NOISE AND VIBRATION IMPACT ASSESSMENT FOR THE SAN FRANCISCO BAY AREA RAPID TRANSIT DISTRICT (BART) WARM SPRINGS EXTENSION PROJECT

DRAFT REPORT

HMMH Report No. 298760-01

February 2003

Prepared for:

Jones & Stokes Associates
2600 V Street
Sacramento, CA 95818-1914

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1. INTRODUCTION AND SUMMARY

This report presents a noise and vibration impact assessment for the Bay Area Rapid Transit (BART) Warm Springs Extension Project. This assessment was carried out for BART by Harris Miller Miller & Hanson Inc. (HMMH) under subcontract to Jones & Stokes Associates. The objective of the study was to assess the potential noise and vibration impacts of the planned BART operations at community locations adjacent to the rail corridor.

The background and results of the assessment are described below. Section 2 provides a discussion of environmental noise and vibration basics, and Section 3 describes the existing noise and vibration conditions and measurement results. The criteria used to assess noise and vibration impact are presented in Section 4, and projections of future noise and vibration conditions are described in Section 5. Section 6 summarizes the impact assessment, and potential mitigation measures are outlined in Section 7. Appendix A includes measurement site photographs, and detailed noise and vibration data are provided in Appendix B and Appendix C, respectively.

1.1 Background

BART is currently planning to expand service to Warm Springs in southern Alameda County. As shown in Figure 1, the Warm Springs Extension alignment extends south and east from the current BART Fremont Station. The alignment goes into subway through Fremont Park and then resurfaces just north of Paseo Padre Parkway where it then runs parallel to the Union Pacific Railroad (UP) alignment south to Auto Mall Parkway. The extension ends just south of the Warm Springs Station.

An alternative to the proposed BART project is a bus alternative that would use rubber-tired transit vehicles. The proposal would include the creation of a paved busway within the UP right-of-way in place of the Proposed Project. The busway would be open to all transit operators and could carry both VTA and AC Transit routes. Passengers would board and alight on any bus operating in the busway, with stops located at the Fremont BART Station and at a proposed Warm Springs Transit Center, located on the same site as the proposed Warm Springs BART Station.

The predominant noise and vibration-sensitive land use along the corridor consists of single and multi-family residences. Other sensitive receptors include churches and schools. Existing noise sources along the corridor include roadway traffic, aircraft overflights, railroad operations and local neighborhood activities.

The proposed BART line will use 75-foot long vehicles operating in ten-car consists. Weekday operations are planned between 4:00 a.m. and 12:00 a.m. with 12-minute headways during peak periods and 20-minute headways during off-peak periods. The trains will operate primarily on ballast-and-tie track with continuous welded rail (CWR), with a maximum speed of 70 mph.

The operating times of the proposed bus alternative were assumed to be identical to that for the Proposed BART Project. The operating plan specifies peak headways of 15 minutes and off-peak headways of 30 minutes for both the VTA and AC Transit routes.

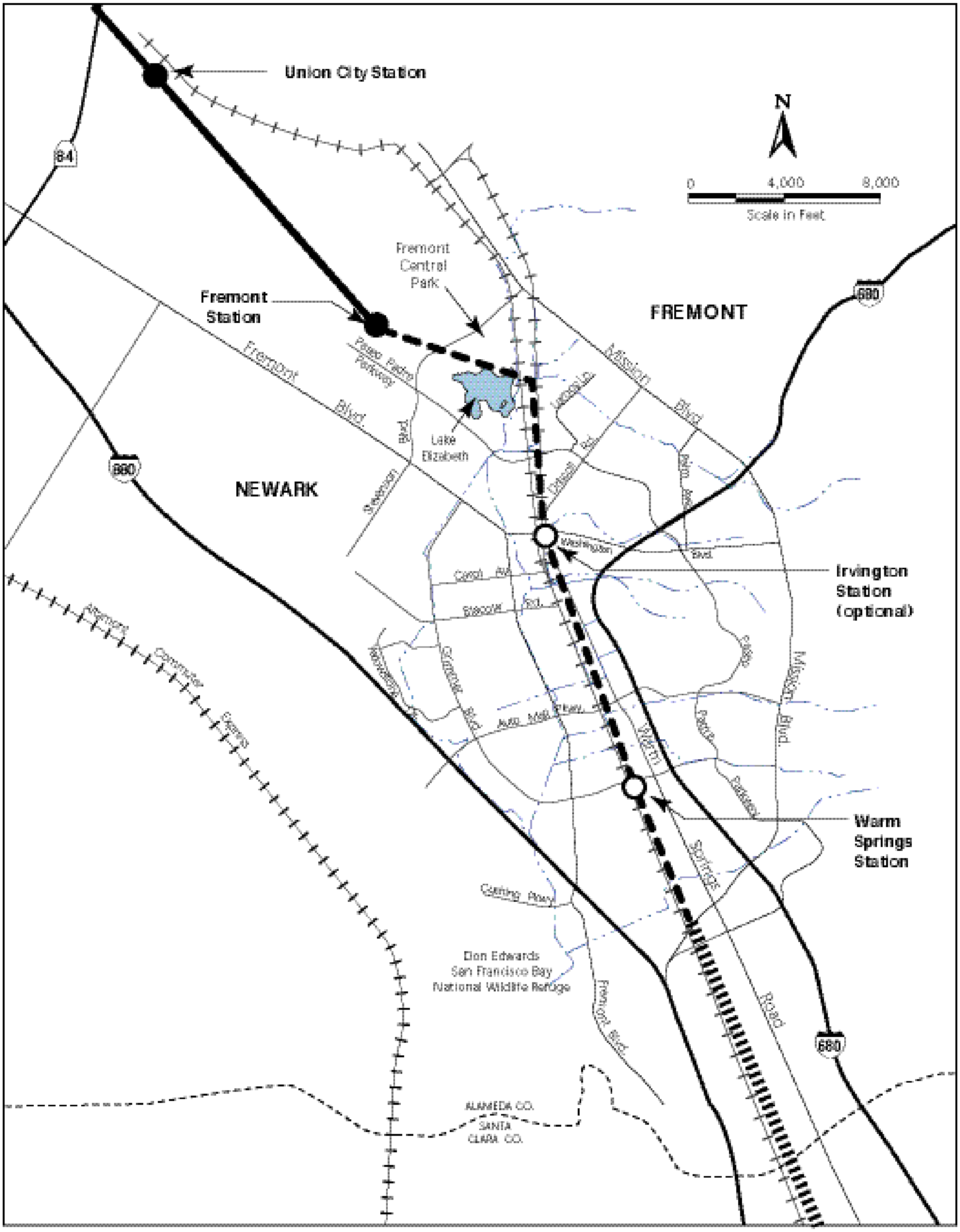

Figure 1. BART Warm Springs Extension Alignment

1.2 Summary of Results

1.2.1 Noise Impact Assessment

1.2.1.1 BART Alternative

The results of the noise analysis for the BART alternative indicate that the existing noise environment at locations near the project alignment is dominated by noise from motor vehicle traffic on nearby and distant roads, railroad operations, aircraft and general community noise. Based on the BART noise criteria, it is predicted that without mitigation, the proposed BART operations will cause project-induced noise impact at 110 residences and one school playground. Without mitigation, the proposed BART operations will cause cumulative noise impact at 146 residences along the corridor. The total number of noise impacts (both residential and institutional) along the BART Warm Springs alignment is 256. 49 of the impacts are both cumulative and project-induced, and are located between Walnut Avenue and Stevenson Boulevard, and between Paseo Padre Parkway and Washington Boulevard.

A number of noise mitigation measures can be considered for the above impacts. The most likely method of noise mitigation is noise barriers. In addition, sound insulation treatments may be applied to buildings in areas where barriers would not be effective. The selection of mitigation will depend on more detailed analysis during final design, including input from abutting neighbors.

1.2.1.2 Bus Alternative

The results of the noise analysis for the bus alternative indicate that the existing noise environment at locations near the project alignment is dominated by noise from motor vehicle traffic on nearby and distant roads, railroad operations, aircraft and general community noise. Without mitigation, the proposed BART operations will cause cumulative noise impact at two residences along the corridor.

A number of noise mitigation measures can be considered for the above impacts. The most likely method of noise mitigation is noise barriers. In addition, sound insulation treatments may be applied to buildings in areas where barriers would not be effective. The selection of mitigation will depend on more detailed analysis during final design, including input from abutting neighbors.

1.2.2 Vibration Impact Assessment

1.2.2.1 BART Alternative

Freight rail operations are a significant source of existing vibration along the alignment. Based on BART vibration criteria, it is predicted that without mitigation, the BART operations will cause vibration impact at a total of 124 residences along the corridor. All of these impacts are related to annoyance effects and not to building damage effects.

There are a number of options available for the mitigation of vibration impacts. The most common method is ballast mats. Ballast mats consist of pads made of rubberlike material placed on an asphalt or concrete base with the normal ballast, ties and rail on top. Because vibration reduction provided by ballast mats is dependent on the frequency content of vibration, they are not always effective at lower frequencies. Mitigation options will be evaluated in more detail during final design, and the most appropriate measures will be selected based on feasibility, cost effectiveness, and community input.

1.2.2.2 Bus Alternative

No vibration impact is projected for the proposed bus alternative.

2. ENVIRONMENTAL NOISE AND VIBRATION BASICS

2.1 Noise Fundamentals and Descriptors

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

The frequency content of noise is related to the tone or pitch of the sound, and is expressed based on the rate of the air pressure fluctuation in terms of cycles per second (called Hertz and abbreviated as Hz). The human ear can detect a wide range of frequencies from about 20 Hz to 17,000 Hz. However, because the sensitivity of human hearing varies with frequency, the A-weighting system is commonly used when measuring environmental noise to provide a single number descriptor that correlates with human subjective response. Sound levels measured using this weighting system are called “A-weighted” sound levels, and are expressed in decibel notation as “dBA.” The A-weighted sound level is widely accepted by acousticians as a proper unit for describing environmental noise. To indicate what various noise levels represent, Figure 2 provides a comparison of representative noise levels for common noise sources and environments. While the extremes of noise are shown to range from 0 dBA (approximate threshold of hearing) to 120 dBA (jet aircraft at 500 feet), most commonly encountered noise levels are shown to fall within the range of 40 dBA to 90 dBA.

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.

Environmental noise can also be viewed on a statistical basis using percentile sound levels, Ln, which refer to the sound level exceeded "n" percent of the time. For example, the sound level exceeded 90 percent of the time, denoted as L90, is often taken to represent the "background" noise in a community. Similarly, the sound level exceeded 33 percent of the time (L33) is often used to approximate the Leq in the absence of loud, intermittent sources such as aircraft and trains.

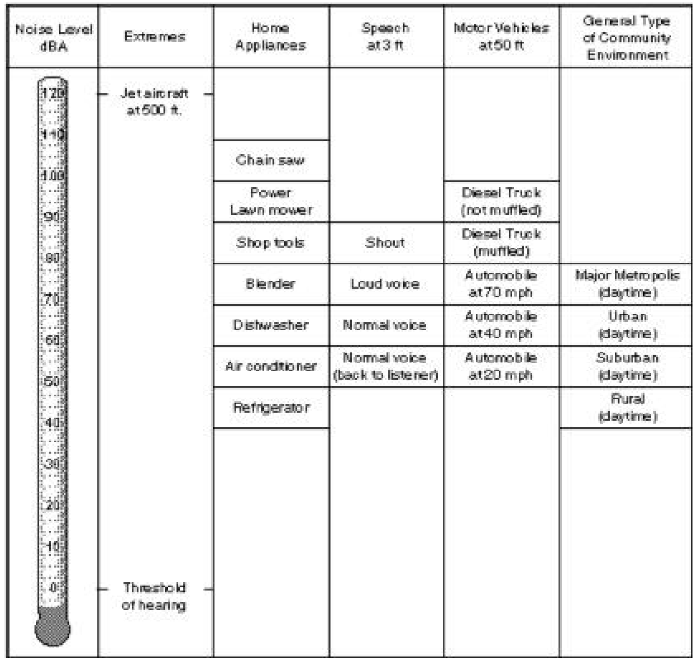

Figure 2. Comparison of Various Noise Levels

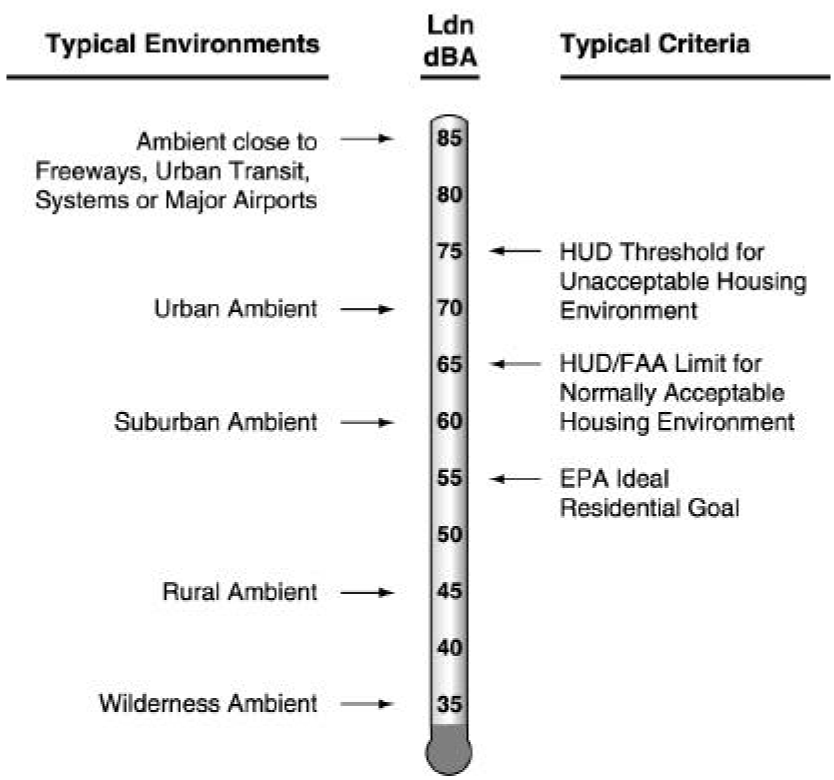

Figure 3. Examples of Typical Outdoor Noise Exposure

2.2 Vibration Fundamentals and Descriptors

Ground-borne vibration is the oscillatory motion of the ground about some equilibrium position, which can be described in terms of displacement, velocity or acceleration. Displacement refers to the distance an object moves away from its equilibrium position, velocity refers to the rate of change in displacement or the speed of this motion, and acceleration refers to the time rate of change in the velocity of the object. At any given frequency of oscillation, vibration displacement, velocity and acceleration are related by a constant factor. However, vibrations are often more complex in the environment, including components at many different frequencies. Therefore, the relationship between the overall vibration levels in terms of these descriptors depends on the frequency content of the vibration energy.

Although displacement is easier to understand than velocity or acceleration, it is rarely used for describing ground-borne vibration. One reason for this is that most sensors used for measuring ground-borne vibration are designed to provide output signals proportional to either velocity or acceleration. Even more important, the response of humans, buildings and equipment to vibration is more accurately described using velocity or acceleration. Because sensitivity to vibration has typically been found to correspond to a constant level of vibration velocity amplitude within the low frequency range of most concern for environmental vibration (roughly 5-100 Hz), vibration velocity is used in this analysis as the primary measure to evaluate the effects of vibration.

There are several different measures used to quantify vibration amplitude. One of the most common is the peak particle velocity (PPV), defined as the maximum instantaneous positive or negative peak of the vibratory motion. PPV is often used in monitoring blasting vibration since it is related to the stresses experienced by building components. Although PPV is appropriate for evaluating the potential for building damage, it is less suitable for evaluating human response, which is better related to an average vibration amplitude. Because the net average of a vibration signal about its equilibrium position is zero, the root mean square (rms) amplitude is often used to describe the "smoothed" vibration amplitude. The rms amplitude is defined as the average of the squared amplitude of the signal, and is typically evaluated over a one-second period of time.

Although vibration velocity is normally described in units of inches per second in the USA, the decibel notation, which acts to compress the range of numbers required to describe vibration, can also be used. In this notation, the vibration magnitude can be expressed in terms of velocity level, in decibels, defined as follows:

$$L_v = 20\log_{10}(v/v_{ref}),\ \text{VdB}$$

where: v = rms velocity, in./sec

v_{ref} = 1×10^{-6} in./sec

Thus, the descriptor used for this assessment of ground-borne vibration is the rms vibration velocity level, L_v, expressed in decibels (VdB) relative to one micro-inch per second. 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 VdB to 100 VdB, from imperceptible background vibration to the threshold of damage. Although the threshold of human perception to vibration is approximately 65 VdB, annoyance is not usually significant unless the vibration exceeds 70 VdB.

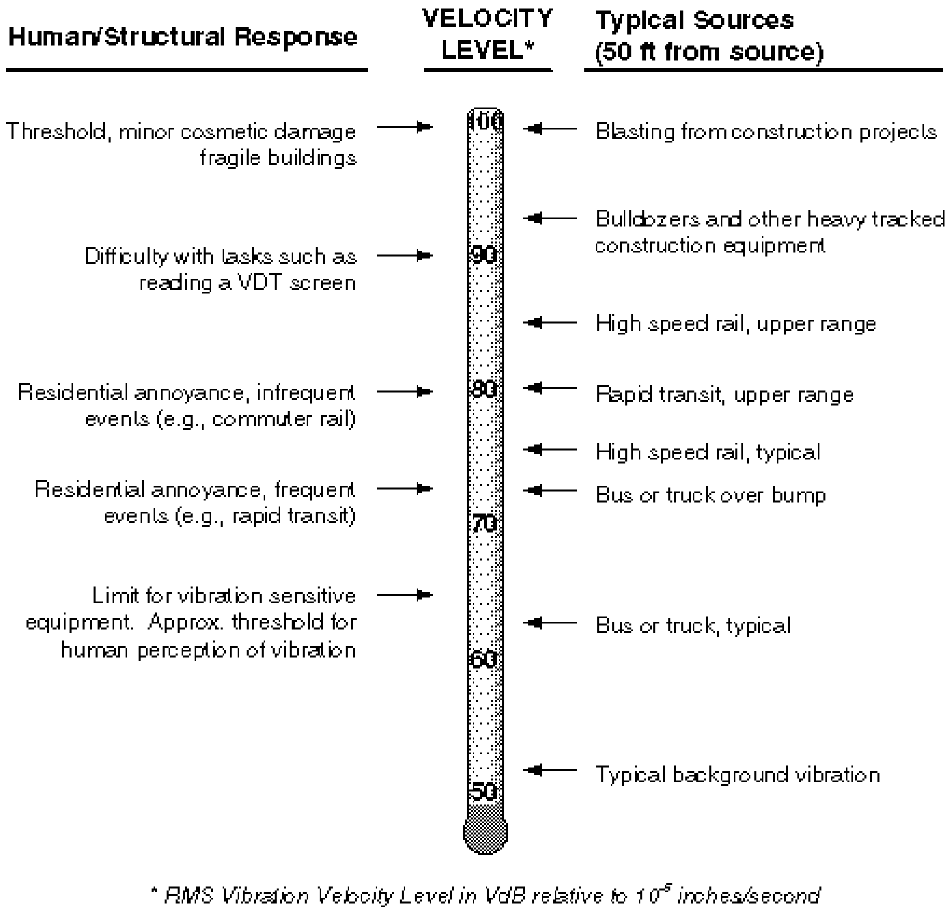

Figure 4. Typical Ground-Borne Vibration Levels and Criteria

3. EXISTING CONDITIONS

The primary sources that contribute to the existing noise environment along the BART Warm Springs Extension are motor vehicle traffic on nearby and distant roadways, aircraft overflights and general community activities. Freight operations on the UP mainline also contribute to the noise and vibration environment in the area.

To characterize the existing baseline noise and vibration conditions in the communities along the corridor, a field measurement program was carried out during the period from May 13 through May 16, 2002.

The measurement program included monitoring of existing noise levels, as well as tests to characterize ground-borne vibration propagation at representative sites. The measurement locations, test procedures and results are described separately below for noise and for vibration.

3.1 Noise Measurements

3.1.1 Locations

Noise measurement sites were selected based on a review of aerial photographs, supplemented by a visual land-use survey of noise-sensitive receptors along the Warm Springs Extension. Nine sites, designated as Sites LT-1 through LT-9, were selected for long-term (typically 24-hour) monitoring and three sites, designated as Sites ST-1 through ST-3, were selected for short-term (one hour) monitoring. The locations of these measurement sites are indicated in Figure 5, and are described below. Site photographs are included in Appendix A.

Site LT-1 was located east of the proposed alignment at the Presidio Apartments. The microphone was located in the parking lot at the edge of the “slot” where the proposed alignment will be located. Traffic on Walnut and local residential activities were the largest contributors to the noise environment. The measured Ldn at this site was 57 dBA.

Site LT-2 was located east of the proposed alignment at the Red Hawk Ranch Apartments. The microphone was located in the parking lot at the edge of the “slot” where the proposed alignment will be located. Distant traffic and neighborhood activities contributed to the noise environment. The measured Ldn at this site was 53 dBA.

Site LT-3 was located east of the proposed alignment, at 1549 Valdez Way. The microphone was located in the backyard of the single-family residence. Dominant sources of noise at this site included freight trains, distant auto traffic and neighborhood activities. The measured Ldn at this site was 53 dBA.

Site LT-4 was located east of the proposed alignment, at 40807 Vaca Road. The microphone was located in the backyard of the single-family residence. An eight-foot wooden fence separates the backyard from the WP tracks. Traffic on the Paseo Parkway was the dominant source of noise at this site. Local activities also contributed to the noise environment. The measured Ldn at this site was 53 dBA.

Site LT-5 was located west of the proposed alignment at 3240 Neal Road. The microphone was placed in the backyard of a multi-family residence with a six-foot fence separating the house and the freight tracks. Freight trains, traffic, and local activities contributed to the noise environment. The measured Ldn at this site was 60 dBA.

Site LT-6 was located east of the proposed alignment, at 3073 Driscoll Road. The microphone was located in the yard of the single-family residence. Freight trains and auto traffic on Driscoll and Washington contributed to the noise environment. The measured Ldn at this site was 54 dBA.

Site LT-7 was located west of the proposed alignment at 3621 Kay Court. The microphone was located in the backyard of the single-family residence at the end of the cul-de-sac. Freight train traffic dominated the noise environment at this site. The measured Ldn at this site was 66 dBA.

Site LT-8 was located west of the proposed alignment at 43244 Newport Drive. The microphone was located behind the single-family residence at the façade of the house. Freight train traffic dominated the noise environment at this site. The measured Ldn at this site was 65 dBA.

Site LT-9 was located west of the proposed alignment at 44788 Old Warm Springs Road. The microphone was placed in the side yard of a single-family residence. Auto traffic on Grimmer and Old Warm Springs Roads dominated the noise environment at this site. The measured Ldn at this site was 61 dBA.

Site ST-1 was located east of the proposed alignment at the park near the walking path off Stevenson Boulevard. Distant traffic and construction contributed to the noise environment at this site. The measured one-hour Leq at this site was 49 dBA.

Site ST-2 was located at the two churches on Driscoll Road. The noise measurement was taken from the loudest peak-hour at LT-3, which was located next to the churches at a single-family residence. The contributors to the noise at this site included traffic on Driscoll Road. The measured one-hour Leq at this site was 54 dBA.

Site ST-3 was located west of the proposed alignment at the E.M. Grimmer Elementary School. The microphone was located in the playing fields near the freight tracks. Airplane overflights and local activities contributed to the noise environment at this site. The measured one-hour Leq at this site was 53 dBA.

