Appendix B

Construction Noise & Vibration Assessment

2850 WEST BAYSHORE ROAD
CONSTRUCTION NOISE & VIBRATION ASSESSMENT

PALO ALTO, CALIFORNIA

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INTRODUCTION

This report evaluates the potential of the construction of a multi-family residential project at 2850 Bayshore Road in Palo Alto, California to result in significant noise and vibration impacts and identifies noise and vibration control measures that could be incorporated into the project to avoid potentially significant impacts on surrounding noise sensitive land uses. The subject multi-family residential project would include 48 residential units in eight three-story townhome style buildings on a ± 2.34 Acre site which is current occupied by a vacant office building and associated surface parking and is bordered by The Head's Up Child development center and the Emerson School to the north, Greer Park to the west and south and W. Bayshore Road and U.S. Highway 101 (U.S. 101) to the east.

This report is divided into two sections: 1) the Setting Section which provides a brief description of the fundamentals of environmental noise and groundborne vibration, summarizes applicable regulatory criteria, and discusses the results of the ambient noise monitoring survey completed to document existing noise conditions; and 2) the Impacts and Control Measures Section which describes the criteria used to evaluate potential project impacts, provides a discussion of each project impact, and identifies measures to control and reduce the potential impacts on sensitive receptors in the vicinity.

SETTING

FUNDAMENTALS OF ENVIRONMENTAL NOISE

Noise may be defined as unwanted sound. Noise is usually objectionable because it is disturbing or annoying. The objectionable nature of sound could be caused by its *pitch* or its *loudness*. *Pitch* is the height or depth of a tone or sound, depending on the relative rapidity (*frequency*) of the vibrations by which it is produced. Higher pitched signals sound louder to humans than sounds with a lower pitch. *Loudness* is intensity of sound waves combined with the reception characteristics of the ear. Intensity may be compared with the height of an ocean wave in that it is a measure of the amplitude of the sound wave.

In addition to the concepts of pitch and loudness, there are several noise measurement scales which are used to describe noise in a particular location. A *decibel (dB)* is a unit of measurement which indicates the relative amplitude of a sound. The zero on the decibel scale is based on the lowest sound level that the healthy, unimpaired human ear can detect. Sound levels in decibels are calculated on a logarithmic basis. An increase of 10 decibels represents a ten-fold increase in acoustic energy, while 20 decibels is 100 times more intense, 30 decibels is 1,000 times more intense, etc. There is a relationship between the subjective noisiness or loudness of a sound and its intensity. Each 10 decibel increase in sound level is perceived as approximately a doubling of loudness over a fairly wide range of intensities. Technical terms are defined in Table 1.

There are several methods of characterizing sound. The most common in California is the *A-weighted sound level (dBA)*. This scale gives greater weight to the frequencies of sound to which the human ear is most sensitive. Representative outdoor and indoor noise levels in units of dBA are shown in Table 2. Because sound levels can vary markedly over a short period of time, a method for describing either the average character of the sound or the statistical behavior of the variations must be utilized. Most commonly, environmental sounds are described in terms of an average level that has the same acoustical energy as the summation of all the time-varying events. This *energy-equivalent sound/noise descriptor* is called L_{eq}. The most common averaging period is hourly, but L_{eq} can describe any series of noise events of arbitrary duration. The scientific instrument used to measure noise is the sound level meter. Sound level meters can accurately measure environmental noise levels to within about plus or minus 1 dBA. Various computer models are used to predict environmental noise levels from sources, such as roadways and airports. The accuracy of the predicted models depends upon the distance the receptor is from the noise source. Close to the noise source, the models are accurate to within about +/-1 to 2 dBA.

