings

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

[1] "Frequent Events" is defined as more than 70 vibration events per day. Most transit projects fall into this category.
[2] "Occasional of Infrequent Events" is defined as fewer than 70 vibration events per day. This category includes most commuter rail systems.
[3] If the building will rarely be occupied when the trains are operating, there is no need to consider impact. As an example consider locating a commuter rail line next to a concert hall. If no commuter trains will operate after 7 pm, it should be rare that the trains interfere with the use of the hall.

Source: Federal Transit Administration, May 2006

3.2.3 Existing Vibration Conditions

There are no significant sources of existing vibration along the Caguas Rail Corridor. For that reason the vibration measurements for this project focused on characterizing the vibration propagation properties of the soil at representative locations along the corridor. Three vibration testing sites were selected to represent the range of soil conditions in areas along the corridor that include a significant number of vibration-sensitive receptors. At each of these sites, ground-borne vibration propagation tests were conducted by impacting the ground and measuring the input force and corresponding ground vibration response at various distances. The resulting force-response transfer function can be combined with the known input force characteristics of a light rail vehicle to predict future vibration levels at locations along the project corridor. The vibration propagation test sites are described below.

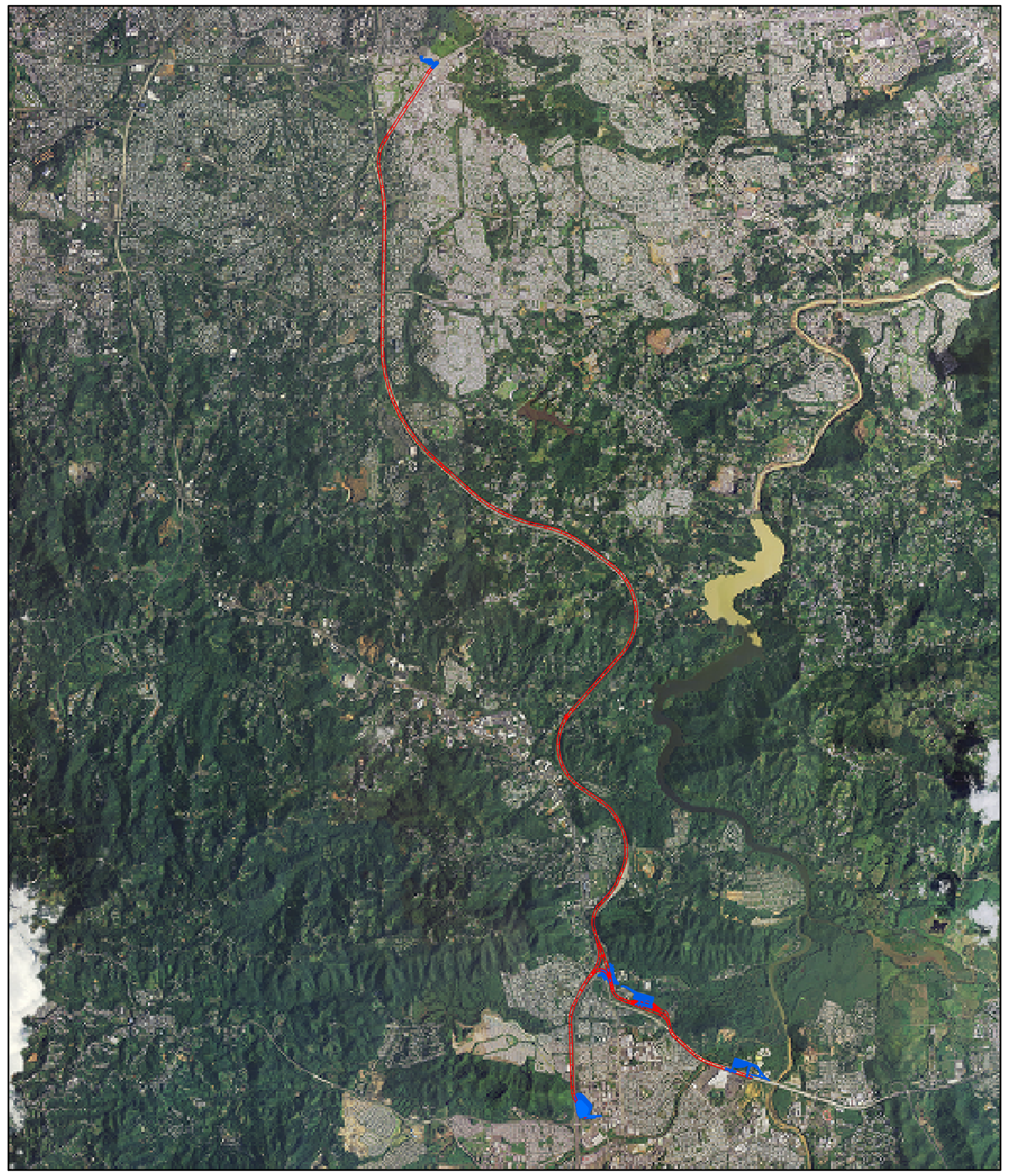
Site V-1: Arbolada, Caguas. This site was located in an empty lot in the Arbolada neighborhood in Caguas. The vibration measurement at this site is representative of the portion of the alignment in Caguas.

