Verdantas

SOUND MODELING – GAGER HILL SOLAR

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1.0 INTRODUCTION

Greenskies Clean Energy, LLC is developing the up to 4.625 MW AC Gager Hill Solar power project ("Project") proposed for Scotland, Connecticut. The engineer for the Project has asked RSG to perform sound propagation modeling to assess sound levels relative to State of Connecticut and local sound level limits. The report includes:

- A Project description,
- Description of sound level limits applicable to the project,
- Sound propagation modeling procedures and results, and
- Conclusions.

A primer of acoustical terminology used in this report is found in Appendix A.

2.0 PROJECT DESCRIPTION

The Gager Hill Solar power project ("Project") is an up to 4.625 MW AC photovoltaic facility located in the Town of Scotland, Connecticut. A map showing the Project in the context of the surrounding area is shown in Figure 1 and a map of the immediate site is shown in Figure 2. The Project site is north and west of Gager Hill Road, 380 meters (1,247 feet) south of State Route 14 and 400 meters (1,312 feet) west of State Route 97.

The Project area is divided into three fenced-in areas, totaling approximately 19 acres of solar panels. Project equipment includes the panels with tracking motors ("trackers") mounted to the racks to align the panels to be normal to the sun, and power conversion equipment, consisting of 37 inverters and 2 transformers. The inverters and transformers are divided into two groups, with each group mounted onto a large equipment pad located near the gravel access road. The inverters are currently planned to be Solectria XGI 1500 125 kW units. Each transformer will be a pad-mounted 2,500 kVA unit. A total of approximately 159 trackers are planned.

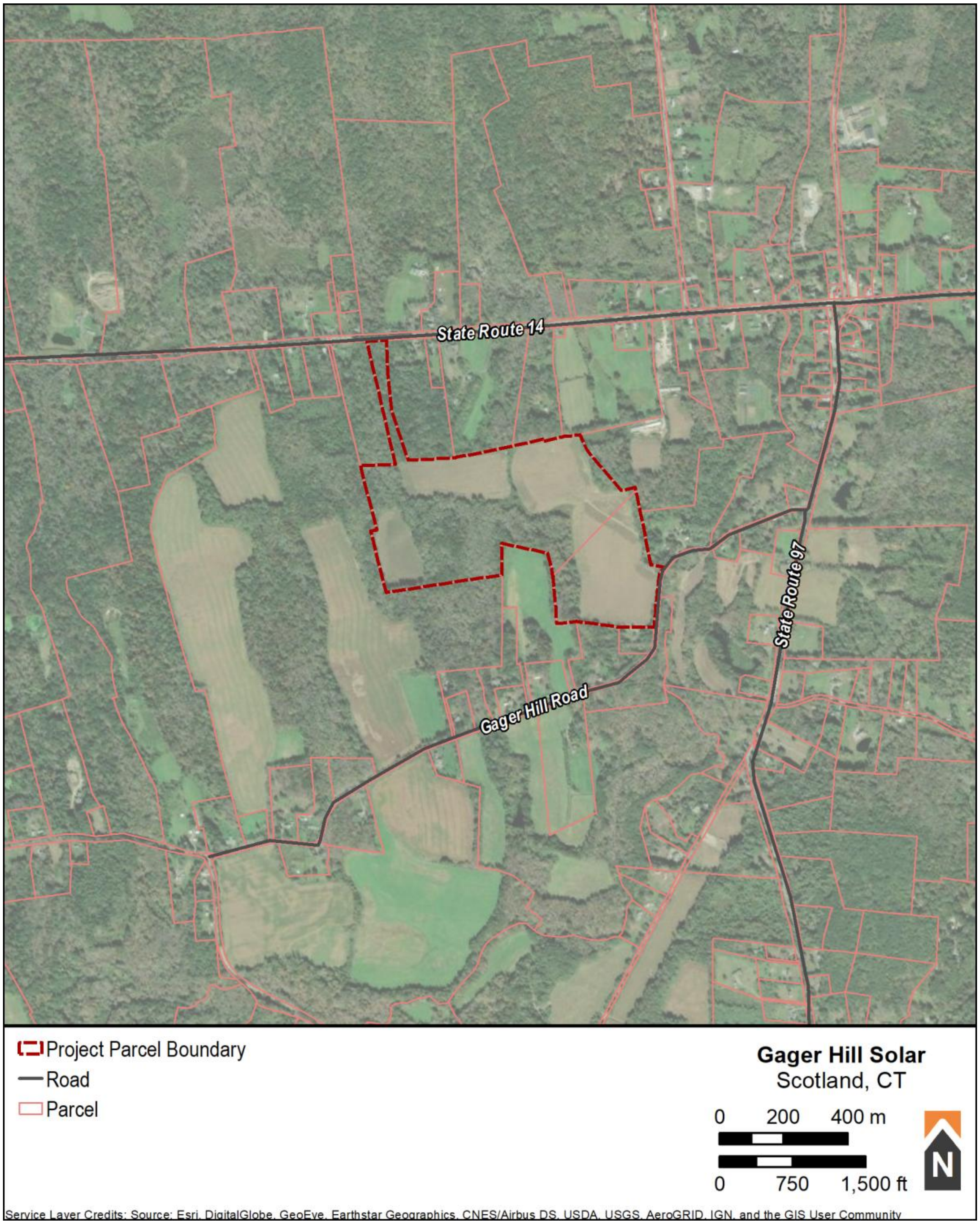

FIGURE 1: PROJECT AREA MAP

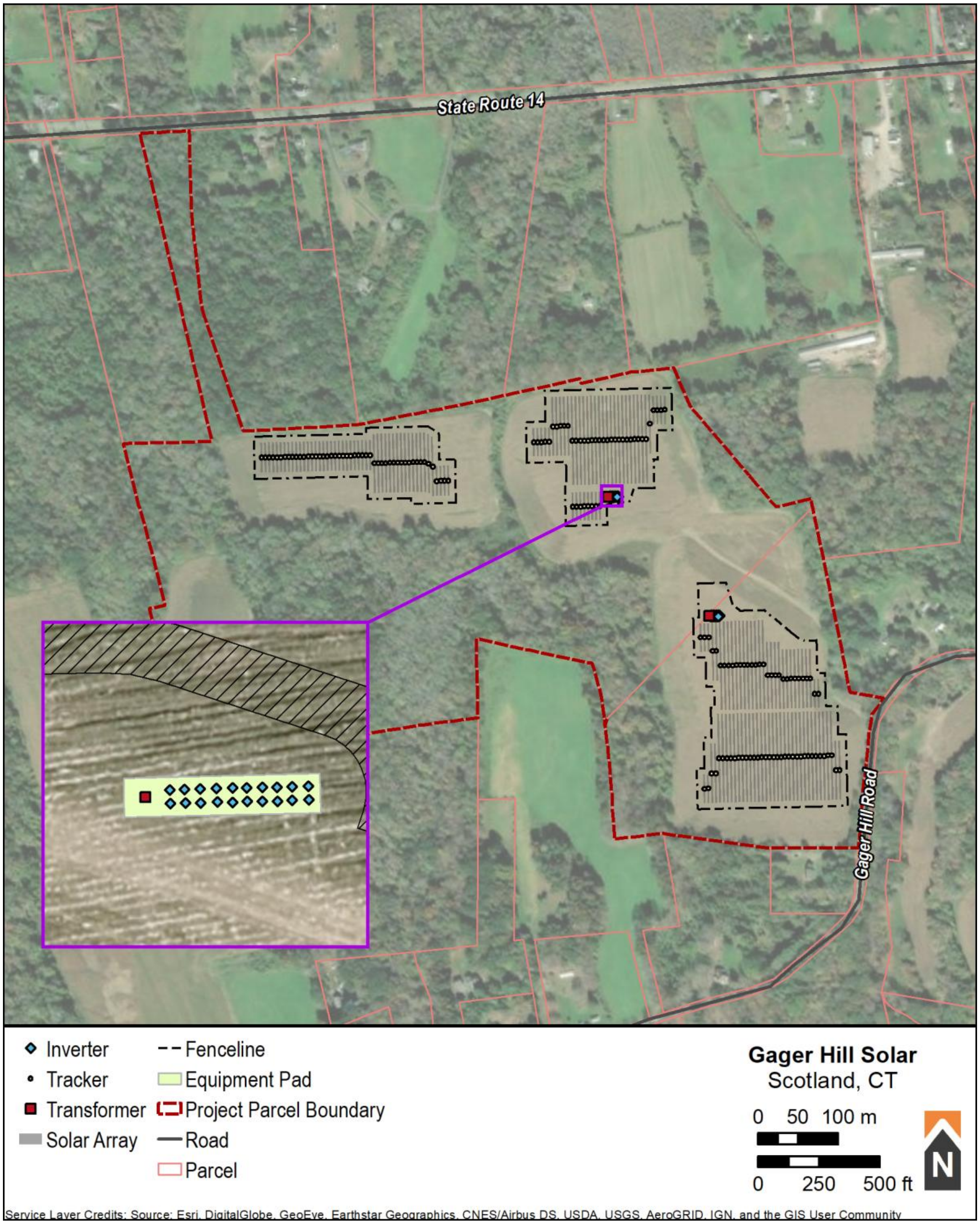

FIGURE 2: PROJECT SITE MAP

3.0 SOUND LEVEL LIMITS

The Town of Scotland does not currently have separate noise limits.