TABLE 1 Definition of Acoustical Terms Used in this Report

Term	Definition
Decibel, dB	A unit describing, the amplitude of sound, equal to 20 times the logarithm to the base 10 of the ratio of the pressure of the sound measured to the reference pressure. The reference pressure for air is 20 micro-Pascals.
Sound Pressure Level	Sound pressure is the sound force per unit area, usually expressed in micro-Pascals (or 20 micro Newtons per square meter), where 1 Pascal is the pressure resulting from a force of 1 Newton exerted over an area of 1 square meter. The sound pressure level is expressed in decibels as 20 times the logarithm to the base 10 of the ratio between the pressures exerted by the sound to a reference sound pressure (e. g., 20 micro-Pascals). Sound pressure level is the quantity that is directly measured by a sound level meter.
Frequency, Hz	The number of complete pressure fluctuations per second above and below atmospheric pressure. Normal human hearing is between 20 Hz and 20,000 Hz. Infrasonic sound are below 20 Hz and Ultrasonic sounds are above 20,000 Hz.
A-Weighted Sound Level, dBA	The sound pressure level in decibels as measured on a sound level meter using the A-weighting filter network. The A-weighting filter de-emphasizes the very low and very high frequency components of the sound in a manner similar to the frequency response of the human ear and correlates well with subjective reactions to noise.
Equivalent Noise Level, L_{eq}	The average A-weighted noise level during the measurement period.
L_{max}, L_{min}	The maximum and minimum A-weighted noise level during the measurement period.
L_{01}, L_{10}, L_{50}, L_{90}	The A-weighted noise levels that are exceeded 1%, 10%, 50%, and 90% of the time during the measurement period.
Day/Night Noise Level, L_{dn} or DNL	The average A-weighted noise level during a 24-hour day, obtained after addition of 10 decibels to levels measured in the night between 10:00 pm and 7:00 am.
Community Noise Equivalent Level, CNEL	The average A-weighted noise level during a 24-hour day, obtained after addition of 5 decibels in the evening from 7:00 pm to 10:00 pm and after addition of 10 decibels to sound levels measured in the night between 10:00 pm and 7:00 am.
Ambient Noise Level	The composite of noise from all sources near and far. The normal or existing level of environmental noise at a given location.
Intrusive	That noise which intrudes over and above the existing ambient noise at a given location. The relative intrusiveness of a sound depends upon its amplitude, duration, frequency, and time of occurrence and tonal or informational content as well as the prevailing ambient noise level.

Source: Handbook of Acoustical Measurements and Noise Control, Harris, 1998.

Since the sensitivity to noise increases during the evening and at night -- because excessive noise interferes with the ability to sleep -- 24-hour descriptors have been developed that incorporate artificial noise penalties added to quiet-time noise events. The *Community Noise Equivalent Level* (*CNEL*) is a measure of the cumulative noise exposure in a community, with a 5 dB penalty added to evening (7:00 pm - 10:00 pm) and a 10 dB addition to nocturnal (10:00 pm - 7:00 am) noise levels. The *Day/Night Average Sound Level* (*DNL* or L_{dn}) is essentially the same as CNEL, with the exception that the evening time period is dropped and all occurrences during this three-hour period are grouped into the daytime period.

TABLE 2 Typical Noise Levels in the Environment

Common Outdoor Activities	Noise Level (dBA)	Common Indoor Activities
	110 dBA	Rock band
Jet fly-over at 1,000 feet		
	100 dBA	
Gas lawn mower at 3 feet		
	90 dBA	
Diesel truck at 50 feet at 50 mph		Food blender at 3 feet
	80 dBA	Garbage disposal at 3 feet
Noisy urban area, daytime		
Gas lawn mower, 100 feet	70 dBA	Vacuum cleaner at 10 feet
Commercial area		Normal speech at 3 feet
Heavy traffic at 300 feet	60 dBA	
		Large business office
Quiet urban daytime	50 dBA	Dishwasher in next room
Quiet urban nighttime	40 dBA	Theater, large conference room
Quiet suburban nighttime		
	30 dBA	Library
Quiet rural nighttime		Bedroom at night, concert hall (background)
	20 dBA	
		Broadcast/recording studio
	10 dBA	
	0 dBA	

Source: Technical Noise Supplement (TeNS), California Department of Transportation, September 2018.

Effects of Noise

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

Annoyance: Attitude surveys are used for measuring the annoyance felt in a community for noises intruding into homes or affecting outdoor activity areas. In these surveys, it was determined that the causes for annoyance include interference with speech, radio and television, house vibrations, and interference with sleep and rest. The L_{dn} as a measure of noise has been found to provide a valid correlation of noise level and the percentage of people annoyed. People have been asked to judge the annoyance caused by aircraft noise and ground transportation noise. There continues to be disagreement about the relative annoyance of these different sources. When measuring the percentage of the population highly annoyed, the threshold for ground vehicle noise is about 50 dBA L_{dn}. At a L_{dn} of about 60 dBA, approximately 12 percent of the population is highly annoyed. When the L_{dn} increases to 70 dBA, the percentage of the population highly annoyed increases to about 25-30 percent of the population. There is, therefore, an increase of about 2 percent per dBA between a L_{dn} of 60-70 dBA. Between a L_{dn} of 70-80 dBA, each decibel increase increases by about 3 percent the percentage of the population highly annoyed. People appear to respond more adversely to aircraft noise. When the L_{dn} is 60 dBA, approximately 30-35 percent of the population is believed to be highly annoyed. Each decibel increase to 70 dBA adds about 3 percentage points to the number of people highly annoyed. Above 70 dBA, each decibel increase results in about a 4 percent increase in the percentage of the population highly annoyed.