Site V-2: Monteheidra Shopping Center, San Juan. This site was located in the parking lot of the Monteheidra Shopping Center in San Juan. The vibration measurement at this site is representative of the portion of the alignment in the southern part of San Juan.

Site V-3: El Senorial Shopping Center, San Juan. This site was located in the parking lot of the El Senorial Shopping Center in San Juan. The vibration measurement at this site is representative of the portion of the alignment in the northern part of San Juan.

(to be added)

Figure 3.6 Vibration Measurement Locations



0 1,250 2,500 5,000 7,500 10,000 Meters

1:44,207

Harris Miller Miller & Hanson Inc. (2008) Noise and Vibration Study.

Figure 3.6
Ambient Noise Monitoring Locations

Fuente: USGS. (2004). Fotografías Aéreas.

LEGEND

- Caguas - San Juan Aligment
- Stations
- Noise Monitoring Locations

BEHAR - YBARRA & ASSOCIATES, P.S.C.
LT-2

Preparado por: *María López Maldonado*

4. NOISE AND VIBRATION

4.1 NOISE

This section presents the analysis of potential noise impacts due to the operation of the proposed project and discusses mitigation measures to minimize adverse impacts.

4.1.1 Noise Impact Assessment

Noise Impact Assessment Methodology

Noise levels were projected based on the standard Diesel Multiple Unit (DMU) vehicle reference noise level contained in the FTA guidance manual, the proposed project's operating plan and the FTA prediction model. Significant factors are summarized below:

- Based on the FTA reference noise level for DMU vehicles, the projections assume that a single DMU vehicle operating at 50 mph on ballast and tie track with continuous welded rail (CWR) generates a maximum noise level of 82 dBA and an SEL of 84 dBA at a distance of 50 feet from the track centerline.
- The operating times of the line would be between 6:00 AM and 11:00 PM. The operating plan for DMU service specifies two-car consists on headways of 12 minutes during the entire day for both the PR-52 and PR-30 legs of the system, for total headways of 6 minutes north of Caguas.
- Vehicle operating speeds are based on information provided by the project design team. The speed is assumed to be 65 mph along the entire corridor north of Caguas and 45 mph for the PR-52 branch of the system in Caguas and 30 mph for the PR-30 branch of the system Caguas.
- The entire alignment is grade separated, so there is no grade crossing noise included in the projections.

