NOISE AND VIBRATION ASSESSMENT GUIDELINES

Adopted November 2005

Amended July 2010

Amended [DATE]

Proposed Draft, July 2025

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FIGURES

1. FUNDAMENTALS OF SOUND

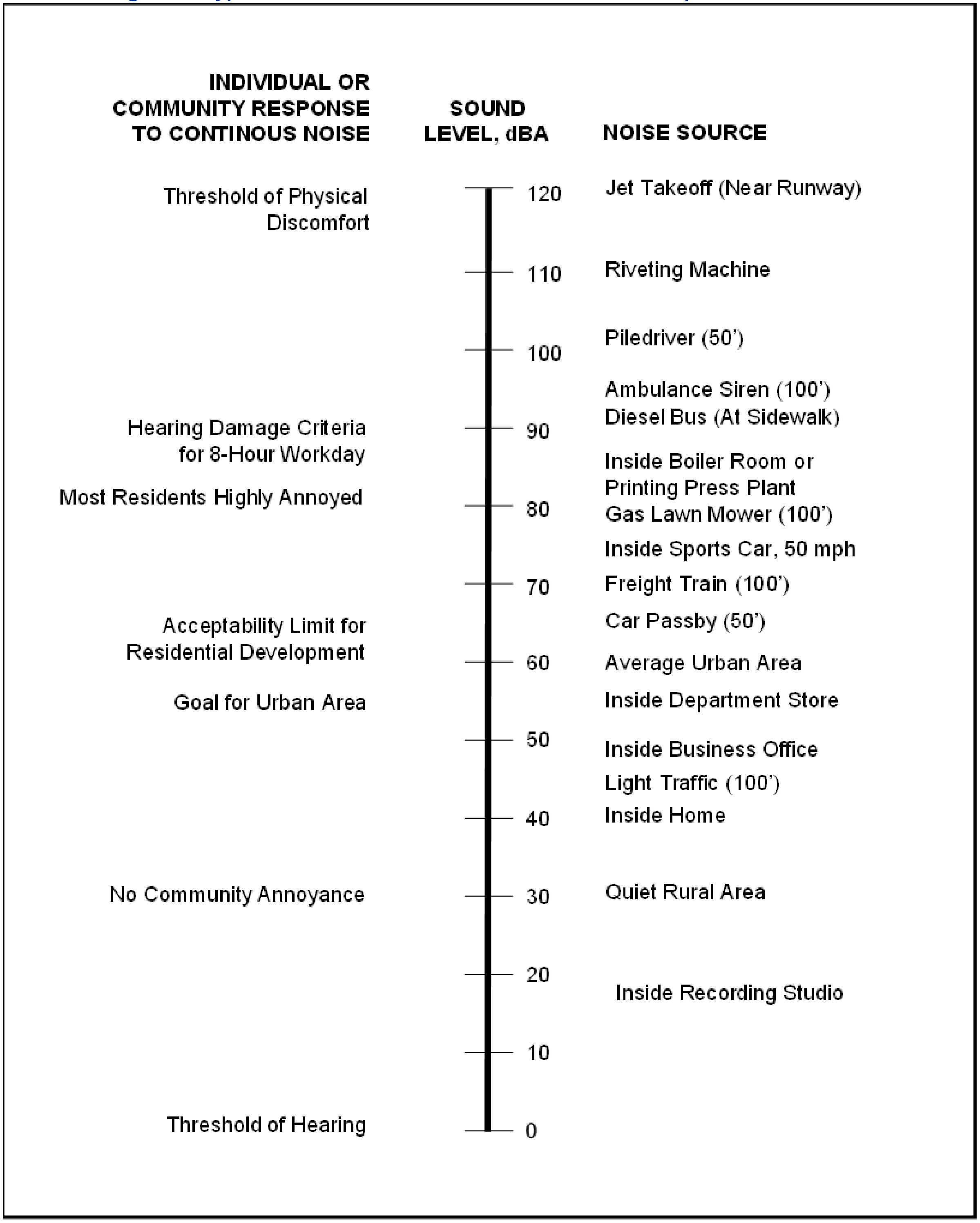
Physically, sound magnitude is measured and quantified in terms of the *decibel* (dB), which is a unit on a logarithmic scale based on the ratio of the measured sound pressure to the reference sound pressure of 20 micropascal (20 μPa = 20 x 10-6 N/m2). Because the dB system is on a logarithmic scale, doubling or halving the number of sources of equal sound (a 2-fold change in acoustic energy) changes the receptor sound by only 3 dB, which is a barely perceptible change in sound loudness for humans. On the other hand, a doubling or halving the sound loudness at the receiver results from a 10 dB change, which also represents a 10-fold change in the acoustic energy.

In addition, the human hearing system exhibits a slow time response and is not equally sensitive to the same sound pressure level at low, middle, and high acoustic frequencies. Because of this variability, a frequency-dependent adjustment called "A-weighting" has been devised so that sound may be measured in a manner similar to the way the human hearing system responds. The *A-weighted sound level*[1] is abbreviated "dBA". Figure 1 gives typical *A-weighted sound levels* for various noise sources and the typical reactions to these levels. All sound levels referred to in this document are *A-weighted*, slow response, sound pressure levels.

The two acoustical metrics most frequently used to provide a single number sound level for time-varying sounds over a given time period are the energy equivalent or energy average sound level (L_{eq}) and the "slow response" maximum sound level (L_{max}). The long-term *A-weighted* energy average sound level, called the 24-hour equivalent sound level, L_{eq}(24h), is the logarithmic average of the individual 24-hourly equivalent sound levels, L_{eq}(hi). Since it has been found that noise is more disturbing in the evening and nighttime when the *ambient noise* is generally quieter, modifications to the 24-hour L_{eq} have been adopted. The Day-Night sound level (DNL or L_{dn}) is a 24-hour energy average noise level based on the daytime and nighttime hourly average L_{eq}(h) noise levels, with a 10 dB penalty added to each hourly nighttime average sound level. Another long-term noise descriptor is the *Community Noise Equivalent Level* (CNEL or L_{den}). The *CNEL* is a 24-hour average noise level based on the daytime, evening and nighttime hourly average noise levels, with a 5 dB penalty added to each of the three evening hourly average noise levels and a 10 dB penalty added to each of the nine hourly nighttime average sound levels. The *CNEL* is used primarily in the State of California.

[1] Terms that appear in this document in italicized font with a subtle dashed green underline, such as *this example*, are defined in Appendix H.

Figure 1. Typical Sound Levels of Noise Sources and Expected Reactions



2. CONSTRUCTION AND NOISE

A distinct difference between the construction industry and other industries is that construction is, in the vast majority of cases, a temporary activity. There are very few construction projects that last several years. Even very large buildings and roads are under construction in a particular area for only a reasonably short time period, seldom more than two years. As the construction project progresses, the noise level changes as the different phases of construction are undertaken. Often a construction contractor can avoid most community complaints by notifying the potentially affected residents and other *noise sensitive uses* regarding the purpose of the project and the expected completion schedule.

Thus, rather than being an operational issue with potentially ongoing noise impacts to address, construction noise is a temporary site-specific issue. As such, there are many factors that contribute to the impacts of construction noise, including the location of *noise sensitive uses*, the type or phase of construction, the combination of equipment used, the site layout, and the construction methods employed. The noise created by construction equipment will vary greatly during a project, depending on such factors as the type of equipment, the specific equipment models, the operation being performed, the care employed by equipment operators and the condition of the equipment being used.

3. NOISE FROM CONSTRUCTION EQUIPMENT AND ACTIVITIES

The equivalent sound level (L_{eq}) as it relates to construction activity depends on several factors including machine power, the manner of operation and the amount of time the equipment is operated over a given time period. The following provides information on typical levels generated by various construction equipment and provides guidance on determining the noise from construction activities.

The most dominant source of noise for the majority of construction equipment is the engine exhaust, which is usually a diesel engine. However, for some construction work, such as impact pile driving or pavement breaking, the noise produced by the work process is the dominant source. Similar construction activities can create different noise impacts, depending on the location of the construction site, the terrain and other intervening features, and the type of receptor populations in the vicinity of the construction site.

For most construction activities, construction equipment is either stationary or mobile. Stationary equipment operates in one small area for one or more days at a time, with either a steady power cycle operation (e.g., pumps, generators, compressors, etc.) or a periodic impulsive operation (e.g., pile drivers, pavement breakers, etc.). Mobile equipment is frequently moved around a much larger area of the construction site with power applied in a rapidly changing, non-steady fashion (e.g., bulldozers, loaders, etc.), or moved to and from the construction site (e.g., haul trucks, material trucks, etc.). These variations in operating power and location add a great deal of complexity in characterizing the source noise level of a given piece of construction equipment.

This complexity can be simplified by determining the equipment noise level at a 50-foot reference distance from the equipment operating at full power and adjusting its full power noise level according to the duty cycle expressed in terms of the “usage factor” of the specific construction activity, and the project phase to determine the characteristic noise level of the operation during each phase. The usage factor is the percentage of time during the work period that the equipment is operating under load or at near full power, whereas each project phase has a different equipment mix depending on the work to be accomplished. Some have more continuous noise, while others may have more impact noise. Typical construction phases and equipment usage factors are given in Appendix A. Construction phase equipment usage factors, combined with receptor distances and equipment noise emissions, can be used in estimating project noise. Such methods are discussed in Appendix B.

The Society of Automotive Engineers has developed standardized procedures for measuring reference noise levels for the certification of mobile and stationary construction equipment. For informational purposes, typical 50-foot reference noise levels from representative pieces of construction equipment are listed in Figure A-1 (see Appendix A). The major noise producing construction activities within the County would likely be pile driving, pavement breaking, demolition, excavation, earth moving, and haul trucking.

4. NOISE SENSITIVE USES

Noise sensitive uses that would be affected by such construction activities include, but are not limited to, those listed in Figure 2, along with their periods of greatest sensitivity to construction noise. *Noise sensitive uses* are generally considered to include those land uses where noise exposure could result in health-related risks to individuals, as well as places where quiet is an essential element of their intended purpose. These uses include residences; schools; nursing homes; historic sites; cemeteries; parks, recreation, and open space areas; hospitals and care facilities; hotels and other short-term lodging (e.g., bed and breakfasts, motels); places of worship; and libraries. These uses are also considered *vibration sensitive uses* in addition to commercial and industrial buildings where vibration would interfere with operations within the building.

Figure 2. Noise Sensitive Uses

Use Description	Typical Sensitive Time Period
Hospitals, Nursing Homes (quasi-residential)	24 hours
Cemeteries	24 hours
Single-Family and Multi-Family Dwellings (residential)	Evening/Night
Hotels/Motels (quasi-residential)	Evening/Night
Schools, Churches, Libraries (when in use)	Daytime/Evening
Historic Sites, Parks, Recreation and Open Space Areas	Evening/Night

5. CONSTRUCTION NOISE THRESHOLDS OF SIGNIFICANCE

Standardized federal or state criteria have not been adopted for assessing construction noise impacts. Therefore, local planning criteria are generally developed and applied on a project-specific basis. Project construction noise criteria consider the existing noise environment, the time-varying noise during the various phases of construction activities, the duration of the construction, and the adjacent land use.

