LIMAR PROPERTY
31 S. MILPITAS BLVD & 345 LOS COCHES ST.
ENVIRONMENTAL NOISE & VIBRATIONASSESSMENT
MILPITAS, CALIFORNIA

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INTRODUCTION

The 31 S. Milpitas Boulevard project proposes the development of 79 single-family residential units on the properties located generally southwest of the intersection of Calaveras Boulevard and Milpitas Boulevard in Milpitas, California at 31 South Milpitas Blvd. and 345 Los Coches Street. Issues related to noise and vibration associated with this project include the compatibility of the proposed residential land uses with the noise environment at the site resulting from vehicular traffic on nearby roadways, railroad train movements on the railroad corridor to the west, and noise generated by commercial and light industrial uses in the vicinity. This assessment, provides a discussion of policies and standards applicable to the project, presents the results of noise and vibration measurements conducted at the site, and provides an evaluation of the potential significance of impacts resulting from the project. Conceptual mitigation measures are presented to reduce potentially significant noise impacts to less-than-significant levels. Persons not familiar with environmental noise and vibration analysis are referred to Appendix A (noise) and/or Appendix B (vibration) for additional discussion.

REGULATORY BACKGROUND

NOISE

The City of Milpitas has established guidelines, regulations, and policies designed to limit noise exposure at noise sensitive land uses. Considering the close proximity to an active commuter rail line and at-grade crossing, sleep disturbance criteria related have been used in this document to address maximum interior noise levels within the project that may result in significant sleep disturbance.

City of Milpitas General Plan Noise Element

The of City of Milpitas General Plan Noise Element sets forth implementing policies to guide the development of residential and commercial land uses. The following implementing policies would be applicable in the residential use of the project site:

6-I-1 Use the guidelines in Table 6-1 (Noise and Land Use Compatibility) as review criteria for development projects.

6-I-2 Require an acoustical analysis for projects located within a "conditionally acceptable" or "normally unacceptable" exterior noise exposure area. Require mitigation measures to reduce noise to acceptable levels.

6-I-3 Prohibit new construction where the exterior noise exposure is considered “clearly unacceptable” for the use proposed.

6-I-4 Where actual or projected rear yard and exterior common open space noise exposure exceeds the "normally acceptable" levels for new single-family and multifamily residential projects, use mitigation measures to reduce sound levels in those areas to acceptable levels.

6-I-5 All new residential development (single family and multifamily) and lodging facilities must have interior noise levels of 45 dBA L_{dn} or less. Mechanical ventilation will be required where use of windows for ventilation will result in higher than 45 dBA L_{dn} interior noise levels.

6-I-15 Promote installations of noise barriers along highways and the railroad corridor where substantial land uses of high sensitivity are impacted by unacceptable noise levels.

Table 6-1 in the General Plan establishes the noise land use compatibility standards for different proposed land uses. For single-family residential land use, up to 60 dBA L_{dn} is considered normally acceptable, up to 70 dBA L_{dn} is considered conditionally acceptable, and above 70 dBA L_{dn} is considered normally unacceptable.

Supplemental Sleep Disturbance Criteria

Though the City noise criteria are typically sufficient to achieve an acceptable interior noise environment with common environmental noise source, when dealing with loud intermittent noise sources, such as the sounding of train horns or engine noise near railroad tracks, the achievement of an L_{dn} of 45 dBA within homes may still result in maximum noise levels within interiors great enough to result in significant sleep disturbance. Studies have been undertaken to determine the effect of short term maximum noise levels on sleep disturbance. The conclusions of these studies typically give a probability of sleep disturbance related to the maximum noise level of the event at the sleep location and the duration of the event. A review of sleep disturbance study data shows that limiting maximum noise levels to 55 dBA within sleeping rooms will limit the probability of waking residents at the subject project when trains pass the site to less than five percent per occurrence[1]. Therefore, though this is not a City requirement, the adoption of additional interior sound level criteria limiting maximum noise levels to 55 dBA within residential living spaces at the project is recommended.

VIBRATION

The City of Milpitas has not identified quantifiable vibration limits that can be used to evaluate the compatibility of land uses with the expected vibration environment. Although there are no local standards which control the allowable vibration in a new residential development, the U.S. Department of Transportation has developed vibration impact assessment criteria for evaluating vibration impacts associated with rapid transit projects.[2] The Federal Transit Administration (FTA) has proposed vibration impact criteria, based on maximum overall levels for a single event. The criteria for groundborne vibration impact are shown in Table 1. Note that there are criteria for frequent events (more than 70 events per day), occasional (between 30 and 70 events per day) and infrequent events (less than 30 events per day).

Table 1 – Groundborne Vibration Impact Criteria

Land Use Category	**Groundborne Vibration Impact Limits**		**VdB re: 1 µinch/sec, RMS**
	Frequent Events[1]	Occasional Events[2]	Infrequent Events [3]
Category 1: Buildings where low ambient is essential for interior operations	65 VdB[4]	65 VdB[4]	65 VdB[4]
Category 2: Residences and buildings where people normally sleep	72 VdB	75 VdB	80 VdB
Category 3: Institutional land uses with primarily daytime use	75 VdB	78 VdB	83 VdB

Notes:

1. "Frequent Events" is defined as more than 70 vibration events per day. Most rapid transit projects fall into this category.
2. "Occasional Events" is defined as between 30 and 70 vibration events of the same source per day. Most commuter trunk lines have this many operations.
3. "Infrequent Events" is defined as fewer than 70 vibration events per day. This category includes most commuter rail systems.
4. This limit is based on levels that are acceptable for most moderately sensitive equipment such as optical microscopes.

[1] Kryter Karl D., The effects of Noise on Man, Second Edition, Academic Press, Inc. London, 1985, p.444-446

[2] U.S. Department of Transportation, Federal Transit Administration, Transit Noise and Vibration Impact Assessment, May 2006, FTA-VA-90-1003-06.