The State of Connecticut noise limits are classified by land use. Both the noise emitter and receptors are classified into Noise Zones as described in Section 22a-69-2 of the State of Connecticut Regulations. A Class A Noise Zone is residential or where humans tend to sleep, a Class B Noise Zone is intended for commercial or institutional uses, and a Class C Noise Zone is industrial.

The Project parcels are zoned as residential, but once a solar power project is built, its land use would be industrial. Within a Class C Noise Zone, an emitter cannot cause an exceedance of the noise level limits at the adjacent Noise Zones provided in Table 1. Surrounding zones are residential and would be considered Class A.

TABLE 1: CONNECTICUT CLASS A NOISE ZONE - LIMITS

	Receptor Noise Zone			
	C	**B**	**A/Day**	**A/Night**
Class C Emitter	70 dBA	66 dBA	61 dBA	51 dBA

Daytime is defined as 7:00 am to 10:00 pm and nighttime is defined as 10:00 pm to 7:00 am. There is a tonal penalty based on 1/3 octave band sound levels.

The Town of Scotland Zoning Regulations do not have noise limits, so the limits stated in the State of Connecticut Regulations Section 22a-69-2 are considered for the Project noise design limits.

3.1 PROJECT NOISE DESIGN LIMITS

Per the state noise limits, the Project should be designed to not exceed 61 dBA during daytime operation at any location at a nearby parcel. Nighttime operation from the Project shall not exceed 51 dBA at the same locations. The tonal penalty applies to the inverters and transformers and will be included in the sound propagational modeling of the Project.

4.0 SOUND PROPAGATION MODELING

4.1 PROCEDURES

Modeling for the project was in accordance with the standard ISO 9613-2, "Acoustics – Attenuation of sound during propagation outdoors, Part 2: General Method of Calculation." The ISO standard states,

> This part of ISO 9613 specifies an engineering method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise at a distance from a variety of sources. The method predicts the equivalent continuous A-weighted sound pressure level … under meteorological conditions favorable to propagation from sources of known sound emissions. These conditions are for downwind propagation … or, equivalently, propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night.

The model considers source sound power levels, surface reflection and absorption, atmospheric absorption, geometric divergence, meteorological conditions, walls, barriers, berms, and terrain. The acoustical modeling software used here was CadnaA® V4.4, from Datakustik GmbH. CadnaA® is a widely accepted acoustical propagation modeling tool, used by many noise control professionals in the United States and internationally.

ISO 9613-2 also assumes downwind sound propagation between every source and every receiver, consequently, all wind directions, including the prevailing wind directions, are taken into account.

Model input parameters are listed in Appendix B. The ground was modeled as soft (G=1), that is suitable for vegetation growth. The exception is for the equipment (inverter and transformer) pads and roadways, which were modeled as hard ground (G=0). Gravel roads were modeled as G=0.6.

Sound levels were calculated at 12 property line receivers and over an area of 1.5 square miles with a grid spacing of 10 meters by 10 meters. The residential receiver heights were placed at 4 meters, while the isoline and property line receivers were modeled at 1.5 meters. Property line receivers were placed at the highest modeled Project sound level along the neighboring parcel boundaries.

Modeled sound sources included 40 Solectria SCG 1500 125 kW inverters, two 2,500 kVA transformers and 159 tracking motors. Although there are 37 proposed inverters, 40 were modeled, making modeling more conservative. Data for the inverters was obtained from a manufacturer test. Sound power levels of the transformers were calculated based on sound emissions from the NEMA TR-1 standard and data that RSG has monitored from similar size transformers. Data for the trackers came from manufacturer's data from a similar tracking motor.

Trackers only operate a small percentage of the time as they track the sun throughout the day, they are assumed to operate eight percent of the time, and their sound powers were estimated by taking the average of their operation over an hour. Transformers and inverters operate continuously over the periods they operate. Both are usually also tonal and so a five dB penalty was added to both types of sources.

During daytime operation, all equipment is assumed to be operating. During nighttime, it is assumed that only the transformers will be operating.

4.2 RESULTS

Sound propagation modeling results are shown in Figure 3 and Figure 4. Discrete receiver results are shown in Appendix C; all results include the 5 dB penalty for tonal sources. Results show sound levels of up to 47 dBA at a residential property line during the daytime and 26 dBA at night. These levels are within the State of Connecticut daytime and nighttime noise limits.