This document is intended to establish construction noise thresholds and standard noise monitoring and control measures. ~~These threshold criteria and monitoring and control measures shall be applied to all discretionary development projects (i.e., public projects, subdivisions, Planned Development Permits, Conditional Use Permits), whether or not the project is exempt from the California Environmental Quality Act (CEQA), and should be applied to ministerial development permits through conditions of approval.~~ Construction noise monitoring methods are discussed in Appendix C. Construction activities that exceed the noise thresholds of significance shall implement effective noise control measures in consideration of the guidelines in Appendix D. ~~The permitting agency/department shall review the construction noise control measures and confirm compliance with the noise thresholds of significance.~~

During daytime hours, construction activities should comply with the County of Ventura construction noise thresholds of significance defined hereafter. Evening or nighttime construction activity is generally not permitted in areas having *noise sensitive uses*. However, in the event such activity is deemed necessary, thresholds of significance are provided for construction that must occur during evening and/or nighttime hours. Emergency construction work is exempt from these construction noise thresholds.

5.1 Daytime Construction

Daytime (6:00 a.m. to 7:00 p.m. Monday through Friday, and from 9:00 a.m. to 7:00 p.m. Saturday, Sunday and local holidays) generally means any time period not specifically defined as a more noise-sensitive time period. The daytime construction noise threshold criteria are provided in Figure 4. Depending on project duration, the daytime noise threshold criteria shall be the greater of the fixed L_{eq}(h) limit (which includes non-construction evening and nighttime noise) or the measured ambient L_{eq}(h) plus 3 dB.

Figure 4. Daytime Construction Activity Noise Threshold Criteria

Noise Threshold Criteria shall be the greater of these noise levels at the nearest *noise sensitive use* or 10 feet from the nearest noise-sensitive building.

Construction Duration Affecting Noise Sensitive Uses	Fixed L_{eq}(h), dBA	Hourly Equivalent Noise Level (L_{eq}), dBA[1, 2]
0 to 3 days	75	Ambient L_{eq}(h) + 3 dB
4 to 7 days	70	Ambient L_{eq}(h) + 3 dB
1 to 2 weeks	65	Ambient L_{eq}(h) + 3 dB
2 to 8 weeks	60	Ambient L_{eq}(h) + 3 dB
Longer than 8 weeks	55	Ambient L_{eq}(h) + 3 dB

1. The instantaneous L_{max} shall not exceed the threshold criteria by 20 dBA more than 8 times per daytime hour.
2. Local ambient L_{eq} measurements shall be made on any mid-week day prior to project work.

5.2 Evening Construction

Evening hours (7:00 p.m. to 10:00 p.m.) are more noise-sensitive time periods. Overall project construction noise, for the noise-sensitive hours specified, shall not exceed the noise threshold criteria listed in Figure 5, at the nearest *noise sensitive use* or 10 feet from the façade of the nearest noise-sensitive building.

Figure 5. Evening Construction Activity Noise Threshold Criteria

Evening Noise Threshold Criteria shall be the greater of these noise levels at the nearest noise sensitive receptor area or 10 feet from the nearest noise-sensitive building.

Fixed L_{eq}(h), dBA	Hourly Equivalent Noise Level (L_{eq}), dBA[1, 2]
50	Ambient L_{eq}(h) + 3 dB

1. The instantaneous L_{max} shall not exceed the threshold criteria by 20 dBA more than 6 times per evening hour.
2. Hourly evening local *ambient noise* measurements shall be made on a typical mid-week evening prior to project work.

5.3 Nighttime Construction

Nighttime hours (10:00 p.m. to 6:00 a.m. Monday through Friday, and from 10:00 p.m. to 9:00 a.m. Saturday, Sunday and local holidays) are the most noise-sensitive time periods. Overall project construction noise, for the noise-sensitive hours specified, shall not exceed the noise threshold criteria listed in Figure 6, at the nearest *noise sensitive use* or 10 feet from the façade of the nearest noise-sensitive building.

Figure 6. Nighttime Construction Activity Noise Threshold Criteria

Nighttime Threshold Criteria shall be the greater of these noise levels at the nearest noise sensitive receptor area or 10 feet from the nearest noise-sensitive building

Fixed L_{eq}(h), dBA	Hourly Equivalent Noise Level (L_{eq}), dBA[1, 2]
45	Ambient L_{eq}(h) + 3 dB

1. The instantaneous L_{max} shall not exceed the threshold criteria by 20 dBA more than 4 times per nighttime hour.
2. Hourly nighttime local *ambient noise* measurements shall be made on a typical mid-weeknight prior to project work.

5.4 Maximum Construction Noise

In addition, the construction-related slow response, instantaneous maximum noise (L_{max}) shall not exceed the noise threshold criteria by 20 dBA more than eight times per daytime hour, more than six times per evening hour and more than four times per nighttime hour.

5.5 Determination of Compliance

The construction noise near *noise sensitive uses* for each construction phase is due to the contributions of each piece of noise producing equipment used in each construction phase. The resulting construction phase noise must be compared to the construction noise threshold criteria to determine whether noise control measures are required. The construction noise monitoring methods are discussed in Appendix C and typical noise control measures are provided in Appendix D. During periods of greater construction noise activity, the construction noise shall be monitored by a designated person trained in the use of a sound meter in accordance with the methods in Appendix C. When construction noise fails to comply with the appropriate noise threshold criteria, or falls out of compliance during use, the designated noise monitor shall immediately identify the non-compliant activity or equipment. Either the non-compliant activity must stop and the equipment removed from service, or effective remedial action must be taken, such as the noise control measures in Appendix D, to restore compliance with the respective noise threshold criteria.

6. CONSTRUCTION NOISE COMPLAINTS

Noise complaints are possible even when construction work complies with the criteria. The project, therefore, must keep a “Complaint Log,” noting date, time, complainant’s name, nature of the complaint, and any corrective action taken. The project manager shall publish and distribute to the potentially affected community a “Hot Line” telephone number that is active during construction working hours, for use by the disturbed public to register complaints.

Noise characteristics other than loudness (e.g., squeals, incessant banging, etc.) can result in complaints. An unusual number of construction noise complaints may require that additional noise control be undertaken. Careful identification of the specific conditions of activity responsible for the noise complaints would be necessary to determine additional appropriate control measures. Appendix D suggests typical measures to be considered for greater noise control than previously implemented. Proper measures shall be applied before continuing the activity responsible for the unusual number of complaints. For especially difficult cases, the assistance of a qualified construction noise control consultant may be required.

7. FUNDAMENTALS OF VIBRATION

Vibration is the periodic oscillation of a medium or object with respect to a given reference point. Sources of vibration include natural phenomena (e.g., earthquakes, volcanic eruptions, sea waves, landslides) and those introduced by human activity (e.g., explosions, machinery, traffic, trains, construction equipment). Vibration sources may be continuous, (e.g., operating factory machinery) or transient in nature (e.g., explosions). Vibration levels can be depicted in terms of amplitude and frequency, relative to displacement, velocity, or acceleration.

Vibration amplitudes are commonly expressed in peak particle velocity (PPV) or root-mean-square (RMS) vibration velocity. PPV and RMS vibration velocity are normally described in inches per second (in/sec) or in millimeters per second. PPV is defined as the maximum instantaneous positive or negative peak of a vibration signal. PPV is typically used in the monitoring of transient and impact vibration and has been found to correlate well to the stresses experienced by buildings.

Although PPV is appropriate for evaluating the potential for building damage, it is not always suitable for evaluating human response. It takes some time for the human body to respond to vibration signals. In a sense, the human body responds to average vibration amplitude. The RMS of a signal is the average of the squared amplitude of the signal, typically calculated over a 1-second period. As with airborne sound, the RMS velocity is often expressed in decibel notation as vibration decibels (VdB), which serves to compress the range of numbers required to describe vibration. This is based on a reference value of 1 micro inch per second.

The typical background vibration-velocity level in residential areas is approximately 50 VdB. Ground vibration is normally perceptible to humans at approximately 65 VdB. For most people, a vibration-velocity level of 75 VdB is the approximate dividing line between barely perceptible and distinctly perceptible levels. *Vibration sensitive use* categories for general vibration assessments are presented in Figure 7 in order of sensitivity.

Figure 7: Vibration Sensitive Uses for General Vibration Assessment Impact Criteria

Use Category	Use Type	Description of Use Category
-	Special Buildings	This category includes special-use facilities that are very sensitive to vibration and noise that are not included in the categories below and require special consideration. However, if the building will rarely be occupied when the source of the vibration (e.g., the train) is operating, there is no need to evaluate for impact. Examples of these facilities include concert halls, TV and recording studios, and theaters.
1	High Sensitivity	This category includes buildings where vibration levels, including those below the threshold of human annoyance, would interfere with operations within the building. Examples include buildings where vibration-sensitive research and manufacturing[1] is conducted, hospitals with vibration-sensitive equipment, and universities conducting physical research operations. The building's degree of sensitivity to vibration is dependent on the specific equipment that will be affected by the vibration. Equipment moderately sensitive to vibration, such as high-resolution lithographic equipment, optical microscopes, and electron microscopes with vibration isolation systems are included in this category.[2] For equipment that is more sensitive, a Detailed Vibration Analysis must be conducted.
2	Residential	This category includes all residential land use and buildings where people normally sleep, such as hotels and hospitals. Transit-generated ground-borne vibration and noise from subways or surface running trains are considered to have a similar effect on receivers.[3]
3	Institutional	This category includes institutions and offices that have vibration-sensitive equipment and have the potential for activity interference such as schools, churches, doctors' offices. Commercial or industrial locations including office buildings are not included in this category unless there is vibration-sensitive activity or equipment within the building. As with noise, the use of the building determines the vibration sensitivity.

1. Manufacturing of computer chips is an example of a vibration-sensitive process.
2. Standard optical microscopes can be impacted at vibration levels below the threshold of human annoyance.
3. Even in noisy urban areas, the bedrooms will often be in quiet buildings with effective noise insulation. However, ground-borne vibration and noise are experienced indoors, and building occupants have practically no means to reduce their exposure. Therefore, occupants in noisy urban areas are just as likely to be exposed to ground-borne vibration and noise as those in quiet suburban areas.

Source: FTA 2018:124

Typical outdoor sources of perceptible ground vibration are construction equipment, steel-wheeled trains, and traffic on rough roads. If a roadway is smooth, the ground vibration is rarely perceptible. The range of interest is from approximately 50 VdB, which is the typical background vibration-velocity level, to 100 VdB, which is the general threshold where minor damage can occur to fragile buildings. Construction activities can generate sufficient ground vibrations to pose a risk to nearby structures. Constant or transient vibrations can weaken structures, crack facades, and disturb occupants.

Vibrations generated by construction activity can be transient, random, or continuous. Transient construction vibrations are generated by blasting and wrecking balls. Continuous vibrations are generated by vibratory pile drivers, large pumps, and compressors. Random vibration can result from jackhammers, pavement breakers, and heavy construction equipment. Figure 8 presents vibration levels for typical pieces of equipment used during construction.

