Sound Technical Report for the Sand Hill Proposed Wind Project Alameda County, California

Prepared for:

New Dimension Energy Company
221 Crescent Street, Suite 103A
Waltham, MA 02453
Contact: Charlie Karustis
781.609.4758

Prepared by:

ICF International
630 K Street, Suite 400
Sacramento, CA 95814
Contact: David Buehler, P.E., INCE Bd. Cert.
916.737.3000

March 2016

ICF International. 2016. *Sound Technical Report for the Sand Hill Proposed Wind Project, Alameda County, California*. March. (ICF 00716.15.) Sacramento, CA. Prepared for Ogin, Inc., Waltham, MA.

Contents

Page

List of Tables and Figures

Acronyms and Abbreviations

°F	degrees Fahrenheit
ANSI	American National Standard Institute
APWRA	Altamont Pass Wind Resource Area
AWEA	American Wind Energy Association
CNEL	Community Noise Equivalent Level
County	Alameda County
CUP	Conditional Use Permit
dB	decibels
dBA	A-weighted sound level
dBC	C-weighted sound level
Hz	Hertz
kHz	kilohertz
kW	kilowatt
L_{dn}	day-night level
L_{eq}	equivalent sound level
L_{eq}(h)	1-hour A-weighted equivalent sound level
L_{max}	maximum A-weighted sound level
L_{min}	minimum A-weighted sound level
L_{xx}	percentile-exceeded sound level
m/s	Meters per second
mPa	micro-Pascals
mph	miles per hour
MW	megawatt
NDEC	New Dimension Energy Company
NREL	National Renewable Energy Laboratory
project applicant	New Dimension Energy Company
proposed project	Sand Hill Wind Project
SLM	sound level meter
WTGS	Wind Turbine Generation Systems

Sound Technical Report for the Proposed Sand Hill Wind Project

New Dimension Energy Company (NDEC) (project applicant) has proposed a repowering program (Sand Hill Wind Project [proposed project]) that would entail the removal and replacement of existing 40–100 kilowatt (kW) wind turbines previously owned by SeaWest Power Resources on multiple parcels in the Altamont Pass Wind Resource Area (APWRA). The project applicant would replace the older, existing turbines with twelve (12) Goldwind GW121-2500 wind turbines at a 90-meter hub height. The proposed project would require a Conditional Use Permit (CUP) in accordance with the Alameda County (County) Zoning Ordinance.

This sound technical report provides an assessment of sound associated with operation of the proposed GW121-2500 wind turbines under three layouts. This report discusses environmental noise fundamentals, applicable noise regulations and policies, existing noise conditions, and an evaluation of effects on sound associated with implementation of the proposed project at five (5) receptor locations.

Project Description

The project includes three separate areas where turbines will be located. Three turbine array scenarios are evaluated:

- Layout 1
- Layout 2
- Layout 3 (Preferred Alternative)

Under each scenario, 12 GW121/2500 2.5 megawatt (MW) turbines would be installed at a 90-meter hub height. Figures 1, 2, and 3 illustrate the project area and the proposed locations of the Layout 1, Layout 2, and Layout 3 turbines, respectively. Each figure also depicts the location of nearby residences and their proximity to the proposed turbine locations.

Environmental Noise Fundamentals

Sound can be described as the mechanical energy of a vibrating object transmitted by pressure waves through a liquid or gaseous medium (e.g., air) to a hearing organ, such as a human ear. *Noise* is defined as sound that is objectionable because it is disturbing or annoying.

In the science of acoustics, the fundamental model consists of a sound (or noise) source, a receiver, and the propagation path between the two. The loudness of the noise source and obstructions or atmospheric factors affecting the propagation path to the receiver determine the sound level and characteristics of the noise perceived by the receiver.

Sound Descriptors

Continuous sound can be described by frequency (pitch) and amplitude (loudness). A low-frequency sound is perceived as low in pitch. Frequency is expressed in terms of cycles per second, or Hertz (Hz) (e.g., a frequency of 250 cycles per second is referred to as 250 Hz). High frequencies are sometimes more conveniently expressed in kilohertz (kHz), or thousands of Hz. The audible frequency range for humans is generally between 20 Hz and 20,000 Hz.

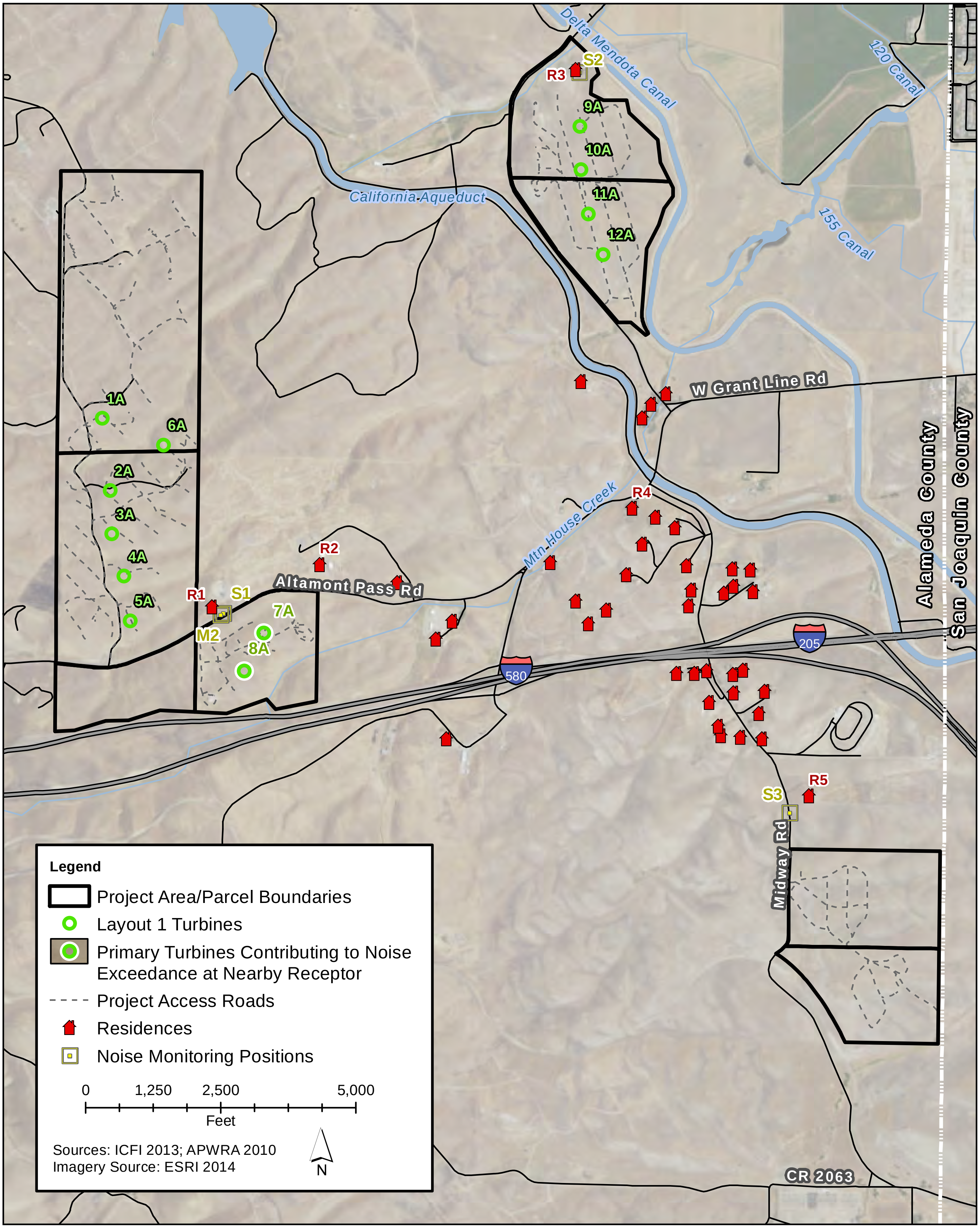
The amplitude of pressure waves generated by a sound source determines the loudness of that source. Sound pressure amplitude is measured in micro-Pascals (mPa). One mPa is approximately one hundred-billionth (0.00000000001) of normal atmospheric pressure. Sound pressure amplitudes for different kinds of noise environments can range from less than 100 to 100,000,000 mPa. Because of this huge range of values, sound is rarely expressed in terms of mPa. Instead, a logarithmic scale is used to describe *sound pressure level* (also referred to simply as *sound level*) in terms of decibels (dB). The threshold of hearing for young people is about 0 dB, which corresponds to 20 mPa.