Fundamentals of Groundborne Vibration

Ground vibration consists of rapidly fluctuating motions or waves with an average motion of zero. Several different methods are typically used to quantify vibration amplitude. One method is the Peak Particle Velocity (PPV). The PPV is defined as the maximum instantaneous positive or negative peak of the vibration wave. In this report, a PPV descriptor with units of mm/sec or in/sec is used to evaluate construction generated vibration for building damage and human complaints. Table 3 displays the reactions of people and the effects on buildings that continuous or frequent intermittent vibration levels produce. The guidelines in Table 3 represent syntheses of vibration criteria for human response and potential damage to buildings resulting from construction vibration.

Construction activities can cause vibration that varies in intensity depending on several factors. The use of pile driving and vibratory compaction equipment typically generates the highest construction related groundborne vibration levels. Because of the impulsive nature of such activities, the use of the PPV descriptor has been routinely used to measure and assess groundborne vibration and almost exclusively to assess the potential of vibration to cause damage and the degree of annoyance for humans.

The two primary concerns with construction-induced vibration, the potential to damage a structure and the potential to interfere with the enjoyment of life, are evaluated against different vibration limits. Human perception to vibration varies with the individual and is a function of physical setting and the type of vibration. Persons exposed to elevated ambient vibration levels, such as people in an urban environment, may tolerate a higher vibration level.

Structural damage can be classified as cosmetic only, such as paint flaking or minimal extension of cracks in building surfaces; minor, including limited surface cracking; or major, that may threaten the structural integrity of the building. Safe vibration limits that can be applied to assess the potential for damaging a structure vary by researcher. The damage criteria presented in Table 3 include several categories for ancient, fragile, and historic structures, the types of structures most at risk to damage. Most buildings are included within the categories ranging from “Historic and some old buildings” to “Modern industrial/commercial buildings”. Construction-induced vibration that can be detrimental to the building is very rare and has only been observed in instances where the structure is at a high state of disrepair and the construction activity occurs immediately adjacent to the structure.

The annoyance levels shown in Table 3 should be interpreted with care since vibration may be found to be annoying at lower levels than those shown, depending on the level of activity or the sensitivity of the individual. To sensitive individuals, vibrations approaching the threshold of perception can be annoying. Low-level vibrations frequently cause irritating secondary vibration, such as a slight rattling of windows, doors, or stacked dishes. The rattling sound can give rise to exaggerated vibration complaints, even though there is very little risk of actual structural damage.

TABLE 3: Reaction of People and Damage to Buildings from Continuous or Frequent Intermittent Vibration Levels

Velocity Level, PPV (in/sec)	Human Reaction	Effect on Buildings
0.01	Barely perceptible	No effect
0.04	Distinctly perceptible	Vibration unlikely to cause damage of any type to any structure
0.08	Distinctly perceptible to strongly perceptible	Recommended upper level of the vibration to which ruins and ancient monuments should be subjected
0.1	Strongly perceptible	Virtually no risk of damage to normal buildings
0.25	Strongly perceptible to severe	Threshold at which there is a risk of damage to historic and some old buildings.
0.3	Strongly perceptible to severe	Threshold at which there is a risk of damage to older residential dwellings such as plastered walls or ceilings
0.5	Severe - Vibrations considered unpleasant	Threshold at which there is a risk of damage to newer residential structures

Source: Transportation and Construction Vibration Guidance Manual, CalTrans, September 2013.

REGULATORY BACKGROUND

This section describes the relevant guidelines, policies, and standards established by the City of Palo Alto. The State CEQA Guidelines, Appendix G, are used to assess the potential significance of impacts pursuant to local General Plan policies and Municipal Code standards. A summary of the applicable regulatory criteria is provided below.

State of California

State CEQA Guidelines.

The California Environmental Quality Act (CEQA) contains guidelines to evaluate the significance of effects of environmental noise attributable to a proposed project. Under CEQA, temporary construction noise and vibration impacts would be considered significant if the project would result in:

(a) Generation of a substantial temporary or permanent increase in ambient noise levels in the vicinity of the project in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies,

(b) Generation of excessive groundborne vibration or groundborne noise levels,

City of Palo Alto

Comprehensive Plan 2030.

