Song Sparrow Solar LLC
Acoustic Assessment

Stantec

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September 1, 2023

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Abbreviations

AC	alternating current
dB	decibel
dB(Z) or dBZ	decibel (unweighted)
dB(A) or dBA	decibel (A-weighted)
dB(C) or dBC	decibel (C-weighted)
DC	direct current
Hz	hertz
L_{eq}	equivalent continuous sound level
L_{max}	maximum sound level
MW	megawatt
Project	Song Sparrow Solar Project
PV	photovoltaic

1.0 Project Description

Song Sparrow Solar LLC, is proposing to construct and operate the Song Sparrow Solar Project (Project) located near the intersection of Gage and Davis Roads approximately 4 miles south of Kevil in Ballard County, Kentucky. The Project location and vicinity is shown on Figure 1. The Project footprint encompasses approximately 655 acres of undeveloped, agricultural land with surrounding rural low density residential development intermixed with forested land (Project area). The generating capacity of the Project will be up to 104 megawatts (MW) alternating current (AC).

Arrays of photovoltaic modules will be mounted on single access trackers arranged in rows. Power conversion systems will be distributed throughout the Project area, comprised of one distribution transformer and a series of power inverters. The equipment will connect via underground electrical wiring to a Project substation and switchyard proposing to interconnect to the existing Grahamville-to-Wickliffe 161kV transmission line located in the southwest corner of the Project area north of Mosstown Road.

Song Sparrow Solar LLC retained the services of Stantec Consulting Services Inc. (Stantec) to conduct an acoustic assessment to evaluate the sound contribution of the Project to the surrounding noise sensitive receptors. An acoustic modeling analysis using CadnaA and RCNM was conducted simulating sound produced during both construction and operation. Operational sound sources consisted primarily of the inverters, distribution transformers, and the main power transformer at the onsite Project substation. The overall objectives of this assessment were to identify Project sound sources and estimate sound propagation characteristics and computer-simulate sound levels using internationally accepted calculation standards.

The main sources of sound emissions from the Project operations will be the solar inverter stations and a substation transformer located in the Project substation. Solar panels produce direct current (DC) voltage which must be converted to alternating current (AC) voltage through a series of inverters. Solar energy facilities operate by converting solar radiation into electricity, meaning the Project will only produce electricity between sunrise and sunset. After sunset, the site no longer receives solar radiation, and the inverters will shift into stand-by mode.

Approximately 27 inverters will be installed in the Project area for the proposed 104-MW Project. The analysis assumed the sound power level of each inverter at full load is 94 decibels, A-weighted (dBA). One main power transformer will be installed in the Project substation. The analysis assumed the sound power level of the substation transformer is 101 dBA.

The loudest sound emissions during construction activities will be impact pile driving. The impact pile driving equipment used to install the solar array posts would generate sound levels of approximately 84 dBA at 50 feet, depending on type and brand. The analysis assumed up to three pile drivers would be operating simultaneously within a solar array. Construction activities are expected to be limited to daytime hours.

2.0 Sound Terminology

Sound is caused by vibrations that generate waves of minute pressure fluctuations in the surrounding air. Sound levels are measured using a logarithmic decibel (dB) scale. Human hearing varies in sensitivity for different sound frequencies, and the frequency sensitivity changes based on the overall sound level. The ear is most sensitive to sound at frequencies between 800 and 8,000 hertz (Hz) and is least sensitive to sound at frequencies below 400 Hz or above 12,500 Hz. Consequently, several different frequency weighting schemes have been used to approximate the way the human ear responds to various frequencies at different sound levels. The A-weighted decibel, or dBA, scale is the most widely used for regulatory requirements, as it discriminates against low frequency noise similar to the response of the human ear at the low to moderate sound levels typical of environmental sources. The C-weighted decibel, or dBC, scale applies less attenuation to low frequency noise to approximate the response of the human ear at higher sound levels. Sound levels without a frequency weighting applied, referred to as unweighted or linear, are generally reported as dB or dBZ.

