Appendix L

Vibration Impact Analysis

February 8, 2022

Ms. Christine Saunders, Director of Environmental Services
SAGECREST PLANNING & ENVIRONMENTAL
2400 E Katella Avenue, Suite 800
Anaheim, California 92806

RE: Orange Palmyra Cemetery Focused Vibration Analysis
Project No. 19358

Dear Ms. Saunders,

Ganddini Group, Inc. is pleased to provide this Focused Vibration Analysis for the Orange Palmyra Cemetery project. This vibration study summarizes our methodology, analysis, and findings. Although this is a technical report, effort has been made to write the report clearly and concisely. A list of common acronyms is provided in Appendix A to assist the reader with technical terms related to the vibration analysis.

PROJECT DESCRIPTION

The approximately 5.95-acre project site is located at 290 South Yorba Street and 2205 east Palmyra Avenue in the City of Orange, California. The Project Site was developed with a 5,262 square foot former multi-purpose activity center (YMCA) in the central portion, a parking lot in the east-central portion, a bicycle motocross (BMX) track in the northern portion, and soccer field in the southern portion; however, the building recently burned down. The Santiago Creek and bike path intersect the northwest portion of the Project Site. The project location map is shown on Figure 1.

The Proposed Project involves building a 5,138 square foot building to support activities associated with funeral and burial practices, with associated administrative offices, a 3,513-gravesite cemetery, and accessory parking, loading, pedestrian paths of travel, and landscaping. The project also includes an approximately 800 square foot accessory shed/structure. Figure 2 illustrates the project site plan.

The majority of the Project Site would be utilized for gravesite purposes. Full buildout of the gravesite space would occur through a 20-year phased plan. A prepared grave consists of a four-sided bottomless pre-cast concrete grave liner (crypt) measuring approximately three-feet by six-feet. During the batching of crypts for each phase, the operator would dig the planned gravesites, place the crypt liner, and refill the gravesite with the soil from initial digging. Due to religious constraints that prevent excavation equipment from traversing occupied crypts, the sequence of batches would commence in the most remote areas of the cemetery and proceed towards the main building. Phased construction of the gravesites would occur in batches of approximately 100-120 crypts. Once a precast crypt houses interred remains, the gravesite would be covered by pebbles and include installation of a gravestone and concrete border to surround each gravesite.

Operational Characteristics

The Proposed Project would operate as a Muslim cemetery, open seven (7) days per week, from 8:00 AM to 5:00 PM with limited operations from 5:00 PM to 7:00 PM (by appointment only). Daily activities would vary during normal business hours and would typically consist of meetings with family members seeking to funeral arrangements (by appointment only), visitations to gravesites, scheduled funeral services, pre- and post-burial family visitations (by appointment only), gravesite preparation for burial, and delivery of the remains of the deceased.

The Proposed Project entails a Muslim cemetery, which requires the timely burial of the deceased, usually within 24-48 hours after death. Consequently, the relatively short notice of the funeral service typically results in a more limited number of visitors as compared to funeral services associated with other religions/cultures.

The Proposed Project would entail approximately 20-25 funeral services per month, which would occur one at a time between 8:00 AM to 5:00 PM; services would not overlap. A typical funeral service would take place over an approximate four-to-five-hour period. Following the burial, guests would reconvene to the Prayer Hall and socialize. Post-burial memorial gatherings would occur over approximately a two-to-three hours period, with the option to include indoor gathering in the Prayer Hall or outdoor gathering on the north outdoor patio.

VIBRATION FUNDAMENTALS

The way in which vibration is transmitted through the earth is called propagation. Propagation of earthborn vibrations is complicated and difficult to predict because of the endless variations in the soil through which waves travel. There are three main types of vibration propagation: surface, compression and shear waves. Surface waves, or Raleigh waves, travel along the ground's surface. These waves carry most of their energy along an expanding circular wave front, similar to ripples produced by throwing a rock into a pool of water. Compression waves, or P-waves, are body waves that carry their energy along an expanding spherical wave front. The particle motion in these waves is longitudinal (i.e., in a "push-pull" fashion). P-waves are analogous to airborne sound waves. Shear waves, or S-waves, are also body waves that carry energy along an expanding spherical wave front. However, unlike P-waves, the particle motion is transverse or "side-to-side and perpendicular to the direction of propagation".

