thoroughbred solar

Attachment G

Noise Report

Exhibit 12 – Site Assessment Report

Haley and Aldrich, Inc.

THOROUGHBRED SOLAR SOUND MODELING STUDY

Report | October 7, 2022

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INTRODUCTION

The Thoroughbred Solar project (“Project”) is a photovoltaic power facility proposed in Hart County, Kentucky. The Project proposes a nameplate capacity of up to 50 MW. As part of the permitting for the Project, RSG has performed modeling of sound emissions from the primary proposed sound producing equipment, including inverters, trackers, and transformers. This report of the assessment includes:

- A Project description;
- A review of applicable sound level criteria;
- Operational sound propagation modeling procedures and results;
- Construction noise modeling results; and
- Conclusions.

A primer on acoustical terminology is included as Appendix A.

1.0 PROJECT DESCRIPTION

The Project is an up to 50 MW photovoltaic facility located in Hart County, Kentucky. The Project is bounded on the west by Interstate 65 (I-65), on the east by South Dixie Highway (U.S. Route 31W), on the north by Rowletts Cave Spring Road, and on the south by G. Wilson Lane. The Project area is primarily agricultural with rural residences and farmsteads. The unincorporated community of Rowletts adjoins the Project to the east. A total of 79 residential receptors located within the Project Area (within ¼ mile) are included in this report.

The primary operational sound sources include one 69 kV high-voltage substation transformer and 15 inverter skids. Each skid includes an inverter and a medium voltage transformer (“MVT”). Secondary operational sound sources include the solar tracking motors of which one has been placed in the center of each row of panel modules, resulting in a total of 1,654 tracking motors. Sound emissions from all of these sources are included in sound propagation modeling.

Typical operations of the Project would include transformers and inverters operating during the day with periodic operation of the solar tracker motors. Only transformers would typically operate at night; however, the inverters may operate sometimes at night for VAR support. Trackers would not operate at night.

A map of the Project Area and layout is shown in Figure 1.

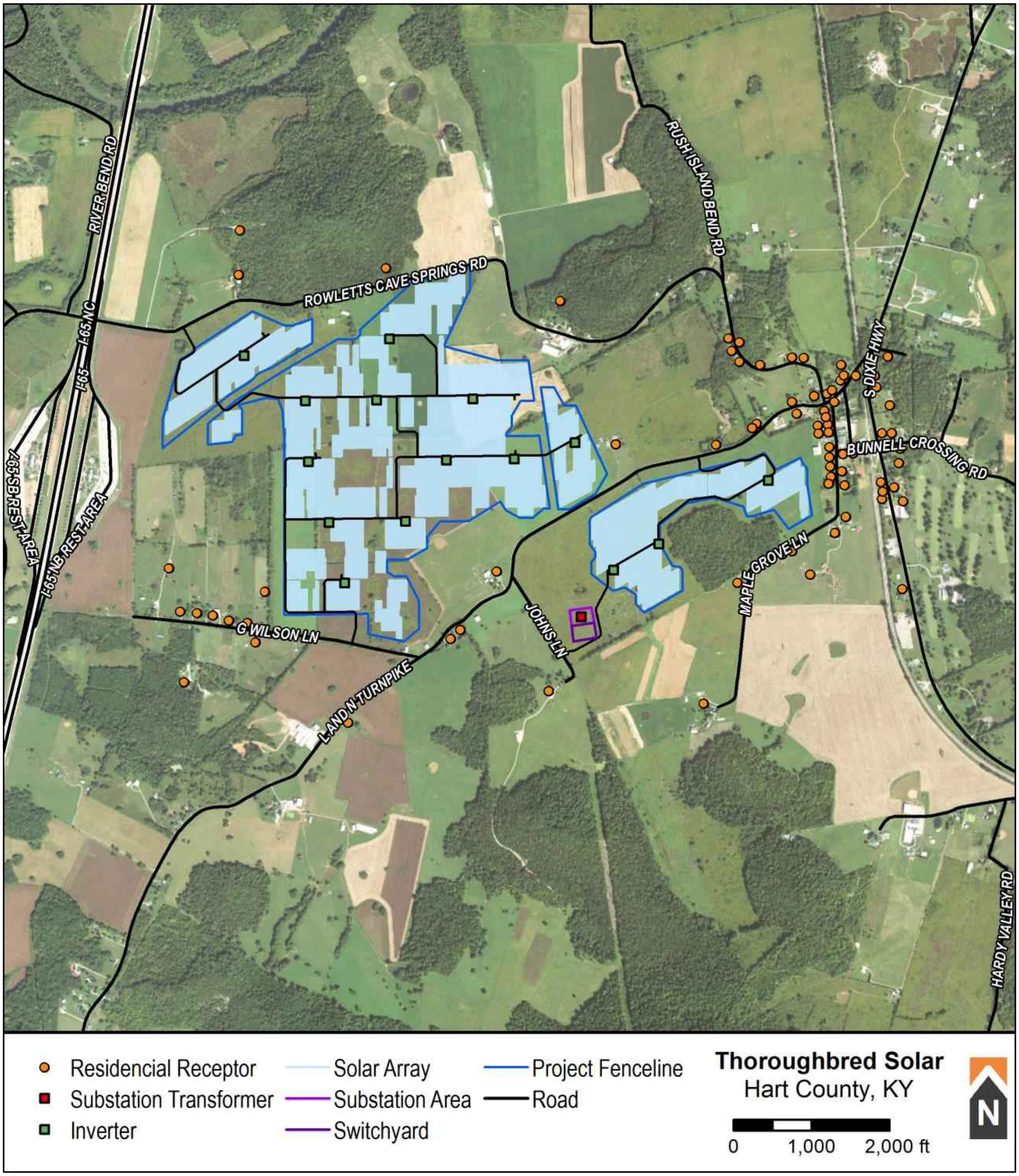

FIGURE 1: THOROUGHBRED SOLAR PROJECT AREA MAP

2.0 APPLICABLE SOUND LEVEL LIMITS

Neither Hart County, nor the Commonwealth of Kentucky have quantitative sound level limits applicable to this project. As a result, the project will develop design goals for comparison with Project sound emissions. The World Health Organization (WHO) has published sound level guidelines for community noise, which are discussed below. These guidelines are among the most comprehensive available and were developed as the culmination of an extensive literature review on the effects of sound on humans.

2.1 WORLD HEALTH ORGANIZATION GUIDELINES

The United Nation's World Health Organization (WHO) has published "Guidelines for Community Noise" (1999) which uses research on the health impacts of noise to develop guideline sound levels for communities. The foreword of the report states, "The scope of WHO's effort to derive guidelines for community noise is to consolidate actual scientific knowledge on the health impacts of community noise and to provide guidance to environmental health authorities and professionals trying to protect people from the harmful effects of noise in non-industrial environments."

