CENSEO
AV+Acoustics

SOUND MODELING AND PREDICTION REPORT

HAWAI'I PUBLIC SHOOTING RANGE AT PU'U ANAHULU

Waikoloa, Hawaii

July 2015

Prepared for:

PBR Hawaii & Associates

Prepared By:

CENSEO AV+Acoustics LLC

WWW.CENSEOAV.COM

Table of Contents

Appendices

List of Figures

List of Tables

1 Executive Summary

The Hawaii Department of Land and Natural Resources (DLNR) has proposed a new public shooting range to be built on existing undeveloped land, the Pu'u Anahulu Public Shooting Range. CENSEO AV+Acoustics LLC completed a comprehensive environmental sound impact assessment of the proposed shooting range on the surrounding community. The study was focused on the potential sound impact on the Waikoloa Resort Area. The sound assessment study consisted of three main parts. A report was issued for each part of the study.

Part 1: Existing Ambient Sound Measurement of the Waikoloa Resort Area
Part 2: Live Fire Sound Measurement for Firearm Sound Source Levels
Part 3: Sound Modeling and Prediction of the Proposed Shooting Range

The data and observations from Parts 1 and 2 of the study were used in Part 3 to predict sound levels from the shooting range and assess its impact on the Waikoloa Resort Area. Sound from a 12 guage Remington Model 870 Shotgun and a .30-06 Springfield M1 Garand Rifle were included in the sound study. The sound radiation from these firearms are expected to be the loudest firearms planned for the proposed shooting range.

The Datakustik CadnaA sound prediction software was used for the sound propagataion analyses. Sound contour maps were developed for both the shotgun and rifle for downwind conditions and the prevailing winds. The aiming direction of the shotgun was also considered for two of the shooting venues. The results from the modeling indicate that sound from the rifle ranges and action ranges will most likely be inaudible to most listeners. The analysis assumes that a "firing shed" (consisting of side walls and a cover, but otherwise untreated for sound absorption) is incorporated into the design of these ranges.

The sound modeling indicates that sound levels from the shotgun will be louder than the rifle. Predicted sound levels from the rifle are expected to be well below the existing ambient sound levels in the Waikoloa Resort Area. For the shotgun, the aiming direction is a critical factor in how much sound is transmitted to the Waikoloa Resort Area. The predictions for the shotgun sound are 20 dB louder in the Waikoloa area when the shotgun is aimed in the northwest direction, compared to the southeast direction. When aimed in the northwest direction, the predicted sound levels from the shotgun are expected to be in the range of approximately 50 dBA to 65 dBA, depending on the wind direction and location within the Waikoloa Resort Area. When aimed in the southeast direction, the predicted sound levels are expected to be the range of approximately 30 dBA to 45 dBA. Although the State noise regulation does not specifically address firearm discharge sound level limits, it does include sound limit for other noises. The daytime maximum permissible sound level for common steady sounds is 60 dBA (or 70 dBA for impulsive sounds).

Sound mitigation of the shotgun courses (Sporting Clays Course and Trap and Skeet Fields Course) could include an earth berm installed close to these courses, such that the berm blocks the line-of-sight to the Waikoloa Resort Area. The berm could reduce sound levels from the shotgun by approximately 5 to 10 decibels, depending on the height of the berm. The report also discusses the option of limiting the aiming direction of the shotgun courses, such that the shooter aims in the mauka direction (southeast), avoiding the northwest direction toward the Waikoloa Resort.

2 Introduction

The Hawaii Department of Land and Natural Resources (DLNR) has proposed a new public shooting range to be built on existing undeveloped land. The Pu'u Anahulu Public Shooting Range facility will be located in the North Kona District on the Island of Hawaii. CENSEO AV+Acoustics LLC (CENSEO) developed a sound propagation model to predict and assess the potential sound impact of the proposed facility on the surrounding community. This report includes the results of the sound propagation model and our assessment of potential sound impacts.

In addition to this report, CENSEO also completed a study of the existing ambient sound environment and a study of the discharge sound from two firearms. These two additional reports can be found in appendices to this report. A glossary of acoustic terminology can be found in Appendix B of this report.

The sound modeling and prediction analyses include many considerations for the "worst case scenario" regarding sound impacts at the Waikoloa Resort Area. These worst case scenario considerations include the following:

- The evaluation of the existing ambient noise environment included some of the quietest locations within the Waikoloa Resort Area.
- Assessment of the existing ambient noise environment also included the 90% exceedance sound levels, L_{90}, which represents the quietest 10% of the day.
- The sound study included sound source data from the loudest firearms that are currently planned to be used at the proposed shooting range. In addition, the impulsive response maximum sound levels, L_{max}, for each firearm were used in the analyses.
- Sound predictions were calculated using environmental conditions that are most favorable for sound propagation.
    - Downwind propagation
    - Fully developed moderate ground based temperature inversion

3 Proposed Pu'u Anahulu Public Shooting Range Project Description

The proposed Pu'u Anahulu Public Shooting Range project is located northeast of the existing Pu'u Anahulu Landfill, and it is in the vicinity of the Waikoloa Resort Area. The existing site is undeveloped land, consisting primarily of open lava fields. For reference, the direct line-of-sight distances between the shooting range and public facilities, resort, and residential areas are provided in Table 1 below.

Table 1. Distance to Pu'u Anahulu Public Shooting Range

Residential , Resort, and Other Areas	Distance to Proposed Shooting Range
Pu'u Anahulu Landfill	0.9 miles
Blue Hawaiian Helicopter Tour Landing Facility	1.0 miles
Waikoloa Beach Villas	1.7 miles
Waikoloa Beach Marriott	2.0 miles
Kings' Land by Hilton	2.0 miles
Fairway Villas	1.9 miles
Colony Villas	2.1 miles
Hilton Waikoloa Village	2.5 miles
Waikoloa Village	4.8 miles

Please refer to Figure 1 below for a vicinity map showing the location of the proposed Pu'u Anahulu Public Shooting range and the surrounding areas.

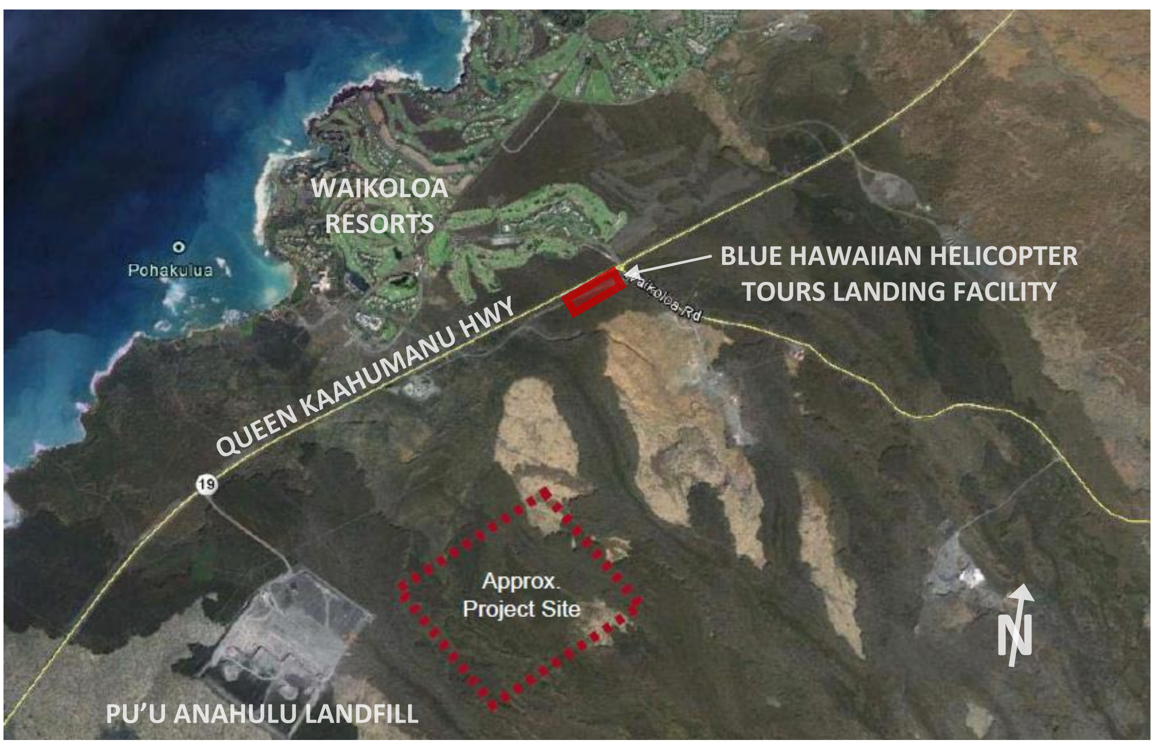


Figure 1. Vicinity Map of the Proposed Pu'u Anahulu Public Shooting Range

3.1 Pu'u Anahulu Shooting Range Activities

The proposed shooting range facility includes the following recreational functions and features:

- 1,000-yard competitive high power rifle range
- 100-yard high power target rifle range
- 100-yard rim-fire/air rifle range
- 50-yard bull's eye pistol range & 50-yard action pistol range
- Skeet and trap ranges
- Ten-station sporting clays course
- 50-yard target archery range & field archery course

The proposed project also includes office structures, a hunter education center, restrooms, picnic areas, and parking areas. Refer to Figure 2 for the proposed shooting range layout.

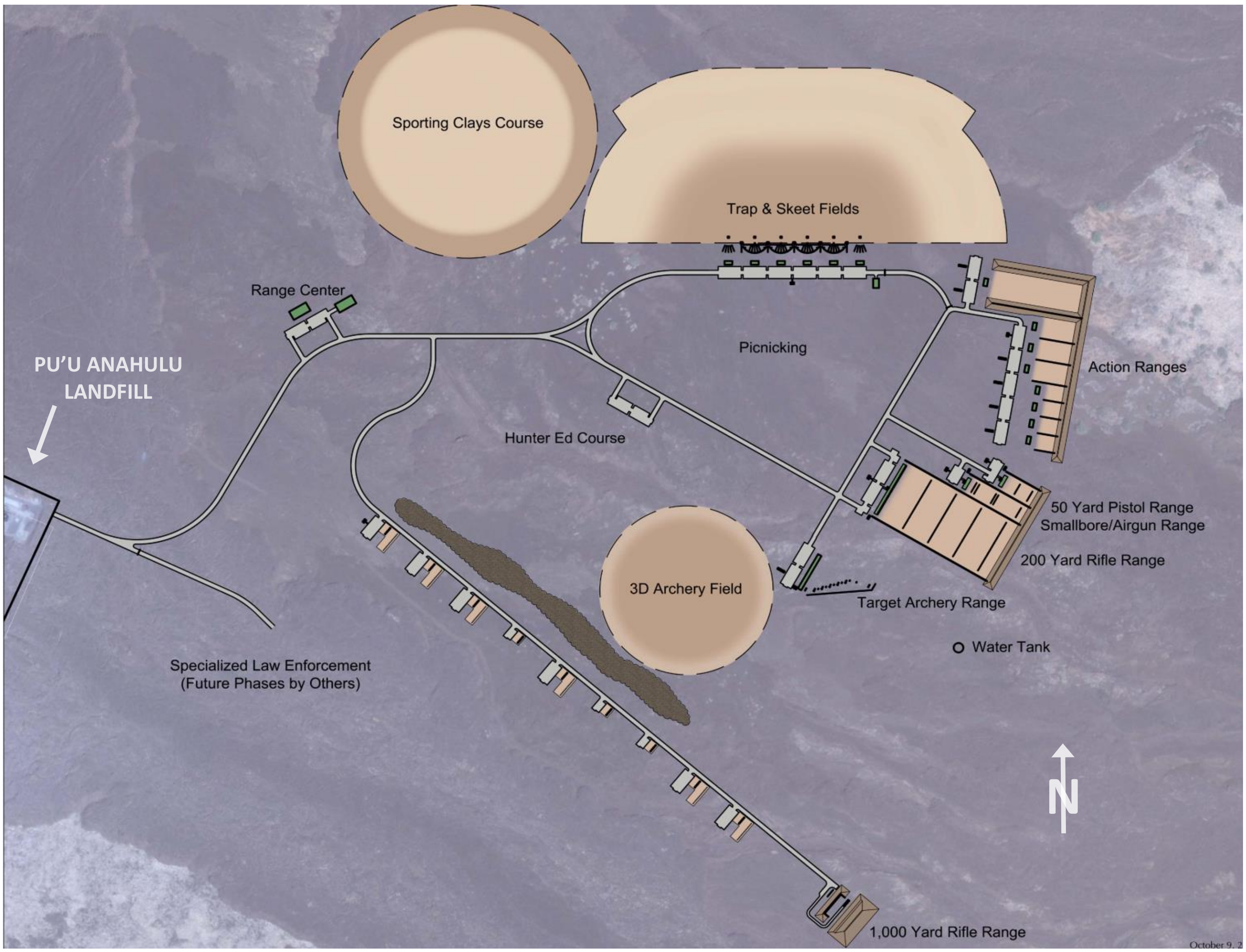


Figure 2. Proposed Pu'u Anahulu Public Shooting Range Schematic Layout

3.2 Pu'u Anahulu Shooting Range Operating Hours

At the time of this report, the specific shooting range operating hours have not been determined. However, since the proposed facility will not include course lighting suitable for nighttime use, the maximum possible operating hours would be during the daytime hours when there is sufficient daylight.

4 Sound Regulations and Guidelines

Although there are no applicable Federal or State regulations that specifically address sound level discharge from firearms, there are a few related standards and regulations that can be used as guidelines for assessment of the potential sound impacts.

4.1 U.S. Environmental Protection Agency (EPA)

In 1977, the United States Environmental Protection Agency published a report titled, *Toward a National Strategy for Noise Control.* This report included goals for limiting exterior environmental sound levels, at the sound receiver location, to 65 dBA based on using the Day-Night averaged sound level metric (L_{dn}). The report included a future goal of not exceeding 55 dBA. The EPA's sound level goals were developed with the intention of the reducing the general effects of noise on the general population.

The EPA's report was a federal program response to the Noise Control Act of 1972, in an effort to minimize noise pollution on communities across the country. However, the EPA's Office of Noise Abatement and Control lost it's funding in 1982, along with a policy shift to transfer the primary responsibility of noise regulations to state and local governments. Although the Noise Control Act of 1972 and the related Quiet Communities Act of 1978 have not been formally rescinded by Congress, they are essentially unfunded and unenforceable.

4.2 U.S. Department of Housing and Urban Development (HUD)

The U.S. Department of Housing and Urban Development developed design criteria and standards for HUD projects receiving federal funding. HUD's regulation titled, *Department of Housing and Urban Development Environmental Criteria and Standards, Title 24, CFR, Part 51,* was developed in 1979 and amended in 1984. The standard was written to establish the acceptability of HUD projects at the sound receiver location due to exterior environmental sources (i.e., roadways, aircraft flyovers, railways, etc.), and is based on the Day-Night averaged sound level (L_{dn}). HUD establishes three categories for the project site: "Acceptable", "Normally Unacceptable", and "Unacceptable", as follows:

HUD Acceptability	Sound Level (dBA)
"Acceptable"	$L_{dn} \leq 65$
"Normally Unacceptable"	$65 < L_{dn} \leq 75$
"Unacceptable"	$L_{dn} > 75$

"Acceptable" projects do not require any special sound mitigation incorporated into the project design due to exterior noises. "Normally Unacceptable" project sites require sound mitigation techniques that are above typical building construction methods. "Unacceptable" project sites will likely require extensive noise mitigation in order to achieve HUD approval.

HUD's, *The Noise Guidebook*, was developed in 1991 for designers, planners, and engineers with a methodology for assessment on the acceptability of project sites for meeting the HUD standards. Within the guidebook, HUD recommends a design goal for sound levels on the interior of the building to be equal to or less than an L_{dn} of 45 dBA. This noise limit is not a HUD requirement but rather a design goal.

4.3 State of Hawaii Administrative Rules, Department of Health (DOH)

Hawaii Administrative Rules, Title 11 – Department of Health, Chapter 46 – Community Noise Control regulates environmental noise limits within the state of Hawaii. The table shows the maximum permissible noise levels for each zoning district.

Zone District	Day Noise Limit 7am – 10pm	Night Noise Limit 10pm – 7am
Class A – Residential, conservation, preservation, public space, open space, or similar	55 dBA	45 dBA
Class B – Multi-family dwellings, apartment, business, commercial, hotel, resort, or similar	60 dBA	50 dBA
Class C – Agriculture, country, industrial, or similar	70 dBA	70 dBA

In mixed zoning areas, the primary land use designation is used for determining the zoning district. The maximum permissible sound levels shall not be exceeded (at or beyond the property line) by more than 10% of the time for any 20-minute period. The maximum permissible sound levels for impulsive sounds can be up to 10 dB above the maximum sound levels in the table above.

These sound level limits apply to "stationary noise sources; and equipment related to agriculture, construction, and industrial activities." The noise regulation further defines stationary sources as "any mechanical source of noise fixed in or on a station, course, or mode within any premises, including but not limited to mechanical air conditioning units, exhaust systems, generators, compressors, pumps, or other similar equipment."

5 Existing Ambient Sound Environment

A sound study of the existing ambient environment in the Waikoloa Resort area was conducted in early 2015. The complete study, *Existing Ambient Sound Measurement Report,* dated March 2015, can be found in Appendix C of this report. The ambient sound measurements included octave band sound levels at two locations, and overall A-weighted sound levels at a third location. The goal of the ambient sound measurements was to collect acoustical data from locations within the Waikoloa Resort area that are not only closest to the proposed Pu'u Anahulu Shooting Range, but locations that also tend to be the quietest areas.

