Appendix 19A Noise Definitions and Noise Calculations

Appendix 19A Noise and Vibration Definitions

19A.1 Noise

Sound is mechanical energy transmitted by pressure waves in a compressible medium such as air. Noise can be defined as unwanted sound. Sound is characterized by various parameters that include the rate of oscillation of sound waves (frequency), the speed of propagation, and the pressure level or energy content (amplitude). In particular, the sound pressure level is the most common descriptor used to characterize the loudness of an ambient sound. The dB scale is used to quantify sound intensity. Because sound pressure can vary enormously within the range of human hearing, the logarithmic decibel scale is used to keep sound intensity numbers at a convenient and manageable level.

Under controlled conditions in an acoustical laboratory the trained, healthy human ear is able to discern 1-dB changes in sound levels, when exposed to steady, single-frequency (pure-tone) signals in the mid-frequency (1,000 Hertz [Hz] to 8,000 Hz) range. It is widely accepted, however, that people are able to begin to detect sound level changes of 3 dB for typical noisy environments. Further, a 10-dB increase is generally perceived as a doubling of loudness. Therefore, doubling sound energy (e.g., doubling the volume of traffic on a highway), which would result in a 3-dB increase in noise, is generally perceived as a detectable, but not substantial, increase in sound level.

The human ear is not equally sensitive to all frequencies in the entire spectrum, so noise measurements are weighted more heavily for frequencies to which humans are sensitive in a process called “A-weighting.” Because humans are less sensitive to low-frequency sound than to high-frequency sound, A-weighted decibel (dBA) levels deemphasize low-frequency sound energy to better represent how humans hear. Table 19A-1 summarizes typical A-weighted sound levels.

Table 19A-1. Typical A-Weighted Sound Levels

Common Outdoor Activities	Noise Level (dBA)	Common Indoor Activities
	—110—	Rock band
Jet flyover at 1,000 feet		
	—100—	
Gas lawnmower at 3 feet		
	—90—	
Diesel truck at 50 feet at 50 miles per hour		Food blender at 3 feet
	—80—	Garbage disposal at 3 feet

Common Outdoor Activities	Noise Level (dBA)	Common Indoor Activities
Noisy urban area, daytime		
Gas lawnmower, 100 feet	—70—	Vacuum cleaner at 10 feet
Commercial area		Normal speech at 3 feet
Heavy traffic at 300 feet	—60—	
		Large business office
Quiet urban daytime	—50—	Dishwasher in next room
Quiet urban nighttime	—40—	Theater, large conference room (background)
Quiet suburban nighttime		
	—30—	Library
Quiet rural nighttime		Bedroom at night, concert hall (background)
	—20—	
		Broadcast/recording studio
	—10—	
	—0—	

Source: California Department of Transportation 2013.
dBA = A-weighted decibel.

Different types of measurements are used to characterize the time-varying nature of sound. These measurements include the equivalent sound level (L_{eq}), the minimum and maximum sound levels (L_{min} and L_{max}), the day-night sound level (L_{dn}), and the CNEL. Below are brief definitions of these measurements and other terminology used in this chapter.

Sound. A vibratory disturbance created by a vibrating object, which, when transmitted by pressure waves through a medium such as air, is capable of being detected by a receiving mechanism, such as the human ear or a microphone.

Noise. Sound that is loud, unpleasant, unexpected, or otherwise undesirable.

Ambient noise. The composite of noise from all sources near and far in a given environment exclusive of particular noise sources to be measured.

Decibel (dB). A unitless measure of sound. A sound level measurement in decibels describes the logarithmic ratio of a measured sound pressure level to a reference sound pressure level of 20 micropascals.

A-Weighted Decibel (dBA). An overall frequency-weighted sound level that approximates the frequency response of the human ear.

Maximum and Minimum Sound Levels (L_{max} and L_{min}). The maximum or minimum sound level measured during a specified interval.