The dB scale alone does not adequately characterize how humans perceive noise. The dominant frequencies of a sound have a substantial effect on the human response to that sound. Although the intensity (energy per unit area) of the sound is a purely physical quantity, the loudness or human response is determined by characteristics of the human ear.

Human hearing is limited in the range of audible frequencies as well as in the way it perceives the sound pressure level in that range. In general, people are most sensitive to the frequency range of 1,000–8,000 Hz and perceive sounds within that range better than sounds of the same amplitude in higher or lower frequencies. To approximate the response of the human ear, sound levels of individual frequency bands are weighted, depending on the human sensitivity to those frequencies. Then, an *A-weighted sound level* (expressed in units of dBA) can be computed based on this information.

The A-weighting network approximates the frequency response of the average young ear when listening to most ordinary sounds. When people make judgments of the relative loudness or annoyance of a sound, their judgments correlate well with the A-scale sound levels of those sounds. Table 1 describes typical A-weighted sound levels for various noise sources.

Other weighting networks have been devised to address high noise levels or other special problems (e.g., B-, C-, and D-scales). C-weighted sound levels are sometimes considered for wind turbine noise analysis. The C-weighted sound level, or dBC, gives more weight to lower frequency noise. C-weighting is very close to an unweighted or *flat* response. When evaluating sounds that have varying amounts of low-frequency energy, A-weighted sound levels will not indicate the low frequency variations, but C-weighted sound levels will.