Selecting ambient sound measurement positions that are located in the quietest areas of the Waikoloa Resort area considers areas where the residents and guests are exposed to the least amount of ambient sound. These are the locations where intermittent sounds (such as the potential sounds from the proposed Shooting Range) would be the easiest to detect. Therefore, the worst case scenario for ambient sound levels is included with this assessment.

For a subjective reference to common sound levels, a few examples are provided below. A more comprehensive list with a wider range of sound levels can be found in Appendix B

Common Outdoor Sounds	Sound Pressure Level (dBA)
Gas lawn mower at 4 feet	90 dBA
Car travelling at 55 mph at 150 feet	60 dBA
Small town residential area	50 dBA
Rustling Leaves	30 dBA

Table 2 below summarizes the octave band sound measurement results for the existing ambient sound environment.

Table 2. Existing Ambient Octave Band Sound Level Data (Hawaii Daylight Hours)

Location	L_{eq} / L_{90}	Sound Levels (L_{eq} and L_{90}) in dBA								
		Octave Band Center Frequency (Hz)								Overall
		31.5	63	125	250	500	1000	2000	4000	
Fairway Villas	L_{eq}	18	31	39	42	43	43	42	42	50
	L_{90}	9	21	28	28	33	35	33	30	41
Beach Villas	L_{eq}	21	31	36	39	42	44	43	42	52
	L_{90}	12	23	28	30	35	39	37	36	44

6 On-Site Live Fire Sound Measurements

Sound level measurements were conducted at the proposed Pu'u Anahulu Public Shooting Range site to obtain sound source level data of two firearms that will likely be used at the proposed shooting range. The complete study, *Live Fire Sound Measurement Report*, dated May 2015, can be found in Appendix D of this report. Sound levels were measured for a .30-06 Springfield M1 Garand (one of the highest caliber firearms that is currently planned for use at the proposed shooting range), and a 12 gauge Remington Model 870 Shotgun. The intent of these sound measurements was to establish sound source data for the loudest firearms to be used at the proposed shooting range. Therefore, the ammunition loads were carefully selected to be the heaviest and loudest available for each firearm.

The data collected includes sound level measurement data for each firearm, not only in the direction of the line of fire but also to the side and behind the shooter, in order to obtain directional sound source data for each firearm. This data was used with the sound prediction modeling software to assess the potential sound impact of the Pu'u Anahulu Public Shooting Range on the surrounding communities.

In addition to the sound measurements conducted in open air, sound measurements were also conducted with the M1 Garand shooting through a field fabricated sound suppressor. The goal of the sound measurements with the sound suppressor was to determine the approximate effectiveness of one potential sound mitigation technique. The sound reduction as a function of the direction with the line of fire was recorded, similar to the open air sound measurements

The octave band L_{max} values and the overall L_{max} measurement results are shown in Table 3 below.

Table 3. Summary of Sound Measurement Results for Each Firearm, at 50 ft

Firearm	Angle from Line-of-Fire	Maximum Sound Pressure Level, L_{max}, (dB)								
		Octave Band Center Frequency (Hz)								Overall
		31.5	63	125	250	500	1000	2000	4000	
Remington 870 Shotgun	0°	109	117	117	123	119	117	117	111	130
	60°	75	91	96	107	101	108	108	106	114
	120°	77	79	87	92	98	101	100	97	106
	180°	73	81	87	92	99	99	99	100	107
.30-06 Springfield M1 Garand Rifle	0°	109	107	121	127	119	116	117	117	132
	60°	98	96	106	116	118	117	110	108	122
	120°	90	85	96	104	111	106	105	104	113
	180°	80	85	97	102	103	104	106	100	111
M1 Garand (with Suppressor)	0°	97	113	112	113	108	112	115	118	126
	60°	102	102	103	106	100	93	101	101	110
	120°	98	95	98	99	95	88	95	93	104
	180°	88	98	102	98	94	98	106	101	109

7 Sound Modeling and Prediction

The primary intent of the Sound Modeling exercise was to predict future sound levels from the proposed shooting range to the noise sensitive areas in the vicinity of the shooting range. Special attention for the sound modeling was focused on the Waikoloa Resort Area, since this area is the nearest community to the proposed project.

7.1 Sound Modeling Procedure and Methodology

The Datakustik CadnaA noise prediction software was used to predict sound levels from the shooting range. The predictions were done according to the methodology of industry standard *ISO 9613-2: Acoustics – Attenuation of sound during propagation outdoors, Part 2: General Method of Calculation.* The ISO standard lays out the methodology to calculate sound levels outdoors in octave bands or broadband values, and we calculated both. The octave band sound source data collected during the on-site live fire sound measurements, including the directivity of each firearm, was used in the sound prediction model. (Refer to Section 6, Table 3 of this report).

Sound levels were predicted using source data obtained by the on-site live fire sound measurements included in our "Live Fire Sound Measurement Report" dated May 2015 (also summarized in Section 6 of this report). The octave band sound levels, as well as the directivity of each firearm, were included in the model. There are different ways to measure the extremely short duration sound of a gunshot. The live fire sound measurements used the "Impulse" response of the sound meter. Therefore, the predicted sound levels are Impulse sound levels for each firearm. The impulsive sound levels are higher than the same gunshot measured with "Slow" or "Fast" response on a sound meter, and lower than if measured using "Peak" response. We believe that the impulsive response is the best indicator of what people perceive and the potential for annoyance.

The duration of an individual gunshot is extremely short in duration (the acoustic disturbance typically lasts approximately 3 to 5 milliseconds). Even when many lanes of a shooting range are in use simultaneously, the occurrence of multiple gunshots occurring precisely at the same time, when the decibel levels would add together (shots fired within the same 3 to 5 millisecond period), is very uncommon. If two gunshots (from identical firearms) occur precisely at the same moment in time, the sound levels would combine and add 3 decibels to the sound level. However, the predicted sound levels presented in this report are for single gunshots. If multiple lanes are in use simultaneously, the gunshots occur more often, but again, it is rare that two gunshots occur precisely at the same time increasing the impulsive sound level.

7.2 Sound Modeling Assumptions

The CadnaA computer model takes into account the distance between the shooting range and the sound receiver locations being evaluated, the terrain and topography, shielding by buildings, walls, berms, the directivity of sound from gunfire, and the atmospheric conditions. The default calculation assumes atmospheric conditions with all of the sound receivers downwind at all times (per ISO 9613-2). In reality this is not possible but provides a conservative worst case condition in all directions at one time. However, the software allows us to evaluate sound transmission under user selected wind direction and atmospheric conditions to evaluate local prevailing wind conditions. To evaluate the local wind conditions, ISO 9613-2 was used (with CadnaA) with CONCAWE meterological effects *(Reference: CONCAWE Report No. 4/81, "The propagaton of noise from petroleum and petrochemical complexes to neighboring communities," 1981).* Atmospheric conditions have a significant effect on sound transmission to distances over 300 feet. In addition to downwind conditions, the ISO standard also assumes that there is a fully developed moderate ground based temperature inversion that is favorable for sound propagation.

The terrain and topography was obtained by USGS maps and topographic drawing of the shooting range site provided by PBR Hawaii. A ground factor (G) of 0.5 is used to calculate ground attenuation per ISO 9613-2.

The sound level predictions for the .30-06 M1 Garand rifle assume that a simple “firing shed” is installed at the firing position for the rifle ranges. The firing shed is planned for the rifle ranges and action ranges to protect the shooter from weather (sun exposure and rain). These firing sheds are also sound barriers which help to reduce sound radiation to the Waikoloa Resort Area. The firing shed consists of full height walls on three sides and open air on the remaining side in the direction of firing. Refer to Figure 3 for an example of a firing shed. The shed also includes a partial roof covering the shooter. For the shotgun courses (Sporting Clays Course and Trap and Skeet Fields), firing sheds are not included in the model due to the nature and use of these activities.

Figure 3. Example of a “Firing Shed” for Rifle and Action Ranges (Photo: Nordtest Report TR 478)

7.2 Sound Modeling and Prediction Results

The resulting output of the CadnaA computer model is a calculated sound contour map, as well as tabulated data for select sound receiver locations. The sound contour maps can be found in Appendix A of this report. There are a total of six (6) sound contour maps, as described in Table 4 below.

Table 4. Description of Sound Contour Maps (See Appendix A)

Sound Contour	Firearm	Course	Wind Condition
Map 1	.30-06 M1 Garand Rifle	200 Yard Rifle Range	All Receivers Downwind *(per ISO 9613-2)*
Map 2	.30-06 M1 Garand Rifle	200 Yard Rifle Range	Northeast Wind *(Trade)*
Map 3	12 Gauge Shotgun	Sporting Clays (Aimed NW)	All Receivers Downwind *(per ISO 9613-2)*
Map 4	12 Gauge Shotgun	Sporting Clays (Aimed NW)	Northeast Wind *(Trade)*
Map 5	12 Gauge Shotgun	Sporting Clays (Aimed SE)	All Receivers Downwind *(per ISO 9613-2)*
Map 6	12 Gauge Shotgun	Sporting Clays (Aimed SE)	Northeast Wind *(Trade)*

The wind direction can be a significant factor for sound propagation due to the distance between the proposed shooting range and the Waikoloa Resort Area (about 2 miles). The sound contour maps were developed to illustrate the difference between the worst-case scenario of the downwind condition compared to the prevailing Northeast winds (trades). The sound contour maps assume no mitigation in the forms of berms or treatment to the firing sheds. The resulting sound levels at several sound receiver locations are shown in Table 5 below. The overall sound levels are shown in A-weighted decibels.

Table 5. Predicted Sound Levels at Sound Receiver Locations

Sound Prediction Description	Waikoloa Beach Villas	Waikoloa Beach Marriott	Kings'Land by Hilton	Fairway Villas	Colony Villas	Hilton Waikoloa Village
Map 1 (Rifle, Downwind)	33 dBA	31 dBA	37 dBA	31 dBA	32 dBA	29 dBA
Map 2 (Rifle, NE winds)	28 dBA	26 dBA	31 dBA	26 dBA	27 dBA	24 dBA
Map 3 (Shotgun aimed NW, Downwind)	65 dBA	64 dBA	56 dBA	63 dBA	62 dBA	60 dBA
Map 4 (Shotgun aimed NW, NE winds)	60 dBA	59 dBA	50 dBA	58 dBA	56 dBA	55 dBA
Map 5 (Shotgun aimed SE, Downwind)	46 dBA	43 dBA	42 dBA	42 dBA	41 dBA	39 dBA
Map 6 (Shotgun aimed SE, NE winds)	39 dBA	39 dBA	33 dBA	37 dBA	34 dBA	31 dBA

The direction of fire is one of the most significant factors for how much sound is transmitted to the resort area. The rifle and action ranges are positioned such that the shooter is in a fixed location and is aimed away from the Waikoloa Resort Area. However, for the Sporting Clays course, the shooter can be aiming the firearm in any direction, since the course is a full circle. The sound model indicates that the predicted sound levels for the shotgun are 20 decibels lower if the shotgun is aimed away from the resorts compared to aiming the shotgun in the direction of the resort area.

At the Fairway Villas and Waikoloa Beach Villas, the predicted octave band sound levels from each sound contour map were compared to the measured existing ambient octave band sound levels at these two locations. For the ambient sound levels, the L_{90} was used instead of the ambient L_{eq} values for comparison because the L_{90} represents the quietest 10% of the day. This type of comparison by using the L_{90} is a worst case evaluation. The octave band sound levels are shown in Table 6 below.

Table 6. Comparison of Octave Band Ambient Sound to Predicted Firearm Sound

Location	Sound Prediction Description	Sound Pressure Level in dBA								
		Octave Band Center Frequency (Hz)								Overall
		31.5	63	125	250	500	1000	2000	4000	
Fairway Villas	**Ambient (L_{90})**	**9**	**21**	**28**	**28**	**33**	**35**	**33**	**30**	**41**
	Map 1 (Rifle)	--	--	18	26	27	22	2	--	31
	Map 2 (Rifle)	--	--	15	21	23	14	--	--	26
	Map 3 (Shotgun)	18	39	48	59	58	54	37	--	63
	Map 4 (Shotgun)	15	36	46	55	54	46	31	--	58
	Map 5 (Shotgun)	--	3	19	30	39	38	22	--	42
	Map 6 (Shotgun)	--	--	17	25	35	31	17	--	37
Waikoloa Beach Villas	**Ambient (L_{90})**	**12**	**23**	**28**	**30**	**35**	**39**	**37**	**36**	**44**
	Map 1 (Rifle)	--	--	19	27	30	25	9	--	33
	Map 2 (Rifle)	--	--	16	23	25	18	3	--	29
	Map 3 (Shotgun)	20	40	50	62	61	58	44	--	65
	Map 4 (Shotgun)	16	37	48	57	56	50	38	--	59
	Map 5 (Shotgun)	--	5	21	32	42	42	30	--	46
	Map 6 (Shotgun)	--	2	19	27	37	34	24	--	37

The results indicate that the predicted sound levels from the .30-06 Springfield M1 Garand rifle are well below the existing ambient sound levels in the Waikoloa Resort Area. The results also show that when the aiming angle is in the mauka direction (southeast direction), the predicted sound levels from the 12-guage shotgun are expected to be close to or below the ambient sound levels at the quietest areas within the Waikoloa Resort Area.

8 Sound Mitigation Methods and Techniques

There are a variety of sound mitigation methods and techniques that can be integrated with an outdoor facility like the proposed shooting range. These techniques are discussed below.

8.1 Firing Shed at Rifle Ranges and Action Ranges

One sound mitigation technique that is already planned for the rifle and action ranges is the implementation of the “firing shed”, which functions as a sound barrier. It is recommend that a sound absorbing treatment be applied to the underside of the roof structure, as well as to the inside surface of the walls to help keep sound levels at a minimum. The absorptive treatment not only helps reduce sound radiation from the shooting range, but it also helps reduce sound levels at the shooter position. Adding absorptive treatment to the shed walls and to the underside of the roof structure may reduce sound levels from the firearm by approximately of 2 to 4 decibels, depending on the orientation and location of the listener, as well as the type and quantity of treatment applied. The use of surface applied sound absorbing treatments are commonly used to mitigate sounds from a variety of sound sources, including outdoor mechanical equipment enclosures, roadway sound barriers, office spaces, etc. The live fire sound measurements (Section 6) included sound data collection of using a field fabricated sound suppressor. The suppressor was lined with fiberglass batt insulation on the inside surface of the suppressor. Fiberglass insulation is a very effective sound absorbing material that is used in many types of acoustical treatment products.

8.2 Aiming Direction of Shooter

As discussed in Section 7.2, the aiming direction of the shooter is one of the most significant factors for the sound levels observed at the Waikoloa Resort Area. The shotgun sound levels experienced at the resort area can be reduced by approximately 20 decibels simply facing the shooter away from the resort area compared to the shooter facing in the direction of the resort area. While recognizing that the direction of the sun is a key consideration for orientation of shotgun venues, for sound reduction purposes, it is recommended that the Sporting Clays Course and Trap and Skeet Fields Course be configured such that the shooter aims the firearm in the mauka direction, opposite of the Waikoloa Resort Area.

8.3 Sound Barrier Walls and/or Earth Berms

The addition of berms and/or sound barrier walls can also help reduce sound levels. A sound barrier is only effective if it blocks the line-of-sight between the sound source and sound receiver. Therefore, the addition of any berms or sound barrier walls should be carefully selected and assessed for the line-of-sight concerns. In general, sound barriers are most effective if positioned close to the sound source (or sound receiver). The acoustical performance of the barrier wall or earth berm depends primarily on its height. The expected sound reduction achieved by implementing an earth berm near the shooting range courses may be in the range of 5 to 10 decibels, which would be a noticeable improvement.

8.4 Relocate Shotgun Courses

From an acoustical perspective, relocating the Sporting Clays Course ant Trap and Skeet Fields Course to a position that is further away from the resorts can help lower sound levels at the Waikoloa Resort Area. However, the expected sound reduction by relocating these courses may be minimal. The sound reduction may likely be 3 dB or less, depending on the final course location.

8.5 "Sound Suppressor" for Rifle/Action Ranges

The "Sound Suppressor" can be an effective sound mitigation technique for reducing sound levels from a rifle or pistol. The sound measurement results included in the *Live Sound Measurement Report* dated May 2015 show the sound reduction that can be achieved by using one type of sound suppressor. For the proposed Pu'u Anahulu Shooting Range, the sound modeling and prediction results indicate that a sound suppressor device should not be needed. The predicted values from the .30-06 Springfield M1 Garand rifle are already well below the existing ambient sound levels.

8.6 Use of Trees, Shrubs, or other Vegetation for Sound Mitigation

The addition of trees, plants, shrubs, or other vegetation is typically not an effective sound mitigation technique. Unless the vegetation is several hundred feet thick, the sound reduction by vegetation is often negligible. Therefore, incorporating vegetation as a method to reduce sound levels from the proposed shooting range is not recommended.