EXISTING NOISE ENVIRONMENT

The project site is located southwest of the intersection of Calaveras Boulevard and Milpitas Boulevard. There is a rail yard west of the project site, a light industrial/manufacturing facility south of the site, office/commercial uses east of the site and Calaveras Boulevard is elevated above the site to the north. All of these transportation and industrial facilities contribute to the existing noise environment. A noise survey was conducted at three long-term locations and one short-term location on the project site. The long-term measurements were made over a continuous 48-hour period beginning at noon on Tuesday May 15th, 2012, and ending at noon on Thursday May 17th, 2012 to quantify existing ambient noise levels in the area, and the short-term measurement was made to determine offset levels from the long-term positions. All noise measurements where conducted with Larson Davis Laboratories (LDL) Type I Model 820 Sound Level Meter fitted with a ½-inch pre-polarized condenser microphone and windscreen. The meters were calibrated with a Larson Davis Model CA250 precision acoustic calibrator prior to and following the measurement survey. The internal clocks of the long-term meters were set to less than one second of each other to ensure both identical sound level response and simultaneous operation. The noise measurement locations are shown on Figure 1.

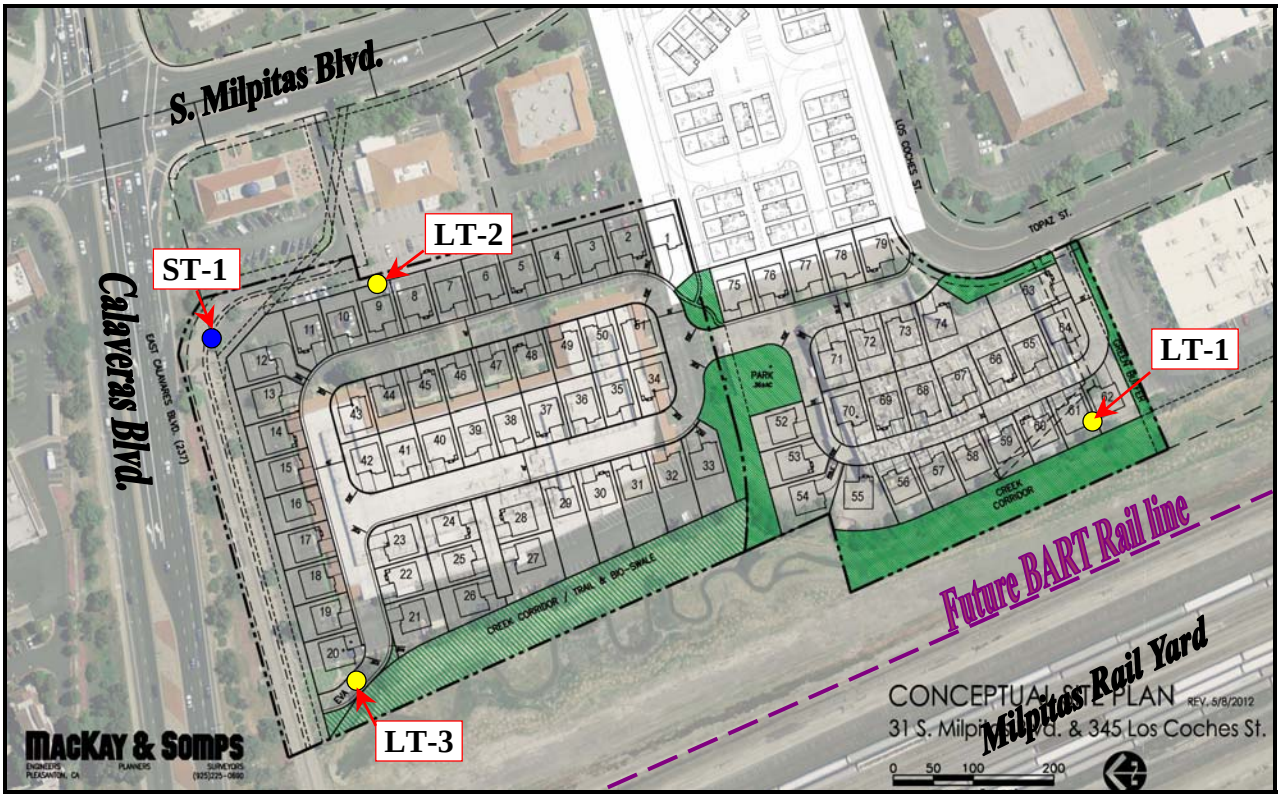
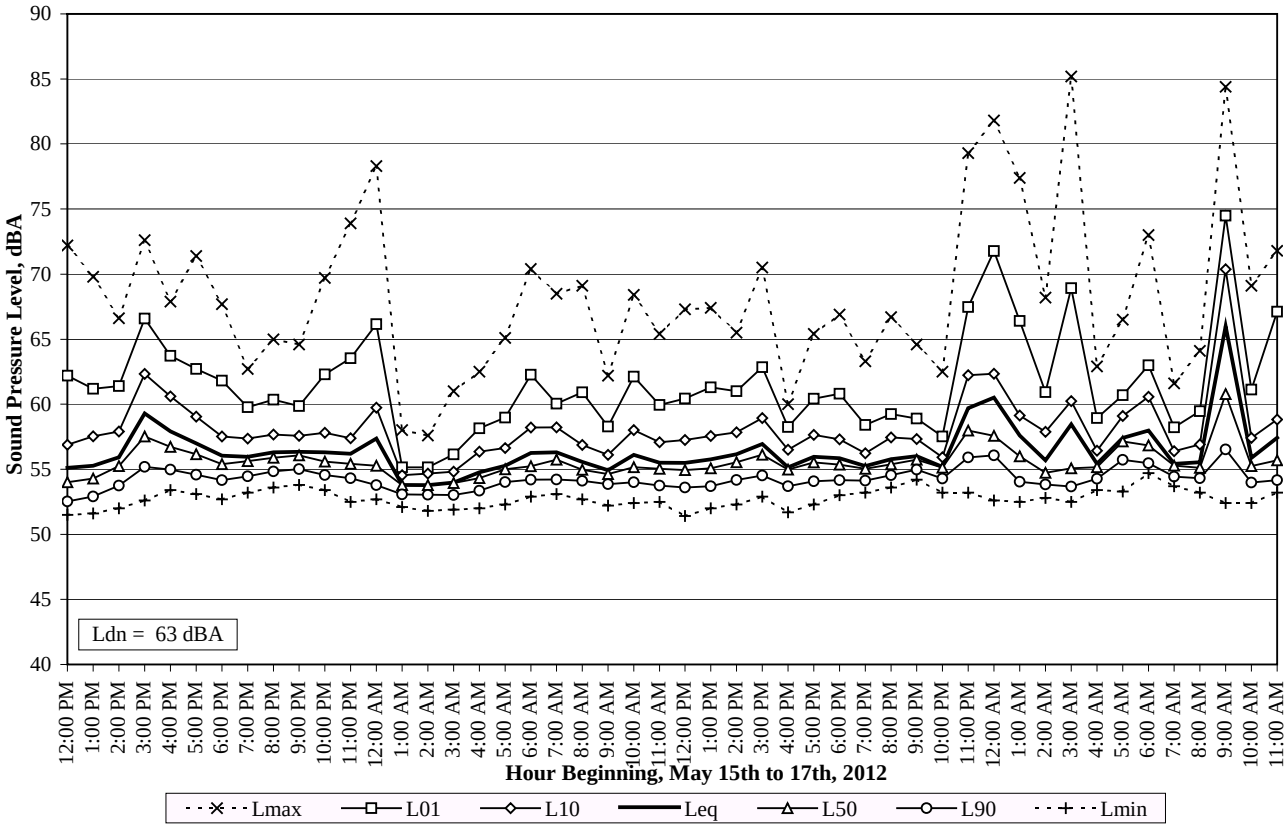