Chapter 4 of the 2030 Comprehensive Plan (Natural Environment) discusses noise. The following goals and policies apply to the construction of the proposed project:

Goal N-6: An environment that minimizes the adverse impacts of noise.

Policy N-6.3 Protect the overall community and especially sensitive noise receptors, including schools, hospitals, convalescent homes, senior and child-care facilities and public conservation land from unacceptable noise levels from both existing and future noise sources, including construction noise.

Policy N-6.7 While a proposed project is in the development review process, the noise impact of the project on existing residential land uses, public open spaces and public conservation land should be evaluated in terms of the increase in existing noise levels for the potential for adverse community impact, regardless of existing background noise levels. If an area is below the applicable maximum noise guideline, an increase in noise up to the maximum should not necessarily be allowed.

Policy N-6.11 Continue to prioritize construction noise limits around sensitive receptors, including through limiting construction hours and individual and cumulative noise from construction equipment.

Municipal Code.

The noise ordinance of the City of Palo Alto limits noise levels caused by stationary noise sources and construction on adjacent properties. The applicable portions of the noise code are as follows:

9.10.020 Definitions.

(a) *"Local ambient"* means the lowest sound level repeating itself during a six-minute period as measured with a precision sound level meter, using slow response and "A" weighting. The minimum sound level shall be determined with the noise source at issue silent, and in the same location as the measurement of the noise level of the source or sources at issue. However, for purposes of this chapter, in no case shall the local ambient be considered or determined to be less than: (1) Thirty (30) dBA for interior noise in Section 9.10.030(b); (2) Forty (40) dBA in all other sections. If a significant portion of the local ambient is produced by one or more individual identifiable sources which would otherwise be operating continuously during the six-minute measurement period and contributing significantly to the ambient sound level, determination of the local ambient shall be accomplished with these separate identifiable noise sources silent.

9.10.030 Residential property noise limits.

No person shall produce, suffer or allow to be produced by any machine, animal, or device, or any combination of same, on residential property, a noise level more than six (6) dB above the local ambient at any point outside the property plane.

9.10.040 Commercial and industrial property noise limits.

No person shall produce, suffer or allow to be produced by any machine or device, or any combination of same, on commercial or industrial property, a noise level more than eight (8) dB above the local ambient at any point outside of the property plane.

9.10.050 Public property noise limits.

No person shall produce, suffer or allow to be produced by any machine or device, or any combination of same, on public property, a noise level more than fifteen (15) dB above the local ambient at a distance of twenty-five feet or more, unless otherwise provided in this chapter.

9.10.060 Special Provisions.

The special exceptions listed in this section shall apply, notwithstanding the provisions of Sections 9.10.030 through 9.10.050. Said exceptions shall apply only to the extent and during the hours specified in each of the following enumerated exceptions.

(a) Construction. Except for construction on residential property, construction, alteration and repair activities which are authorized by valid city building permit shall be prohibited on Sundays and holidays and shall be prohibited except between the hours of eight a.m. and six p.m. Monday through Friday, nine a.m. and six p.m. on Saturday provided that the construction, demolition or repair activities during those hours meet the following standards:

(1) No individual piece of equipment shall produce a noise level exceeding one hundred ten (110) dBA at a distance of twenty-five (25) feet. If the device is housed within a structure on the property, the measurement shall be made out-side the structure at a distance as close to twenty-five feet from the equipment as possible.

(2) The noise level at any point outside of the property plane of the project shall not exceed one hundred ten (110) dBA.

(3) The holder of a valid construction permit for a construction project in a non-residential zone shall post a sign at all entrances to the construction site upon commencement of construction, for the purpose of informing all contractors and subcontractors, their employees, agents, materialmen and all other persons at the construction site, of the basic requirements of this chapter.

EXISTING NOISE ENVIRONMENT

The project site is currently occupied by a vacant office building and an associated surface level parking lot, located west of W. Bayshore Road and U.S. 101 beyond and is bordered by the Head's Up Child development center and the Emerson School to the north and Greer Park to the west and south. The primary ambient noise source affecting the site and surrounding uses is traffic on U.S. 101. The results of a current short-term daytime noise monitoring survey conducted on the project site and those of prior long term noise measurements along the U.S. 101 traffic corridor for the U.S. 101 Managed Lanes Project[1] were used to determine the average daytime ambient noise levels at the Head's Up Child development center and the Emerson School to the north and Greer Park to the west and south.