Table 4.1 of the WHO's "Guidelines for Community Noise" (1999) provides guideline values for community noise in specific environments. The WHO guidelines suggest daytime and nighttime protective noise levels. During the day, the levels are 55 dBA L_{16h}[1], that is, an average over a 16-hour day, to protect against serious annoyance and 50 dBA L_{16h} to protect against moderate annoyance.

During the night, the WHO recommends limits of 45 dBA L_{8h}[2] and an instantaneous maximum of 60 dBA L_{Fmax} (fast response maximum). These are to be measured outside the bedroom window. These guidelines are based on the assumption that sound levels indoors would be reduced by 15 dBA with windows partially open. That is, the sound level inside the bedroom that is protective of sleep is 30 dBA L_{8h}. So long as the sound levels outside of the house remains at or below 45 dBA, sound levels in the bedroom will generally remain below 30 dBA. By closing windows, an additional 10 dB of sound attenuation will typically result, assuming standard residential construction. In addition to protection against annoyance, these guidelines are intended to protect against speech disturbance, sleep disturbance, and hearing impairment. Of these factors, protection against annoyance and sleep disturbance require the lowest limits.

The WHO long-term guideline to protect against hearing impairment is 70 dBA L_{24h} over a lifetime exposure, and higher for occupational or recreational exposure.

Since the WHO guidelines were developed to protect human health, all suggested limits apply to sound levels at residences or areas where humans typically frequent. For example, the

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[1] This is the equivalent average sound level, averaged over sixteen nighttime hours, measured outside the residence.

[2] This is the equivalent average sound level, averaged over eight nighttime hours, measured outside the bedroom window.

guidelines reflective of sleep disturbance are specified to be measured outside the bedroom window.

In October 2009, WHO Europe conducted an updated literature review and built upon WHO's guidelines for nighttime noise. They added an *annual average* nighttime guideline level to protect against adverse effects on sleep disturbance. This guideline is 40 dBA $L_{\text{night, outside}}$, measured outside the bedroom window.

Neither the 1999 nor 2009 guidelines were developed specifically for noise from solar power generation.

Based on the discussion above, we recommend a nighttime sound level design goal of 45 dBA L_{8h} at night and 50 dBA L_{16h} during the day, as assessed at residences. The 2009 guideline is tedious to measure in practice, so we do not recommend its adoption as a design threshold

3.0 SOUND PROPAGATION MODELING

3.1 PROCEDURES

Sound Propagation modeling for the project is being conducted in accordance with the international 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 algorithm takes into account source sound power levels, ground surface reflection and absorption, atmospheric absorption, geometric divergence, meteorological conditions, walls, barriers, berms, and terrain. The acoustical modeling software used to implement 9613-2 was CadnaA, 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.

For solar facilities, the ISO 9613-2 model is likely to overestimate sound levels. First, the barrier-effect of the solar panels in blocking sound from interior sources, especially inverters and medium-voltage transformers, is not taken into account in the modeling done for this Project. Second, sound emissions of solar equipment tend to be highest during sunny days. Under these conditions, the sound is refracted upwards, lowering the sound levels measured near the ground. Under the modeling assumptions used in this report, the meteorological conditions are always downward refracting, such as occurs during cloudy days with moderate downwind conditions or a well-developed moderate nighttime temperature inversion.

Model Inputs and Assumptions

The Project Area was modeled with partially hard and partially porous ground at the substation (G=0.6), hard ground (G=0) under the inverter pads, and porous ground (G=1.0) throughout the remainder of the study area. A temperature of 10 degrees Celsius with 70 percent relative humidity was used.

A total of 79 discrete receivers were placed at residences within ¼ mile of the Project at a height of 13 feet above ground level. In addition, modeling was done at every point in a 65-foot by 65-foot grid, with receivers placed at a height of 13 feet.

Modeled equipment includes the following:

- Array Inverter Skids – There are 15 inverter skids scattered throughout the Project. Each skid includes an inverter and a medium voltage transformer (MVT). These convert the DC electricity generated by the solar panels to low-voltage AC power to medium-voltage AC power for transmission to the substation. The Project proposes a to use the Sungrow SG3600UD inverter skid, which is specified to produce a sound power level of 96 dBA. The inverters have fans whose speed is a function of temperature and load. For the modeling in this report, the fans are assumed to operate at 100 percent during all daytime and nighttime hours.
- Substation Transformer – There will be one 69 kV substation transformer, which steps up the medium voltage AC power to the high voltage of the transmission line. Sound emissions were calculated from sound power levels given in a test report for the unit and spectra from RSG measurements of similar-size transformers. To account for uncertainty in the test report, 3 dB was added to the test report results. The substation transformer is modeled with a sound power of 96 dBA with cooling fans on and 82 dBA with cooling fans off, including the 3 dB uncertainty factor. The fans will typically operate only during daylight.
- Tracking Motors – Tracking motors, which tilt the solar panels to follow the sun, are a secondary operational sound source. One tracking motor is assumed to be located on each row of panel modules, resulting in a total of 1,654 tracking motors. Trackers only operate for a few seconds every 10 minutes during daylight, so the model accounts for the trackers operating 4.8 minutes per hour or 8.3% of the time resulting in L_{eq} levels that are about 11 dB lower than the maximum sound level during operation. These have a sound power level of 70 dBA L_{eq}.

All equipment were modeled at the manufacturer's published maximum broadband sound power levels. Sound sources were modeled as point sources with the substation transformer modeled at a height of 9.8 feet, the inverters at a height of 8.2 feet, and the trackers at a height of 4.9 feet.

Results calculated with these parameters are used to model the average sound level during the following scenarios:

1) Daytime – This assumes the Project is generating its nameplate capacity. All equipment is producing maximum sound emissions and transformer cooling fans are operating.
2) Nighttime – This assumes that the Project is not producing any energy. Inverters are operating for VAR control, but tracking motors are not operating. Transformers are energized, but the substation transformer cooling fans are off.

The sources operating under each scenario are shown in Table 1. The highest sound levels occur during the daytime scenario, as all equipment would be operating at their maximum sound output at the same time.

TABLE 1: EQUIPMENT OPERATION SCENARIOS

Sound Source	Modeled Sound Power Level	Operation Scenario	
		Daytime	Nighttime
Inverter Skids (Inverters & MVT)	96	y	y
Tracking Motors	70	y	n
Substation Transformer with Fans (ONAF)	95	y	n
Substation Transformer without Fans (ONAN)	82	n	y

Model input parameters are listed in Appendix B including the modeled sound power spectra for each source.