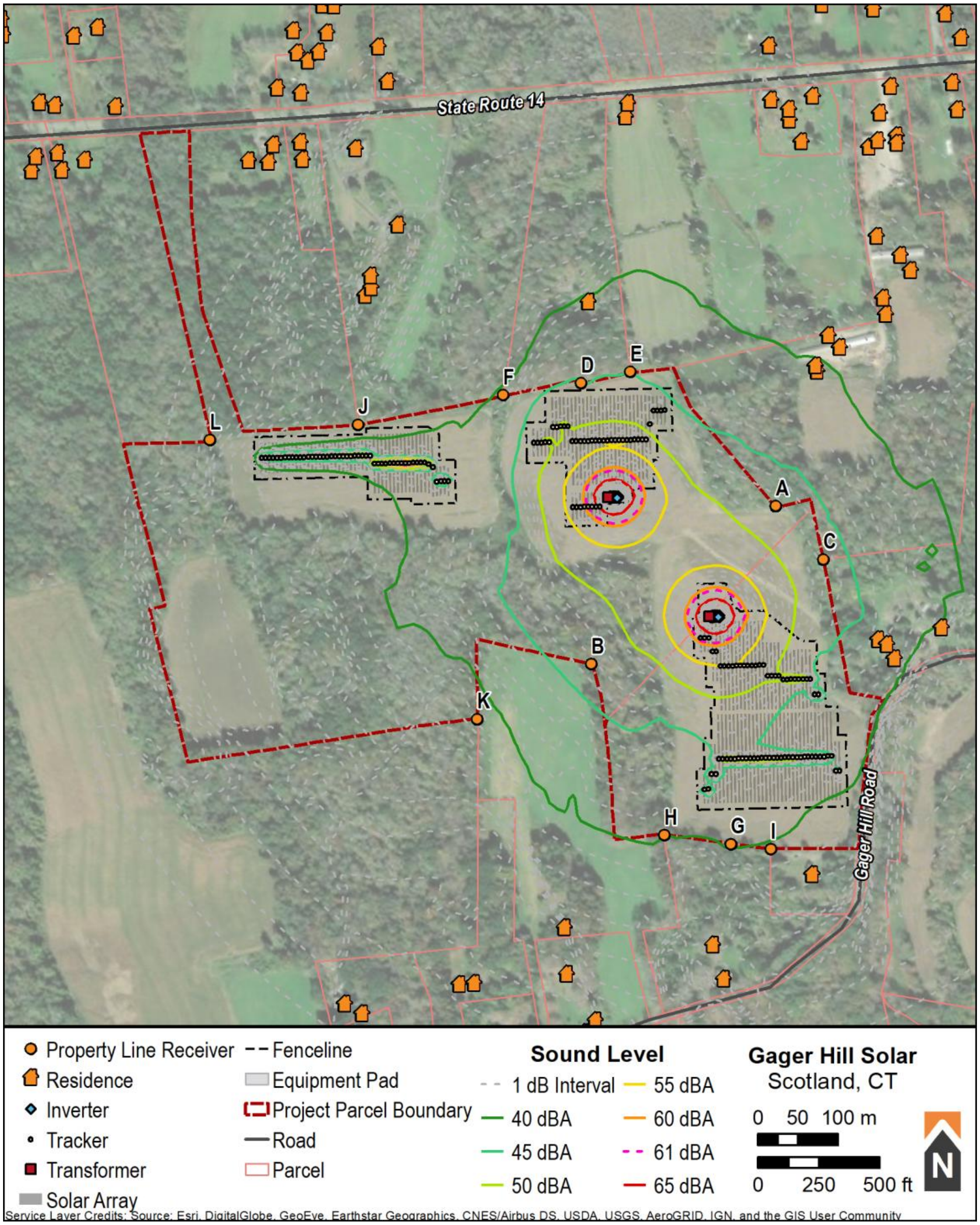

FIGURE 3: SOUND PROPAGATION MODELING RESULTS – DAYTIME OPERATION

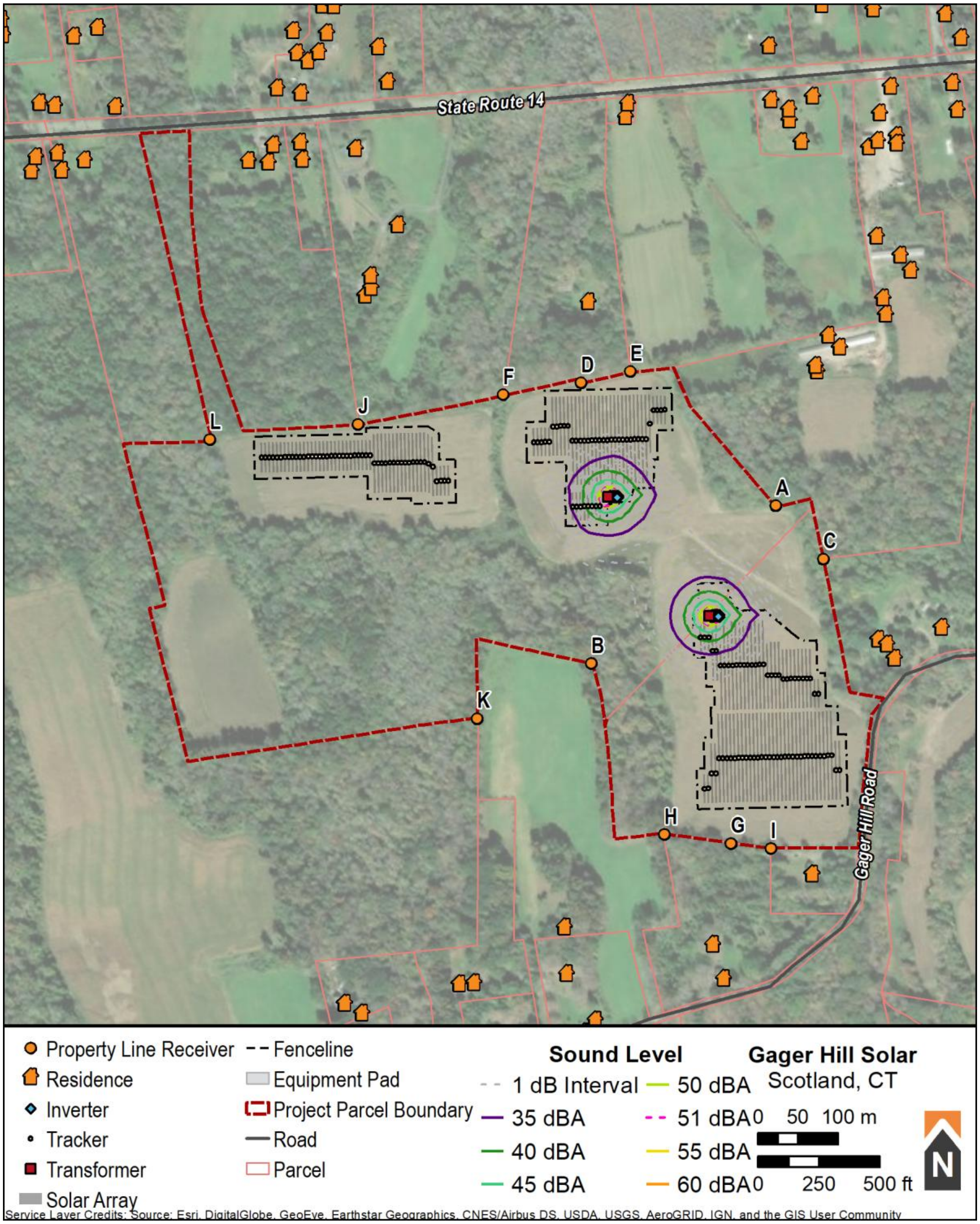

FIGURE 4: SOUND PROPAGATION MODELING RESULTS - NIGHTTIME OPERATION

5.0 CONCLUSIONS

Greenskies Clean Energy, LLC is in the process of developing the up to 4.625 MW AC Gager Hill Solar power project ("Project"), proposed for Scotland, Connecticut. Verdantas, the engineer for the project, asked RSG to assess sound levels of the Project relative to noise limits of the State of Connecticut and Scotland. Conclusions are as follows:

- Sound propagation modeling was performed using Datakustik's Cadna/A implementation of the ISO 9613-2 sound propagation modeling algorithm. The sound producing sources are the inverters, trackers, and transformers.
- Daytime operation assumes that trackers, inverters, and transformers are operating at full capacity. Nighttime operation assumes that only the transformers are operating.
- State noise limits require that the Project does not exceed sound levels of 61 dBA during the daytime and 51 dBA at nighttime at any location on a nearby residential property. Modeled property line receivers were placed at the "worst-case" location along residential property lines based on the isoline sound levels from the Project. Receivers were also placed at residential locations within a search radius of 3,000 meters encapsulating the Project.
- The highest modeled sound levels at a nearby residential property lines were 47 dBA during daytime operation and 26 dBA during nighttime operation.

APPENDIX A. ACOUSTICS PRIMER

Expressing Sound in Decibel Levels

The varying air pressure that constitutes sound can be characterized in many different ways. The human ear is the basis for the metrics that are used in acoustics. Normal human hearing is sensitive to sound fluctuations over an enormous range of pressures, from about 20 micropascals (the "threshold of audibility") to about 20 pascals (the "threshold of pain").[1] This factor of one million in sound pressure difference is challenging to convey in engineering units. Instead, sound pressure is converted to sound "levels" in units of "decibels" (dB, named after Alexander Graham Bell). Once a measured sound is converted to dB, it is denoted as a level with the letter "L".

The conversion from sound pressure in pascals to sound level in dB is a four-step process. First, the sound wave's measured amplitude is squared and the mean is taken. Second, a ratio is taken between the mean square sound pressure and the square of the threshold of audibility (20 micropascals). Third, using the logarithm function, the ratio is converted to factors of 10. The final result is multiplied by 10 to give the decibel level. By this decibel scale, sound levels range from 0 dB at the threshold of audibility to 120 dB at the threshold of pain.

Typical sound sources, and their sound pressure levels, are listed on the scale in Figure 5.

Human Response to Sound Levels: Apparent Loudness

For every 20 dB increase in sound level, the sound pressure increases by a *factor* of 10; the sound *level* range from 0 dB to 120 dB covers 6 factors of 10, or one million, in sound *pressure*. However, for an increase of 10 dB in sound *level* as measured by a meter, humans perceive an approximate doubling of apparent loudness: to the human ear, a sound level of 70 dB sounds about "twice as loud" as a sound level of 60 dB. Smaller changes in sound level, less than 3 dB up or down, are generally not perceptible.

[1] The pascal is a measure of pressure in the metric system. In Imperial units, they are themselves very small: one pascal is only 145 millionths of a pound per square inch (psi). The sound pressure at the threshold of audibility is only 3 one-billionths of one psi: at the threshold of pain, it is about 3 one-thousandths of one psi.