As vibration waves propagate from a source, the energy is spread over an ever-increasing area such that the energy level striking a given point is reduced with the distance from the energy source. This geometric spreading loss is inversely proportional to the square of the distance. Wave energy is also reduced with distance as a result of material damping in the form of internal friction, soil layering, and void spaces. The amount of attenuation provided by material damping varies with soil type and condition as well as the frequency of the wave.

Vibration amplitudes are usually expressed as either peak particle velocity (PPV) or the root mean square (RMS) velocity. The PPV is defined as the maximum instantaneous peak of the vibration signal in inches per second. The RMS of a signal is the average of the squared amplitude of the signal in vibration decibels (VdB), ref one micro-inch per second. The Federal Railroad Administration uses the abbreviation "VdB" for vibration decibels to reduce the potential for confusion with sound decibel.

PPV is appropriate for evaluating the potential of building damage and VdB is commonly used to evaluate human response. Decibel notation acts to compress the range of numbers required in measuring vibration. Similar to the noise descriptors, L_{eq} and L_{max} can be used to describe the average vibration and the maximum vibration level observed during a single vibration measurement interval. Figure 3 illustrates common vibration sources and the human and structural responses to ground-borne vibration. As shown in the figure, the threshold of perception for human response is approximately 65 VdB; however, human response to vibration is not usually substantial unless the vibration exceeds 70 VdB. Vibration tolerance limits for sensitive instruments such as magnetic resonance imaging (MRI) or electron microscopes could be much lower than the human vibration perception threshold.

APPLICABLE STANDARDS

The City currently does not have any adopted standards, guidelines, or thresholds relative to ground-borne vibration. Ground-borne noise refers to the noise generated by ground-borne vibration. Ground-borne noise that accompanies the building vibration is usually perceptible only inside buildings and typically is only an issue at locations with subway or tunnel operations where there is no airborne noise path or for buildings with substantial sound insulation such as a recording studio.[1] As such, available guidelines from the California Department of Transportation (Caltrans) are utilized to assess impacts due to ground-borne vibration.

Caltrans has adopted standards associated with human annoyance for groundborne vibration impacts. As shown in Table 1, vibration become strongly perceptible at a PPV of 0.1 in/sec. Caltrans has also adopted vibration standards that are used to evaluate potential building damage impacts related to construction activities. As shown in Table 2, the threshold at which there is a risk to "architectural" damage to historic and some older buildings is a peak particle velocity (PPV) of 0.25 in/sec, at older residential structures a PPV of 0.3 in/sec, and at new residential structures and modern commercial/industrial buildings a PPV of 0.5 in/sec. In addition,

Therefore, impacts would be significant if construction activities result in groundborne vibration of 0.3 PPV or higher at residential structures.

DISCUSSION AND RECOMMENDATIONS

Groundborne Vibration Impacts

There are several types of construction equipment that can cause vibration levels high enough to annoy persons in the vicinity and/or result in architectural or structural damage to nearby structures and improvements. For example, as shown in Table 3, a vibratory roller could generate up to 0.21 PPV inches per second (in/sec) at a distance of 25 feet; and operation of a large bulldozer (0.089 PPV in/sec) at a distance of 25 feet (two of the most vibratory pieces of construction equipment). Groundborne vibration at sensitive receptors associated with this equipment would drop off as the equipment moves away. For example, as the vibratory roller moves further than 100 feet from the sensitive receptors, the vibration associated with it would drop below 0.0026 PPV in/sec. It should be noted that these vibration levels are reference levels and may vary slightly depending upon soil type and specific usage of each piece of equipment.

<u>Architectural Damage</u>

Vibration generated by construction activity generally has the potential to damage structures. This damage could be structural damage, such as cracking of floor slabs, foundations, columns, beams, or wells, or cosmetic architectural damage, such as cracked plaster, stucco, or tile. (California Department of Transportation, 2020)

Table 2 identifies a PPV level of 0.3 in/sec as the threshold at which there is a risk to "architectural" damage to older residential structures. As shown in Table 4 and the analysis for annoyance below, temporary vibration levels associated with project construction would be less than significant. No mitigation is required. Vibration worksheets are provided in Appendix B.

[1] Federal Transit Administration, Transit Noise and Vibration Impact Assessment, May 2018, pp 108, 112.

Annoyance to Persons

The primary effect of perceptible vibration is often a concern. However, secondary effects, such as the rattling of a china cabinet, can also occur, even when vibration levels are well below perception. Any effect (primary perceptible vibration, secondary effects, or a combination of the two) can lead to annoyance. The degree to which a person is annoyed depends on the activity in which they are participating at the time of the disturbance. For example, someone sleeping or reading will be more sensitive than someone who is running on a treadmill. Reoccurring primary and secondary vibration effects often lead people to believe that the vibration is damaging their home, although vibration levels are well below minimum thresholds for damage potential (California Department of Transportation, 2020).