3.2 MODELING RESULTS

A summary of the sound propagation model results is provided in Table 2, and Appendix C provides a list of the calculated overall sound pressure levels at each discrete receiver. As shown in Table 2, all residences are projected at 41 dBA or less during the daytime and nighttime, which is below the nighttime Project daytime and nighttime design thresholds of 45 L_{8h} and 50 dBA L_{16h}, respectively.

TABLE 2: SUMMARY OF MODELED SOUND PRESSURE LEVELS (dBA)

Receptor Type	Daytime Sound Level – L_{eq} (dBA)			Nighttime Sound Level – L_{eq} (dBA)		
	Min.	Max.	Avg.	Min.	Max.	Avg.
Residences	26	41	32	24	41	31

The highest sound level of 41 dBA during the day and at night would be experienced at Receptor R55. This residence is located in the central portion of the Project area and is about 525 feet from the nearest inverter. The modeled sound level at Receptor R55 is due primarily to the adjacent inverter. Sound levels at this location are lower at night without operation of the trackers but the difference is less than 1 dB. The closest receptor to the Project substation (R77) is modeled to have a daytime sound level of 36 dBA with the operation of the transformer cooling fans and a nighttime sound level of 33 dBA without the cooling fans. A map of projected sound levels throughout the Project Area is provided in Figure 2 for the daytime scenario and Figure 3 for the nighttime scenario.