Figure 8: Vibration Levels of Typical Construction Equipment

Equipment		PPV at 25 ft, in/sec	Approximate L_v at 25 ft
Pile Driver (impact)	upper range	1.518	112
	typical	0.644	104
Pile Driver (sonic)	upper range	0.734	105
	typical	0.17	93
Clam shovel drop (slurry wall)		0.202	94
Hydromill (slurry wall)	in soil	0.008	66
	in rock	0.017	75
Vibratory Roller		0.21	94
Hoe Ram		0.089	87
Large bulldozer		0.089	87
Caisson drilling		0.089	87
Loaded trucks		0.076	86
Jackhammer		0.035	79
Small bulldozer		0.003	58

PPV= peak particle velocity; L_v = *RMS velocity in decibels, VdB re 1 micro-in/sec; ft=feet
Source: FTA 2018:184

8. CONSTRUCTION VIBRATION THRESHOLDS OF SIGNIFICANCE

Standardized federal or state criteria have not been adopted for assessing construction vibration impacts. Therefore, municipal planning criteria are generally developed and applied on a project-specific basis. Construction project vibration criteria consider the existing building structure construction material and the level of human annoyance. Characterizing structures using FTA criteria would be less ambiguous as opposed to structure condition and age.

Specific construction vibration limits for *vibration sensitive uses* are not currently specified in the General Plan or Ventura County Ordinance Code. This document, therefore, is intended to establish construction vibration thresholds and standard vibration control measures. ~~The threshold criteria below and control measures in Appendix E shall be applied to all discretionary development projects (i.e., public projects, subdivisions, Planned Development Permits, Conditional Use Permits), whether or not the project is exempt from CEQA, and should be applied to ministerial development permits through conditions of approval.~~ Construction projects that exceed the construction vibration damage threshold criteria within 500 feet of *vibration sensitive uses* shall implement effective vibration control measures in consideration of the guidelines of Appendix E. ~~The permitting agency/department shall review the construction vibration control measures and confirm compliance with the vibration threshold criteria.~~

Figure 9: Vibration Damage Threshold Criteria

Building/Structural Category	PPV, in/sec
I. Reinforced-concrete, steel or timber (no plaster)	0.5
II. Engineered concrete and masonry (no plaster)	0.3
III. Non-engineered timber and masonry buildings	0.2
IV. Buildings extremely susceptible to vibration damage	0.12

Notes: PPV=peak particle velocity
Source: FTA 2018:186

9. GROUND-BORNE VIBRATION THRESHOLDS OF SIGNIFICANCE

Figure 10 denotes the ground-borne vibration threshold criteria for each *vibration sensitive use* category. Consider indoor use of the buildings when determining land use categories for ground-borne vibration and noise, since impact is experienced indoors. Concert halls, TV studios, and recording studios should be evaluated using the threshold criteria for Sensitive Land Use Category 1. Auditoriums and theaters should be evaluated using the threshold criteria for Sensitive Land Use Category 2. Projects that exceed the ground-borne vibration threshold criteria within 500 feet of a sensitive land use category shall implement effective vibration control measures in consideration of the guidelines of Appendix E.

Figure 10: Ground-Borne Vibration (GBV) Threshold Criteria

Vibration Sensitive Use Category	GBV Impact Levels (VdB re 1 micro-inch /sec)		
	Frequent Events	Occasional Events	Infrequent Events
Category 1: Buildings where vibration would interfere with interior operations.	65 VdB	65 VdB	65 VdB
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: GBV= ground-borne vibration; VdB= vibration decibels; Frequent events: More than 70 events per day; Occasional events: 30-70 events per day; Infrequent events: Fewer than 30 events per day
Source: Table based on FTA 2018:126

10. TRANSIT RELATED VIBRATION THRESHOLDS OF SIGNIFICANCE

Transit use is a public transportation option that conveys passengers such as, but not limited to a bus, light rail system, or passenger train.

Transit-Oriented Development (TOD) is a type of pedestrian-friendly, mixed-use development that maximizes the amount of residential, business and leisure space within walking distance of public transport (e.g., bus, light rail, and railroad stops and stations). It promotes a symbiotic relationship between dense, compact urban form and public transport use. A transit priority area, as defined in California Public Resources Code Section 21099, an area within one-half mile of a major transit stop that is existing or planned, if the planned stop is scheduled to be completed within the planning horizon included in an adopted federal transportation improvement program or applicable regional transportation plan.

A major transit stop, as defined in California Public Resources Code Section 21064.3, refers to a site containing an existing rail or bus rapid transit station; a ferry terminal served by either a bus or rail transit service; or the intersection of two or more major bus routes with a frequency of service interval of 15 minutes or less during the morning and afternoon peak commute periods.

TOD projects are desirable as they create compact, mixed-use communities near transit where people enjoy easy access to jobs and services. However, projects within a transit priority area or proposing a major transit stop may expose residents and workers to vibration impacts. Figure 11 below lists the screening distances for vibration-generating *transit uses*, based on the type of *transit use* and the location of the *transit use* in relation to *vibration sensitive uses*. If a project would result in a *transit use* located within any of the specified screening distances, a General Vibration Assessment or if deemed necessary, a Detailed Vibration Analysis shall be prepared consistent with the assessment procedures outlined in Chapter 10 and Chapter 11, respectively, of the FTA Transit Noise and Vibration Impact Assessment Manual.

Figure 11: Screening Distances for Transit Related Vibration

Vibration-Generating Transit Use	Distance from Vibration Sensitive Use Categories[1] Distance from Right-of-Way or Property Line (feet)		
	Category 1	Category 2	Category 3
Steel-Wheeled/Steel-Rail Vehicle Transit Uses			
Conventional Commuter Railroad	600	200	120
Rail Rapid Transit	600	200	120
Light Rail Transit	450	150	100
Intermediate Capacity Transit	200	100	50
Rubber-Tire Heavy Vehicle Uses			
Rubber-Tire Heavy Vehicles (if not previously screened out)[2]	100	50	--

1. See the FTA Transit Noise and Vibration Impact Assessment Manual, Appendix A, for the definitions of vibration-generating *transit uses* listed in this table. For the purposes of screening procedures, concert halls and television studios should be evaluated as Category 1, and theaters and auditoriums should be evaluated as Category 2.
2. See the discussion below.

Source: FTA Transit Noise and Vibration Impact Assessment Manual, 2018.

10.1 Steel-Wheeled/Steel-Rail Vehicle Transit Uses

The Federal Transit Administration (FTA) has prepared and periodically updates the Transit Noise and Vibration Impact Assessment Manual, which includes technical guidelines for assessing noise and vibration impacts related to transit uses. As discussed in the FTA Transit Noise and Vibration Impact Assessment Manual, steel-wheeled vehicles may produce vibrations and noise at a higher level than that of rubber tires. However, noise level depends on an assortment of variables such as the smoothness of the steel wheel and rails, the vehicle's suspension system, and other geologic and mechanical considerations. In order to determine whether a project has the potential to generate a significant impact through the use of steel-wheeled/steel-rail vehicles, the agency that is responsible for administering the project shall determine whether any *vibration sensitive uses* are located within the screening distances identified in Figure 11. This information can be gathered by observation during a site visit and using the aerial imagery in RMA GIS.

If the project site is located outside of the screening distance for the *vibration sensitive use*, the project would have a less than significant impact.

If the project site is located within the screening distance for the *vibration sensitive use*, the project shall be evaluated for potential vibration impacts using the General Vibration Assessment or Detailed Vibration Analysis methodology, criteria, and reporting procedures, as appropriate, provided in the FTA Transit Noise and Vibration Impact Assessment Manual. The project applicant shall be responsible for selecting a qualified consultant, with approval from the agency responsible for administering the project, to prepare the analysis. The analysis must include an Initial Study checklist and discussion that meets the requirements of the ISAGs. If the project exceeds the applicable base curve for ground-borne vibration, with adjustments where appropriate as provided for in the FTA Manual (see ~~Chapter 10~~Steps 1 and 2 in Section 6.4 of the FTA Manual), the project shall be considered to have a significant impact and vibration control measures would be required.

Both project-specific and cumulative impacts shall be evaluated. Cumulative impacts shall be evaluated by incorporating into the assessment all past, present, and reasonably foreseeable probable future projects located within the vicinity of the project site that have the potential to contribute to cumulative impacts relating to vibration.

10.2 Rubber-Tire Heavy Vehicle Transit Uses

Rubber-tire heavy vehicles traveling on roadways typically would not produce a significant vibration impact, except in situations where a large number of heavy vehicles (e.g., semi-trucks or buses) are traveling along uneven roadways within the specified screening distance of a *vibration sensitive use*. Therefore, if a project would generate new rubber-tire heavy vehicle trips, or generate new heavy vehicle (e.g., semi-truck or bus) trips on uneven roadways within the specified screening distance of a *vibration sensitive use*, the following initial screening questions must be asked to determine if the project would result in a potentially significant vibration impact:

- Would the project result in expansion joints, speed bumps, or other design features that would result in unevenness in the road near the *vibration sensitive use*? Such roadway irregularities can result in perceptible ground-borne vibration at distances up to 75 feet away.
- Would the project result in buses, trucks or other heavy vehicles operating near a *vibration sensitive use*?
- Would the project result in the operation of vehicles inside or directly underneath buildings that are vibration sensitive? Special considerations are often required for shared-use facilities such as a bus station located inside an office building complex.

If the answer is "no" to all three of the initial screening questions above, the project would have a less than significant impact.

If the answer is "yes" to any one of the initial screening questions above, the project shall be evaluated for potential vibration impacts using the General Vibration Assessment or Detailed Vibration Analysis methodology, criteria, and reporting procedures, as appropriate, provided in the FTA Transit Noise and Vibration Impact Assessment Manual. The project applicant shall be responsible for selecting a qualified consultant, with approval from the agency responsible for administering the project, to prepare the analysis. The analysis must include an Initial Study checklist and discussion that meets the requirements of the ISAGs. If the project exceeds the applicable base curve for ground-borne vibration, with adjustments where appropriate as provided for in the FTA Manual (see Steps 1 and 2 in Section 6.4~~Chapter 10~~ of the FTA Manual), the project shall be considered to have a significant impact and vibration control measures would be required.

Both project-specific and cumulative impacts shall be evaluated. Cumulative impacts shall be evaluated by incorporating into the assessment past, present, and reasonably foreseeable probable future projects located within the vicinity of the project site that have the potential to contribute to cumulative impacts relating to vibration.