ICF INTERNATIONAL

Figure 1
Noise Impacts - Layout 1

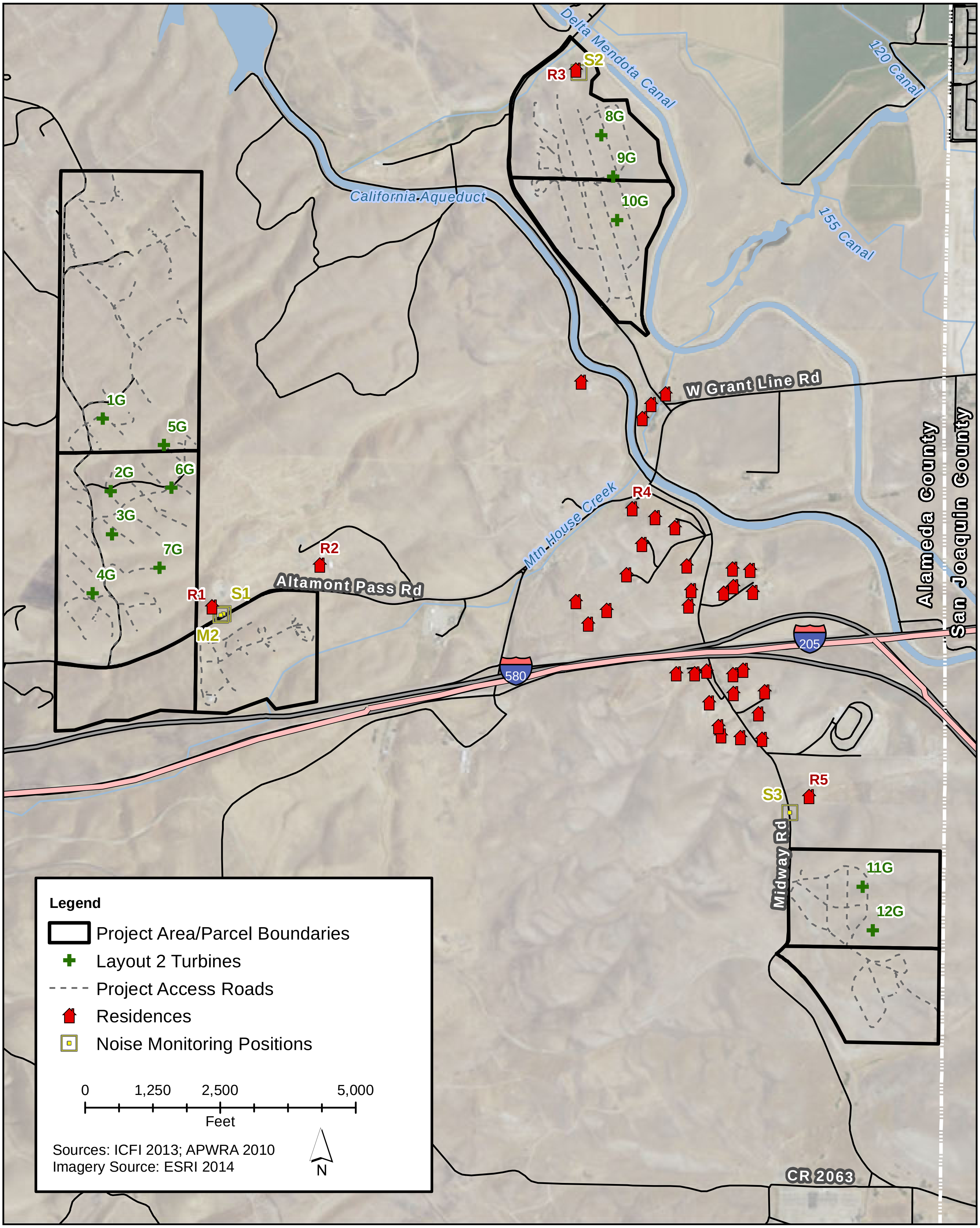


Figure 2
Noise Impacts - Layout 2

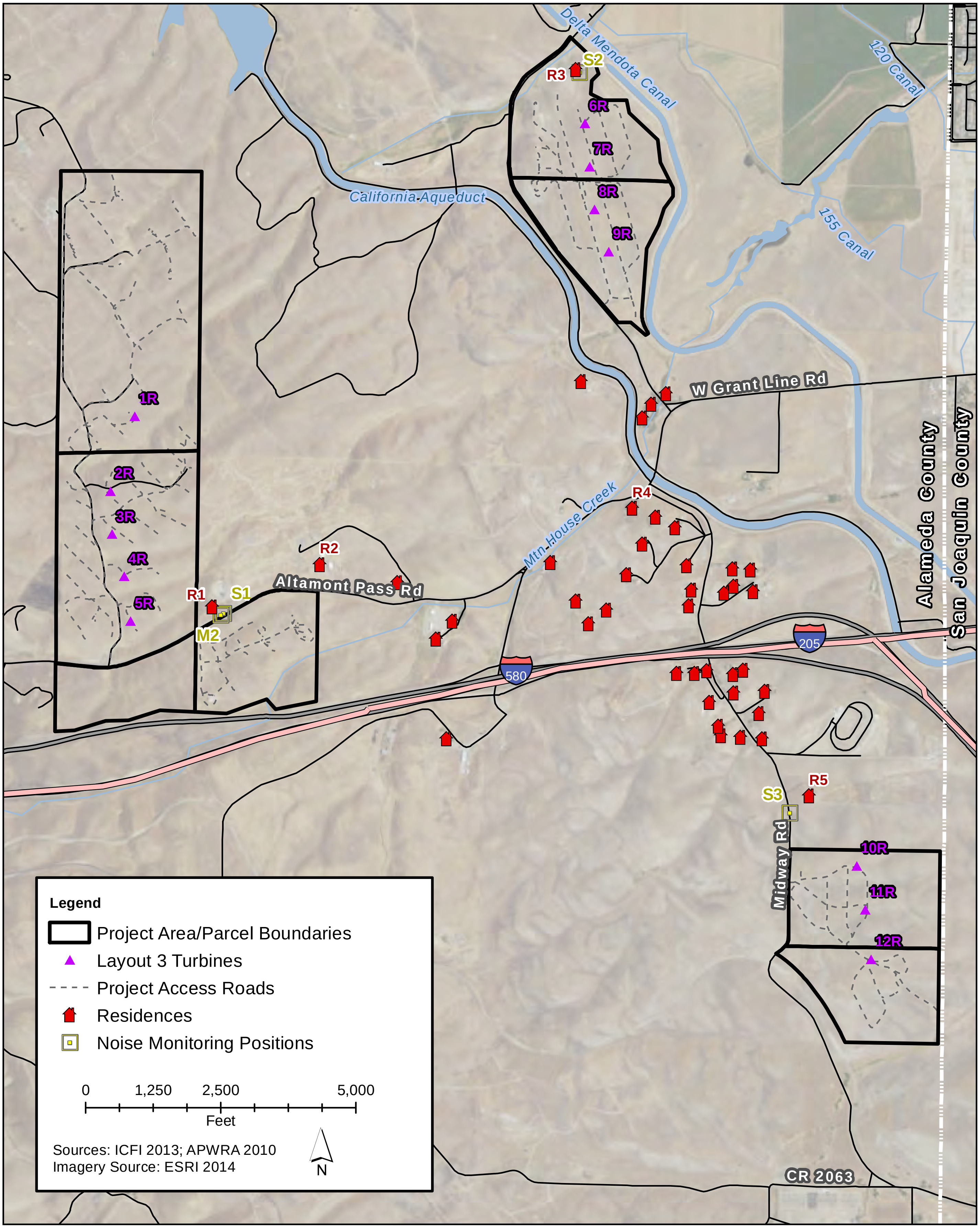


Figure 3
Noise Impacts - Layout 3

Table 1. Typical A-Weighted Sound Levels

Common Outdoor Activities	Sound Level (dBA)	Common Indoor Activities
	— 110 —	Rock band
Jet flying at 1,000 feet		
	— 100 —	
Gas lawn mower at 3 feet		
	— 90 —	
Diesel truck at 50 feet at 50 mph		Food blender at 3 feet
	— 80 —	Garbage disposal at 3 feet
Noisy urban area, daytime		
Gas lawn mower, 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 next room
Quiet urban nighttime	— 40 —	Theater, large conference room (background)
Quiet suburban nighttime		
	— 30 —	Library
Quiet rural nighttime		Bedroom at night
	— 20 —	
		Broadcast/recording studio
	— 10 —	
Lowest threshold of human hearing	— 0 —	Lowest threshold of human hearing

Source: California Department of Transportation 2013.
dBA = A-weighted sound level
mph = miles per hour

Noise in most typical environments fluctuates over time. Various noise descriptors have been developed to describe time-varying noise levels. The following are the noise descriptors most commonly used in environmental noise analysis.

- **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 1-hour A-weighted equivalent sound level (L_{eq}[h]) is the energy average of A-weighted sound levels occurring during a 1-hour period.
- **Percentile-Exceeded Sound Level (L_{xx}):** L_{xx} represents the sound level exceeded for a given percentage of a specified period (e.g., L_{10} is the sound level exceeded 10% of the time, and L_{90} is the sound level exceeded 90% of the time).
- **Minimum and Maximum Sound Level (L_{min} and L_{max}):** L_{min} is the lowest A-weighted sound level during a specified period, while L_{max} is the highest.

- **Day-Night Level (L_{dn}):** L_{dn} is the energy average of A-weighted sound levels occurring over a 24-hour period, with a 10-dB penalty added to A-weighted sound levels occurring between 10:00 p.m. and 7:00 a.m.
- **Community Noise Equivalent Level (CNEL):** Much like L_{dn}, CNEL is the energy average of the A-weighted sound levels occurring over a 24-hour period, with a 10-dB penalty added to A-weighted sound levels occurring between 10:00 p.m. and 7:00 a.m. and a 5-dB penalty added to the A-weighted sound levels occurring between 7:00 p.m. and 10:00 p.m.

Decibel Addition

Because decibels are logarithmic units, sound pressure levels cannot be added or subtracted through ordinary arithmetic. On the dB scale, a doubling of sound energy corresponds to a 3-dB increase. In other words, when two identical sources are each producing sound of the same loudness, their combined sound level at a given distance would be 3 dB higher than one source under the same conditions. For example, if one wind turbine produces a sound pressure level of 70 dBA, two wind turbines would not produce 140 dBA—rather, they would combine to produce 73 dBA. The cumulative sound level of any number of sources such as wind turbines can be determined using decibel addition.