The sound power level (PWL or Lw) of a noise source is the strength or intensity of noise that the source emits regardless of the environment in which it is placed. Sound power is a property of the source, and therefore is independent of distance. The radiating sound power then produces a sound pressure level (SPL or Lp) at a point of which human beings can perceive as audible sound. The sound pressure level is dependent on the acoustical environment (e.g., indoor, outdoor, absorption, reflections) and the distance from the noise source. While both sound power and sound pressure are expressed in decibels, they are wholly different quantities. Decibel levels of sound power are referenced to a power of 1 pico-watt (pW), while decibel levels of sound pressure are referenced to a pressure of 20 micro-pascals (μPa). Unless otherwise stated, sound levels in this report are sound pressure levels.

Numerous metrics and indices have been developed to quantify the temporal characteristics (changes over time) of community noise. The equivalent continuous sound level, Leq, metric is the level of a hypothetical steady sound that would have the same energy as the fluctuating sound level over a defined period of time. The Leq represents the time average of the fluctuating sound pressure level. The maximum and minimum sound levels, or Lmax and Lmin, are the loudest and quietest instantaneous sound levels occurring during a period of time.

Sound is a naturally occurring phenomenon, while noise is generally defined as the threshold when sound becomes an annoyance. A change in sound levels of 3 decibels is generally considered to be the threshold of perception, whereas a change of 5 decibels is clearly perceptible, and a change of 10 decibels is perceived as a doubling or halving of loudness.

Examples of A-weighted sound levels in common environments are shown on Figure 2.

3.0 Regulatory Environment

A review was conducted of noise regulations applicable to the Project at the federal, state, county, and local levels. There are no federal, state, county, or local environmental noise requirements specific to this Project. However a Ballard County resolution was recently passed that includes minimum setback distances and limits on construction hours[1]. As per this resolution the project footprint of the solar facility is considered to be the outermost panels and any equipment necessary for the equipment to function, such as transformers and inverters. The solar facility must be at least 250 feet from non-participating receptors, 100 feet from adjoining non-participating parcel lines, 50 feet from adjacent primary road centerlines and 25 feet from adjacent secondary road centerlines. Additionally, construction and decommissioning activities shall take place Monday through Saturday between the hours of 6:00 am and 7:00 pm.

4.0 Existing Noise Conditions

4.1 NOISE SENSITIVE RECEPTORS

In this analysis, noise sensitive receptors were considered to include non-participating residences, schools, churches, hospitals, parks, and cemeteries. Noise sensitive receptor locations were identified within 1,000 feet of the Project boundaries (Study area) by reviewing high resolution aerial imagery and structure data provided by Song Sparrow. The receptor locations, named with the prefix "R" and shown on Figures 3 and 4, include 29 residential dwellings. There are no churches or other non-residential noise sensitive receptor types within the Study area. Four additional residential dwellings are considered participating parcels in the Project and are shown on the figures but not considered to be a noise sensitive receptor in this analysis. Residential structures that were observed to be obviously abandoned were not considered in the analysis.

There are no residential receptors located within the Study area that meet the definition of "residential neighborhood" according to KRS 278.700, which include populated areas of five or more acres containing at least one residential structure per acre.

Table 1 shows the nearest residential receptor locations to Project boundaries and equipment, throughout the Project area. Receptor R-21 is located approximately 492 feet northeast of the nearest inverter. Receptor R-06 is located approximately 1,312 feet southeast of the Project substation.

[1] County of Ballard Resolution Number 2023-04-18-01. A Resolution Relating to the Policies and Procedures Concerning Commercial Solar Energy Systems. April 18, 2023.

Table 1. Nearest Receptors to the Project

Land use	Nearest Receptor to	Section of Study Area	Distance from Fence	Distance from Nearest Solar Panel	Distance from Nearest Inverter or Transformer
Residence (R-21)	Inverter	Northeast	281ft	301 ft	492 ft (inverter)
Residence (R-06)	Substation transformer	Southwest	3,625 ft	3,679 ft	1,312 ft (transformer)
Residence (R-09)	Panel tracking system and Project fence	Central	226 ft	256 ft	1,172 ft (inverter)

4.2 EXISTING NOISE FROM ADJACENT PROPERTIES

The primary sources of noise from the surrounding area are likely to be vehicle traffic on rural roads and adjacent agricultural activities, including but not limited to, tractors, farm machinery, trucks, and all-terrain vehicles (ATVs). Traffic from Kentucky Highway 473 also contributes to noise in the vicinity of the Project area. Additionally, wildlife such as insects, birds and frogs also contribute to the existing noise environment.