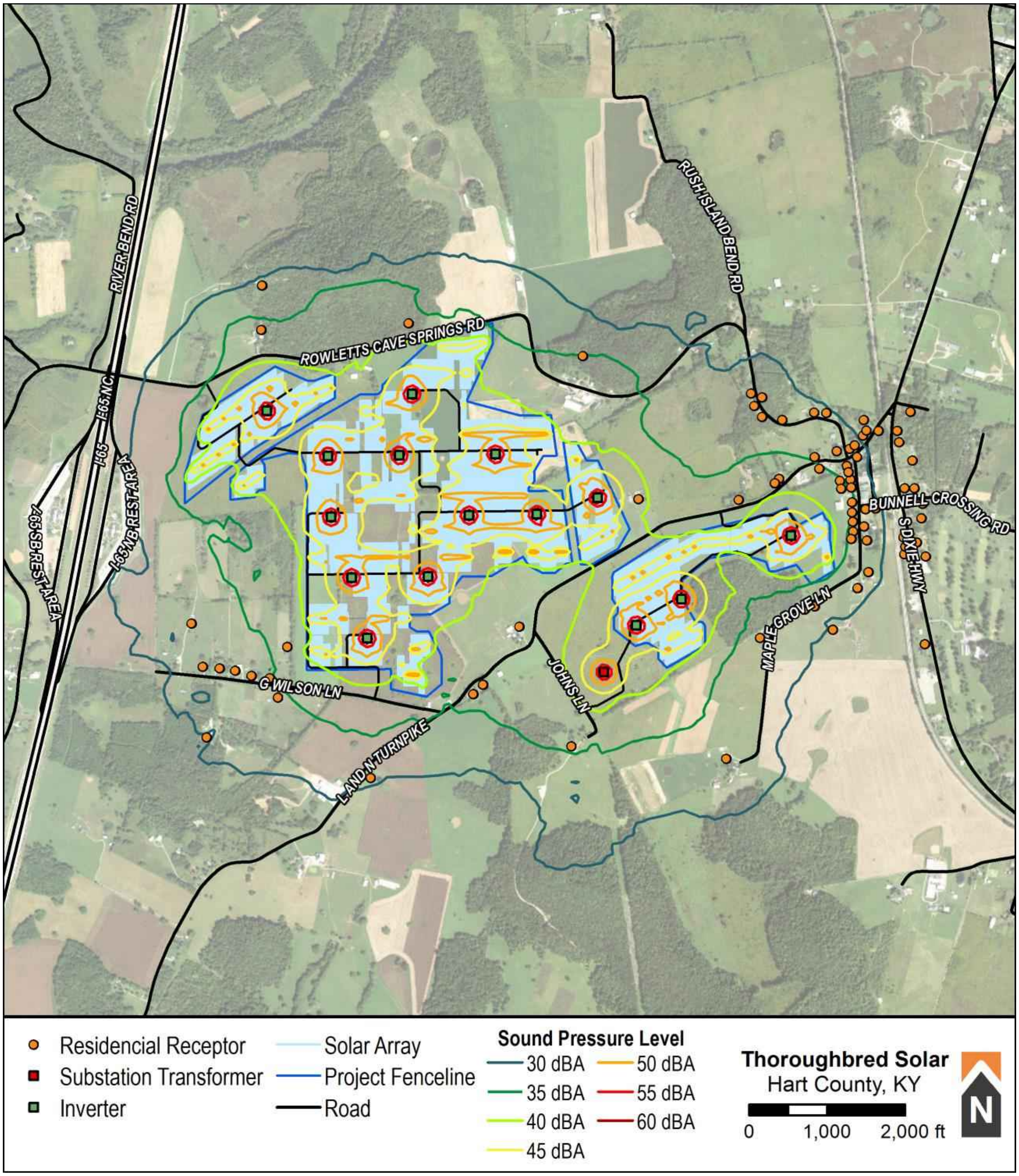

FIGURE 2: SOUND PROPAGATION MODELING RESULTS – DAYTIME SCENARIO

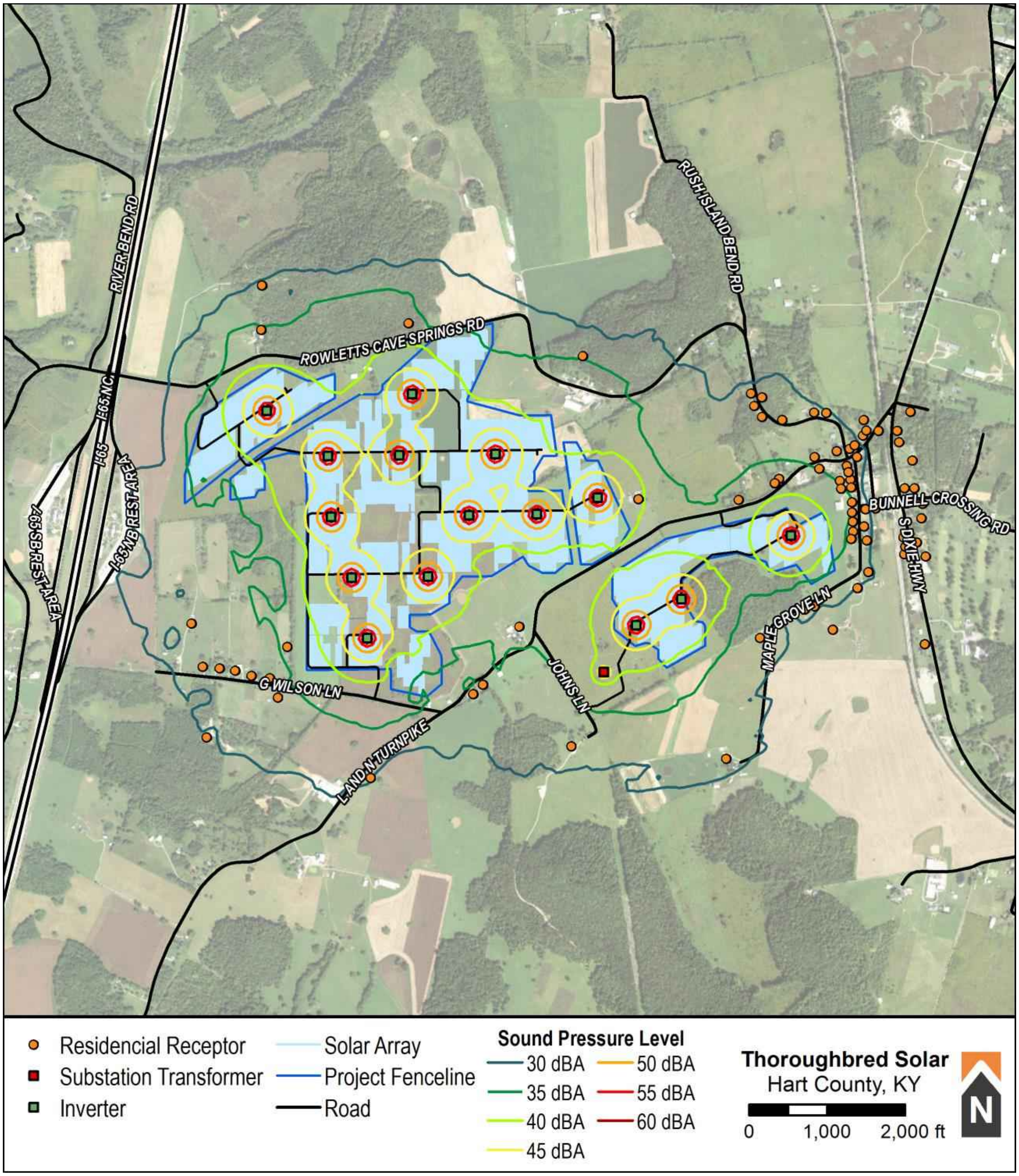

FIGURE 3: SOUND PROPAGATION MODELING RESULTS – NIGHTTIME SCENARIO

4.0 CONSTRUCTION NOISE

Construction activities are anticipated to include road construction, substation construction, trenching, inverter installation, piling and racking. Construction will be relatively short in duration at any specific location, particularly for road construction, trenching, piling, and racking. Construction of substations typically lasts longer than these other activities. Road construction would take place within and adjacent to the solar arrays. Trenching would take place along the underground collection line routes. Inverter installation would take place at each inverter pad location. Piling and racking will take place throughout the solar arrays and will tend to move relatively quickly throughout the array. Total construction is expected to be 12 months. Louder construction activity such as drilling and piling will be restricted to daytime hours.

Equipment used for each activity will vary. Representative pieces of equipment[3] are shown in Table 3 along with the approximate maximum average sound pressure levels at 50 feet and 280 feet, the closest distance between a residence and a solar array where racking and piling will take place. Table 4 shows worst-case cumulative sound pressure levels under each phase of construction, assuming all construction equipment for that phase were to operate simultaneously at the distance indicated.

TABLE 3: SOUND LEVELS FROM CONSTRUCTION EQUIPMENT

Equipment	Sound Pressure Level at 50 feet (dBA)	Sound Pressure Level at 280 feet (dBA)[4]
Excavator	76	61
Dozer	80	65
Grader	78	63
Roller	82	67
Dump Truck	82	67
Concrete Mixing Truck	81	66
Concrete Pumper Truck	84	69
Man-lift	72	57
Flatbed Truck	74	59
Crane	74	59
Trencher	83	68
Plate Compactor	75	60
Forklift	88	73
Boom Truck	88	73
Small Pile Driver	84	69
HDD	87	72
Skid Steer	79	64

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[3] Sound source information, where available, was obtained from Project 25-49 Data, National Cooperative Highway Research Program, October 2018. For the pile driving equipment, noise data for a representative solar array post driver was used.

[4] Assumes hard ground around construction site, and no vegetation. Actual sound levels will likely be lower given the prevalence of vegetation and soft ground around the site.

Equipment	Sound Pressure Level at 50 feet (dBA)	Sound Pressure Level at 280 feet (dBA)[4]
Diesel Generator	67	52
Rock Drill	92	77

TABLE 4: SOUND LEVELS FROM CONSTRUCTION BY PHASE

Construction Phase	Equipment	Sound Pressure Level at 50 feet (dBA)	Sound Pressure Level at 280 feet (dBA)[5]
Road Construction	Excavator, Dozer, Grader, Roller, Dump Truck	87	72
Substation Construction	Excavator, Dozer, Grader, Roller, Dump Truck, Concrete Mixing Truck, Concrete Pumper Truck, Man-lift, Flatbed Truck, Crane (2)	90	75
Trenching	Excavator, Dozer, Trencher, Roller, Compactor, Flatbed Truck, Forklift,	91	76
Inverter Construction	Excavator, Dozer, Grader, Roller, Dump Truck, Concrete Mixing Truck, Concrete Pumping Truck	90	75
Piling	Flatbed Truck, Boom Truck, Pile Driver	90	75
Racking	Flatbed Truck (2), Forklift (2)	91	76
Laydown Area	Forklift (2), Skid Steer (2), Flatbed Truck, Diesel Generator	89	74
Boring	Horizontal Bore Drill, Excavator	87	72
Rock Drilling	Rock Drill	92	77

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[5] Assumes hard ground around construction site, and no vegetation reduction. Actual sound levels will likely be lower given the prevalence of vegetation and soft ground around the site.

5.0 CONCLUSIONS

The Thoroughbred Solar power project (“Project”) is a 50 Megawatt (MW) solar power project, proposed in Hart County, Kentucky. As part of the permitting for the project, RSG has performed modeling of sound emissions from the primary sound producing equipment proposed for the Project, including inverters, trackers, and transformers. Sound propagation modeling was performed in accordance with ISO 9613-2 at 79 receptors throughout the Project Area. Both Daytime and Nighttime scenarios were modeled.