The current short-term noise measurement survey was conducted between 12:00pm and 1:10 pm September 13, 2021[2], with Larson Davis Laboratories (LDL) Type I Model LXT Sound Level Meters fitted with a ½-inch pre-polarized condenser microphones and windscreens. The meters were calibrated with a Larson Davis Model CA250 precision acoustic calibrator prior to and following the measurement survey. For this survey a fixed monitor (ST-1), which logged noise data at 10-minute intervals was placed on the northern project property line the approximate setback of the adjacent education buildings to the north from U.S 101 (approximately 150 feet from the highway) and 10-minute duration noise measurements were conducted simultaneously with this monitor at the middle of the northern property line (ST-2), the northwest corner of the site (ST-3), the southwest corner of the site (ST-4), and at the middle of western property line (ST-5). These measurement locations are shown in Figure 1, following. The measurement results including the energy equivalent noise level (L_{eq}), maximum (L_{max}), minimum (L_{min}), and the noise levels exceeded 10, 50 and 90 percent of the time (indicated as L_{10}, L_{50} and L_{90}) are shown in Table 3, below.

Table 3: Short term Noise Measurement Survey Results (dBA, 9/13/2021)

Time	Location	L_{max}	L_{01}	L_{10}	L_{eq}	L_{50}	L_{90}	L_{min}	L_{dn}[1]
12:00 to 12:10pm	ST-2 (North PL ~250 ft. to 101 CL.)	72	72	69	68	68	65	62	**72**
	ST-1 (North PL, 150 ft. to 101 CL.)	*79*	*77*	*74*	*73*	*72*	*70*	*65*	***77***
12:20 to 12:30pm	ST-3 (NW corner, ~350 ft. to 101 CL.)	69	67	65	63	63	61	58	**67**
	ST-1 (North PL, 150 ft. to 101 CL.)	*78*	*76*	*74*	*72*	*72*	*70*	*68*	***77***
12:40 to 12:50pm	ST-4 (SW corner, ~350 ft. to 101 CL.)	66	65	63	62	62	60	58	**66**
	ST-1 (North PL, 150 ft. to 101 CL.)	*79*	*77*	*75*	*73*	*73*	*71*	*65*	***77***
13:00 to 13:10pm	ST-5[2] (West PL ~350 ft. to 101 CL.)	63	60	53	52	50	49	48	**55**
	ST-1 (North PL, 150 ft. to 101 CL.)	*86*	*78*	*75*	*73*	*72*	*70*	*67*	***77***

[1] The L_{dn} at ST-1 is approximated by correlation to the corresponding measurement period for the Managed Lanes long-term measurements, and the L_{dn} at ST-1 through ST-5 is approximated by correlation to the corresponding measurement period at ST-1

[2] Noise levels at ST-5 received significant U.S. 101 noise shielding from existing site buildings.

Daytime noise data from long term measurements made for the U.S.101 Managed Lanes to the north and south of the project site and the positions were used to calculate the estimated maximum, average and minimum daytime noise levels at the short-term measurement positions on the site

[1] Illingworth & Rodkin, Inc., "U.S. 101 Managed Lanes Project Noise Study Report," October 2017.

[2] Construction Activities will occur during the daytime hours. Based on the U.S. 101 Managed Lanes Project long-term measurement results the average daytime noise levels were at a relatively constant peak between the hours of 6am and 4pm. Short terms measurements were conducted during this period to document typical peak site noise levels and allow for appropriate comparison to the Managed Lanes peak hour data.

perimeter[3]. The results of these calculations are shown in Table 4.