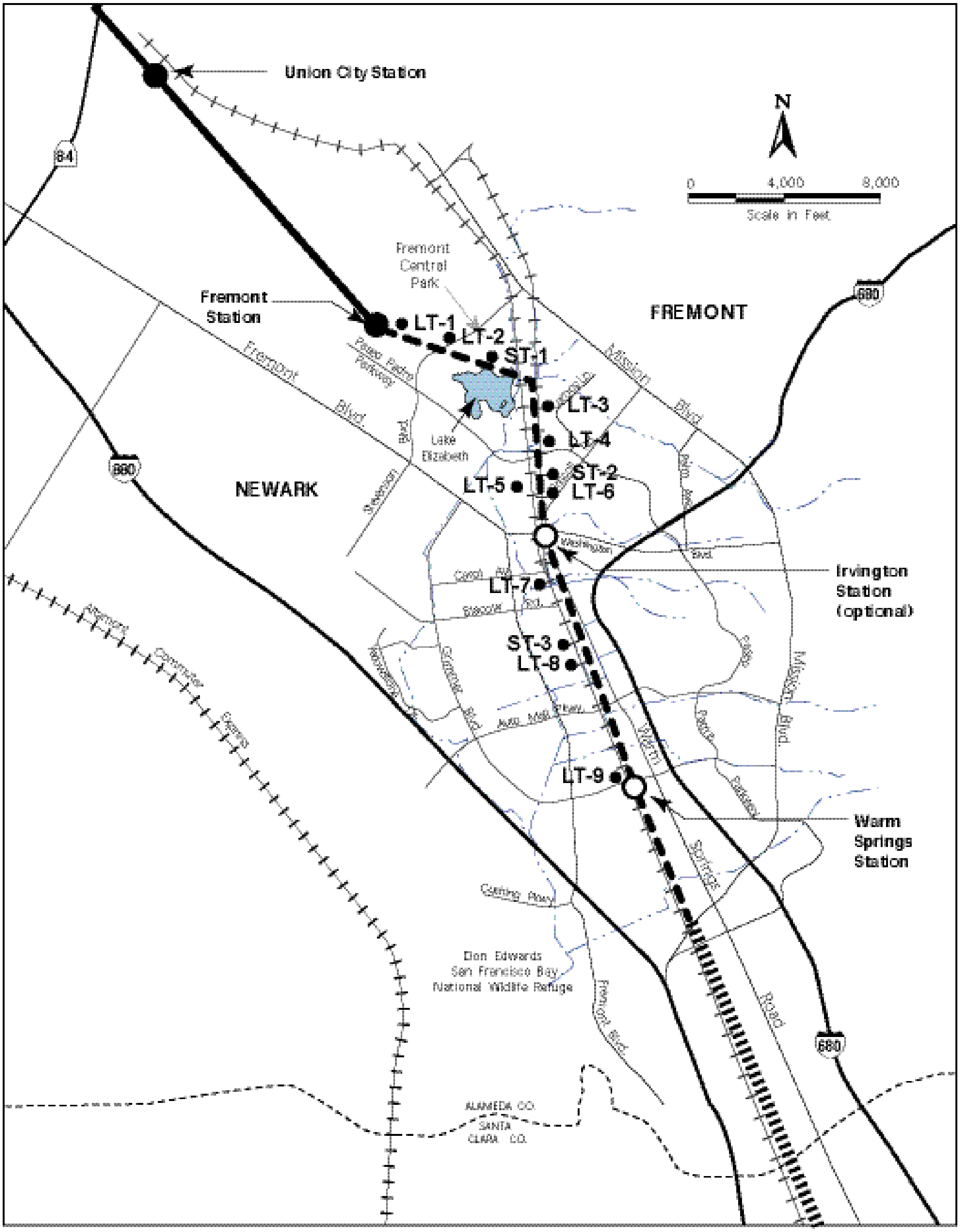

Figure 5. Existing Ambient Noise Measurement Locations

3.1.2 Instrumentation and Procedures

Long-term, ambient noise measurements were conducted at Sites LT-1 through LT-9, described above. At each of these locations, unattended Larson Davis Model 870 portable, automatic noise monitors were used to continuously sample the A-weighted sound level (with slow response), typically over one 24-hour period. The noise monitors were programmed to record hourly results, including the maximum sound level (Lmax), the equivalent sound level (Leq) and the statistical percentile sound levels (Ln). The day-night equivalent sound level (Ldn) was subsequently computed from the hourly Leq data.

Short-term, ambient noise measurements were conducted at Sites ST-1 through ST-3, described above. At these locations, an attended Larson Davis Model 870 portable, automatic noise monitor was used to continuously sample the A-weighted sound for 1-minute intervals over one hour periods. The one-minute Leq data were then combined to obtain the Leq for the hour periods.

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.

3.1.3 Results

A summary of the existing ambient noise measurement results is provided in Table 1, and detailed data are included in Appendix B.

Table 1. Summary of Existing Ambient Noise Measurement Results

Site No.	Measurement Location Description	Start of Measurement		Meas. Time (hrs)	Noise Exposure (dBA)	
		Date	Time		Ldn	Leq
LT-1	M.F. Res @ Presidio Apartment Complex	5/15/02	10:00	24	57	--
LT-2	M.F. Res @ Red Hawk Ranch Apartments	5/15/02	10:00	24	53	--
LT-3	S.F. Res @ 1549 Valdez Way	5/13/02	17:00	24	53	--
LT-4	S.F. Res @ 40807 Vaca Road	5/13/02	17:00	24	53	--
LT-5	M.F. Res @ 3240 Neal Road	5/13/02	18:00	24	60	--
LT-6	S.F. Res @ 3073 Driscol Road, Apt A	5/13/02	18:00	24	54	--
LT-7	S.F. Res @ 3621 Kay Court	5/14/02	18:00	24	66	--
LT-8	S.F. Res @43244 Newport Drive	5/14/02	18:00	24	65	--
LT-9	S.F. Res @ 44788 Old Warm Springs Road	5/15/02	19:00	24	61	--
ST-1	Fremont Central Park Near Walking Path	5/16/02	7:35	1	--	49
ST-2	St. Anne's Episcopal Church/Church of Christ	5/13/02	17:00	1	--	54
ST-3	E.M. Grimmer Elementary School	5/16/02	16:56	1	--	53

The long-term measurement results in Table 1 indicate Ldn ranging from 53 dBA to 66 dBA along the corridor. The lowest Ldn values, in the range of 53 dBA to 57 dBA, were measured on the east side of the alignment north of Washington Boulevard, while the highest Ldn values were measured at locations west of the corridor between Washington Boulevard and the southern terminus of the project. These results were used as a basis for determining the existing noise conditions at all noise-sensitive receptors along the Warm Springs Extension as follows:

- Walnut Avenue to Stevenson Boulevard (Northbound Side): The existing Ldn in this area is estimated to be 57 dBA for the Presidio Apartment Complex (Site LT-1) and 53 dBA for the Red Hawk Ranch Apartments (Site LT-2). The higher Ldn at the Presidio Apartments is due to the proximity of Walnut Avenue.

- Walnut Avenue to Stevenson Boulevard (Southbound Side): The Ldn in this area is estimated to be 53 dBA, based on the measurement results at the Red Hawk Ranch Apartments (Site LT-2).

- Valdez Way/Vaca Road (Northbound Side): The existing Ldn in this area is estimated to be 53 dBA, as measured on Valdez Way and Vaca Road (Sites LT-3 and LT-4).

- Paseo Padre Parkway to Washington Boulevard (Southbound Side): The Ldn in this area is estimated to be 60 dBA, based on the measurement results at the multi-family housing on Neal Road (Site LT-5).

- Paseo Padre Parkway to Washington Boulevard (Northbound Side): The existing Ldn in this area is estimated to be 53 dBA, as measured on Vaca Road (Sites LT-4) for the residences along Valero Drive and 54 dBA for the residences on Driscol Road, as measured on Driscol Road (LT-6). In addition, both St. Anne's Episcopal Church and the Church of Christ have a peak-hour Leq of 54 dBA (Site ST-2).

- Washington Boulevard to Blacow Road (Northbound Side): The Ldn in this area is estimated to be 54 dBA, for the residences next to the proposed Irvington Station, based on the measurement results on Driscol Road (Site LT-6) and 66 dBA for the residences closer to the road and the railroad corridor, based on the measurement on Kay Court (Site LT-7).

- Washington Boulevard to Blacow Road (Southbound Side): The existing Ldn in this area is estimated to be 66 dBA, as measured on Kay Court (Sites LT-7).

- Blacow Road to Auto Mall Parkway (Southbound Side): The Ldn in this area is estimated to be 65 dBA, based on the measurement results on Newport Drive (Site LT-8). In addition, the E. M. Grimmer Elementary School has a peak-hour Leq of 53 dBA (Site ST-3).

- Auto Mall Parkway to South Grimmer Road (Southbound Side): The existing Ldn in this area is estimated to be 61 dBA, as measured on Old Warm Springs Road (Sites LT-9).

3.2 Vibration Measurements

3.2.1 Locations and Tests

The only significant sources of existing ground-borne vibration along the project corridor are the Union Pacific freight trains operating along the existing tracks in the corridor. Figure 6 shows the existing vibration levels from the freight trains as a function of the distance from the track. In addition to measuring the vibration levels from the existing freight trains, the vibration measurements for this project focused on characterizing the vibration propagation characteristics of the soil at representative locations.

Four vibration testing sites (V-1 though V-4), at the locations shown in Figure 7, were selected to represent a range of soil conditions in areas along the corridor that include a significant number of vibration-sensitive receptors. During the period from May 14 through May 15, 2002, a ground-borne vibration propagation test was conducted at each of these sites 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 the BART vehicle to predict future vibration levels at locations along the project corridor.

Site V-1 was located along the proposed alignment near the Red Hawk Ranch Apartments, at the southern end of the "slot". This site is representative of the vibration-sensitive receptors in the northern section of the corridor.

Site V-2 was located east of the proposed alignment next to Paseo Padre Parkway. This site is representative of vibration-sensitive sites on both sides of Paseo Padre Parkway.

Site V-3 was located west of the proposed alignment at the E.M. Grimmer Elementary School. This site is representative of vibration-sensitive receptors to the west of the corridor south of Washington Boulevard.

Site V-4 was located east of the proposed alignment at an industrial area on Osgood Court. The measurements were performed across the alignment from a residential area north of Auto Mall Parkway. This site is representative of vibration-sensitive receptors at the southern end of the project.

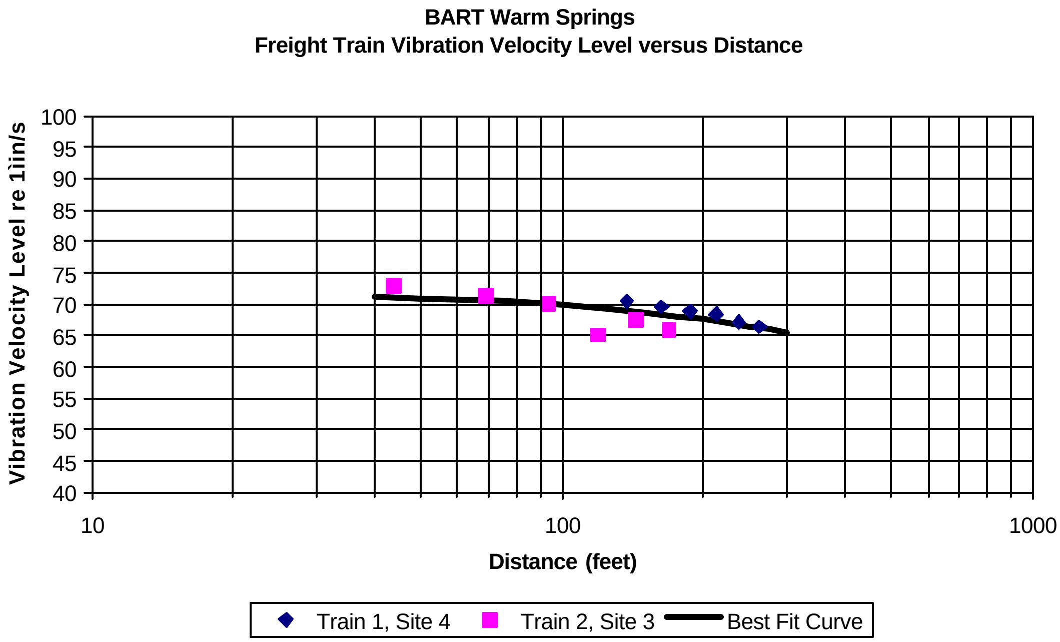

Figure 6. Maximum Existing Union Pacific Freight Train Vibration

3.2.2 Instrumentation and Procedures

The ground vibration measurements 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 recorded on a TEAC Model RD-130-TE 8-channel digital audio tape (DAT) recorder and subsequently analyzed in the HMMH laboratory.

The vibration propagation test procedure is shown schematically in Figure 8. As shown in the cross section view at the top, the test basically consists of dropping a 60 lb weight from a height of 3 to 4 feet onto the ground. A load cell is used to measure the force of the impact and accelerometers are used to measure the resulting vibration pulses at various distances from the ground. The relationship between the input force and the ground surface vibration, called the transfer mobility, characterizes vibration propagation at this location. It is possible to estimate the ground vibration that would be caused by another source, such as a train, by substituting the impact force with the train forces.

The bottom sketch in Figure 8 shows how the dropped weight point source is used to simulate a line vibration source such as a train. Impact tests are made at regular intervals in a line along the rail alignment. For these tests, impacts were done at eleven points, spaced 15 feet apart along a line perpendicular to the line of accelerometers.

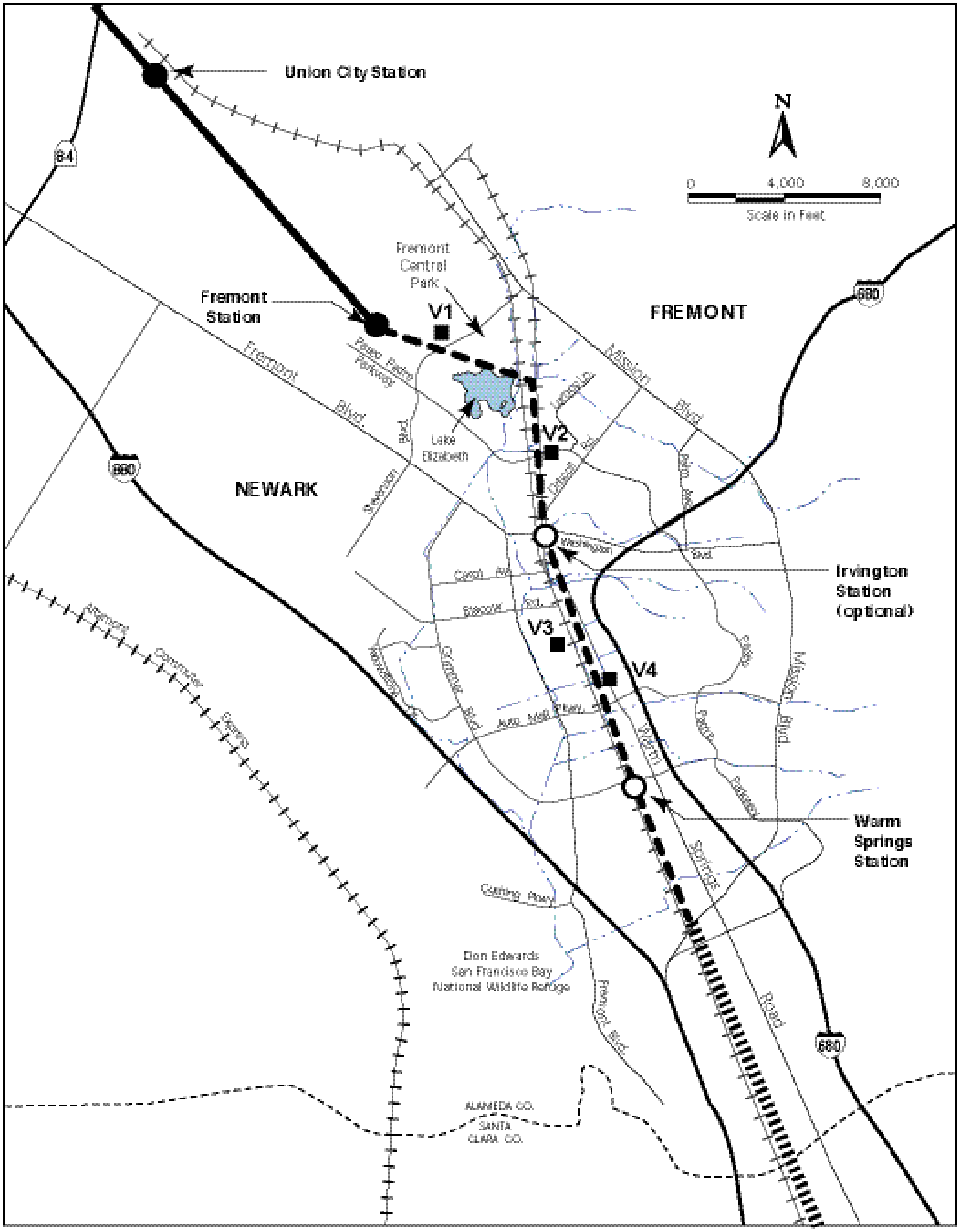

Figure 7. Vibration Measurement Test Locations

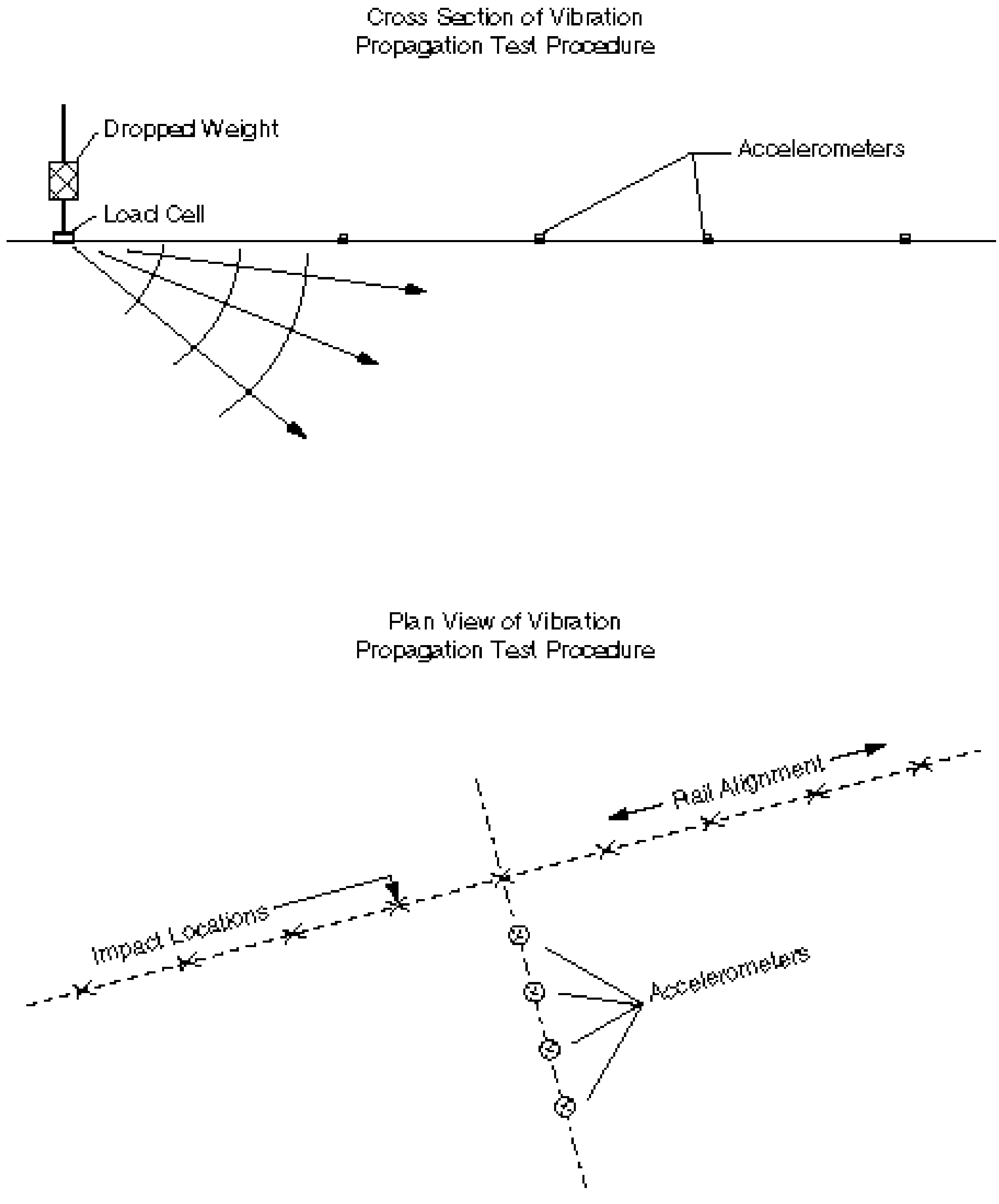

Figure 8. Vibration Propagation Test Procedure

3.2.3 Results

For laboratory analysis of the ground vibration propagation test data, a Tektronix Model 2630 multi-channel spectrum analyzer was used to obtain the transfer mobility relationship for each accelerometer/impact pair. The basic steps taken to calculate 1/3-octave band transfer functions are summarized below:

1. A multi-channel spectrum analyzer was used to get narrowband transfer functions. A minimum of 20 impacts was used to obtain signal-enhanced transfer functions for each impact site-accelerometer pair. Numerical integration was used to change from acceleration to velocity.

2. The 1/3 octave band transfer mobility was calculated for each accelerometer/impact pair.

3. Each set of 1/3-octave band point-source transfer mobilities was combined using Simpson's Rule for numerical integration to estimate the equivalent line-source transfer mobility.

4. For each 1/3-octave band, a smooth curve was fit to the line source transfer mobility values. The end result is an estimate of line source transfer mobility as a function of distance from the source.

Examples of the resulting smoothed line source transfer mobilities are given in Figure 9, which provides spectra at a distance of 100 feet for each of the four test sites. More details on the propagation test and analysis procedures are given the U. S. Federal Transit Administration (FTA) guidance manual *Transit Noise and Vibration Impact Assessment* (FTA Report DOT-T-95-16, April 1995). Detailed test data for the Warm Springs Extension are included in Appendix C of this report.

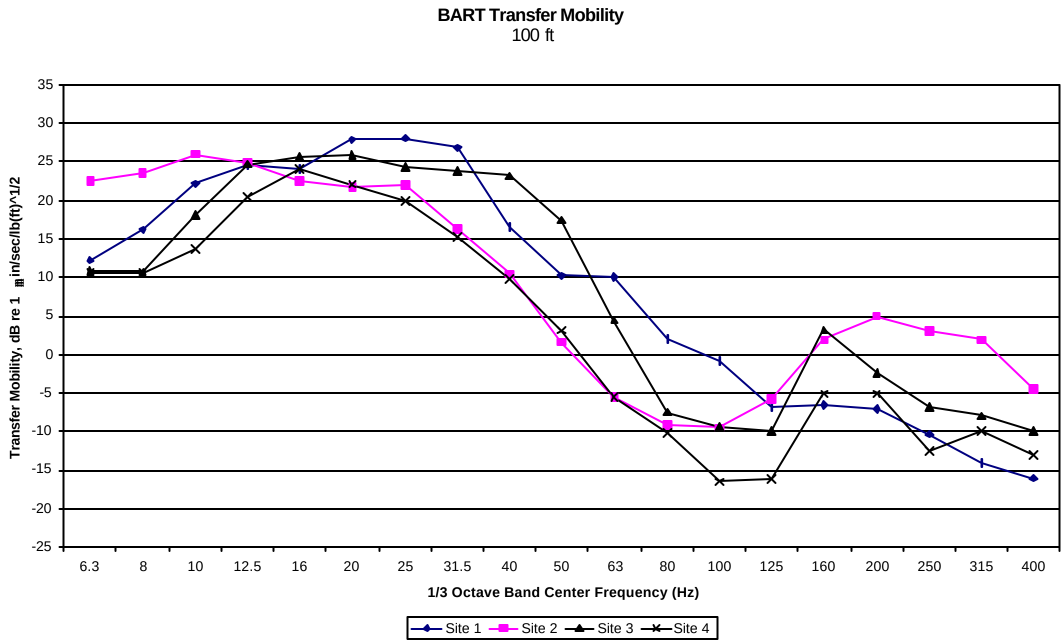

Figure 9. Line Source Transfer Mobilities for BART Warm Springs Extension Sites

4. NOISE AND VIBRATION IMPACT CRITERIA

Experience suggests that noise and vibration can be major public concerns with regard to the effects of a rail transit project. This section summarizes the impact limits as applicable to the Warm Springs Extension Project.