There are currently no quantitative sound level limits that are applicable to the Project. As a result, we have developed Project design goals based on World Health Organization (WHO) guidelines. These design goals are 50 dBA L_{16h} during the daytime and 45 dBA L_{8h} at night.

Our conclusions are as follows:

- Modeled sound levels at the worst-case residence are 41 dBA for both the daytime and nighttime scenarios.
- Modeled sound levels were at least 4 to 9 dB below design goal sound level thresholds at all homes surrounding the Project.
- Construction is expected to take place over approximately 12 months. Some construction activities such as inverter and substation construction will take longer, but will be relatively far from residences (at least 490 feet). Other activities such as panel installation and clearing will be shorter duration at each location but closer to residences (as close as 280 feet).

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").[6] 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 4.

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.

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[6] 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.

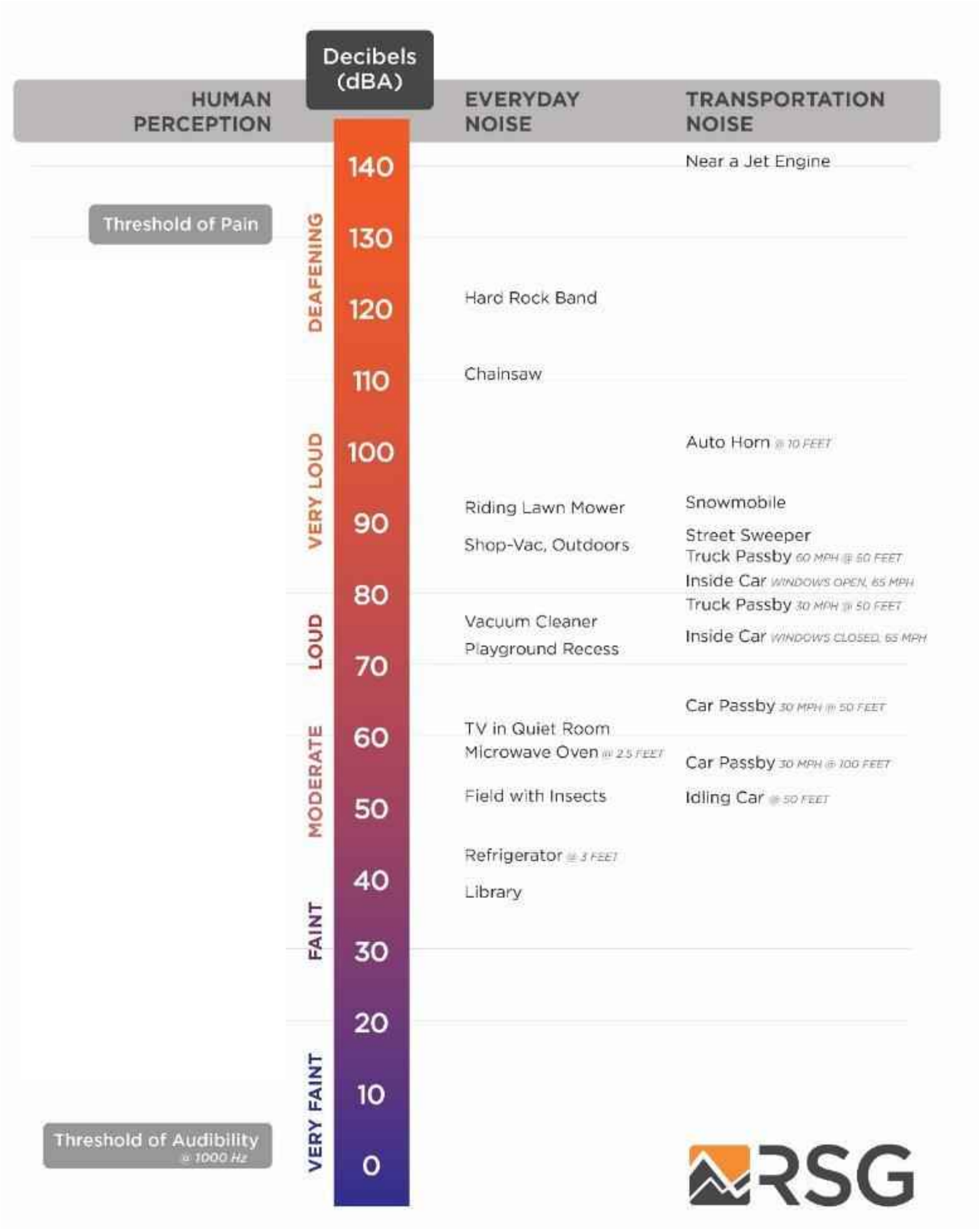

FIGURE 4: A SCALE OF SOUND PRESSURE LEVELS FOR TYPICAL SOUND SOURCES

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.[7] 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_{EQmax}.

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 5. 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 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 5, 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.

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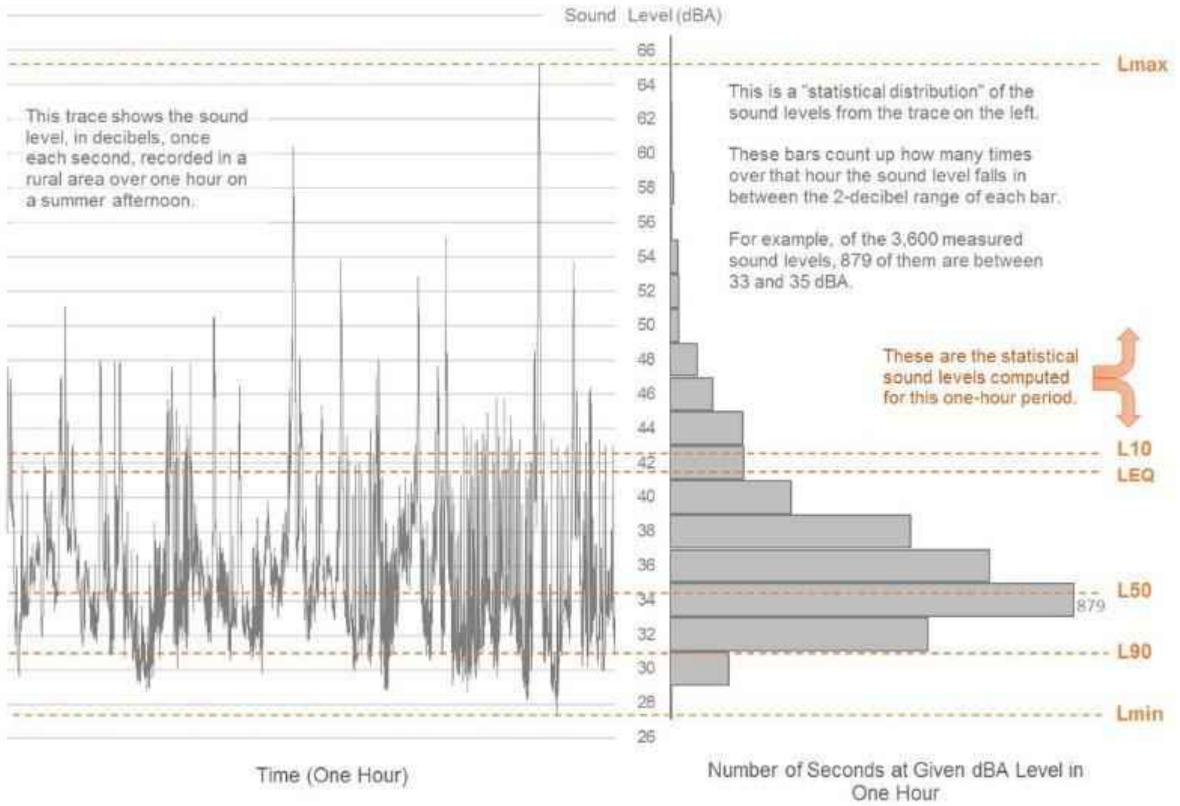
[7] There is a third time response defined by standards, the “Impulse” response. This response was defined to enable use of older, analog meters when measuring very brief sounds; it is no longer in common use.