Figure 1: Site Plan and Noise Measurement Locations

Measurement Location LT-1 was located at the southwestern corner of the site in a tree on the project's property line at 150 feet east of the nearest railroad track, 300 feet from the center of the more distant rail yard, and 250 feet north of the closest identified noise producing area of the adjacent industrial building. The site was selected to represent the setback of the row of homes from to rail activities and the closest homes at the adjacent industrial facility. Potential noise sources in this area of the site included railroad operations and mechanical equipment at the industrial facility south of the site. Distant vehicular traffic on Milpitas and Calaveras Boulevards contributed to background noise levels at this location. The measured noise levels at

site LT-1, including the energy equivalent noise level (L_{eq}), maximum (L_{max}), minimum (L_{min}), and the noise levels exceeded 10, 50 and 90 percent of the time (indicated as L_{10}, L_{50} and L_{90}) are shown on Chart 1. The L_{eq} noise level is typically considered the average noise level, while the L_1 is considered the intrusive level, the L_{50} is considered the median noise level and the L_{90} is considered the background or ambient noise level. The very steady nature of the measured noise and the tight statistical distribution shown in Chart 1 reflects the effects of the steady mechanical equipment noise from the adjacent industrial use. This machinery generated a very steady noise level ranging from 51-55 dBA. The average daytime noise levels at this location ranged from 55 to 66 dBA L_{eq} and the average hourly nighttime noise levels ranged from 54 to 60 dBA L_{eq}. Elevated noise levels, from 70 to 85 dBA, also occurred at this site during both daytime, late night and early morning periods. The Day/Night Average Noise Level (L_{dn}) over the two-day measurement period at LT-1 was calculated to be 63 dBA.

Chart 1: Measured Noise Levels at LT-1



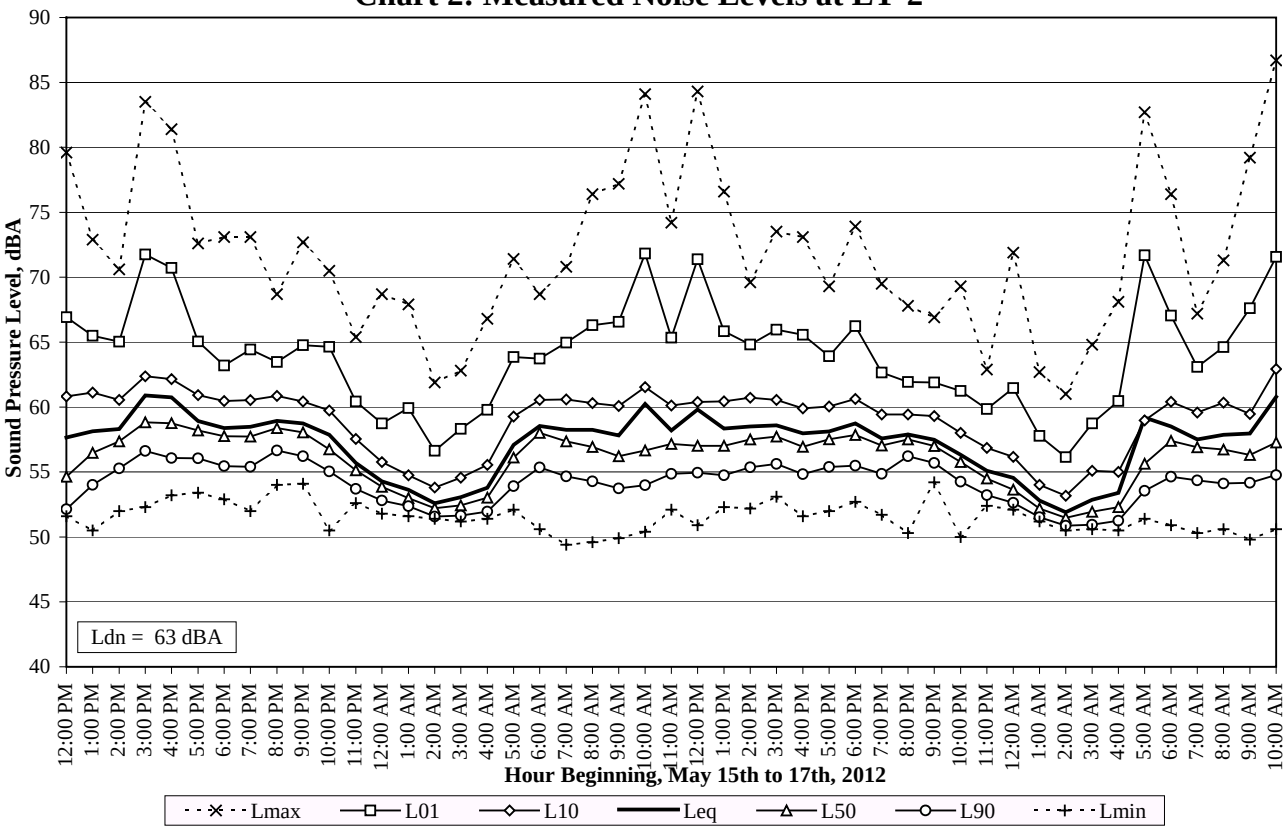
During the noise survey it was noted that delivery trucks associated with some of the other businesses in the area would sometimes park at the northern end of the adjacent lot, and that loading activities from the adjacent industrial building could also result in high noise levels. It was also noted that the closest railroad tracks to the site appeared abandoned, but that the more distant rail yard appeared to be active. Based on these observations, while elevated daytime levels may have been produced by the adjacent industrial use or rail yard activities, elevated levels in the late night and early morning hours are judged to be due to activities at the adjacent rail yard.