Figure 1: Short-term noise measurement locations

Table 4: Estimated existing daytime ambient noise levels at site perimeter, dBA

Location		L_{max}	L_{eq}	L_{01}	L_{10}	L_{50}	L_{90}	L_{min}
ST-1 (North PL, 150 ft. to 101 CL.)	maximum	**93**	**76**	88	77	73	71	68
	Average	**80**	**72**	77	74	71	69	66
	minimum	**73**	**69**	72	71	68	65	62
ST-2 (North PL 250 ft. to 101 CL.)	maximum	**86**	**71**	83	72	68	66	65
	Average	**74**	**67**	72	69	66	64	63
	minimum	**67**	**64**	67	66	63	61	59
ST-3 (NW corner, 350 ft. to 101 CL.)	maximum	**84**	**67**	79	68	64	61	59
	Average	**72**	**63**	69	64	62	59	56
	minimum	**64**	**60**	63	62	59	56	53
ST-4 (SW corner, 350 ft. to 101 CL.)	maximum	**80**	**65**	76	66	62	60	61
	Average	**68**	**61**	65	62	60	59	59
	minimum	**60**	**58**	60	59	57	55	55
ST-5 (West PL 350 ft. to 101 CL.) *Measured noise reduced by significant noise shielding from existing site buildings.*	maximum	**69**	**54**	70	55	51	50	49
	Average	**57**	**50**	59	52	49	48	47
	minimum	**50**	**47**	54	49	46	45	43

[3] These sites are identified as L117 (Rear yard of 2047 Edgewood Drive, Palo Alto), and L122 (Rear yard of 3381 Kenneth Drive, Palo Alto), were made at respective distances of approximately 180 and 475 feet from the centerline of U.S. 101.

POTENTIAL NOISE AND VIBRATION IMPACTS

SIGNIFICANCE CRITERIA

The following criteria were used to evaluate the significance of noise and vibration resulting from the project:

1. A significant noise impact would be identified if the project would generate a substantial temporary or permanent noise level increase over ambient noise levels at existing noise-sensitive receptors surrounding the project site and that would exceed applicable noise standards presented in the City of Palo Alto's Comprehensive Plan or Municipal Code at existing noise-sensitive receptors surrounding the project site.
   a. Pursuant to Section 9.10.060 of the Municipal Code the allowable construction hours between 8:00 a.m. and 6:00 p.m. Monday through Friday and between 9:00 a.m. and 6:00 p.m. on Saturdays, no individual piece of equipment shall exceed 110 dBA at a distance of 25 feet or at a distance of 25 feet from the structure in which the equipment is enclosed. Further, 110 dBA shall not be exceeded at any point beyond the property plane of the construction site during allowable hours. For construction activities outside the allowable hours, noise levels shall not exceed local ambient levels at adjacent school properties by 8 dBA or at the adjacent public parks by 15 dBA.
2. A significant vibration impact would be identified if the construction of the project would generate excessive vibration levels surrounding receptors. Groundborne vibration levels exceeding 0.3 in/sec PPV would have the potential to result in cosmetic damage to normal buildings.

Potential Impact 1: Temporary Construction Noise. Existing noise-sensitive land uses would be exposed to a temporary increase in ambient noise levels due to project construction activities. **This is a less-than-significant impact with the incorporation of standard controls.**

Noise impacts resulting from construction depend upon the noise generated by various pieces of construction equipment, the timing and duration of noise-generating activities, and the distance between construction noise sources and noise-sensitive areas. Construction noise impacts primarily result when construction activities occur during noise-sensitive times of the day, the construction occurs in areas immediately adjoining noise-sensitive land uses, or when construction lasts over extended periods of time.

Project construction is anticipated to begin in July of 2022 and to be completed in early 2024. This extended construction schedule accounts for any potential delays or setbacks to the project due to current uncertain social/economic conditions. Construction of the project would involve demolition, site preparation, grading and excavation, trenching, building erection, interior/architectural coating, and paving. Typical equipment for each of these phases was used as inputs into the Federal Highway Administration (FHWA) Roadway Construction Noise Model 2 (RCNM2) to predict the combined average noise level for each phase.

To model worst-case conditions, it was assumed that all construction equipment per phase would be operating simultaneously. For construction noise, the use of multiple pieces of equipment simultaneously would add together as a collective noise source. Thus, while every piece of equipment per phase may be scattered throughout the site, the noise-sensitive receptors surrounding the site would be subject to the collective noise source generated by all equipment operating at once. Considering this and to conduct a conservative assessment of construction noise impacts at the receiving property lines of noise-sensitive receptors, the collective worst-case hourly average noise level for each phase was considered with all equipment at the geometrical center of the nearest building footprint to the receptor and propagated to the near property line of this use.

From a review of the project plans it was determined that the geometrical centers of the project buildings nearest to the Head's Up Child development center and the Emerson School to the north are approximately 35 feet and 70 feet from the shared property line, and the shared with geometrical centers of the project buildings nearest to Greer Park are 70 feet from this shared property line. Table 5 shows the anticipated construction noise levels calculated for each phase of construction at distances of 35 and 70 feet from the center of activities determined using the Roadway Construction Noise Model 2 (RCNM2).