Projected Sound Levels

For the proposed alignment, detailed comparisons of the existing and future noise levels are presented in Table 4-1 and Table 4-2. Table 4-1 includes results for the Category 2 receptors along the alignment with both daytime and nighttime sensitivity to noise (e.g. residences, hotels, and hospitals). Table 4-2 is a listing of all Category 3 receptors along the alignment, consisting of institutional sites that are not sensitive to noise at night (e.g. schools, churches, parks and medical offices). In addition to the civil station, distance to the near track and proposed speed, each table includes the existing noise level, the projected noise level from DMU operations and the impact criteria for each receptor or receptor group. Based on a comparison of the predicted project noise level with the impact criteria, the impact category is listed, along with the predicted total noise level and projected noise increase due to the introduction of DMU service. Table 4-1 also includes an inventory of the number of moderate and severe impacts at each sensitive receptor location.

Table 4-1. Projected Noise Impacts for Category 2 Land Use

Location	Civil Stn	Side of Track	Dist To Near Track (ft/m)	Speed (mph/ kmph)	Exist. Noise Level[1]	Project Noise Level[1] Pred.[2]	Impact Criteria Mod	Impact Criteria Sev	Impact Category	Total Noise Level[1]	Noise Level Increase[1]	# of Res. Impacts Mod	# of Res. Impacts Sev
Santa Juana	21+50	W	139/43	30/48	58	57	57	62	Moderate	61	2.3	3	0
Santa Juana	23+00	W	41/13	30/48	58	63	57	62	Severe	64	5.8	11	2
Santa Juana	25+00	W	21/7	30/48	58	65	57	62	Severe	66	7.9	1	4
Santa Juana	27+00	W	41/13	30/48	58	63	57	62	Severe	64	5.8	12	3
Estancias de Bairoa	66+00	W	119/36	45/72	72	55	65	70	None	72	0.1	0	0
Industrial Bairoa	68+00	E	225/69	45/72	73	51	65	72	None	73	0.0	0	0
Arbolada	71+00	W	71/22	45/72	72	59	65	70	None	72	0.2	0	0
Bairoa	78+00	E	156/47	45/72	73	53	65	72	None	73	0.0	0	0
Bairoa	81+00	E	87/26	45/72	73	57	65	72	None	73	0.1	0	0
Bairoa Park	78+00	W	69/21	45/72	72	59	65	70	None	72	0.2	0	0
Bairoa Park	83+00	W	66/20	45/72	72	70	65	70	Moderate	74	2.1	8	0
Bairoa Park	88+00	W	361/110	45/72	73	53	65	72	None	73	0.0	0	0
El Retiro	90+50	W	211/64	45/72	73	60	65	72	None	73	0.2	0	0
Quintas de San Luis	99+00	W	242/74	65/105	73	56	65	72	None	73	0.1	0	0
Quintas de San Luis	105+50	E	152/46	65/105	73	60	65	72	None	73	0.2	0	0
Quintas de San Luis	120+00	E	190/58	65/105	73	58	65	72	None	73	0.1	0	0
Bo. San Antonio	130+00	W	190/58	65/105	69	58	63	68	None	69	0.3	0	0
Bo. San Antonio	146+00	W	225/69	65/105	69	57	63	68	None	69	0.3	0	0
Bo. San Antonio	175+00	W	156/47	65/105	69	59	63	68	None	69	0.5	0	0
Bo. San Antonio	187+50	E	173/53	65/105	69	59	63	68	None	69	0.4	0	0
Montehiedra	197+50	E	190/58	65/105	70	58	64	69	None	70	0.3	0	0
Parque Forestal	206+00	E	190/58	65/105	70	58	64	69	None	70	0.3	0	0
Villa Nova	209+00	W	190/58	65/105	73	58	65	71	None	73	0.1	0	0
La Campina	213+00	W	173/53	65/105	73	58	65	71	None	73	0.2	0	0
Borinquen Gardens	214+50	E	156/47	65/105	70	59	64	69	None	70	0.4	0	0
Alturas de Borinquen Gardens	215+00	W	173/53	65/105	73	59	65	71	None	73	0.2	0	0
La Cumbre	220+00	W	218/66	65/105	73	57	65	71	None	73	0.1	0	0
Villa Pilar	226+00	W	208/63	65/105	73	57	65	71	None	73	0.1	0	0
El Remanso	220+50	E	149/45	65/105	70	60	64	69	None	70	0.4	0	0
Villas Del Parana	228+50	E	156/47	65/105	70	59	64	69	None	70	0.4	0	0
De Diego	236+00	E	121/37	45/72	69	63	64	69	None	70	0.9	0	0
De Diego	239+00	E	300/92	45/72	69	58	64	69	None	70	0.3	0	0
Total:												**35**	**9**