Equivalent Sound Level (L_{eq}). L_{eq} represents an average of the sound energy occurring over a specified period. In effect, L_{eq} is the steady-state sound level containing the same acoustical energy as the time-varying sound that actually occurs during the same period. The duration of the measurement is commonly indicated in the subscript; for example, a 1-hour L_{eq} sound level would be indicated as dBA L_{eq}(1h).

Day-night level (L_{dn}). The energy average of the A-weighted sound levels occurring during a 24-hour period, with 10 dB added to the A-weighted sound levels occurring during the period from 10:00 p.m. to 7:00 a.m. This metric is also sometimes referred as day-night level or DNL.

Community noise equivalent level (CNEL). The energy average of the A-weighted sound levels occurring during a 24-hour period with 5 dB added to the A-weighted sound levels occurring during the period from 7:00 p.m. to 10:00 p.m. and 10 dB added to the A-weighted sound levels occurring during the period from 10:00 p.m. to 7:00 a.m. L_{dn} and CNEL values rarely differ by more than 1 dB. As a matter of practice, L_{dn} and CNEL values are considered to be equivalent.

In general, human sound perception is such that a change in sound level of 3 dB is just noticeable, a change of 5 dB is clearly noticeable, and a change of 10 dB is perceived as doubling or halving in sound level.

For a point source, such as a stationary compressor, sound attenuates based on geometry at a rate of 6 dB per doubling of distance. For a line source, such as free-flowing traffic on a freeway, sound attenuates at a rate of 3 dB per doubling of distance. Atmospheric conditions including wind, temperature gradients, and humidity can change how sound propagates over distance and can affect the level of sound received at a given location. The degree to which the ground surface absorbs acoustical energy also affects sound propagation. Sound that travels over an acoustically absorptive surface such as grass attenuates at a greater rate than sound that travels over a hard surface such as pavement. The increased attenuation is typically in the range of 1 dB to 2 dB per doubling of distance. Barriers, such as buildings and topography that block the line of sight between a source and receptor, also increase the attenuation of sound over distance.

Auditory and non-auditory impacts can result from excessive or chronic exposure to elevated noise levels. Auditory impacts of noise on people can include temporary or permanent hearing loss. Non-auditory impacts of exposure to elevated noise levels include sleep disturbance, speech interference, and psychological effects such as annoyance. Land use compatibility standards for noise typically are based on research related to these non-auditory impacts.

19A.2 Vibration

In contrast to airborne sound, groundborne vibration is not a phenomenon that most people experience every day. Vibration is an oscillatory motion through a solid medium in which the motion's amplitude can be described in terms of displacement, velocity, or acceleration. The background vibration velocity level in residential areas is usually much lower than the threshold of human perception. Most perceptible indoor vibration is caused by sources within buildings, such as mechanical equipment while in operation, people moving, or doors slamming. Typical outdoor sources of perceptible groundborne vibration are construction equipment, steel-wheeled trains, and traffic on rough roads. Dynamic construction equipment, such as pile drivers, can create vibrations that radiate along the surface and downward into the earth. These surface waves can be felt as groundborne vibration. Vibration can result in impacts that range from annoyance to structural damage. Variations in geology and distance result in different vibration levels with different frequencies and displacements.

Groundborne vibration can be expressed in terms of root-mean-square (RMS) vibration velocity to evaluate human response to vibration levels. RMS is defined as the average of the squared amplitude of the vibration signal. The vibration amplitude is expressed in terms of vibration decibels (VdB), which use a reference level of 1 micro-inch per second. Vibration can also be measured by peak particle velocity (PPV), defined as the maximum instantaneous peak of the vibration signal in inches per second.

At higher frequencies, groundborne vibration can be perceived as a noise source. At sufficiently high amplitudes, propagation of vibration waves through the ground can cause building elements to vibrate at a frequency that is audible to the human ear. Groundborne noise could result in rattling of windows, walls, or other items coupled to building surfaces. Groundborne vibration levels resulting in groundborne noise are often experienced as a combination of perceptible vibration and low frequency noise. Tunnel construction equipment and trains operating inside of tunnels are common sources of groundborne noise.