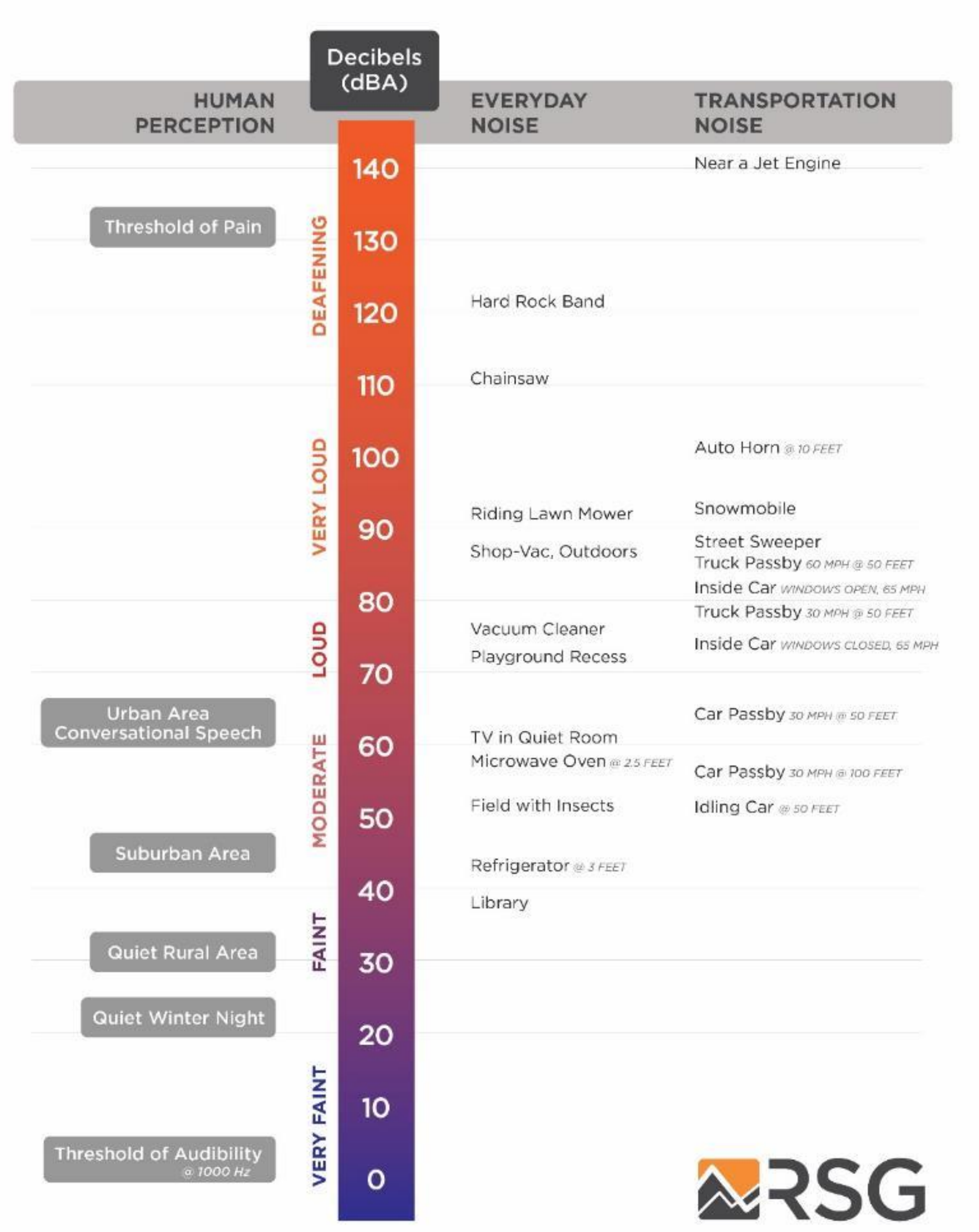

FIGURE 5: A SCALE OF SOUND PRESSURE LEVELS FOR TYPICAL SOUND SOURCES

Frequency Spectrum of Sound

The “frequency” of a sound is the rate at which it fluctuates in time, expressed in Hertz (Hz), or cycles per second. Very few sounds occur at only one frequency: most sound contains energy at many different frequencies, and it can be broken down into different frequency divisions, or bands. These bands are similar to musical pitches, from low tones to high tones. The most common division is the standard octave band. An octave is the range of frequencies whose upper frequency limit is twice its lower frequency limit, exactly like an octave in music. An octave band is identified by its center frequency: each successive band’s center frequency is twice as high (one octave) as the previous band. For example, the 500 Hz octave band includes all sound whose frequencies range between 354 Hz (Hertz, or cycles per second) and 707 Hz. The next band is centered at 1,000 Hz with a range between 707 Hz and 1,414 Hz. The range of human hearing is divided into 10 standard octave bands: 31.5 Hz, 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1,000 Hz, 2,000 Hz, 4,000 Hz, 8,000 Hz, and 16,000 Hz. For analyses that require finer frequency detail, each octave-band can be subdivided. A commonly-used subdivision creates three smaller bands within each octave band, or so-called 1/3-octave bands.

Human Response to Frequency: Weighting of Sound Levels

The human ear is not equally sensitive to sounds of all frequencies. Sounds at some frequencies seem louder than others, despite having the same decibel level as measured by a sound level meter. In particular, human hearing is much more sensitive to medium pitches (from about 500 Hz to about 4,000 Hz) than to very low or very high pitches. For example, a tone measuring 80 dB at 500 Hz (a medium pitch) sounds quite a bit louder than a tone measuring 80 dB at 60 Hz (a very low pitch). The frequency response of normal human hearing ranges from 20 Hz to 20,000 Hz. Below 20 Hz, sound pressure fluctuations are not “heard”, but sometimes can be “felt”. This is known as “infrasound”. Likewise, above 20,000 Hz, sound can no longer be heard by humans; this is known as “ultrasound”. As humans age, they tend to lose the ability to hear higher frequencies first; many adults do not hear very well above about 16,000 Hz. Most natural and man-made sound occurs in the range from about 40 Hz to about 4,000 Hz. Some insects and birdsongs reach to about 8,000 Hz.

To adjust measured sound pressure levels so that they mimic human hearing response, sound level meters apply filters, known as “frequency weightings”, to the signals. There are several defined weighting scales, including “A”, “B”, “C”, “D”, “G”, and “Z”. The most common weighting scale used in environmental noise analysis and regulation is A-weighting. This weighting represents the sensitivity of the human ear to sounds of low to moderate level. It attenuates sounds with frequencies below 1000 Hz and above 4000 Hz; it amplifies very slightly sounds between 1000 Hz and 4000 Hz, where the human ear is particularly sensitive. The C-weighting scale is sometimes used to describe louder sounds. The B- and D- scales are seldom used. All of these frequency weighting scales are normalized to the average human hearing response at

1000 Hz: at this frequency, the filters neither attenuate nor amplify. When a reported sound level has been filtered using a frequency weighting, the letter is appended to “dB”. For example, sound with A-weighting is usually denoted “dBA”. When no filtering is applied, the level is denoted “dB” or “dBZ”. The letter is also appended as a subscript to the level indicator “L”, for example “L_A” for A-weighted levels.

Time Response of Sound Level Meters

Because sound levels can vary greatly from one moment to the next, the time over which sound is measured can influence the value of the levels reported. Often, sound is measured in real time, as it fluctuates. In this case, acousticians apply a so-called “time response” to the sound level meter, and this time response is often part of regulations for measuring sound. If the sound level is varying slowly, over a few seconds, “Slow” time response is applied, with a time constant of one second. If the sound level is varying quickly (for example, if brief events are mixed into the overall sound), “Fast” time response can be applied, with a time constant of one-eighth of a second.[2] The time response setting for a sound level measurement is indicated with the subscript “S” for Slow and “F” for Fast: L_S or L_F. A sound level meter set to Fast time response will indicate higher sound levels than one set to Slow time response when brief events are mixed into the overall sound, because it can respond more quickly.

In some cases, the maximum sound level that can be generated by a source is of concern. Likewise, the minimum sound level occurring during a monitoring period may be required. To measure these, the sound level meter can be set to capture and hold the highest and lowest levels measured during a given monitoring period. This is represented by the subscript “max”, denoted as “L_{max}”. One can define a “max” level with Fast response L_{Fmax} (1/8-second time constant), Slow time response L_{Smax} (1-second time constant), or Continuous Equivalent level over a specified time period $L_{eq,max}$.

Accounting for Changes in Sound Over Time

A sound level meter’s time response settings are useful for continuous monitoring. However, they are less useful in summarizing sound levels over longer periods. To do so, acousticians apply simple statistics to the measured sound levels, resulting in a set of defined types of sound level related to averages over time. An example is shown in Figure 6. The sound level at each instant of time is the grey trace going from left to right. Over the total time it was measured (1 hour in the figure), the sound energy spends certain fractions of time near various levels, ranging from the minimum (about 27 dB in the figure) to the maximum (about 65 dB in the figure). The simplest descriptor is the average sound level, known as the Equivalent Continuous

[2] There is a third time response defined by standards, the “Impulse” response. This response was defined to enable use of older, analog meters when measuring very brief sounds; it is no longer in common use.