4.3 EXISTING NOISE ON THE PROJECT SITE

Existing sound sources on the Project site are likely those typical of agricultural activities. These sources include tractors, trucks, and ATVs. Rural wildlife noises also contribute to the existing noise environment including birds, frogs, and insects. Typical sound levels in a variety of outdoor environments are shown on Figure 2.

5.0 Construction Sound Assessment

5.1 SOUND SOURCES AND ASSESSMENT METHODOLOGY

Construction activities related to the development of the Project will occur over a period of approximately 12 to 18 months. Construction will occur in phases, starting with site preparation activities, such as vegetation clearing, installation of stormwater controls, and access road construction. Construction of the Project substation along with the trenching and installation of the underground electrical collection system will likely be occurring concurrently with the solar array installation activities. The construction process is progressive in nature; therefore, several locations may see activity during the same time period, with installation activities then progressing to other array sites.

Construction activities will be conducted during daylight hours Monday through Saturday (6:00 a.m. to 7:00 p.m. or dusk if sunset occurs after 7:00 p.m.). Heavy construction equipment including, but not limited to, backhoes, bulldozers, excavators, and haul trucks may be present and operational at different points during the first phase of the construction period. The second phase of construction at each array site will include impact pile drivers to install posts for the tracking system. This analysis assumes that up to three pile drivers may be operating simultaneously within a solar array field.

Major components of the solar facility include solar modules, a module tracking system, inverters, and a Project substation. Assembly will occur within the Project site several hundred to thousands of feet from the nearest receptors. Assembly will take place during construction hours and will be of limited duration at any given location within the Project.

Traffic noise is expected to increase temporarily during construction due to the mobilization of labor and materials, equipment and staff moving between sections of the Project, and construction and equipment vehicles entering and leaving the site.

Noise levels from construction equipment will vary by type, age of equipment, and overall condition. Typical construction equipment sound emission levels from the Federal Highway Administration (FHWA) Roadway Construction Noise Model (RCNM)[2] database are presented in Table 2. These sound levels are representative of typical infrastructure construction equipment and were used for this assessment; however, the types of pile drivers used for solar array post installation generate less noise than pile drivers used for heavy infrastructure construction. Pile driving was modeled assuming an L_{max} sound level of 84 dBA at 50 feet based on typical impact pile drivers used for solar energy projects. Sound levels associated with the types of equipment expected to be used will vary from approximately 74 to 85 dBA at 50 feet. For comparison, typical sound levels generated by common sources are shown on Figure 2.

The FHWA RCNM model was used to assess sound levels during construction at the nearest receptor to solar panel arrays (R-09) where pile driving would occur. RCNM accounts for the attenuation of sound with distance from equipment and estimates both L_{max} and L_{eq} sound levels. Equipment included in the RCNM model predictions included three pile drivers, one crane, one pickup truck, and one front end loader. The distance to a sound level of 55 dBA resulting from the use of three pile drivers in a solar field was also estimated using the CadnaA model, which is described in section 6.1.

Table 2. Typical Construction Equipment Sound Emission Levels

Equipment Description	Acoustical Use Factor, %	Sound Level at 50 feet, dBA	
		L_{max}	L_{eq}
Backhoe	40	78	74
Compactor (ground)	20	83	76
Compressor (air)	40	78	74
Crane	16	81	73
Dozer	40	82	78

[2] Federal Highway Administration Roadway Construction Noise Model User's Guide. January 2006.

Equipment Description	Acoustical Use Factor, %	Sound Level at 50 feet, dBA	
		L_{max}	L_{eq}
Dump Truck	40	76	72
Excavator	40	81	77
Flat Bed Truck	40	74	70
Front End Loader	40	79	75
Generator	50	81	78
Impact Pile Driver*	20	101	94
Paver	50	77	74
Pickup Truck	40	75	71
Pneumatic Tools	50	85	82
Pumps	50	81	78
Roller	20	80	73
Tractor	40	84	80
Vibratory Pile Driver	20	101	94
Welder/Torch	40	74	70

Source: FHWA Roadway Construction Noise Model User's Guide.

*Typical equipment presented in this table includes heavy infrastructure pile drivers. Typical pile drivers used for solar energy projects are somewhat quieter and a value of L_{max} 84 dBA at 50 feet was used for this study.