19A.3 References

California Department of Transportation (Caltrans). 2013. *Technical Noise Supplement to the Traffic Noise Analysis Protocol for New Highway Construction, Reconstruction, and Retrofit Barrier Projects*. May. Sacramento, CA

Appendix 19A Noise Calculations

Source Data			Reference Maximum Sound Level at 50 ft. (Lmax, dBA)	Utilization Factor (% of hour)	Equivalent Sound Level (Leq, dBA)
Construction Phase	Demolition and Clearing				
Equipment Type #1	Bulldozer		85	0.50	82
Equipment Type #2	Off Road Truck		84	0.50	81
Equipment Type #3	Roller		85	0.50	82
Average Height of Sources, ft.		10			
Average Height of Receiver, ft.		5			
Ground Type		soft			
Allowable Sound Level, daytime Leq		50			
Allowable Sound Level, nighttime Leq		45			

Calculated Data	
Combined Equipment Sound Level, Leq dBA at 50 ft.	86
Effective Source Height, ft.	7.50
Ground factor, G	0.62
Distance to Allowable Daytime Sound Level, ft.	1,240
Distance to Allowable Nighttime Sound Level, ft.	1,920

Distance Between Source and Receiver (ft.)	Geometric Attenuation (dB)	Ground Effect Attenuation (dB)	Equivalent Sound Level (Leq, dBA)
50	0	0	86
100	-6	-2	79
200	-12	-4	71
300	-16	-5	66
400	-18	-6	63
500	-20	-6	60
750	-24	-7	56
1000	-26	-8	52
1500	-30	-9	48
2000	-32	-10	45
2500	-34	-10	42
3000	-36	-11	40

Calculations based on FTA 2018.

Note: This calculation does not include the effects, if any, of local shielding from walls, topography or other barriers which may reduce sound levels further.

Source Data		Reference Maximum Sound Level at 50 ft. (Lmax, dBA)	Utilization Factor (% of hour)	Equivalent Sound Level (Leq, dBA)
Construction Phase	Sacramento River Diversion and Conveyance to Regulating Reservoirs			
Equipment Type #1	Pile Driver	95	0.50	92
Equipment Type #2	Grader	85	0.50	82
Equipment Type #3	Scraper	85	0.50	82
Average Height of Sources, ft.	10			
Average Height of Receiver, ft.	5			
Ground Type	soft			
Allowable Sound Level, daytime Leq	50			
Allowable Sound Level, nighttime Leq	45			

Calculated Data	
Combined Equipment Sound Level, Leq dBA at 50 ft.	93
Effective Source Height, ft.	7.50
Ground factor, G	0.62
Distance to Allowable Daytime Sound Level, ft.	2,330
Distance to Allowable Nighttime Sound Level, ft.	3,610

Distance Between Source and Receiver (ft.)	Geometric Attenuation (dB)	Ground Effect Attenuation (dB)	Equivalent Sound Level (Leq, dBA)
50	0	0	93
100	-6	-2	85
200	-12	-4	77
300	-16	-5	72
400	-18	-6	69
500	-20	-6	67
750	-24	-7	62
1000	-26	-8	59
1500	-30	-9	54
2000	-32	-10	51
2500	-34	-10	48
3000	-36	-11	46

Calculations based on FTA 2018.

Note: This calculation does not include the effects, if any, of local shielding from walls, topography or other barriers which may reduce sound levels further.