As shown in Table 1, vibration becomes strongly perceptible to people in buildings at a PPV of 0.1 in/sec.

The closest off-site buildings are the single-family residential dwelling units located approximately 60 feet south of the project sites' southern property line. As shown in Table 4, at 60 feet, the use of a vibratory roller would be expected to generate a PPV of 0.056 in/sec and a bulldozer would be expected to generate a PPV of 0.024 in/sec. Therefore, use of vibratory equipment would not result in annoyance to the receptors to the south.

The next closest off-site building is the single-family residential dwelling unit located approximately 72 feet from the southwest corner of the project site,[2] use of a vibratory roller would be expected to generate a PPV of 0.043 in/sec and a bulldozer would be expected to generate a PPV of 0.018 in/sec. Therefore, use of either a vibratory roller or a large bulldozer could be considered annoying to the receptor to the north. Therefore, use of vibratory equipment would not result in annoyance to the receptors to the southwest.

At 78 feet, which is the distance to the next closest off-site buildings, the single-family residential dwelling units to the southeast of the project site, use of a vibratory roller would be expected to generate a PPV of 0.038 in/sec and a bulldozer would be expected to generate a PPV of 0.016 in/sec (see Table 4). Therefore, use of vibratory equipment would not result in annoyance to the receptors to the southeast.

The school use located adjacent to the east of the project site has structures (i.e., sheds) located as close as approximately 114 feet from the project's eastern property line. As shown in Table 4, at 114 feet, use of a vibratory roller would be expected to generate a PPV of 0.022 in/sec and a bulldozer would be expected to generate a PPV of 0.009 in/sec. Therefore, use of vibratory equipment would not result in annoyance to the receptors to the east.

Annoyance is expected to be short-term, occurring only during site grading and preparation. Impacts related to annoyance are less than significant.

CONCLUSIONS

Construction related vibration impacts associated with the proposed Orange Palmyra Cemetery project are anticipated to be less than significant. No mitigation is required.

[2] On September 1, 2020, the City of Orange issued a building permit (No. 2008-192) for the demolition of the single-family residence and pool located immediately adjacent to the south of the Project Site, identified as 334 S. Jennifer Lane (APN 392-052-06). The applicant of record for the building permit is the County of Orange. Subsequently, on October 9, 2020, the City finalized the building permit and the Jennifer Lane property is vacant. As a result of this demolition, the nearest single-family residential sensitive receptor from the southwest corner of the project is the dwelling unit located approximately 72-feet south of the Project Site's southern property line.

It has been a pleasure to assist you with this project. Should you have any questions or if we can be of further assistance, please do not hesitate to call at (714) 975-3100.

Sincerely,
GANDDINI GROUP, INC.

Roma Stromberg, INCE, M.S.
Senior Noise Analyst

Table 1
Guideline Vibration Annoyance Potential Criteria

Human Response	Maximum PPV (in/sec)	
	Transient Sources	Intermittent Sources
Barely perceptible	0.04	0.01
Distinctly perceptible	0.25	0.04
Strongly perceptible	0.9	0.10
Severe	2.0	0.4

Source: California Department of Transportation. Transportation and Construction Vibration Guidance Manual, Chapter 7 Table 20, April 2020.

Notes:

(1) Transient sources create a single isolated vibration event, such as blasting or drop balls. Continuous/frequent intermittent sources include impact pile drivers, pogo-stick compactors, crack-and-seat equipment, vibratory pile drivers, and vibratory compaction equipment.

Table 2
Guideline Vibration Damage Potential Threshold Criteria

Structure Condition	Maximum PPV (in/sec)	
	Transient Sources	Continuous/Frequent Intermittent Sources
Extremely fragile historic buildings, ruins, anceint monuments	0.12	0.08
Fragile buildings	0.2	0.1
Historic and some old buildings	0.5	0.25
Older residential structures	0.5	0.3
New residential structures	1.0	0.5
Modern industrial/commercial buildings	2.0	0.5

Source: California Department of Transportation. Transportation and Construction Vibration Guidance Manual, Chapter 7 Table 19, April 2020.