5.2 CONSTRUCTION SOUND ASSESSMENT RESULTS

Table 3 shows the results of the construction sound modeling at the nearest receptor to Project construction activities (R-09). The table shows the expected loudest instantaneous sound level (L_{max}) as well as the average sound level (L_{eq}) due to multiple pieces of equipment operating simultaneously in a solar field. Because pile drivers will only be used during solar panel post installations, results have been presented both with and without pile drivers in use.

Table 3. Estimated Sound Levels at Nearest Receptor Due to Construction (Sunrise to Sunset)

Condition	Distance to Solar Array (ft)	Estimated L_{max} Sound Level (dBA)	Estimated L_{eq} Sound Level (dBA)
With pile driver	256	70	69
Without pile driver		66	64

The estimated sound levels of 64 to 70 dBA during construction at the nearest sensitive receptor are comparable to sound levels of a location 50 feet from highway traffic (Figure 2), and construction sound levels are expected to be lower at other receptors.

The distance to a sound level of 55 dBA resulting from the use of three pile drivers in a solar field was projected to be approximately 1,000 feet. The resulting 55 dBA construction sound level contour is presented on Figure 3 and represents the geographic limits of where sound levels during construction are anticipated to reach 55 dBA on a temporary basis.

6.0 Operational Sound Assessment

6.1 SOUND SOURCES AND ASSESSMENT METHODOLOGY

The Project, as currently proposed, includes 27 inverters within the solar generation arrays and one substation transformer, as shown in Figures 3 and 4. These are the primary operational sound sources associated with the Project. Solar panels produce DC voltage which must be converted to AC voltage through a series of inverters. Solar energy facilities operate by converting solar radiation into electricity, meaning the Project will only produce electricity between sunrise and sunset. After sunset, the site no longer receives solar radiation, and the inverters will shift into stand-by mode. During nighttime hours, the substation transformer will be energized; however, it will produce minimal sound. Thus, operational sound levels generated by the Project will be highest during daytime hours.

The solar arrays associated with the Project include single-axis tracking panels. Tracking systems involve the panels being driven by small, 24-volt brushless DC motors to track the arc of the sun to maximize each panel's potential for solar absorption. Panels would turn no more than five (5) degrees every 15 minutes and would operate no more than one (1) minute out of every 15-minute period during daylight hours. The tracking motors are a potential source of intermittent (occasional) mechanical noise.

This assessment assumed a sound power level of 99 dBA for each inverter based on manufacturer data for a Power Electronics HEM solar inverter. The 155 MVA Project substation transformer sound power level was estimated to be 101 dBA, which corresponds to a NEMA noise rating[3] of 81 dBA using calculation methods in the Edison Electric Institute Electric Power Plant Environmental Noise Guide[4]. When panel tracking motors are running, the analysis assumed that the maximum sound level is 70 dBA at 1 meter (3.28 feet) based on manufacturer data for a NEXTracker Horizon Single Access Tracker.

Sound attenuates between a source and receptor location due to a variety of factors, including but not limited to, distance between source and receptor, atmospheric absorption, ground type, topography, shielding from solid structures, vegetation, and meteorological conditions. Operational sound levels from the proposed Project equipment were estimated using the CadnaA model by Datakustik, which utilizes the ISO 9613-2 standard[5] algorithms for outdoor sound propagation.

A CadnaA base model was first developed by importing topographic data from the U.S. Geological Survey National Elevation Dataset and aerial imagery. The inverter and substation transformer noise sources were then modeled as point sources within CadnaA based on the current Project layout provided by Song Sparrow. Receptor points were added for the identified

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3 National Electrical Manufacturers Association (NEMA) Standards Publication TR 1-2013 (R2019). Transformers, Step Voltage Regulators and Reactors.

4 Edison Electric Institute. Electric Power Plant Environmental Noise Guide. Volume 1 2nd Edition.

5 ISO 9613-2: 1996. Acoustics – Attenuation of sound during propagation outdoors. Part 2: General method of calculation.

sensitive receptor locations. Additional conservative assumptions that were used to estimate worst-case daytime operational sound levels included the following:

- All inverter and substation transformer sources operate simultaneously.
- Ground attenuation factor of G=0.5 (on a scale of 0.0 representing hard ground to 1.0 representing porous ground).
- No sound attenuation from vegetation (foliage) to simulate a worst-case condition when leaves have fallen off trees.
- Meteorological conditions are conducive to sound propagation with all receptors located downwind of all noise sources.