9 Potential Sound Impacts Due to the Proposed Shooting Range

As mentioned above, the sound modeling and prediction analyses include many considerations for the "worst case scenario" regarding sound impacts at the Waikoloa Resort Area. These worst case scenario considerations include the following:

- The evaluation of the existing ambient noise environment included some of the quietest locations within the Waikoloa Resort Area.
- Assessment of the existing ambient noise environment also included the 90% exceedance sound levels, L_{90}, which represents the quietest 10% of the day.
- The sound study included sound source data from the loudest firearms that are currently planned to be used at the proposed shooting range. In addition, the impulsive response maximum sound levels, L_{max}, for each firearm were used in the analyses.
- Sound predictions were calculated using environmental conditions that are most favorable for sound propagation.
    - Downwind propagation
    - Fully developed moderate ground based temperature inversion

9.1 Sound Impact of Rifle Ranges and Action Ranges on the Waikoloa Resort Area

The sound level predictions at the Waikoloa Resort Area indicate that sound impacts due to the rifle ranges and action ranges are not expected. For downwind conditions that are favorable for sound propagation, sound levels due to a firearm discharge at these courses are below the ambient sound levels. The octave band analysis also shows that rifle sounds are below ambient sound levels at all frequency bands. For other wind conditions less favorable for sound propagation, such as the prevailing northeast winds, sound levels from the rifle are well below the ambient sound levels. Subjectively, sounds from the rifle would likely be inaudible for most listeners, even for listeners positioned in some of the quietest areas of the Waikoloa Resort Area.

9.2 Sound Impact of Shotgun Courses on the Waikoloa Resort Area

The shotgun courses, the Sporting Clays Course and the Trap and Skeet Fields Course, allow the shooter to aim the firearm in different directions. Because the shotgun is a highly directional sound source, the predicted sound levels at the Waikoloa Resort Area depend significantly on the aiming direction of the shooter. The shooter aiming angles were included in the assessment for sound impacts.

9.2.1 Compliance with State of Hawaii Regulations

The State of Hawaii Administrative Rules regarding sound level limits does not specifically address firearm sounds. However, *Chapter 46 - Community Noise Control* of the Hawaii Administrative Rules does address sound level limits for unspecified impulsive sounds. The rules state that impulsive sounds can be 10 dB above the maximum permissible noise limits. The Waikoloa Resort Area is considered a Class B Zoning District for noise regulation purposes. The daytime maximum permissible noise level for a Class B Zoning District is 60 dBA. Therefore the maximum permissible sound level for impulsive sounds would be 70 dBA during the day. Although the sound from a gunshot is impulsive in nature, firearm sounds are not identified as being one of the sound sources included under the noise regulation. The maximum permissible limits specified in the regulation apply to “stationary noise sources; and equipment related to agricultural, construction, and industrial activities.”

The sound level predictions for the shotgun indicate that the sound levels observed at the Waikoloa Resort may exceed 60 dBA if the shotgun is aimed in the northwest direction. If the shotgun is aimed in the southeast direction, sound levels due to the shotgun will likely be well below 60 dBA within the Waikoloa Resort Area. In fact, with this aiming direction sound levels from the shotgun are predicted to be close to the ambient sound levels. Sound levels from the shotgun are predicted to be less than 70 dBA for all aiming angles and wind conditions.

It is important to note that although the State regulation may not apply specifically to firearm sounds, the regulation can still be used as a guideline for assessing the potential sound impact.

9.2.2 Reference to the HUD Noise Guidelines

The sound criteria found in the HUD Noise Guidelines includes the Day-Night Level (L_{dn}) metric, which is a 24-hour averaged sound level incorporating a 10 dB penalty for noise levels during the night hours. This metric is often used for assessing environmental noises. However, it is not commonly used for assessing impulsive noises, such as firearm sounds because the sound levels are averaged over such a long period of time compared to the short duration of a firearm discharge. However, HUD's acceptability of exterior sound levels, with an L_{dn} < 65 dBA, can be useful guideline for the general acceptance of exterior noise levels.

9.2.3 Audibility of Shotgun Sounds at the Waikoloa Resort Area

The sound prediction results show that sounds from the shotgun will be audible in the Waikoloa Resort Area when the shotgun is aimed in the northwest direction. With the firearm aimed in the southeast direction, the shotgun sounds may still be audible, but they will be much less noticeable because the predicted sound levels are expected to be close to the ambient sound or below the ambient sound levels at the quietest areas within the Waikoloa Resort Area.

Building a berm near the shotgun courses could help reduce sound levels transmitted to the Waikoloa Resort area, if properly designed. If a tall berm is constructed such that an 8 to 10 decibel reduction is achieved, sounds from a shotgun aimed in the southeast direction will be difficult to detect, even for environmental conditions that are favorable for sound propagation. However, even with a tall berm, a shotgun aimed in the northwest direction will still likely be audible for some listeners in the Waikoloa Resort Area. Therefore, limiting the shooter aiming direction to be in the southeast direction, plus or minus approximately 60 degrees, should be considered.

10 Conclusions

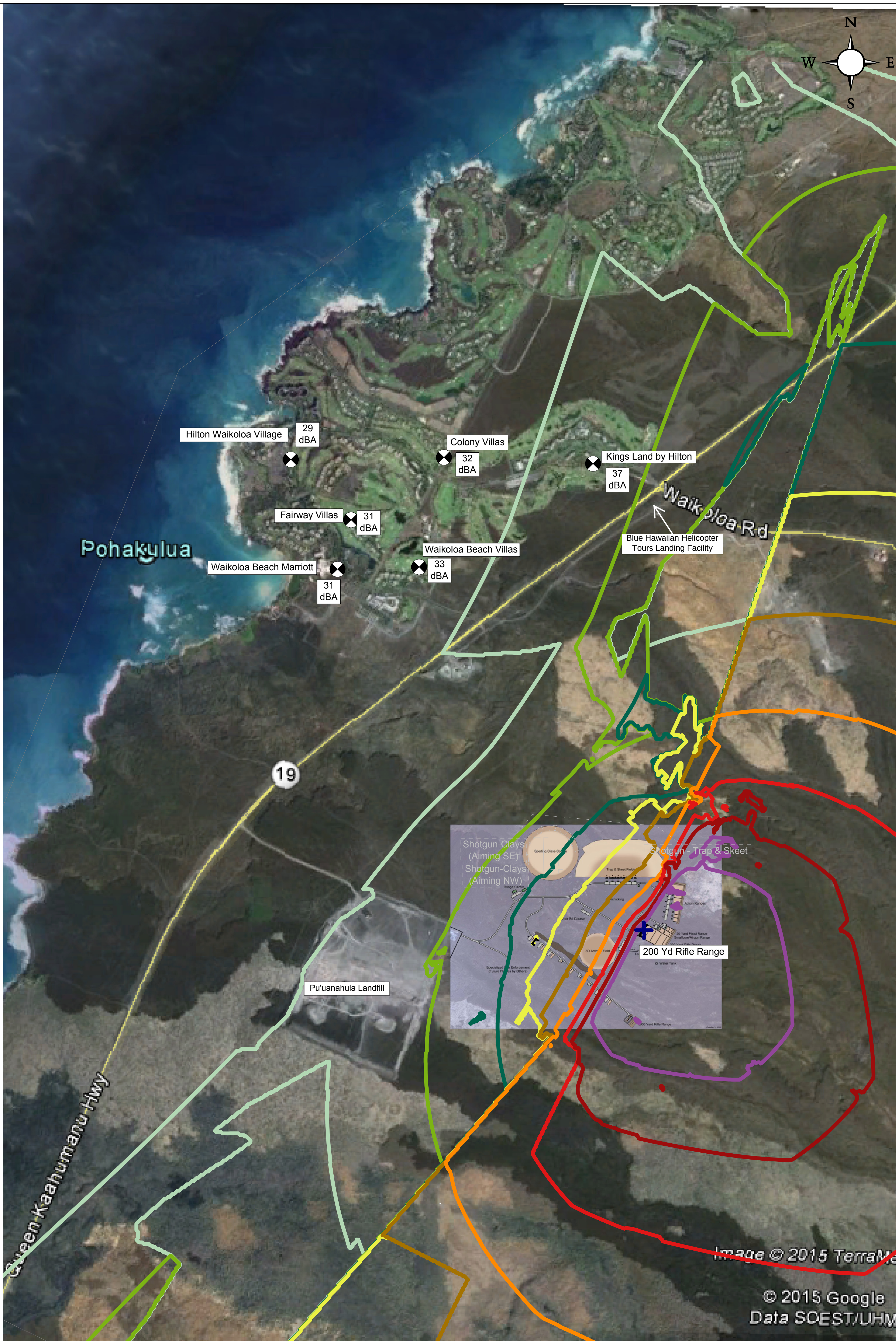
Sound level predictions for the rifle and action ranges are below ambient sound levels at the quietest areas of the Waikoloa Resort Area. Therefore, sound impacts from the rifle and action ranges are not expected based on the current layout, range orientation, and incorporation of the firing sheds.

For the shotgun courses, the firearm aiming direction significantly affects the predicted sound levels experienced within the Waikoloa Resort Area. Limiting the aiming angle to the mauka direction, the predicted sound levels are expected to be close to the ambient sound levels at the quietest areas within the Waikoloa Resort Area. The analysis assumes the worst-case scenario for atmospheric conditions that are most favorable for sound propagation. With thoughtful mitigation treatment, sound from the shotgun courses could be reduced to be satisfactory below the existing ambient sound levels, such that the shotgun sounds are inaudible or nearly inaudible at the quietest areas of the Waikoloa Resort Area.

APPENDIX A

Sound Contour Maps

(11 x 17)



CENSEO
AV+Acoustics

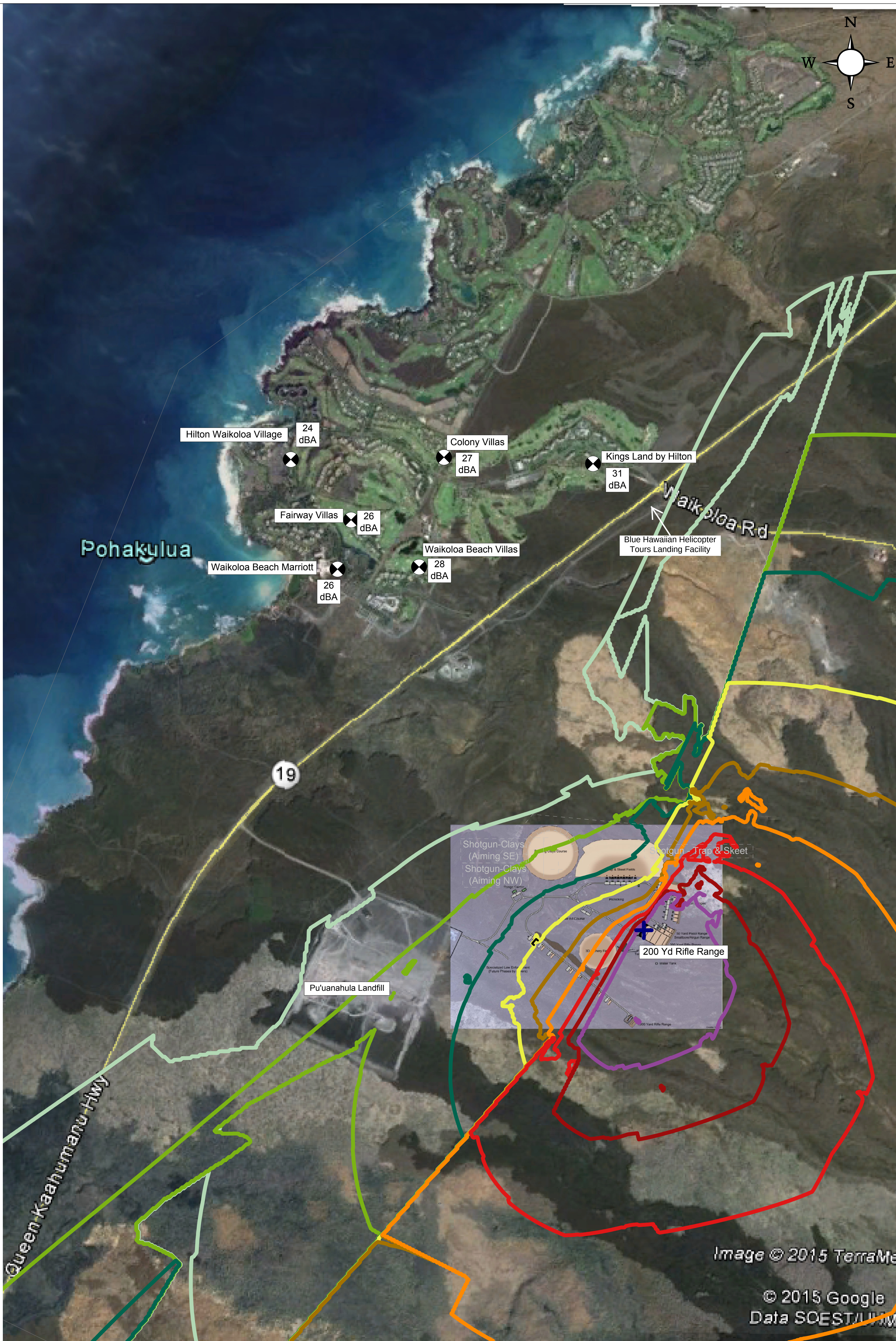
Sound Contour Map 1
Hawaii Public Shooting Range at Pu'u Anahulu

Course: 200 Yard Rifle Range
Firearm: .30-06 Springfield M1 Garand Rifle
Wind: All Receivers Downwind (per ISO 9613-2)

July 23, 2015

LEGEND

- 35 dBA
- 40 dBA
- 45 dBA
- 50 dBA
- 55 dBA
- 60 dBA
- 65 dBA
- 70 dBA
- 75 dBA



CENSEO
AV+Acoustics

Sound Contour Map 2
Hawaii Public Shooting Range at Pu'u Anahulu

Course: 200 Yard Rifle Range
Firearm: .30-06 Springfield M1 Garand Rifle
Wind: Northeast Wind (Trade)

July 23, 2015

LEGEND

- 35 dBA
- 40 dBA
- 45 dBA
- 50 dBA
- 55 dBA
- 60 dBA
- 65 dBA
- 70 dBA
- 75 dBA

CENSEO
AV+Acoustics

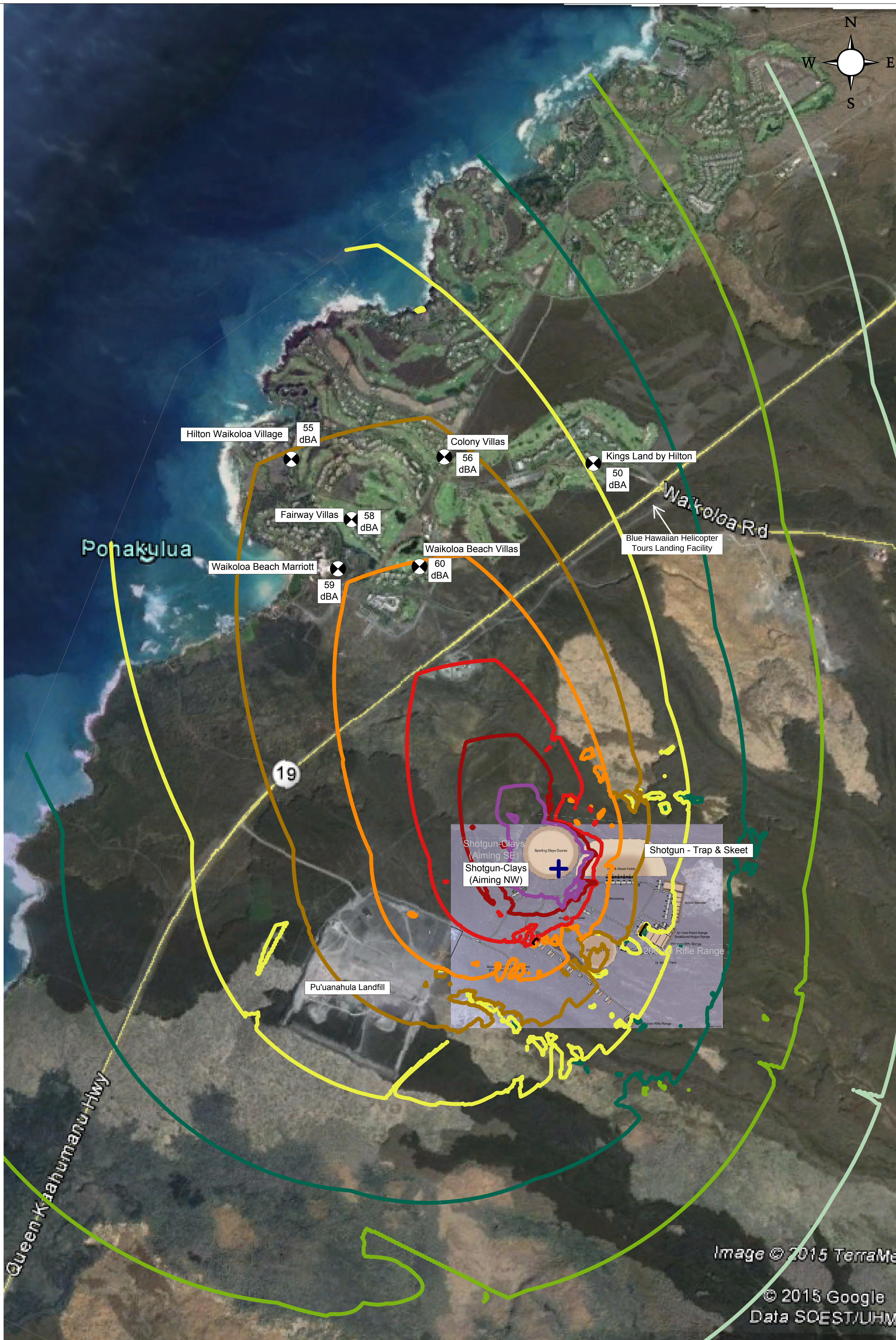
Sound Contour Map 3
Hawaii Public Shooting Range at Pu'u Anahulu