This trace shows the sound level, in decibels, once each second, recorded in a rural area over one hour on a summer afternoon.

This is a "statistical distribution" of the sound levels from the trace on the left.

These bars count up how many times over that hour the sound level falls in between the 2-decibel range of each bar.

For example, of the 3,600 measured sound levels, 879 of them are between 33 and 35 dBA.

These are the statistical sound levels computed for this one-hour period.

FIGURE 5: 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 often a good representation of the "ambient sound" in an area. This 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. MODELING INFORMATION

TABLE 5: SOUND PROPAGATION MODELING PARAMETERS

Parameter	Setting
Ground Absorption	Spectral for all sources, porous ground (G=1), mostly porous ground (G=0.6) for substations, hard ground (G=0) for inverter pads
Atmospheric Absorption	Based on 10 Degrees Celsius, 70% Relative Humidity
Reflections	None
Receiver Height	13.2 feet for residences and grid
Search Distance	5 miles

TABLE 6: MODELED SOUND POWER SPECTRA, dBZ UNLESS OTHERWISE NOTED

Source	1/1 Octave Band Sound Power (dBZ)									Sum (dBA)	Sum (dBZ)	Reference
	31.5 Hz	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz			
Substation Transformer ONAF[8]	102	100	101	94	93	89	82	80	76	95	106	Custom 69 kV MPT test report & RSG measured representative spectrum
Substation Transformer ONAN[7]	92	86	91	82	79	74	69	70	66	56	82	Custom 69 kV MPT test report & RSG measured representative spectrum
Inverter Skid	90	91	93	92	97	89	87	83	80	96	101	Sungrow SG3600UD Test Report
Tracker					73					70	73	Calculated based on test report

TABLE 7: SOURCE INPUT DATA

Source	Modeled Sound Power Level (dBA)		Relative Height (ft)	Latitude	Longitude	Absolute Elevation (ft)
	Day	Night				
Sub Transformer	94.6	81.7	9.8	37.233259	-85.905500	611
Inverter Skid	96.1	96.1	8.2	37.242597	-85.920228	588
Inverter Skid	96.1	96.1	8.2	37.240976	-85.917563	589
Inverter Skid	96.1	96.1	8.2	37.240981	-85.914413	606
Inverter Skid	96.1	96.1	8.2	37.240986	-85.910177	608
Inverter Skid	96.1	96.1	8.2	37.238841	-85.911367	600
Inverter Skid	96.1	96.1	8.2	37.238845	-85.908381	628
Inverter Skid	96.1	96.1	8.2	37.238832	-85.917450	586

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[8] ONAN – Oil Natural Air Natural (Fans off), ONAF – Oil Natural Air Forced (Fans On)

Source	Modeled Sound Power Level (dBA)		Relative Height (ft)	Latitude	Longitude	Absolute Elevation (ft)
	Day	Night				
Inverter Skid	96.1	96.1	8.2	37.236694	-85.913209	601
Inverter Skid	96.1	96.1	8.2	37.234546	-85.915920	612
Inverter Skid	96.1	96.1	8.2	37.234897	-85.904060	613
Inverter Skid	96.1	96.1	8.2	37.235801	-85.902053	641
Inverter Skid	96.1	96.1	8.2	37.237993	-85.897186	659
Inverter Skid	96.1	96.1	8.2	37.239398	-85.905686	624
Inverter Skid	96.1	96.1	8.2	37.236689	-85.916576	595
Inverter Skid	96.1	96.1	8.2	37.243126	-85.913821	605
Inverter Skid	96.1	96.1	8.2	37.233259	-85.905500	611
Inverter Skid	96.1	96.1	8.2	37.242597	-85.920228	588
Inverter Skid	96.1	96.1	8.2	37.240976	-85.917563	589
Inverter Skid	96.1	96.1	8.2	37.240981	-85.914413	606
Inverter Skid	96.1	96.1	8.2	37.240986	-85.910177	608
Inverter Skid	96.1	96.1	8.2	37.238841	-85.911367	600
Inverter Skid	96.1	96.1	8.2	37.238845	-85.908381	628
Inverter Skid	96.1	96.1	8.2	37.238832	-85.917450	586
Inverter Skid	96.1	96.1	8.2	37.236694	-85.913209	601
Inverter Skid	96.1	96.1	8.2	37.234546	-85.915920	612
Inverter Skid	96.1	96.1	8.2	37.234897	-85.904060	613
Inverter Skid	96.1	96.1	8.2	37.235801	-85.902053	641
Inverter Skid	96.1	96.1	8.2	37.237993	-85.897186	659
Inverter Skid	96.1	96.1	8.2	37.239398	-85.905686	624
Inverter Skid	96.1	96.1	8.2	37.236689	-85.916576	595
Inverter Skid	96.1	96.1	8.2	37.243126	-85.913821	605
Trackers[9]	72.8	0	5			

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[9] This is a representative tracker. There are 1,654 trackers assumed for this analysis.