Illingworth & Rodkin, Inc. has measured noise levels from rail yards. A relevant survey was conducted at the Pier A Rail Yard at the Port of Los Angeles in November 2005. Noise measurements were made at distance of about 200 feet from where the engines were operating.

The activity consisted of a train engine coupling to and uncoupling from groups of railroad cars, shuttling the cars back and forth on different tracks, and re-coupling the cars to other strings of railroad cars. Noise sources included the engine, the train horn, the crunching sounds associated with the slack action of the strings of cars starting and stopping, and the sounds of the impacts of cars being coupled together. During one hour of attended noise measurements, maximum noise levels resulting from these activities typically ranged from about 65 dBA to 75 dBA at distance of about 200-300 feet from the source of the noise. Occasionally, the sound of cars crunching together when coupling ranged from 78-80 dBA. This range of maximum noise levels concurs with those measured at LT-1.

Measurement Location LT-2 was made on a light standard at a height of 12 feet above ground near the eastern edge of the site at approximately 300 feet from the center of Milpitas Boulevard in the central portion of the site. The site was selected to represent the setback of the first row of homes from S. Milpitas Blvd. and the closest homes to the adjacent commercial uses. Vehicular traffic on Milpitas Boulevard, distant traffic on Calaveras Boulevard, vehicles circulating in the parking lots, and occasional aircraft overflights all contributed to measured noise levels. The measured noise levels at site LT-2, including the energy equivalent noise level (L_{eq}), maximum (L_{max}), minimum (L_{min}), and the noise levels exceeded 10, 50 and 90 percent of the time (indicated as L_{10}, L_{50} and L_{90}) are shown on Chart 2.

Chart 2: Measured Noise Levels at LT-2

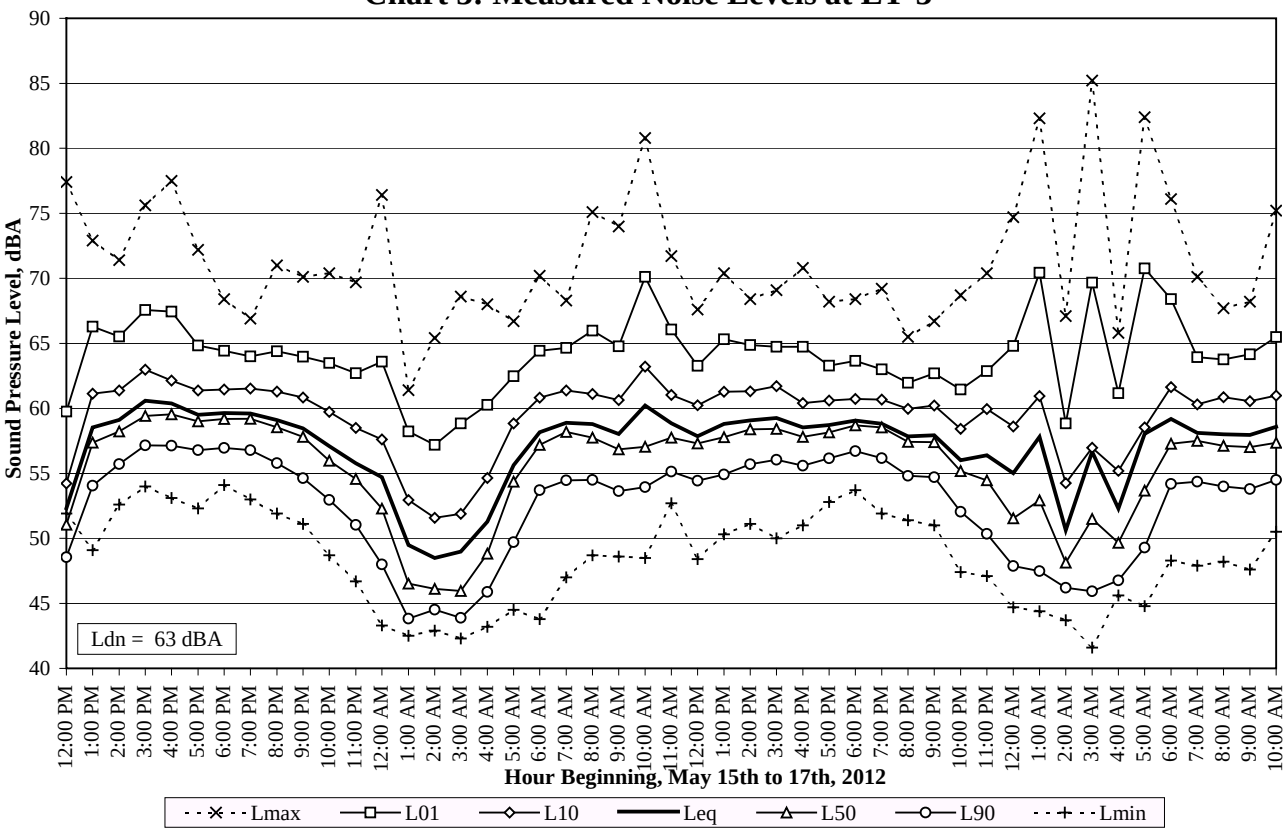


A review of Chart 2 indicates that the noise levels at site LT-2 followed a somewhat subdued diurnal pattern characteristic of traffic noise, where the average daytime noise levels ranging from 58 to 61 dBA L_{eq} and the average hourly nighttime noise levels ranging from 52 to 59 dBA L_{eq}. The Day/Night Average Noise Level (L_{dn}) over the two-day measurement period at LT-1 was calculated to be 63 dBA. Due to the somewhat subdued diurnal pattern, where nighttime levels did not drop to far below daytime levels, the area noise environment appears to be

influenced by mechanical equipment noise from the adjacent commercial and industrial uses. Elevated noise levels, from 76 to 86 dBA, also occurred at this site during both daytime, and early morning periods. These elevated levels are judged to be due to noise produced by vehicles and trucks in the parking lot adjacent to the monitoring position.