Sound Level. Statistical levels are used to determine for what percentage of time the sound is louder than any given level. These levels are described in the following sections.

Equivalent Continuous Sound Level - L_{eq}

One straightforward, common way of describing sound levels is in terms of the Continuous Equivalent Sound Level, or L_{eq}. The L_{eq} is the average sound pressure level over a defined period of time, such as one hour or one day. L_{eq} is the most commonly used descriptor in noise standards and regulations. L_{eq} is representative of the overall sound to which a person is exposed. Because of the logarithmic calculation of decibels, L_{eq} tends to favor higher sound levels: loud and infrequent sources have a larger impact on the resulting average sound level than quieter but more frequent sounds. For example, in Figure 6, even though the sound levels spends most of the time near about 34 dBA, the L_{eq} is 41 dBA, having been “inflated” by the maximum level of 65 dBA and other occasional spikes over the course of the hour.

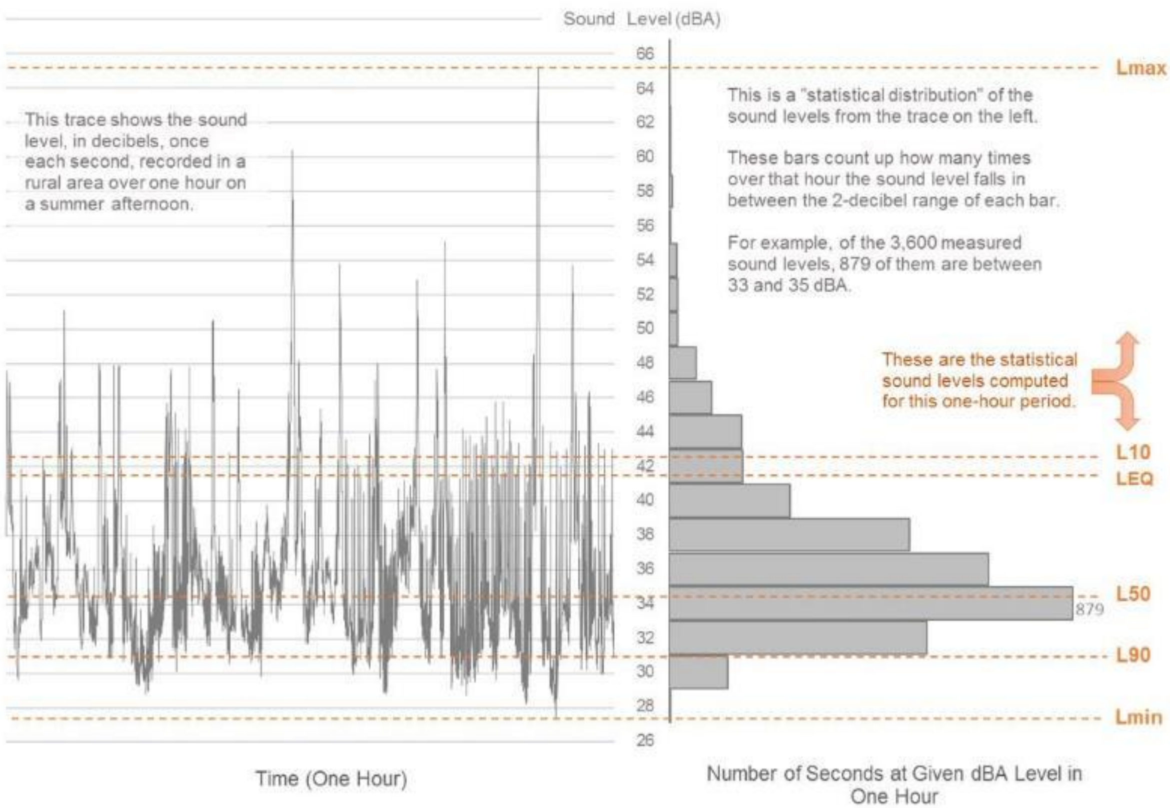

FIGURE 6: EXAMPLE OF DESCRIPTIVE TERMS OF SOUND MEASUREMENT OVER TIME

Percentile Sound Levels – L_n

Percentile sound levels describe the statistical distribution of sound levels over time. “L_N” is the level above which the sound spends “N” percent of the time. For example, L_{90} (sometimes called the “residual base level”) is the sound level exceeded 90% of the time: the sound is louder than L_{90} most of the time. L_{10} is the sound level that is exceeded only 10% of the time. L_{50} (the “median level”) is exceeded 50% of the time: half of the time the sound is louder than L_{50}, and half the time it is quieter than L_{50}. Note that L_{50} (median) and L_{eq} (mean) are not always the same, for reasons described in the previous section.

L_{90} is the sound that persists for longer periods, and below which the overall sound level seldom falls. It tends to filter out other short-term environmental sounds that aren’t part of the source being investigated. L_{10} represents the higher, but less frequent, sound levels. These could include such events as barking dogs, vehicles driving by and aircraft flying overhead, gusts of wind, and work operations. L_{90} represents the background sound that is present when these event sounds are excluded.

Note that if one sound source is very constant and dominates the soundscape in an area, all of the descriptive sound levels mentioned here tend toward the same value. It is when the sound is varying widely from one moment to the next that the statistical descriptors are useful.

APPENDIX B. SOUND SOURCE INFORMATION

TABLE 2: SOUND PROPAGATION MODELING PARAMETERS

Parameter	Setting
Ground Absorption	Spectral for all sources, soft ground (G=1), hard ground (G=0) for equipment pads and roads, G=0.6 for gravel roads
Atmospheric Attenuation	Based on 10 Celsius, 70% relative humidity
Receiver Height	1.5 meters (4.9 feet) for property line receivers and isoline contours, 4 meters (13 feet) for residences
Search Radius	3,000 meters

TABLE 3: EQUIPMENT SOUND POWER

	1/1 Octave Band Center Frequency Sound Power (dBZ)										
Sound Source	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	Sum (dBA)	Sum (dBZ)
Yaskawa XGI 1500-166/166 @ 3m	80	75	79	73	79	81	76	78	77	85	88
Transformer: 2500kVA	75	80	86	85	75	71	62	54	47	79	89
Tracker					70					67	70

TABLE 4: SOUND SOURCE INFORMATION

Source ID	Equipment Type	Modeled Sound Power (dBA)	Relative Height (m)	Coordinates (UTM NAD83 Z18N)		
				X (m)	Y (m)	Z (m)
Inverter 01[3]	Inverter	90	1.6	741916	4619838	88
Inverter 02	Inverter	90	1.6	741927	4619839	88
Inverter 03	Inverter	90	1.6	741927	4619837	87
Inverter 04	Inverter	90	1.6	741916	4619836	88
Inverter 05	Inverter	90	1.6	741917	4619839	88
Inverter 06	Inverter	90	1.6	741918	4619839	88
Inverter 07	Inverter	90	1.6	741919	4619839	88
Inverter 08	Inverter	90	1.6	741921	4619839	88
Inverter 09	Inverter	90	1.6	741922	4619839	88
Inverter 10	Inverter	90	1.6	741923	4619839	88
Inverter 11	Inverter	90	1.6	741924	4619839	88
Inverter 12	Inverter	90	1.6	741925	4619839	88
Inverter 13	Inverter	90	1.6	741917	4619836	88

[3] Of the 40 inverter locations shown here, only 37 will be installed.