Source Data		Reference Maximum Sound Level at 50 ft. (Lmax, dBA)	Utilization Factor (% of hour)	Equivalent Sound Level (Leq, dBA)
Construction Phase	Tunnels, inlet and outlet (above-ground equipment)			
Equipment Type #1	Concrete Truck	84	0.50	81
Equipment Type #2	Fuel Truck	84	0.50	81
Equipment Type #3	Water Truck	84	0.50	81
Average Height of Sources, ft.	10			
Average Height of Receiver, ft.	5			
Ground Type	soft			
Allowable Sound Level, daytime Leq	50			
Allowable Sound Level, nighttime Leq	45			

Calculated Data	
Combined Equipment Sound Level, Leq dBA at 50 ft.	86
Effective Source Height, ft.	7.50
Ground factor, G	0.62
Distance to Allowable Daytime Sound Level, ft.	1,160
Distance to Allowable Nighttime Sound Level, ft.	1,810

Distance Between Source and Receiver (ft.)	Geometric Attenuation (dB)	Ground Effect Attenuation (dB)	Equivalent Sound Level (Leq, dBA)
50	0	0	86
100	-6	-2	78
200	-12	-4	70
300	-16	-5	65
400	-18	-6	62
500	-20	-6	60
750	-24	-7	55
1000	-26	-8	52
1500	-30	-9	47
2000	-32	-10	44
2500	-34	-10	41
3000	-36	-11	39

Calculations based on FTA 2018.
Note: This calculation does not include the effects, if any, of local shielding from walls, topography or other barriers which may reduce sound levels further.

Source Data			Reference Maximum Sound Level at 50 ft. (Lmax, dBA)	Utilization Factor (% of hour)	Equivalent Sound Level (Leq, dBA)
Construction Phase	Dams and Dykes				
Equipment Type #1	Pile Driver (Vibratory/CIDH)		95	0.25	89
Equipment Type #2	Scraper		85	0.50	82
Equipment Type #3	Bulldozer		85	0.50	82
Average Height of Sources, ft.		10			
Average Height of Receiver, ft.		5			
Ground Type		soft			
Allowable Sound Level, daytime Leq		50			
Allowable Sound Level, nighttime Leq		45			

Calculated Data	
Combined Equipment Sound Level, Leq dBA at 50 ft.	90
Effective Source Height, ft.	7.50
Ground factor, G	0.62
Distance to Allowable Daytime Sound Level, ft.	1,760
Distance to Allowable Nighttime Sound Level, ft.	2,730

Distance Between Source and Receiver (ft.)	Geometric Attenuation (dB)	Ground Effect Attenuation (dB)	Equivalent Sound Level (Leq, dBA)
50	0	0	90
100	-6	-2	83
200	-12	-4	75
300	-16	-5	70
400	-18	-6	67
500	-20	-6	64
750	-24	-7	60
1000	-26	-8	56
1500	-30	-9	52
2000	-32	-10	49
2500	-34	-10	46
3000	-36	-11	44

Calculations based on FTA 2018.

Note: This calculation does not include the effects, if any, of local shielding from walls, topography or other barriers which may reduce sound levels further.

Source Data			Reference Maximum Sound Level at 50 ft. (Lmax, dBA)	Utilization Factor (% of hour)	Equivalent Sound Level (Leq, dBA)
Construction Phase	Conveyance to Sacramento River				
Equipment Type #1	Pile Driver (Vibratory/CIDH)		95	0.50	92
Equipment Type #2	Grader		85	0.50	82
Equipment Type #3	Scraper		85	0.50	82
Average Height of Sources, ft.		10			
Average Height of Receiver, ft.		5			
Ground Type		soft			
Allowable Sound Level, daytime Leq		50			
Allowable Sound Level, nighttime Leq		45			

Calculated Data	
Combined Equipment Sound Level, Leq dBA at 50 ft.	93
Effective Source Height, ft.	7.50
Ground factor, G	0.62
Distance to Allowable Daytime Sound Level, ft.	2,160
Distance to Allowable Nighttime Sound Level, ft.	3,350

Distance Between Source and Receiver (ft.)	Geometric Attenuation (dB)	Ground Effect Attenuation (dB)	Equivalent Sound Level (Leq, dBA)
50	0	0	93
100	-6	-2	85
200	-12	-4	77
300	-16	-5	72
400	-18	-6	69
500	-20	-6	67
750	-24	-7	62
1000	-26	-8	59
1500	-30	-9	54
2000	-32	-10	51
2500	-34	-10	48
3000	-36	-11	46

Calculations based on FTA 2018.