4.1 Noise Criteria

4.1.1 Project-Induced Noise Criteria

Noise impact for this project is based on the BART criteria adopted in the 1992 "Extensions Program System Design Criteria." The criteria are based on the maximum noise level (Lmax) of a BART transit vehicle passby and depend on the type of the receptor (single family, multi-family, commercial) and the area land use category. Table 2 presents the BART Noise Criteria. The bottom section of the table gives the criteria for special receptors.

Table 2. BART Design Criteria for Operational Noise

BART Area Category	Maximum Passby Noise Levels (dBA)		
	Single Family Dwellings	Multi Family Dwellings	Commercial Buildings
I Low Density Residential	70	75	80
II Average Residential	75	75	80
III High Density Residential	75	80	85
IV Commercial	80	80	85
V Industrial/Highway	80	85	85
	Maximum Passby Noise Levels (dBA)		
"Quiet" Outdoor Recreation Areas	70		
Concert Halls, Radio, and TV Studios	70		
Churches, Theaters, Schools, Hospitals	75		

4.1.2 Cumulative Noise Criteria

The cumulative noise impact for this project is based on the criteria defined in the U. S. Federal Transit Administration (FTA) guidance manual *Transit Noise and Vibration Impact Assessment* (FTA Report DOT-T-95-16, April 1995). 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, churches and active parks.

Ldn is used to characterize noise exposure for residential areas (Category 2). For other noise sensitive land uses, such as outdoor amphitheaters 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.

Impact: In this range of noise impact, sometimes referred to as moderate 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 cumulative noise impact criteria are summarized in Table 3. The project would result in a significant impact if the operational noise contributes to a cumulative increase in noise level that would be considered as a severe impact by the FTA criteria as shown in Table 3.

Table 3. Cumulative Noise Level Increase Allowed by FTA Criteria

Existing Noise Exposure Leq or Ldn	Impact Threshold for Increase in Cumulative Noise Exposure (dBA)			
	Category 1 or 2 Sites		Category 3 Sites	
	Impact	Severe Impact	Impact	Severe Impact
45	8	14	12	19
46	7	13	12	18
47	7	12	11	17
48	6	12	10	16
49	6	11	10	16
50	5	10	9	15
51	5	10	8	14
52	4	9	8	14
53	4	8	7	13
54	3	8	7	12
55	3	7	6	12
56	3	7	6	11
57	3	6	6	10
58	2	6	5	10
59	2	5	5	9
60	2	5	5	9
61	1.9	5	4	9
62	1.7	4	4	8
63	1.6	4	4	8
64	1.5	4	4	8
65	1.4	4	3	7
66	1.3	4	3	7
67	1.2	3	3	7
68	1.1	3	3	6
69	1.1	3	3	6
70	1.0	3	3	6
71	1.0	3	3	6
72	0.8	3	2	6
73	0.6	2	1.8	5
74	0.5	2	1.5	5
75	0.4	2	1.2	5

Note: Ldn is used for land uses where nighttime sensitivity is a factor;
maximum 1-hour Leq is used for land use involving only daytime activities.

4.2 Vibration Criteria

Vibration impact for this project is based on the BART criteria adopted in the 1992 "Extensions Program System Design Criteria." The criteria are based on the maximum vibration level (Lmax) of a passby and depend on the type of the receptor (single-family, multi-family, commercial) and the area land use category. Table 4 presents the BART Vibration Criteria. The bottom section of the table shows the criteria for special receptors.

Table 4. BART Design Criteria for Operational Ground-Borne Vibration

BART Area Category	Ground-Borne Vibration Maximum Passby Velocity Levels (VdB, μin/sec)		
	Single Family Dwellings	**Multi Family Dwellings**	**Commercial Buildings**
I Low Density Residential	70	70	70
II Average Residential	70	70	75
III High Density Residential	70	75	75
IV Commercial	70	75	75
V Industrial/Highway	75	75	75
	Maximum Passby Noise Levels (dBA)		
Concert Halls and TV Studios	65		
Churches and Theaters	70-75		
Hospital Sleeping Rooms	70-75		
Courtrooms, Schools, Libraries	75		
Offices	75-80		
Commercial and Industrial Buildings	75-85		
Vibration-Sensitive Industry or Research	60-70		

4.3 Noise Criteria for Ancillary Equipment

BART policy specifies that noise from fixed facilities, such as electrical substations and vent shaft noise from a passing train, be kept at or below maximum permissible municipal levels. These limits, summarized in Table 5 below, give permissible levels for both transient and continuous noise sources.

Table 5. BART Design Criteria for Noise from Ancillary Equipment

BART Area Category	Maximum Noise Levels (dBA)	
	Transient	**Continuous**
I Low Density Residential	50	40
II Average Residential	55	45
III High Density Residential	60	50
IV Commercial	65	55
V Industrial/Highway	70	65
Note: Criteria are reduced by 5 dBA for noises with pure tone components.		

4.4 Construction Noise Criteria

Construction noise criteria are based on the BART specifications. These criteria, summarized in Table 6 below, are based on land use and type of noise, either intermittent (day or night) or continuous.

Table 6. BART Specifications for Construction Noise

Land Use of Receptor	Maximum Daytime Intermittent Noise Level (dBA)	Maximum Nighttime Intermittent Noise Level (dBA)	Maximum Continuous Noise Level (dBA)
Single Family Residential	75	60	60
Commercial Areas (including hotels)	80	70	70
Industrial Areas (without Hotels)	85	85	70
Note: Maximum noise levels (Lmax) for intermittent activities apply to non-repetitive, short-term noises not lasting more than a few hours. Maximum continuous noise levels (Lmax) apply to either repetitive or long-term noise lasting more than a few hours. Outdoor recreational areas in the project corridor are designated with the criteria for “Commercial Areas (including hotels)”.			

4.5 Construction Vibration Criteria

Construction vibration criteria are based on the BART specifications. Significant impact would result if ground-borne vibration from construction activities exceeds the BART criteria of 80 VdB (more than one hour per day), 90 VdB (less than one hour per day), or 100 VdB (less than 10 minutes per day), or the damage threshold of 0.20 inches per second ppv for fragile buildings or structures.

5. FUTURE BUILD CONDITIONS

This section summarizes the models used to predict future noise and vibration levels for potential sources of community impact related to the BART Warm Springs Extension. These sources include BART train operation, bus and automobile traffic at stations, ancillary equipment and construction activities. The projection models for these sources are described below.

5.1 BART Noise Projections

The primary component of wayside noise from BART train operations is wheel/rail noise, which results from the steel wheels rolling on steel rails. Secondary sources, such as vehicle air-conditioning and other ancillary equipment, will sometimes be audible, but are not expected to be significant factors. The Warm Springs Extension noise levels were projected based on noise measurements conducted by Wilson, Ihrig & Associates, Inc. (WIA)[1], the speed profile designed by Bay Area Transit Consultants and the plan and profile maps of the alignment. Significant factors are summarized below:

- Based on the WIA memorandum, the predictions assume that a single 75-foot long vehicle operating at 80 mph on ballast and tie track with continuous welded rail (CWR) generates a maximum noise level of 84 dBA at a distance of 50 feet from the track centerline.
- The operating times of the BART Warm Springs Extension will be between 4:00 AM and 12:00 AM. The operating plan for BART service specifies peak headways of twelve minutes and an off-peak headway of 20 minutes, for both the Richmond Service and the 24th Street Service. Ten-car BART vehicles will operate throughout the day.
- Peak operations will occur between 4:00 AM and 7:00 PM and off-peak operations will occur between 7:00 PM and 12:00 AM.
- Vehicle operating speeds are based on the speed profile. The speed limits range from 50 mph to 70 mph along the corridor.

The projected unshielded Lmax, Ldn and peak-hour Leq(hr) are shown in Figures 10, 11 and 12, respectively, as a function of distance for several BART train speeds.

1 "Wayside Noise Measurements: BART Rehabilitated Vehicles," Wilson, Ihrig & Associates, Inc., July 1998.

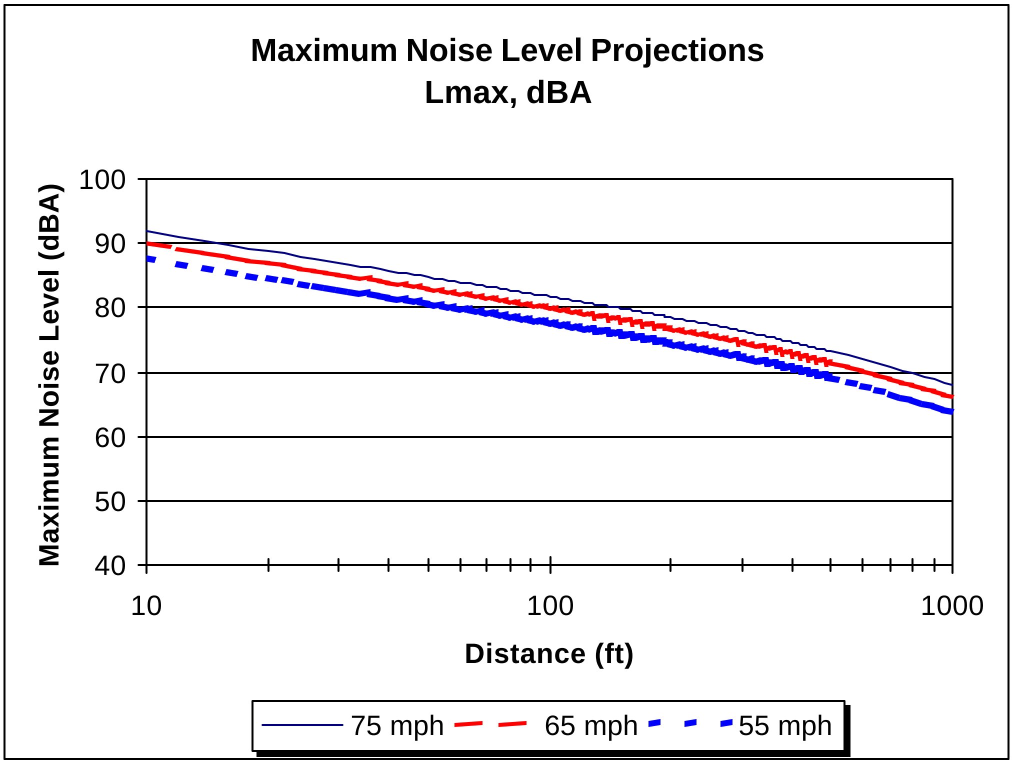

Figure 10. Projected Maximum BART Noise Levels

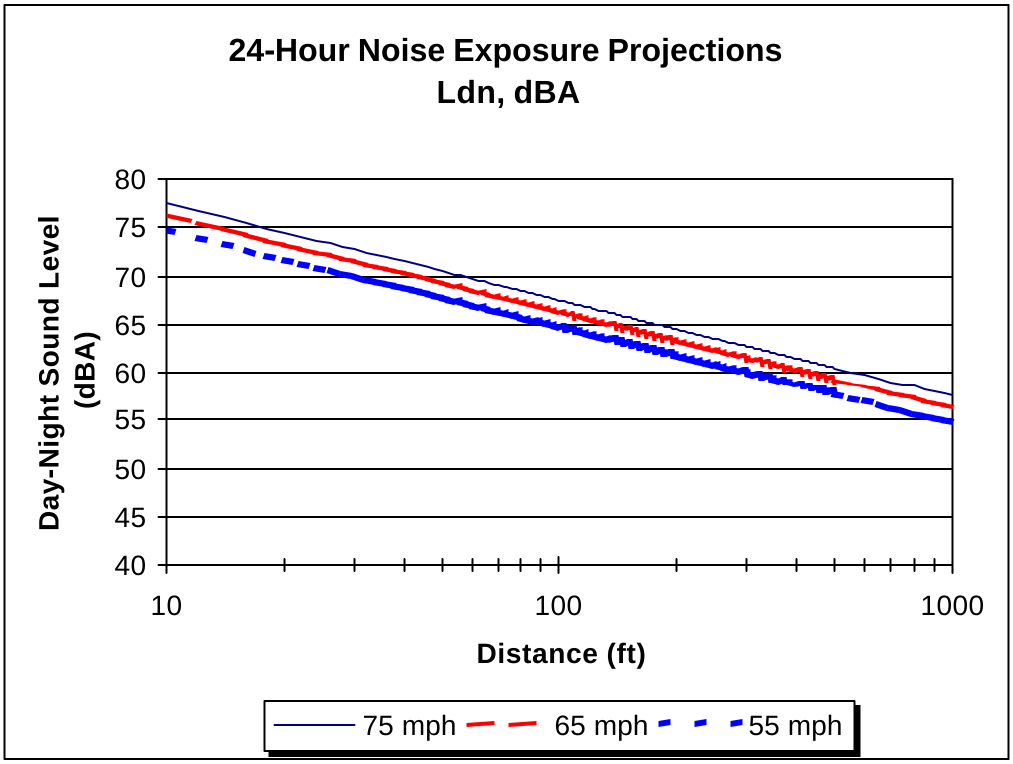

Figure 11. Projected 24-Hour Noise Exposure From BART Operations

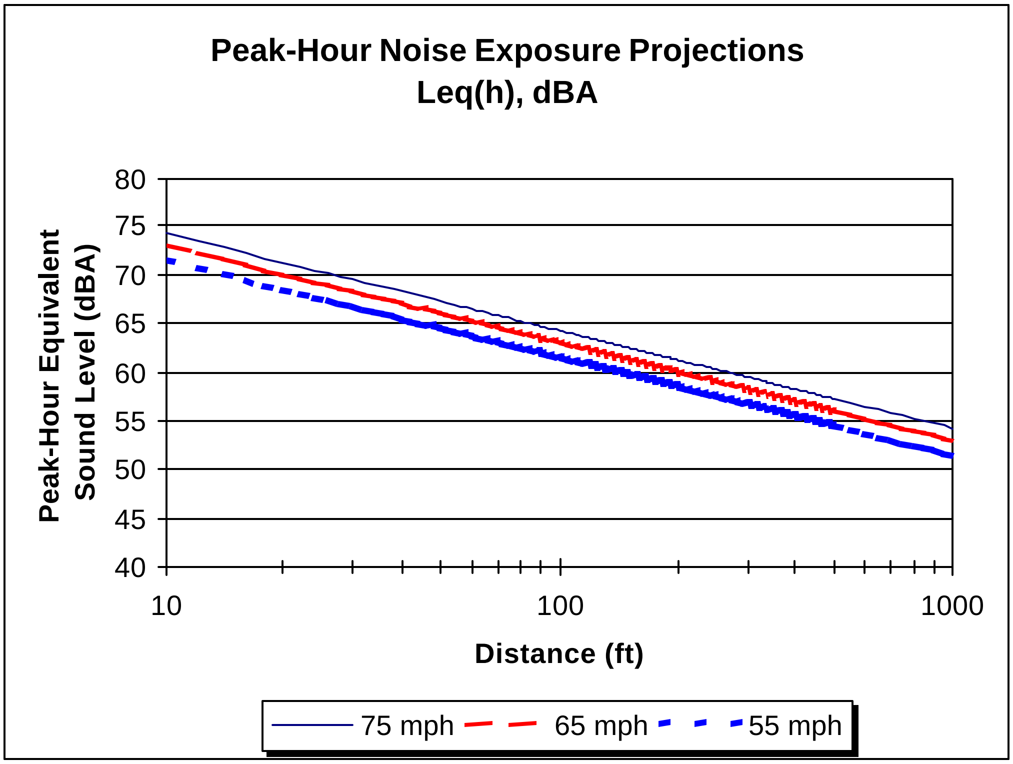

Figure 12. Projected Peak-Hour Noise Exposure From BART Operations

5.2 BART Vibration Projections

The projection of ground-borne vibration from BART operations on the Warm Springs Extension was based on the following:

- Vibration source levels were based on measurements previously conducted on vehicles operating on the existing BART System by WIA.[2]
- Vibration propagation tests were conducted at four sites along the corridor near sensitive receptors. These tests measured the response of the ground to an input force. The results of these tests were combined with the vibration source level measurements to provide projections of future vibration levels from vehicles operating on the Warm Springs Extension.
- Vehicle operating speeds are based on the BART speed profile. The speed limits range from 50 mph to 70 mph along the corridor.

The assumed vehicle vibration characteristics (represented by the force density spectrum in Figure 13) were combined with the ground vibration propagation test results (represented by transfer mobility spectra such as those shown in Figure 9) to project vibration levels as a function of distance for each of the four test sites. The results of these transfer mobility tests and the projected BART vibration spectra at each site are presented in Appendix C. The results suggested dividing the rail corridor into four regions for the purposes of vibration projection, defined as follows:

- Region A – Walnut Street to Stevenson Boulevard. (Represented by Test Site 1)
- Region B – Stevenson Boulevard to Washington Boulevard. (Represented by Test Site 2)
- Region C – Washington Boulevard to Channel I. (Represented by Test Site 3)
- Region D – Channel I to South Grimmer Road. (Represented by Test Site 4)

The resulting projections of maximum ground vibration levels from BART operations at 75 mph for each of the above four regions are provided in Figure 14. Each of the curves has a different level vs. distance characteristic, which determines the impact distance in each of the regions. The results suggest that Region C has the highest projected levels close to the track. Maximum ground vibration level projections at various BART train speeds are provided separately for Regions A, B, C, and D in Figures 15, 16, 17, and 18, respectively.