Measurement Location LT-3 was located near the northwestern corner of the site in a tree on the project property line at a position 250 feet south of the center of Calaveras Boulevard, 250 feet east of the nearest railroad track, and 350 feet east from the center of the more distant rail yard. The site was selected to represent the setback of the first row of homes from Calaveras Blvd. and the closest homes in the northwestern corner of the site to rail activities. Calaveras Blvd. is above site grade opposite the measurement location, and actually decreases in height above grade as it proceeds from west to east on a fill section to accommodate the over crossing at the railroad tracks. The measured noise levels at site LT-3, including the energy equivalent noise level (L_{eq}), maximum (L_{max}), minimum (L_{min}), and the noise levels exceeded 10, 50 and 90 percent of the time (indicated as L_{10}, L_{50} and L_{90}) are shown on Chart 3.

Chart 3: Measured Noise Levels at LT-3



A review of Chart 3 indicates that the noise levels at site LT-3 followed a diurnal pattern characteristic of traffic noise, with the average daytime noise levels ranging from 52 to 61 dBA L_{eq} and the average hourly nighttime noise levels ranging from 49 to 59 dBA L_{eq}. The Day/Night Average Noise Level (L_{dn}) over the two-day measurement period at LT-3 was calculated to be 63 dBA.

Vehicular traffic on Calaveras Blvd was the primary source of noise contributing to measured levels. Calaveras Blvd at this location functions as a portion of State Route 237 and carries a high volume of automobile and truck traffic. A simultaneous short-term measurement was also

conducted at the northeasterly corner of the site where there is the differential in grade between the project site and Calaveras Blvd is the lowest (see location ST-1, Figure 1). The purpose for the measurement was to determine the acoustical shielding provided by the grade differential. The measurements indicated that average and maximum noise levels from vehicle traffic are attenuated about 3 dBA by the grade differential at the long term versus the short-term measurement location. Noise levels along the northern property line are, therefore, expected to range from about 66 dBA L_{dn} at the northeastern corner of the site to 63 dBA at the northwestern corner of the site.

Elevated noise levels, from 70 to 85 dBA, also occurred at this site during both daytime, late night and early morning periods. A comparison of the timing of these elevated noise levels to those measured at position LT-1 (also adjacent to the rail lines) indicates that these heightened noise levels were not a result of passing trains, but rather more fixed distant sources and/or separate localized events.

FUTURE CONDITIONS

NOISE ENVIRONMENT

Roadway Traffic

The future exterior noise environment across the project site would continue to result primarily from traffic along Calaveras and South Milpitas Blvd. Based on a review of existing versus future traffic volumes on these roadways as allowable under the build-out of the City's General Plan, future noise levels along Calaveras Blvd are expected to increase by 1 dBA over current levels by 2030, and future noise levels along S. Milpitas Blvd are expected to increase by 2 dBA over current levels by 2030. Therefore, based on future traffic volumes, an Ldn of 65 dBA would characterize exterior noise levels on the eastern edge of the project site, and an Ldn of between 64 to 67 dBA would characterize exterior noise levels on the northern edge of the project site.

Railroad Traffic

Under future conditions the rail track nearest to the project site, the centerline of which would be located between 150 to 250 feet from the western property line, will carry BART rail traffic per the planned Silicon Valley BART extension. The Noise section of the Final EIS for this project contains projects for future noise levels produced by BART train passbys[3], such that a single 75-foot-long train operating at a maximum speed of 80 mph would generate noise of 84 dBA at a distance of 50 feet from track centerline. The noise section gives future track usage at ten-car BART trains running from 4:00 a.m. to 1:30 a.m. on 6-minute headways during peak service (6:00 a.m. to 7:30 p.m.), and 20-minute headways during off-peak service (4:00 a.m. to 6:00 a.m. and 7:30 p.m. to 1:30 a.m.) at an average speed of 67 mph. A review of the Noise section of the Final EIS indicates that this usage would result in a Day/Night Average Noise Level (L_{dn}) at 100 feet from the track centerline of up to 65 dBA. Based on these, expected, future levels, maximum (L_{max}) noise levels at the facades of homes on the western edge of the site would reach 77 to 79 dBA during to BART train passbys, L_{dn} noise levels at the western property line of the

[3] Silicon Valley Rapid Transit Corridor Final EIS, Environmental Consequences 5.10-5 Noise and Vibration: http://www.vta.org/bart/images/Environmental/final_eis/05.10_NoiseVibration_EC.pdf

project due to BART trains would be between 61 and 63 dBA, and with the addition of future Calaveras Blvd. traffic, L_{dn} noise levels at the northwestern corner of the site would be 65 dBA.

GROUNDBORNE VIBRATION ENVIRONMENT

The vibration section of the Final EIS for this project contains projections of future groundborne vibration levels at various distances to the rail tracks under various ground conditions. Ground vibration levels reported at the Terrace Gardens Senior Housing, immediately north Calaveras Blvd, which would have similar ground conditions to the site are reported at a maximum third octave band level of 73 VdB at 143 feet from the centerline of the near tracks. A review of the project site plan indicates that the facades of homes on the western edge of the site will be located between 170 to 260 feet from the centerline of the near tracks. Using these distances and geometric and material vibration damping factors for typical ground conditions, the maximum third octave band ground borne vibration levels due to passing high speed BART trains at homes on the project site are expected to be between 68 and 71 VdB.

NOISE ASSESSMENT

EXTERIOR NOISE

Based on the existing and future environmental noise levels presented above, residential lots on the northern edge of the site are expected to be exposed to future L_{dn} levels of between 65 and 67 dBA, lots at the eastern edge of the site are expected to be exposed to L_{dn} levels of 65 dBA, lots at the southern edge of the site along Topaz Street, away from the rail line, are expected to be exposed to L_{dn} levels of between 58 and 60 dBA, and lots at the western edge of the site would be exposed to L_{dn} levels of between 65 and 66 dBA with the Silicon Valley BART extension in place. Noise levels in the interior portions of the site are expected to lower than those at the site perimeter.