Source ID	Equipment Type	Modeled Sound Power (dBA)	Relative Height (m)	Coordinates (UTM NAD83 Z18N)		
				X (m)	Y (m)	Z (m)
Inverter 14	Inverter	90	1.6	741918	4619836	88
Inverter 15	Inverter	90	1.6	741920	4619837	88
Inverter 16	Inverter	90	1.6	741921	4619837	88
Inverter 17	Inverter	90	1.6	741922	4619837	88
Inverter 18	Inverter	90	1.6	741923	4619837	88
Inverter 19	Inverter	90	1.6	741924	4619837	88
Inverter 20	Inverter	90	1.6	741925	4619837	88
Inverter 21	Inverter	90	1.6	742054	4619690	82
Inverter 22	Inverter	90	1.6	742043	4619689	82
Inverter 23	Inverter	90	1.6	742043	4619687	82
Inverter 24	Inverter	90	1.6	742054	4619687	82
Inverter 25	Inverter	90	1.6	742044	4619689	82
Inverter 26	Inverter	90	1.6	742045	4619689	82
Inverter 27	Inverter	90	1.6	742046	4619689	82
Inverter 28	Inverter	90	1.6	742047	4619689	82
Inverter 29	Inverter	90	1.6	742048	4619690	82
Inverter 30	Inverter	90	1.6	742049	4619690	82
Inverter 31	Inverter	90	1.6	742050	4619690	82
Inverter 32	Inverter	90	1.6	742052	4619690	82
Inverter 33	Inverter	90	1.6	742044	4619687	82
Inverter 34	Inverter	90	1.6	742045	4619687	82
Inverter 35	Inverter	90	1.6	742046	4619687	82
Inverter 36	Inverter	90	1.6	742047	4619687	82
Inverter 37	Inverter	90	1.6	742048	4619687	82
Inverter 38	Inverter	90	1.6	742049	4619687	82
Inverter 39	Inverter	90	1.6	742051	4619688	82
Inverter 40	Inverter	90	1.6	742052	4619688	82
Tracker 001	Tracker	67	1.5	742204	4619495	77
Tracker 002	Tracker	67	1.5	742199	4619495	77
Tracker 003	Tracker	67	1.5	742194	4619513	77
Tracker 004	Tracker	67	1.5	742189	4619513	77
Tracker 005	Tracker	67	1.5	742184	4619513	76
Tracker 006	Tracker	67	1.5	742177	4619591	77
Tracker 007	Tracker	67	1.5	742179	4619513	76
Tracker 008	Tracker	67	1.5	742173	4619591	77
Tracker 009	Tracker	67	1.5	742174	4619513	77

Source ID	Equipment Type	Modeled Sound Power (dBA)	Relative Height (m)	Coordinates (UTM NAD83 Z18N)		
				X (m)	Y (m)	Z (m)
Tracker 010	Tracker	67	1.5	742167	4619610	77
Tracker 011	Tracker	67	1.5	742170	4619513	77
Tracker 012	Tracker	67	1.5	742162	4619610	78
Tracker 013	Tracker	67	1.5	742165	4619513	77
Tracker 014	Tracker	67	1.5	742158	4619610	78
Tracker 015	Tracker	67	1.5	742160	4619513	77
Tracker 016	Tracker	67	1.5	742153	4619610	78
Tracker 017	Tracker	67	1.5	742155	4619513	77
Tracker 018	Tracker	67	1.5	742148	4619610	78
Tracker 019	Tracker	67	1.5	742150	4619512	77
Tracker 020	Tracker	67	1.5	742143	4619610	78
Tracker 021	Tracker	67	1.5	742145	4619512	77
Tracker 022	Tracker	67	1.5	742138	4619609	79
Tracker 023	Tracker	67	1.5	742140	4619512	77
Tracker 024	Tracker	67	1.5	742133	4619609	79
Tracker 025	Tracker	67	1.5	742136	4619512	77
Tracker 026	Tracker	67	1.5	742128	4619614	79
Tracker 027	Tracker	67	1.5	742131	4619512	77
Tracker 028	Tracker	67	1.5	742123	4619614	79
Tracker 029	Tracker	67	1.5	742126	4619512	77
Tracker 030	Tracker	67	1.5	742119	4619614	79
Tracker 031	Tracker	67	1.5	742121	4619512	77
Tracker 032	Tracker	67	1.5	742114	4619614	80
Tracker 033	Tracker	67	1.5	742116	4619512	77
Tracker 034	Tracker	67	1.5	742109	4619627	80
Tracker 035	Tracker	67	1.5	742111	4619511	77
Tracker 036	Tracker	67	1.5	742104	4619627	80
Tracker 037	Tracker	67	1.5	742106	4619511	77
Tracker 038	Tracker	67	1.5	742099	4619627	80
Tracker 039	Tracker	67	1.5	742102	4619511	77
Tracker 040	Tracker	67	1.5	742094	4619627	80
Tracker 041	Tracker	67	1.5	742097	4619511	77
Tracker 042	Tracker	67	1.5	742089	4619627	81
Tracker 043	Tracker	67	1.5	742092	4619511	77
Tracker 044	Tracker	67	1.5	742084	4619627	81
Tracker 045	Tracker	67	1.5	742087	4619511	77

Source ID	Equipment Type	Modeled Sound Power (dBA)	Relative Height (m)	Coordinates (UTM NAD83 Z18N)		
				X (m)	Y (m)	Z (m)
Tracker 046	Tracker	67	1.5	742079	4619627	81
Tracker 047	Tracker	67	1.5	742082	4619511	77
Tracker 048	Tracker	67	1.5	742075	4619626	81
Tracker 049	Tracker	67	1.5	742077	4619511	77
Tracker 050	Tracker	67	1.5	742070	4619626	81
Tracker 051	Tracker	67	1.5	742072	4619511	77
Tracker 052	Tracker	67	1.5	742065	4619626	81
Tracker 053	Tracker	67	1.5	742068	4619510	77
Tracker 054	Tracker	67	1.5	742060	4619626	81
Tracker 055	Tracker	67	1.5	742063	4619510	77
Tracker 056	Tracker	67	1.5	742055	4619626	81
Tracker 057	Tracker	67	1.5	742058	4619510	77
Tracker 058	Tracker	67	1.5	742050	4619644	81
Tracker 059	Tracker	67	1.5	742053	4619510	77
Tracker 060	Tracker	67	1.5	742045	4619644	81
Tracker 061	Tracker	67	1.5	742049	4619491	77
Tracker 062	Tracker	67	1.5	742040	4619661	81
Tracker 063	Tracker	67	1.5	742044	4619491	77
Tracker 064	Tracker	67	1.5	742035	4619661	81
Tracker 065	Tracker	67	1.5	742039	4619472	77
Tracker 066	Tracker	67	1.5	742030	4619661	81
Tracker 067	Tracker	67	1.5	742034	4619472	77
Tracker 068	Tracker	67	1.5	741480	4619887	102
Tracker 069	Tracker	67	1.5	741689	4619879	94
Tracker 070	Tracker	67	1.5	741616	4619890	99
Tracker 071	Tracker	67	1.5	741611	4619890	99
Tracker 072	Tracker	67	1.5	741607	4619889	99
Tracker 073	Tracker	67	1.5	741602	4619889	99
Tracker 074	Tracker	67	1.5	741597	4619889	99
Tracker 075	Tracker	67	1.5	741592	4619889	100
Tracker 076	Tracker	67	1.5	741587	4619889	100
Tracker 077	Tracker	67	1.5	741582	4619889	100
Tracker 078	Tracker	67	1.5	741577	4619889	100
Tracker 079	Tracker	67	1.5	741573	4619889	100
Tracker 080	Tracker	67	1.5	741568	4619889	100
Tracker 081	Tracker	67	1.5	741563	4619888	100

Source ID	Equipment Type	Modeled Sound Power (dBA)	Relative Height (m)	Coordinates (UTM NAD83 Z18N)		
				X (m)	Y (m)	Z (m)
Tracker 082	Tracker	67	1.5	741558	4619888	100
Tracker 083	Tracker	67	1.5	741553	4619888	100
Tracker 084	Tracker	67	1.5	741548	4619888	100
Tracker 085	Tracker	67	1.5	741485	4619887	102
Tracker 086	Tracker	67	1.5	741490	4619887	102
Tracker 087	Tracker	67	1.5	741495	4619887	102
Tracker 088	Tracker	67	1.5	741500	4619887	102
Tracker 089	Tracker	67	1.5	741505	4619887	102
Tracker 090	Tracker	67	1.5	741509	4619887	102
Tracker 091	Tracker	67	1.5	741514	4619887	102
Tracker 092	Tracker	67	1.5	741519	4619887	101
Tracker 093	Tracker	67	1.5	741524	4619888	101
Tracker 094	Tracker	67	1.5	741529	4619888	101
Tracker 095	Tracker	67	1.5	741534	4619888	101
Tracker 096	Tracker	67	1.5	741539	4619888	101
Tracker 097	Tracker	67	1.5	741543	4619888	101
Tracker 098	Tracker	67	1.5	741675	4619881	95
Tracker 099	Tracker	67	1.5	741670	4619880	95
Tracker 100	Tracker	67	1.5	741665	4619880	95
Tracker 101	Tracker	67	1.5	741660	4619880	96
Tracker 102	Tracker	67	1.5	741655	4619880	96
Tracker 103	Tracker	67	1.5	741650	4619880	96
Tracker 104	Tracker	67	1.5	741646	4619880	96
Tracker 105	Tracker	67	1.5	741641	4619880	97
Tracker 106	Tracker	67	1.5	741636	4619880	97
Tracker 107	Tracker	67	1.5	741631	4619880	97
Tracker 108	Tracker	67	1.5	741626	4619879	98
Tracker 109	Tracker	67	1.5	741621	4619879	98
Tracker 110	Tracker	67	1.5	741684	4619881	94
Tracker 111	Tracker	67	1.5	741680	4619881	95
Tracker 112	Tracker	67	1.5	741694	4619875	94
Tracker 113	Tracker	67	1.5	741700	4619857	93
Tracker 114	Tracker	67	1.5	741704	4619857	92
Tracker 115	Tracker	67	1.5	741709	4619858	92
Tracker 116	Tracker	67	1.5	741714	4619858	92
Tracker 117	Tracker	67	1.5	741870	4619825	88