2 Personal communication with Richard Carmen, WIA, June 2002.

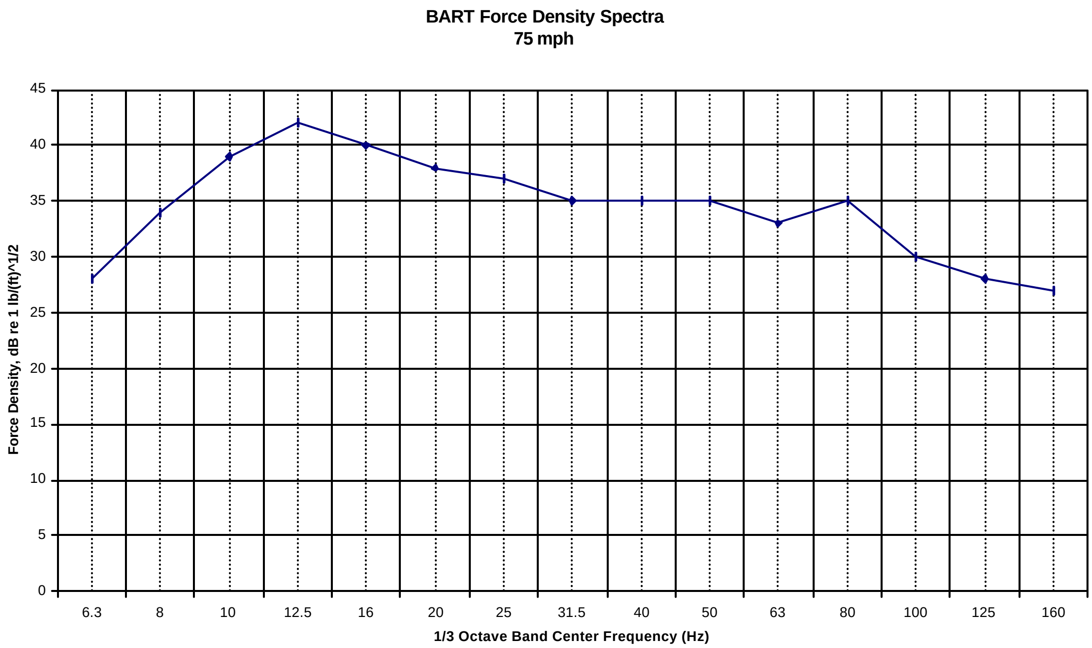

Figure 13. BART Vehicle Force Density Spectrum

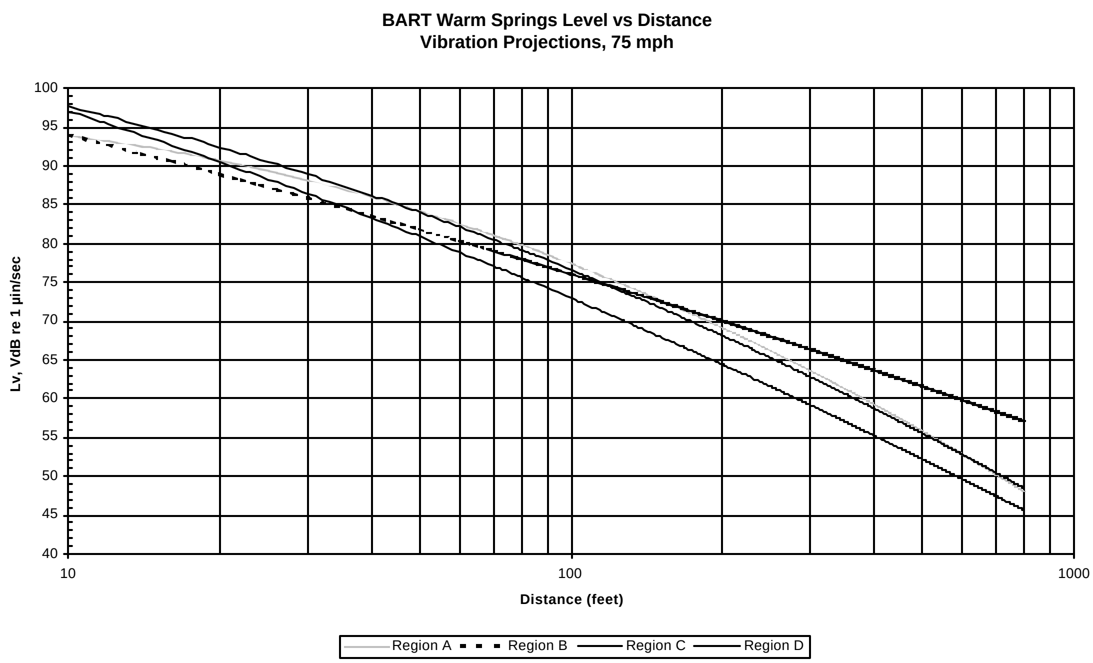

Figure 14. Projected Maximum Vibration Levels for BART Operations at 75 mph

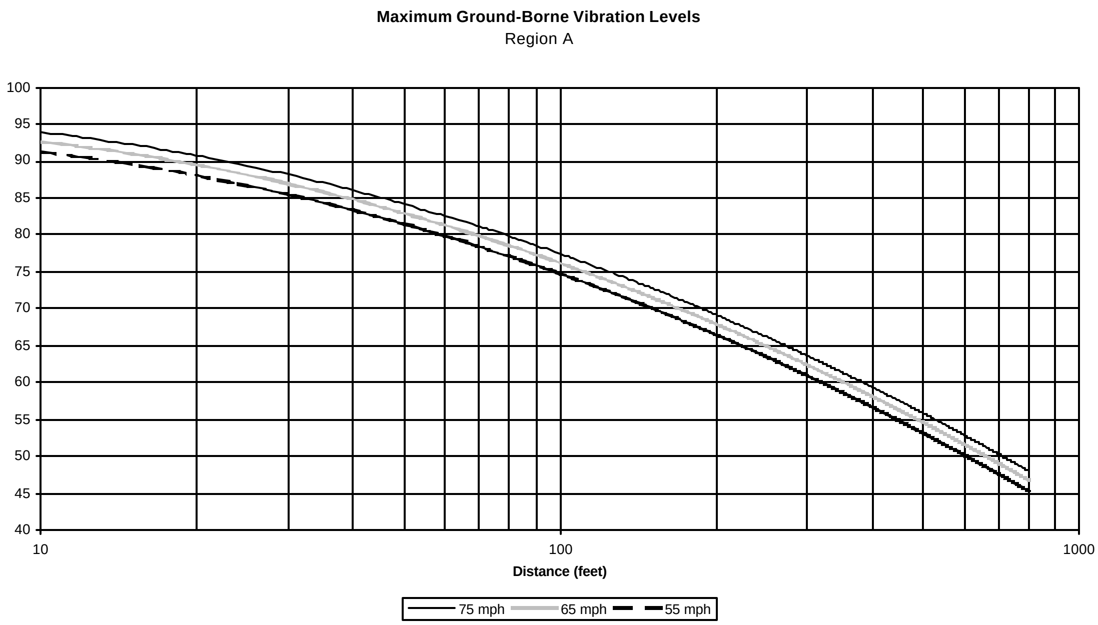

Figure 15. Projected Maximum Vibration Levels for BART Operations in Region A

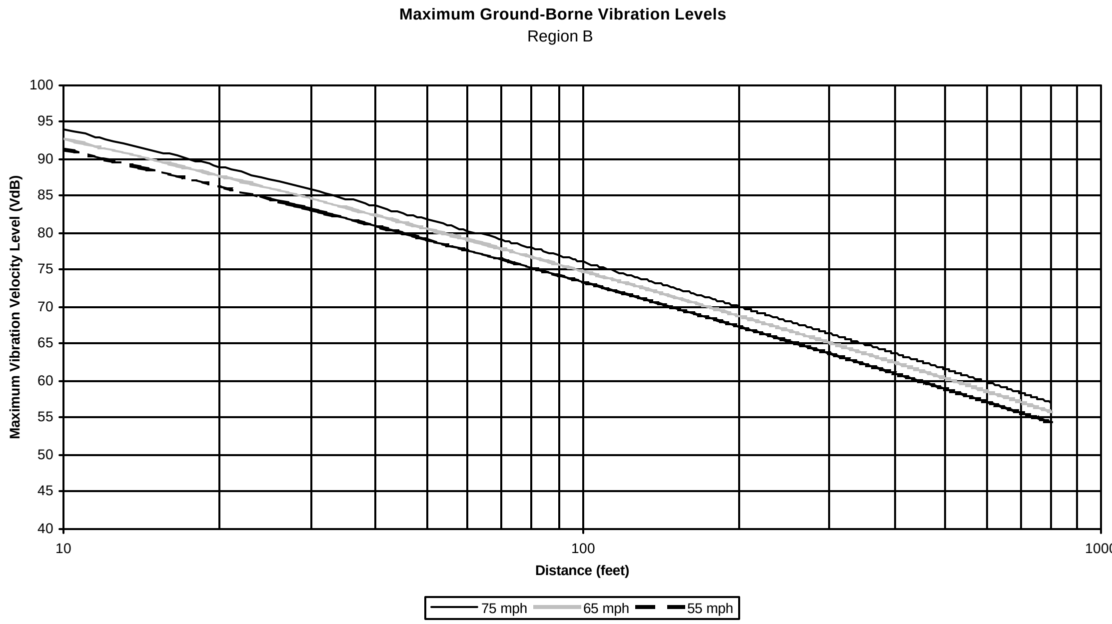

Figure 16. Projected Maximum Vibration Levels for BART Operations in Region B

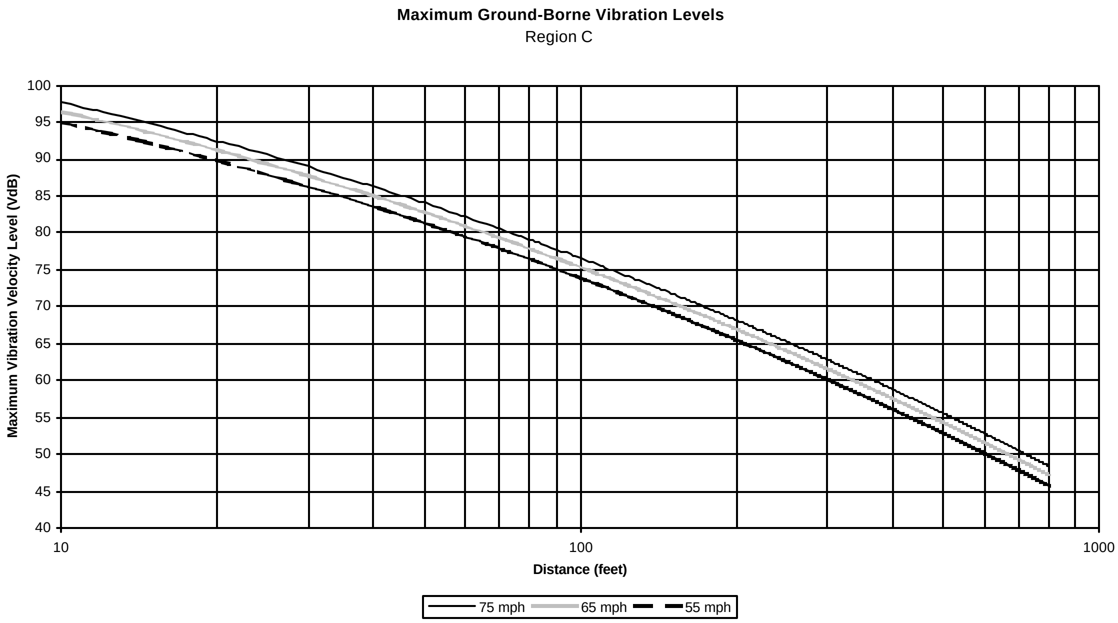

Figure 17. Projected Maximum Vibration Levels for BART Operations in Region C

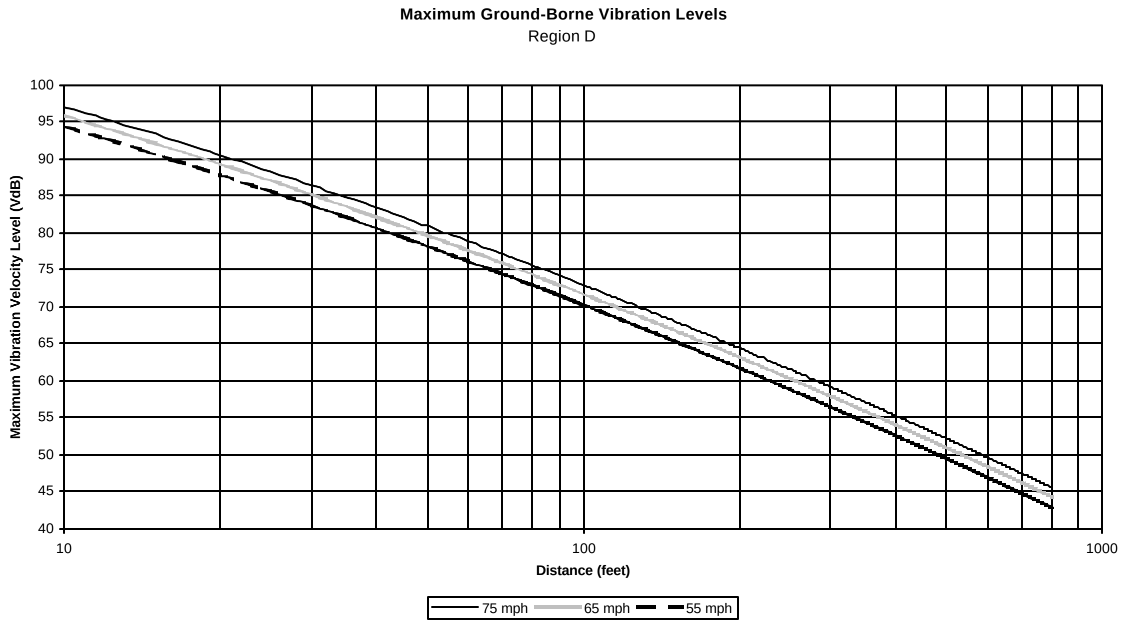

Figure 18. Projected Maximum Vibration Levels for BART Operations in Region D

5.3 Bus Alternative Noise and Vibration Projections

5.3.1 Noise Projections

The bus noise projections for the proposed bus alternative were developed using methods described in the FTA Guidance Manual. The assumptions used in the analysis are shown below:

- Based on the reference levels given in the FTA Guidance Manual, the predictions assume that a single bus operating at 50 mph on a normal roadway generates a maximum noise level of 85 dBA at 50 feet.
- Bus speeds were assumed to be 50 mph for the project corridor.
- The operating times of the proposed bus alternative were assumed to be identical to that for the Proposed Project. The operating plan specifies peak headways of 15 minutes and off-peak headways of 30 minutes for both the VTA and AC Transit routes.

5.3.2 Vibration Projections

The proposed bus alternative is not expected to result in any vibration impacts. Traffic, even heavy trucks and buses, rarely creates perceptible ground-borne vibration unless the vehicles are operating very close to buildings or there are irregularities, such as potholes or expansion joints, in the roadway. The pneumatic tires and suspensions systems of normal automobiles, trucks and buses are sufficient to eliminate most significant ground-borne vibration forces.

5.4 Ancillary Equipment Noise Projections

The transit power substations and tunnel vent shafts are the only ancillary equipment with much potential to cause noise impact. The major noise sources associated with substations are magnetostriction of the transformer core and cooling fans. For vent shafts, the exhaust fans are the major source of noise. It is generally possible to eliminate potential for noise impact from substations and vent shafts by including noise limits in the procurement documents.

The evaluation of noise from ancillary equipment is based on the method included in the FTA Guidance Manual.

For substations, the relationship is:

$L(d) = 97 - 20\,log(d)$ where "d" is the distance from the substation building in feet.

For vent shafts, the relationship is:

$L(d) = 99 - 20\,log(d)$ where "d" is the distance from the vent shaft building in feet.

5.5 Maintenance Facility Noise Projections

The proposed maintenance facility for the BART Warm Springs Project is located near the southern terminus of the alignment.

The noise impact methodology for the proposed maintenance facilities uses the FTA Guidance Manual general assessment method to estimate the noise levels generated by the operation of the facilities and to determine the potential noise impacts associated with each proposed site. The general assessment is based on the number of train movements per hour at the facility. The FTA Guidance Manual specifies a reference Sound Exposure Level (SEL) of 118 dBA at a distance of 50 feet for 20 train movements per hour.

5.6 Construction Noise Projections

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.

Table 7 summarizes some of the available data on noise emissions of construction equipment from the FTA Guidance Manual. Shown are the average of the Lmax values at a distance of 50 feet. Although the noise levels in the table represent typical values, there can be wide fluctuations in the noise emissions of similar equipment. Construction noise at a given noise-sensitive location depends on the magnitude of noise during each construction phase, the duration of the noise, and the distance from the construction activities.

Table 7. Construction Equipment Noise Emission Levels

Equipment Type	Typical Sound Level at 50 ft (dBA)
Backhoe	80
Bulldozer	85
Compactor	82
Compressor	81
Concrete Mixer	85
Concrete Pump	82
Crane, Derrick	88
Crane, Mobile	83
Loader	85
Pavement Breaker	88
Paver	89
Pile Driver, Impact	101
Pump	76
Roller	74
Truck	88

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 amount of time during the day that a piece of equipment is in use). Using the typical sound emission characteristics, as given in Table 7, it is then possible to estimate Lmax at various distances from the construction site.

The noise impact assessment for a construction site is based on:

- estimates 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 such as those in Table 8, and
- estimates 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.

5.7 Construction Vibration Projections

The curves in Figure 19 represent the projected vibration levels from construction vibrations for four representative worst-case vibration sources. The vibration levels of other types of construction equipment would be lower than these levels. The curves show the relationship between vibration level and distance from the source. The vibration curves can be used to assess the potential for annoyance from construction vibration during construction.

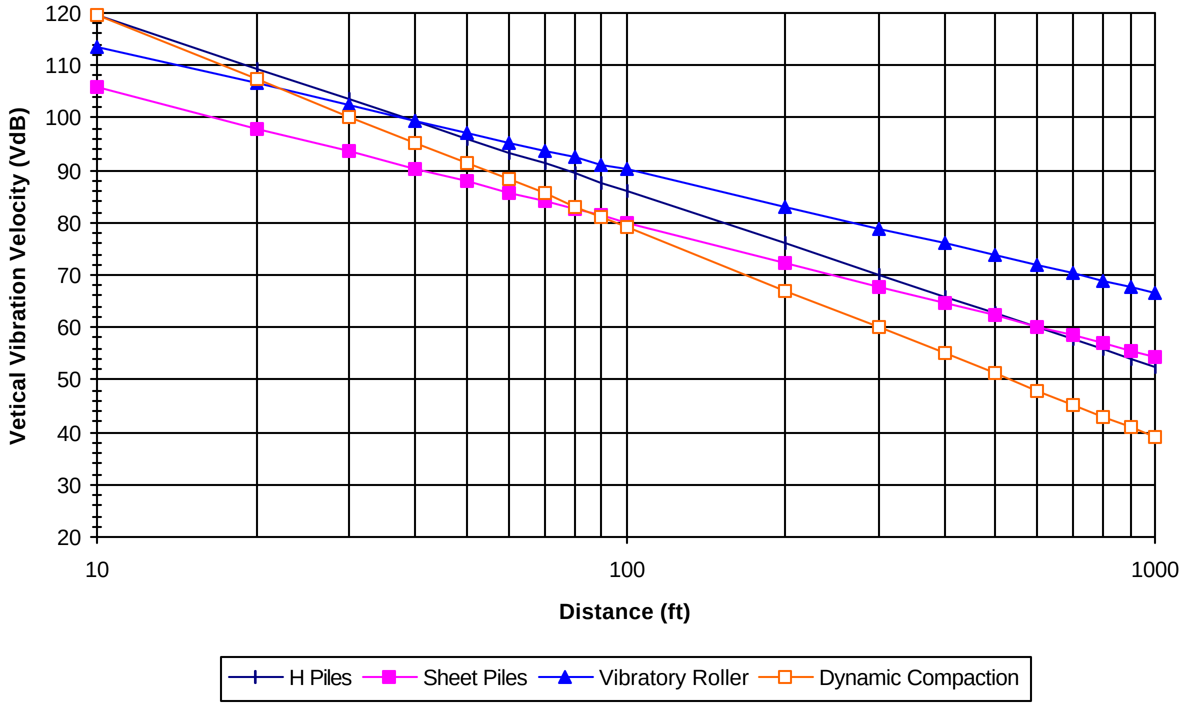

Figure 19. Construction Equipment Vibration Levels[3]

[3] C.H. Dowding, "Construction Vibrations," Prentice Hall International Series in Civil Engineering and Engineering Mechanics, 1996.

6. NOISE AND VIBRATION IMPACT ASSESSMENT

A detailed noise and vibration impact assessment was performed based on the criteria discussed in Section 4 and on the projections described in Section 5. The assessment methods and results for the various project sources are described below.

6.1 BART Noise Assessment

6.1.1 Approach

The assessment of noise impact from BART train operations is based on both the maximum noise levels generated by operations and on a comparison of existing and projected future noise exposure for different land use categories. The following steps were performed to assess train noise impact:

- A detailed land-use survey was conducted along the project corridor to identify and classify all noise-sensitive receptors according to the categories defined in Section 4.1. The vast majority of these receptors are single and multi-family residences, falling under FTA Category 2 and BART Design Criteria Category II Average and Category III High Density Residential. The remaining receptors were institutional sites falling under FTA Category 3 and BART Design Criteria Category for Churches, Theaters, Schools, and Hospitals, including two churches, an elementary school, and the school's playground.

- The receptors were clustered based on distance to the tracks, acoustical shielding between the receptors and the tracks, and location relative to crossovers.

- The existing noise exposure at each cluster of receptors was estimated based on the ambient noise measurements discussed in Section 3.1, and was used to determine the thresholds for cumulative impact using the criteria presented in Section 4.1.

- Projections of future BART noise at each cluster of receptors were developed based on distance from the tracks, train schedule and train speed using the methods described in Section 5.1.

- In areas where the projections show either project-induced or cumulative noise impact, mitigation options were evaluated and new projections were developed assuming mitigation of impacts.

6.1.2 Project-Induced Noise Impacts

Detailed comparisons of the existing and future noise levels are presented in Tables 8 and 9, which include results for the Category II and Category III receptors along the alignment with both daytime and nighttime sensitivity to noise (e.g. residences and hotels) and institutional receptors. In addition to the civil station, distance to the near track and proposed BART speed, each table includes the existing noise level, the projected maximum noise level from BART operations and the impact criteria for each receptor or receptor group. Based on a comparison of the predicted maximum project noise level with the impact criteria, the impacts due to the introduction of BART service are listed.

Table 8. BART Project-Induced Residential Noise Impacts Without Mitigation

Location	Civil Stn	Side of Track	Dist to Near Track (ft)	Speed (mph)	Maximum Passby Noise Level (dBA)	BART Design Criterion (dBA)[1]	# of Impacts
Walnut Ave to Stevenson Blvd	2227 to 2242	NB	145	50/70	71	75	0
Walnut Ave to Stevenson Blvd	2230 to 2238	SB	45	50/70	81	75	12
Valdez Way/Vaca Road	2290 to 2304	NB	300	70	70	75	0
Paseo Padre Parkway to Washington Blvd	2308 to 2334	SB	390	70	73	75	0
Paseo Padre Parkway to Washington Blvd	2308 to 2334	NB	20	70	89	75	31
Washington Blvd to Blacow Road	2339 to 2370	NB	340	70	69	75	0
Washington Blvd to Blacow Road	2339 to 2368	SB	95	70	79	75	12
Blacow Road to Auto Mall Parkway	2370 to 2415	SB	130	70	76	75	55
Auto Mall Parkway to South Grimmer Road	2415 to 2451	SB	230	70	72	75	0
Total:							**110**

1. BART design criterion of 75 dBA is based on the Average Density Residential and High Density Residential Categories for Single and Multi-Family Dwellings. (See Table 2)

As shown in Table 8, project-induced noise impact is anticipated for a total of 110 residences. The following are brief discussions of each impacted area:

Walnut Avenue to Stevenson Boulevard (east side). No residences in this location are expected to have project-induced noise impact.

Walnut Avenue to Stevenson Boulevard (west side). Three buildings in the Fremont Villas condominiums, each with four units for a total of 12 residences, are expected to have project-induced noise impact. The noise impact will result from a combination of the speed of the BART vehicles and the proximity of the buildings (less than 50 feet for some buildings) to the tracks.

Valdez Way/Vaca Road (east side). No residences in this location are expected to have project-induced noise impact. The residences are located at distances of over 300 feet from the tracks.

Paseo Padre Parkway to Washington Boulevard (west side). No residences in this location are expected to have project-induced noise impact. The residences are located at distances of more than 400 feet from the tracks.

Paseo Padre Parkway to Washington Boulevard (east side). There are 31 single-family residences in this area that are expected to have project-induced noise impact. Along Valero Drive, 22 residences are located within 170 feet of the tracks. The crossover between points 2309 and 2315 is projected to contribute to the noise impact at these residences in addition to the proximity of the residences to the tracks and the speed of the BART vehicles. Nine additional residences located just to the south of this area along Driscoll Road are also projected to experience noise impact. The noise impacts at this location result primarily from the small distance between the tracks and the residences (20 feet for the closest residence).

Washington Boulevard to Blacow Road (east side). No residences in this location are expected to have project-induced noise impact. The residences are located at distances of more than 300 feet from the tracks.

Washington Boulevard to Blacow Road (west side). Twelve single-family residences expected to sustain project-induced noise impact. The noise impacts result from a combination of the speed of the BART vehicles (70 mph) and the proximity of the residences to the tracks (within 100 feet).

Blacow Road to Auto Mall Parkway (west side). A total of 55 single-family residences are expected to sustain project-induced noise impact. The noise impacts result from a combination of the speed of the BART vehicles (70 mph) and the proximity of the residences to the tracks (within 100 feet).

Auto Mall Parkway to South Grimmer Road (west side). No residences in this location are expected to sustain project-induced noise impact. The residences are located at distances of more than 200 feet from the tracks.

Similar to the residential analysis, an assessment of noise impact for institutional receptors was also conducted. This assessment was also based on a comparison of the predicted maximum noise level with the BART Criterion for these types of land uses.

Table 9. BART Project-Induced Institutional Noise Impacts Without Mitigation

Location	Civil Stn	Side of Track	Dist to Near Track (ft)	Speed (mph)	Maximum Passby Noise Level (dBA)	BART Design Criterion (dBA)[1]	Impact?
St. Anne's Episcopal Church	2329	NB	390	70	68	75	No
Church of Christ	2330	NB	290	70	70	75	No
E.M. Grimmer Elementary School	2391	SB	300	70	68	75	No
E.M. Grimmer Elementary School Playground	2391	SB	95	70	77	75	Yes

1. BART design criterion of 75 dBA is based on the maximum passby noise level for churches, theaters, schools, and hospitals. (See Table 2)

As indicated in Table 9, the results predict project-induced noise impact at the E. M. Grimmer Elementary School Playground. The noise impact is due to the proximity of the nearest active areas of the playground to the tracks, and the speed (70 mph) of the BART vehicles.

6.1.3 Cumulative Noise Impacts

For the BART alternative, detailed projections were made of the future noise exposure along the proposed corridor. The future noise levels were compared to the measured existing noise levels (as presented in Section 3.1.3) to determine locations where cumulative impacts are projected due to BART operations. Table 10 includes results for the residential receptors from north to south along the alignment with both daytime and nighttime sensitivity to noise (e.g. residences and hotels). Table 11 lists all institutional receptors from north to south along the alignment, consisting of sites that are not sensitive to noise at night (e.g. schools and churches). Both tables include the locations along the alignment, the civil station, side of track, distance to the near track and the vehicle speed. The distance from the near track and the projected noise level represent the worst case within the group of residences.

Table 10 includes the existing and future noise levels in terms of Ldn, the projected increase in cumulative noise, the amount of increase allowed by the BART Design Criteria, and the number of impacts. Table 11 contains the same information, but the noise levels are presented in terms of the Peak-Hour Leq, instead of the Ldn.

Table 10. BART Cumulative Residential Noise Impacts Without Mitigation

Location	Civil Stn	Side of Track	Dist to Near Track (ft)	Speed (mph)	Noise Level (Ldn, dBA)		Cumulative Noise Exposure (Ldn, dBA)[1]		# of Impacts
					Existing	Future	Increase	Impact Criterion	
Walnut Ave to Stevenson Blvd	2227 to 2242	NB	145	50/70	57	63	8.4	6.6	84
Walnut Ave to Stevenson Blvd	2230 to 2238	SB	45	50/70	53	70	16.3	8.2	12
Valdez Way/Vaca Road	2290 to 2304	NB	300	70	53	60	7.4	8.8	0
Paseo Padre Parkway to Washington Blvd	2308 to 2334	SB	410	70	60	65	4.6	5.0	0
Paseo Padre Parkway to Washington Blvd	2308 to 2334	NB	20	70	54	77	22.7	7.6	44
Washington Blvd to Blacow Road	2339 to 2370	NB	340	70	54	60	5.8	7.6	0
Washington Blvd to Blacow Road	2339 to 2368	SB	95	70	66	70	3.8	3.4	6
Blacow Road to Auto Mall Parkway	2370 to 2415	SB	130	70	65	68	3.1	3.9	0
Auto Mall Parkway to South Grimmer Road	2415 to 2451	SB	230	70	61	63	2.0	4.7	0
Total:									**146**

Notes:
1. Increases in noise level and the impact criterion are reported to 0.1 decibels so that rounding errors in the results do not lead to confusion.