1. Noise levels are based on Ldn and are measured in dBA. Noise levels are rounded to the nearest decibel except for the increase in noise level, which is given to the nearest one-tenth decibel to provide a better resolution for assessing noise impact.
2. The reported noise levels represent the highest noise levels for each location.

The results in Table 4-1 identify 35 moderate noise impacts and 9 severe noise impacts along the Caguas corridor at two locations: along PR-30, at the residences behind the existing noise barrier, and just north of Caguas, where the PR-30 and PR-52 legs meet. Because of the high existing noise levels along the Caguas corridor from traffic on Route 52, and the relatively low volume of DMU operations, there is only a minimal increase in the noise levels projected due to introduction of DMU service at all other locations along the corridor.

The following are brief discussions of each impacted Category 2 land use area:

Santa Juana, Caguas – Severe noise impact is projected at 9 single-family residences and moderate noise impact at an additional 27 single-family residences on the west side of PR-30 in this location. The noise impacts are due the very close proximity of the DMU tracks to the residences, and because the existing highway noise barrier is not high enough to provide any shielding from proposed DMU operations on the aerial structure.

Bairoa Park, Caguas – Moderate noise impact is projected at eight single-family residences to the west of PR-52 in this location. The noise impacts are due to the presence of the crossover at the junction of the yard lead track to the PR-52 leg of the proposed system in Caguas. Wheel impacts at the gap in the track in a crossover increase the noise levels significantly in the immediate vicinity.

Similar to the Category 2 analysis, an assessment of noise impact for Category 3 receptors was also conducted. This assessment was based on a comparison of the existing ambient noise level with the predicted project noise levels in terms of the peak transit hour Leq. As indicated in Table 4-2, no impact is predicted at any of these locations.

Table 4-2. Projected Noise Impacts for Category 3 Land Use

Location	Civil Stn	Dist. to near track (ft/m)	Speed (mph/ kmph)	Exist. Noise Level[1]	Project Noise Level[1]			Impact Category	Total Noise Level[1]	Noise Level Increase[1]
					Pred.	Impact Criteria				
						Mod	Sev			
School – Industrial Bairoa	71+50	270/82	65/105	73	51	70	77	None	73	0.0
Church – Bairoa Park	75+00	93/29	65/105	72	58	70	75	None	72	0.2

1. Noise levels are based on Peak Hour Leq and are measured in dBA. Noise levels are rounded to the nearest decibel except for the increase in noise level, which is given to the nearest one-tenth decibel to provide a better resolution for assessing noise impact.

4.1.2 Noise Impact Mitigation

As discussed in Chapter 3, FTA states that in implementing noise impact criteria, severe impacts should be mitigated unless there are no practical means to do so. At the moderate impact level, more discretion should be used, and other project-specific factors should be included in the consideration of mitigation. These other factors can include the predicted increase over existing noise levels, the types and number of noise-sensitive land uses affected, existing outdoor-to-indoor sound insulation and the cost-effectiveness of mitigating noise to more acceptable levels.

Mitigation Options

Potential mitigation measures for reducing noise impacts from DMU operation for the proposed project are described below.