Appendix A. Typical Construction Equipment Noise and Use Factors

Figure A-1. Construction Equipment Noise

Equipment Type Noise Source	Dominant Noise Components[1]	50-Foot Noise Level (L_{eq}) dBA[2, 3]	Noise Level Range (L_p) dBA[2, 3]	50-Foot Maximum Noise Level (L_{max}) dBA[2, 3]
Air Compressor (portable)[4]	E, C, H, I	81	76-89	89
Air Compressor (stationary)	E, C, H, I	82	76-89	89
Auger, Drilled Shaft Rig	E, C, F, I, W	82	76-89	89
Backhoe	E, C, F, I, H, W	85	81-90	90
Bar Bender	E, P, W	82	78-88	85
Chain Saw	E, W, C	85	72-88	88
Compactor	E, C, F, I, W	82	81-85	85
Concrete Batch Plant	W, E, C	92	80-96	96
Concrete Mixer (small trailer)	W, E, C	67	65-68	68
Concrete Mixer Truck	E, C, F, W, T	85	69-89	89
Concrete Pump Trailer	E, C, H	82	74-84	84
Concrete Vibrator	W, E, C	76	68-81	81
Crane, Derrick	E, C, F, I, T	88	79-90	90
Crane, Mobile	E, C, F, I, T	83	80-85	85
Dozer (Bulldozer)	E, C, F, I, H	80	77-90	90
Excavator	E, C, F, I, H, W	87	83-92	92
Forklift	E, C, I, W	84	81-86	86
Front End Loader	E, C, F, I, H	79	77-90	90
Generator	E, C	78	71-87	87
Gradall	E, C, F, I, W	82	78-85	85
Grader	E, C, F, I, W	85	79-89	89
Grinder	W	80	75-82	82
Hydraulic Hammer	W, E, C, H	102	99-105	105
Impact Wrench	W, P	85	75-85	85
Jack Hammer	P, W, E, C	82	75-88	88
Paver	E, D, F, I	89	82-92	92

Equipment Type Noise Source	Dominant Noise Components[1]	50-Foot Noise Level (L_{eq}) dBA[2, 3]	Noise Level Range (L_p) dBA[2, 3]	50-Foot Maximum Noise Level (L_{max}) dBA[2, 3]
Pile Driver (Impact/ Sonic/ Hydraulic)	W, P, E	101 / 96 / 65	94-107 / 90-99 / 65	107 / 99 / 65
Pavement Breaker	W, E, P	82	75-85	85
Pneumatic Tool	P, W, E, C	85	78-88	88
Pump	E, C	76	68-80	80
Rock Drill	W, E, P	98	83-99	99
Roller	E, C, F, I, W	74	70-83	83
Sand Blaster	W, E, C, H, I	85	80-87	87
Saw, Electric	W	78	59-80	80
Scraper	E, C, F, I, W	88	82-91	91
Shovel	E, C, F, I, W	82	77-90	90
Tamper	W, E, C	86	85-88	88
Tractor	E, C, F, I, W	82	77-90	90
Trencher		83	81-85	85
Trucks (Under Load)	E, C, F, I, T	88	81-95	95
Water Truck	W, E, C, F, I, T	90	89-94	94
Other Equipment with Diesel	E, C, F, I	82	75-88	88

1. Ranked noisy components. C=Casing, E=Exhaust, F=Fan, H=Hydraulics, I=Intake air, P=Pneumatic exhaust, T=Transmission, W=Work tool.
2. Table based on EPA studies and measured data from various construction equipment and manufacturer's data.
3. Equipment noise levels are at 50 feet from individual construction equipment and with no other noise contributors.
4. Portable air compressor rated at 75 cfm or greater and operating at greater than 50 psi.

Figure A-2. Construction Equipment and Use Factors for Housing Projects

Equipment Item	50-Foot L_{eq}, dBA	Mitigated[1] L_{eq}, dBA	Highest Hourly Use Percentage per Construction Phase				
			Clear	Excavate	Base	Build	Finish
Air Compressor	81	75	--[2]	10	--	--	25
Backhoe	85	75	2	4	--	--	2
Concrete Mixer	85	75	--	--	4	8	16
Concrete Pump	82	75	--	--	--	--	--
Concrete Vibrator	76	75	--	--	--	--	--
Crane, Derrick	88	75	--	--	--	--	--
Crane, Mobile	83	75	--	--	--	10	4
Dozer	80	75	4	8	--	--	4
Generator	78	75	4	--	--	--	--
Grader	85	75	5	--	--	--	2
Jack Hammer	82	75	--	--	--	--	3
Loader	79	75	4	8	--	--	4
Paver	89	80	--	--	--	--	3
Pile Driver	101	95	--	--	--	--	--
Pneumatic Tool	85	80	--	--	4	10	4
Pump	76	75	--	4	7	--	--
Rock Drill	98	80	--	1	--	--	0.5
Roller	74	74	--	--	--	--	4
Saw, Electric	78	75	--	--	4 (2)[3]	10 (2)	4 (2)
Scraper	88	80	5	--	--	--	1
Shovel	82	75	--	2	--	--	--
Truck	88	75	16	40	--	--	16

1. Estimated level obtainable by quieter methods or equipment and implementing feasible noise controls.
2. "--" indicates typically zero or very little use during construction phase.
3. Numbers in parentheses are greatest multiple number of same items in use.

Figure A-3. Construction Equipment and Use Factors for Large Buildings and Institutions

Construction Equipment	50-Foot L_{eq}, dBA	Mitigated[1] L_{eq}, dBA	Highest Hourly Use Percentage per Construction Phase				
			Clear	Excavate	Base	Build	Finish
Air Compressor	81	75	--[2]	100 (2)[3]	100 (2)	100 (2)	40 (2)
Backhoe	85	75	04	16	--	--	4
Concrete Mixer	85	75	--	--	40	40	16
Concrete Pump	82	75	--	--	40	8	8
Concrete Vibrator	76	75	--	--	40	10	4
Crane, Derrick	88	75	--	--	--	16	4
Crane, Mobile	83	75	--	--	--	16 (2)	4 (2)
Dozer	80	75	16	40	--	--	16
Generator	78	75	40 (2)	100 (2)	--	--	--
Grader	85	75	8	--	--	--	2
Jack Hammer	82	75	--	10	4	4	4
Loader	79	75	16	40	--	--	16
Paver	89	80	--	--	--	--	10
Pile Driver	101	95	--	--	4	--	--
Pneumatic Tool	85	80	--	--	4	16 (2)	4 (2)
Pump	76	75	--	100 (2)	100 (2)	40	--
Rock Drill	98	80	--	4	--	--	0.5
Roller	74	74	--	--	--	--	--
Saw, Electric	78	75	--	--	4 (3)	100 (3)	--
Scraper	88	80	55	--	--	--	--
Shovel	82	75	--	40	--	--	--
Truck	88	75	16 (2)	40	--	--	16

1. Estimated level obtainable by quieter methods or equipment and implementing feasible noise controls.
2. "--" indicates typically zero or very little use during construction phase.
3. Numbers in parentheses are greatest number of same items in use during any hour.

Figure A-4. Construction Equipment and Use Factors for Commercial and Industrial Projects

Construction Equipment	50-Foot L_{eq}, dBA	Mitigated[1] L_{eq}, dBA	Highest Hourly Use Percentage per Construction Phase				
			Clear	Excavate	Base	Build	Finish
Air Compressor	81	75	--[2]	100	40	40	40
Backhoe	85	75	4	16	--	--	4
Concrete Mixer	85	75	--	--	40	16	16
Concrete Pump	82	75	--	--	40	--	8
Concrete Vibrator	76	75	--	--	--	--	--
Crane, Derrick	88	75	--	--	--	4	2
Crane, Mobile	83	75	--	--	--	8	4
Dozer	80	75	4	16	--	--	4
Generator	78	75	40	40	--	--	--
Grader	85	75	5	--	--	--	2
Jack Hammer	82	75	--	10	4	4	4
Loader	79	75	16	16	--	--	4
Paver	89	80	--	--	--	--	12
Pile Driver	101	95	--	--	4	--	--
Pneumatic Tool	85	80	--	--	4	10 (3)[3]	4 (3)
Pump	76	75	--	40	100 (2)	40	--
Rock Drill	98	80	--	4	--	--	5
Roller	74	74	--	--	--	--	10
Saw, Electric	78	75	--	--	4 (2)	10 (2)	--
Scraper	88	80	14	--	--	--	8
Shovel	82	75	--	20	--	--	6
Truck	88	75	16 (2)	16 (2)	--	--	16

1. Estimated level obtainable by quieter methods or equipment and implementing feasible noise controls.
2. "--" indicates typically zero or very little use during construction phase.
3. Numbers in parentheses are greatest number of same items in use during any hour.

Figure A-5. Construction Equipment and Use Factors for Public Works and Roadway Projects

Construction Equipment	50-Foot L_{eq}, dBA	Mitigated[1] L_{eq}, dBA	Highest Hourly Use Percentage per Construction Phase				
			Clear	Excavate	Base	Build	Finish
Air Compressor	81	75	--[2]	100 (2)[3]	40	40	40 (2)
Backhoe	85	75	4	40	--	--	16
Concrete Mixer	85	75	--	--	16 (2)	40 (2)	16 (2)
Concrete Pump	82	75	--	--	--	--	--
Concrete Vibrator	76	75	--	--	--	--	--
Crane, Derrick	88	75	--	10	4	4	--
Crane, Mobile	83	75	--	--	--	16	--
Dozer	80	75	4	40	--	--	16
Generator	78	75	100 (2)	40 (2)	40 (2)	40	40 (2)
Grader	85	75	8	--	--	20	8
Jack Hammer	82	75	--	--	--	4	10 (2)
Loader	79	75	4	40	--	--	16
Paver	89	80	--	--	--	--	--
Pile Driver	101	95	--	--	--	--	--
Pneumatic Tool	85	80	--	--	4 (2)	10	4
Pump	76	75	--	40 (2)	100 (2)	40 (2)	--
Rock Drill	98	80	--	4	--	--	--
Roller	74	74	--	--	100	--	--
Saw, Electric	78	75	--	--	4 (2)	--	--
Scraper	88	80	8		20	8	8
Shovel	82	75	4	40	4	--	4
Truck	88	75	16 (2)	16	40 (2)	--	16 (2)

1. Estimated level obtainable by quieter methods or equipment and implementing feasible noise controls.
2. "--" indicates typically zero or very little use during construction phase.
3. Numbers in parentheses are greatest number of same items in use during any hour.

APPENDIX B. ESTIMATING CONSTRUCTION NOISE

For project planning purposes, it is possible to estimate potential construction noise impacts by developing an inventory of noisy construction equipment and processes for the various stages and phases of the project. Such screening methods assist construction project managers and estimators in planning for potential noise control.

Construction Equipment Inventory

An inventory of the number and type of noisy construction equipment to be used during planned daytime, evening and nighttime construction activities, their associated noise emissions, and other relevant information can be included on Figure B-2, Construction Phase Receptor Noise Estimation Worksheet. Using this form, construction noise levels for the various phases of construction can be estimated using the phase's equipment inventory, the typical 50-foot equipment noise levels (listed in Figure A-1 of Appendix A) along with typical by-phase construction equipment use factors, provided in Figures A-1 through A-5 of Appendix A.

Construction Noise Estimates

Calculations can be performed to estimate the daytime, evening and nighttime maximum (L_{max}) and one-hour energy average (L_{eq}) noise levels expected at the *noise sensitive use*, based on the typical maximum equipment noise levels listed in Figure A-1 in Appendix A. The calculations are to be made for the various activities and locations where project construction noise will result in the greatest noise impact (noise levels at other sensitive locations can also be calculated, if necessary). The calculations and results should be entered on a form similar to Figure B-2, the Construction Phase Receptor Noise Estimation Worksheet. The result of a sample construction noise calculation is provided in Figure B-1.

The following calculation procedures may be used to estimate the construction noise by phase.

1. Calculate each phase's L_{max} according to the following method:

$$L_{max}(equipment\ type) = ML - 20\, log_{10}\left(\frac{D}{50}\right)$$

Variables:

ML	Typical single equipment maximum noise level (L_{max}) at 50 feet, in dBA. (This may be replaced by a measured, under-load, maximum noise level).
D	Distance from the equipment to the noise-sensitive location, in feet.