As shown in Table 10, cumulative noise impact is anticipated for a total of 146 residences. The following are brief discussions of each impacted area:

Walnut Avenue to Stevenson Boulevard (east side). Three buildings in the Red Hawk Ranch Apartments complex with 84 total units are projected to sustain cumulative noise impacts. The noise impact results from a combination of the speed of the BART vehicles and the proximity of the buildings (less than 100 feet for some buildings) to the tracks.

Walnut Avenue to Stevenson Boulevard (west side). Three buildings in the Fremont Villas condominiums with four units each (for a total of twelve residences) are projected to experience cumulative noise impacts. The noise impacts result from a combination of the speed of the BART vehicles and the proximity of the buildings (less than 50 feet for some buildings) to the tracks.

Valdez Way/Vaca Road (east side). No residences in this location are projected to sustain cumulative noise impacts. The residences are located at distances of over 300 feet from the tracks.

Paseo Padre Parkway to Washington Boulevard (west side). No residences in this location are projected to experience cumulative noise impact. The residences are located at distances of over 400 feet from the tracks.

Paseo Padre Parkway to Washington Boulevard (east side). A total of 44 single-family residences in this area are projected to sustain cumulative noise impacts. Of these, 24 are located along Valero Drive (including the Senior Housing Project) within 170 feet of the tracks. In addition to the proximity of the residences to the tracks and the speed of the BART vehicles, the crossover between Stations 2309 and 2315 is projected to contribute to the noise impact at these residences. 20 additional residences located just to the south of this area along Driscoll Road are projected to experience noise impact. The noise impacts at this location will result primarily from the small distance between the tracks and the residences (20 feet for the closest residence).

Washington Boulevard to Blacow Road (east side). No residences in this location are projected to sustain cumulative noise impacts. The residences are located at distances of over 300 feet from the tracks.

Washington Boulevard to Blacow Road (west side). Six residences in this location are projected to experience cumulative noise impacts. The noise impacts at this location will result primarily from the speed of the BART vehicles (70 mph).

Blacow Road to Auto Mall Parkway (west side). No residences in this location are projected to experience cumulative noise impacts. The existing noise levels are high (65 dBA L_{dn}) because of freight trains, and the addition of the BART operations contributes only slightly to cumulative noise increases.

Auto Mall Parkway to South Grimmer Road (west side). No residences in this location are projected to experience cumulative noise impacts. The residences are located at distances of more than 200 feet from the tracks.

Similar to the residential analysis, an assessment of noise impact for institutional receptors was also conducted. This assessment was also based on a comparison of the predicted maximum noise level with the BART Criteria for these types of buildings.

Table 11. BART Cumulative Institutional Noise Impacts Without Mitigation

Location	Civil Stn	Side of Track	Dist to Near Track (ft)	Speed (mph)	Noise Level (Peak Hour Leq, dBA)		Cumulative Noise Exposure (Peak Hour Leq, dBA) [1]		Impact?
					Existing	Future	Increase	Impact Criterion	
St. Anne's Episcopal Church	2329	NB	390	70	54	57	3.3	12.7	No
Church of Christ	2330	NB	290	70	54	58	4.5	12.7	No
E.M. Grimmer Elementary School	2391	SB	300	70	53	57	4.3	13.3	No
E.M. Grimmer Elementary School Playground	2391	SB	95	70	53	63	10.8	13.3	No

Notes:
1. Increases in noise level and the impact criterion are reported to 0.1 decibels so that rounding errors in the results do not lead to confusion.

As indicated in Table 11, the results predict no cumulative noise impact at any institutional locations.

The total number of noise impacts (both residential and institutional) along the BART Warm Springs alignment is 256. 49 of the impacts are both cumulative and project-induced, and are located between Walnut Avenue and Stevenson Boulevard, and between Paseo Padre Parkway and Washington Boulevard.

6.2 BART Vibration Assessment

6.2.1 Approach

The assessment of vibration impact from BART train operations is based on the maximum projected vibration levels at sensitive receptors along the Warm Springs Extension alignment. The approach used for assessing vibration impact generally follows the approach used for the noise impact, except that the existing vibration is not considered, and cumulative impact is not assessed.

6.2.2 Vibration Impacts

Table 12 summarizes the results of the analysis of vibration-sensitive locations listed as Category II land use along the alignment in terms of anticipated exceedances of the BART Criterion. The table lists the locations from north to south, the civil station, the distance to the near track, and the projected BART speed at each location. In addition, the predicted project maximum vibration level and the BART impact criterion level are indicated along with the number of impacts projected for each receptor or receptor group.

Table 12. BART Project-Induced Vibration Impacts Without Mitigation

Location	Civil Stn	Side of Track	Dist to Near Track (ft)	Speed (mph)	Max Project Vibration Level[1, 2]	BART Vibration Impact Criterion[1]	# of Res. Impacts
Walnut Ave to Stevenson Blvd	2227 to 2242	NB	95	50/70	74	70	54
Walnut Ave to Stevenson Blvd	2230 to 2238	SB	45	50/70	81	70	12
Valdez Way/Vaca Road	2290 to 2304	NB	300	70	62	70	0
Paseo Padre Parkway to Washington Blvd	2308 to 2334	SB	390	70	60	70	0
Paseo Padre Parkway to Washington Blvd	2308 to 2334	NB	20	70	87	70	8
Washington Blvd to Blacow Road	2339 to 2370	NB	340	70	55	70	0
Washington Blvd to Blacow Road	2339 to 2368	SB	95	70	73	70	10
Blacow Road to Auto Mall Parkway	2370 to 2415	SB	115	70	71	70	40
Auto Mall Parkway to South Grimmer Road	2415 to 2451	SB	230	70	55	70	0
Total:							**124**

1. Vibration levels are measured in VdB referenced to 1 ìin/sec.
2. The vibration levels in this column represent to the highest vibration levels at a receptor in this location.

Table 12 indicates that there are 124 residences with potential vibration impact. A discussion of the impacted receptors follows:

<u>Walnut Avenue to Stevenson Boulevard (east side)</u>. Two buildings in the Red Hawk Ranch Apartments complex with a total of 54 units, are projected to sustain vibration impact. The vibration impacts result from a combination of the speed of the BART vehicles and the proximity of the buildings (less than 100 feet for some buildings) to the tracks.

<u>Walnut Avenue to Stevenson Boulevard (west side)</u>. Three buildings in the Fremont Villas condominiums with four units each (for a total of 12 residences) are projected to experience vibration impact. The vibration impacts result from a combination of the speed of the BART vehicles and the proximity of the buildings (less than 50 feet for some buildings) to the tracks.

<u>Valdez Way/Vaca Road (east side)</u>. No residences in this location are projected to experience vibration impact. The residences are located at distances of more than 300 feet from the tracks.

<u>Paseo Padre Parkway to Washington Boulevard (west side)</u>. No residences in this location are projected to sustain vibration impact. The residences are located at distances of over 400 feet from the tracks.

Paseo Padre Parkway to Washington Boulevard (east side). Eight single-family residences in this area are projected to experience vibration impact. Three residences along Valero Drive are located within 170 feet of the tracks. In addition to the proximity of the residences to the tracks and the speed of the BART vehicles, the crossover between points 2309 and 2315 is expected to contribute to the vibration impact at these residences. Five additional residences located just to the south of this area along Driscoll Road are also projected to experience vibration impact. The vibration impacts result primarily from the small distance between the tracks and the residences (20 feet for the closest residence).

Washington Boulevard to Blacow Road (east side). No residences in this location are projected to sustain vibration impact. The residences are located at distances of more than 300 feet from the tracks.

Washington Boulevard to Blacow Road (west side). Ten single-family residences projected to sustain vibration impact. The vibration impacts result from a combination of the speed of the BART vehicles (70 mph) and the proximity of the residences to the tracks (within 100 feet).

Blacow Road to Auto Mall Parkway (west side). 40 single-family residences in this location are projected to sustain vibration impact. The vibration impacts result from a combination of the speed of the BART vehicles (70 mph) and the proximity of the residences to the tracks (within 100 feet).

Auto Mall Parkway to South Grimmer Road (west side). No residences in this location are projected to experience vibration impact. The residences are located at distances of more than 200 feet from the tracks.

Similar to the residential analysis, an assessment of vibration impact for institutional receptors was also conducted.

Table 13. BART Project-Induced Institutional Vibration Impacts Without Mitigation

Location	Civil Stn	Side of Track	Dist to Near Track (ft)	Speed (mph)	Max Project Vibration Level[1]	BART Vibration Impact Criterion[1]	Impact ?
St. Anne's Episcopal Church	2324	NB	390	70	63	75	No
Church of Christ	2325	NB	290	70	66	75	No
E.M. Grimmer Elementary School	2386	SB	300	70	61	75	No

1. Vibration levels are measured in VdB referenced to 1 ìin/sec.

As shown in Table 13, no potential institutional vibration impacts were identified along the Warm Springs Extension.

6.3 Bus Alternative Noise and Vibration Assessment

The assessment of noise impact from bus operations is based on both the maximum noise levels generated by operations and on a comparison of existing and projected future noise exposure for different land use categories. The following steps were performed to assess train noise impact:

- A detailed land-use survey was conducted along the project corridor to identify and classify all noise-sensitive receptors according to the categories defined in Section 4.1. The vast majority of these receptors are single and multi-family residences, falling under FTA Category 2 and BART Design Criteria Category II Average and Category III High Density Residential. The remaining receptors were institutional sites falling under FTA Category 3 and BART Design Criteria Category for Churches, Theaters, Schools, and Hospitals, including two churches, an elementary school, and the school's playground.

- The receptors were clustered based on distance to the tracks, acoustical shielding between the receptors and the tracks, and location relative to crossovers.

- The existing noise exposure at each cluster of receptors was estimated based on the ambient noise measurements discussed in Section 3.1, and was used to determine the thresholds for cumulative impact using the criteria presented in Section 4.1.

- Projections of future bus noise at each cluster of receptors were developed based on distance from the busway, bus schedule and bus speed using the methods described in Section 5.3.

In areas where the projections show either project-induced or cumulative noise impact, mitigation options were evaluated and new projections were developed assuming mitigation of impacts.

6.3.1 Project-Induced Noise Impacts

Because the BART project-induced noise criteria were developed exclusively for the BART transit vehicles, it is not appropriate to use the criteria to assess noise impact from buses. The noise impact analysis for the bus alternative uses the FTA Guidance Manual criteria, and is discussed below in the cumulative noise impacts section.

6.3.2 Cumulative Noise Impacts

Detailed projections were made of the future noise exposure along the Proposed bus alternative alignment. Noise projections were only made for those sections of the alignment operating on the exclusive busway. No cumulative noise impacts are expected on freeways or local roads included as a part of the project. The future noise levels were compared to measured existing noise levels presented in Section 3.1 to determine locations where cumulative impacts are expected to result from operation of the Proposed Project. Table 14 includes results for the residential receptors from north to south along the alignment with both daytime and nighttime sensitivity to noise (e.g., residences and hotels). Table 15 lists all institutional receptors from north to south along the alignment, consisting of sites that are not sensitive to noise at night (e.g., schools and churches). Both tables include the locations along the alignment, the civil station, side of busway, distance to the busway and the vehicle speed. The distance from the busway and the projected noise level represent the worst case within the group of residences. All the receptors along the alignment fall into FTA categories 2 or 3 for the cumulative noise impact analysis.

Table 14 includes the existing and future noise levels in terms of L_{dn}, the projected increase in cumulative noise, the amount of increase allowed by the BART design criteria, and the number of impacts. Table 15 contains the same information, but the noise levels are presented in terms of the Peak-Hour L_{eq}, instead of the L_{dn}.

Table 14. Proposed Bus Alternative Cumulative Residential Noise Impacts

Location	Civil Stn[1]	Side of Busway	Dist to Bus-way (ft)	Speed (mph)	Noise Level (Ldn, dBA)		Cumulative Noise Exposure (Ldn, dBA)[2]		# of Impacts
					Existing	Future	Increase	Impact Criterion	
Paseo Padre Parkway to Washington Blvd	2308 to 2334	SB	410	50	60	61	0.2	5.0	0
Paseo Padre Parkway to Washington Blvd	2308 to 2334	NB	20	50	54	67	13.4	7.6	2
Washington Blvd to Blacow Road	2339 to 2370	NB	340	50	54	55	0.9	7.6	0
Washington Blvd to Blacow Road	2339 to 2368	SB	95	50	66	66	0.4	3.4	0
Blacow Road to Auto Mall Parkway	2370 to 2415	SB	130	50	65	65	0.4	3.9	0
Auto Mall Parkway to South Grimmer Road	2415 to 2451	SB	230	50	61	62	0.3	4.7	0
Total:									**2**

1. Civil stations refer to the stations for the Proposed Project.
2. Increases in noise level and the impact criterion are reported to 0.1 decibels so that rounding errors in the results do not lead to confusion.

As shown in Table 14, cumulative noise impact is anticipated for two residences. A brief discussion of the impacted area follows.

- Paseo Padre Parkway to Washington Boulevard (east side). There are two single-family residences in this area that are expected to have project-induced noise impact. The residences are located on Driscoll road and are within 20 feet of the proposed busway for the closest residence.

Similar to the residential analysis, an assessment of cumulative noise impact for institutional receptors was also conducted.

Table 15. Proposed Bus Alternative Cumulative Institutional Noise Impacts

Location	Civil Stn[1]	Side of Track	Dist to Near Track (ft)	Speed (mph)	Noise Level (Peak Hour Leq, dBA)		Cumulative Noise Exposure (Peak Hour Leq, dBA) [2]		Impact?
					Existing	Future	Increase	Impact Criterion	
St. Anne's Episcopal Church	2324	NB	390	70	54	57	0	12.7	No
Church of Christ	2325	NB	290	70	54	58	0	12.7	No
E.M. Grimmer Elementary School	2386	SB	300	60	53	57	0.5	13.3	No
E.M. Grimmer Elementary School Playground	2386	SB	95	60	53	63	2.1	13.3	No

1. Civil stations refer to the stations for the Proposed Project.
2. Increases in noise level and the impact criterion are reported to 0.1 decibels so that rounding errors in the results do not lead to confusion.

As indicated in Table 15, there are no projected cumulative noise impacts at any institutional locations.

6.3.3 Vibration Impacts

No vibration impact is projected for the proposed bus alternative.

6.4 Ancillary Equipment Noise Assessment

As described in Section 4.3, the noise criteria for ancillary equipment are based on the BART design criteria. Using the prediction equations in Section 5.4 for electrical substations and vent shafts, Table 16 lists the potential impact distances for Category II Average Residential receptors.

The screening distances presented should be used as a guide in the placement of these facilities along the alignment, taking into account the potential for noise impact to adjacent noise sensitive land use. The noise source levels are based on a generalized unshielded substation. The drawings for a typical substation contained in the conceptual design drawings indicate a concrete wall around the perimeter all but one of the substations. This wall would act as a noise barrier to reduce the noise levels generated by the substation. Noise measurements of typical BART substations (both with and without a concrete wall around the perimeter) should be performed during the engineering and design phases to determine the actual noise levels generated by these facilities. In addition, detailed noise projections should be performed when the locations for the substations have been finalized. Potential impacts will be evaluated during final design when specific equipment locations are identified.

Table 16. Summary of BART Ancillary Equipment Noise Impact Assessment

Equipment Type	Projected Impact Distance (ft)			
	Transient Noise		Continuous Noise	
	Broadband	Tonal	Broadband	Tonal
Substation	125	225	400	700
Vent Shaft	160	280	500	900

6.5 Maintenance Facility Noise Assessment

The maintenance facility is not located near any noise sensitive receptors. No noise impact is projected for the maintenance facility.

6.6 Construction Noise Assessment

Based on the criteria in Section 4.4, and assuming that construction noise is reduced by 6 decibels for each doubling of distance from the center of the construction site, screening distances for potential construction noise impact can be estimated. For a typical piece of construction equipment, such as a bulldozer, the impact screening distances for single-family residential (the strictest set of criteria) would be 160 feet for intermittent daytime activities, and up to 900 feet for intermittent nighttime or continuous activities, as defined in Table 6. Potential construction noise impacts will be evaluated during final design.

6.7 Construction Vibration Assessment

Based on the criteria in Section 4.5, and using the vibration level versus distance curves in Figure 19, screening distances for potential construction vibration impact can be estimated. Table 17 lists the potential impact distances for construction vibration. Potential construction vibration impacts will be evaluated during final design.

Table 17. Summary of BART Construction Vibration Impact Assessment

Equipment Type	Projected Impact Distance (ft)		
	80 VdB	90 VdB	100 VdB
H Piles	150	75	40
Sheet Piles	100	40	15
Vibratory Roller	260	100	40
Dynamic Compaction	95	55	30

7. MITIGATION OF NOISE AND VIBRATION IMPACTS

7.1 BART Noise Mitigation Measures

Potential mitigation measures for reducing noise impacts from BART operation 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 (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 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.

- **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 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.

- **Special Trackwork at Crossovers –** Crossovers are special trackwork that allow transit vehicles to switch between tracks. Crossovers contain gaps in the track to allow the wheels to move from one track to the other, and these gaps generate additional noise as the vehicle moves through the crossover. Because the impacts of BART wheels over rail gaps at track crossover locations increases BART 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.

The BART Design Criteria consider noise impacts to be significant if they exceed either the project-induced noise criteria or the cumulative noise criteria, and mitigation should be applied unless there are no practical means to do so.

Based on the results of the noise assessment, potential mitigation measures have been identified. The primary mitigation measure would be the construction of sound barrier walls to shield areas where impact is projected. Table 18 indicates the approximate noise barrier locations, lengths, and side of track as well as the number of impacts that would be reduced. Other measures to be considered include relocating the crossover near Station 2309.

A combination of noise barriers and relocation of the crossover near Station 2309 would eliminate all noise impacts, except for two, along the BART Warm Springs Extension. Sound insulation may be required at these residences to mitigate the noise impacts.

Table 18. Potential Locations for Noise Barriers

Location	Civil Stn	Side of Track	Length (Feet)	Impacts Without Mitigation		Impacts With Mitigation [1]	
				Project Induced	Cumulative	Project Induced	Cumulative
Walnut Ave to Stevenson Blvd	2232 to 2242	NB	1000	0	84	0	0
Walnut Ave to Stevenson Blvd	2228 to 2240	SB	1200	12	12	0	0
Paseo Padre Parkway to Washington Blvd	2308 to 2337	NB	2900	31	44	2	2
Washington Blvd to Blacow Road	2353 to 2370	SB	1700	12	6	0	0
Blacow Road to Auto Mall Parkway	2370 to 2415	SB	4500	55	0	0	0
Total:			**11,300**	**110**	**146**	**2**	**2**

Notes:
1. The mitigation assessment assumes a minimum of 8 dB of noise reduction for a noise barrier. Detailed barrier design and mitigation projections should be made during the design phase of the project.

Table 18 represents potential mitigation measures for the noise impacts along the BART Warm Springs Extension. Specific noise mitigation measures, including noise barriers and crossover relocations will be addressed in more detail during final design.

7.2 BART Vibration Mitigation Measures

The assessment assumes that the BART 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 BART operation, 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 Fasteners** – A number of resilient fastening systems for reducing vibration are available. However, many resilient fasteners are suitable for direct fixation only, and would not work for ballast and tie track. Resilient fasteners reduce the amount of vibration energy that is transferred into the track substructure and are effective in reducing ground-borne vibration in frequencies above 30 Hz.

- **Special Trackwork at Crossovers** – Crossovers are special trackwork that allow transit vehicles to switch between tracks. Crossovers contain gaps in the track to allow the wheels to move from one track to the other, and these gaps generate additional vibration as the vehicle moves through the crossover. Because the impacts of wheels over rail gaps at track crossover locations increases vibration by about 10 VdB, 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 (and noise impacts also) 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 BART criteria are considered significant, and warrant mitigation, if reasonable and feasible. Table 19 indicates the areas along the corridor where mitigation has been recommended to reduce the vibration levels. At a minimum, mitigation would require the installation of ballast mats. However, more extensive measures or a combination of measures may be required to mitigate impacts at some locations. In addition, relocation of the crossover near Station 2309 would reduce the vibration levels for adjacent residences.

Table 19. Potential Locations for Vibration Mitigation

Location	Civil Stn	Length (Feet)	Impacts
Walnut Ave to Stevenson Blvd	2230 to 2245	1500	66
Paseo Padre Parkway to Washington Blvd	2325 to 2332	700	5
Washington Blvd to Blacow Road	2354 to 2384 and 2388 to 2408	5000	50
Total		**7200**	**121**

Table 19 represents potential vibration mitigation locations for impacts along the BART Warm Springs Extension. Specific implementation of the vibration mitigation measures described above, including details regarding the specific locations and types of mitgitation will be addressed in detail during preliminary engineering and final design. During preliminary engineering and final design, further detail about track and receiver elevation, track location and other pertinent information will be available. This information will be utilized to adopt the mitigation measures presented above on a site-specific basis and allow design at an appropriate level of detail. Implementation of these mitigation measures is expected to reduce significant impacts to a less-than-significant level. However there may be some situations where implementation of all feasible mitigation will not reduce the impact to a less than significant level. The situations where this could occur cannot be determined until the detailed vibration mitigation design is developed. Because there may be some situations where significant vibration impacts cannot be mitigated to a less than significant level, this impact is considered to be significant and unavoidable.

7.3 Bus Alternative Noise and Vibration Mitigation Measures

7.3.1 Noise Mitigation

Potential mitigation measures for reducing noise impacts from bus operations are described below:

- **Noise Barriers** – Construction of barriers is a common approach to reducing noise impacts from surface transportation sources. 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 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 4 and 8 feet.

- **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 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 greatest 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.

The area identified for noise mitigation starts at Station 2325 and continues to Station 2331. Either noise barriers or sound insulation would be acceptable mitigation to eliminate the noise impacts.

7.3.2 Vibration Impacts

No vibration impact is projected for the proposed bus alternative so no mitigation is recommended.

7.4 Ancillary Equipment Noise Mitigation Measures

The results in Section 6.4 indicate the potential for noise impact for electrical substations located within up to 700 feet of residences, and the potential for noise impact for the vent shaft in the Fremont Central Park up to 900 feet from the structure, depending on the type of noise generated by the substations and the vent shaft. Specific impacts will be identified during final design based on actual substation locations and measures will be taken to mitigate such impacts. It is generally possible to eliminate substation and vent shaft noise impacts by including appropriate noise limits in the procurement documents.

7.5 Maintenance Facility Noise Mitigation Measures

No noise impact is projected for the proposed maintenance facility so no mitigation is recommended.

7.6 Construction Noise Mitigation Measures

Construction activities will be carried out in compliance with all applicable local noise regulations and BART specifications for construction noise. In addition, specific residential property line noise limits will be developed during final design and included in the construction specifications for the project, and noise monitoring will be performed during construction to verify compliance with the limits. This approach allows the contractor flexibility to meet the noise limits in the most efficient and cost-effective manner. Noise control measures that will be applied as needed to meet the noise limits include the following:

- Local residents should be made aware of construction activities and community outreach should inform residents of what to expect during construction.
- Avoiding nighttime construction in residential neighborhoods.
- Using specially quieted equipment with enclosed engines and/or high-performance mufflers.
- 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.
- Re-routing construction-related truck traffic along roadways that will cause the least disturbance to residents.
- Avoiding impact pile driving near noise-sensitive areas, where possible. Drilled piles or the use of a sonic or vibratory pile driver are quieter alternatives where the geological conditions permit their use. If impact pile drivers must be used, their use will be limited to the periods between 8:00 a.m. and 5:00 p.m. on weekdays.