Noise Barriers - This is a common approach to reducing noise impacts from surface transportation sources. The primary requirements for an effective noise barrier are that:

- the barrier must be high enough and long enough to break the line-of-sight between the sound source and the receiver;

- the barrier must be of an impervious material with a minimum surface density of 4 lb/sq. ft.; and
- the barrier must not have any gaps or holes between the panels or at the bottom.

Because numerous materials meet these requirements, the selection of materials for noise barriers is usually dictated by aesthetics, durability, cost and maintenance considerations. Depending on the proximity of the barrier to the tracks and on the track elevation, transit system noise barriers typically range in height from between four and eight feet.

<u>Building Sound Insulation</u> - 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 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 any 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.

<u>Special Trackwork at Crossovers</u> - Because the impacts of DMU wheels over rail gaps at track crossover locations increases DMU 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 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.

<u>Property Acquisitions or Easements</u> – Additional options for avoiding noise impacts are for the transit 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.

Recommended Mitigation
Santa Juana – The recommended mitigation at this location would be to construct a 6 ft high noise barrier on the west side of the elevated structure from approximately Station 21+00 to 28+00.

Bairoa Park – The recommended mitigation at this location would be to replace the standard crossover at Station 83+00 with a moveable point or spring-rail frog, to eliminate the gap at the crossover. Alternatively, a 6-8 ft high noise barrier could be constructed on the west side of the elevated structure from approximately Station 82+00 to 84+00.

4.2 VIBRATION

4.2.1 Ground Vibration Impact Assessment

Vibration Impact Assessment Methodology

The potential vibration impact from DMU operations was assessed on an absolute basis using the criteria and methodology contained in the FTA guidance manual. The same representative sensitive receptors identified in noise impact section were considered for the vibration impact assessment. The following factors were used in determining potential vibration impacts along the project corridor:

- Vibration propagation tests were conducted at three sites along the corridor near sensitive receptors. These tests measured the response of the ground to an input force.
- The vibration source level measurements were based on a typical DMU force density curve for a vehicle similar to the one proposed for the Caguas Corridor. The vehicle force density curve and the vibration propagation of the soil were combined to project vibration levels from DMU operations along the corridor.
- Vehicle operating speeds are based on information provided by the project design team. The speed is assumed to be 65 mph along the entire corridor north of Caguas and 45 mph for the PR-52 branch of the system in Caguas and 30 mph for the PR-30 branch of the system Caguas.

Projected Vibration Levels
For the proposed Alternative, the estimated root mean square (RMS) velocity levels (VdB re 1 micro-in./sec.) for sensitive receptors at representative distances are provided in Tables 4-3 and 4-4. These tables summarize the results of the analysis in terms of anticipated exceedances of the FTA criteria for "frequent events" (defined as more than 70 events per day). The criteria are discussed in more detail in Chapter 3.

Vibration-sensitive locations along the proposed alignment are listed in Table 4-3 for Category 2 land use and in Table 4-4 for Category 3 land use. Each table lists the locations, the civil station, the distance to the near track, and the projected speed at each location. In addition, the predicted project vibration level and the impact criterion level are indicated along with the number of impacts projected for each receptor or receptor group.