6.2 OPERATIONAL SOUND ASSESSMENT RESULTS

Operational sound levels estimated using the CadnaA model for the 29 sensitive receptors identified in the vicinity of the Project area are provided in tabular format in Appendix A. The estimated sound levels represent daytime sound levels from the Project inverters and the substation transformer. The table in Appendix A also shows the distance from each receptor to the nearest inverter, substation transformer, and panel tracking system.

Sound level contours for daytime operation with all Project inverters and the substation transformer operating at full load are displayed in Figure 4. The figure displays the overall project-generated sound levels in the vicinity of the Project area and illustrates how sound is expected to propagate in the area. Table 4 provides a summary of the expected sound levels at receptors within 1,000 feet of the Project boundaries during daytime hours.

Table 4. Summary of Estimated Daytime Operational Sound Levels at Sensitive Receptors

Expected Sound Level (L_{eq})	Number of Receptors
35 dBA or less	6
35 to 40 dBA	15
40 to 45 dBA	7
Greater than 45 dBA	1

The results of the operational sound modeling demonstrate that the highest expected daytime sound level at nearby sensitive receptors is 46 dBA at receptor R-21, which is the in the northeast portion of the study area. Nighttime operation will result in lower sound emissions, as power will not be generated and therefore the solar inverters and substation transformer will be operating in stand-by mode. A sound level of 35 dBA is comparable to a quiet suburban nighttime environment and 50 dBA is comparable to outdoor daytime sound levels in rural to quiet urban environments (Figure 2.)

The nearest sensitive receptor to solar arrays with tracking motors (R-09) is expected to be approximately 256 feet away from the edge of the nearest solar array. The sound level from the tracking system is expected to be less than 32 dBA at 256 feet. During the approximately four minutes per hour that tracker motors are operating, the sound generated by the motors is likely to be masked by existing daytime ambient sound sources and inaudible at this distance.