Repeat the above calculation for each item of potentially noisy equipment. Then, select the noisiest individual pieces of equipment that operate in their loudest mode at the very same time and combine them logarithmically to estimate the overall maximum construction noise level (L_{max}) at the noise-sensitive location(s) for each project phase, as follows:

$$L_{max}(overall\ project\ at\ receptor) = 10\, log_{10}\left(\sum 10^{\left(L_{max}\frac{equipment\ type}{10}\right)}\right)$$

2. Calculate each phase's one-hour L_{eq} according to the method recommended by the U.S. Federal Highway Administration[2] as follows:

   First, the construction phase's one-hour L_{eq} is to be calculated at the sensitive receptor location for each item of potentially noisy equipment using the following equation:

$$L_{eq}(h)(equipment\ type) = ML - 20\,log_{10}\left(\frac{D}{50}\right) + 10\,log_{10}\left(N \times \frac{HP}{100}\right)$$

   Variables:

ML	Typical single equipment maximum noise level (L_{max}) at 50 feet, in dBA. (This may be replaced by a measured, under-load, maximum noise level).
D	Shortest distance (feet) from the equipment type to the nearest noise- sensitive location, or if a more sensitive receptor is further away, to the noise-sensitive receptor with the greatest impact. If the distance is measured in meters, use the ratio D/15 instead of D/50.
N	Maximum number of the same equipment type operating hourly on the project during the construction phase.
HP	"Hourly percentage," expressed as the greatest nominal percent of time that the equipment is operated under load at the project site. This factor is based on EPA values or is estimated based on past experience with similar projects. Thus, the effective usage factor is (EUF) = N x HP/100.

   Repeat the above calculations for each item of potentially noisy equipment. Then, the individual contribution of every item of equipment are to be combined logarithmically to obtain the overall construction hourly L_{eq} at the noise-sensitive location(s) for each project phase, as follows:

$$L_{eq}(h)(overall\ project\ at\ receptor) = 10\,log_{10}\left(\sum 10^{\left(one-hour\ L_{eq}\frac{equipment\ type}{10}\right)}\right)$$

3. The calculated L_{max} and L_{eq}(h) levels can then be compared with the construction noise threshold criteria. Where it is estimated that the criteria would be exceeded, noise control planning can be undertaken.

[2] Highway Construction Noise: Measurement, prediction and mitigation," U.S. Department of Transportation, Federal Highway Administration Special Report, March 1977

Figure B-1. Example of Construction Phase Receptor Noise Estimation Worksheet

Construction Phase Equipment Item	# of Items	Item L_{max} at 50 feet, dBA	Distance to Receptor	Item Usage Percent	Usage Factor	Distance Adj., dB	Usage Adj., dB	Receptor Item L_{max}, dBA	Receptor Item L_{eq}, dBA
1. Dozer	1	90	100	70	0.70	-6	-1.6	84.0	82.4
2. Grader	1	89	200	75	0.75	-12	-1.2	77.0	75.7
3. Scraper	2	91	150	20	0.40	-6	-4.0	81.5	77.5
4. Water Truck	1	94	50	5	0.05	-6	-13.0	94.0	81.0
5.									
6.									
							Log Sum	94.7	86.0

Log_{10} Sums of Receptor Item L_{eq} Yield the Combined Receptor L_{eq}, dBA

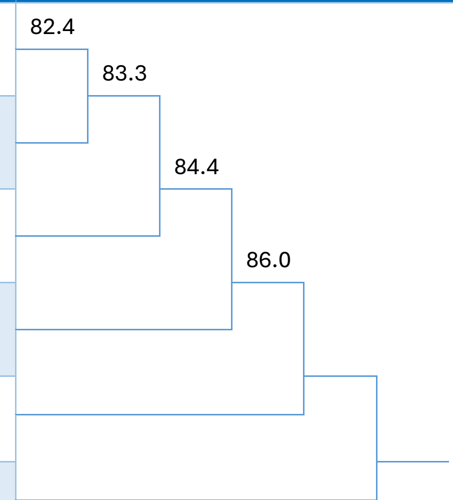


Figure B-2. Construction Phase Receptor Noise Estimation Worksheet

Construction Phase Equipment Item	# of Items	Item L_{max} at 50 feet, dBA	Distance to Receptor	Item Usage Percent	Usage Factor	Distance Adj., dB	Usage Adj., dB	Receptor Item L_{max}, dBA	Receptor Item L_{eq}, dBA	Log_{10} Sums of Receptor Item L_{eq} Yield the Combined Receptor L_{eq}, dBA
1.										
2.										
3.										
4.										
5.										
6.										
							Log Sum			

APPENDIX C. CONSTRUCTION NOISE MONITORING

This appendix outlines the noise measurement instrumentation and monitoring procedures.

Noise Measurement Instruments

1. Noise measurements shall be performed with an instrument that is in compliance with or exceeds the criteria for a Type 2 (General Purpose) Sound Level Meter, as defined in the most recent revision of ANSI Standard S1.4.2.
2. Sound level meters shall be capable of measuring the slow response L_{max} and one-hour L_{eq} on the *A-Weighted* scale, as required by the construction noise thresholds of significance and project construction noise limits. Where possible, integrating-type instruments may monitor the percentile (L_1, L_{50}, etc.) noise levels to show construction noise statistics.
3. Sound level meters, microphones, and field calibrators shall be calibrated by a certified laboratory at least once a year. A valid certificate of calibration conformance shall be obtained and be available for each instrument before using sound level meters. Updated certificates shall be maintained following subsequent yearly calibrations and upon the completion of repairs to noise monitoring instruments.

Noise Measurement Procedure

1. The sound level meter shall be calibrated using an acoustic calibrator according to the manufacturer's specifications just before each measurement.
2. Except as otherwise indicated, measurements shall be performed using the A-weighting network and the slow response setting of the sound level meter.
3. Impulsive or impact noises shall be measured using the C-weighting network and the fast response setting of the sound level meter.
4. The measurement microphone shall be fitted with an appropriate windscreen and the sound level meter shall be placed at the location of the sensitive receptor with the microphone approximately 5 feet above the ground or floor and at least 10 feet away from any vertical surfaces.
5. *Ambient noise* measurements shall be taken during periods of the least noise-producing activity in the vicinity of *noise sensitive uses* that may be impacted by the construction operations. *Ambient noise* measurements shall be conducted for at least 20 minutes at representative locations for potentially impacted receptors.
6. Construction noise measurements shall be taken during periods of greatest noise-producing activity at *noise sensitive uses* in the vicinity of the construction site a minimum of once each shift and also after a sustained perceptible change in noise-producing construction activity or location. Noise measurements shall be conducted for at least 20 minutes each monitoring session.
7. Construction noise measurements shall coincide with daytime, evening and nighttime daily time periods of maximum noise-generating construction activity and shall be taken or repeated during the construction phase or activity that has the greatest potential to create annoyance or to exceed applicable noise regulations and restrictions.

8. If, in the estimation of the person performing the measurements, non-project related noise sources contribute significantly to the measured noise level, additional measurements (with the same non-project noise source contributions) shall be repeated when project construction is inactive to determine the non-project ambient background noise level.
9. Noise data shall be logged using the Noise Measurement Report Form and maintained for at least six months following the completion of the construction project. The type of measurement (e.g. baseline ambient, on-going construction, major change, etc.) shall be noted on the form.
10. Monitoring locations shall be clearly identified and sketched on the Noise Measurement Report Form along with the locations of and monitoring site distances to the *noise sensitive uses*.
11. Construction equipment operating during the noise monitoring period and their locations shall be identified and sketched on the Noise Measurement Report Form, along with the locations of and equipment distances to the *noise sensitive uses*.

Figure C-1. Noise Measurement Report Form - Part A

Project: ______________________ Contract No(s): ______________

Date: __________ Day of Week: ______________ Time: __________

Monitoring Site Number: ______ Monitoring Site Address: ______________________

Measurement Taken By: ______________________ of ______________________

Approx. Wind Speed: ____ ☐ mph ☐ km/hr Approx. Wind Direction: From the __________

Approx. distance of Sound Level Meter from Receptor Location: ______________________

Approx. distance of Sound Level Meter from Construction Site: ______________________

(Leave Blank for Baseline Ambient)

Receptor Land Use (Check One): ☐ Residential/Institutional ☐ Commercial/Recreational

Sound Level Meter: Make and Model: ______________________ Serial Number: ______

Meter Setting: ☐ A-Weighted Sound Level (SLOW) ☐ C-Weighted Sound Level (FAST) for Impacts

Duration of Measurement: ______________________ (at least 20 minutes)

Check the measurement purpose:

☐ Baseline Condition ☐ Ongoing Construction ☐ Major Change ☐ Complaint Response

Measurement Results:

Measurement Type	Measured Level	Noise Threshold Criteria	Exceedance
CALIBRATION		n/a	n/a
L_{eq}			
L_{max}			
L_1		n/a	n/a
L_8 or L_{10} (circle which)		n/a	n/a
L_{25}		n/a	n/a
L_{50}		n/a	n/a
L_{90}		n/a	n/a

Field Notes:

1. ____________________
2. ____________________
3. ____________________
4. ____________________

Complete all that apply below:

Active Equipment: ____________________

(List construction equipment that contribute to measured noise)

Complaint Response: ____________________

(Describe complaint; include log-in number)

Complaint Control Measure(s): ____________________

(Describe complaint response noise control)

Figure C-2. Noise Measurement Report Form - Part B

Project: ______________________ Contract No(s): ______________________

Date: ____________ Day of Week: ______________________ Time: ____________

Monitoring Site Number: ________ Monitoring Site Address: ______________________

Site Map

Field Notes:

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________

Noise Monitor's Signature: ______________________ Date: ______________

APPENDIX D. CONSTRUCTION NOISE CONTROL MEASURES

Construction noise is to be monitored at the location of the most affected sensitive use (10 feet from the construction activity side of a noise sensitive building or at the outdoor living area). Noise measurements are to be conducted using the procedures in this Appendix and the measurement results logged in a format similar to that of the Construction Noise Control Form in this Appendix. Where the construction noise thresholds of significance are exceeded at *noise sensitive uses*, noise impact control measures, such as those in this Appendix, are to be implemented and adequate noise reduction achieved to bring the construction activities into compliance with the construction noise threshold criteria.

Construction noise control may be achieved using various combinations of equipment source noise reduction, propagation path noise reduction, and sensitive receptor noise reduction.

Construction Equipment Noise Reduction Methods

Feasible and reasonable equipment noise control measures may need to be implemented to meet the construction noise thresholds of significance. Examples of equipment noise reduction methods are listed in this section. The implementation of one or more of these measures, along with those identified in the other sections/appendices, may be necessary to achieve compliance with the construction noise thresholds of significance.