Course: Sporting Clays (Aimed Northwest)
Firearm: Remington 870 Shotgun
Wind: All Receivers Downwind (per ISO 9613-2)

July 23, 2015

LEGEND

- 35 dBA
- 40 dBA
- 45 dBA
- 50 dBA
- 55 dBA
- 60 dBA
- 65 dBA
- 70 dBA
- 75 dBA



CENSEO
AV+Acoustics

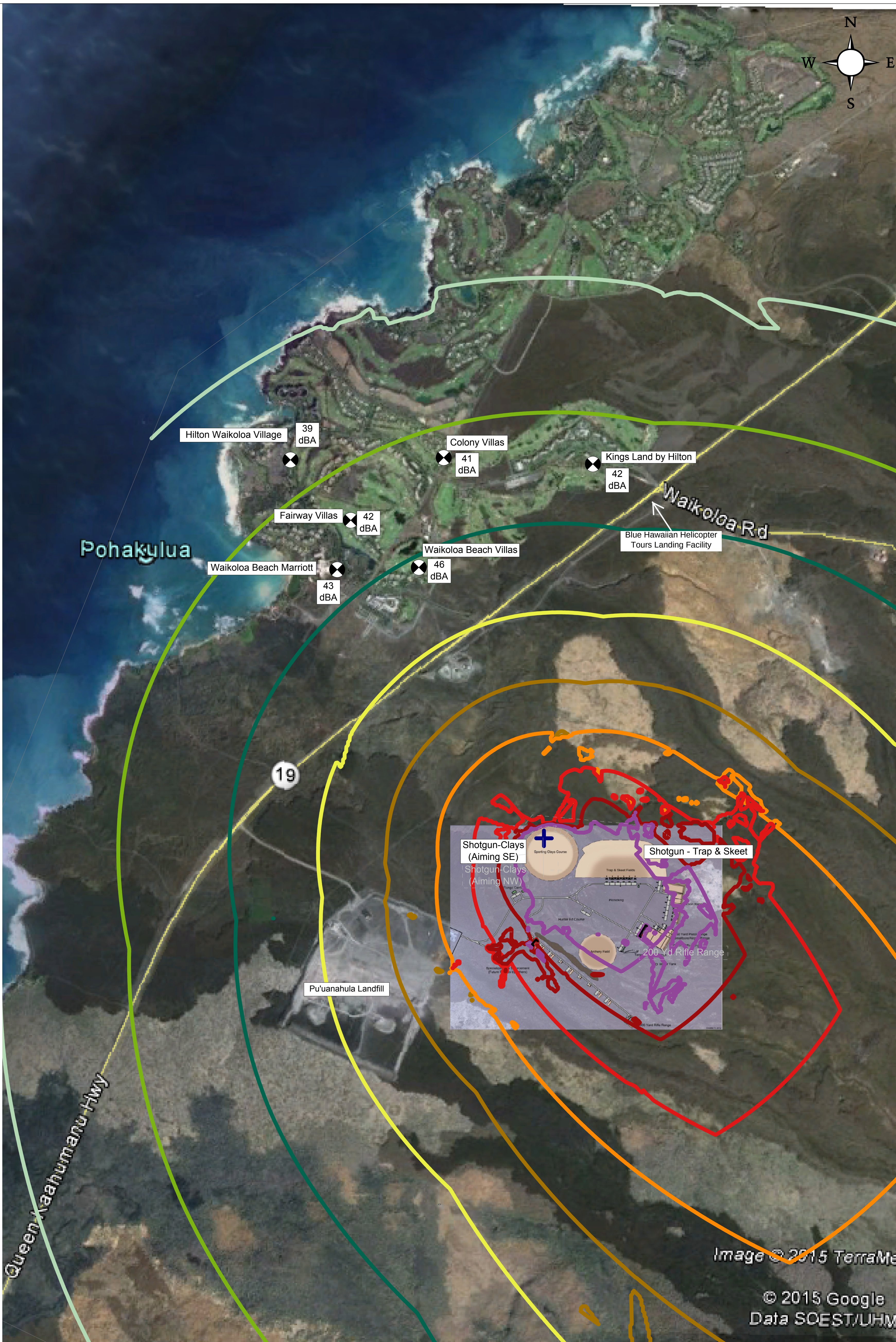
Sound Contour Map 4
Hawaii Public Shooting Range at Pu'u Anahulu

Course: Sporting Clays (Aimed Northwest)
Firearm: Remington 870 Shotgun
Wind: Northeast Wind (Trade)

July 23, 2015

LEGEND

35 dBA
40 dBA
45 dBA
50 dBA
55 dBA
60 dBA
65 dBA
70 dBA
75 dBA



CENSEO
AV+Acoustics

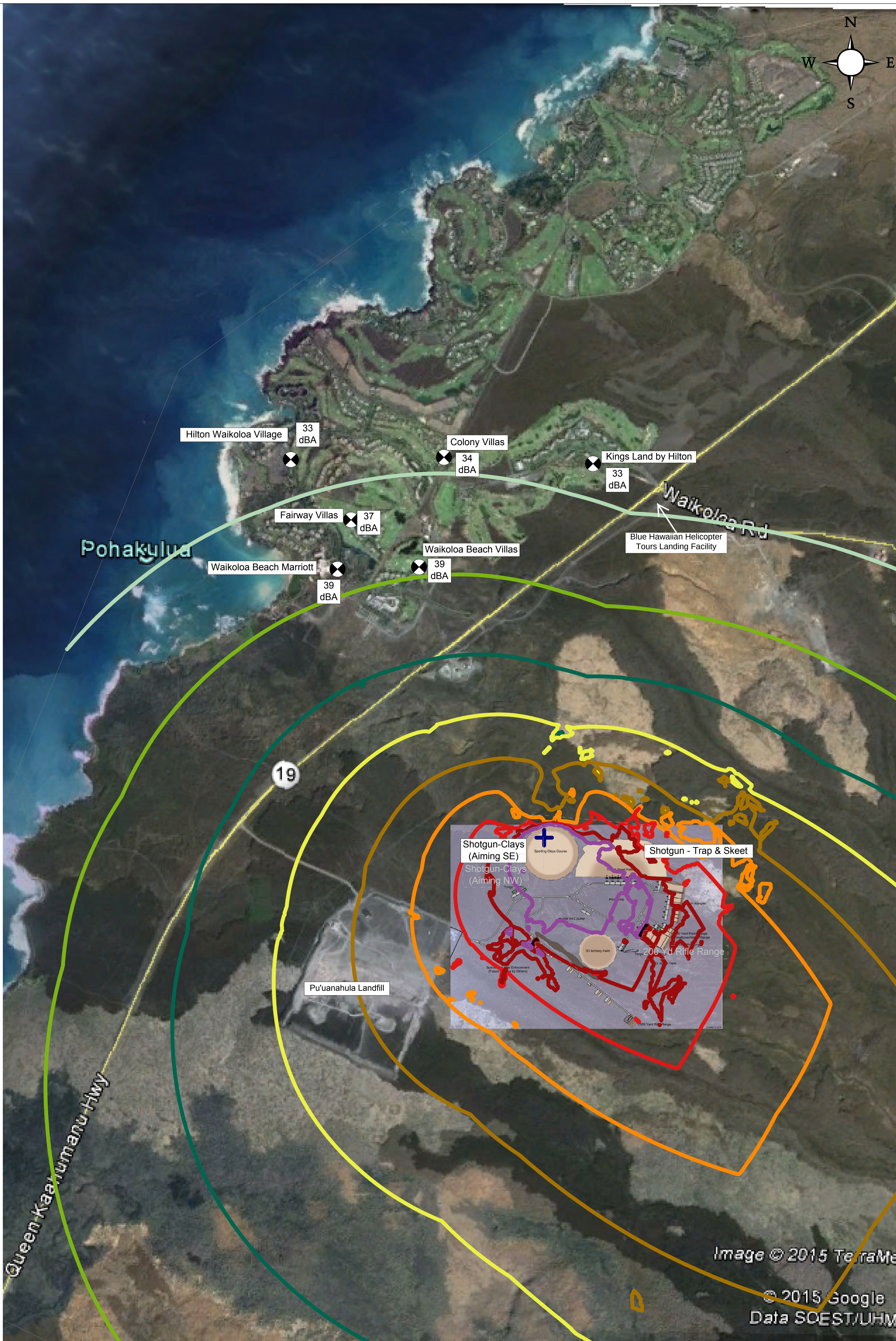
Sound Contour Map 5
Hawaii Public Shooting Range at Pu'u Anahulu

Course: Sporting Clays (Aimed Southeast)
Firearm: Remington 870 Shotgun
Wind: All Receivers Downwind (per ISO 9613-2)

July 23, 2015

LEGEND

- 35 dBA
- 40 dBA
- 45 dBA
- 50 dBA
- 55 dBA
- 60 dBA
- 65 dBA
- 70 dBA
- 75 dBA



CENSEO
AV+Acoustics

Sound Contour Map 6
Hawaii Public Shooting Range at Pu'u Anahulu

Course: Sporting Clays (Aimed Southeast)
Firearm: Remington 870 Shotgun
Wind: Northeast Wind (Trade)

July 23, 2015

LEGEND

- 35 dBA
- 40 dBA
- 45 dBA
- 50 dBA
- 55 dBA
- 60 dBA
- 65 dBA
- 70 dBA
- 75 dBA

APPENDIX B

Acoustic Terminology

Sound Pressure Level
Sound pressure level (SPL) is a logarithmic measure of the sound pressure relative to a reference value, as defined by the follow equation:

$$SPL = 10Log_{10}\left(\frac{{p_{rms}}^2}{{p_o}^2}\right) = 20Log_{10}\left(\frac{p_{rms}}{p_o}\right) \text{ [dB]}$$

Where, p_{rms} is the room mean square sound pressure, measured in Pa, and p_o is the reference sound pressure, measured in Pa. Typically, p_o is defined as being 20 µPa, the smallest sound pressure detectable by the human ear.

It is common that a 1 to 2 dB increase or decrease of sound is too difficult for most listeners to discern. A 3 dB change in sound level is often considered to be the "just noticeable difference". A 6 dB change in sound level is significant to most listeners, and a 10 dB change in sound level is often considered to be twice (or half) as loud.

A-Weighted Sound Level (re: dBA)
A-weighting is applied measured sound levels in effort to account for the relative loudness perceived by the human ear. The typical human ear is less sensitive to low frequency sounds and high frequency sounds. Individual weighting values (applied for either octave bands or one-third octave bands) are determined by the A-weighting curve as an international standard.

Equivalent Sound Level, L_{eq}
The Equivalent Sound Level (L_{eq}) is a type of average which represents the steady level that, integrated over a time period, would produce the same energy as the actual signal. The actual *instantaneous* noise levels typically fluctuate above and below the measured L_{eq} during the measurement period. The A-weighted L_{eq} is a common index for measuring environmental noise.

Exceedance/Statistical Sound Level, L_N
The Exceedance/Statistical Sound Level is the A-weighted sound levels equaled or exceeded by a fluctuating sound level for "N" percent of the time. In other words an L_{90} equal to 63 dBA means that the sound levels equal 63 dBA, or higher, for 90% of the measurement period. The L_{10} level is commonly called the 'intrusive sound level', and the L_{90} is commonly called the 'residual sound level'. The L_{90} is often used in environmental measurements and assessments.

Common Sound Levels in dBA

Common Outdoor Sounds	Sound Pressure Level (dBA)	Common Indoor Sounds	Subjective Evaluation
Auto horn at 10 ft Jackhammer at 50 ft	**100**	Printing plant	Deafening
Gas lawn mower at 4 ft Pneumatic drill at 50 ft	**90**	Auditorium during applause Food blender at 3 ft	Very Loud
Concrete mixer at 50 ft Jet flyover at 5000 ft	**80**	Telephone ringing at 8 ft Vacuum cleaner at 5 ft	
Large dog barking at 50 ft Large transformer at 50 ft	**70**	Electric shaver at 1 ft	Loud
Automobile at 55 mph at 150 ft Urban residential	**60**	Normal conversation at 3 ft	
Small town residence	**50**	Office noise Dishwasher in adjacent room	Moderate
	40	Soft stereo music in residence Library	
Rustling leaves	**30**	Average bedroom at night Soft whisper at 3 ft	Faint
Quiet rural nighttime	**20**	Broadcast and recording studio	
	10	Human breathing	Very Faint
	0	Threshold of hearing (audibility)	

Day-Night Equivalent Sound Level, L_{dn}

The Day-Night level is the A-weighted equivalent sound level for a 24 hour period. During the nighttime hours (10PM to 7AM) a 10 dB “penalty” is added to the hourly L_{eq}. This artificial penalty is added to account for the decrease in community background noise during the nighttime hours. Many organizations and agencies use the L_{dn} metric in developing sound and noise guidelines, including the Federal Aviation Administration.

APPENDIX C

Existing Ambient Sound Measurement Report – March 2015

EXISTING AMBIENT SOUND MEASUREMENT REPORT

HAWAI'I PUBLIC SHOOTING RANGE AT PU'U ANAHULU

Waikoloa, Hawaii

March 2015

Prepared for:

PBR Hawaii & Associates

Prepared By:

CENSEO AV+Acoustics LLC

TABLE OF CONTENTS

List of Figures

List of Tables

1 Introduction

Existing Ambient sound level measurements were conducted in the Waikoloa Resort area in the vicinity of the proposed Pu'u Anahulu Public Shooting Range. The sound level measurements consisted of a continuous week-long data collection at each measurement location. The measurement locations were carefully selected based on their proximity (or rather lack thereof) to sound sources. The goal of the measurements was to collect acoustical data from locations within the Waikoloa Resort area that are not only near the proposed Pu'u Anahulu Shooting Range, but locations that also tend to be the quietest areas. Measurement locations near the Queen Kaahumanu Highway or other busy roadways or sound sources were intentionally avoided because those locations might indicate higher background/ambient sound levels than other quieter locations within the Waikoloa Resort area.

Selecting ambient sound measurement positions that are located in the quietest area of the Waikoloa Resort area considers areas where the residents and guests are exposed to the least amount of ambient sound. These are the locations where intermittent sounds (such as the potential sounds from the proposed Shooting Range) would be the easiest to detect. Therefore, the worst case scenario for ambient sound levels is included with this assessment.

2 Proposed Pu'u Anahulu Public Shooting Range Project Description

Figure 1. Approximate Location of Proposed Pu'u Anahulu Public Shooting Range

The proposed Pu'u Anahulu Public Shooting Range project is located near Waikoloa on the Big Island of Hawaii, as shown in Figure 1 above.

The current plans for the project site include a sporting clays course, trap & skeet fields, a 3D archery field, target archery range, 200 yard rifle range, 50 yard pistol range, small bore/airgun range, and action ranges. A comprehensive description of the proposed project will be provided in the Sound Modeling and Prediction report, as well as other environment reports related to the project. The focus of this report is to describe the existing ambient sound environment within the Waikoloa Resort area.

3 Sound Measurement Equipment and Procedure

During the months of January and February 2015, ambient sound level measurements were conducted at three locations. Sound levels were recorded continuously throughout the measurement period. The sound data was stored and averaged for each 20-minute period. The measurement equipment used for the sound measurements is described in the table below.

Table 1. List of Sound Measurement Equipment

Measurement Equipment	Manufacturer / Model
Type 1 Sound Level Meter (Spectrum) Type 1 Prepolarized Free-Field Microphone (with Random Incidence microphone correction), ½-inch Type 1 Microphone Preamplifier	Larson Davis Model 831 PCB Model 377B02 PCB Model PRM831
Type-1 Sound Level Meter Type-1 Random Incidence Microphone, ½-inch Type 1 Microphone Preamplifier	Larson Davis Model 820 Larson Davis Model 2560 Larson Davis PRM828
Acoustic Calibrator	Larson Davis Model CAL200
Weather station	RainWise Model WindLog

At two of the three measurement locations, the sound level meter with spectrum capability was used. At these locations a portable weather station was also used to measure wind speed and wind direction. The equipment used for the remaining measurement location consisted of a sound level meter that measured the overall sound levels. The sound level meters measured continuous, 20-minute averaged, statistical sound levels during the measurement period.

At each sound monitoring station, the microphone was mounted on a tripod (approximately 5 feet above grade). The microphone was connected to a sound level meter with a microphone cable. The sound level meter was secured in a weather resistant case. An open-cell polyurethane foam wind screen covered the microphone. The equipment was checked for calibration before and after the measurement period. All of the sound measurement equipment has been certified by the manufacturer within the recommended calibration period.

Efforts were made to position the sound monitoring stations in locations that were generally representative of the surrounding ambient sound environment. For example, the measurement locations were selected to minimize the effect of mechanical equipment, such as outdoor condensing units, on the sound measurement data.

4 Sound Measurement Locations

The sound level measurements were conducted at three locations, as shown in Figure 2 below.