Table 5: Calculated Construction Noise Levels for Each Phase of Construction

Construction Phase	At Distance of 35 ft.		At Distance of 70 ft.	
	L_{eq}, dBA	L_{max}, dBA	L_{eq}, dBA	L_{max}, dBA
Demolition	79	90	73	84
Site Preparation	84	91	78	85
Grading/Excavation	85	92	79	86
Trenching/Foundation	82	91	76	85
Building – Exterior	83	88	77	82
Building – Interior/Architectural Coating	69	70	63	64
Paving	88	91	82	85

As indicated in Table 5, at the center of the project buildings nearest the northern (school use) property line, maximum instantaneous noise levels generated by project construction equipment are calculated to range from 64 to 92 dBA L_{max} and 63 to 88 dBA L_{eq} while the center of the project buildings nearest the western and southern (park use) property line, are calculated to range from 64 to 85 dBA L_{max} and 63 to 82 dBA $L_{eq.}$

A comparison of the estimated construction noise levels at the northern, western, and southern property lines to the existing (ambient) noise levels in these areas are shown in Table 6.

Table 6: Estimated existing daytime ambient noise levels at site perimeter, dBA

	North[1] and Southeast PL (ST-1)		North[1] and Southcentral PL (ST-2)		Western PL not obstructed (ST-3, ST-4)		Western PL obstructed[2] (ST-5)	
	L_{max}	L_{eq}	L_{max}	L_{eq}	L_{max}	L_{eq}	L_{max}	L_{eq}
Average Ambient	**80**	**72**	**74**	**67**	**68-72**	**61-63**	**57**	**50**
Demolition	84	73	90	79	84	73	84	73
Site Preparation	85	78	91	84	85	78	n.a.	n.a.
Grading/Excavation	86	79	92	85	86	79	n.a.	n.a.
Trenching/Foundation	85	76	91	82	85	76	n.a.	n.a.
Building - Exterior	82	77	88	83	82	77	n.a.	n.a.
Building - Interior/Arch. Ctg.	64	63	70	69	64	63	n.a.	n.a.
Paving	85	82	91	88	85	82	n.a.	n.a.

[1] Though sound levels on the northern and southern sides of the property would differ somewhat sue to similar setbacks from U.S. 101 (the primary noise source), they consider the same for the purpose of this analysis.
[2] After the existing structures on the site are demolished and removed the ambient condition on the western property line will be similar to those reported for unobstructed conditions.

These noise level comparisons indicate that the average ambient maximum (L_{max}) and average (L_{eq}) sound levels at the northern and southern property lines may be exceeded by up to 18 to 27 dBA during the loudest and closest demolition and construction activities. However, considering that all site demolition and construction will occur within the City's allowable construction hours of 8:00 a.m. and 6:00 p.m. Monday through Friday and between 9:00 a.m. and 6:00 p.m. on Saturdays, and that no individual pieces of equipment would produce a noise level exceeding one hundred ten (110) dBA at any point outside of the property plane, noise from project construction would not exceed the City of Palo Alto's noise ordinance of the limits and this impact would be considered **less-than-significant**.

However, seeing that the school use to the north would be operating during the City's allowable construction hours, that high construction noise levels may interfere with educational activities at this use, and that the school buildings are single story structures where technically and economically feasible the following construction best management practices and noise controls should considered as part of the conditions of approval:

1. All construction activity should be conducted to minimize the noise impact at the adjacent property boundaries wherever possible.
2. Construction equipment should be well maintained and used judiciously to be as quiet as practical.
3. Equip all internal combustion engine-driven equipment with mufflers, which are in good condition and appropriate for the equipment.
4. Utilize "quiet" models of air compressors and other stationary noise sources where feasible. Select hydraulically or electrically powered equipment and avoid pneumatically powered equipment where feasible.
5. Prohibit unnecessary idling of internal combustion engines, by requiring that all equipment shall be turned off if not in use for more than 5 minutes.
6. Where possible combine noisy operations so that they occur in the same time period. The total noise level produced will not be significantly greater than the level produced if the operation were performed separately (and the noise will be of shorter duration).
7. Erect construction noise barriers, such as mass loaded construction blankets on temporary fencing or a solid plywood construction barrier, at the northern perimeter of the site prior to commencement of ground level construction activities in such a way as to block direct noise transfer to exposed facades of the adjacent school grounds and buildings. These noise barriers should be installed without cracks or gaps in the face or large or continuous gaps at the base. Barriers can be built of 3/4" plywood panels or other solid sheet materials with a minimum surface weight of 2.5 lb./sq. ft. or using mass loaded construction noise barrier blankets on temporary fencing, hung off of guy wires, or laid over existing structures, with a minimum STC rating of 25. Barriers on the site perimeter should have a minimum height of eight (8) feet above the surrounding grade. These barriers should remain in place during all ground level work such as demolition, excavation, grading, shoring, building pad preparation, foundation work, and first & second floor framing and finish work. A closable gate made of solid barrier material is allowable but must be maintained closed when not in use.
8. Exterior building sheathing at the upper floors should be installed as early as is feasible to act as a barrier to noise at the adjacent uses.
9. Locate large equipment, compressors, or generators at least 30 feet from the site perimeters when work is not being done near these uses. Where such equipment is not shielded by other construction noise barriers, install temporary noise barriers or partial enclosures at the perimeter of this equipment in such a way as to block the line of sight from this equipment to adjacent residential or commercial uses.