Source ID	Equipment Type	Modeled Sound Power (dBA)	Relative Height (m)	Coordinates (UTM NAD83 Z18N)		
				X (m)	Y (m)	Z (m)
Tracker 118	Tracker	67	1.5	741870	4619908	91
Tracker 119	Tracker	67	1.5	741875	4619825	88
Tracker 120	Tracker	67	1.5	741874	4619908	91
Tracker 121	Tracker	67	1.5	741879	4619825	88
Tracker 122	Tracker	67	1.5	741879	4619908	91
Tracker 123	Tracker	67	1.5	741884	4619826	88
Tracker 124	Tracker	67	1.5	741884	4619908	91
Tracker 125	Tracker	67	1.5	741889	4619826	88
Tracker 126	Tracker	67	1.5	741889	4619908	91
Tracker 127	Tracker	67	1.5	741894	4619826	88
Tracker 128	Tracker	67	1.5	741894	4619908	91
Tracker 129	Tracker	67	1.5	741899	4619826	88
Tracker 130	Tracker	67	1.5	741899	4619908	91
Tracker 131	Tracker	67	1.5	741904	4619826	87
Tracker 132	Tracker	67	1.5	741904	4619909	91
Tracker 133	Tracker	67	1.5	741908	4619909	91
Tracker 134	Tracker	67	1.5	741913	4619909	91
Tracker 135	Tracker	67	1.5	741918	4619909	91
Tracker 136	Tracker	67	1.5	741923	4619909	91
Tracker 137	Tracker	67	1.5	741928	4619909	91
Tracker 138	Tracker	67	1.5	741933	4619909	90
Tracker 139	Tracker	67	1.5	741938	4619909	90
Tracker 140	Tracker	67	1.5	741942	4619909	90
Tracker 141	Tracker	67	1.5	741947	4619910	90
Tracker 142	Tracker	67	1.5	741952	4619910	90
Tracker 143	Tracker	67	1.5	741957	4619910	89
Tracker 144	Tracker	67	1.5	741962	4619910	89
Tracker 145	Tracker	67	1.5	741966	4619929	89
Tracker 146	Tracker	67	1.5	741971	4619946	90
Tracker 147	Tracker	67	1.5	741976	4619946	90
Tracker 148	Tracker	67	1.5	741980	4619946	89
Tracker 149	Tracker	67	1.5	741985	4619946	89
Tracker 150	Tracker	67	1.5	741864	4619926	92
Tracker 151	Tracker	67	1.5	741859	4619926	92
Tracker 152	Tracker	67	1.5	741855	4619926	92
Tracker 153	Tracker	67	1.5	741850	4619926	93

Source ID	Equipment Type	Modeled Sound Power (dBA)	Relative Height (m)	Coordinates (UTM NAD83 Z18N)		
				X (m)	Y (m)	Z (m)
Tracker 154	Tracker	67	1.5	741845	4619926	93
Tracker 155	Tracker	67	1.5	741821	4619906	93
Tracker 156	Tracker	67	1.5	741826	4619906	92
Tracker 157	Tracker	67	1.5	741831	4619906	92
Tracker 158	Tracker	67	1.5	741836	4619906	92
Tracker 159	Tracker	67	1.5	741840	4619906	92
Transformer 1	Transformer	84	1.7	742041	4619688	82
Transformer 2	Transformer	84	1.7	741914	4619838	88