7.0 Summary

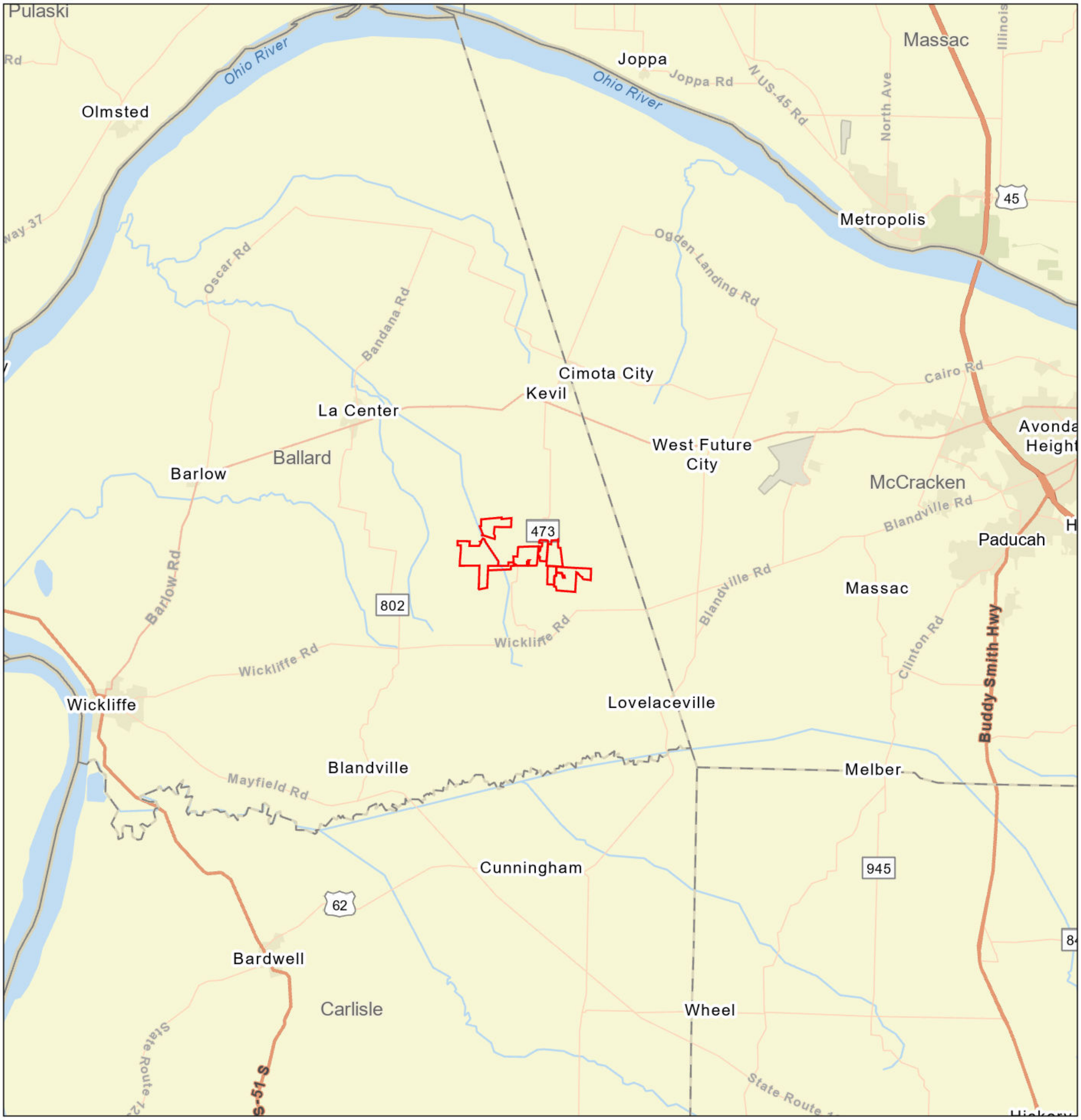
An operational sound analysis was completed for the Project, considering 27 solar inverters and one substation in full operation. The highest daytime sound level expected at a residence due to operation of the Project is estimated to be 46 dBA. The solar facility will generate power during daylight hours only. Sound from the inverters and substation will be minimal during the nighttime hours, due to equipment operating in an energized stand-by mode.

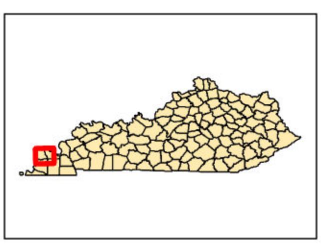
A construction sound analysis was completed considering impact pile driving and other typical construction equipment. Worst-case construction sound levels at the nearest residence are expected to range from 64 to 70 dBA with multiple pieces of equipment operating simultaneously. In compliance with the Ballard County Solar Resolution, construction related activity is expected to occur during daylight hours, Monday through Saturday (6:00 a.m. to 7:00 p.m. or dusk if sunset occurs after 7:00 p.m.). At times, construction activities will be audible to nearby residences or other sensitive receptors; however, not all equipment will be operating at the same time, and activities will be temporary in duration and spread throughout the Project area.

FIGURES

Figure 1

Vicinity Map





Legend
Project Boundary

0 15,000 30,000 Feet

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1:250,000

Stantec

Project Location
Ballard County, KY

Prepared by GRG on 2023-08-14
TR by ALC on 2023-08-24
IR Review by JP on 2023-08-24

Client/Project
172607907
Kentucky Solar
Song Sparrow Solar Facility Sound Study

Figure No.
1

Title
Vicinity Map

Notes
1. Coordinate System: NAD 1983 UTM Zone 16N
2. Data Sources: ESRI, Stantec, Song Sparrow Solar
3. Background: World Street Map: Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, EPA, NPS, USDA