Note: This calculation does not include the effects, if any, of local shielding from walls, topography or other barriers which may reduce sound levels further.

Source Data			Reference Maximum Sound Level at 50 ft. (Lmax, dBA)	Utilization Factor (% of hour)	Equivalent Sound Level (Leq, dBA)
Construction Phase	Road Construction				
Equipment Type #1	Bulldozer		85	0.50	82
Equipment Type #2	Grader		85	0.50	82
Equipment Type #3	Scraper		85	0.50	82
Average Height of Sources, ft.		10			
Average Height of Receiver, ft.		5			
Ground Type		soft			
Allowable Sound Level, daytime Leq		50			
Allowable Sound Level, nighttime Leq		45			

Calculated Data	
Combined Equipment Sound Level, Leq dBA at 50 ft.	87
Effective Source Height, ft.	7.50
Ground factor, G	0.62
Distance to Allowable Daytime Sound Level, ft.	1,270
Distance to Allowable Nighttime Sound Level, ft.	1,970

Distance Between Source and Receiver (ft.)	Geometric Attenuation (dB)	Ground Effect Attenuation (dB)	Equivalent Sound Level (Leq, dBA)
50	0	0	87
100	-6	-2	79
200	-12	-4	71
300	-16	-5	66
400	-18	-6	63
500	-20	-6	61
750	-24	-7	56
1000	-26	-8	53
1500	-30	-9	48
2000	-32	-10	45
2500	-34	-10	42
3000	-36	-11	40

Calculations based on FTA 2018.

Note: This calculation does not include the effects, if any, of local shielding from walls, topography or other barriers which may reduce sound levels further.

Source Data			Reference Maximum Sound Level at 50 ft. (Lmax, dBA)	Utilization Factor (% of hour)	Equivalent Sound Level (Leq, dBA)
Construction Phase	Batch Plant				
Equipment Type #1	Batch Plant		84	1.00	84
Equipment Type #2	Concrete and Rock Processing		84	1.00	84
Equipment Type #3	Recycling Plant		84	1.00	84
Average Height of Sources, ft.		10			
Average Height of Receiver, ft.		5			
Ground Type		soft			
Allowable Sound Level, daytime Leq		50			
Allowable Sound Level, nighttime Leq		45			

Calculated Data	
Combined Equipment Sound Level, Leq dBA at 50 ft.	89
Effective Source Height, ft.	7.50
Ground factor, G	0.62
Distance to Allowable Daytime Sound Level, ft.	1,520
Distance to Allowable Nighttime Sound Level, ft.	2,360

Distance Between Source and Receiver (ft.)	Geometric Attenuation (dB)	Ground Effect Attenuation (dB)	Equivalent Sound Level (Leq, dBA)
50	0	0	89
100	-6	-2	81
200	-12	-4	73
300	-16	-5	68
400	-18	-6	65
500	-20	-6	63
750	-24	-7	58
1000	-26	-8	55
1500	-30	-9	50
2000	-32	-10	47
2500	-34	-10	44
3000	-36	-11	42

Calculations based on FTA 2018.
Note: This calculation does not include the effects, if any, of local shielding from walls, topography or other barriers which may reduce sound levels further.