Perception of Sound Level Changes

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 (1,000–8,000 Hz) range. In typical noisy environments, changes in sound of 1–2 dB are generally not perceptible. However, it is widely accepted that people are able to begin to detect sound level increases of 3 dB in typical noisy environments. Further, a 5-dB increase is generally perceived as a distinctly noticeable increase, and a 10-dB increase is generally perceived as a doubling of loudness. Accordingly, a doubling of sound energy (e.g., doubling the volume of traffic on a highway) that would result in a 3-dB increase in sound would generally be barely detectable.

Sound Propagation

When sound propagates over distance, it changes in level and frequency. The manner in which sound reduces with distance depends on the factors described in the next sections.

Geometric Spreading

Sound from a stationary localized source (i.e., a point source) propagates uniformly outward in a spherical pattern. The sound level attenuates (i.e., decreases) at a rate of 6 dB for each doubling of distance from a point source. The strength of the source is often characterized by its sound power level. Sound power level is independent of the distance a receiver is from the source and is a property of the source alone. If the sound power level of an idealized source and its distance from a receiver are known, sound pressure level at the receiver point can be calculated based on geometric spreading. This approach is applied to wind turbine generators in the standard measurement techniques for determining the sound power or source level (Illingworth & Rodkin 2009).

A number of factors can modify the sound level associated with spherical spreading. The first factor is the ground, which acts as a reflecting plane. If the ground is hard, sound energy is reflected off the ground and typically increases A-weighted sound levels by 3 dB. If the ground plane is acoustically soft or absorptive (such as grassland or a plowed field), some sound energy is absorbed by the ground and the increase from reflection will be less than 3 dB.

Other Factors that Affect Propagation

Additional factors that affect sound propagation are often grouped under the term *excess attenuation*. Excess attenuation is any additional attenuation that is not attributed to simple spherical spreading. Excess attenuation includes shielding effects from barriers (e.g., hills or structures); attenuation effects associated with vegetation, trees, rain, sleet, snow, or fog; and attenuation associated with wind and temperature gradients. Excess attenuation is almost always present under outdoor propagation conditions. For sound propagating over soft ground at near grazing angles of incidence, excess attenuations of 20–30 dB can be measured as a result of the interference effect of the direct and reflected sound. However, under certain meteorological conditions, some of these excess attenuation mechanisms are reduced or eliminated, leaving spherical spreading as the primary determinant of sound level at a receiver location (Illingworth & Rodkin 2009).

Other Factors Related to Wind Turbines

Operating wind turbines can generate two types of sound: mechanical sound from components such as gearboxes, generators, yaw drives, and cooling fans; and aerodynamic sound from the flow of air over and past the rotor blades. Modern wind turbine design has greatly reduced mechanical sound, which can generally be ignored in comparison to the aerodynamic sound, which is often described as a swishing or whooshing sound.

Wind turbines produce a broadband sound (i.e., the sound covers a wide range of frequencies, including low frequencies). Low-frequency sounds are in the range of 20–100 Hz, and infrasonic sound (or infrasound) is low-frequency sound of less than 20 Hz. Low-frequency sound propagates over longer distances than higher frequency sound, is transmitted through buildings more readily, and can excite structural vibrations (e.g., rattling windows or doors). The threshold of perception, in decibels, also increases as the frequency decreases. For example, in the frequency range where humans hear best (in the low kH), the threshold of hearing is at about 0 dB, but at a frequency of only 10 Hz, the threshold of hearing is about 100 dB (Rogers et al. 2006).

Older wind turbines—particularly those in which the blades were on the downwind side of the tower—produced more low-frequency sound because their towers blocked wind flow, causing the blades to pass through more turbulent air. Modern, upwind turbines produce a broadband sound that includes low-frequency sounds, but not at significant levels. A primary cause for low-frequency sounds in modern turbines is the blade passing through the change in air flow at the front of the tower, and this can be aggravated by unusually turbulent wind conditions. This effect is generally referred to as blade amplitude modulation because the aerodynamic sound generated by the blades (i.e., the swishing sound) is modulated as the turbine blades pass through uneven air velocities. The uneven air that causes this effect may be due to interaction of other turbines, excessive wind shear, or topography (Bowdler 2008).

Wind generates sound. The amount of sound generated can vary widely depending primarily on the amount of vegetation in the area and the speed of the wind. For a given wind speed, the sound level in a desert with no trees or vegetation will be different than in a highly vegetated area. When trees are in full leaf, wind rustling through the leaves produces high frequency sound. The amount of sound generated depends on wind speed, the distance to the trees or foliage, and the approximate frontal area of the trees or foliage as seen from the observed position. Sound levels generated by wind can range from approximately 20–60 dBA for wind speeds in the range of 2–20 miles per hour (mph) (Hoover & Keith 2000).

Regulatory Setting

Federal, state, and local agencies regulate different aspects of environmental noise. Generally, the federal government establishes noise standards for transportation-related noise sources closely linked to interstate commerce. These sources include aircraft, locomotives, and heavy-duty trucks. The state government sets noise standards for transportation noise sources such as automobiles, light trucks, and motorcycles. Noise sources associated with industrial, commercial, and construction activities are generally subject to local control through noise ordinances and general plan policies. Local general plans identify general principles intended to guide and influence development plans. No federal or state regulations are directly applicable to the proposed project. The local regulatory setting is discussed below.

Local

County General Plan Noise Element

The County's General Plan Noise Element (Alameda County 1975) contains goals, objectives, and implementation programs to provide county residents with an environment that is free from excessive noise, and promotes compatibility of land uses with respect to noise. The Noise Element does not explicitly define the acceptable outdoor noise level for the backyards of single-family homes or common outdoor spaces of multifamily housing projects, but it recognizes the U.S. Environmental Protection Agency noise level standards for residential land uses. These standards are an exterior L_{dn} of 55 dBA and an interior L_{dn} of 45 dBA. (The L_{dn} measurement, which also includes a 10 dB weighting for nighttime sound, is approximately equal to the CNEL for most environmental settings.) The Noise Element also references noise and land use compatibility standards developed by an Association of Bay Area Governments–sponsored study.

East County Area Plan

The County's *East County Area Plan* (Alameda County 2000) contains a goal, policies, and implementation programs related to community noise and windfarms.

Goal: To minimize East County residents and workers exposure to excessive noise.

Policy 170: The County shall protect nearby existing uses from potential traffic, noise, dust, visual, and other impacts generated by the construction and operation of windfarm facilities.

Policy 288: The County shall endeavor to maintain acceptable noise levels throughout East County.

Policy 289: The County shall limit or appropriately mitigate new noise sensitive development in areas exposed to projected noise levels exceeding 60 dB based on the California Office of Noise Control Land Use Compatibility Guidelines.

Policy 290: The County shall require noise studies as part of development review for projects located in areas exposed to high noise levels and in areas adjacent to existing residential or other sensitive land uses. Where noise studies show that noise levels in areas of existing housing will exceed "normally acceptable" standards (as defined by the California Office of Noise Control Land Use Compatibility Guidelines), major development projects shall contribute their pro-rated share to the cost of noise mitigation measures such as those described in Program 104.