Table 4-3. Projected Vibration Impacts for Category 2 Land Use

Location[1]	Civil Stn	Side of Track	Dist to Near Track (ft/m)	Speed (mph/ kmph)	Project Vibration Level[2]	Vibration Impact Criterion[2]	# of Impacts
Santa Juana	21+50	W	139/43	30/48	48	72	0
Santa Juana	23+00	W	41/13	30/48	59	72	0
Santa Juana	25+00	W	21/7	30/48	69	72	0
Santa Juana	27+00	W	41/13	30/48	59	72	0
Estancias de Bairoa	66+00	W	119/36	45/72	63	72	0
Industrial Bairoa	68+00	E	225/69	45/72	58	72	0
Arbolada	71+00	W	71/22	45/72	67	72	0
Bairoa	78+00	E	156/47	45/72	61	72	0
Bairoa	81+00	E	87/26	45/72	65	72	0
Bairoa Park	78+00	W	69/21	45/72	67	72	0
Bairoa Park	83+00	W	66/20	45/72	68	72	0
Bairoa Park	88+00	W	361/110	45/72	46	72	0
El Retiro	90+50	W	211/64	45/72	49	72	0
Quintas de San Luis	99+00	W	242/74	65/105	61	72	0
Quintas de San Luis	105+50	E	152/46	65/105	64	72	0
Quintas de San Luis	120+00	E	190/58	65/105	63	72	0
Bo. San Antonio	130+00	W	190/58	65/105	63	72	0
Bo. San Antonio	146+00	W	225/69	65/105	61	72	0
Bo. San Antonio	175+00	W	156/47	65/105	64	72	0
Bo. San Antonio	187+50	E	173/53	65/105	63	72	0
Montehiedra	197+50	E	190/58	65/105	63	72	0
Parque Forestal	206+00	E	190/58	65/105	63	72	0
Villa Nova	209+00	W	190/58	65/105	63	72	0
La Campina	213+00	W	173/53	65/105	63	72	0
Borinquen Gardens	214+50	E	156/47	65/105	64	72	0
Alturas de Borinquen Gardens	215+00	W	173/53	65/105	63	72	0
La Cumbre	220+00	W	218/66	65/105	62	72	0
Villa Pilar	226+00	W	208/63	65/105	62	72	0
El Remanso	220+50	E	149/45	65/105	64	72	0
Villas Del Parana	228+50	E	156/47	65/105	64	72	0
De Diego	236+00	E	121/37	45/72	53	72	0
De Diego	239+00	E	300/92	45/72	46	72	0
Total:							**0**

1. Vibration levels are measured in VdB referenced to 1 μin/sec.
2. The reported vibration level represents the maximum vibration level for each location.

The results in Table 4-3 identify no vibration impacts along the Caguas corridor. This is due primarily to the inefficient soil propagation conditions along the project corridor and the distance from the proposed alignment to sensitive receptors.

Similar to the Category 2 analysis, an assessment of vibration impact for Category 3 receptors was also conducted. As shown in Table 4-4, no potential impacts were identified for Category 3 receptors.

Table 4-4. Projected Vibration Impacts for Category 3 Land Use

Location[1]	Civil Stn	Dist to Near Track (ft/m)	Speed (mph/ kmph)	Project Vibration Level[2]	Vibration Impact Criterion[2]	# of Impacts
School – Industrial Bairoa	71+50	270/82	45/72	57	75	0
Church – Bairoa Park	75+00	93/29	45/72	65	75	0
Total:						**0**

1. Vibration levels are measured in VdB referenced to 1 µin/sec.
2. The reported vibration level represents the maximum vibration level for each location.

4.2.2 Ground-Borne Noise Impact Assessment

As indicated in Chapter 3, airborne noise tends to mask ground-borne noise for above ground (i.e. at-grade or elevated) rail systems; therefore ground-borne noise impact was not assessed along the project corridor.

4.2.3 Ground-Borne Vibration Mitigation

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 transit 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.

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.

Relocation of Crossovers or Special Trackwork - 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.

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, and their use for at-grade track is rare. Although floating slabs are designed to provide vibration reduction at lower frequencies than ballast mats, they are extremely expensive.

Property Acquisitions or Easements – Additional options for avoiding vibration impacts are for the transit 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 vibration conditions. These approaches are usually taken only in isolated cases where other mitigation options are infeasible, impractical, or too costly.

Vibration impacts that exceed FTA criteria are considered to be significant and to warrant mitigation, if reasonable and feasible. Because no vibration impacts are projected along the Caguas Corridor, no vibration mitigation is recommended.