Equipment Noise Reduction

1. Minimize the use of impact devices, such as jackhammers, pavement breakers, and hoe rams. Where possible, use concrete crushers or pavement saws rather than hoe rams for tasks such as concrete or asphalt demolition and removal.
2. Pneumatic impact tools and equipment used at the construction site shall have intake and exhaust mufflers recommended by the manufacturers thereof to meet relevant noise limitations.
3. Provide impact noise producing equipment, e.g., jackhammers and pavement breaker(s), with noise attenuating shields, shrouds, portable barriers, or enclosures to reduce operating noise.
4. Line or cover hoppers, conveyor transfer points, storage bins, and chutes with sound-deadening material (e.g., apply wood or rubber liners to metal bin impact surfaces).
5. Provide upgraded mufflers, acoustical lining, or acoustical paneling for other noisy equipment, including internal combustion engines.
6. Avoid blasting and impact-type pile driving.
7. Use alternative procedures of construction and select a combination of techniques that generate the least overall noise and vibration. Such alternative procedures could include the following:
    a. Use electric welders powered by remote generators.
    b. Mix concrete at non-sensitive off-site locations, instead of on-site.
    c. Erect prefabricated structures instead of constructing buildings on-site.

8. Use construction equipment manufactured or modified to reduce noise and vibration emissions, such as:
    a. Electric instead of diesel-powered equipment.
    b. Hydraulic tools instead of pneumatic tools.
    c. Electric saws instead of air- or gasoline-driven saws.
9. Turn off idling equipment when not in use for periods longer than 30 minutes.
10. A hydraulic crusher (also called smasher, densifier, processor, or pulverizer) shall be used to break up the material.
11. Hydraulic splitters shall be used to break up concrete. These devices apply lateral force against the inside of holes drilled into the concrete.
12. Saws or rotary rock-cutting heads shall be used to cut bridge decks or concrete slabs into small sections that can be loaded onto trucks for disposal.
13. Chemicals can be used to split concrete.
14. Pavement and concrete demolition shall be limited to the daytime hours between 7:00 a.m. to 7:00 p.m. on weekdays or 9:00 a.m. to 7:00 p.m. on weekends and holidays.

Operational Noise Reduction Methods

In no case shall the following control measures alter the project's responsibility for compliance with applicable federal, state, and local safety ordinances and regulations, as well as project-specific construction specifications.

1. Operate equipment so as to minimize banging, clattering, buzzing, and other annoying types of noises, especially near residential and other *noise sensitive uses* during the evening and nighttime hours.
2. To the extent feasible, configure the construction site in a manner that keeps noisier equipment and activities as far as possible from *noise sensitive uses* and nearby buildings.
3. All back-up alarms should be disarmed at 8:00 p.m. and not reactivated until 7:00 a.m. on weekdays and 9:00 a.m. on weekends and local holidays. Signal persons and strobe lights must be used during periods when the back-up alarms are disarmed.
4. Maximize physical separation, as far as practicable, between noise generators and noise receptors. Separation includes the following measures:
    a. Provide enclosures for stationary items of equipment and noise barriers around particularly noisy areas at the project site.
    b. Locate stationary equipment so as to minimize noise and vibration impacts on community.
5. Minimize noise-intrusive impacts during the most noise sensitive hours.
    a. Plan noisier operations during times of highest *ambient noise* levels.
    b. Keep noise levels relatively uniform; avoid excessive and impulse noises.
    c. Turn off idling equipment.

   d. Phase in start-up and shut-down of project site equipment.

6. Select truck routes for material delivery and spoils disposal so that noise from heavy-duty trucks will have a minimal impact on *noise sensitive uses*. Proposed truck haul routes are to be submitted to the County Transportation Division for approval.
   a. Conduct truck loading, unloading, and hauling operations so noise and vibration are kept to a minimum.
   b. Route construction equipment and vehicles carrying soil, concrete or other materials over streets and routes that will cause the least disturbance to residents in the vicinity of construction sites and haul roads.
   c. Do not operate haul trucks on streets within 250 feet of school buildings during school hours or hospitals and nursing homes at any time, without a variance.
   d. Submit haul routes and staging areas to the County Transportation Division for approval at least 30 days before the required usage date.

A summary of equipment noise control methods is given in Figure D-1.

Construction Noise Propagation Path Reduction Methods

Feasible and reasonable propagation path control measures may need to be implemented to help meet the construction noise thresholds of significance. Examples of propagation path noise reduction methods are listed in this section. The implementation of one or more of these measures, along with those identified in the other sections, may be necessary to achieve compliance with the construction noise thresholds of significance.

Construction Site Noise Barriers

Moveable noise barriers can be positioned and relocated along a construction corridor, while fixed noise barriers can be located at a fixed construction site.

Moveable Construction Noise Blankets

1. Install moveable frame-mounted noise curtains, blankets or enclosures adjacent to or around noisy equipment where required to meet the project noise limits. Noise control shields shall be made of a durable, flexible composite material featuring a noise barrier layer bonded to a weather-protected, sound-absorptive material on the construction-activity side of the noise shield.
2. Provide readily removable and moveable noise shields so that they may be repositioned, as necessary, to provide noise abatement for non-stationary and stationary processes along a construction corridor as the construction process moves.
3. Installation and Maintenance:
   a. Install noise blanket shields with sound-absorptive surfaces facing the noise source.
   b. Maintain the moveable noise shields and repair damage that occurs, including, but not limited to, keeping noise shields clean and free from graffiti, and maintaining structural integrity. Promptly repair or replace gaps, holes, weaknesses in the noise shields, and openings between or under the noise shield blankets.

Moveable Construction Noise Barriers

1. Install moveable paneled noise shields, barriers or enclosures adjacent to or around noisy equipment where required to meet the project noise limits. Noise control shields shall be made of panels featuring a solid panel with a weather-protected, sound-absorptive material on the construction-activity side of the noise shield.
2. Provide readily removable and moveable noise shields so that they may be repositioned, as necessary, to provide noise abatement for non-stationary and stationary processes along a construction corridor as the construction process moves.
3. Installation and Maintenance
   a. Install paneled noise shields with sound-absorptive surfaces facing the noise source.
   b. Maintain the moveable noise shields and repair damage that occurs, including, but not limited to, keeping noise shields clean and free from graffiti, and maintaining structural integrity. Promptly repair or replace gaps, holes, weaknesses in the noise shields, and openings between or under the noise shield panels.

Fixed Construction Noise Curtains

1. Install frame-mounted noise control curtains or noise control blankets in locations adjacent to or around noisy equipment as required to meet the noise thresholds of significance and to shield the public from excessive construction noise. Noise control curtains shall be made of a durable, flexible composite material featuring a noise barrier layer bonded to a weather-protected, sound-absorptive material on one or both sides. The supporting structure shall be engineered and erected according to applicable codes.
2. Noise control curtains shall be installed, as necessary, to provide greater noise abatement for non-stationary and stationary processes.
3. Installation, Maintenance, and Removal
   a. Noise control curtains shall be installed without any gaps and with the sound absorptive side facing the construction activity area.
   b. Maintain the noise control curtains and promptly repair any damage that may occur. Gaps, holes, weaknesses in the curtain, or openings between the curtain and the ground shall be promptly repaired.
   c. The fixed noise control curtains and associated elements shall be completely removed, and the site appropriately restored upon the conclusion of the construction activity.

Fixed Noise Control Barriers

1. Install solid noise control panels or enclosures in locations adjacent to or around noisy equipment as required to meet the noise thresholds of significance and to shield the public from excessive construction noise. Noise control panels shall be made of a solid, heavy noise barrier material with a weather- protected, sound-absorptive material on the construction-activity side of the barrier. The supporting structure shall be engineered and erected according to applicable codes.
2. Noise control panels shall be erected, as necessary, to provide greater noise abatement for non-stationary and stationary processes.

3. Installation, Maintenance, and Removal
    a. Solid noise control panels shall be installed without any gaps and with the sound absorptive side facing the construction activity area.
    b. Maintain the noise control panels and promptly repair any damage that may occur. Gaps, holes, weaknesses in the panels, or openings between the panels and the ground shall be promptly repaired.
    c. The fixed noise control panels and associated elements shall be completely removed, and the site appropriately restored upon the conclusion of the construction activity.

Construction Noise Reduction Methods for Sensitive Uses

Feasible and reasonable receptor noise control measures may be implemented to meet the construction noise thresholds of significance. Examples of noise reduction methods to reduce construction noise impacts at or near sensitive uses are listed in this section. The implementation of one or more of these measures, along with those of the other sections, may be necessary to achieve compliance with the construction noise thresholds of significance.

Receptor Building Interior Noise Control Measures

1. For noise reduction at fixed, mid-term construction sites, install removable secondary acoustic window inserts (i.e., Quiet Window or equal) to existing windows in noise sensitive buildings as required to meet the identified noise threshold criteria.
2. For noise reduction at fixed, long-term construction sites, install permanent replacement acoustic windows with a STC rating 5 dB greater than the construction noise reduction needed. Where sliding doors are exposed to excessive construction noise, acoustic sliding patio doors may be installed. Careful attention must be taken to seal the frame airtight to the existing structure.
3. Install properly fitted, tubular compression-type weather strip gasketing around the door frames (jamb and head) and install automatic drop thresholds and threshold plates to exposed swinging doors. Careful attention must be taken to seal the existing door frame airtight to the existing structure.

Moveable Exterior Receptor Noise Control Barriers

1. For construction along a construction corridor, install moveable paneled noise shields or barriers at *noise sensitive uses*. Noise control shields shall be made of panels featuring a solid panel with a weather-protected, sound-absorptive material on the construction-activity side of the noise shield.
2. Provide readily removable and moveable noise shields so that they may be repositioned, as necessary, to provide greater noise abatement along a construction corridor as the construction process moves.
3. Installation and Maintenance:
    a. Install paneled noise shields with sound-absorptive surfaces facing the noise source.
    b. Maintain the moveable noise shields and repair damage that occurs, including, but not limited to, keeping noise shields clean and free from graffiti, and maintaining structural

integrity. Promptly repair or replace gaps, holes, weaknesses in the noise shields, and openings between or under the noise shield panels.

Fixed Exterior Receptor Noise Control Barriers

1. Install solid noise control panels at *noise sensitive uses* as required to meet the noise thresholds of significance and to shield the sensitive receptor from excessive construction noise. Noise control panels shall be made of a solid, heavy noise barrier material with a weather-protected, sound-absorptive material on the construction-activity side of the barrier. The supporting structure shall be engineered and erected according to applicable building codes.
2. Noise control panels shall be erected, as necessary, to provide greater noise abatement for non-stationary and stationary processes at fixed construction sites.
3. Installation, Maintenance, and Removal:
    a. Solid noise control panels shall be installed without any gaps and with the sound absorptive side facing the construction activity area.
    b. Maintain the noise control panels and promptly repair any damage that may occur. Gaps, holes, weaknesses in the panels, or openings between the panels and the ground shall be promptly repaired.
    c. The fixed noise control panels and associated elements shall be completely removed, and the site appropriately restored upon the conclusion of the construction activity.

Construction Noise Reduction Methods for Traffic Noise

Noise control measures may include increased vegetation, roadway pavement improvements and maintenance, and site and building design features. If such measures are not sufficient to reduce a project’s fair-share of traffic-generated noise at sensitive uses, a sound wall barrier may be constructed.