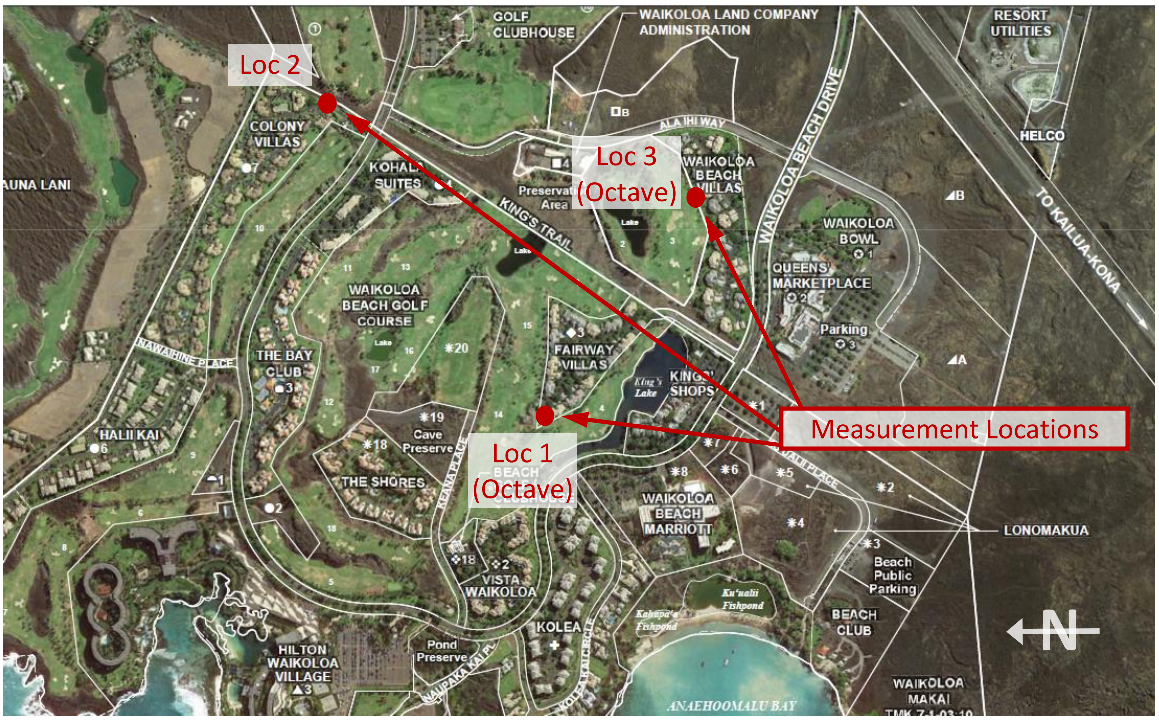


Figure 2. Sound Measurement Locations

These sound level measurement locations, along with the type of measurement completed at each location, are described in Table 2 below.

Table 2. Description of Sound Measurement Locations

Location #	Location Description	Measurement Description	Measurement Dates
Location 1 (Octave)	Fairway Villas	Spectrum Sound Level Data with Wind Data	1/22/2015 – 1/30/2015
Location 2	Colony Villas	Overall Sound Level Data	1/22/2015 – 1/30/2015
Location 3 (Octave)	Beach Villas	Spectrum Sound Level Data with Wind Data	1/30/2015 – 2/10/2015

Location 1 – Fairway Villas Waikoloa (Octave Band Levels & Wind Data)

The sound level meter and weather station were set up at the property line between the Fairway Villas Waikoloa and the Waikoloa Beach Golf Course. The equipment was located approximately 35 feet northwest of Building E as shown in Figure 3 below. The dominant and secondary sound sources are noted below:

Dominant Sound Sources:	Occasional landscaping equipment, wind, and birds
Secondary Sound Sources:	Faint Villa AC condensing unit, occasional aircraft flyovers, and sound from pedestrians and people in the nearby Villas and the adjacent golf course

Figure 3. Measurement Equipment Setup Location 1 – Fairway Villas Waikoloa

Location 2 – Colony Villas Waikoloa (Overall Sound Levels)

The sound level meter was set up at the Colony Villas property line near the entrance to the villas and adjacent to the King's Trail. The equipment was located approximately 100 feet south of Building #16 and about 4 feet west of the Colony Villas property line as shown in Figure 4 below. The dominant and secondary sound sources are noted below:

Dominant Sound Sources:	Vehicular traffic on Colony Villas entrance road, wind, and birds
Secondary Sound Sources:	Faint hum from Villa AC condensing units, occasional landscaping equipment, occasional aircraft flyovers, pedestrians and people in the nearby Villas and the adjacent King's Trail

Figure 4. Measurement Equipment Setup Location 2 – Colony Villas Waikoloa

Location 3 – Beach Villas Waikoloa (Octave Band Levels & Wind Data)

The sound level meter and weather station were set up at the northwest property line between the Beach Villas Waikoloa and the Waikoloa Beach Golf Course. The equipment was located approximately 45 feet northwest of Building M as shown in Figure 5 below. The dominant and secondary sound sources are noted below:

Dominant Sound Sources:	Occasional landscaping equipment, wind, and occasional sounds from the golf course.
Secondary Sound Sources:	Faint hum from Villa AC condensing units, occasional aircraft flyovers, birds, Coqui frogs, pedestrians and people in the nearby Villas, and vehicular traffic on nearby roads

Figure 5. Measurement Equipment Location - Beach Villas Waikoloa

5 Sound Measurement Results – Time History

The sound measurement results are graphically shown below in Figures 6 through 8.

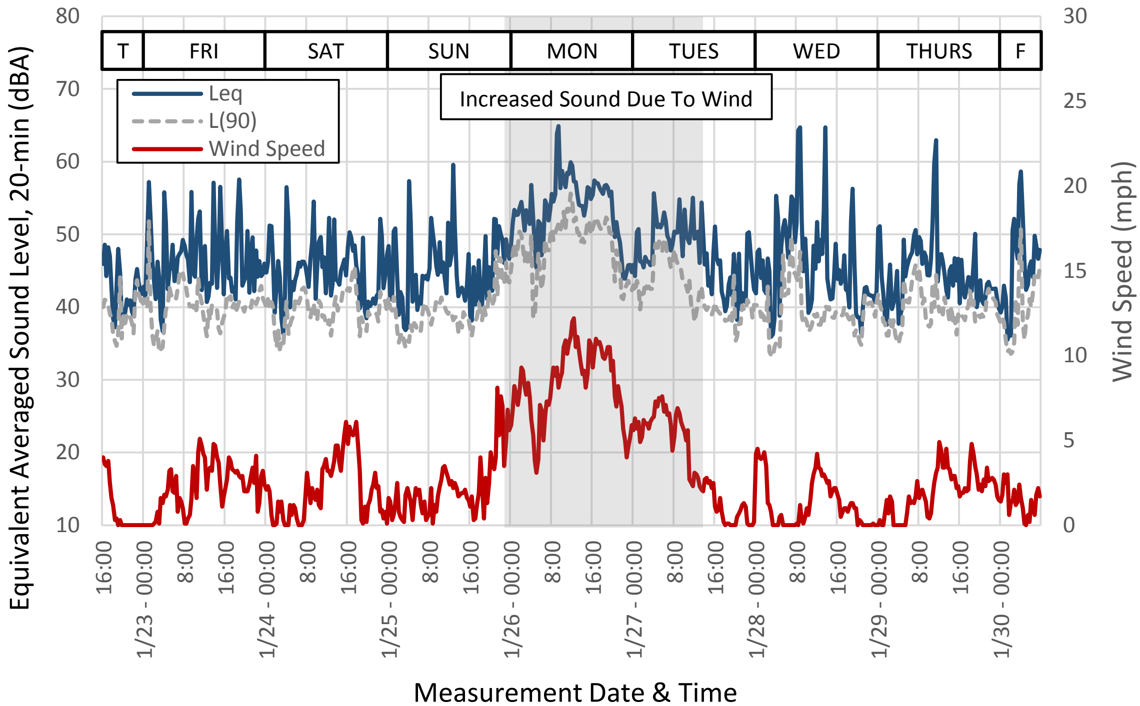


Figure 6. Measured L_{eq}, L_{90}, and Wind Speed: Location 1 – Fairway Villas Waikoloa

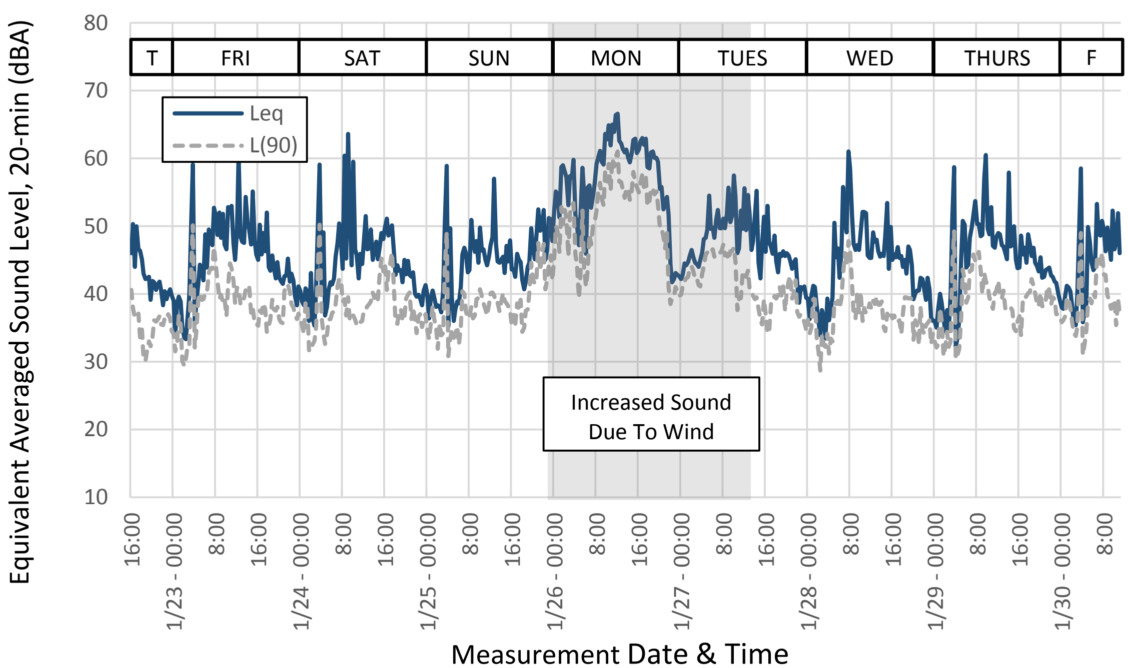


Figure 7. Measured L_{eq}, L_{90}: Location 2 – Colony Villas Waikoloa

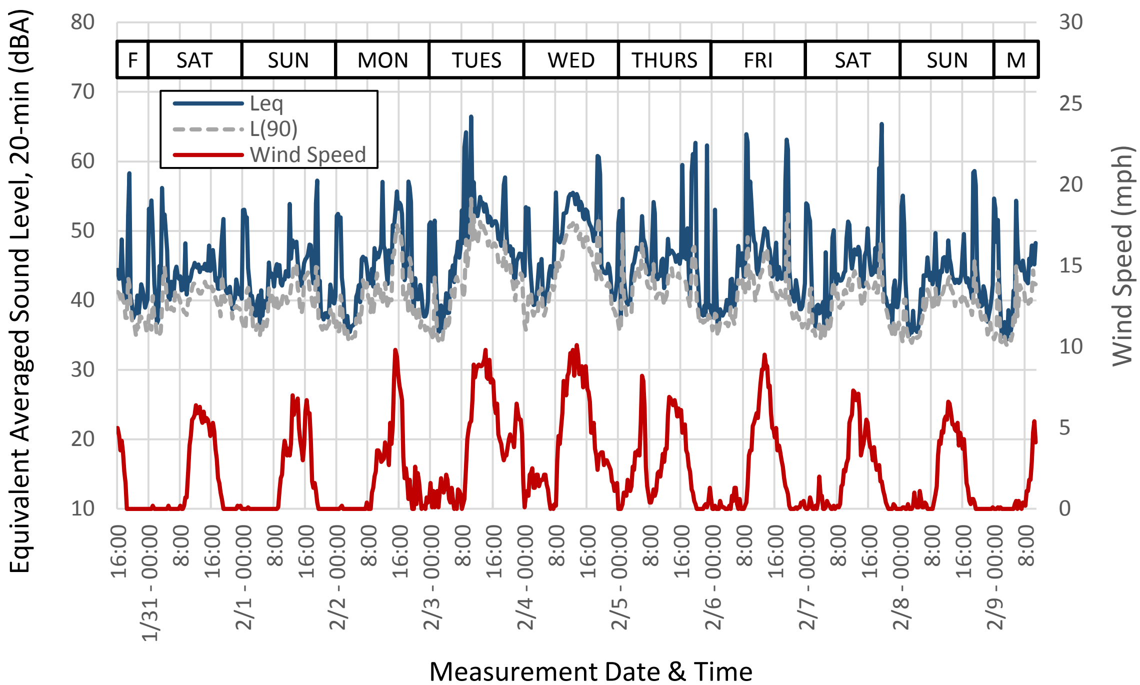


Figure 8. Measured L_{eq}, L_{90}, and Wind Speed: Location 3 – Beach Villas Waikoloa

The above graphs show the measured equivalent sound level (L_{eq}) and the 90% exceedance level (L_{90}) in A-weighted decibels (dBA) as a function of the measurement date and time. The L_{90} and L_{eq} are both common metrics that are used for assessing environmental sound environments. Figures 6 and 8 also show the measured wind speed in miles per hour (mph).

Effect of Wind on Sound Levels

Wind speed can have an effect on ambient sound levels in the area. During periods of high winds, blowing vegetation tends to increase the ambient sound levels compared to periods of calm winds. Waikoloa is commonly a dynamic environment with respect to wind speeds. While there are many periods with very calm winds, there are also periods throughout the day with higher winds. During the measurement period the data shows that the average wind speed (based on 20-minute averages) can often approach or exceed 10 mph (with wind gusts up to 25 mph) during the day. However, winds during the morning hours are often very calm with average wind speeds of approximately 0 to 2 mph.

During the first week of sound measurements, on 1/26/15 and 1/27/15, unusually high winds were recorded. This period of high winds increased the ambient sound levels during the same period. Since these conditions of excessively high winds are not typical, the sound data during these periods have been omitted from the calculations of the average sound levels for the measurement period.

Overall Daily Average Sound Level Calculations

The calculated overall daily average sound levels for each measurement location are shown below in Table 3. These values represent the average daily values for the measurement period.

Table 3. Summary of Overall Ambient Sound Levels at Each Measurement Location

Location		Daily Average Sound Level		Daily Average Sound Level		Daily Average Day-Night Level
		L_{eq} (Day) (dBA)	L_{90} (Day) (dBA)	L_{eq} (Night) (dBA)	L_{90} (Night) (dBA)	L_{dn} (dBA)
Loc 1 Fairway Villas	Low	47	40	45	39	53
	Mean	**50**	**41**	**48**	**41**	**55**
	High	54	41	50	42	56
Loc 2 Colony Villas	Low	48	40	45	36	52
	Mean	**50**	**42**	**47**	**40**	**54**
	High	52	47	48	41	54
Loc 3 Beach Villas	Low	45	41	43	37	52
	Mean	**51**	**44**	**47**	**39**	**54**
	High	55	48	51	43	57

L_{eq} (Day): An average of the hourly equivalent sound levels during the daytime hours of 7:00 am to 10:00 pm within a 24-hour measurement period.

L_{90} (Day): An average of the L_{90} exceedance level during the daytime hours of 7:00 am to 10:00 pm within a 24-hour measurement period.

L_{eq} (Night): An average of the hourly equivalent sound levels during the nighttime hours of 10:00 pm to 7:00 am within a 24-hour measurement period.

L_{90} (Night): An average of the L_{90} exceedance level during the nighttime hours of 10:00 pm to 7:00 am within a 24-hour measurement period.

L_{dn}: The calculated average day-night level from the measurement period.

6 Octave Band Sound Measurement Results (Full Day)

Octave Band Measurement Results – Full Day

Although the overall average sound levels are often used when assessing the ambient sound environment, it can be useful to also consider the frequency spectrum of the ambient sound levels. Therefore, at the Fairway Villas and Colony Villas octave band sound levels were recorded throughout the measurement period. The results of the octave band sound levels can be seen in Figures 9 and 10. These figures show the range of values at each octave band for the daytime equivalent sound levels and nighttime equivalent sound levels. Also shown in the figures is the logarithmic mean for the daytime L_{eq} and nighttime L_{eq}.

The data shows that the daytime levels are more dynamic than the nighttime levels, which is expected. The spectrum of sound data is relatively “broadband”, however, the A-weighted ambient sound environment is generally quieter at low frequencies compared to mid and high frequency sound levels.