Notes:
(1) Transient sources create a single isolated vibration event, such as blasting or drop balls. Continuous/frequent intermittent sources include impact pile drivers, pogo-stick compactors, crack-and-seat equipment, vibratory pile drivers, and vibratory compaction equipment.

Table 3
Construction Equipment Vibration Source Levels

Equipment		PPV at 25 ft, in/sec	Approximate Lv* at 25 ft
Pile Driver (impact)	upper range	1.518	112
	typical	0.644	104
Pile Driver (sonic)	upper range	0.734	105
	typical	0.170	93
clam shovel drop (slurry wall)		0.202	94
Hydromill (slurry wall)	in soil	0.008	66
	in rock	0.017	75
Vibratory Roller		0.210	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

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

*RMS velocity in decibels, VdB re 1 micro-in/sec

Table 4
Construction Vibration Levels at the Nearest Receptors

Receptor Location	Distance from Property Line to Nearest Structure (feet)	Equipment	Vibration Level (PPV in/sec)	Damage Threshold Exceeded?[1]	Annoyance Threshold Exceeded?[1]
Residential to Southwest	72	Vibratory Roller	0.043	No	No
	72	Large Bulldozer	0.018	No	No
Residential to South	60	Vibratory Roller	0.056	No	No
	60	Large Bulldozer	0.024	No	No
Residential to Southeast	78	Vibratory Roller	0.038	No	No
	78	Large Bulldozer	0.016	No	No
School to East	114	Vibratory Roller	0.022	No	No
	114	Large Bulldozer	0.009	No	No

<u>Notes:</u>

(1) Caltrans identifies a PPV level of 0.3 in/sec as the threshold at which there is a risk to "architectural" damage to older residential buildings (see Table 2). In addition, the annoyance threshold is 0.1 in/sec PPV as this is the level in which vibration becomes strongly perceptible to sensitive receptors (see Table 1).