With the incorporation of the appropriate noise mitigation measures, impacts from construction-generated noise should not be significant. To provide added assurance, a complaint resolution procedure will also be put in place to rapidly address any noise problems that may develop during construction.

7.7 Construction Vibration Mitigation Measures

Mitigation of construction vibration requires consideration of equipment location and use. The following measures should be implemented during the construction phase:

- Local residents should be made aware of construction activities and community outreach should inform residents of what to expect during construction.
- Equipment should be placed as far from vibration-sensitive structures as possible.

- Demolition, earthmoving, and ground impacting operations should be scheduled so as not to occur during the same periods. Vibration levels could be higher when multiple operations are conducted simultaneously.

- Avoid nighttime construction in residential neighborhoods.

- Try to avoid those construction processes that will generate the highest vibration levels. For example, it may be possible to reduce or eliminate impact pile driving with drilled or pushed piles.

- Avoid vibratory rolling whenever possible. This process can generate some of the highest vibration levels, and as such, should be avoided or replaced with other methods near vibration-sensitive structures.

APPENDIX A. MEASUREMENT SITE PHOTOGRAPHS

Figure A-1. Site LT-1, Presidio Apartment Complex

Figure A-2. Site LT-2, Red Hawk Ranch Apartments

Figure A-3. Site LT-3, 1549 Valdez Way

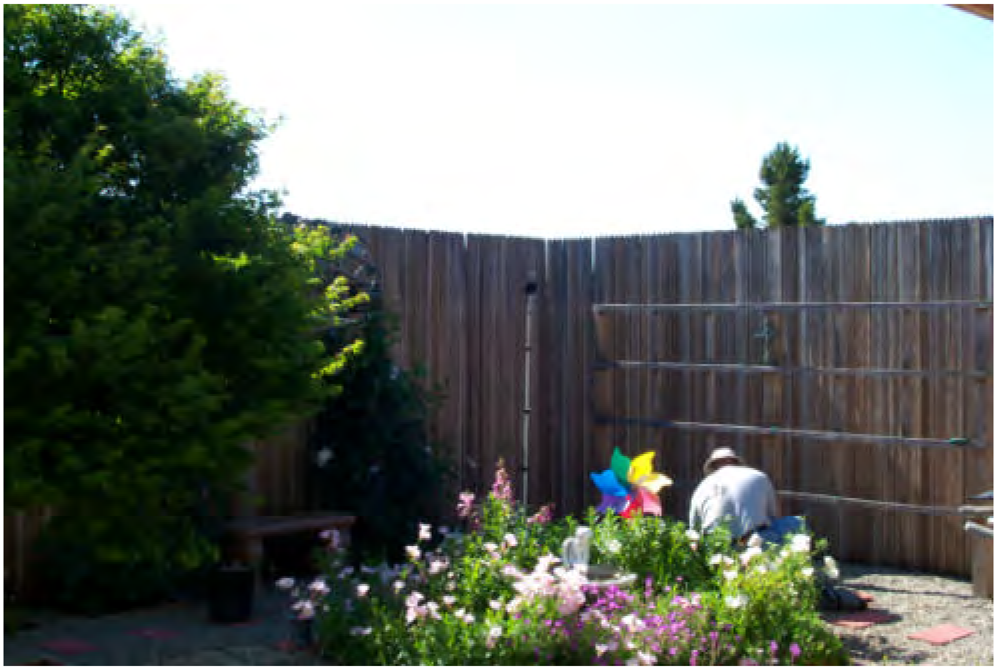

Figure A-4. Site LT-4, 40807 Vaca Road

Figure A-5. Site LT-5, 3240 Neal Road

Figure A-6. Site LT-6, 3073 Driscoll Road, Apt A

Figure A-7. Site LT-7, 3621 Kay Court

Figure A-8. Site LT-8, 43244 Newport Drive

Figure A-9. Site LT-9, 44788 Old Warm Springs Road

Figure A-10. Site V-1, Red Hawk Ranch Apartments

Figure A-11. Site V-2, Paseo Padre Parkway

Figure A-12. Site V-3, E.M. Grimmer Elementary School

Figure A-13. Site V-4, Osgood Court

APPENDIX B. NOISE MEASUREMENT DATA

Site 1: Presidio Apartments

Ldn: 57 dBA

Table B-1. Noise Survey Results, Site 1

Start Hour	LEQ	LMAX	LMIN	L1	L10	L33	L60	L90	L99
10:00:00	52.5	65.6	43.8	60.3	55.4	52.0	50.7	47.5	45.2
11:00:00	52.7	68.3	44.1	61.7	55.1	51.7	50.4	47.4	45.8
12:00:00	53.5	71.1	45.3	65.1	54.6	51.7	50.7	47.8	46.1
13:00:00	52.8	66.3	46.9	60.7	55.0	52.5	51.4	49.1	47.6
14:00:00	53.9	66.7	47.8	61.7	56.2	53.5	52.4	50.1	48.4
15:00:00	54.3	69.1	47.8	62.6	56.5	53.9	52.8	50.4	48.7
16:00:00	53.2	64.8	46.6	59.1	55.7	53.4	52.3	49.5	47.9
17:00:00	55.6	71.9	47.4	65.4	57.3	54.1	53.2	50.5	49.1
18:00:00	56.5	81.3	46.9	65.3	56.4	53.6	52.3	49.4	47.8
19:00:00	53.4	70.4	45.5	60.8	55.9	53.2	52.0	48.2	46.3
20:00:00	53.4	72.0	43.9	64.2	55.8	52.0	50.6	47.0	45.0
21:00:00	50.3	69.4	41.8	58.6	52.2	49.1	47.9	44.6	43.0
22:00:00	49.1	63.3	41.2	58.1	51.6	48.0	46.7	43.4	42.1
23:00:00	50.2	70.7	40.3	63.0	49.4	46.1	44.9	42.5	41.1
00:00:00	46.3	63.0	38.9	56.8	48.5	44.3	42.8	40.7	39.4
01:00:00	43.7	60.7	39.0	51.8	45.3	43.0	42.3	40.4	39.3
02:00:00	43.9	58.3	37.3	55.7	45.1	41.7	40.8	39.1	37.6
03:00:00	43.6	58.5	37.4	54.0	45.5	41.8	40.8	39.0	37.5
04:00:00	46.5	63.4	38.6	57.2	49.5	44.2	42.5	39.8	38.6
05:00:00	54.7	80.8	40.6	65.9	56.2	51.3	49.9	45.6	43.0
06:00:00	52.1	67.3	46.4	59.7	54.2	51.6	50.6	48.3	47.1
07:00:00	52.6	62.5	45.7	59.7	55.2	52.3	51.2	48.7	47.1
08:00:00	53.2	67.2	45.9	61.2	55.9	52.5	51.3	48.7	46.9
09:00:00	54.8	70.6	45.8	64.6	58.2	52.8	51.5	48.3	46.3

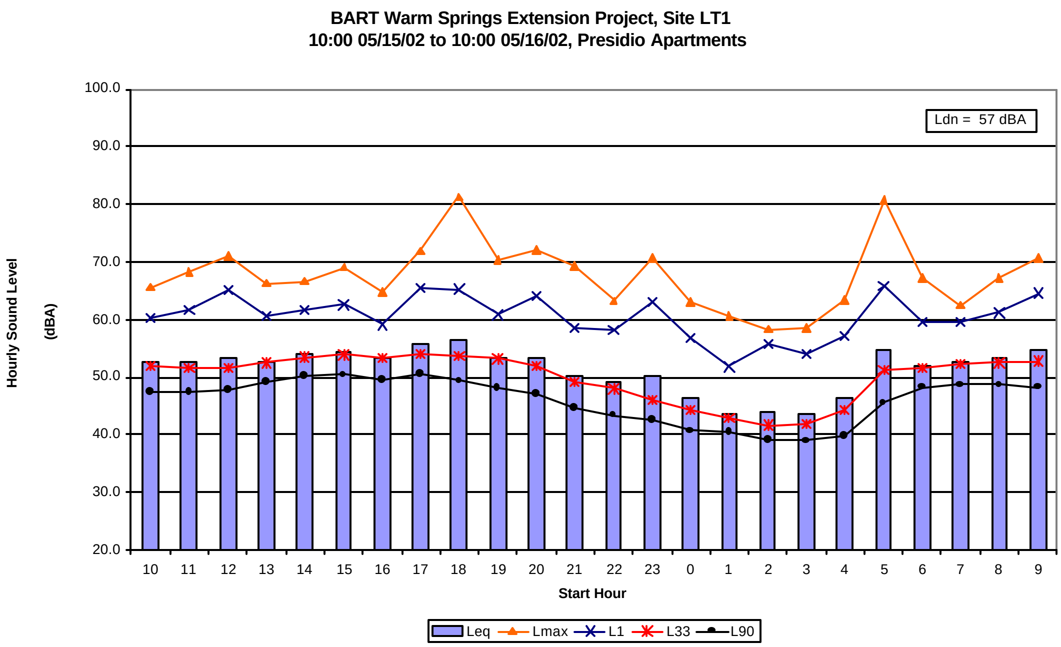

Figure B-1. Noise Survey Results, Site 1

Site 2: Red Hawk Ranch Apartments

Ldn: 53 dBA

Table B-2. Noise Survey Results, Site 2

Start Hour	LEQ	LMAX	LMIN	L1	L10	L33	L60	L90	L99
10:00:00	48.4	67.4	36.8	58.9	50.9	45.3	43.2	40.0	38.2
11:00:00	51.7	71.2	37.3	63.7	54.1	46.3	44.0	40.2	38.2
12:00:00	47.5	68.3	38.8	56.2	50.0	46.1	44.3	41.4	39.9
13:00:00	48.4	67.1	40.1	59.1	49.9	45.8	44.7	42.5	41.2
14:00:00	49.8	67.4	42.3	60.6	52.1	47.7	46.6	44.4	43.2
15:00:00	50.4	69.2	41.6	61.0	52.6	47.9	46.7	44.3	42.6
16:00:00	48.8	64.6	40.6	57.7	51.8	47.4	46.0	43.3	42.0
17:00:00	50.2	65.4	42.3	60.5	52.8	48.3	47.0	44.6	43.2
18:00:00	49.6	72.5	40.1	59.1	50.8	46.0	44.9	42.6	41.2
19:00:00	48.7	65.5	40.6	57.6	52.2	46.9	45.1	42.5	41.2
20:00:00	50.0	73.5	40.3	59.5	53.7	46.8	44.9	42.4	41.1
21:00:00	46.5	66.0	37.2	58.5	47.1	42.8	41.8	39.8	38.1
22:00:00	46.0	62.1	37.4	57.7	48.5	42.7	41.3	39.2	38.1
23:00:00	49.1	70.2	36.8	63.1	44.5	40.3	39.5	38.2	37.2
00:00:00	44.1	61.9	35.0	56.7	44.8	39.4	37.9	36.1	35.1
01:00:00	40.5	57.1	35.7	48.8	42.2	39.3	38.6	37.2	36.2
02:00:00	41.3	59.7	33.0	55.0	40.6	37.3	36.4	34.6	33.3
03:00:00	41.1	58.7	32.5	53.7	41.7	37.5	36.0	34.0	33.1
04:00:00	43.1	62.9	33.8	54.7	44.7	39.6	38.3	35.7	34.4
05:00:00	51.3	69.3	37.5	62.7	54.5	46.1	44.7	40.6	38.6
06:00:00	46.5	63.1	41.4	54.7	47.8	45.7	44.8	42.9	42.0
07:00:00	49.0	72.2	39.6	58.6	50.9	46.3	45.0	42.2	40.7
08:00:00	49.4	70.6	40.0	61.0	51.6	46.3	45.0	42.3	40.7
09:00:00	47.6	65.5	38.6	58.4	49.6	45.0	43.5	40.6	39.3

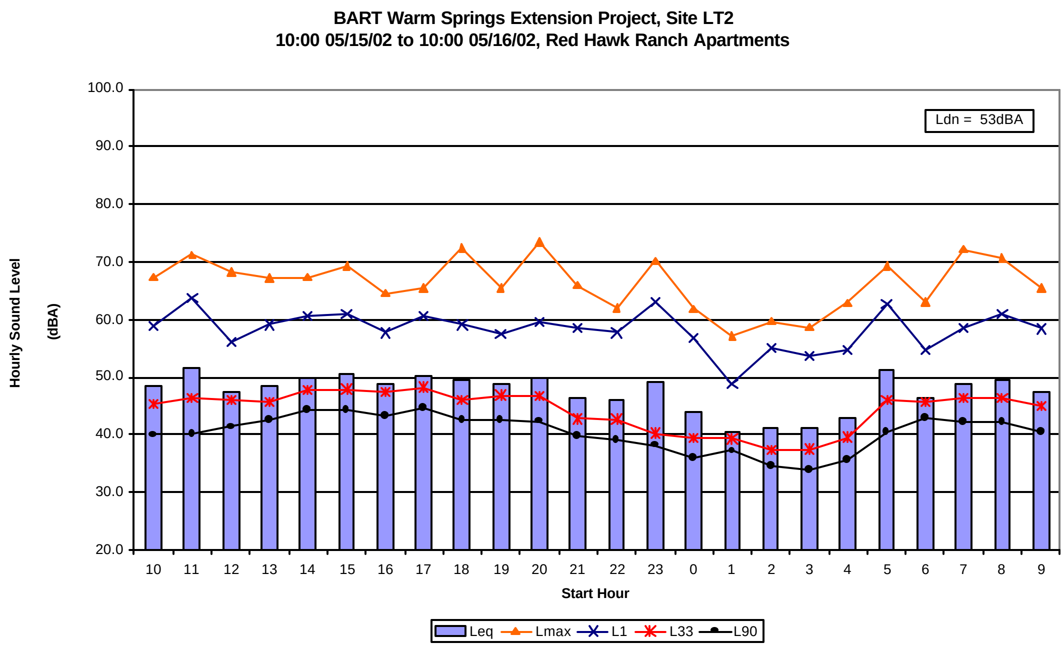

Figure B-2. Noise Survey Results, Site 2

Site 3: 1549 Valdez Way

Ldn: 53 dBA

Table B-3. Noise Survey Results, Site 3

Start Hour	LEQ	LMAX	LMIN	L1	L10	L33	L60	L90	L99
17:00:00	54.3	71.6	42.7	59.7	56.9	54.4	53.2	49.3	44.8
18:00:00	54.9	69.1	41.2	63.3	57.4	54.9	53.4	46.5	42.7
19:00:00	55.2	68.3	39.7	63.8	57.8	55.1	53.4	49.1	41.3
20:00:00	49.4	58.8	38.9	57.1	53.6	49.5	45.8	41.3	40.0
21:00:00	42.5	56.8	36.8	50.2	44.8	41.9	41.1	38.8	37.7
22:00:00	48.6	67.6	36.3	59.5	52.7	45.7	42.7	38.5	37.3
23:00:00	44.6	59.3	35.2	55.3	47.1	43.5	41.4	38.1	36.4
00:00:00	41.8	60.6	34.2	51.0	43.7	40.0	38.8	36.7	35.3
01:00:00	48.1	63.1	35.3	57.9	52.5	43.8	41.8	38.0	36.4
02:00:00	43.5	57.5	32.1	50.7	46.3	43.5	42.3	36.0	33.2
03:00:00	43.8	63.6	33.0	56.5	42.2	37.9	37.2	35.1	33.7
04:00:00	42.3	64.1	33.4	53.4	41.2	39.7	38.8	36.6	35.2
05:00:00	47.2	68.3	34.9	57.6	48.3	44.6	42.7	37.1	35.4
06:00:00	44.9	59.6	38.9	53.3	47.7	43.8	42.5	40.4	39.3
07:00:00	44.6	60.1	34.6	56.0	46.7	41.2	39.5	36.5	35.2
08:00:00	46.2	66.3	35.6	58.5	46.8	42.8	40.9	37.6	36.2
09:00:00	43.9	59.5	35.1	54.2	47.0	41.7	39.6	37.0	35.6
10:00:00	48.1	62.7	37.1	58.5	51.7	45.5	43.2	39.5	38.2
11:00:00	48.9	61.5	37.3	58.3	51.8	47.9	46.2	42.3	38.6
12:00:00	48.9	62.4	37.8	58.4	52.1	47.8	45.8	40.9	38.5
13:00:00	48.7	62.6	39.3	56.3	51.8	48.5	47.0	43.0	40.3
14:00:00	48.9	65.2	37.0	58.6	51.6	48.1	46.5	40.5	37.7
15:00:00	52.1	63.4	37.7	59.7	55.0	52.4	50.7	44.7	40.0
16:00:00	52.4	65.0	39.7	58.3	55.3	52.8	51.2	46.6	41.6

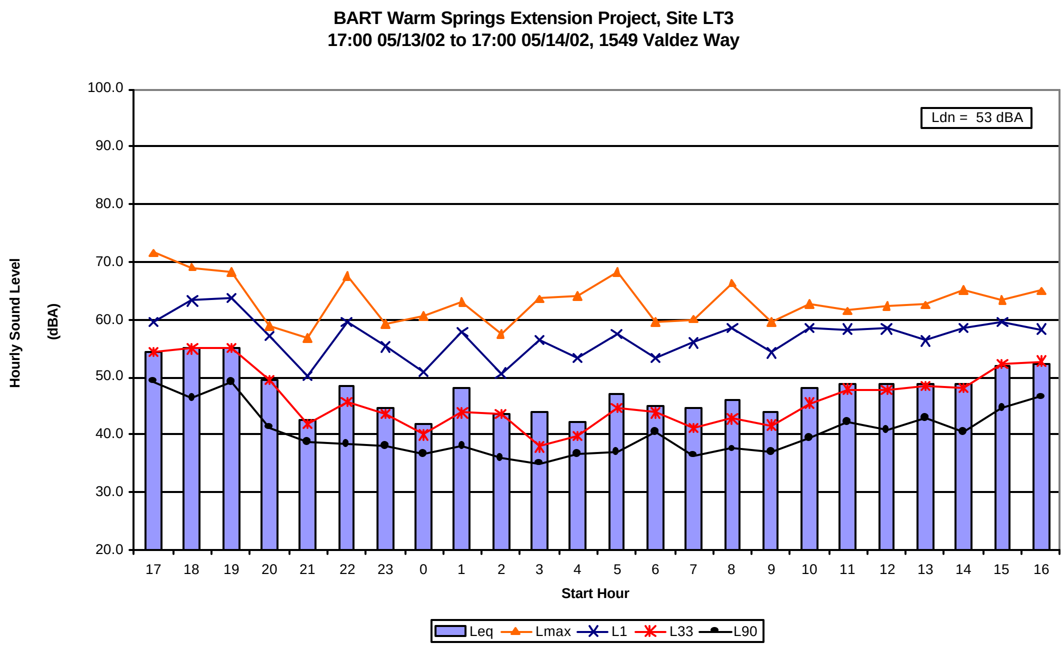

Figure B-3. Noise Survey Results, Site 3

Site 4: 40807 Vaca Road

Ldn: 53 dBA

Table B-4. Noise Survey Results, Site 4

Start Hour	LEQ	LMAX	LMIN	L1	L10	L33	L60	L90	L99
17:00:00	57.5	80.2	41.5	64.8	59.2	54.0	50.8	45.2	43.1
18:00:00	54.0	78.2	39.4	63.7	56.7	51.6	49.2	44.0	41.6
19:00:00	53.7	77.0	39.3	64.1	56.7	49.7	47.8	44.3	41.5
20:00:00	44.9	55.5	37.4	51.6	47.6	45.0	43.7	40.2	38.3
21:00:00	42.4	57.1	35.7	48.1	44.7	42.6	41.5	38.5	36.9
22:00:00	49.0	72.8	33.0	59.6	51.3	42.1	40.3	36.4	34.3
23:00:00	43.5	63.6	31.1	55.8	45.3	39.6	37.7	34.0	32.0
00:00:00	39.5	59.6	30.1	50.6	40.3	36.1	34.7	32.2	30.7
01:00:00	46.8	65.7	29.9	57.9	49.2	38.1	36.0	33.1	31.4
02:00:00	38.7	58.5	27.2	51.3	38.0	35.4	34.4	30.8	28.4
03:00:00	44.5	67.8	29.0	58.1	41.0	35.7	34.6	31.6	29.5
04:00:00	40.3	58.8	30.0	52.1	40.3	37.1	36.0	33.2	30.5
05:00:00	44.9	65.0	30.9	56.5	44.8	41.9	40.4	35.5	32.7
06:00:00	44.8	58.6	39.2	51.0	46.8	44.7	43.7	41.4	40.0
07:00:00	46.0	62.5	37.7	56.9	47.0	44.7	43.7	40.8	39.0
08:00:00	47.8	65.9	36.0	59.9	48.8	45.4	44.1	40.6	38.3
09:00:00	44.2	61.2	34.8	54.1	46.4	43.4	41.9	38.5	36.6
10:00:00	45.9	64.2	35.7	56.8	48.7	43.0	41.3	38.1	36.5
11:00:00	48.6	63.2	36.4	57.8	51.6	47.1	45.9	43.6	38.1
12:00:00	49.2	70.0	37.1	58.1	52.1	45.9	44.1	39.7	38.1
13:00:00	46.1	60.4	36.0	56.0	49.5	44.0	42.5	39.3	37.3
14:00:00	46.7	59.2	34.2	56.6	50.4	44.9	42.8	38.4	35.6
15:00:00	53.3	72.4	39.0	61.8	57.3	51.7	48.7	42.8	40.3
16:00:00	53.6	65.1	39.6	61.7	57.6	53.3	50.8	44.5	41.5