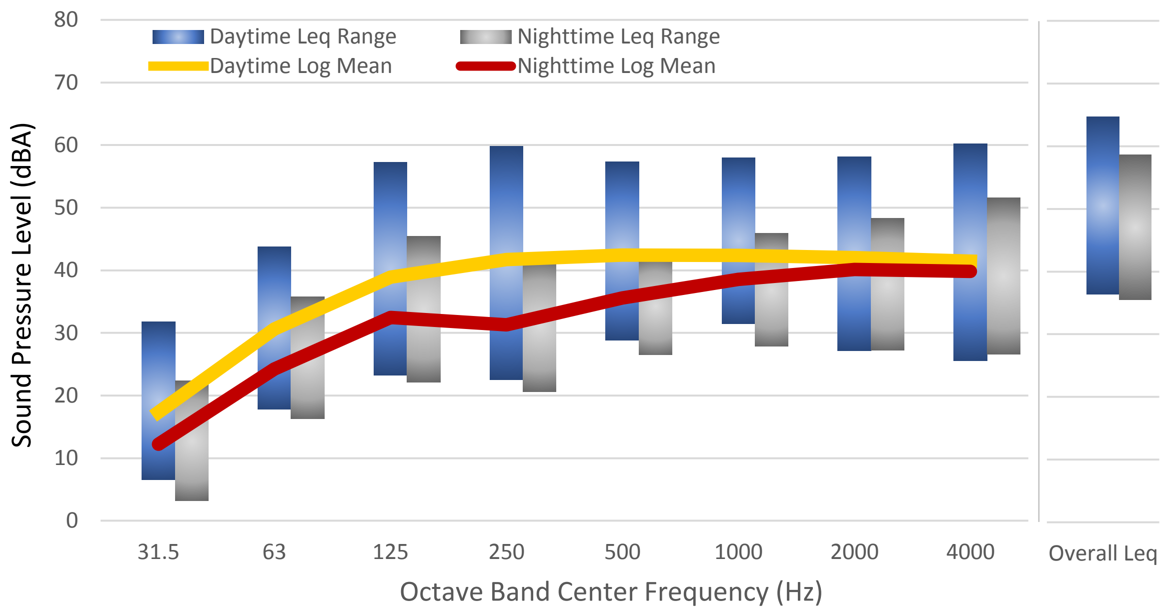


Figure 9. Octave Band Sound Level Data: Loc 1 - Fairway Villas Waikoloa (Full Day)

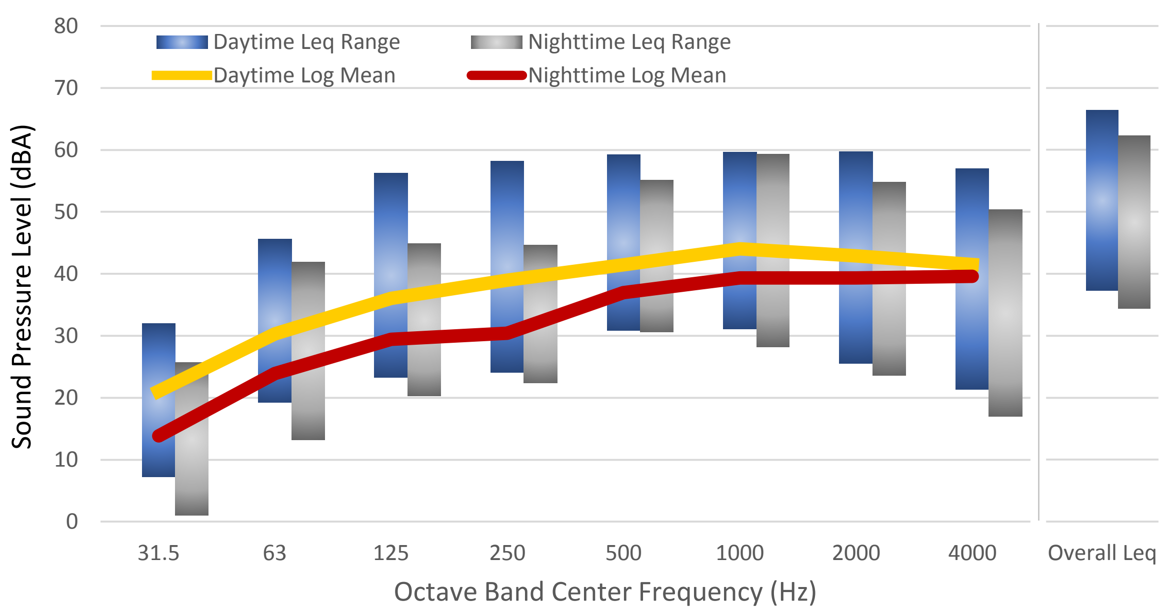


Figure 10. Octave Band Sound Level Data: Loc 3 - Beach Villas Waikoloa (Full Day)

The logarithmic mean shown on the graphs above is representative of the average daytime and nighttime sound levels over the entire measurement period. These mean values can be seen in Table 4 below.

Table 4. Summary of Octave Band Sound Level Data (Full Day)

Location			Equivalent Sound Levels (L_{eq}) in dBA								
			Octave Band Center Frequency (Hz)								Overall L_{eq}
			31.5	63	125	250	500	1000	2000	4000	
Loc 1 - Fairway Villas	Daytime	Low	7	18	23	23	29	31	27	26	36
		Mean	**17**	**31**	**39**	**42**	**42**	**42**	**42**	**41**	**50**
		High	32	44	57	60	57	58	58	60	65
	Nighttime	Low	3	16	22	21	26	28	27	27	36
		Mean	**12**	**24**	**32**	**31**	**36**	**39**	**40**	**40**	**48**
		High	22	36	45	42	42	46	48	52	59
Loc 3 - Beach Villas	Daytime	Low	7	19	23	24	31	31	26	21	37
		Mean	**21**	**30**	**36**	**39**	**41**	**44**	**43**	**42**	**51**
		High	32	46	56	58	59	60	60	57	66
	Nighttime	Low	1	13	20	22	31	28	24	17	34
		Mean	**14**	**24**	**29**	**30**	**37**	**39**	**39**	**40**	**47**
		High	26	42	45	45	55	59	55	50	62

7 Octave Band Sound Measurement Results (Hawaii Daylight Hours)

At the time of this report, the hours of operation for the Public Shooting Range are not known. Therefore, the analysis and measurement results in this section of the report are limited to the Hawaiian Daylight Hours to ensure that all conceivable hours of operation for the range are considered. During the summer, the earliest sunrise is approximately 5:50 am, and the latest sunset is approximately 7:16 pm (13 hours and 26 minutes of total daylight hours). While there will be many times of the year when the days will be shorter, the longest day of the year is used so that the ambient sound levels during quietest potential operating times are considered. Since the data was collected/stored every 20 minute period, the Hawaii Daylight Hours have been approximated to be 6:00 am to 7:20 pm. The results are shown in the figures and table below.

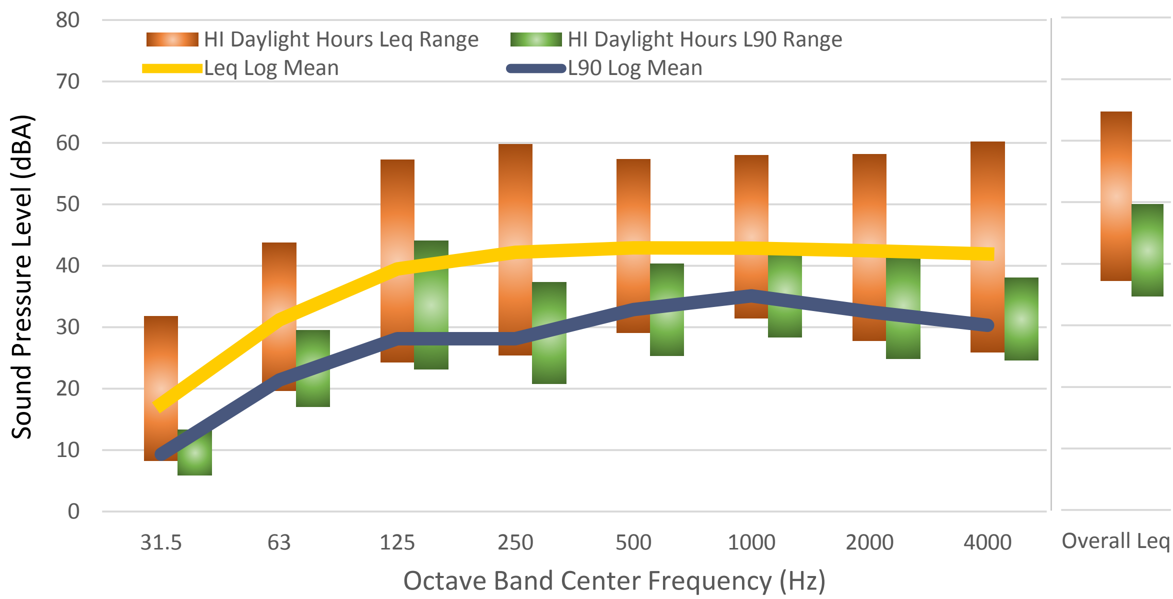


Figure 11. Octave Band Sound Level Data: Loc 1 - Fairway Villas Waikoloa (Hawaii Daylight Hours)

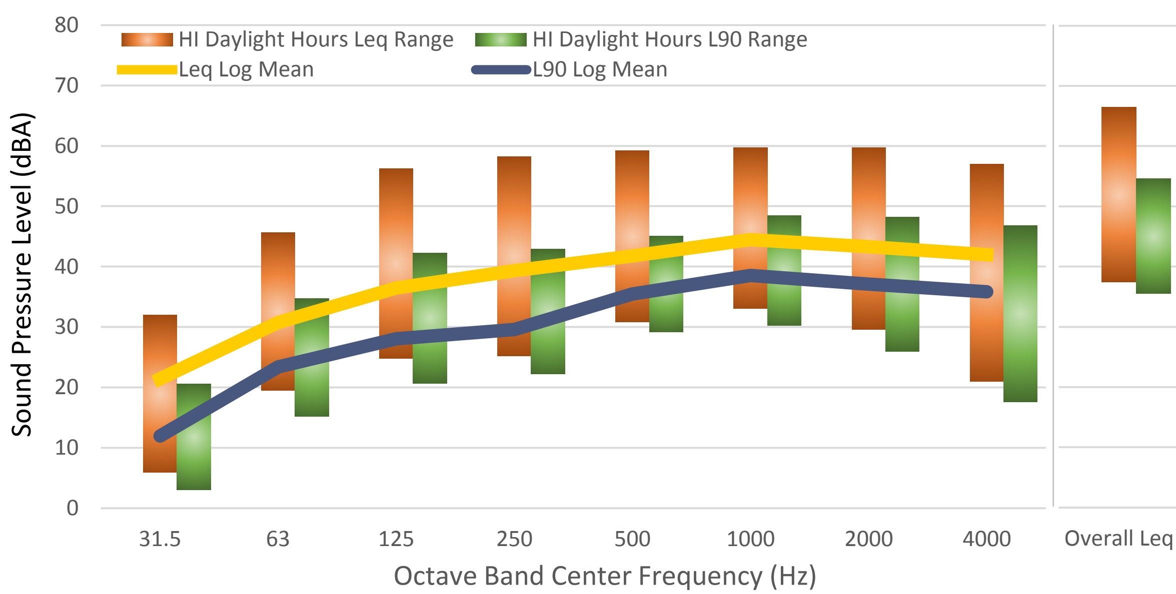


Figure 12. Octave Band Sound Level Data: Loc 3 - Beach Villas Waikoloa (Hawaii Daylight Hours)

The L_{90} metric is very useful when assessing the ambient sound environment because it represents the quietest sound levels for 90% of the measurement period. The L_{90} is an exceedance sound level that is defined as the sound level equaled to or exceeded by for 90% of the measurement period. For example, if the measured L_{90} is 50 dBA for a 1-hour measurement period, that means that the sound levels were 50 dBA or greater for 54 minutes of the 60 minute measurement period.

The data shown in Figures 11 and 12 is tabulated below for the Hawaii Daylight Hours. At each measurement location the low, logarithmic mean, and high values are indicated.

Table 5. Summary of Octave Band Sound Level Data (Hawaii Daylight Hours)

Location	L_{eq} / L_{90}	Hawaii Daylight Hrs (6a–7:20p)	Sound Levels (L_{eq} and L_{90}) in dBA								
			Octave Band Center Frequency (Hz)								Overall
			31.5	63	125	250	500	1000	2000	4000	
Loc 1 - Fairway Villas	L_{eq}	Low	8	20	24	25	29	31	28	26	37
		Mean	**18**	**31**	**39**	**42**	**43**	**43**	**42**	**42**	**50**
		High	32	44	57	60	57	58	58	60	65
	L_{90}	Low	6	17	23	21	25	28	25	25	35
		Mean	**9**	**21**	**28**	**28**	**33**	**35**	**33**	**30**	**41**
		High	13	30	44	37	40	43	42	38	50
Loc 3 - Beach Villas	L_{eq}	Low	6	19	25	25	31	33	30	21	37
		Mean	**21**	**31**	**36**	**39**	**42**	**44**	**43**	**42**	**52**
		High	32	46	56	58	59	60	60	57	66
	L_{90}	Low	3	15	21	22	29	30	26	18	36
		Mean	**12**	**23**	**28**	**30**	**35**	**39**	**37**	**36**	**44**
		High	21	35	42	43	45	49	48	47	55

8 Summary of Results and Conclusions

General Overview

The ambient sound environment in the Waikoloa Resort area is relatively quiet, with ambient sound levels that are typical for multi-family residential zones in non-urban environments. As expected the daytime sound levels are more dynamic than the nighttime sound levels primarily due to typical daytime human activities. The minimum sound levels for both the daytime and nighttime are somewhat similar (with the daytime minimum sound levels slightly higher than the nighttime levels). These similar minimum values indicate that there are periods of the day which can be quiet, with sound levels similar to nighttime sound levels.

Consistency of Sound Measurement Data

The data shown in Tables 4 and 5 shows reasonably consistent measurement data for both Location 1 (Fairway Villas) and Location 3 (Beach Villas). The logarithmic mean L_{eq} and L_{90} values are within 0 to 3 dB of each other for both locations. Therefore, ambient sound levels at other locations within the Waikoloa Resort area are very likely to be similar to the measured sound levels, or louder. Because these sound measurement locations were selected to be some of the quietest areas within the Waikoloa Resort development, sound levels are expected to be louder in busier areas of the resort, such as the Queen's MarketPlace, Kings' Shops, or areas closer to roadways. Higher ambient sound levels are also expected for locations that are closer to the Queen Ka'ahumanu Highway.

Windy Conditions for Waikoloa

Within the Waikoloa, area wind conditions are very dynamic, sometimes even within the same day. Wind speeds and wind direction can vary significantly. Calm winds near 0 mph were observed on the same day as wind gusts in excess of 20 mph. During the winter months (January through March), Kona winds (SW or SSW) are very common and are generally noticeable 40% to 60% of the time. During the summer months the trade winds (NE or ENE) prevail 90% of the time.

The most significant factor of windy conditions regarding sound levels is the increase of the ambient sound environment due to blowing vegetation and other objects. In general, quiet ambient sound levels are noticeable during periods of calm winds. During periods of high winds the wind induced sounds often mask sounds from individual sources because the ambient sound level increases during windy periods.

Octave Band L_{90} Sound Levels During Hawaii Daylight Hours

Using the octave band L_{90} sound levels during the Hawaii Daylight Hours is recommended for assessing the potential sound impact of the planned Hawaii Public Shooting Range. Sound levels do not propagate the same at all frequencies, therefore, the octave band graphs and tables better describe the ambient sound environment compared to the overall sound levels. In addition, the L_{90} values represent the quietest sound levels for 90% of the Hawaii Daylight Hour time periods. Using the Hawaii Daylight Hours in the analysis and calculations is considered to be a worst case scenario for assessing potential sound impacts of the planned shooting range because this time period represents the maximum conceivable operating hours for the range.

APPENDIX A

Acoustic Terminology

Sound Pressure Level

Sound pressure level (SPL) is a logarithmic measure of the sound pressure relative to a reference value, as defined by the follow equation:

$$SPL = 10Log_{10}\left(\frac{p_{rms}^{2}}{p_{o}^{2}}\right) = 20Log_{10}\left(\frac{p_{rms}}{p_{o}}\right) \text{ [dB]}$$

Where, p_{rms} is the room mean square sound pressure, measured in Pa, and p_o is the reference sound pressure, measured in Pa. Typically, p_o is defined as being 20 µPa, the smallest sound pressure detectable by the human ear.

It is common that a 1 to 2 dB increase or decrease of sound is too difficult for most listeners to discern. A 3 dB change in sound level is often considered to be the "just noticeable difference". A 6 dB change in sound level is significant to most listeners, and a 10 dB change in sound level is often considered to be twice (or half) as loud.

A-Weighted Sound Level (re: dBA)

A-weighting is applied measured sound levels in effort to account for the relative loudness perceived by the human ear. The typical human ear is less sensitive to low frequency sounds and high frequency sounds. Individual weighting values (applied for either octave bands or one-third octave bands) are determined by the A-weighting curve as an international standard.

Equivalent Sound Level, L_{eq}

The Equivalent Sound Level (L_{eq}) is a type of average which represents the steady level that, integrated over a time period, would produce the same energy as the actual signal. The actual *instantaneous* noise levels typically fluctuate above and below the measured L_{eq} during the measurement period. The A-weighted L_{eq} is a common index for measuring environmental noise.

Exceedance/Statistical Sound Level, L_N

The Exceedance/Statistical Sound Level is the A-weighted sound levels equaled or exceeded by a fluctuating sound level for "N" percent of the time. In other words an L_{90} equal to 63 dBA means that the sound levels equal 63 dBA, or higher, for 90% of the measurement period. The L_{10} level is commonly called the 'intrusive sound level', and the L_{90} is commonly called the 'residual sound level'. The L_{90} is often used in environmental measurements and assessments.