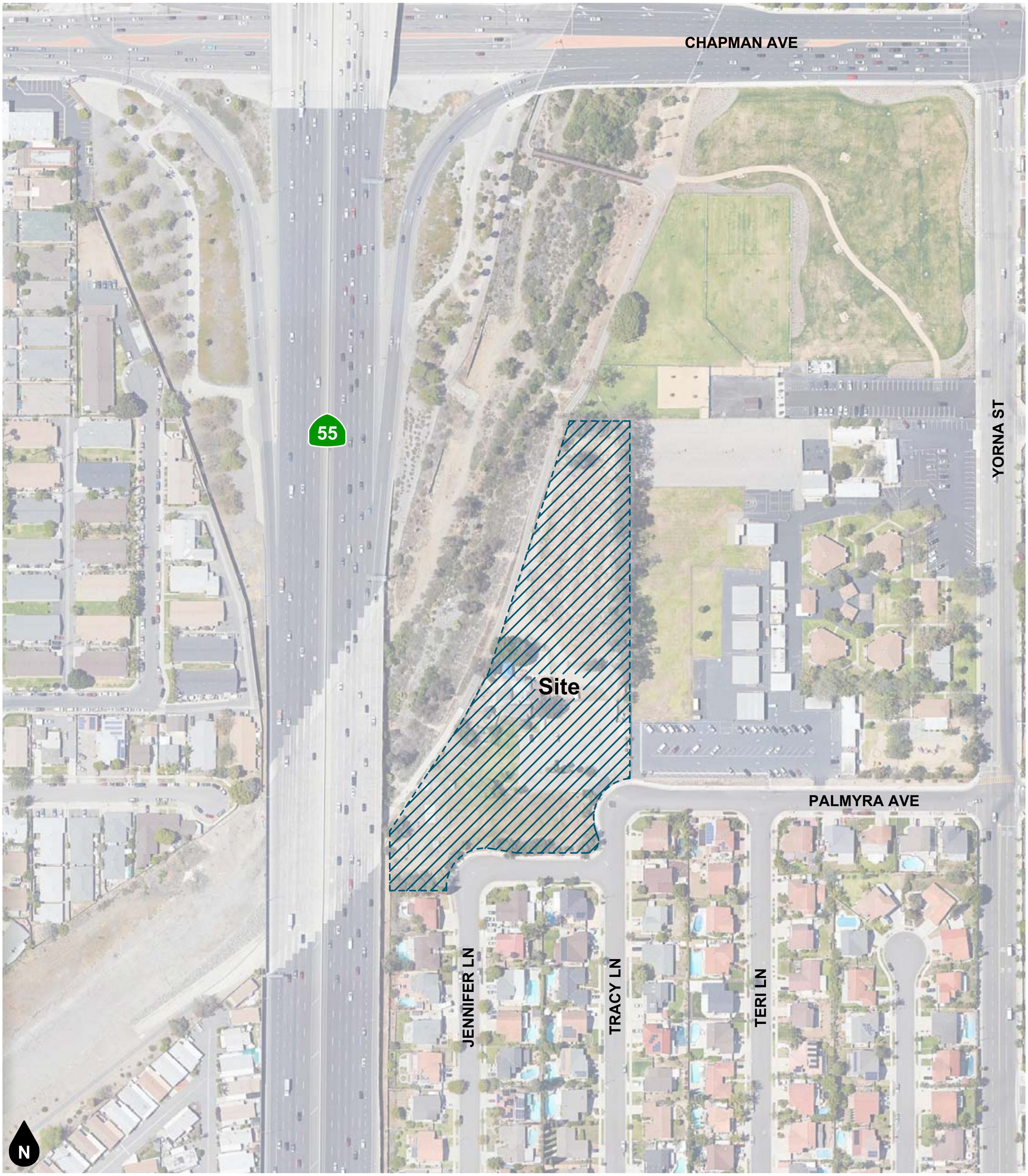


Figure 1
Project Location Map

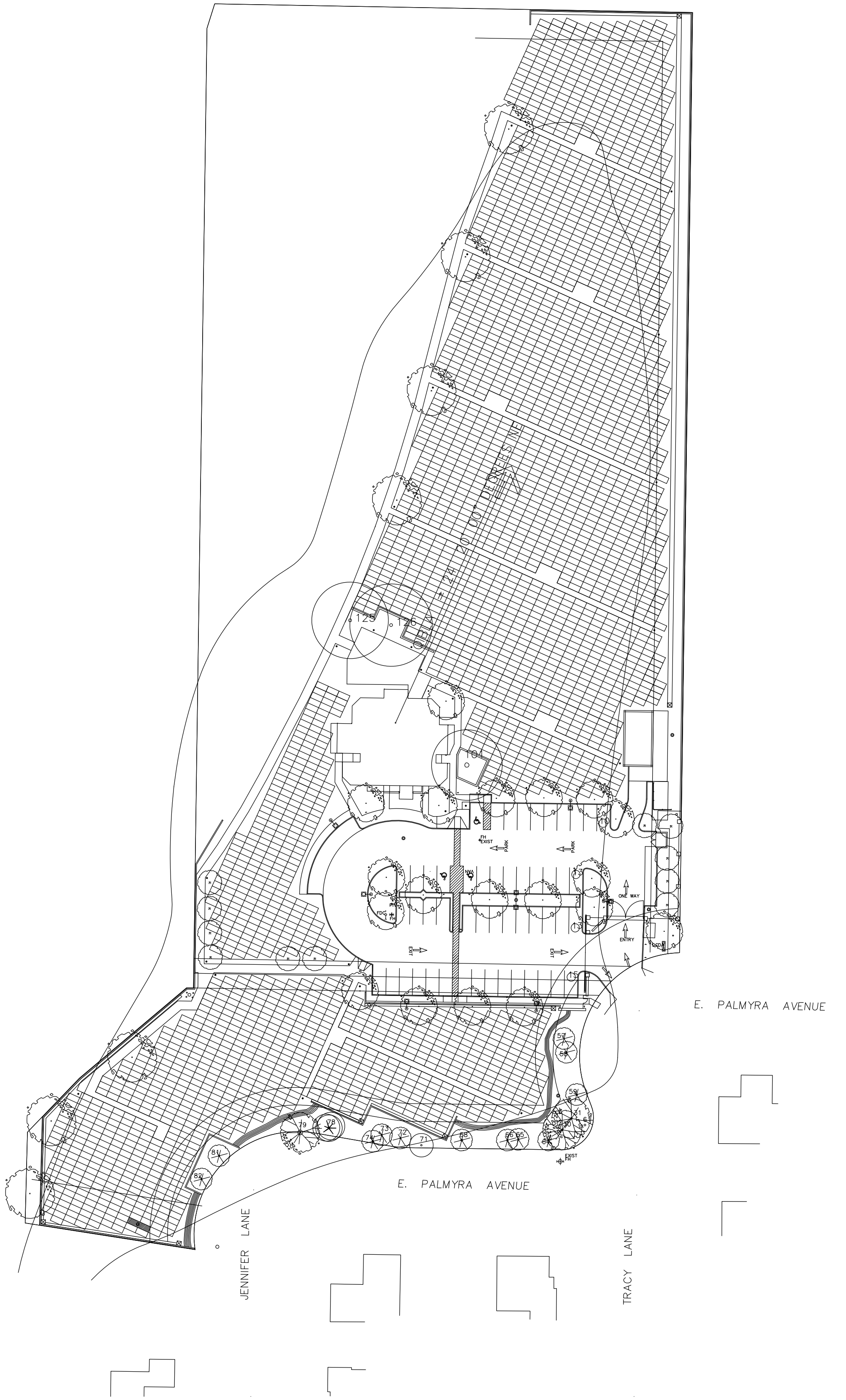
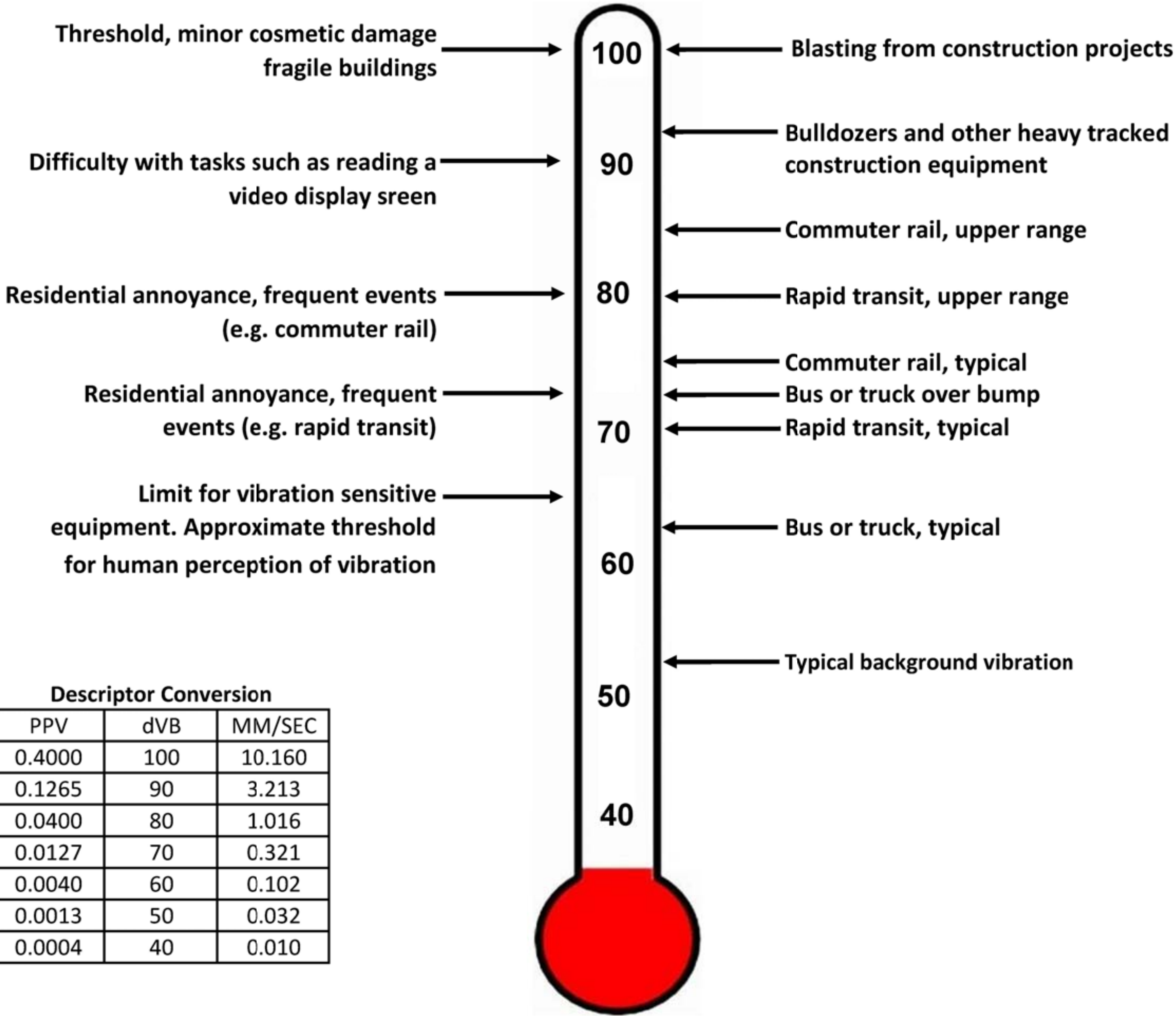


Figure 2
Site Plan



Descriptor Conversion

PPV	dVB	MM/SEC
0.4000	100	10.160
0.1265	90	3.213
0.0400	80	1.016
0.0127	70	0.321
0.0040	60	0.102
0.0013	50	0.032
0.0004	40	0.010

Source: FRA, 2012. Federal Railroad Administration High-Speed Ground Transportation Noise and Vibration Impact Assessment. Office of Railroad Policy Development, Washington, D.C. DOT/FRA/ORD-12/15. September.