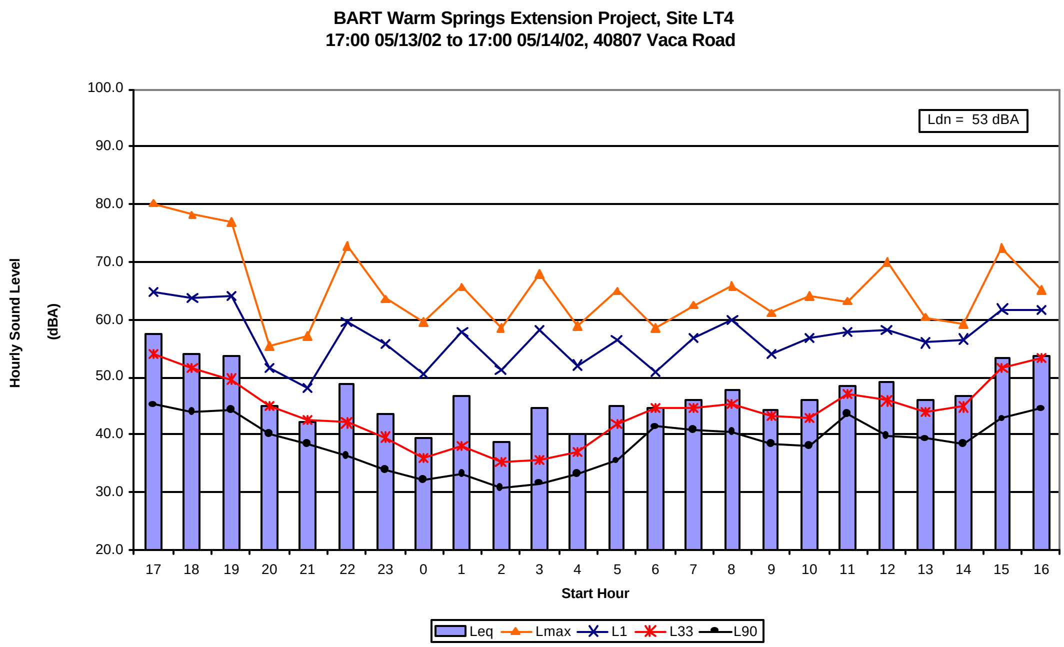

Figure B-4. Noise Survey Results, Site 4

Site 5: 3240 Neal Road

Ldn: 60 dBA

Table B-5. Noise Survey Results, Site 5

Start Hour	LEQ	LMAX	LMIN	L1	L10	L33	L60	L90	L99
18:00:00	55.8	77.2	37.5	69.7	53.5	47.7	44.5	40.4	38.5
19:00:00	63.0	86.5	36.3	74.9	68.5	45.0	42.8	39.5	37.7
20:00:00	42.3	58.0	35.6	52.1	44.4	40.7	39.7	37.7	36.5
21:00:00	40.7	54.0	34.6	47.8	43.5	40.6	38.9	36.4	35.2
22:00:00	59.2	79.2	34.1	72.3	53.9	40.7	39.6	37.1	35.3
23:00:00	46.5	69.2	31.5	59.1	43.8	41.6	40.6	36.3	33.4
00:00:00	39.5	57.4	30.9	48.2	40.5	38.9	38.1	34.0	32.1
01:00:00	59.9	79.7	31.4	72.7	52.5	39.9	38.0	34.0	32.1
02:00:00	38.1	59.1	27.8	51.9	36.1	32.6	31.2	29.2	28.1
03:00:00	48.4	71.3	27.5	60.7	40.9	31.0	30.2	28.7	27.7
04:00:00	39.3	62.8	29.2	50.2	37.8	34.1	32.8	30.7	30.0
05:00:00	47.2	64.7	33.3	57.7	51.2	42.6	40.6	36.2	34.2
06:00:00	49.0	62.9	40.3	57.5	52.6	47.7	46.3	43.6	41.6
07:00:00	48.0	65.1	38.2	59.5	50.3	45.0	43.7	40.5	39.1
08:00:00	48.7	66.1	38.6	61.2	50.3	46.0	44.1	40.9	39.2
09:00:00	51.0	69.0	38.5	61.9	54.1	50.0	45.8	41.4	39.5
10:00:00	48.1	62.7	36.6	58.4	51.9	46.1	42.9	38.7	37.3
11:00:00	49.5	66.1	37.8	60.7	52.7	47.3	44.5	40.2	39.0
12:00:00	55.2	75.3	37.4	66.9	55.1	48.6	45.1	39.7	38.1
13:00:00	48.0	63.1	37.2	58.9	51.0	46.6	43.8	39.4	38.0
14:00:00	46.5	66.7	37.0	56.7	49.2	44.4	42.4	39.1	37.8
15:00:00	51.0	72.5	37.2	62.9	49.9	44.4	42.8	39.9	38.2
16:00:00	46.7	63.6	38.1	55.7	49.6	45.9	44.3	40.6	39.1
17:00:00	61.2	85.6	38.9	71.0	66.8	47.5	45.1	41.9	40.0

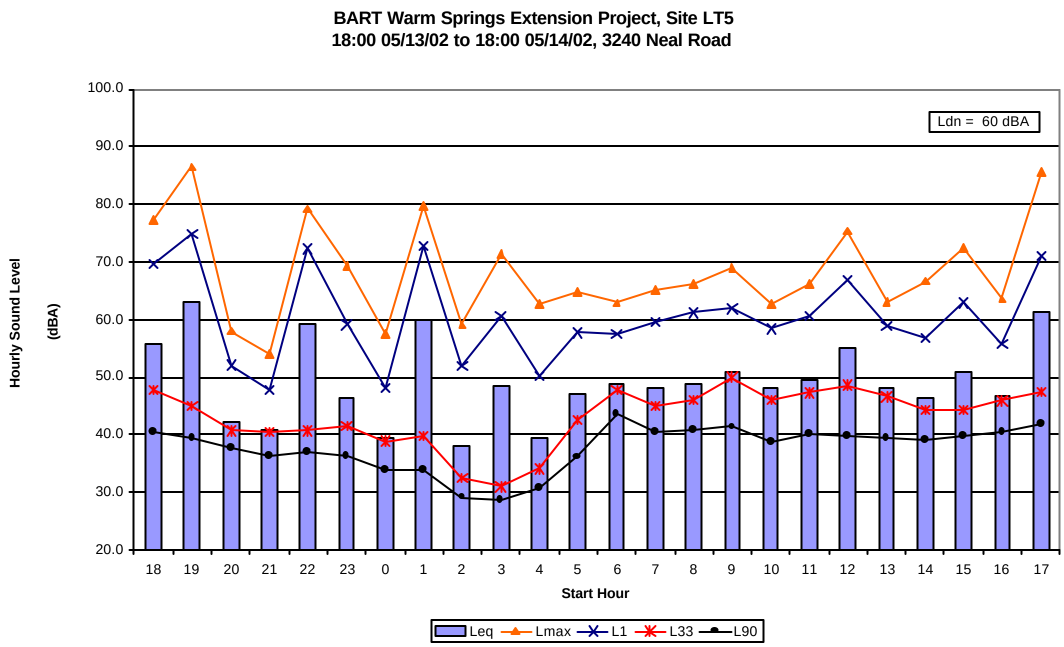

Figure B-5. Noise Survey Results, Site 5

Site 6: 3073 Driscoll Road, Apt A

Ldn: 54 dBA

Table B-6. Noise Survey Results, Site 6

Start Hour	LEQ	LMAX	LMIN	L1	L10	L33	L60	L90	L99
18:00:00	52.7	75.4	41.0	63.5	53.2	47.4	46.3	44.1	42.4
19:00:00	53.5	74.5	41.4	63.6	58.0	47.9	45.9	43.4	42.1
20:00:00	46.4	62.3	40.2	53.8	49.1	45.8	44.6	42.5	41.3
21:00:00	45.6	59.6	40.2	51.9	48.6	44.8	43.8	42.0	41.0
22:00:00	50.9	73.3	37.8	61.6	53.8	45.0	43.1	40.3	38.7
23:00:00	46.0	67.6	37.2	57.7	43.9	41.3	40.5	38.8	37.7
00:00:00	40.0	59.2	36.0	46.5	40.9	39.4	38.8	37.3	36.4
01:00:00	50.5	71.5	35.5	62.7	55.4	41.9	40.2	37.5	36.2
02:00:00	39.2	56.3	35.0	50.1	39.4	37.7	37.1	36.0	35.1
03:00:00	46.3	69.0	33.5	58.4	41.6	37.0	36.3	34.7	34.0
04:00:00	41.1	56.7	35.1	49.9	43.7	39.7	38.3	36.4	35.4
05:00:00	46.0	61.5	36.7	55.3	48.9	45.1	43.1	38.7	37.3
06:00:00	46.7	60.3	42.2	53.1	48.5	46.6	45.8	44.0	42.9
07:00:00	47.4	63.4	40.1	57.9	48.7	45.9	44.9	42.6	41.0
08:00:00	48.8	65.2	39.5	61.0	50.2	46.7	45.4	42.9	41.2
09:00:00	47.3	66.2	39.9	56.3	49.1	45.7	44.6	42.4	41.1
10:00:00	47.5	65.8	37.2	57.1	50.1	45.7	44.3	41.1	38.7
11:00:00	48.6	67.5	40.2	59.7	50.8	46.0	44.7	42.4	41.1
12:00:00	54.4	81.5	40.6	65.3	53.9	47.2	45.0	42.3	41.1
13:00:00	49.2	65.0	40.2	58.7	52.2	47.8	45.9	43.0	41.5
14:00:00	49.8	66.0	40.7	58.8	52.2	49.1	47.8	44.0	42.1
15:00:00	50.4	71.8	40.7	61.3	52.3	46.5	45.5	43.4	42.1
16:00:00	48.1	65.1	40.5	57.0	50.5	46.9	45.8	43.3	41.6
17:00:00	53.7	80.8	43.2	64.3	56.4	48.6	46.9	44.9	44.0

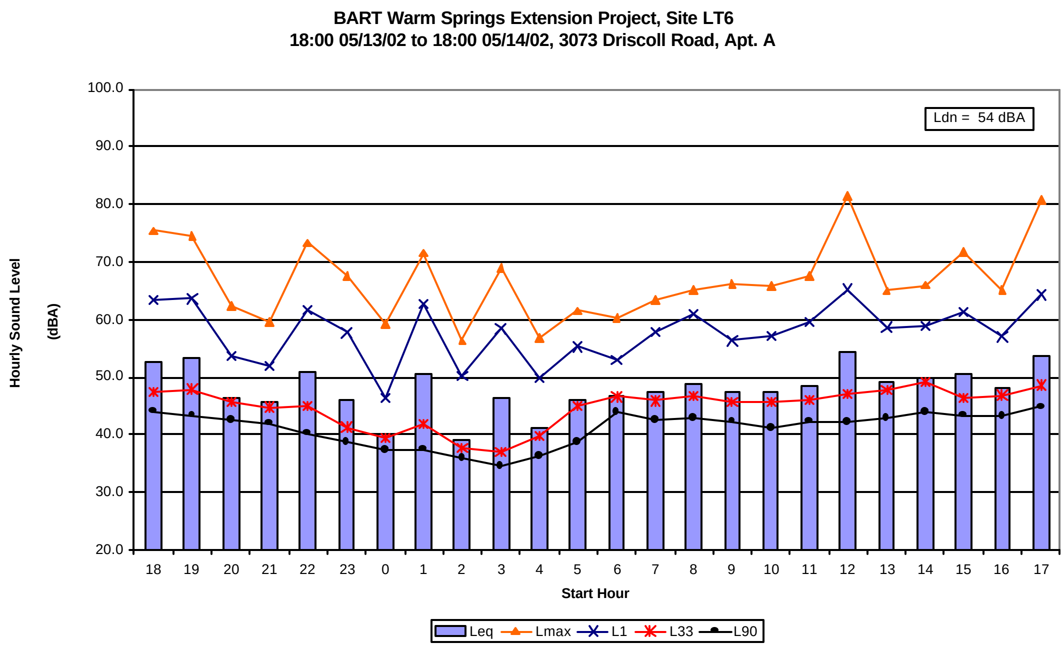

Figure B-6. Noise Survey Results, Site 6

Site 7: 3621 Kay Court

Ldn: 66 dBA

Table B-7. Noise Survey Results, Site 7

Start Hour	LEQ	LMAX	LMIN	L1	L10	L33	L60	L90	L99
18:00:00	61.1	89.7	42.9	72.4	57.8	54.3	52.4	46.2	43.7
19:00:00	59.0	79.1	43.0	73.7	56.7	52.5	50.5	45.6	43.7
20:00:00	48.4	60.4	40.6	55.0	51.5	48.4	46.7	43.3	41.4
21:00:00	45.9	60.8	39.5	53.9	49.1	45.0	43.6	41.2	40.0
22:00:00	63.8	83.4	37.1	75.6	52.2	43.8	42.2	39.4	37.9
23:00:00	61.3	81.0	35.2	75.0	47.5	41.6	40.0	37.6	36.1
00:00:00	40.6	58.3	33.7	50.6	42.0	38.5	37.7	36.1	34.5
01:00:00	38.4	55.2	33.4	48.4	39.0	37.2	36.4	34.5	33.8
02:00:00	38.8	61.2	33.3	42.9	40.1	38.1	37.3	35.1	33.7
03:00:00	42.6	62.6	33.5	55.7	43.4	38.4	37.4	35.2	34.1
04:00:00	41.5	58.8	35.6	50.2	42.6	40.7	39.8	37.5	36.2
05:00:00	46.0	60.0	38.1	54.1	48.2	46.2	45.2	40.1	38.8
06:00:00	63.3	80.3	38.8	77.7	51.4	45.7	44.6	41.9	40.1
07:00:00	47.8	62.8	41.7	54.7	49.9	47.8	46.8	44.2	42.4
08:00:00	47.8	68.6	39.8	57.9	48.7	45.7	44.6	42.2	40.7
09:00:00	48.3	66.4	40.1	55.7	51.2	48.5	46.7	42.2	40.5
10:00:00	56.7	79.2	38.9	69.5	49.7	45.2	43.8	41.3	39.7
11:00:00	49.8	65.7	39.4	61.5	52.6	47.1	45.1	41.5	40.1
12:00:00	56.7	77.4	38.8	65.2	60.6	52.2	47.2	41.2	39.6
13:00:00	74.9	95.7	39.4	88.6	75.9	53.0	49.6	42.2	40.2
14:00:00	53.9	65.4	41.1	60.8	57.5	54.3	52.2	45.5	42.2
15:00:00	60.3	82.4	41.7	73.3	60.1	56.1	54.0	46.4	43.0
16:00:00	58.2	77.4	40.1	72.6	56.9	52.5	49.9	42.8	41.0
17:00:00	52.9	68.8	40.2	61.2	56.7	52.6	50.1	43.6	41.2

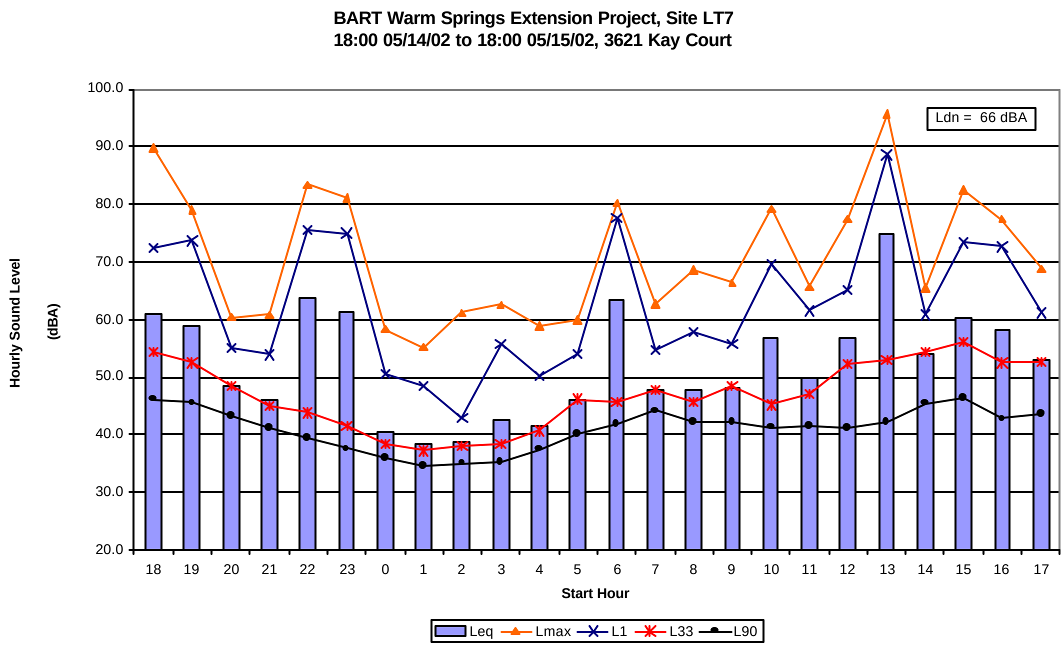

Figure B-7. Noise Survey Results, Site 7

Site 8: 43244 Newport Drive

Ldn: 65 dBA

Table B-8. Noise Survey Results, Site 8

Start Hour	LEQ	LMAX	LMIN	L1	L10	L33	L60	L90	L99
18:00:00	54.4	78.9	44.3	66.6	54.6	50.4	49.1	46.8	45.2
19:00:00	53.8	74.2	42.2	66.7	51.3	48.3	47.3	44.7	43.1
20:00:00	49.3	60.7	40.9	53.8	51.7	50.3	49.3	43.5	42.1
21:00:00	50.1	60.0	45.9	53.7	51.4	50.3	49.8	48.5	47.4
22:00:00	59.2	74.4	41.6	71.5	53.2	49.1	47.7	44.3	42.9
23:00:00	65.7	94.3	39.2	72.4	49.0	46.1	45.1	42.5	40.5
00:00:00	44.4	60.1	35.4	50.2	46.6	44.7	43.4	39.9	37.2
01:00:00	43.9	52.7	37.8	49.3	46.4	44.2	43.2	40.3	38.7
02:00:00	46.0	54.8	39.3	50.9	48.2	46.6	45.6	42.3	40.3
03:00:00	48.9	73.5	38.6	58.6	49.9	46.5	45.1	41.8	39.7
04:00:00	49.9	56.3	41.3	53.6	51.8	50.5	49.8	46.9	44.0
05:00:00	51.9	58.8	46.8	56.0	53.7	52.3	51.5	49.7	48.4
06:00:00	61.2	80.2	43.1	73.7	54.1	50.8	48.5	45.2	43.8
07:00:00	51.4	65.1	44.8	57.1	53.5	51.8	50.9	47.0	45.4
08:00:00	55.9	79.9	41.0	65.8	49.9	46.9	45.8	43.5	42.1
09:00:00	47.7	61.3	42.2	54.3	50.2	47.6	46.5	44.1	43.0
10:00:00	61.5	86.7	40.6	75.7	52.5	47.4	45.8	43.2	42.0
11:00:00	49.4	77.6	41.0	57.5	49.9	46.8	45.6	43.1	41.9
12:00:00	57.9	83.6	40.9	69.0	52.6	47.3	45.4	42.9	41.7
13:00:00	52.3	73.1	40.6	60.1	55.8	52.4	50.1	42.7	41.2
14:00:00	50.1	68.9	42.5	59.1	51.9	49.0	48.0	44.9	43.3
15:00:00	67.0	98.1	41.5	71.0	55.8	49.7	47.9	44.6	42.9
16:00:00	51.5	69.0	40.7	64.0	53.7	48.7	46.7	43.2	41.4
17:00:00	50.8	70.7	39.3	61.1	53.5	48.4	46.9	43.3	41.1

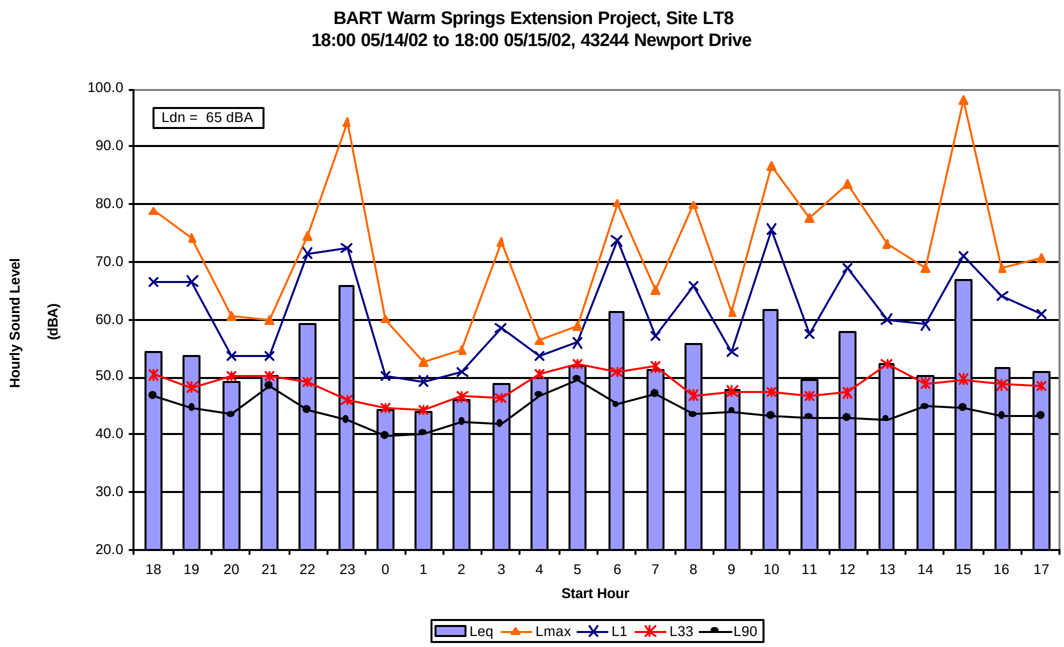

Figure B-8. Noise Survey Results, Site 8

Site 9: 44788 Old Warm Springs Road

Ldn: 61 dBA

Table B-9. Noise Survey Results, Site 9

Start Hour	LEQ	LMAX	LMIN	L1	L10	L33	L60	L90	L99
19:00:00	52.2	64.8	44.2	59.8	55.0	52.1	50.6	46.7	45.1
20:00:00	52.6	66.1	44.3	60.5	55.6	52.3	50.6	47.1	45.1
21:00:00	51.7	71.2	42.0	60.4	54.5	50.7	48.7	44.7	42.5
22:00:00	50.9	70.1	41.5	58.6	55.2	49.0	47.2	43.7	42.1
23:00:00	49.0	64.4	39.8	58.5	53.4	46.5	44.7	41.5	40.2
00:00:00	53.0	76.7	37.3	60.9	56.3	52.6	46.4	39.1	38.0
01:00:00	52.3	71.8	41.8	64.3	54.1	49.7	48.1	44.4	43.0
02:00:00	49.5	65.8	42.0	60.1	50.9	47.7	46.7	44.5	43.1
03:00:00	50.0	67.3	42.9	59.7	52.0	48.5	47.4	45.1	43.6
04:00:00	53.9	71.6	42.9	61.4	55.3	53.9	53.1	49.2	44.3
05:00:00	57.7	74.8	51.6	63.2	59.5	57.6	56.8	55.0	53.2
06:00:00	59.3	76.6	54.0	66.8	61.8	58.6	57.8	56.2	54.5
07:00:00	57.2	73.6	49.3	64.7	59.5	56.8	55.8	52.9	50.8
08:00:00	56.0	70.9	46.4	65.4	59.2	54.9	53.2	49.9	47.7
09:00:00	55.1	70.3	44.8	65.0	58.0	54.0	52.2	48.1	45.9
10:00:00	54.3	69.5	45.8	64.9	56.6	52.8	51.5	48.2	46.4
11:00:00	54.1	68.9	47.0	62.9	56.3	53.4	52.1	49.3	47.8
12:00:00	54.2	68.7	46.8	62.3	56.9	53.5	52.2	49.5	47.7
13:00:00	53.7	68.2	47.0	61.5	56.5	52.9	51.7	49.3	48.0
14:00:00	55.3	69.7	48.9	62.0	57.8	55.0	54.0	51.6	50.0
15:00:00	55.4	70.2	50.3	62.7	57.7	55.1	54.0	52.0	51.0
16:00:00	55.5	70.5	50.2	62.5	57.8	55.1	54.1	52.0	50.7
17:00:00	56.1	74.2	48.9	64.6	57.7	55.0	53.9	51.5	50.0
18:00:00	65.3	82.8	46.9	77.7	69.2	58.1	54.9	50.2	48.2