APPENDIX C. RECEIVER INFORMATION

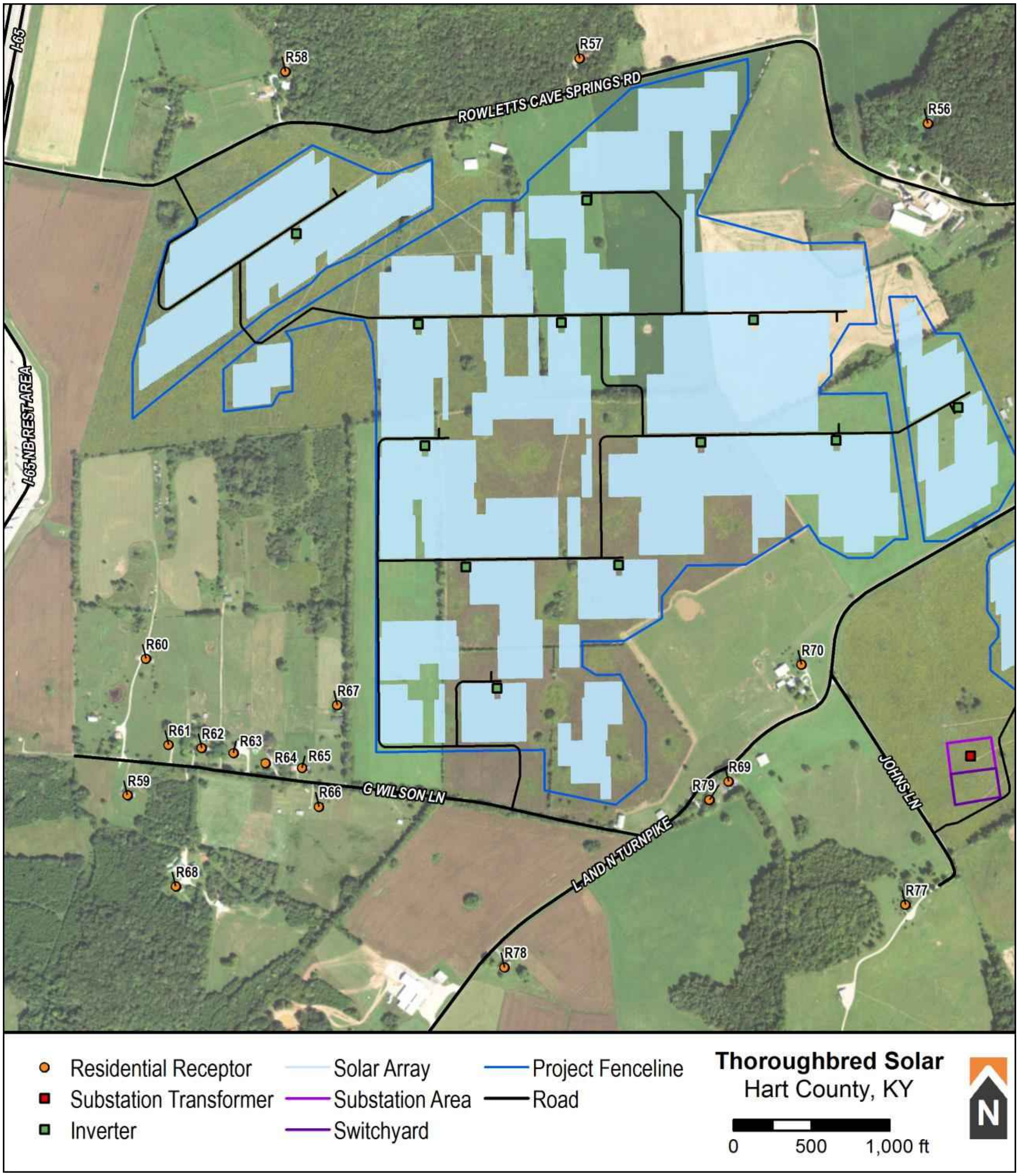

FIGURE 6 : RECEIVER LOCATIONS – WESTERN PROJECT AREA

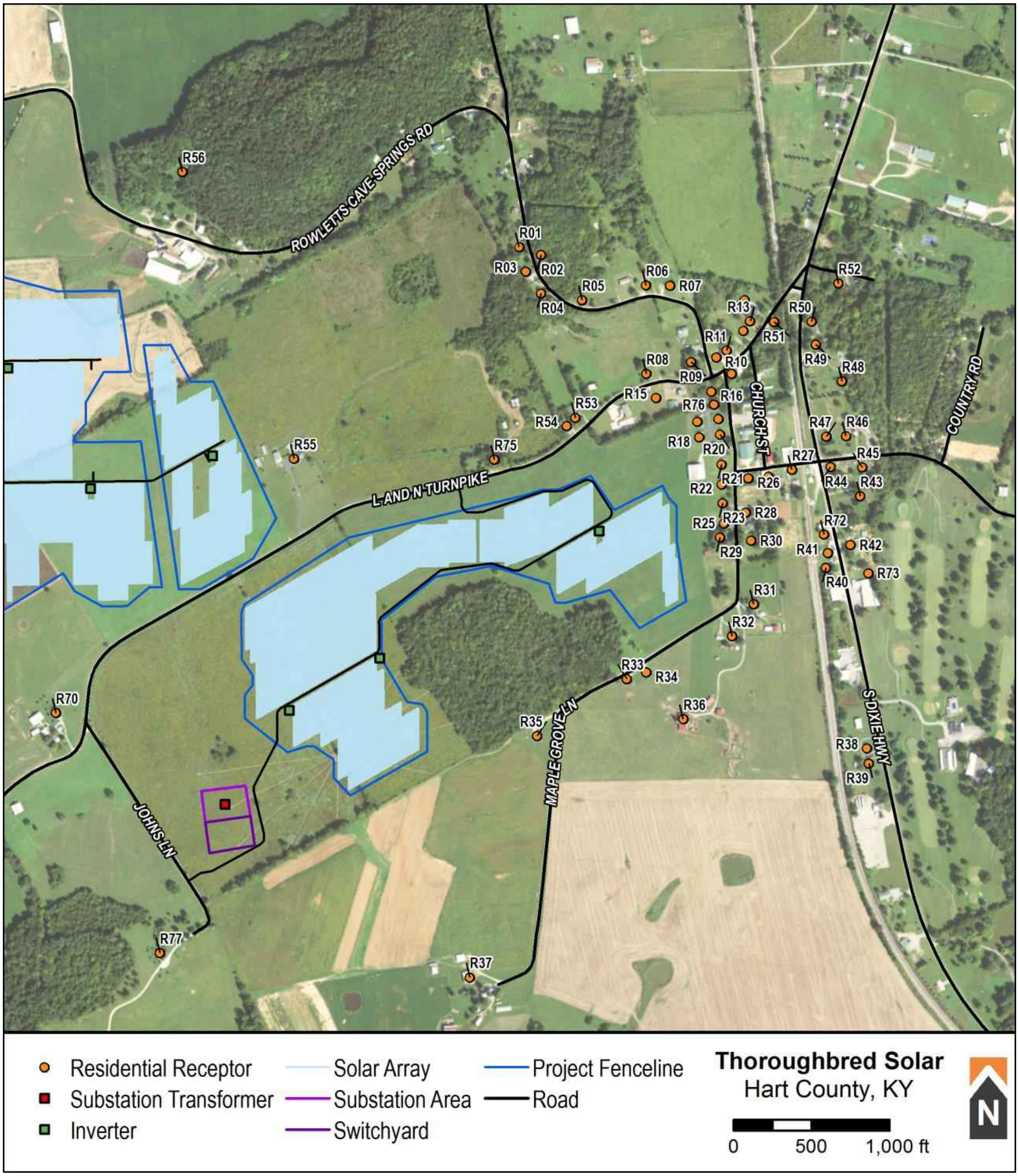

FIGURE 7: RECEIVER LOCATIONS – EASTERN PROJECT AREA

TABLE 8: DISCRETE SOUND PROPAGATION MODELING RESULTS

Receiver ID	Land Use	Sound Pressure Level (dBA)		Relative Height (ft)	Coordinates (Decimal Degrees)		Absolute Elevation (ft)
		Day	Night		Latitude	Longitude	
R01	Residence	32	32	13	37.24302	-85.89888	703
R02	Residence	32	31	13	37.24287	-85.89839	718
R03	Residence	33	32	13	37.24258	-85.89874	702
R04	Residence	33	33	13	37.24219	-85.89840	707
R05	Residence	33	33	13	37.24207	-85.89750	727
R06	Residence	31	31	13	37.24232	-85.89609	731
R07	Residence	31	30	13	37.24230	-85.89556	726
R08	Residence	35	34	13	37.24076	-85.89610	684
R09	Residence	33	33	13	37.24096	-85.89512	696
R10	Residence	32	32	13	37.24103	-85.89456	697
R11	Residence	32	31	13	37.24115	-85.89433	695
R12	Residence	28	27	13	37.24149	-85.89396	689
R13	Residence	28	27	13	37.24166	-85.89380	687
R14	Residence	28	26	13	37.24204	-85.89393	686
R15	Residence	35	35	13	37.24033	-85.89590	675
R16	Residence	34	33	13	37.24043	-85.89468	685
R17	Residence	35	35	13	37.23990	-85.89499	677
R18	Residence	36	35	13	37.23963	-85.89496	677
R19	Residence	34	34	13	37.23994	-85.89453	676
R20	Residence	35	34	13	37.23967	-85.89450	675
R21	Residence	36	35	13	37.23915	-85.89447	675
R22	Residence	35	34	13	37.23879	-85.89448	671
R23	Residence	33	32	13	37.23846	-85.89445	666
R24	Residence	32	32	13	37.24074	-85.89423	687
R25	Residence	33	32	13	37.23811	-85.89443	663
R26	Residence	31	30	13	37.23889	-85.89388	660
R27	Residence	29	28	13	37.23904	-85.89292	651
R28	Residence	32	31	13	37.23829	-85.89395	657
R29	Residence	34	32	13	37.23786	-85.89452	661
R30	Residence	32	30	13	37.23780	-85.89383	655
R31	Residence	32	31	13	37.23668	-85.89380	653
R32	Residence	31	30	13	37.23612	-85.89428	655
R33	Residence	32	31	13	37.23538	-85.89661	669
R34	Residence	32	31	13	37.23550	-85.89618	664
R35	Residence	33	32	13	37.23440	-85.89861	658
R36	Residence	30	29	13	37.23466	-85.89538	646
R37	Residence	32	31	13	37.23016	-85.90015	657