Program 74: The County shall amend the Zoning Ordinance to incorporate siting and design standards for wind turbines to mitigate biological, visual, noise, and other impacts generated by windfarm operations.

Program 104: The County shall require the use of noise reduction techniques (such as buffers, building design modifications, lot orientation, sound walls, earth berms, landscaping, building setbacks, and real estate disclosure notices) to mitigate noise impacts generated by transportation-related and stationary sources as specified in the California Office of Noise Control Land Use Compatibility Guidelines.

County General Code

Several components of the County's General Code are applicable to the proposed project. The County's Noise Ordinance (County General Code, Chapter 6.60) allows higher noise exposure levels for commercial properties than for residential uses, schools, hospitals, churches, or libraries. These standards augment the state-mandated requirements of the County Building Code, which establishes standards for interior noise levels consistent with the noise insulation standards in the California State Building Code. Table 2 shows the number of cumulative minutes that a particular external noise level is permitted, as well as the maximum noise allowed under the County General Code.

Table 2. Alameda County Exterior Noise Standards

Cumulative Number of Minutes in any 1-hour Period	Daytime (7:00 a.m. to 10:00 p.m.) (dBA)	Nighttime (10:00 p.m. to 7:00 a.m.) (dBA)
Residential uses, schools, hospitals, churches, and libraries		
30	50	45
15	55	50
5	60	55
1	65	60
Maximum (0)	70	65
Commercial uses		
30	65	60
15	70	65
5	75	70
1	80	75
Maximum (0)	85	80
dBA = A-weighted sound level		

The County Zoning Ordinance (County General Code, Chapter 17) restricts noise from commercial activities by prohibiting any use that would generate a noise or vibration that is discernible without instruments beyond the property line. This performance standard does not apply to transportation activities or temporary construction work. The provisions of the zoning ordinance do not apply to noise sources associated with construction, provided the activities do not take place before 7:00 a.m. or after 7:00 p.m. on any day except Saturday or Sunday, or before 8:00 a.m. or after 5:00 p.m. on Saturday or Sunday.

County Conditional Use Permits

The County's CUPs for the continued operation of the APWRA windfarms after 2005, regulated by Resolution Number R-2005-463, identify the following specific conditions regarding noise.

21. Noise Standards: Wind turbines shall be operated so as to not exceed the County's noise standard of 55 dBA (L_{dn}) or 70 dBC (L_{dn}) as measured in both cases at the exterior of any dwelling unit. If the dwelling unit is on land under lease from the Permittee, the applicable standard shall be 65 dBA (L_{dn}) and 70 dBC (L_{dn}).

22. Noise Complaints: In the event a reasonable complaint is received by the Building Official alleging the presence of sound levels from a wind turbine or windfarm exceeding 55 dBA (L_{dn}) at a dwelling that was existing at the time this permit was issued (or 65 dBA [L_{dn}] if the dwelling is on land under lease for a windfarm), or 70 dBC (L_{dn}) as measured at the exterior of the dwelling:

    a. The Building Official shall report this matter to the Permittee and to the Planning Director and upon receipt of such report, this matter shall be brought to hearing pursuant to Section 17.54.650 and may be considered as provided by Section 17.54.030 of the Alameda County Ordinance Code; and

    b. Upon receipt of the report of the Building Official, the Planning Director shall commission a qualified firm to make a site specific study and furnish a report and recommendation on the circumstances, if any, which would render the project in conformance with all applicable noise conditions; the report shall also include a recommendation to the Board of Zoning Adjustments who will make the final determination as to whether subsection (d) shall be imposed.

    c. For a minimum 30-day period from the date of notification, at the time and place as may be agreed upon by the parties involved, Permittee shall attempt in good faith to negotiate a resolution of this matter with the party making the allegation; any such resolution shall be reported to the Planning Director in a timely manner; and

    d. Following the review period as provided under subsection (c) and until the conclusion of the revocation procedures as provided by Section 17.54.030, up to one fourth of the wind turbines authorized by this permit to be constructed or maintained that are in closest proximity to the dwelling of the party making the allegation, shall be made inoperative.

    Methods for measuring and reporting acoustic emissions from wind turbines and windfarms shall be equal to or exceed the minimum standards for precision described in American Wind Energy Association (AWEA) Standard AWEA 2.1-1989: *Procedures for the Measurement and Reporting of Acoustic Emissions from Wind Turbine Generation Systems (WTGS) Volume I: First Tier.*

    The Planning Director, in consultation with the Alameda County Environmental Health Services Agency, shall establish criteria for noise samples and measurement parameters such as the duration of data collection, time of day, wind speed, atmospheric conditions and direction as set forth in the Wyle Research Report.

23. Noise Enforcement Deposits: The Permittee shall as condition of the continued operation of the Facility as approved under this Permit maintain a $2,000.00 cash deposit for use in the

> investigation and evaluation of a noise complaint as provided in Condition 22 herein above. If all or any part of said cash deposit is depleted by such activities, the Permittee shall restore the balance of the deposit to the original $2,000.00. In the course of the review of this permit on the third anniversary of its issuance, if warranted by the record, the requirement of this $2,000.00 deposit may be deleted and funds paid by the Permittee may be returned to the Permittee.

The Resolution approving the CUPs for windfarm operations included a finding that as a land use, the wind energy use "is properly related to other land uses and transportation and service facilities in the vicinity, in that … d) Although some residents may object to the visual, noise, or other effects of the turbines, the County has determined that the wind energy projects are in compliance with the conditions of approval and are an acceptable use in the area."

Existing Sound Environment

Land around the project area is primarily agricultural land with some scattered rural residences. Sound sources in the project area include traffic on local and distant roadways, existing wind turbines, and natural sources such as birds and wind blowing through tall grass.

Short-Term Monitoring

Short-term (1–2 minute average) measurements were collected at three monitoring locations located near residences (receptors) R1, R3, and R5 and designated as S1, S2, and S3, respectively (Figures 1 and 2). ICF was not granted landowner access to the R1 and R5 properties so position S1 and S2 were located in the public right-of-way directly adjacent to Altamont Pass Road and Midway Road, respectively. ICF was granted access to the property at R2 by the land owner.

Position S1 was located approximately 150 feet southeast of receptor R1. Position S2 was located on the property near the residence. Position S3 was located approximately 375 feet southwest of receptor R3.

Monitoring was conducted at S1, S2, and S3 on Monday, January 25, 2016, at 11:21 a.m., 11:53 a.m., and 12:31 p.m., respectively, using a Larson Davis Model 831 sound level meter (SLM). This SLM is classified as Type 1 (precision-grade) instrument, as defined in American National Standard Institute (ANSI) specification S1.4-1984 and International Electrotechnical Commission publications 804 and 651. The meters were set to the "slow" time-response mode and the A-weighting filter network.