Based on this finding, the noise environment at perimeter lots along Topaz Street, away from the rail line, and those in the project interior would be exposed to noise levels considered “normally acceptable” for single-family residential development by the City’s General Plan noise land use compatibility standards. However, lots on the eastern, northern, and western site perimeter would, be considered “conditionally acceptable” by these standards. Under these conditions single-family homes on the western, northern and eastern site edges would require mitigation to be considered normally acceptable for residential use under City Guidelines. This is a potentially significant impact, which can be mitigated with the incorporation of Mitigation Measure 1, below.

Mitigation Measure:

1. **Noise Barriers**: Rear yard noise barrier fences, with heights of six (6) or eight (8) feet above finished grade as shown in Figure 2. To be effective as a noise barrier, these noise-barrier fences should be built without cracks or gaps in the face or large or continuous gaps at the base and have a minimum surface weight of 3.0 lbs. per sq. ft. For a wood wall to meet these requirements we typically recommend that a homogenous sheet material, such as 3/4" plywood, be used as a backing for typical 1" thick (nominal) wood fence slats. Using the plywood ensures the continued effectiveness of the barrier with age, since wood slats alone have a tendency to warp and separate with age allowing gaps to form and the barrier effect of the wall to diminish.

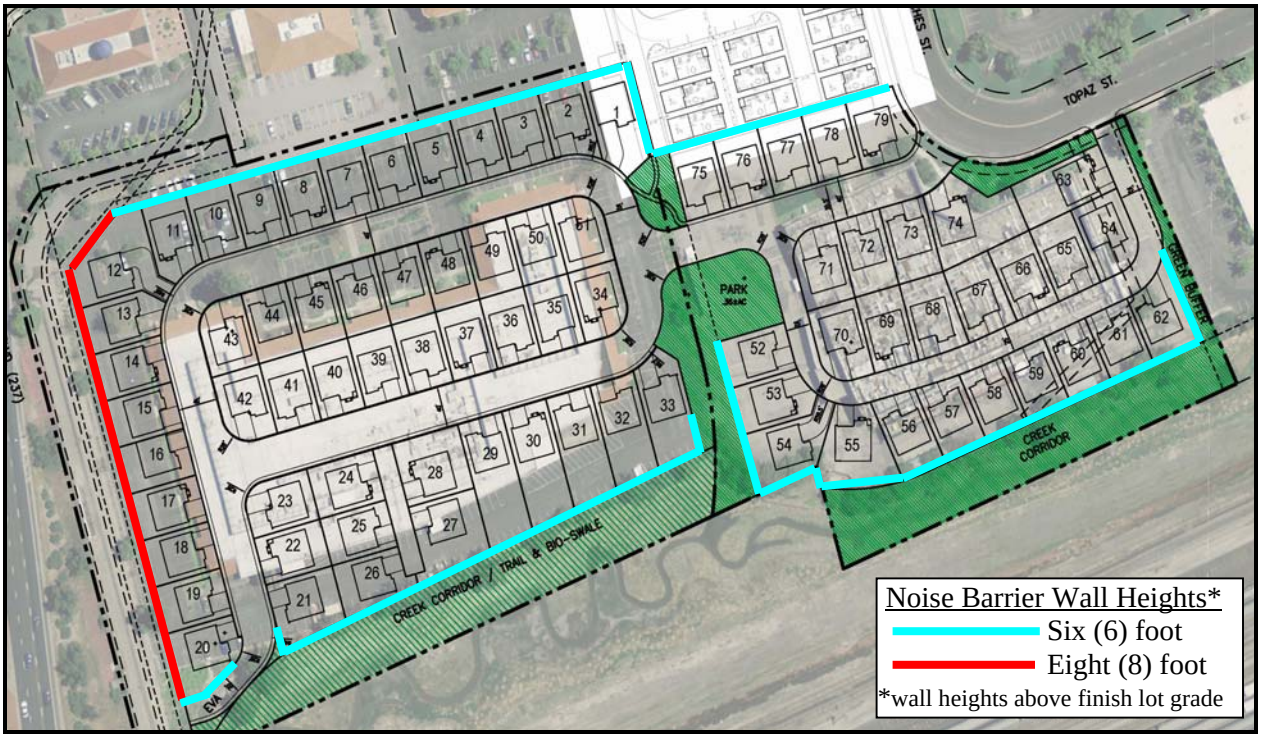


Figure 2: Site Plan, Noise Barrier Locations and Heights

INTERIOR NOISE

Typical wood frame construction techniques with standard thermal insulating glass in closed windows will reduce traffic noise levels by between 20 to 25 dBA. When windows open, the traffic noise attenuation from exterior to interior is reduced to between 12 to 15 dBA. Based on this average exterior to interior noise attenuation, interior L_{dn} levels in all residences, with the exception of those at the eastern, western and northern perimeter of the site, will be below the City's 45 dBA L_{dn} interior noise standard when standard thermal insulating windows are closed for the purpose of noise control. Residences at the eastern, western and northern perimeter of the site may be exposed to an interior L_{dn} level of 45 dBA with closed standard thermal insulating windows and thus will require the use of sound rated window assemblies. Noise levels within all perimeter residences would exceed an L_{dn} of 45 dBA with open windows.

Using these average exterior to interior noise attenuation values, maximum noise levels due to BART train passbys at homes on the western edge of the site would be between 52 to 59 dBA with closed standard thermal insulating windows and between 62 to 69 dBA when windows are open. Considering this, interior L_{max} levels in the residences at the western site edge may exceed the recommended 55 dBA L_{max} standard with closed standard thermal insulating windows and thus will require the use of sound rated window assemblies. This is a potentially significant impact, which can be mitigated with the incorporation of Mitigation Measures 2 and 3, below.

Mitigation Measures:

2. **Sound Rated Windows:** Homes on lots on the eastern, western and northern edges of the site will require sound rated windows to meet average (45 dBA Ldn) interior noise standards, and homes on the western perimeter will require sound rated windows to meet maximum (55 dBA L_{max}) interior noise standards. The needed Sound Transmission Class (STC) ratings of

the windows of theses homes are expected to range from 30 to 32, with second floor windows facing or perpendicular to the rail line likely requiring somewhat higher sound ratings of between 33 to 36. However, these rating cannot be defined at this stage in the project design. When building plans and elevations are available for these lots, an acoustical consultant should be retained to determine the needed window STC ratings necessary to achieve the 45 dBA L_{dn} and 55 dBA L_{max} interior noise limits.