APPENDIX C. RECEIVER INFORMATION

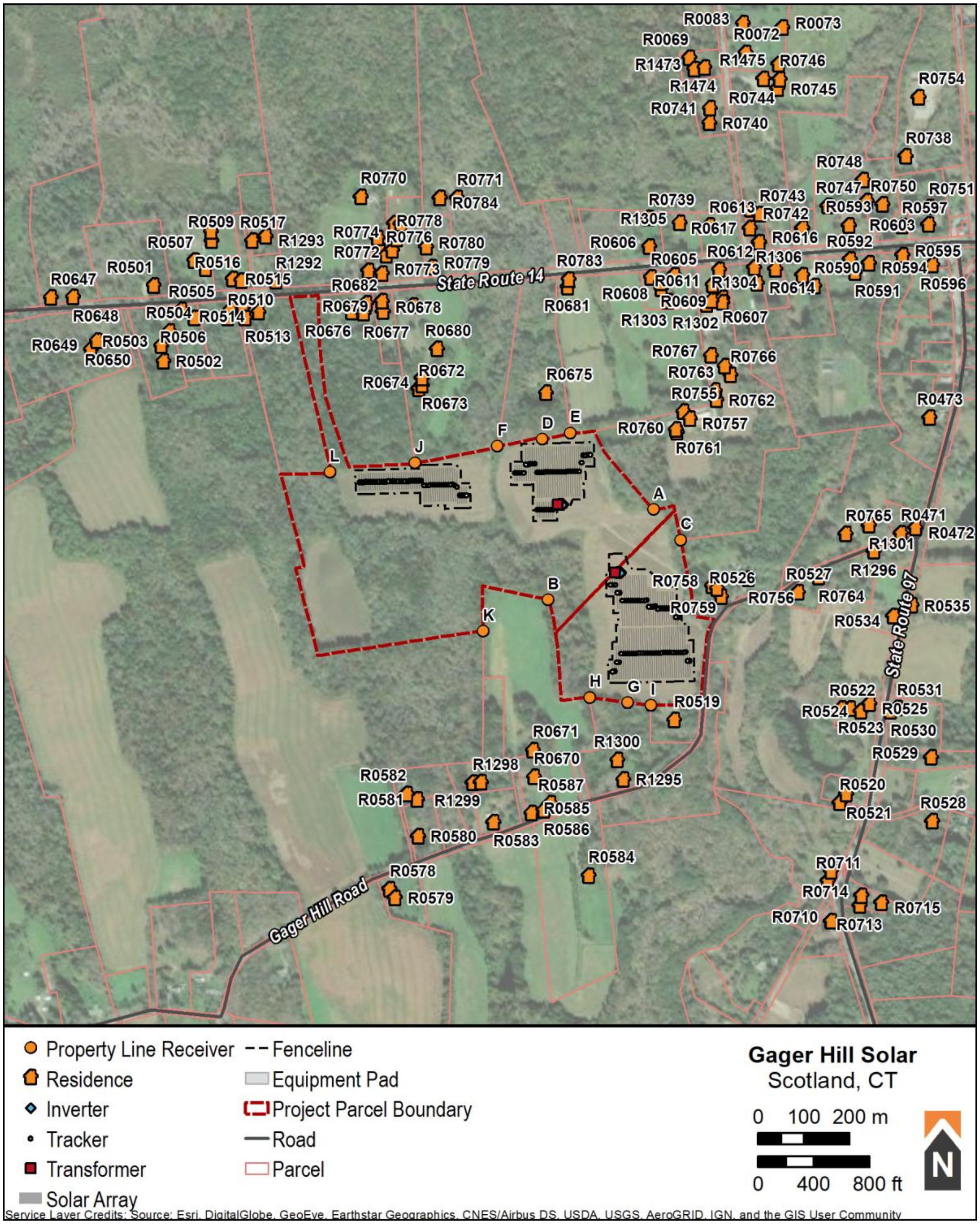

FIGURE 7: RECEIVER LOCATIONS

TABLE 5: DISCRETE RECEIVER MODELING RESULTS

Receiver ID	Sound Level (dBA)		Relative Height (m)	Coordinates (UTM NAD83 Z18N)		
	Daytime	Nighttime		X (m)	Y (m)	Z (m)
A	47	26	1.5	742124	4619826	81
B	47	25	1.5	741893	4619629	82
C	47	24	1.5	742184	4619760	78
D	45	23	1.5	741880	4619980	93
E	45	23	1.5	741942	4619994	93
F	41	20	1.5	741782	4619966	94
G	40	19	1.5	742068	4619404	76
H	40	19	1.5	741985	4619415	75
I	40	18	1.5	742118	4619397	77
J	39	18	1.5	741601	4619928	102
K	38	18	1.5	741750	4619560	87
L	31	11	1.5	741416	4619909	104
R0069	24	7	4	742203	4620816	108
R0072	24	7	4	742326	4620828	95
R0073	23	6	4	742407	4620883	94
R0083	23	6	4	742321	4620893	99
R0471	34	15	4	742666	4619775	82
R0472	34	15	4	742699	4619786	83
R0473	30	11	4	742729	4620029	81
R0501	18	5	4	741029	4620317	101
R0502	25	8	4	741050	4620151	111
R0503	24	7	4	741046	4620186	110
R0504	24	7	4	741064	4620217	110
R0505	25	7	4	741089	4620264	111
R0506	25	8	4	741118	4620246	114
R0507	24	7	4	741118	4620372	110
R0508	25	8	4	741143	4620355	111
R0509	24	7	4	741156	4620416	111
R0510	26	9	4	741192	4620246	116
R0511	26	9	4	741198	4620264	116
R0512	27	9	4	741224	4620269	116
R0513	27	9	4	741230	4620247	117
R0514	27	9	4	741259	4620260	116
R0515	26	8	4	741202	4620332	114
R0516	26	9	4	741221	4620328	114

Receiver ID	Sound Level (dBA)		Relative Height (m)	Coordinates (UTM NAD83 Z18N)		
	Daytime	Nighttime		X (m)	Y (m)	Z (m)
R0517	25	8	4	741245	4620415	112
R0518	24	7	4	741154	4620436	110
R0519	39	19	4	742169	4619366	79
R0520	32	12	4	742532	4619184	77
R0521	32	12	4	742547	4619203	77
R0522	34	14	4	742536	4619391	79
R0523	34	14	4	742554	4619390	79
R0524	33	13	4	742579	4619385	80
R0525	33	13	4	742597	4619401	80
R0526	43	22	4	742272	4619636	80
R0527	38	18	4	742441	4619646	80
R0528	26	8	4	742735	4619144	86
R0529	31	11	4	742732	4619284	88
R0530	33	13	4	742644	4619384	82
R0531	32	13	4	742658	4619391	83
R0534	34	14	4	742649	4619593	82
R0535	33	14	4	742690	4619617	82
R0578	30	11	4	741547	4618995	105
R0579	30	11	4	741558	4618976	105
R0580	29	11	4	741609	4619111	91
R0581	30	12	4	741606	4619192	88
R0582	32	12	4	741584	4619204	90
R0583	30	12	4	741773	4619142	87
R0584	33	13	4	741982	4619025	80
R0585	31	13	4	741856	4619162	82
R0586	34	14	4	741884	4619168	81
R0587	35	15	4	741898	4619183	81
R0590	29	11	4	742477	4620317	85
R0591	28	10	4	742566	4620347	84
R0592	29	10	4	742554	4620374	86
R0593	27	9	4	742552	4620450	87
R0594	27	9	4	742596	4620366	84
R0595	26	9	4	742669	4620384	83
R0596	29	9	4	742735	4620363	86
R0597	26	8	4	742668	4620448	84
R0603	27	9	4	742726	4620451	85

Receiver ID	Sound Level (dBA)		Relative Height (m)	Coordinates (UTM NAD83 Z18N)		
	Daytime	Nighttime		X (m)	Y (m)	Z (m)
R0605	33	14	4	742118	4620335	101
R0606	32	13	4	742115	4620403	102
R0607	31	13	4	742275	4620291	91
R0608	34	14	4	742141	4620310	99
R0609	33	14	4	742140	4620324	100
R0610	33	14	4	742170	4620340	99
R0611	31	13	4	742254	4620319	92
R0612	30	12	4	742268	4620352	92
R0613	29	11	4	742246	4620449	95
R0614	30	12	4	742351	4620323	88
R0615	29	11	4	742345	4620357	89
R0616	29	11	4	742356	4620413	89
R0617	28	11	4	742336	4620443	89
R0618	29	11	4	742391	4620354	88
R0647	22	5	4	740804	4620291	96
R0648	22	6	4	740852	4620292	99
R0649	23	6	4	740892	4620178	105
R0650	23	6	4	740905	4620197	105
R0670	35	15	4	741862	4619241	87
R0671	37	17	4	741860	4619300	91
R0672	38	18	4	741610	4620091	114
R0673	38	17	4	741617	4620100	114
R0674	37	17	4	741617	4620115	114
R0675	42	22	4	741889	4620082	101
R0676	30	12	4	741463	4620260	123
R0677	30	12	4	741488	4620257	124
R0678	34	14	4	741531	4620261	124
R0679	34	14	4	741529	4620283	125
R0680	37	17	4	741651	4620179	113
R0681	32	14	4	741936	4620314	103
R0682	30	12	4	741494	4620279	125
R0683	35	15	4	741597	4620274	122
R0710	29	9	4	742514	4618925	78
R0711	30	10	4	742506	4619012	77
R0712	30	11	4	742513	4619034	76
R0713	29	10	4	742576	4618959	83

Receiver ID	Sound Level (dBA)		Relative Height (m)	Coordinates (UTM NAD83 Z18N)		
	Daytime	Nighttime		X (m)	Y (m)	Z (m)
R0714	29	10	4	742580	4618981	82
R0715	29	9	4	742624	4618965	82
R0738	24	7	4	742677	4620600	87
R0739	29	11	4	742114	4620466	101
R0740	26	8	4	742247	4620674	98
R0741	26	8	4	742248	4620707	99
R0742	28	10	4	742337	4620485	90
R0743	28	10	4	742357	4620474	89
R0744	24	7	4	742365	4620770	92
R0745	24	7	4	742396	4620749	91
R0746	24	7	4	742401	4620770	92
R0747	27	9	4	742506	4620492	87
R0748	25	8	4	742583	4620549	83
R0749	26	8	4	742591	4620503	83
R0750	26	8	4	742626	4620495	82
R0751	25	7	4	742728	4620489	85
R0754	23	6	4	742705	4620731	89
R0755	40	20	4	742190	4620041	90
R0756	42	21	4	742331	4619675	78
R0757	41	20	4	742204	4620026	89
R0758	44	24	4	742252	4619660	80
R0759	44	23	4	742263	4619654	80
R0760	42	21	4	742176	4619996	89
R0761	42	21	4	742173	4620003	89
R0762	38	18	4	742262	4620067	88
R0763	38	18	4	742258	4620088	89
R0764	38	18	4	742486	4619679	81
R0765	36	17	4	742545	4619773	82
R0766	34	15	4	742293	4620122	87
R0767	36	16	4	742250	4620165	90
R0768	31	13	4	742275	4620281	91
R0769	34	15	4	742280	4620141	88
R0770	27	9	4	741483	4620512	118
R0771	28	10	4	741694	4620510	107
R0772	29	11	4	741500	4620350	124
R0773	29	11	4	741529	4620344	124

Receiver ID	Sound Level (dBA)		Relative Height (m)	Coordinates (UTM NAD83 Z18N)		
	Daytime	Nighttime		X (m)	Y (m)	Z (m)
R0774	29	11	4	741524	4620394	124
R0775	28	10	4	741520	4620422	122
R0776	29	11	4	741538	4620384	124
R0777	32	12	4	741552	4620395	123
R0778	31	12	4	741562	4620419	121
R0779	33	13	4	741638	4620358	115
R0780	32	13	4	741626	4620402	115
R0781	28	10	4	741557	4620454	119
R0782	29	10	4	741571	4620453	118
R0783	32	14	4	741938	4620331	103
R0784	28	10	4	741656	4620510	110
R1292	26	9	4	741297	4620327	116
R1293	25	8	4	741275	4620426	114
R1295	37	16	4	742058	4619235	75
R1296	36	16	4	742607	4619736	82
R1297	27	10	4	742450	4620444	88
R1298	31	13	4	741728	4619228	88
R1299	31	13	4	741746	4619230	89
R1300	38	17	4	742045	4619278	75
R1301	35	16	4	742596	4619793	82
R1302	32	14	4	742241	4620277	91
R1303	34	15	4	742156	4620283	98
R1304	31	13	4	742252	4620284	91
R1305	29	11	4	742181	4620455	98
R1306	29	11	4	742450	4620340	87
R1473	25	7	4	742214	4620792	104
R1474	25	7	4	742236	4620796	104
R1475	24	7	4	742398	4620802	92