Figure D-1. Typical Construction Equipment Noise Sources and Control Measures

<table>
<thead>
<tr><th>Construction Equipment</th><th>Source(s) of noise</th><th colspan="2">Possible control measures (may need to be discussed with equipment manufacturer)</th><th>Possible alternative construction methods[1]</th></tr>
</thead>
<tbody>
<tr><td rowspan="4">Impact Pile Driver</td><td>Pneumatic/diesel hammer or steam winch vibrator driver</td><td colspan="2">Enclose hammer head and top of pile in an acoustical screen or acoustical blankets, apply acoustical damping to sheet steel piles to reduce vibration and resonant noise</td><td rowspan="4">1) Use alternative methods of pile driving, e.g., drill and drop, poured in place, hydraulic driver, etc.
2) Alternative methods of soil retention and ground improvement, e.g., retaining walls, ground anchors, shafts formed of pre-cast concrete segments sunk into the ground, etc.</td></tr>
<tr><td>Impact on pile</td><td colspan="2">Use resilient pad between pile and hammer head.</td></tr>
<tr><td>Crane cables, pile guides and attachments</td><td colspan="2">Careful alignment of pile and rig, lubricate screeching cables, guides and pulleys.</td></tr>
<tr><td>Power unit</td><td colspan="2">Install more efficient exhaust silencer; apply acoustical damping and protected internal noise absorption layers to vibrating panels and covers. Manufacturer’s access panels should be kept closed. Use properly ventilated acoustical enclosures where possible.</td></tr>
<tr><td>Bulldozer</td><td rowspan="9">Engine</td><td colspan="2" rowspan="9">1) Install more efficient exhaust silencer.
2) Apply acoustical damping and protected internal noise absorption layers to vibrating panels and covers.
3) Enclosure panels should be kept closed.
4) Operate without excessive engine revving.</td><td rowspan="9"></td></tr>
<tr><td>Compactor</td></tr>
<tr><td>Crane</td></tr>
<tr><td>Dump truck</td></tr>
<tr><td>Excavator</td></tr>
<tr><td>Grader</td></tr>
<tr><td>Loader</td></tr>
<tr><td>Scraper</td></tr>
<tr><td>Shovel</td></tr>
<tr><td>Compressor</td><td>Engine</td><td>Install more efficient exhaust silencer.</td><td rowspan="2">Locate the compressor or generator within an acoustical enclosure or behind an absorptive, three-sided sound wall.</td><td rowspan="2">Use electric motors instead of diesel or gasoline engines to drive compressors. If there is no electrical supply, use a reduced noise compressor or generator. A remote electrical generator can be used to supply power to several pieces of equipment.</td></tr>
<tr><td>Generator</td><td>Compressor or generator</td><td>1) Apply acoustical damping and protected noise absorption layers to internal of vibrating panels and covers.
2) Enclosure panels should be kept closed.</td></tr>
</tbody>
</table>

Construction Equipment	Source(s) of noise	Possible control measures (may need to be discussed with equipment manufacturer)		Possible alternative construction methods[1]
Pneumatic concrete breaker and tools	Tool	Install a muffler and acoustic shroud to reduce noise without impairing efficiency	Operate equipment inside a portable acoustical enclosure	Use rotary drill and buster. Use hydraulic and electric equipment. A thermal lance can be used to burn holes in concrete and to cut through large sections of concrete. For breaking large areas of concrete, use equipment which breaks concrete by bending it.
	Bit	Use a damped bit to eliminate "bit ringing." Noise drops as surface is broken through		
	Air line	Stop all air line leaks.		
	Motor	Install muffler to pneumatic saws		
Power saws	Vibration of blade and cut material	Keep saw blades sharp. Use a damped blade. Use blades with random tooth spacing. Tightly clamp material during cutting, if possible		
Rotary drills, diamond drilling and boring	Drive motor and bit	Use equipment inside an acoustical enclosure.		Use thermal lance.
Riveters	Impact on rivets	Enclose working area with acoustic barriers.		Use high tensile steel bolts instead of rivets.
Cartridge gun	Cartridge blast	Use a muffled cartridge gun.		Drilled attachments.
Pump	Engine or motor, pulsing, cavitation	Use an acoustical enclosure (allow for engine cooling and exhaust) or use motor suction and girdle mutes.		
Batch plant	Engine	1) Install more efficient silencer on diesel or gasoline engine. 2) Enclose engine.	Locate batch or mixing plant as far as possible from noise-sensitive receptors.	Use electric motor instead of diesel or gasoline engine.
Concrete mixer	Filling	Keep aggregate from falling from an excessive height.		
	Cleaning	Do not hammer the drum.		
Hammer	Impact on nail			Use screw attachment.
Impact chisel	Impact on stock			Use rotary hand milling machine.
Materials handling	Impact of material	Prevent high material drops. Shield drop areas, especially for conveyor systems		Cover surface with resilient material or unload remotely.

Construction Equipment	Source(s) of noise	Possible control measures (may need to be discussed with equipment manufacturer)	Possible alternative construction methods[1]
Steam cleaning	Escaping jet of steam, interaction with surface	Pass escaping steam through silencer or screen the cleaning area and use quieter nozzles.	

1. Care should be taken when selecting a quieter process, so that ancillary equipment noise sources, such as cranes and compressors, are mitigated so they do not become new dominant noise sources.

Figure D-2. Construction Noise Control Form

Part A – Construction Equipment Control Measures

Project: ______________ Contract No(s): ______________ Construction Phase: ______________

Measured By: ______________ of ______________ Date: ______________ Time: ______________

IMPORTANT: Attach construction equipment noise measurement location sketches (also identify other noise sources in area).

Construction Phase Equipment Inventory: Overall Project Phase Noise Reduction Requirement[1]: ______________ dBA

Code Letter (a)	Equipment				Typical 50-Ft Noise Level (dBA) (f)	Measured 50-Ft Noise Level (dBA) (g)	Equipment Noise Control Measure (h)	Measured 50-Ft Controlled Noise (dBA) (i)
	Equipment Item (b)	Make & Model (c)	ID# (d)	HP (e)				
Example	Front End Loader	Caterpillar 988	50W043xxx	375	85	91	Critical muffler	79

Notes:

1. The noise reduction requirement is the exceedance between the overall construction phase noise from Appendix C and the noise thresholds of significance.

Column (a): Code letter in sketch to indicate position of equipment during noise measurement.

Column (b): Equipment item from Figure B-2.

Column (c): Equipment manufacturer and model.

Column (d): Unique identifier (ID), such as VIN or registration number.

Column (e): Equipment rated horsepower.

Column (f): Equipment typical noise level from Figure B-2.

Column (q): Estimated noise level at 50 ft. If greater than the level in Column (f), control measures (e.g. mufflers, lower throttle, etc.) shall be implemented.

Column (h): Noise control measure(s) implemented to help achieve compliance with the noise threshold criteria at the sensitive receptor location.

Column (i): Estimated or measured controlled noise level at 50 ft

Figure D-3. Construction Noise Control Form

Part B – Propagation Path Control Measures

Project: ______________________ Contract No(s): ______________ Construction Phase: ______________

Measured By: ______________________ of ______________________ Date: ____________ Time: ____________

(Attach Construction Vicinity Sketch)

Sensitive Receptor Measurement Location During Construction Activities Without Control Measures	Measured Noise Level at Receptor Location, (dBA)*			
	Ambient L_{eq} (dBA)	L_{eq} w/ Project (dBA)	Ambient L_{max} (dBA)	L_{max} w/ Project (dBA)
Noise Threshold Level:	n/a		n/a	
1.				
2.				
3.				
4.				

Propagation Path Noise Abatement Measures	Anticipated Results
1.	1.
2.	2.
3.	3.
4.	4.

Sensitive Receptor Measurement Location During Construction Activities with Additional Control Measures	Measured Noise Level at Receptor Location, (dBA)*			
	Ambient L_{eq} (dBA)	L_{eq} w/ Project (dBA)	Ambient L_{max} (dBA)	L_{max} w/ Project (dBA)
Noise Threshold Level:	n/a		n/a	
1.				
2.				
3.				
4.				

Figure D-4. Construction Noise Control Form

Part C – Sensitive Receptor Control Measures

Project: ____________________ Contract No(s): ____________ Construction Phase: ____________

Measured By: ____________________ of ____________________ Date: __________ Time: __________

(Attach Construction Vicinity Sketch)

Sensitive Receptor Measurement Location During Construction Activities Without Control Measures	Measured Noise Level at Receptor Location, (dBA)*			
	Ambient L_{eq} (dBA)	L_{eq} w/ Project (dBA)	Ambient L_{max} (dBA)	L_{max} w/ Project (dBA)
Noise Threshold Level:	n/a		n/a	
1.				
2.				
3.				
4.				

Sensitive Receptor Noise Control Measures	Anticipated Results
1.	1.
2.	2.
3.	3.
4.	4.

Sensitive Receptor Measurement Location During Construction Activities With Additional Control Measures	Measured Noise Level at Receptor Location, (dBA)*			
	Ambient L_{eq} (dBA)	L_{eq} w/ Project (dBA)	Ambient L_{max} (dBA)	L_{max} w/ Project (dBA)
Noise Threshold Level:	n/a		n/a	
5.				
6.				
7.				
8.				

APPENDIX E. ESTIMATING CONSTRUCTION VIBRATION

Vibration source levels from typical construction equipment and operations are provided in Figure 8, and procedures on how to estimate construction vibration for damage and annoyance are provided below. For additional guidance, refer to the recommended procedure for Construction Vibration Assessment in the Federal Transit Administration's Transit Noise and Vibration Impact Assessment Manual.

Damage Assessment

Assess for building damage for each piece of equipment individually. Construction vibration is generally assessed in terms of peak particle velocity (PPV), as described in Section 7, Fundamentals of Vibration.

Determine the vibration source level (PPV_{ref}) for each piece of equipment at a reference distance of 25 feet as described in Figure 8.

Use the below equation to apply the propagation adjustment to the source reference level to account for the distance from the equipment to the receiver. Note that the equation is based on point sources with normal propagation conditions.

$$PPV_{equip} = PPV_{ref} \times \left(\frac{25}{D}\right)^{1.5}$$

Variables:

PPV_{equip}	The peak particle velocity of the equipment adjusted for distance, measured in in/sec.
PPV_{ref}	The source reference vibration level at 25 feet, measured in in/sec.
D	Distance from the equipment to the receiver, measured in feet.

Compare the PPV for each piece of equipment to the vibration damage criteria in Figure 9, which is presented by building/structural category, to assess impact.

Annoyance Assessment

Assess for annoyance for each piece of equipment individually. Ground-borne vibration related to human annoyance is related to rms velocity levels, expressed in VdB as described in Section 7, Fundamentals of Vibration.

Estimate the vibration level (L_v) using the following equation:

$$L_{v.distance} = L_{vref} - 30\,log\left(\frac{D}{25}\right)$$

Variables:

$L_{v.distance}$	The RMS velocity level adjusted for distance, measured in Vd.
L_{vref}	the source reference vibration level at 25 feet, measured in VdB.

D	Distance from the equipment to the receiver, measured in feet.

Compare the L_v determined in the equation above to the criteria in Figure 11 to assess annoyance or interference with vibration-sensitive activities due to construction vibration.

APPENDIX F. VIBRATION CONTROL MEASURES

There are several methods for reducing vibration and mitigating significant impacts from projects that exceed vibration thresholds. Examples of methods to reduce construction vibration impacts near sensitive uses are listed below.