3. **Mechanical Ventilation:** All residences on lots at the site perimeter of the will require mechanical ventilation to allow the windows to remain closed at the residents' option as the interior noise standards would not be met with open windows. Typically such a system must meet the following airflow provisions:

   "If interior noise levels are met by requiring that windows remain unopenable or closed, the design of the design for the structure must also specify a ventilation system to provide a habitable interior environment. The ventilation system must not compromise the dwelling unit or guest room noise reduction."

   In our experience a standard central air conditioning system or a central heating system equipped with a 'summer switch' which allows the fan to circulate air without furnace operation in each residence requiring mechanical ventilation will provide a habitable interior environment and meet the airflow provisions referenced above.

VIBRATION

The project site adjoins the Milpitas railroad yard and the future Silicon Valley BART corridor. The nearest track at the railroad yard would be located approximately 300 feet from the nearest (western) building façade and would generate an insignificant degree ambient groundborne vibration. Facades of homes on lots at the western edge of the site will be located between 170 to 260 feet from the centerline of the future BART line. Using data contained in the vibration section of the Silicon Valley Rapid Transit Corridor Final EIS along with observed and expected site distance, geometric, and material vibration damping factors for typical ground conditions, ground borne vibration levels due to passing high speed BART trains at home facades on the western edge of the project site were found to be between 68 and 71 VdB. Such vibration levels would not exceed the FTA impact criteria for frequent events and therefore no mitigation for the project is warranted. This is a less-than-significant impact and will not require mitigation.

Mitigation Measures:

None required.

APPENDIX A:
FUNDAMENTALS OF ENVIRONMENTAL NOISE

Noise is defined as unwanted sound. Airborne sound is a rapid fluctuation of air pressure above and below atmospheric pressure. Sound levels are usually measured and expressed in decibels (dB) with 0 dB corresponding roughly to the threshold of hearing. Decibels and other technical terms are defined in Table A1.

Table A1: Definitions of Acoustical Terms Used in this Report

Term	Definitions
Decibel, dB	A unit describing, the amplitude of sound, equal to 20 times the logarithm to the base 10 of the ratio of the pressure of the sound measured to the reference pressure. The reference pressure for air is 20.
Sound Pressure Level	Sound pressure is the sound force per unit area, usually expressed in micro Pascals (or 20 micro Newtons per square meter), where 1 Pascal is the pressure resulting from a force of 1 Newton exerted over an area of 1 square meter. The sound pressure level is expressed in decibels as 20 times the logarithm to the base 10 of the ratio between the pressures exerted by the sound to a reference sound pressure (e.g., 20 micro Pascals). Sound pressure level is the quantity that is directly measured by a sound level meter.
Frequency, Hz	The number of complete pressure fluctuations per second above and below atmospheric pressure. Normal human hearing is between 20 Hz and 20,000 Hz. Infrasonic sound are below 20 Hz and Ultrasonic sounds are above 20,000 Hz.
A-Weighted Sound Level, dBA	The sound pressure level in decibels as measured on a sound level meter using the A-weighting filter network. The A-weighting filter de-emphasizes the very low and very high frequency components of the sound in a manner similar to the frequency response of the human ear and correlates well with subjective reactions to noise.
Equivalent Noise Level, Leq	The average A-weighted noise level during the measurement period.
L_{max}, L_{min}	The maximum and minimum A-weighted noise level during the measurement period.
L_{01}, L_{05}, L_{10}, L_{90}	The A-weighted noise levels that are exceeded 1%, 5%, 10%, and 90% of the time during the measurement period.
Day/Night Noise Level, L_{dn}	The average A-weighted noise level during a 24-hour day, obtained after addition of 10 decibels to levels measured in the night between 10:00 pm and 7:00 am.
Community Noise Equivalent Level, CNEL	The average A-weighted noise level during a 24-hour day, obtained after addition of 5 decibels in the evening from 7:00 pm to 10:00 pm and after addition of 10 decibels to sound levels measured in the night between 10:00 pm and 7:00 am.
Ambient Noise Level	The composite of noise from all sources near and far. The normal or existing level of environmental noise at a given location.
Intrusive	That noise which intrudes over and above the existing ambient noise at a given location. The relative intrusiveness of a sound depends upon its amplitude, duration, frequency, and time of occurrence and tonal or informational content as well as the prevailing ambient noise level.

Most of the sounds we hear in the environment do not consist of a single frequency, but rather a broad band of frequencies, with each frequency differing in sound level. The intensities of each frequency add together to generate a sound. The method commonly used to quantify environmental sounds consists of evaluating all of the frequencies of a sound in accordance with

a weighting that reflects the facts that human hearing is less sensitive at low frequencies and extreme high frequencies than in the frequency mid-range. This is called "A" weighting, and the decibel level so measured is called the A-weighted sound level (dBA). In practice, the level of a sound source is conveniently measured using a sound level meter that includes an electrical filter corresponding to the A-weighting curve. Typical A-weighted levels measured in the environment and in industry are shown in Table A2 for different types of noise.

Table A2: Typical Noise Levels in the Environment

Common Outdoor Noise Source	Noise Level (dBA)	Common Indoor Noise Source
	120 dBA	
Jet fly-over at 300 meters		Rock concert
	110 dBA	
Pile driver at 20 meters	100 dBA	
		Night club with live music
	90 dBA	
Large truck pass by at 15 meters		
	80 dBA	Noisy restaurant
		Garbage disposal at 1 meter
Gas lawn mower at 30 meters	70 dBA	Vacuum cleaner at 3 meters
Commercial/Urban area daytime		Normal speech at 1 meter
Suburban expressway at 90 meters	60 dBA	
Suburban daytime		Active office environment
	50 dBA	
Urban area nighttime		Quiet office environment
	40 dBA	
Suburban nighttime		
Quiet rural areas	30 dBA	Library
		Quiet bedroom at night
Wilderness area	20 dBA	
Most quiet remote areas	10 dBA	Quiet recording studio
Threshold of human hearing	0 dBA	Threshold of human hearing

Although the A-weighted noise level may adequately indicate the level of environmental noise at any instant in time, community noise levels vary continuously. Most environmental noise

includes a conglomeration of noise from distant sources, which create a relatively steady background noise in which no particular source is identifiable. To describe the time-varying character of environmental noise, the statistical noise descriptors, L_{01}, L_{10}, L_{50}, and L_{90}, are commonly used. They are the A-weighted noise levels equaled or exceeded during 1%, 10%, 50%, and 90% of a stated time period. A single number descriptor called the L_{eq} is also widely used. The L_{eq} is the average A-weighted noise level during a stated period of time.