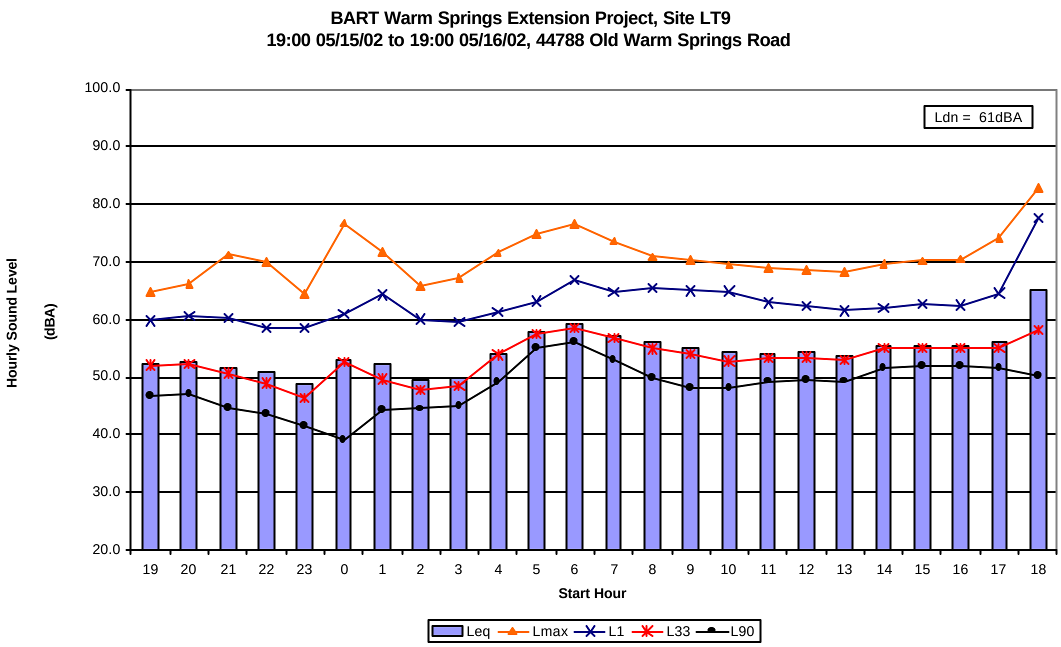

Figure B-9. Noise Survey Results, Site 9

APPENDIX C. VIBRATION MEASUREMENT DATA AND PROJECTIONS

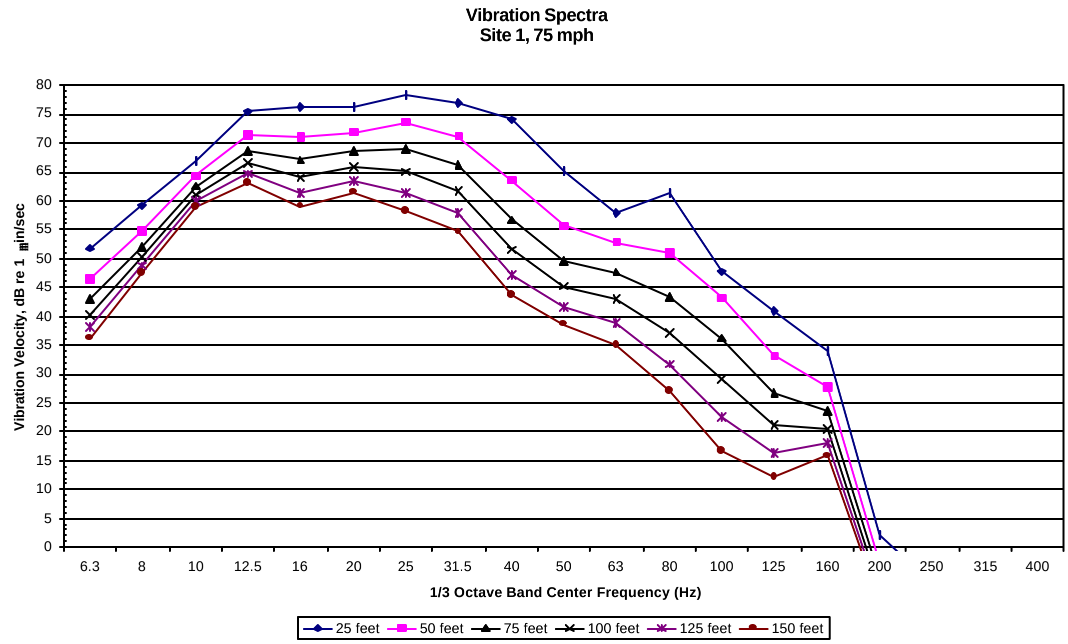

Figure C-1. Projected BART Vibration Spectra, Site 1, 75 mph

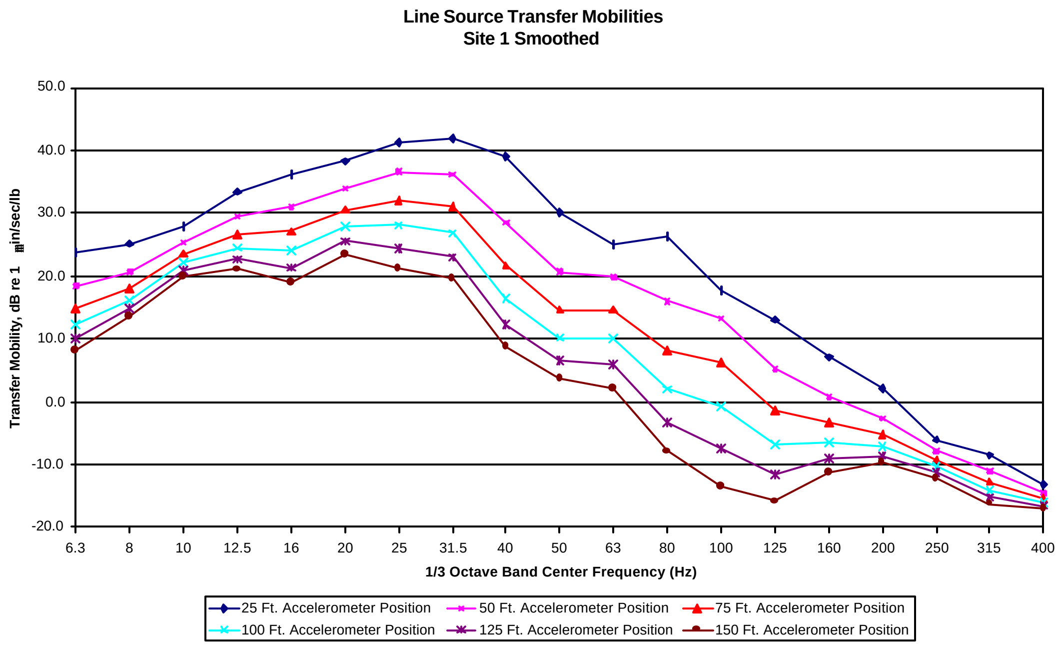

Figure C-2. Representative Transfer Mobility Functions, Site 1

Table C-1. Line Source Transfer Mobility Coefficients, Site 1

Frequency (Hz)	A	B	C
6.3	37.66651	-3.40004	-4.65455
8	45.90478	-14.8571	0
10	31.93833	1.916592	-3.40785
12.5	37.6589	5.22793	-5.90369
16	36.56394	13.69664	-9.9893
20	36.1466	14.67637	-9.4107
25	11.31606	51.72305	-21.6767
31.5	20.57119	43.49897	-20.1934
40	66.45751	-7.1833	-8.89631
50	61.30546	-14.6467	-5.45012
63	-11.4963	61.80204	-25.5234
80	27.12788	27.39327	-19.9786
100	-86.7604	148.4246	-52.7206
125	-5.32703	45.41172	-23.0828
160	24.29744	-5.17457	-5.11207
200	27.20913	-19.6298	1.22826
250	-7.32485	6.619636	-4.06199
315	-4.76978	1.96581	-3.31546
400	-9.12307	-1.62039	-0.90904

TM = A + B*log (d) + C*(log (d))^2

Where:

TM = Transfer Mobility in dB re 1ìin/sec/lb/(ft)^1/2

d = Distance in feet

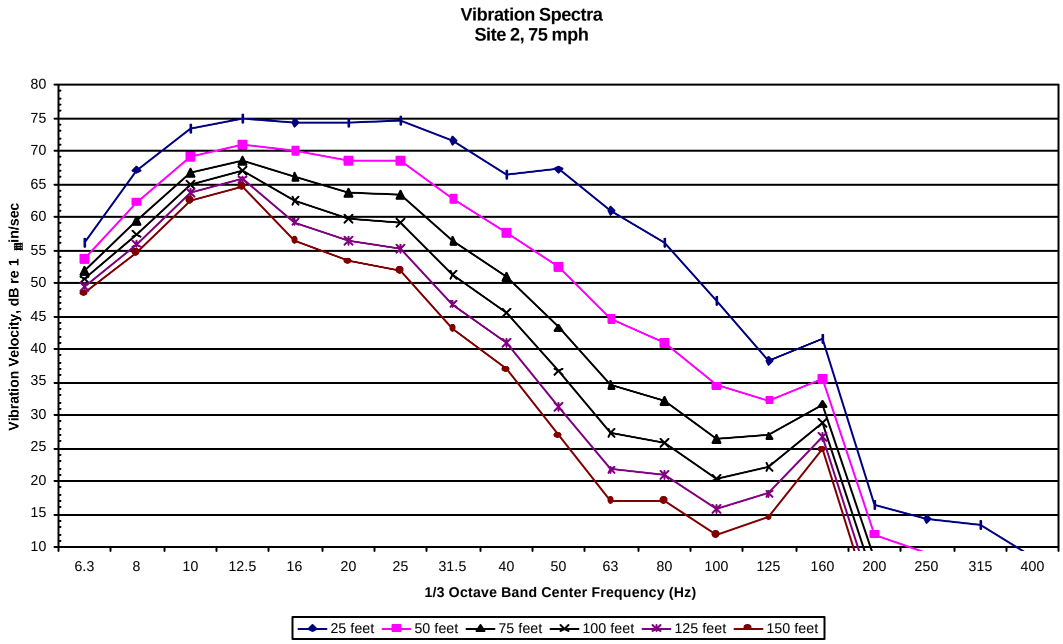

Figure C-3. Projected BART Vibration Spectra, Site 2, 75 mph

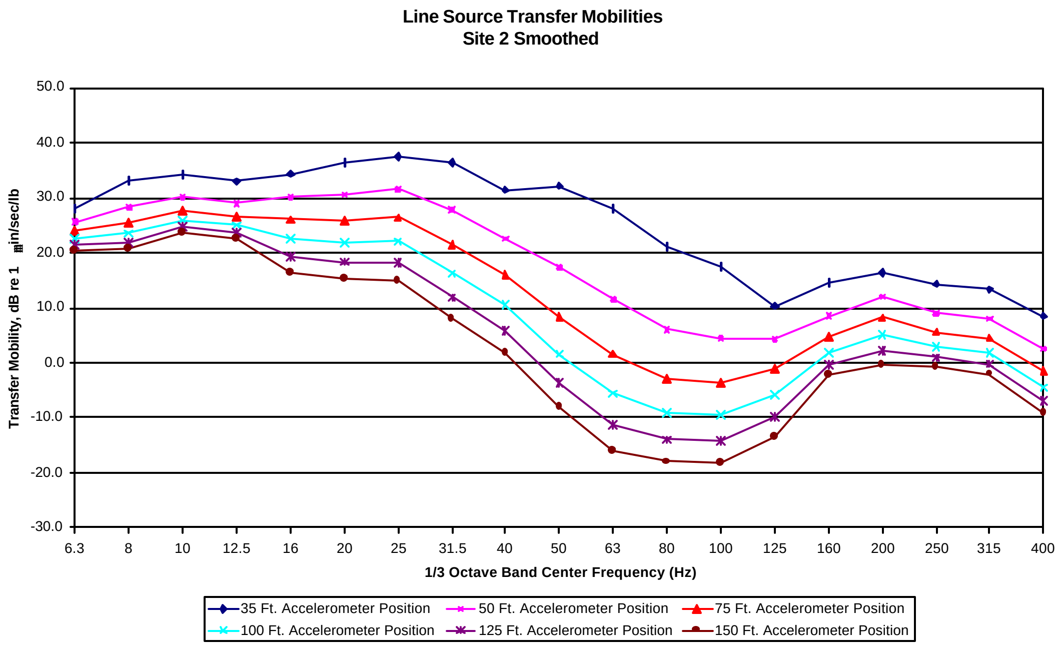

Figure C-4. Representative Transfer Mobility Functions, Site 2

Table C-2. Line Source Transfer Mobility Coefficients, Site 2

Frequency (Hz)	A	B	C
6.3	30.61441	3.220252	-3.62959
8	55.57336	-16.0521	0
10	53.65472	-13.8481	0
12.5	51.60403	-13.322	0
16	9.990582	43.40628	-18.5902
20	23.63472	32.25038	-16.5885
25	20.84021	38.32224	-18.8604
31.5	38.9395	20.54615	-15.9582
40	29.87631	26.21432	-17.9537
50	87.53067	-31.7878	-5.58577
63	95.04329	-42.7144	-3.80081
80	91.42214	-50.2688	0
100	63.37352	-24.7324	-5.84987
125	-14.2033	48.53578	-22.1623
160	35.08774	-10.3185	-3.1377
200	2.917646	29.64047	-14.2996
250	30.50771	-6.48155	-3.63615
315	27.91334	-4.46373	-4.27147
400	22.71023	-2.2472	-5.67896

TM = A + B*log (d) + C*(log (d))^2

Where:

TM = Transfer Mobility in dB re 1ìin/sec/lb/(ft)^1/2

d = Distance in feet

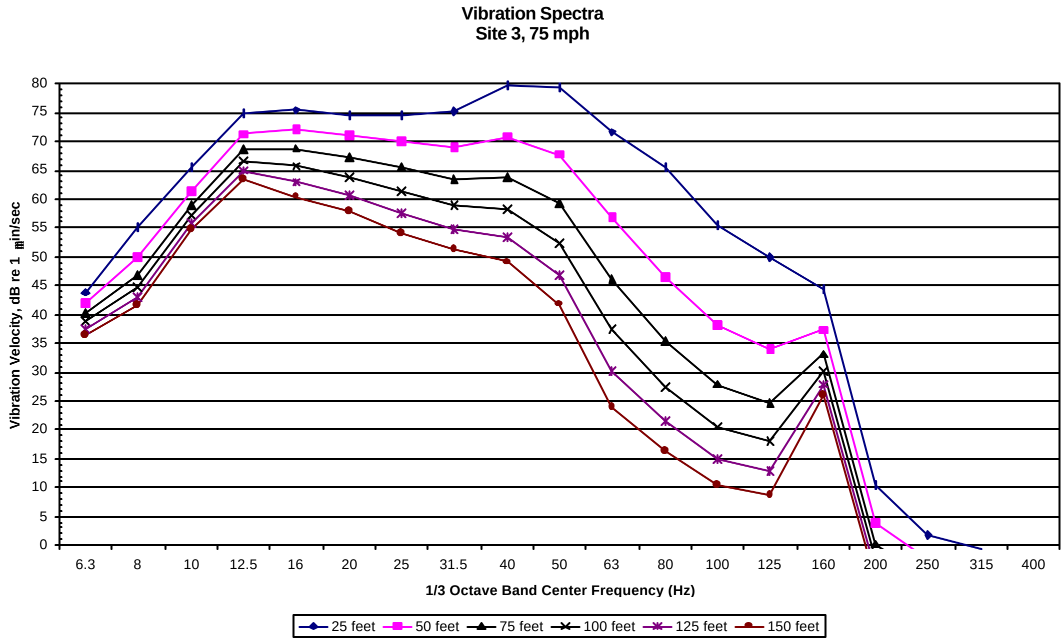

Figure C-5. Projected BART Vibration Spectra, Site 3, 75 mph

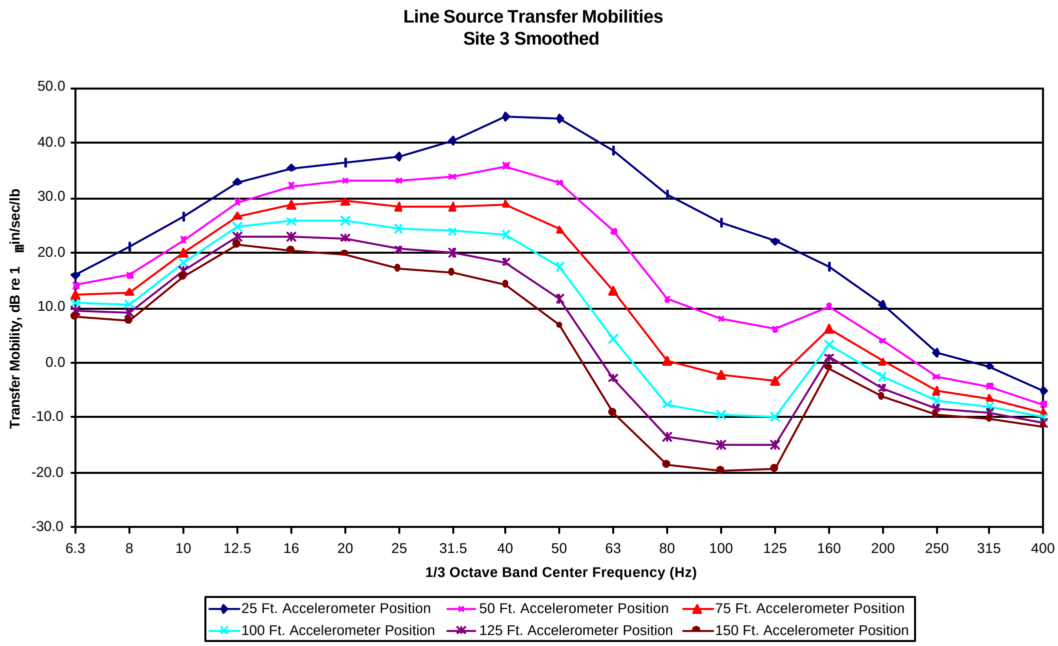

Figure C-6. Representative Transfer Mobility Functions, Site 3

Table C-3. Line Source Transfer Mobility Coefficients, Site 3

Frequency (Hz)	A	B	C
6.3	6.918808	16.7387	-7.39905
8	45.24398	-17.257	0
10	45.92896	-13.8952	0
12.5	36.97152	4.588307	-5.36601
16	9.337628	43.01268	-17.4155
20	0.352027	56.11232	-21.682
25	0.187482	60.4697	-24.2019
31.5	22.98605	40.01785	-19.7887
40	37.60802	33.72539	-20.4682
50	50.44385	23.89101	-20.2023
63	46.37822	30.21966	-25.5874
80	118.8587	-63.1613	0
100	106.4241	-57.889	0
125	96.15152	-53.0158	0
160	50.40565	-23.598	0
200	40.41468	-21.4474	0
250	21.83431	-14.3337	0
315	16.56105	-12.2506	0
400	5.367225	-6.95234	-0.36564

$$TM = A + B*\log(d) + C*(\log(d))^2$$

Where:

TM = Transfer Mobility in dB re 1ìin/sec/lb/(ft)^1/2

d = Distance in feet

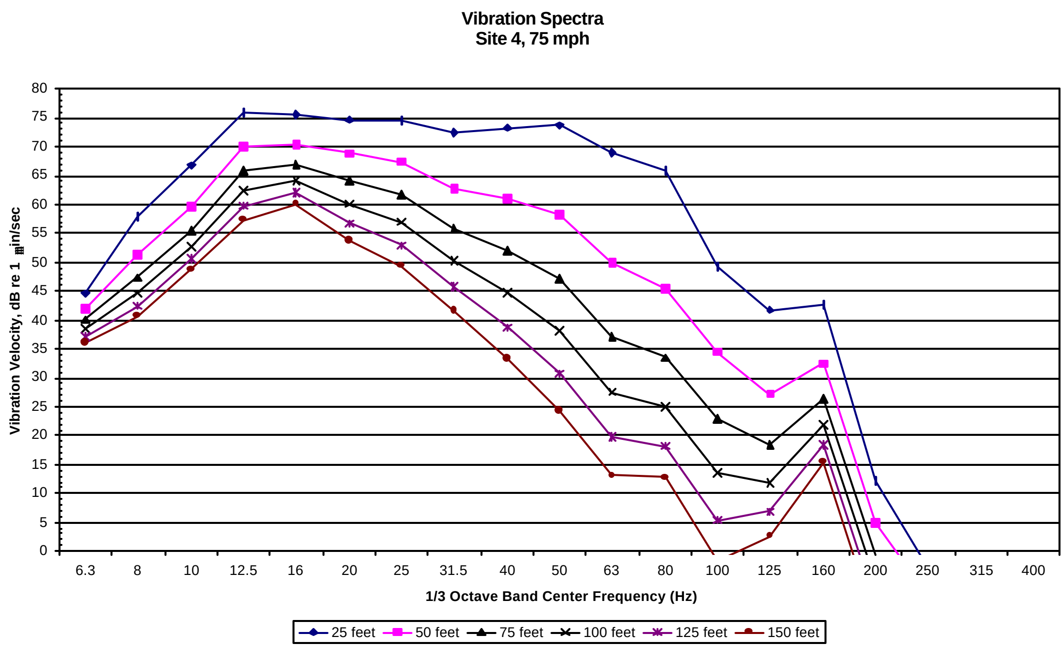

Figure C-7. Projected BART Vibration Spectra, Site 4, 75 mph

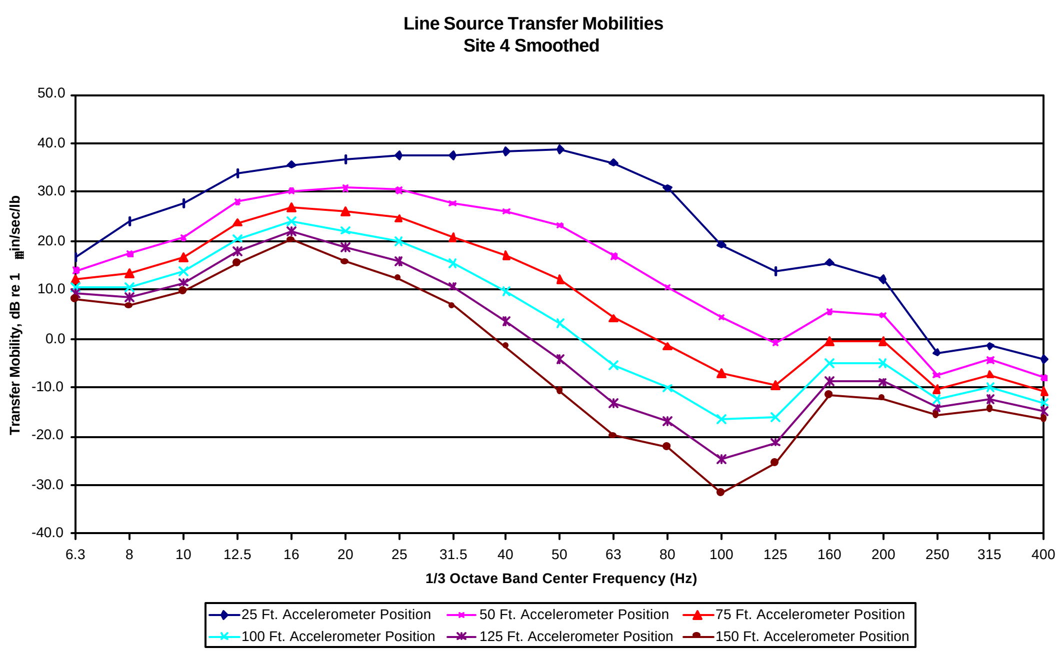

Figure C-8. Representative Transfer Mobility Functions, Site 4

Table C-4. Line Source Transfer Mobility Coefficients, Site 4

Frequency (Hz)	A	B	C
6.3	16.78197	6.848319	-4.99465
8	55.14129	-22.2622	0
10	63.46194	-27.0703	1.099193
12.5	40.23835	7.841895	-8.85553
16	50.04376	-4.09304	-4.43079
20	25.99769	29.82247	-15.8817
25	26.61934	33.45324	-18.3844
31.5	46.26689	15.09913	-15.2933
40	40.70489	30.07002	-22.7579
50	50.57765	26.86847	-25.289
63	83.91301	-10.0344	-17.3149
80	121.4471	-62.6444	-1.56458
100	6.545525	57.03375	-34.2783
125	71.62022	-35.6606	-4.09977
160	56.19041	-25.2687	-2.68824
200	9.500761	23.21093	-15.2557
250	15.30519	-10.7159	-1.59334
315	-23.2846	36.22235	-14.7742
400	-2.45262	8.33262	-6.80787

TM = A + B*log (d) + C*(log (d))^2

Where:

TM = Transfer Mobility in dB re 1ìin/sec/lb/(ft)^1/2

d = Distance in feet