Vibration Reduction Methods for Construction Equipment

Reduction for Impact Pile Drivers

1. Alternatives to traditional pile driving (e.g., sonic pile driving, jetting, cast-in-place, auger cast piles, non-displacement piles, pile cushioning, torque or hydraulic piles) shall be considered and implemented where feasible to reduce vibration levels. These include the following:
2. Jetting is a pile driving aid in which a mixture of air and water is pumped through high-pressure nozzles to erode the soil adjacent to the pile to facilitate placement of the pile. Jetting can be used to bypass shallow, hard layers of soil that would generate high levels of vibration at or near the surface if an impact pile driver was used.
3. If pile driving is used, pile holes shall be predrilled to the maximum feasible depth to reduce the number of blows required to seat a pile. Predrilling a hole for a pile can be used to place the pile at or near its ultimate depth, thereby eliminating most or all impact driving.
4. The use of cast-in-place or auger cast piles eliminate impact driving and limits vibration generation to the small amount generated by drilling, which is negligible.
5. Non-displacement piles such as H piles may reduce vibration from impact pile driving because this type of pile achieves its capacity from end bearing rather than from large friction transfer along the pile shaft.
6. With pile cushioning, a resilient material is placed between the driving hammer and the pile to increase the period of time over which the energy from the driver is imparted to the pile. Keeping fresh, resilient cushions in the system can reduce the vibration generated by as much as a factor of 2.
7. The use of alternative nonimpact drivers shall be considered when pile driving is used. Several types of proprietary pile driving systems have been designed specifically to reduce impact-induced vibration by using torque and down-pressure or hydraulic static loading. These methods would be expected to significantly reduce adverse vibration effects from pile placement. The applicability of these methods depends in part on the type of soil.
    a. **Fundex Tubex:** Tubex piles are installed with minimal vibration by using torque and down-pressure to produce true soil displacement piles. A patented cast-steel boring drill tip is welded to the pipe casing; then, the Tubex machine installs the pile by gripping the outside of the pipe casing with hydraulic clamps and, in essence, screwing the pile into the ground. Grout injection ports are located at the base of the tip, which allows for the injection of water as a drilling medium and for the injection of grout to produce a soil-cement mixture around the steel casing. Once the steel shell is installed and grouted, concrete and reinforcing are conventionally placed inside the pipe as structurally required by design, or the pile is left unfilled as a simple pipe pile.

b. **Still Worker:** Still Worker is a static load piling system that hydraulically installs and retrieves H-piles, pipe, and sheet piles, generating significantly less vibration than is generally associated with conventional impact and vibratory pile drivers. The system uses hydraulics to push in piles in a smooth, fluid motion that virtually eliminates vibration commonly associated with the installation of piling. Although there are no available vibration data for the system, it appears to substantially reduce vibration from pile driving. A product called the "Silent Piler" operates in a similar fashion.

c. **Vibratory pile driver:** Using a vibratory pile driver instead of an impact pile driver can reduce some vibration problems, but vibration amplitudes are similar to those of an impact pile driver because a resonance can occur as the vibratory pile driver starts up and shuts down. One alternative to conventional vibratory pile drivers is a resonance-free vibrator, or variable eccentric moment vibrator. These vibrators do not vibrate during start up and shut down, thereby avoiding the excessive vibrations that are commonly associated with traditional vibratory units.

8. Ground vibration-producing activities, such as pile driving and blasting, shall be limited to the daytime hours between 7:00 a.m. to 7:00 p.m. on weekdays or 9:00 a.m. to 7:00 p.m. on weekends and holidays. Adverse effects can be avoided if pile driving is not scheduled for times at which vibration could disturb equipment or people.

9. Minimum setback requirements for different types of ground vibration-producing activities (e.g., pile driving and blasting) for the purpose of preventing damage to nearby structures shall be established. Factors to be considered include the specific nature of the vibration-producing activity (e.g., type and duration of pile driving), local soil conditions, and the fragility/resiliency of the nearby structures. Established setback requirements (as determined by the CEQA analysis, if applicable) can be breached if a project specific, site-specific analysis is conducted by a qualified geotechnical engineer or ground vibration specialist that indicates that no structural damage would occur at nearby buildings or structures. All vibration-inducing activity within the distance parameters determined by the CEQA analysis if applicable shall be monitored and documented for ground vibration noise and vibration noise levels at the nearest sensitive land use and associated recorded data submitted to the Lead Agency so as not exceed the recommended FTA levels.

10. Minimum setback requirements for different types of ground vibration-producing activities (e.g., pile driving and blasting) for the purpose of preventing negative human response shall be established based on the specific nature of the vibration-producing activity (e.g., type and duration of pile driving), local soil conditions, and the type of sensitive receptor. Established setback requirements (as determined by the CEQA analysis, if applicable) can be breached only if a project-specific, site-specific, technically adequate ground vibration study indicates that the buildings would not be exposed to ground vibration levels in excess of 80 VdB, and ground vibration measurements performed during the construction activity confirm that the buildings are not being exposed to levels in excess of 80 VdB. All vibration-inducing activity within the distance parameters determined by the CEQA analysis shall be monitored and documented for ground vibration noise and vibration noise levels at the nearest sensitive land use and associated recorded data submitted to the Lead Agency so as not exceed the recommended FTA levels.

General Reduction for Construction Equipment

1. The use of wave barriers shall be used to treat the transmission path between the source and the receiver. The purpose of a barrier is to reflect or absorb wave energy, thereby reducing the propagation of energy between a source and a receiver. A wave barrier is typically a trench or a thin wall made of sheet piles or similar structural members. The depth and width of a wave barrier must be proportioned to the wavelength of the wave intended for screening.
2. Heavily loaded trucks shall be rerouted away from residential streets and onto streets with fewer homes.
3. Maximize distance between the source and receiver. All construction equipment on construction sites shall be operated as far away from vibration sensitive sites as reasonably possible.
4. Temporary relocation of residents shall be considered in the event that significant noise and vibration impacts cannot be mitigated to a reasonable level.
5. In the absence of measures than can physically reduce induced ground vibration, the public shall be informed about the project and the potential effects of construction activities to avoid adverse reactions.
6. Earthmoving, blasting and ground-impacting operations shall be phased so as not to occur simultaneously in areas close to sensitive receptors, to the extent feasible[3]. The total vibration level produced could be significantly less when each vibration source is operated at separate times.
7. If damage to a historic building cannot be mitigated, the contractor shall use the Secretary of the Interior's Standards to repair or reinforce historic buildings.

[3] "Feasible" means "capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, legal, social, and technological factors." This definition is consistent with the definition of "feasible" set forth in CEQA (Pub. Res. Code, § 21066.1) and the CEQA Guidelines (§ 15164). The County shall be solely responsible for making this feasibility determination.

APPENDIX G. RESOURCES & REFERENCES

Source	Managing Agency/Organization	Online Access
Resources		
Ventura County CEQA Implementation Manual	Ventura County Resource Management Agency (RMA) Planning Division	PDF | Website
Ventura County Initial Study Assessment Guidelines	Ventura County RMA Planning Division	PDF | Website
Ventura County Initial Study Checklist Template	Ventura County RMA Planning Division	PDF | Website
References		
Noise and Vibration Guidance from the California Department of Transportation	California Department of Transportation (Caltrans)	Website
Transportation and Construction Vibration Guidance Manual	Caltrans	PDF | Website
Transit Noise and Vibration Impact Assessment Manual	Federal Transit Administration	PDF | Website
Current Practices to Address Construction Vibration and Potential Effects to Historic Buildings Adjacent to Transportation Projects	Wilson Ihrig	PDF | Website
Highway Construction Noise Handbook	Federal Highway Administration	Website

APPENDIX H. GLOSSARY

Ambient Noise. Defined in the General Plan, as may be amended, which states: the composite of noise from all sources; the normal or existing level of environmental noise at a given location. The ambient noise levels are expressed as L_{eqT} or *CNEL* as judged appropriate to the situation.

A-Weighted Sound Level (dBA or dB(A)). Defined in the General Plan, as may be amended, which states: the sound pressure level in decibels as measured on a sound level meter using the A-weighting filter network specified in the American National Standards Institute Specification for Sound Level Meters, ANSI S 1.4–1983. 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.

Community Noise Equivalent Level (CNEL). Defined in the General Plan, as may be amended, which states: the average *A-weighted sound level* during a 24-hour day, obtained after addition of five decibels to noise levels occurring in the evening from 7:00 p.m. to 10:00 p.m. and the addition of 10 decibels to sound levels measured in the night between 10:00 p.m. and 7:00 a.m.

Decibel (dB). Defined in the General Plan, as may be amended, which states: a physical unit commonly used to describe noise levels. It is a unit for describing the amplitude of sound, as heard by the human ear. A dB is the logarithmic ratio of two like pressure quantities, with one pressure quantity being a reference sound pressure. For sound pressure in air the standard reference quantity is generally considered to be 20 micropascals, which directly corresponds to the threshold of human hearing and is equivalent to 0 dB, the quietest sound a human can hear. The use of the decibel is a convenient way to handle the million-fold range of sound pressures to which the human ear is sensitive.

Noise Sensitive Uses. Defined in the General Plan, as may be amended, which states: land uses where noise exposure could result in health-related risks to individuals, as well as places where quiet is an essential element of their intended purpose. These uses include residences; schools; nursing homes; historic sites; cemeteries; parks, recreation, and open space areas; hospitals and care facilities; hotels and other short-term lodging (e.g., bed and breakfasts, motels); places of worship; and libraries.

Transit Use. A public transportation option that conveys passengers such as, but not limited to a bus, light rail system, or passenger train.

Vibration Sensitive Uses. Defined in the Federal Transit Administration's Transit Noise and Vibration Assessment Manual as:

- **Vibration Sensitive Use Category 1 (High Sensitivity) –** Buildings where vibration levels, including those below the threshold of human annoyance, would interfere with operations within the building. Examples include buildings where vibration sensitive research and manufacturing is conducted, including computer chip manufacturing, hospitals with vibration sensitive equipment, and universities conducting physical research operations. The building's degree of sensitivity to vibration is dependent on the specific equipment that will be affected by the vibration. Equipment moderately sensitive to vibration, such as high-resolution lithographic equipment, optical microscopes which can be impacted at vibration levels below the threshold of human annoyance, and electron microscopes with vibration isolation systems are included in this category. For equipment that is more sensitive, a Detailed Vibration Analysis must be conducted.

- **Vibration Sensitive Use Category 2 (Residential) –** All residential land uses and buildings where people normally sleep, such as hotels and hospitals. Transit-generated ground-borne vibration and noise from subways or surface running trains are considered to have a similar effect on receivers. Even in noisy urban areas, the bedrooms will often be in quiet buildings with effective noise insulation. However, ground-borne vibration and noise are experienced indoors, and building occupants have practically no means to reduce their exposure. Therefore, occupants in noisy urban areas are just as likely to be exposed to ground-borne vibration and noise as those in quiet suburban areas.
- **Vibration Sensitive Use Category 3 (Institutional) –** Institutions and offices that have vibration- sensitive equipment and have the potential for activity interference such as schools, places of worship, medical offices. Commercial or industrial uses including office buildings are not included in this category unless there is vibration sensitive activity or equipment within the building. As with noise, the use of the building determines the vibration sensitivity.