Wind speed, temperature, and relative humidity measurements were taken during the sound measurement periods with a handheld Kestrel 3000 portable weather meter. Weather conditions were generally calm with occasional gusts to 5 or 6 mph. Skies were overcast, with temperature at 53 degrees Fahrenheit (°F) and relative humidity at 75%. The sound level measurements were taken during calm, quiet periods when there were no vehicles or other obvious sources of sound. None of the existing turbines in the immediate area were operating. Tables 3 through 5 summarize the short-term sound level measurement results at each monitoring position.

Table 3. Summary of Measurements at S1

Position	Start Time	Duration	L_{eq}	L_{max}	L_{min}	L_{10}	L_{33}	L_{50}	L_{90}
S1	11:21 a.m.	1 min	40.8	57.2	35.7	43.1	39.1	38.1	36.9

Latitude, Longitude Coordinates: 37.743639°, -121.603321°
L_{eq} = equivalent sound level
L_{max} = maximum A-weighted sound level
L_{min} = minimum A-weighted sound level
L_{xx} = percentile-exceeded sound level (e.g., 10 percent, 33 percent, 50 percent, and 90 percent)

Table 4. Summary of Measurements at S2

Position	Start Time	Duration	L_{eq}	L_{max}	L_{min}	L_{10}	L_{33}	L_{50}	L_{90}
S2	11:53 a.m.	2 min	34.9	44.1	27.1	38.5	34.0	32.6	28.7

Latitude, Longitude Coordinates: 37.771322°, -121.580955°
L_{eq} = equivalent sound level
L_{max} = maximum A-weighted sound level
L_{min} = minimum A-weighted sound level
L_{xx} = percentile-exceeded sound level (e.g., 10 percent, 33 percent, 50 percent, and 90 percent)

Table 5. Summary of Measurements at S3

Position	Start Time	Duration	L_{eq}	L_{max}	L_{min}	L_{10}	L_{33}	L_{50}	L_{90}
S3	12:31 a.m.	2 min	48.2	62.4	42.6	51.9	48.5	47.4	44.3

Latitude, Longitude Coordinates: 37.733864°, -121.566979°
L_{eq} = equivalent sound level
L_{max} = maximum A-weighted sound level
L_{min} = minimum A-weighted sound level
L_{xx} = percentile-exceeded sound level (e.g., 10 percent, 33 percent, 50 percent, and 90 percent)

Long-Term Monitoring

Long-term sound level data was also collected at monitoring positions S1, S2, and S3 in 1-hour increments on Tuesday, January 26, and Wednesday, January 27, 2016 beginning at midnight and ending at midnight. Monitoring was conducted using three Piccolo SLM-P3 sound level meters, a Type 2 instrument, as defined in ANSI specification S1.4-1984 and International Electrotechnical Commission publications 804 and 651. As previously noted, positions S1 and S3 were located in the public right-of-way directly adjacent to the roadway. Accordingly, the measurements at these positions were strongly influenced by traffic and represent sound levels that are higher than at the nearby residences; the results at these positions are provided for general reference. Table 6 summarizes the measurement results.

Table 6. Summary of Long-term Measurements

Location	Tuesday January 26 (L_{dn})	Wednesday January 27 (L_{dn})
S1*	77.5	77.2
S2	50.8	49.5
S3*	67.0	65.5

*Measurement location abutting roadway and is strongly influenced by traffic. This measurement value represents a sound level higher than on the nearby residential property.
L_{dn} = day-night level

Impact Discussion

Analysis Methods

Wind Turbine Sound

The project applicant provided one-third octave band A-weighted sound power data for the GW121/2500. A copy of the data corresponding to a wind speed of 10 meters per second (m/s) is provided in Appendix A. For analysis purposes, octave band sound power levels were used and determined by summing the one-third octave band sound power levels associated with each octave band. Table 7 summarizes the resulting A-weighted octave band sound power levels and the overall A-weighted sound power level.

Table 7. A-Weighted Sound Power Levels

Overall (dBA)	Octave Bands								
	31.5	63	125	250	500	1000	2000	4000	8000
	A-Weighted Sound Power Levels								
106.8	80.1	88.2	92.4	98.7	102.4	100.8	94.1	93.5	96.0

dBA = A-weighted sound level

Sound levels at various distances are calculated on the basis of hemispherical point source attenuation using the following equation (Hoover & Keith 2000):

$$L_p = L_w - 10\log 2\pi d^2 + 10$$

Where:

L_p = sound pressure level
L_w = sound power level
d = distance from source in feet

Atmospheric molecular absorption based on “standard” day conditions (64°F and 70% humidity) was also included in the calculation (Hoover & Keith 2000). Attenuation values per 1,000 feet are summarized in Table 8.

Table 8. Octave Band Sound Levels for Proposed Turbines

Octave band	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz
Atmospheric absorption	0.1	0.2	0.4	0.7	1.5	3.0	7.6	13.7

Hz = Hertz
kHZ = kilohertz

Table 9 incorporates the data from Table 7 and Table 8 to provide a summary of the single turbine sound levels at various distances.

Table 9. Predicted Sound Levels at Various Distances from a Single Turbine

Distance (feet)	dBA
500	54.0
1,000	47.4
1,500	43.4
2,000	40.4
2,500	38.1
3,000	36.1
3,500	34.4
4,000	32.9

dBA = A-weighted sound level

Analysis

Each layout would involve the operation of 12 turbines. The cumulative sound level at five key receptor locations was calculated by applying geometric attenuation and atmospheric attenuation from Table 8. No other attenuation factors or safety factors were applied. Receptor locations are shown in Figures 1 and 2.

Table 10 summarizes the calculated A-weighted L_{eq} and L_{dn} sound levels at each receptor location for Layout 1.

Table 10. Modeling Results for Layout 1

Receptor	L_{eq} (dBA)	L_{dn} (dBA)	L_{dn} (dBC)
R1	51.1	**57.5**	**71.8**
R2	45.8	52.2	67.4
R3[1]	48.5	54.9[1]	69.2[1]
R4	36.7	43.1	60.6
R5	29.2	35.6	55.7

L_{eq} = equivalent sound level
L_{dn} = day-night level
dBA = A-weighted sound level
dBC = C-weighted sound level
[1] Dwelling is on land under lease by permittee so criteria are 65 L_{dn}-A and 70 L_{dn}-C.

The results show an exceedance of the County 55 L_{dn} (A) and 70 L_{dn} (C) noise standards at R1 (shown in bold in Table 10). The exceedance is primarily driven by turbines 7A and 8A, the turbines closest to R1. R3 is on land under lease with the project. As such, the applicable noise standard increases to 65 L_{dn} (A).

One approach for reducing the L_{dn} sound levels to a compliant level at R1 would be to curtail the operation of turbines 7A and 8A at night. The resulting modeled sound levels are 54.6 L_{dn} (A) and 69.2 L_{dn} (C). However, this strategy is not economically feasible given the wind speeds are typically higher during the evening and early morning hours.