In determining the daily level of environmental noise, it is important to account for the difference in response of people to daytime and nighttime noises. During the nighttime, exterior background noises are generally lower than the daytime levels. However, most household noise also decreases at night and exterior noise becomes very noticeable. Further, most people sleep at night and are very sensitive to noise intrusion. To account for human sensitivity to nighttime noise levels, a descriptor, L_{dn} (average day/night sound level), was developed. The L_{dn} divides the 24-hour day into the daytime of 7:00 AM to 10:00 PM and the nighttime of 10:00 PM to 7:00 AM. The nighttime noise level is weighted 10 dB higher than the daytime noise level. .

Effects of Noise

Sleep and Speech Interference: The thresholds for speech interference indoors are about 45 dBA if the noise is steady and above 55 dBA if the noise is fluctuating. Outdoors the thresholds are about 15 dBA higher. Steady noise of sufficient intensity; above 35 dBA, and fluctuating noise levels above about 45 dBA have been shown to affect sleep. Interior residential standards for multi-family dwellings are set by the State of California at 45 dBA L_{dn}. Typically, the highest steady traffic noise level during the daytime is about equal to the L_{dn} and nighttime levels are 10 dBA lower. The standard is designed for sleep and speech protection and most jurisdictions apply the same criterion for all residential uses. Typical structural attenuation is 12-17 dBA with open windows. With closed windows in good condition, the noise attenuation factor is around 20 dBA for an older structure and 25 dBA for a newer dwelling. Sleep and speech interference is therefore possible when exterior noise levels are about 57-62 dBA L_{dn} with open windows and 65-70 dBA L_{dn} if the windows are closed. Levels of 55-60 dBA are common along collector streets and secondary arterials, while 65-70 dBA is a typical value for a primary/major arterial. Levels of 75-80 dBA are normal noise levels at the first row of development outside a freeway right-of-way. In order to achieve an acceptable interior noise environment, bedrooms facing secondary roadways need to be able to have their windows closed, those facing major roadways and freeways typically need special glass windows.

Annoyance: Attitude surveys are used for measuring the annoyance felt in a community for noises intruding into homes or affecting outdoor activity areas. In these surveys, it was determined that the causes for annoyance include interference with speech, radio and television, house vibrations, and interference with sleep and rest. The L_{dn} as a measure of noise has been found to provide a valid correlation of noise level and the percentage of people annoyed. People have been asked to judge the annoyance caused by aircraft noise and ground transportation noise. There continues to be disagreement about the relative annoyance of these different sources. When measuring the percentage of the population highly annoyed, the threshold for ground vehicle noise is about 55 dBA L_{dn}. At an L_{dn} of about 60 dBA, approximately 2 percent of the population is highly annoyed. When the L_{dn} increases to 70 dBA, the percentage of the population highly annoyed increases to about 12 percent of the population. There is, therefore, an increase of about 1 percent per dBA between an L_{dn} of 60-70 dBA. Between an L_{dn} of 70-80 dBA, each decibel increase increases by about 2 percent the percentage of the population highly annoyed.

APPENDIX B:
FUNDAMENTALS OF GROUNDBORNE VIBRATION

Railroad operations are potential sources of substantial ground vibration depending on distance, the type and the speed of trains, and the type of railroad track. People's response to ground vibration has been correlated best with the velocity of the ground. The velocity of the ground is expressed on the decibel scale. The reference velocity is 1×10^{-6} in./sec. RMS, which equals 0 VdB, and 1 in./sec. equals 120 VdB. Although not a universally accepted notation, the abbreviation "VdB" is used in this document for vibration decibels to reduce the potential for confusion with sound decibels.

Typical background vibration levels in residential areas are usually 50 VdB or lower, well below the threshold of perception for most humans. Perceptible vibration levels inside residences are attributed to the operation of heating and air conditioning systems, door slams and foot traffic. Construction activities, train operations, and street traffic are some of the most common external sources of vibration that can be perceptible inside residences. Table B1 illustrates some common sources of vibration and the association to human perception or the potential for structural damage.

One of the problems with developing suitable criteria for groundborne vibration is the limited research into human response to vibration and more importantly human annoyance inside buildings. However, experience with rapid transit systems over the last few decades has developed rational vibration limits that can be used to evaluate human annoyance to groundborne vibration. These criteria are primarily based on experience with passenger train operations, such as rapid transit and commuter rail systems. The main difference between passenger and freight operations is the time duration of individual events; a passenger train lasts few seconds whereas a long freight train may last several minutes, depending on speed and length. Although these criteria are based on shorter duration events reflected by passenger trains, they are also used in this assessment to evaluate the potential of vibration annoyance on the site due to large freight trains.

Table B1 – Typical Levels of Groundborne Vibration

Human/Structural Response	Velocity Level, VdB (re 1µinch/sec, RMS)	Typical Events (50 –foot setback)
Threshold, minor cosmetic damage	100	Blasting, pile driving, vibratory compaction equipment
		Heavy tracked vehicles (Bulldozers, cranes, drill rigs)
Difficulty with tasks such as reading a video or computer screen	90	
		Commuter rail, upper range
Residential annoyance, infrequent events	80	Rapid transit, upper range
Residential annoyance, frequent events		Commuter rail, typical Bus or truck over bump or on rough roads
	70	Rapid transit, typical
Approximate human threshold of perception to vibration		Buses, trucks and heavy street traffic
	60	
		Background vibration in residential settings in the absence of activity
Lower limit for equipment ultra-sensitive to vibration	50	

Source: Illingworth & Rodkin, Inc. and U.S. Department of Transportation, Federal Transit Administration, Transit Noise and Vibration Impact Assessment, May 2006, FTA-VA-90-1003-06