R38	Residence	26	24	13	37.23411	-85.89134	633
R39	Residence	26	24	13	37.23384	-85.89130	634

Receiver ID	Land Use	Sound Pressure Level (dBA)		Relative Height (ft)	Coordinates (Decimal Degrees)		Absolute Elevation (ft)
		Day	Night		Latitude	Longitude	
R40	Residence	28	27	13	37.23730	-85.89219	645
R41	Residence	28	27	13	37.23756	-85.89215	645
R42	Residence	28	26	13	37.23770	-85.89164	650
R43	Residence	27	26	13	37.23856	-85.89142	665
R44	Residence	28	27	13	37.23908	-85.89207	653
R45	Residence	27	26	13	37.23907	-85.89137	671
R46	Residence	27	26	13	37.23962	-85.89172	676
R47	Residence	28	27	13	37.23961	-85.89215	661
R48	Residence	29	29	13	37.24059	-85.89180	691
R49	Residence	27	26	13	37.24124	-85.89236	682
R50	Residence	27	26	13	37.24164	-85.89245	682
R51	Residence	27	26	13	37.24164	-85.89327	676
R52	Residence	26	24	13	37.24231	-85.89185	682
R53	Residence	38	37	13	37.24000	-85.89768	667
R54	Residence	38	38	13	37.23985	-85.89787	659
R55	Residence	41	41	13	37.23934	-85.90389	631
R56	Residence	35	35	13	37.24441	-85.90628	701
R57	Residence	38	38	13	37.24563	-85.91394	676
R58	Residence	36	35	13	37.24546	-85.92043	641
R59	Residence	31	30	13	37.23274	-85.92409	599
R60	Residence	33	32	13	37.23514	-85.92365	612
R61	Residence	32	32	13	37.23362	-85.92317	595
R62	Residence	33	32	13	37.23355	-85.92244	586
R63	Residence	33	32	13	37.23346	-85.92175	584
R64	Residence	34	33	13	37.23328	-85.92104	583
R65	Residence	35	34	13	37.23319	-85.92024	586
R66	Residence	34	34	13	37.23250	-85.91987	593
R67	Residence	37	36	13	37.23428	-85.91944	580
R68	Residence	29	28	13	37.23112	-85.92305	627
R69	Residence	36	35	13	37.23286	-85.91084	630
R70	Residence	37	35	13	37.23490	-85.90920	619
R71	Residence	30	29	13	37.23892	-85.89344	654
R72	Residence	28	27	13	37.23789	-85.89223	648
R73	Residence	27	26	13	37.23720	-85.89127	651
R74	Residence	33	32	13	37.24702	-85.92037	698
R75	Residence	37	36	13	37.23928	-85.89948	632
R76	Residence	34	33	13	37.24020	-85.89462	680
R77	Residence	36	33	13	37.23066	-85.90697	677
R78	Residence	31	30	13	37.22963032	-85.9158266	637
R79	Residence	36	35	13	37.2325439	-85.91127024	637