Table 11 summarizes the calculated sound levels at each receptor location under Layout 2. The A-weighted L_{eq} and L_{dn} at each receptor location are provided.

Table 11. Modeling Results for the Layout 2

Receptor	L_{eq} (dBA)	L_{dn} (dBA)	L_{dn} (dBC)
R1	48.5	54.9	69.5
R2	42.6	49.0	64.8
R3[1]	46.6	53.0[1]	67.5[1]
R4	35.5	41.9	59.8
R5	42.4	48.8	63.9

L_{eq} = equivalent sound level
L_{dn} = day-night level
dBA = A-weighted sound level
dBC = C-weighted sound level
[1] Dwelling is on land under lease by permittee so criteria are 65 L_{dn}-A and 70 L_{dn}-C.

The results in Table 11 do not show an exceedance of the County 55 and 65 L_{dn} (A) and 70 L_{dn} (C) noise standards. However, the calculated L_{dn} value at receptor R1 is however within 0.5 dB of the 55 L_{dn} (A) and L_{dn} (C) noise standards.

Table 12 summarizes the calculated sound levels at each receptor location under Layout 3 (Preferred Alternative). The A-weighted L_{eq} and L_{dn} at each receptor location are provided.

Table 12. Modeling Results for the Layout 3 (Preferred Alternative)

Receptor	L_{eq} (dBA)	L_{dn} (dBA)	L_{dn} (dBC)
R1	47.2	53.6	68.2
R2	40.6	47.0	63.3
R3[1]	48.9	55.3[1]	69.5[1]
R4	36.4	42.8	60.4
R5	45.0	51.4	66.1

L_{eq} = equivalent sound level
L_{dn} = day-night level
dBA = A-weighted sound level
dBC = C-weighted sound level
[1] Dwelling is on land under lease by permittee so criteria are 65 L_{dn}-A and 70 L_{dn}-C.

The results in Table 11 do not show an exceedance of the County 55 and 65 L_{dn} (A) and 70 L_{dn} (C) noise standards.

Discussion and Conclusions

Calculated sound for the proposed GW121-2500 wind turbines for Layout 3 does not exceed County noise standards at any nearby residences. Although the calculated sound for the proposed GW121-2500 wind turbines at receptor R1 exceeds County noise standards under Layout 1, and is close to exceeding the standards under Layout 2, it is important to put these calculated sound levels in context. Large numbers of wind turbines have operated in the project area near these receptors for several decades; for purposes of this discussion, these existing turbines are referred to as legacy turbines. The following is a discussion of previous measurements and modeling that have been used to characterize sound conditions when legacy turbines were previously operating.

Measurements with Legacy Turbines Operating

ICF conducted sound level measurements near receptor R1 in July 2013 at a position designated as M2 (Figures 1 and 2) about 400 feet southwest of the residence (ICF International 2013). At that time, a number of the legacy turbines were operating. The average wind speed as measured with a handheld meter during the measurement period was approximately 12 mph (5.4 m/s). Table 13 summarizes key measurement data recorded. Sound from the legacy turbines and sound from wind blowing through the grass was audible. Measurements were taken in the absence of nearby traffic or other specific sources of sound.

Table 13. Summary of Measurements at M2 (July 2013)

Position	Start Time	Duration	L_{eq}	L_{max}	L_{min}	L_{10}	L_{33}	L_{50}	L_{90}
M2	10:38 a.m.	5 min	56.1	62.6	53.6	57.6	56.0	55.5	54.3

Latitude, Longitude Coordinates: 37.743564°, -121.603492°
L_{eq} = equivalent sound level
L_{max} = maximum A-weighted sound level
L_{min} = minimum A-weighted sound level
L_{xx} = percentile-exceeded sound level (e.g., 10 percent, 33 percent, 50 percent, and 90 percent)

The measured L_{eq} value at M2 was 56.1 dBA. The sound levels at M2 are considered to be reasonably representative of the sound levels at R1 in the absence of traffic.

Modeling of Legacy Turbines

To provide further context, a sound model was developed assuming 399 legacy turbines were operating within the project area. Table 14 summarizes the models, ratings, and number of legacy turbines.

Table 14. Legacy Turbines in the Project Area

Turbine Name	Rating (kWs)	Number of Turbines
Enertech	40	136
Micon 65 kW	65	225
Windmatic 15S	66	26
Polenki 100	100	12

kW = kilowatt

Manufacturer sound power level or octave-band data are not available for these legacy turbines. There is, however, a study conducted by the National Renewable Energy Laboratory (NREL) (National Renewable Energy Laboratory 2003) that provides measured A-weighted sound power levels associated with several types of small wind turbines that are similar in size to the legacy turbines. Table 15 lists theses turbine models along with their power ratings and sound power levels.

Table 15. Sound Power Levels for Small Turbines (≤100 kW)

Name	Rating (kW)	Sound Power (dBA) for Wind at 8 m/s
Southwest AIR 403	0.4	81.2
Southwest Whisper H40	0.9	84.9
Bergey Excel-S	10	98.4
Atlantic Orient AOC 15/50	50	101.1
NPS North Wind 100	100	93.8

Source: National Renewable Energy Laboratory 2003.
kW = kilowatt
dBA = A-weighted sound level
m/s = meters per second

To estimate the sound power of the legacy turbines, a logarithmic curve fit line was developed using the NREL measured sound power levels. The estimated sound power levels are summarized in Table 16 and plotted in Figure 4.

Table 16. Estimated Sound Power Levels for Legacy Turbines

Name	Rating (kW)	Sound Power (dBA) for Wind at 8 m/s
Enertech	40	97.1
Micon 65 kW	65	98.5
Windmatic 15S	66	98.6
Polenki 100	100	99.8