10. Designate a "disturbance coordinator" who would be responsible for responding to any local complaints about construction noise. The disturbance coordinator will determine the cause of the noise complaint (e.g., starting too early, bad muffler, etc.) and will require that reasonable measures warranted to correct the problem be implemented. The disturbance coordinator shall record all noise complaints received and actions taken in response and submit this record to the project planner upon request. The name and telephone number of the disturbance coordinator should be conspicuously posted at the construction site.

The use of the construction noise barriers and the early installation of building sheathing outlined in the control plan (above) are expected to reduce noise levels at area uses on the order of 10 to 15 dBA when work is being done at the site perimeter and on the order of 8 to 12 dBA when work is being done in the central portions of the site. With implementation of these best management practices the impact would be considered **less-than-significant**

Mitigation Measures: None required

Potential Impact 2: Exposure to Excessive Groundborne Vibration due to Construction. Construction-related vibration levels resulting from activities at the project site would not exceed 0.3 in/sec PPV at the nearest sensitive receptor. **This is a less than significant impact.**

The construction of the project may generate vibration when heavy equipment or impact tools (e.g. hoe rams) are used in close proximity to existing buildings. Construction activities would include grading, foundation work, paving, and new building framing and finishing. Considering the height and type of structures proposed, pile driving, which can cause excessive levels of vibration, is not anticipated as a method of construction. Other project construction activities, such as the use of jackhammers, rock drills, and other high-power or vibratory tools, and rolling stock equipment (tracked vehicles, compactors, etc.) have the potential to generate substantial vibration in the immediate vicinity. Erection of the building structure is not anticipated to be a source of substantial vibration with the exception of sporadic events such as dropping of heavy objects, which should be avoided to the extent possible.

The closest structures to the project site are the school buildings located as close as 25 feet from the perimeter of the closest proposed building on the project site. The geometric centers of the closest site structures would be approximately 45 and 80 feet from the closest school buildings. Table 6 presents typical vibration levels that could be expected from construction equipment at distances 25, 45 and 80 feet using a Rayleigh (surface) wave propagation model[4] using factors for ground and average building damping ratios[3,5].

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[4] Amick, H., and Gendreau, M., "Construction Vibrations and Their Impact on Vibration Sensitive Facilities", Presented at the ASCE Construction Congress 6, Orlando, Florida, February 22, 2000.

[5] H. Bachmann, et al., Vibration Problems in Structures, Birkhauser Verlag, Berlin, 1995.

TABLE 6 Vibration Source Levels for Construction Equipment (in/sec PPV)

Equipment		At 25 feet	At 45 feet	At 80 feet
Clam shovel drop		0.202	0.084	0.035
Hydromill (slurry wall)	in soil	0.003	0.001	0.0003
	in rock	0.007	0.003	0.001
Vibratory Roller		0.210	0.087	0.037
Hoe Ram		0.089	0.037	0.016
Large bulldozer		0.089	0.037	0.016
Caisson drilling		0.089	0.037	0.016
Loaded trucks		0.076	0.031	0.013
Jackhammer		0.035	0.014	0.006
Small bulldozer		0.003	0.004	0.001

Source: Transit Noise and Vibration Impact Assessment, United States Department of Transportation, Office of Planning and Environment, Federal Transit Administration, October 2018

The calculated levels in Table 6 indicate that construction-related vibration levels resulting from activities at the project site would not exceed 0.3 in/sec PPV at the nearest sensitive structures during construction. This is a **less-than-significant impact.**

Mitigation Measures: None required