Source Data			Reference Maximum Sound Level at 50 ft. (Lmax, dBA)	Utilization Factor (% of hour)	Equivalent Sound Level (Leq, dBA)
Construction Phase	Recreation Areas				
Equipment Type #1	Bulldozer		85	0.50	82
Equipment Type #2	Grader		85	0.50	82
Equipment Type #3	Roller		85	0.50	82
Average Height of Sources, ft.		10			
Average Height of Receiver, ft.		5			
Ground Type		soft			
Allowable Sound Level, daytime Leq		50			
Allowable Sound Level, nighttime Leq		45			

Calculated Data	
Combined Equipment Sound Level, Leq dBA at 50 ft.	87
Effective Source Height, ft.	7.50
Ground factor, G	0.62
Distance to Allowable Daytime Sound Level, ft.	1,270
Distance to Allowable Nighttime Sound Level, ft.	1,970

Distance Between Source and Receiver (ft.)	Geometric Attenuation (dB)	Ground Effect Attenuation (dB)	Equivalent Sound Level (Leq, dBA)
50	0	0	87
100	-6	-2	79
200	-12	-4	71
300	-16	-5	66
400	-18	-6	63
500	-20	-6	61
750	-24	-7	56
1000	-26	-8	53
1500	-30	-9	48
2000	-32	-10	45
2500	-34	-10	42
3000	-36	-11	40

Calculations based on FTA 2018.
Note: This calculation does not include the effects, if any, of local shielding from walls, topography or other barriers which may reduce sound levels further.

Source Data			Reference Maximum Sound Level at 50 ft. (Lmax, dBA)	Utilization Factor (% of hour)	Equivalent Sound Level (Leq, dBA)
Construction Phase	Pumping Plants				
Equipment Type #1	Pump		77	1.00	77
Equipment Type #2			0	1.00	0
Equipment Type #3			0	1.00	0
Average Height of Sources, ft.		10			
Average Height of Receiver, ft.		5			
Ground Type		soft			
Allowable Sound Level, daytime Leq		50			
Allowable Sound Level, nighttime Leq		45			

Calculated Data	
Combined Equipment Sound Level, Leq dBA at 50 ft.	77
Effective Source Height, ft.	7.50
Ground factor, G	0.62
Distance to Allowable Daytime Sound Level, ft.	1,270
Distance to Allowable Nighttime Sound Level, ft.	1,970

Distance Between Source and Receiver (ft.)	Geometric Attenuation (dB)	Ground Effect Attenuation (dB)	Equivalent Sound Level (Leq, dBA)
50	0	0	77
100	-6	-2	69
200	-12	-4	61
300	-16	-5	57
400	-18	-6	53
500	-20	-6	51
750	-24	-7	46
1000	-26	-8	43
1500	-30	-9	38
2000	-32	-10	35
2500	-34	-10	33
3000	-36	-11	30

Calculations based on FTA 2018.
Note: This calculation does not include the effects, if any, of local shielding
from walls, topography or other barriers which may reduce sound levels further.

Source Data			Reference Maximum Sound Level at 50 ft. (Lmax, dBA)	Utilization Factor (% of hour)	Equivalent Sound Level (Leq, dBA)
Construction Phase	Pumping Plants				
Equipment Type #1	Pump		77	1.00	77
Equipment Type #2	Generator		82	1.00	82
Equipment Type #3	Crane		83	0.25	77
Average Height of Sources, ft.		10			
Average Height of Receiver, ft.		5			
Ground Type		soft			
Allowable Sound Level, daytime Leq		50			
Allowable Sound Level, nighttime Leq		45			

Calculated Data	
Combined Equipment Sound Level, Leq dBA at 50 ft.	84
Effective Source Height, ft.	7.50
Ground factor, G	0.62
Distance to Allowable Daytime Sound Level, ft.	1,010
Distance to Allowable Nighttime Sound Level, ft.	1,560

Distance Between Source and Receiver (ft.)	Geometric Attenuation (dB)	Ground Effect Attenuation (dB)	Equivalent Sound Level (Leq, dBA)
50	0	0	84
100	-6	-2	76
200	-12	-4	68
300	-16	-5	64
400	-18	-6	60
500	-20	-6	58
750	-24	-7	53
1000	-26	-8	50
1500	-30	-9	45
2000	-32	-10	42
2500	-34	-10	40
3000	-36	-11	38

Calculations based on FTA 2018.

Note: This calculation does not include the effects, if any, of local shielding from walls, topography or other barriers which may reduce sound levels further.