kW = kilowatt
dBA = A-weighted sound level
m/s = meters per second

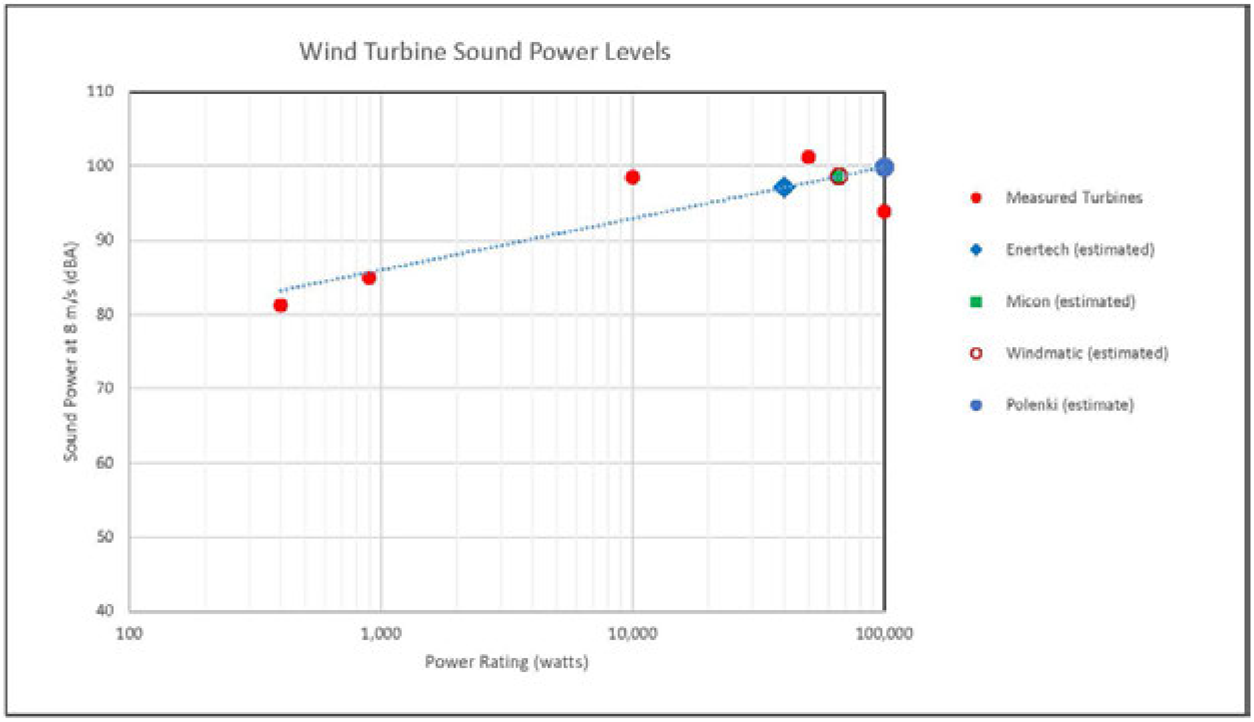


Figure 4. Sound Power Levels for Small Turbines

A legacy turbine sound model was then developed using the Table 16 results and employing the same methods as those described for the proposed GW121-2500 turbines. For comparison, Table 17 summarizes the calculated sound levels at receptor R1 for the legacy turbines, the sound level measured at position M2, and the calculated sound levels for the two GW121-2500 layouts.

Table 17. Calculated Sound Levels at R1 for Legacy Turbines and GW121-2500 Layouts (with measured sound level at Position M2)

Condition	L_{eq} (dBA)	L_{dn} (dBA)
Legacy	56.6	63.0
M2 (measured)	56.1	NA
Layout 1 – GW121-2500	51.1	57.5
Layout 2 – GW121-2500	48.5	54.9
Layout 3 – GW121-2500	47.2	53.6

L_{eq} = equivalent sound level
L_{dn} = day-night level
dBA = A-weighted sound level
NA = not applicable

The modeling results show that the calculated L_{eq} of 56.6 dBA for the legacy turbines is consistent with the 56.1 dBA measured at M2. Further, the result show that the calculated sound levels for receptor R1 from the operation of the three GW121-2500 layouts are likely lower than sound levels experienced at that location during the operation of the 399 legacy turbine array.

References Cited

Alameda County. 1975. *Alameda County General Plan Noise Element*.

Alameda County. 2000. *East County Area Plan*.

Bowdler, D. 2008. Amplitude Modulation of Wind Turbine Noise. A Review of the Evidence. *Institute of Acoustics Bulletin* 33:4. Available: http://docs.wind-watch.org/bowdler-amofwindturbines.pdf. Accessed: June 27, 2013. Clydebank, UK: New Acoustics.

California Department of Transportation. 2013. *Technical Noise Supplement to the Traffic Noise Analysis Protocol*. Sacramento, CA.

Hoover & Keith, Inc. 2000. *Noise Control for Buildings, Manufacturing Plants, Equipment and Products.* Lecture notes, first published 1981. Houston, TX.

ICF International. 2013. *Sand Hill Wind Project Draft Environmental Impact Report*. November. (ICF 00151.13.) Sacramento, CA. Prepared for Alameda County, Hayward, CA.

Illingworth & Rodkin, Inc. 2009. *Shiloh III Wind Project Noise Technical Report, Solano County, California*. Petaluma, CA.

National Renewable Energy Laboratory. 2003. Acoustic tests of small wind turbines. Golden, CO.

Rogers, A. L., J. F. Manwell, and S. Wright. 2006. *Wind Turbine Acoustic Noise*. Available: http://ceere.org/rerl/publications/whitepapers/Wind_Turbine_Acoustic_Noise_Rev2006.pdf. Amherst, MA: Renewable Energy Research Laboratory, Department of Mechanical and Industrial Engineering, University of Massachusetts at Amherst. Accessed: June 27, 2013.

Appendix A
GW121-2500 Wind Turbine Sound Power Levels

f [Hz]	spec. 1 [dB]	spec. 2 [dB]	spec. 3 [dB]	$L_{Aeq,i}$ [dB]	$L_{WA,i}$ [dB]	U_a [dB]	U_c [dB]
25	21.8	20.3	20.7	21.0	70.8	0.8	2.1
31.5	26.2	23.5	24.0	24.7	74.5	1.4	2.5
40	29.2	27.3	27.6	28.1	77.9	1.0	2.2
50	31.7	30.6	30.8	31.0	80.8	0.6	2.1
63	34.3	34.0	34.2	34.2	84.0	0.2	2.0
80	34.9	34.7	34.9	34.8	84.6	0.1	2.0
100	35.5	35.4	35.6	35.5	85.3	0.1	2.0
125	37.6	37.7	37.7	37.7	87.5	0.0	2.0
160	39.5	39.4	39.4	39.4	89.2	0.0	2.0
200	42.0	42.0	41.9	42.0	91.8	0.0	2.0
250	43.9	43.8	43.6	43.8	93.6	0.2	2.0
315	45.7	45.8	45.5	45.7	95.5	0.1	2.0
400	47.1	47.1	47.0	47.1	96.9	0.1	2.0
500	47.8	47.8	47.7	47.8	97.6	0.0	2.0
630	48.6	48.6	48.6	48.6	98.4	0.0	2.0
800	47.5	47.5	47.6	47.5	97.3	0.1	2.0
1000	46.4	46.4	46.5	46.4	96.2	0.1	2.0
1250	43.9	44.0	44.2	44.0	93.8	0.1	2.0
1600	41.2	41.2	41.4	41.3	91.1	0.1	2.0
2000	38.7	38.7	38.9	38.7	88.5	0.1	2.0
2500	37.6	37.6	37.7	37.6	87.4	0.1	2.0
3150	38.2	38.2	38.2	38.2	88.0	0.0	2.0
4000	39.0	39.0	39.1	39.0	88.8	0.0	2.0
5000	39.6	39.6	39.7	39.6	89.4	0.0	2.0
6300	40.4	40.3	40.4	40.4	90.2	0.0	2.0
8000	41.2	41.2	41.2	41.2	91.0	0.0	2.0
10000	42.4	42.3	42.4	42.4	92.2	0.0	2.0

One third octave analysis result at 10 m/s (dB, A weight)