Common Sound Levels in dBA

Common Outdoor Sounds	Sound Pressure Level (dBA)	Common Indoor Sounds	Subjective Evaluation
Auto horn at 10 ft Jackhammer at 50 ft	**100**	Printing plant	Deafening
Gas lawn mower at 4 ft Pneumatic drill at 50 ft	**90**	Auditorium during applause Food blender at 3 ft	Very Loud
Concrete mixer at 50 ft Jet flyover at 5000 ft	**80**	Telephone ringing at 8 ft Vacuum cleaner at 5 ft	
Large dog barking at 50 ft Large transformer at 50 ft	**70**	Electric shaver at 1 ft	Loud
Automobile at 55 mph at 150 ft Urban residential	**60**	Normal conversation at 3 ft	
Small town residence	**50**	Office noise Dishwasher in adjacent room	Moderate
	40	Soft stereo music in residence Library	
Rustling leaves	**30**	Average bedroom at night Soft whisper at 3 ft	Faint
Quiet rural nighttime	**20**	Broadcast and recording studio	
	10	Human breathing	Very Faint
	0	Threshold of hearing (audibility)	

<u>Day-Night Equivalent Sound Level, L_{dn}</u>

The Day-Night level is the A-weighted equivalent sound level for a 24 hour period. During the nighttime hours (10PM to 7AM) a 10 dB "penalty" is added to the hourly L_{eq}. This artificial penalty is added to account for the decrease in community background noise during the nighttime hours. Many organizations and agencies use the L_{dn} metric in developing sound and noise guidelines, including the Federal Aviation Administration.

APPENDIX D

Live Sound Measurement Report
May 2015

LIVE FIRE SOUND MEASUREMENT REPORT

HAWAI'I PUBLIC SHOOTING RANGE AT PU'U ANAHULU

Waikoloa, Hawaii

May 2015

Prepared for:

PBR Hawaii & Associates

Prepared By:

CENSEO AV+Acoustics LLC

WWW.CENSEOAV.COM

Table of Contents

List of Figures

List of Tables

1 Introduction

Sound level measurements were conducted at the proposed Pu'u Anahulu Public Shooting Range to obtain sound source level data of two firearms that will likely be used at the proposed shooting range. One of the firearms, the .30-06 Springfield M1 Garand is one of the highest caliber firearms that is currently planned for use at the proposed shooting range. The second firearm, a 12 gauge Remington Model 870 Shotgun is also expected to be a common and typically used firearm at the proposed facility. The intent of these sound measurements was to establish sound source data for the loudest firearms to be used at the proposed shooting range. Therefore, the ammunition loads were carefully selected to be the heaviest and loudest available for each firearm.

The data collected includes sound level measurement data for each firearm, not only in the direction of the line of fire but also to the side and behind the shooter, in order to obtain directional sound source data for each firearm. This data will be used with the sound prediction modeling software to assess the potential sound impact of the Pu'u Anahulu Public Shooting Range on the surrounding communities (See Sound Modeling and Prediction Report).

In addition to the sound measurements conducted in open air, sound measurements were also conducted with the M1 Garand shooting through a field fabricated Sound Suppressor. The goal of the sound measurements with the sound suppressor was to determine the approximate effectiveness of one potential sound mitigation technique. The sound reduction as a function of the direction with the line of fire was recorded, similar to the open air sound measurements.

2 Sound Measurement Test Site Location

All sound measurements were conducted on the site of the proposed Pu'u Anahulu Public Shooting Range, in close proximity to the proposed 1,000 yard rifle range. The test site was positioned next to the existing 4x4 trail, due east of the existing Pu'u Anahulu Landfill. The GPS coordinates and direction of the line-of-fire is described in Table 1 below.

Table 1. GPS Coordinates and Line-of-Fire Direction for the Live Fire Sound Measurements

GPS Coordinates of Shooter for Sound Measurements	Line-of-Fire Direction
Latitude 19^o 53' 18.9" North Longitude 155^o 52' 1.6" West	120^o from North (Aimed East Southeast)

The approximate test site location is shown in Figure 1 below. The test site had a direct line-of-site with the Waikoloa Resort area.

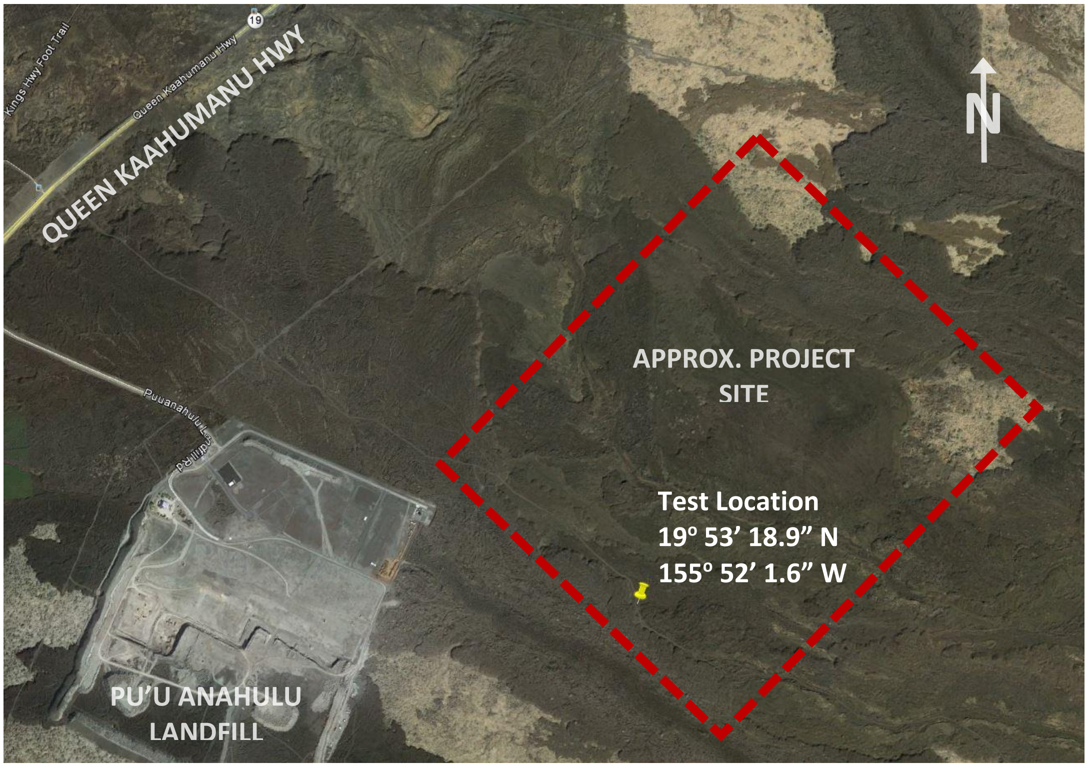


Figure 1. Location of Shooter for Sound Measurements

3 Tested Firearms, Ammunition, and Sound Suppressor

Sound measurements were conducted for the rifle and shotgun, as described in Table 2 below. Figure 2 shows photographs of each firearm used during the sound measurements.

Table 2. List of Firearms for Sound Measurements

Firearm	Ammunition	
Remington Model 870 Shotgun	Gauge	12
	Dram Eq.	3
	Oz. Shot	1-1/8
	Shot	8
M1 Garand Rifle	Springfield .30-06	

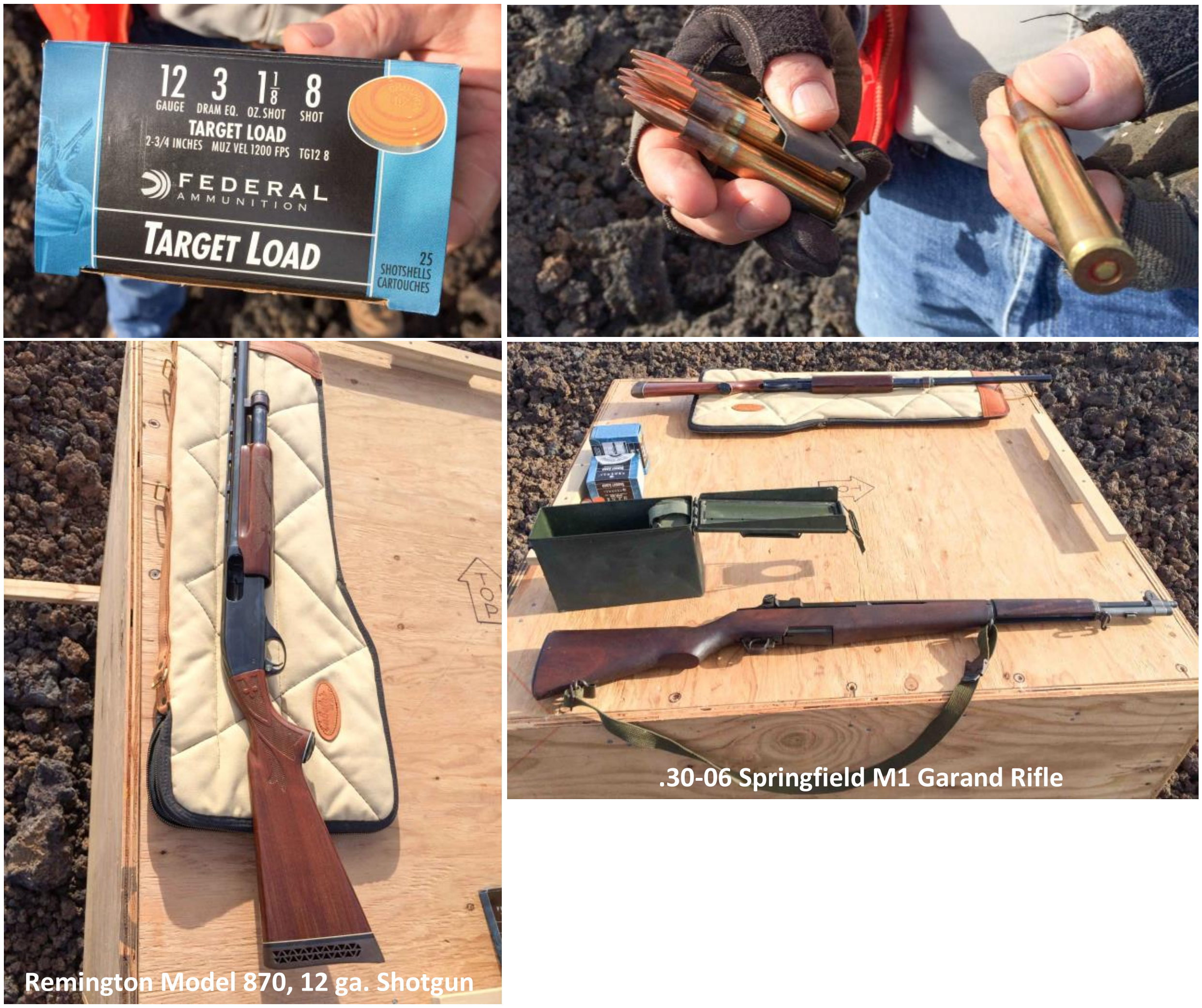


Figure 2. Photographs of Firearms and Ammunition

The Sound Suppressor consisted of a 4 ft x 4 ft x 4ft cube shaped box, constructed using ¾-inch thick plywood. An 18-inch diameter was cut through the box on two opposing sides, horizontal to the ground. Fiberglass batt insulation filled the voids of the plywood box. Wire mesh fencing in the shape of a cylinder (18-inch diameter, 4ft long) connected the two 18-inch holes, allowing the shooter to shoot through the opening in the box. The barrel of the firearm was placed approximately in the center of the box (2 ft into the box). Photos of the Sound Suppressor are shown in Figure 3 below.

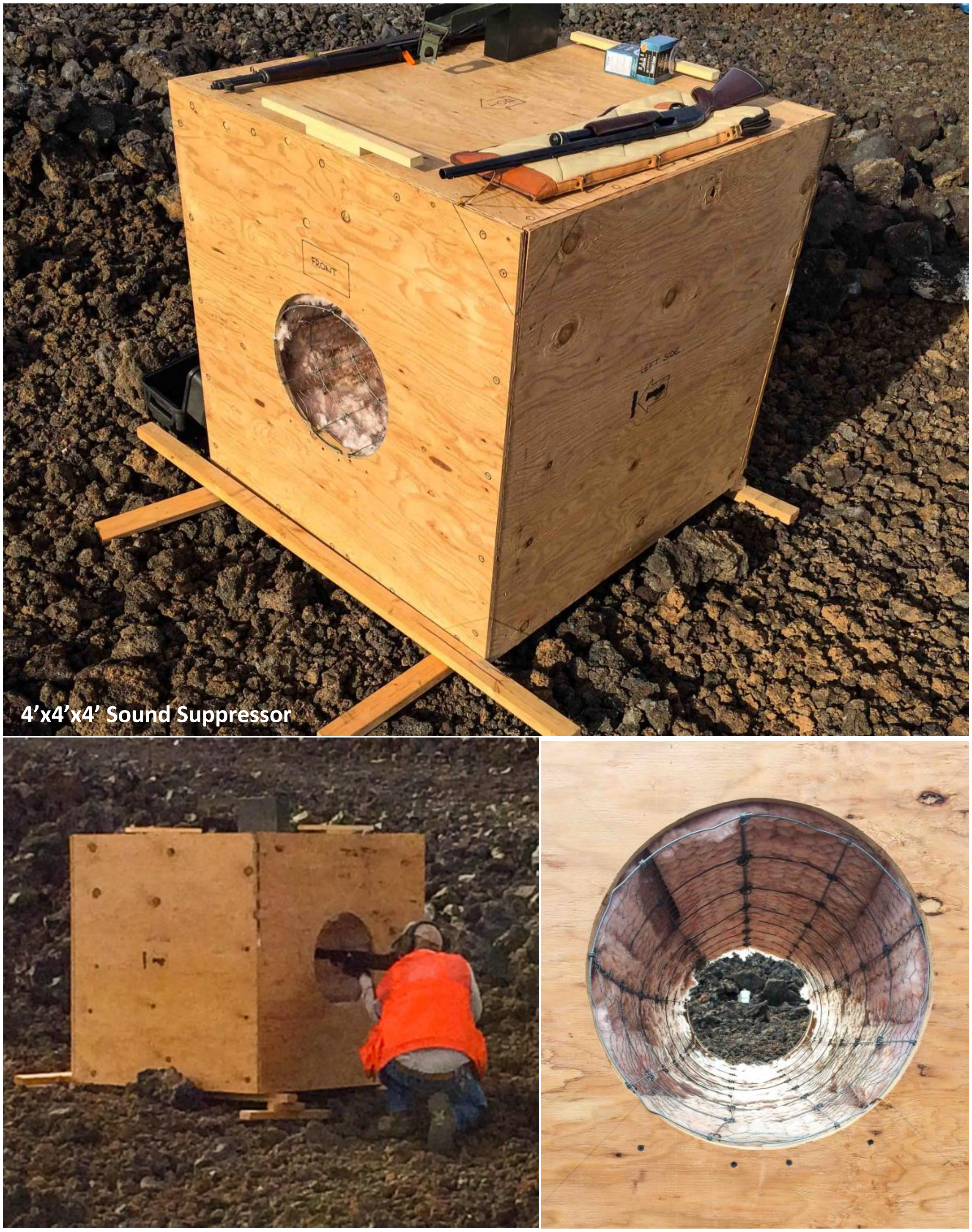


Figure 3. Photographs of Sound Suppressor

4 Sound Measurement Equipment and Procedure

The live fire sound measurements were conducted on December 4, 2014. The sound measurements were conducted at four discrete positions in a semi-circle around the shooter to determine the directional nature of the sound output of each firearm. Measurements were conducted both with and without the Sound Suppressor for the M1 Garand rifle. The Sound Suppressor was not used with the shotgun. The measurement equipment used for the sound measurements is described in the table below.

Table 3. List of Sound Measurement Equipment

Measurement Equipment	Manufacturer / Model
Type 1 Sound Level Meter	Larson Davis Model 831
Type 1 Prepolarized Free-Field Microphone, ½-inch (with Random Incidence microphone correction)	PCB Model 377B02
Type 1 Microphone Preamplifier	PCB Model PRM831
Acoustic Calibrator	Larson Davis Model CAL200

Sound levels were measured at four different positions in a semi-circle pattern around the shooter. The first position was on axis with the direction of the line-of-fire (at 0^{O}). Sound measurements were also conducted at 60^{O}, 120^{O}, and directly behind the shooter at 180^{O} from the direction of the line-of-fire. All microphone positions were at a distance of 50 feet from the firearm. Figure 4 below shows a diagram of the sound measurement positions.