Figure 3
Typical Levels of Groundborne Vibration

Appendix A

List of Acronyms

TERMS	DEFINITIONS
ADT	Average Daily Traffic volume
ANSI	American National Standard Institute
APN	Assessor's Parcel Number
Caltrans	California Department of Transportation
Calveno	California Vehicle Noise
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
CNEL	Community Noise Equivalent Level
D/E/N	Day/Evening/Night
dB	Decibel
dBA or dB(A)	Decibel "A-Weighted"
EIR	Environmental Impact Report
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
Hz	Hertz
INCE	Institute of Noise Control Engineering
L_{02},L_{08},L_{50},L_{90}	A-weighted Noise Levels at 2 percent, 8 percent, 50 percent, and 90 percent, respectively, of the time period
DNL	Day-Night Average Noise Level
$L_{eq(x)}$	Equivalent Noise Level for "x" period of Time
L_{max}	Maximum Level of Noise (measured using a sound level meter)
L_{min}	Minimum Level of Noise (measured using a sound level meter)
LOS C	Level of Service C
MPH	Miles Per Hour
NEPA	National Environmental Policy Act
OPR	California Governor's Office of Planning and Research
Peak Hour L_{eq}	Peak Hour Equivalent Sound Level
PPV	Peak Particle Velocity
RCNM	Road Construction Noise Model
RMS	Root Mean Square
SEL	Single Event Level or Sound Exposure Level
SPL	Sound Pressure Level
STC	Sound Transmission Class
VdB	Vibration Velocity Decibels

APPENDIX B

VIBRATION WORKSHEETS

GROUNDBORNE VIBRATION ANALYSIS			
Project:	19358 Orange Palmyra Cemetery	Date:	9/15/21
Source:	Vibratory Roller		
Scenario:	Unmitigated		
Location:	Residential Adjacent to Southwest		
Address:			
PPV = PPVref(25/D)^n (in/sec)			

INPUT			
Equipment = Type	1	Vibratory Roller	INPUT SECTION IN GREEN
PPVref =	0.21	Reference PPV (in/sec) at 25 ft.	
D =	72.00	Distance from Equipment to Receiver (ft)	
n =	1.50	Vibration attenuation rate through the ground	

Note: Based on reference equations from Vibration Guidance Manual, California Department of Transportation, 2006, pgs 38-43.

RESULTS			
PPV =	0.043	IN/SEC	OUTPUT IN BLUE

GROUNDBORNE VIBRATION ANALYSIS			
Project:	19358 Orange Palmyra Cemetery	Date:	9/15/21
Source:	Large Bulldozer		
Scenario:	Unmitigated		
Location:	Residential Adjacent to Southwest		
Address:			
PPV = PPVref(25/D)^n (in/sec)			
INPUT			
Equipment = Type	2	Large Bulldozer	INPUT SECTION IN GREEN
PPVref =	0.089	Reference PPV (in/sec) at 25 ft.	
D =	72.00	Distance from Equipment to Receiver (ft)	
n =	1.50	Vibration attenuation rate through the ground	
Note: Based on reference equations from Vibration Guidance Manual, California Department of Transportation, 2006, pgs 38-43.			
RESULTS			
PPV =	0.018	IN/SEC	OUTPUT IN BLUE

GROUNDBORNE VIBRATION ANALYSIS			
Project:	19358 Orange Palmyra Cemetery	Date:	9/15/21
Source:	Vibratory Roller		
Scenario:	Unmitigated		
Location:	Residential to South (across Palmyra Ave)		
Address:			
PPV = PPVref(25/D)^n (in/sec)			
INPUT			
Equipment = Type	1	Vibratory Roller	INPUT SECTION IN GREEN
PPVref =	0.21	Reference PPV (in/sec) at 25 ft.	
D =	60.00	Distance from Equipment to Receiver (ft)	
n =	1.50	Vibration attenuation rate through the ground	
Note: Based on reference equations from Vibration Guidance Manual, California Department of Transportation, 2006, pgs 38-43.			
RESULTS			
PPV =	0.056	IN/SEC	OUTPUT IN BLUE