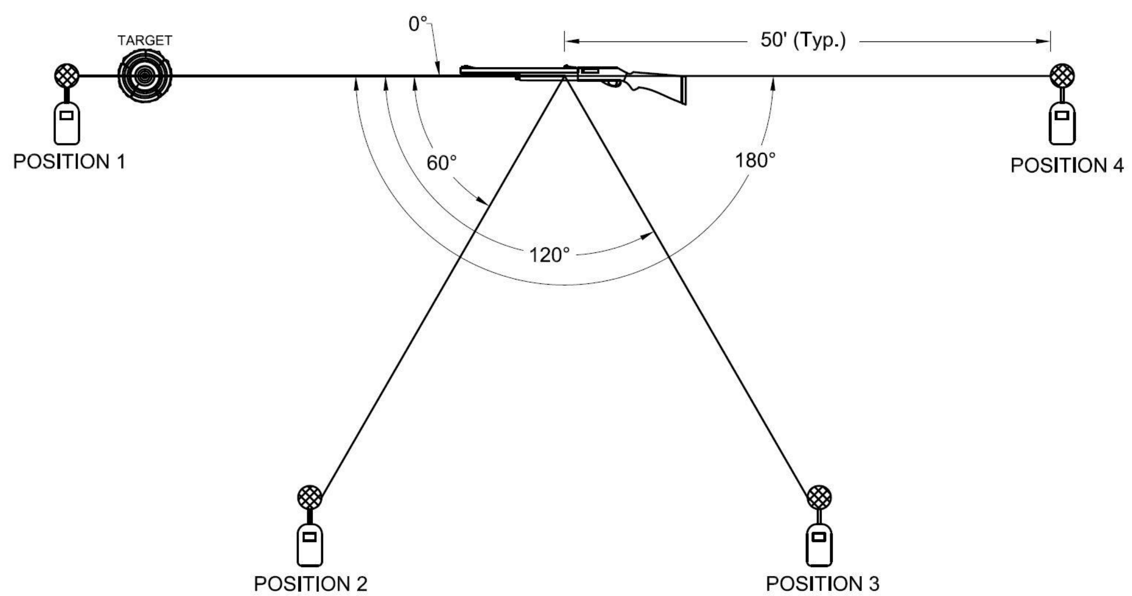


Figure 4. Diagram of Sound Measurement Positions

At each sound measurement position, the microphone and preamplifier were mounted on a tripod approximately 5 feet above grade. An open-cell polyurethane foam wind screen covered the microphone. The microphone and preamplifier were connected to the sound level meter using a microphone extension cable. The sound level meter was handheld during the measurements. The equipment was checked for calibration before and after the measurements.

A total of 10 shots were fired in each sound measurement position, with a shot cadence of approximately 3 to 5 seconds between shots. A time history of the shooting sequence was recorded. The sound level meter recorded maximum levels, L_{max} for the overall un-weighted and A-weighted sound levels. To obtain frequency spectrum sound data of each firearm, the L_{max} levels at each octave band were also recorded. These octave band L_{max} sound levels are maximum levels at each individual octave band during the shooting event, which means that the maximum levels at each octave band may not have occurred all at the same instant in time. However, these values are the maximum levels for the loudest single shot. Due to the impulsive nature of the sounds from the firearm discharge, the response time of the sound level meter was set to Impulse Response.

The full set of four microphone positions (a total of 40 shots per firearm) was conducted for the following sound measurement scenarios:

1. Remington Model 870, 12 ga. Shotgun fired in open air
2. .30-06 Springfield M1 Garand Rifle fired in open air
3. .30-06 Springfield M1 Garand Rifle fired through the Sound Suppressor

5 Sound Measurement Results

Sound radiation due to a firearm discharge is often inconsistent from one shot to the next. The variation in sound level can vary significantly, especially in the lower frequency bands. For this reason, a total of 10 shots were fired in each sound measurement position so that the variation of sound levels could be observed. In an effort to consider the maximum potential sound radiation of each firearm, the loudest of the 10 rounds is reported in the figures and tables below. The data has not been averaged over the 10 rounds. Instead, only the loudest of the 10 rounds is presented below.

It is important to evaluate not only the overall noise levels from each firearm, but also the frequency content of the firearm's sound radiation. Therefore, the sound measurement results shown below include the unweighted L_{max} octave band sound levels, as well as the A-weighted overall L_{max} sound levels.

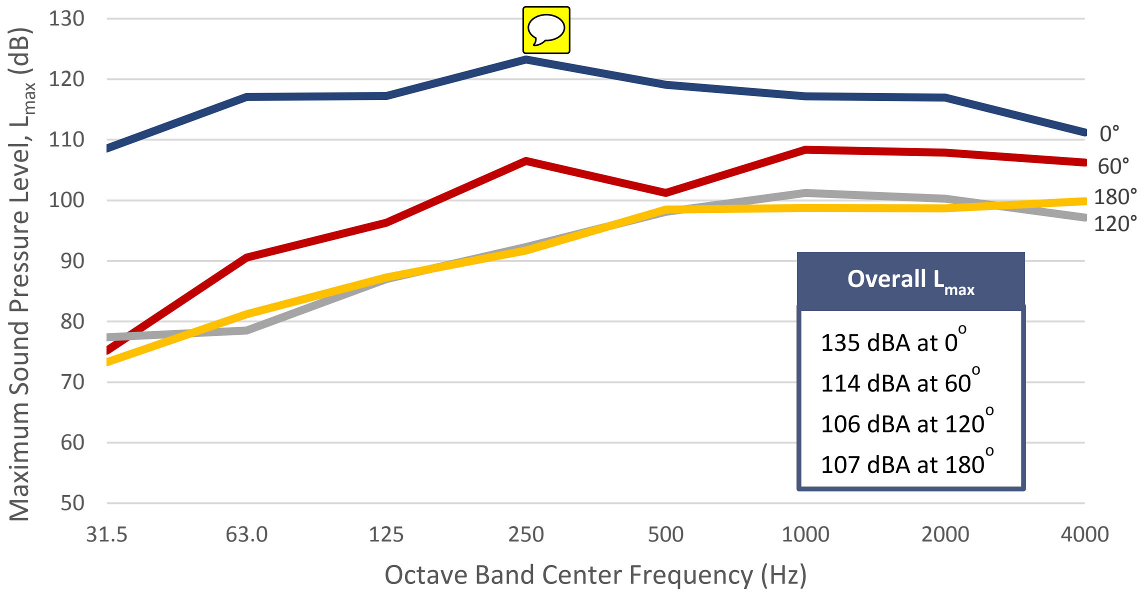


Figure 5. Measured L_{max}, Impulse Response for the Remington Model 870, 12 ga. Shotgun at 50 ft

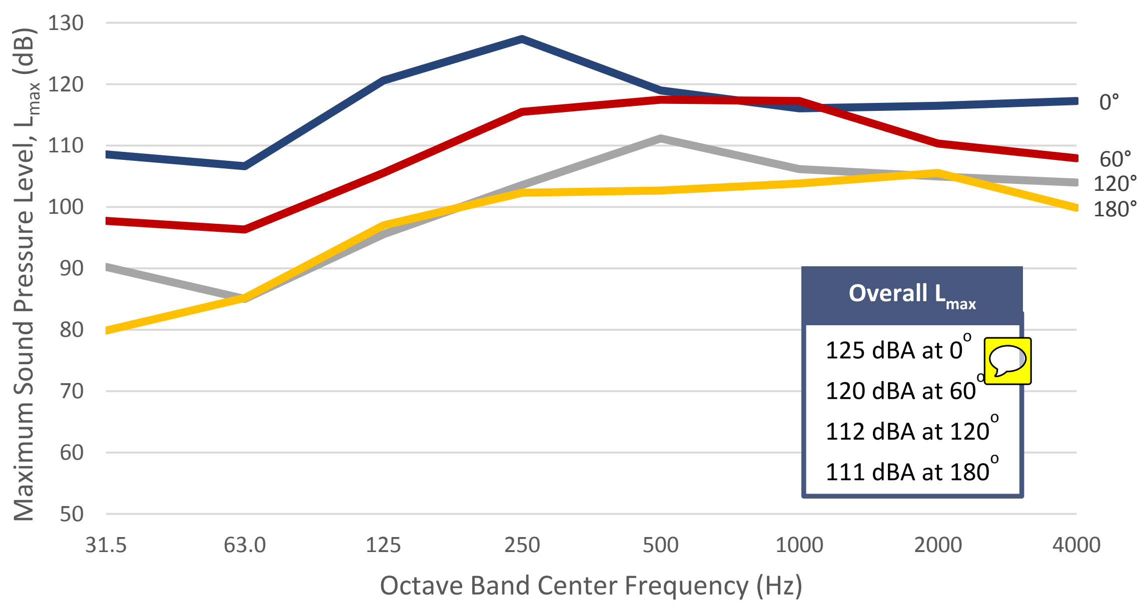


Figure 6. Measured L_{max}, Impulse Response for the Springfield M1 Garand Rifle No Suppressor at 50 ft

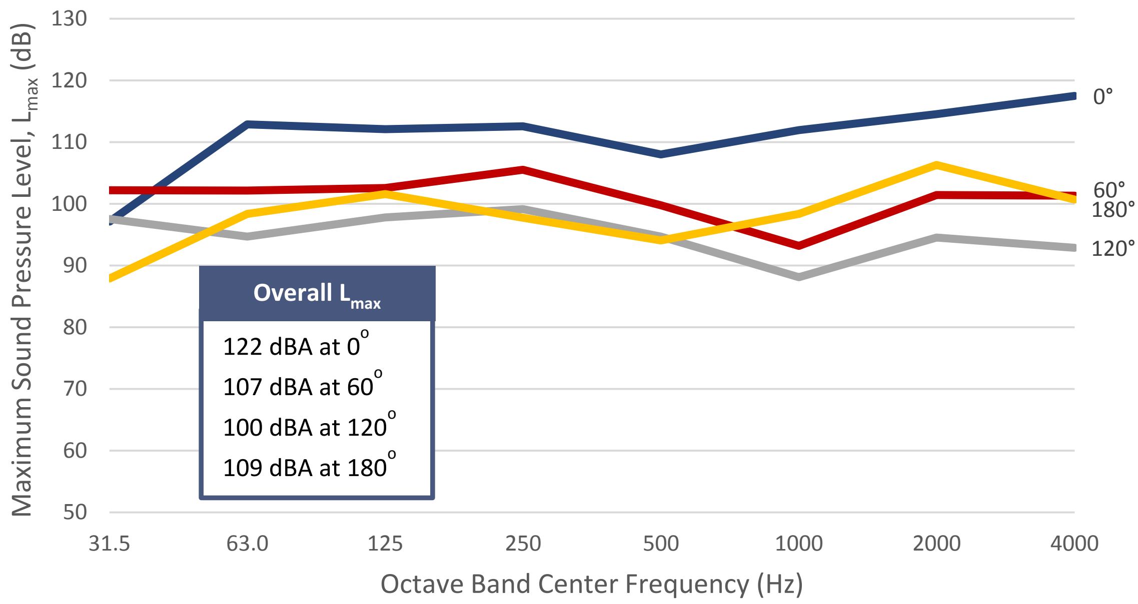


Figure 7. Measured L_{max}, Impulse Response for the Springfield M1 Garand Rifle with Suppressor at 50 ft

The octave band L_{max} values and the overall L_{max} sound measurement results are also shown in Table 4 below.

Table 4. Summary of Sound Measurement Results for Each Firearm, at 50 ft

Firearm	Angle from Line-of-Fire	Maximum Sound Pressure Level, L_{max}, (dB) Octave Band Center Frequency (Hz) 31.5	63	125	250	500	1000	2000	4000	Overall L_{max} (dB)	Overall L_{max} (dBA)
Shotgun	0°	109	117	117	123	119	117	117	111	130	125
	60°	75	91	96	107	101	108	108	106	114	114
	120°	77	79	87	92	98	101	100	97	106	106
	180°	73	81	87	92	99	99	99	100	107	107
M1 Garand	0°	109	107	121	127	119	116	117	117	132	125
	60°	98	96	106	116	118	117	110	108	122	120
	120°	90	85	96	104	111	106	105	104	113	112
	180°	80	85	97	102	103	104	106	100	111	111
M1 Garand (with Suppressor)	0°	97	113	112	113	108	112	115	118	126	122
	60°	102	102	103	106	100	93	101	101	110	107
	120°	98	95	98	99	95	88	95	93	104	100
	180°	88	98	102	98	94	98	106	101	109	109

As expected, the high caliber .30-06 is louder than the shotgun, although in the direction of firing the two firearms have similar overall sound levels. The orientation and direction of firing plays a key role in the sound transmission of sound from the proposed firing range to the surrounding areas. Sound levels in front of the shooter are typically 15 to 20 decibels louder than the sound levels behind the shooter.

Performance of the Sound Suppressor

The Sound Suppressor was fabricated in the field to show an example of the potential improvement gained by implementing sound mitigation in the design of the proposed firing range. This specific Sound Suppressor may not be utilized and incorporated into the proposed firing range. The intent of these sound measurements was simply to measure the performance of this technique. Other techniques may be incorporated into the proposed firing range. Figure 8 compares the measurement results for the M1 Garand with and without the Sound Suppressor.

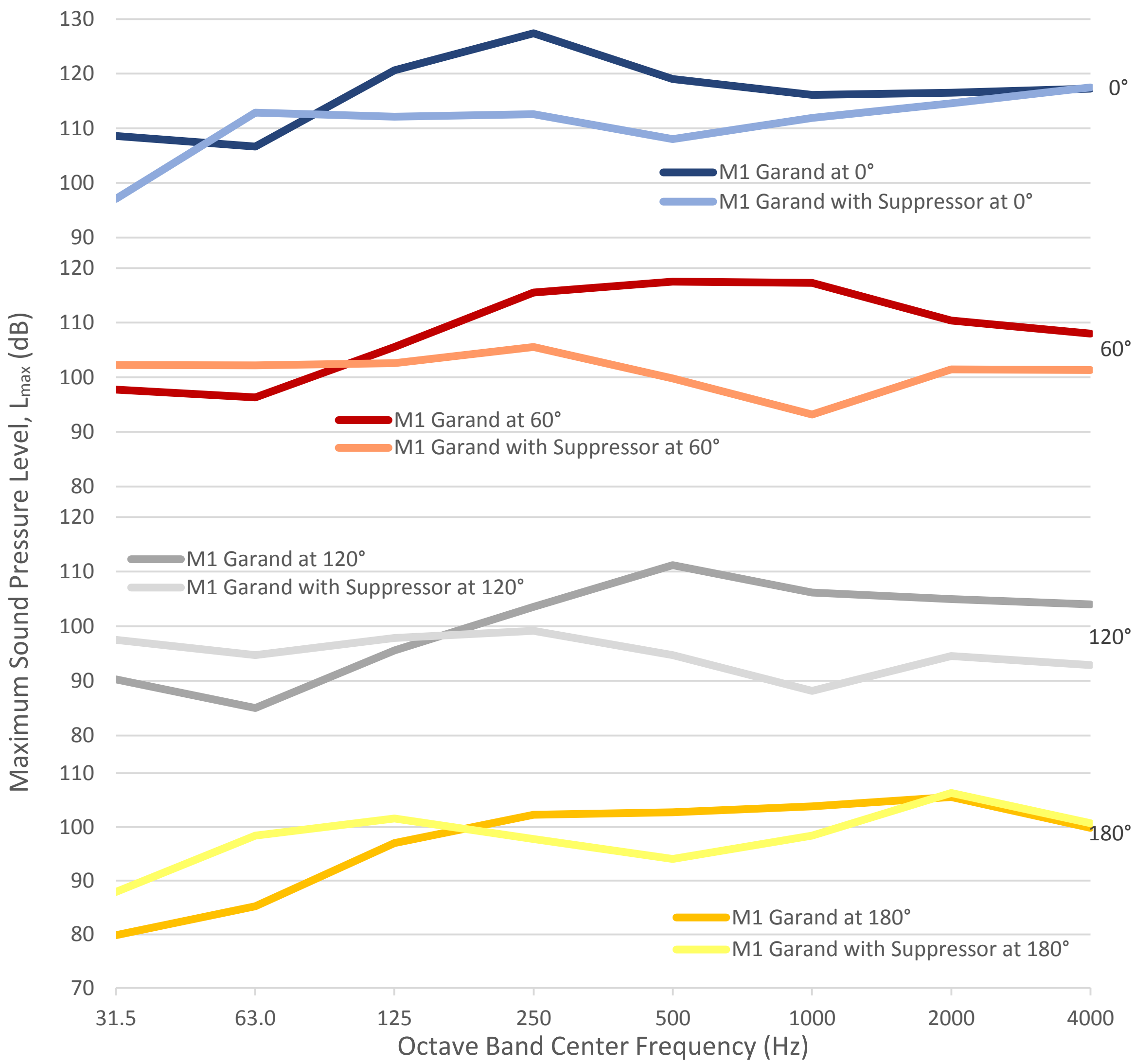


Figure 8. Comparison of the Octave Band L_{max}, Sound Levels with and without the Sound Suppressor

The data indicates that the sound suppressor provides a significant reduction in the mid frequency and high frequency sounds measured off-axis, at 60^{O} and 120^{O} from the line-of-fire. At 0^{O} the sound reduction is noticeable between the 125 Hz and 1,000 Hz octave bands. At 180^{O} the sound reduction improvement is not very significant, although some moderate sound reduction is noticeable between 250 Hz and 1,000 Hz. The results also indicate that the Sound Suppressor is not effective for lower frequency sounds, below 125 Hz.

6 Summary of Results and Conclusions

General Overview

The M1 Garand rifle and Remington 870 shotgun are expected to be two of the loudest firearms used at the proposed Pu'u Anahulu Public Shooting Range. The sound measurements results show that the orientation of the shooter and the direction of firing have an impact on the propagation of sound to the surrounding areas, including the Waikoloa Resort area. Sound levels in the direction of firing can exceed 125 dBA (Overall L_{max}, impulse response, A-weighted). Behind the shooter, in the opposite direction of firing, the observed sound levels are approximately 110 dBA (Overall L_{max}, impulse response, A-weighted).

The data collected during these sound measurements will be used as sound source data for the software modeling of the sound impact of the proposed Public Shooting Range on the Waikoloa Resort Area (See Sound Modeling and Prediction Report).

Use of the Sound Suppressor

The use of the Sound Suppressor can help reduce sound levels to the surrounding areas. However, there are many other sound mitigation techniques that can also be effective for reducing sound levels, if sound mitigation is required. Sound mitigation of the proposed Public Shooting Range is discussed in more detail in the Sound Modeling and Prediction Report.