GROUNDBORNE VIBRATION ANALYSIS			
Project:	19358 Orange Palmyra Cemetery	Date:	9/15/21
Source:	Large Bulldozer		
Scenario:	Unmitigated		
Location:	Residential to South (across Palmyra Ave)		
Address:			
PPV = PPVref(25/D)^n (in/sec)			
INPUT			
Equipment = Type	2	Large Bulldozer	INPUT SECTION IN GREEN
PPVref =	0.089	Reference PPV (in/sec) at 25 ft.	
D =	60.00	Distance from Equipment to Receiver (ft)	
n =	1.50	Vibration attenuation rate through the ground	
Note: Based on reference equations from Vibration Guidance Manual, California Department of Transportation, 2006, pgs 38-43.			
RESULTS			
PPV =	0.024	IN/SEC	OUTPUT IN BLUE

GROUNDBORNE VIBRATION ANALYSIS			
Project:	19358 Orange Palmyra Cemetery		Date: 9/15/21
Source:	Vibratory Roller		
Scenario:	Unmitigated		
Location:	Residential to Southeast (across corner of Palmyra Ave & Tracy Lane)		
Address:			
PPV = PPVref(25/D)^n (in/sec)			
INPUT			
Equipment = Type	1	Vibratory Roller	INPUT SECTION IN GREEN
PPVref =	0.21	Reference PPV (in/sec) at 25 ft.	
D =	78.00	Distance from Equipment to Receiver (ft)	
n =	1.50	Vibration attenuation rate through the ground	
Note: Based on reference equations from Vibration Guidance Manual, California Department of Transportation, 2006, pgs 38-43.			
RESULTS			
PPV =	0.038	IN/SEC	OUTPUT IN BLUE

GROUNDBORNE VIBRATION ANALYSIS			
Project:	19358 Orange Palmyra Cemetery	Date:	9/15/21
Source:	Large Bulldozer		
Scenario:	Unmitigated		
Location:	Residential to Southeast (across corner of Palmyra Ave & Tracy Lane)		
Address:			
PPV = PPVref(25/D)^n (in/sec)			
INPUT			
Equipment = Type	2	Large Bulldozer	INPUT SECTION IN GREEN
PPVref =	0.089	Reference PPV (in/sec) at 25 ft.	
D =	78.00	Distance from Equipment to Receiver (ft)	
n =	1.50	Vibration attenuation rate through the ground	
Note: Based on reference equations from Vibration Guidance Manual, California Department of Transportation, 2006, pgs 38-43.			
RESULTS			
PPV =	0.016	IN/SEC	OUTPUT IN BLUE

GROUNDBORNE VIBRATION ANALYSIS			
Project:	19358 Orange Palmyra Cemetery		Date: 9/15/21
Source:	Vibratory Roller		
Scenario:	Unmitigated		
Location:	School to East		
Address:			
PPV = PPVref(25/D)^n (in/sec)			
INPUT			
Equipment = Type	1	Vibratory Roller	INPUT SECTION IN GREEN
PPVref =	0.21	Reference PPV (in/sec) at 25 ft.	
D =	114.00	Distance from Equipment to Receiver (ft)	
n =	1.50	Vibration attenuation rate through the ground	
Note: Based on reference equations from Vibration Guidance Manual, California Department of Transportation, 2006, pgs 38-43.			
RESULTS			
PPV =	0.022	IN/SEC	OUTPUT IN BLUE

GROUNDBORNE VIBRATION ANALYSIS			
Project:	19358 Orange Palmyra Cemetery	Date:	9/15/21
Source:	Large Bulldozer		
Scenario:	Unmitigated		
Location:	School to East		
Address:			
PPV = PPVref(25/D)^n (in/sec)			
INPUT			
Equipment = Type	2	Large Bulldozer	INPUT SECTION IN GREEN
PPVref =	0.089	Reference PPV (in/sec) at 25 ft.	
D =	114.00	Distance from Equipment to Receiver (ft)	
n =	1.50	Vibration attenuation rate through the ground	
Note: Based on reference equations from Vibration Guidance Manual, California Department of Transportation, 2006, pgs 38-43.			
RESULTS			
PPV =	0.009	IN/SEC	OUTPUT IN BLUE