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Figure 2

Common Sound Levels

Figure 2. Common Sound Levels

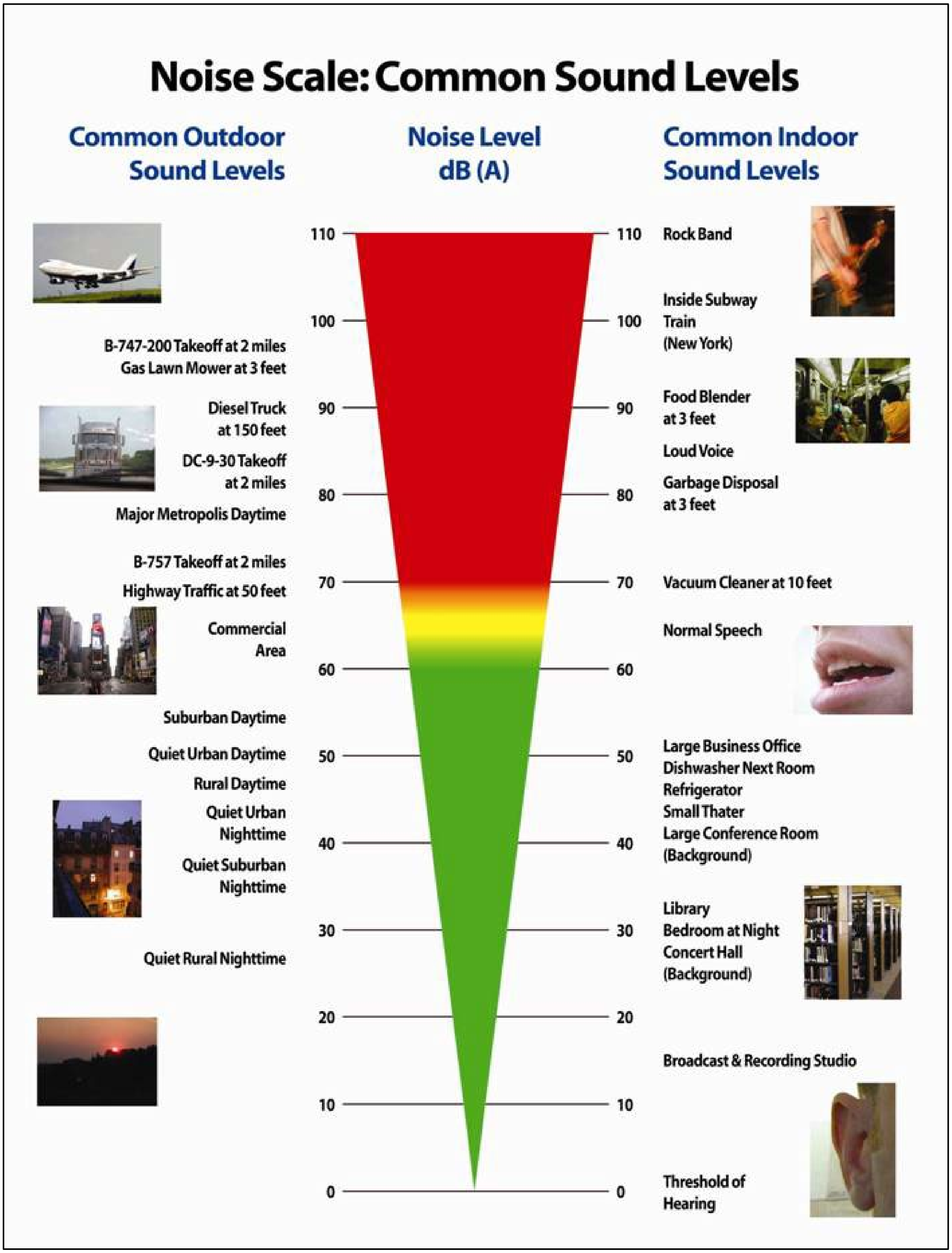
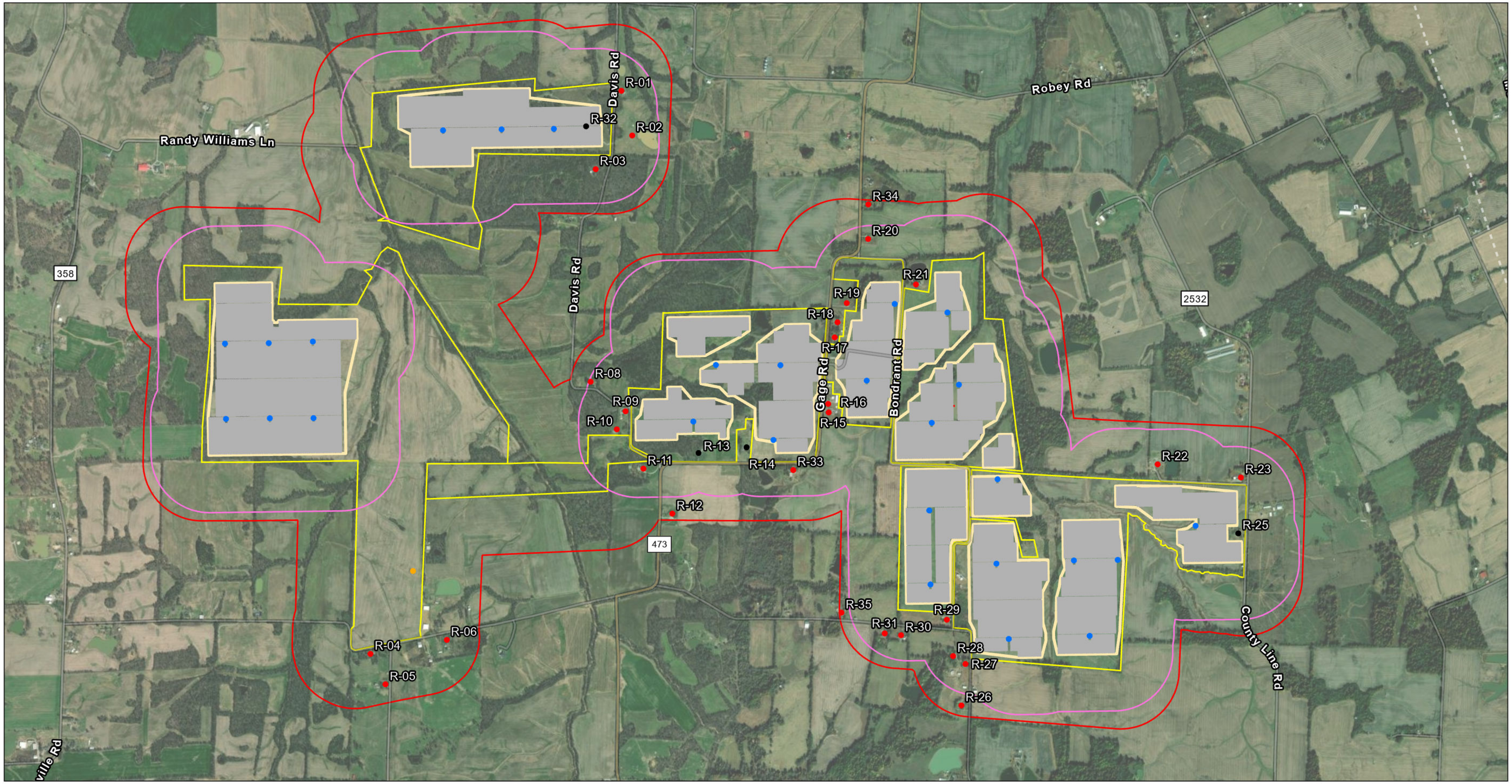
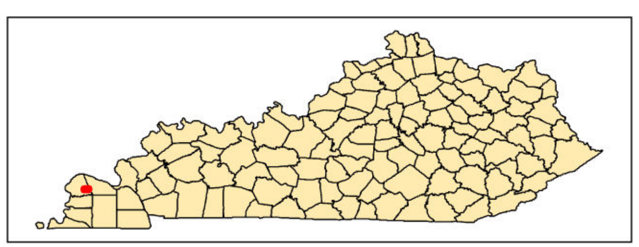


Figure 3

Noise Sensitive Receptor Locations





Legend
- Project Boundary
- 1000 ft Noise Assessment Area
- Potential Fence Line
- Noise Sensitive Receptors
- Participating Structures
- Potential PV Layout
- Potential Inverter Locations
- Potential Substation Location
- 55dBA Temporary Contruction Noise Limit

0 3,000 6,000 Feet

N

(At original document size of 8.5x11)
1:22,000

Notes
1. Coordinate System: NAD 1983 UTM Zone 16N
2. Data Sources: ESRI, Stantec, Song Sparrow Solar
3. Background: Hybrid Reference Layer: Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/ NASA, USGS, EPA, NPS, US Census Bureau, USDA
World Imagery: Maxar

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Figure No.
3

Title
Noise Sensitive Receptors

Figure 3

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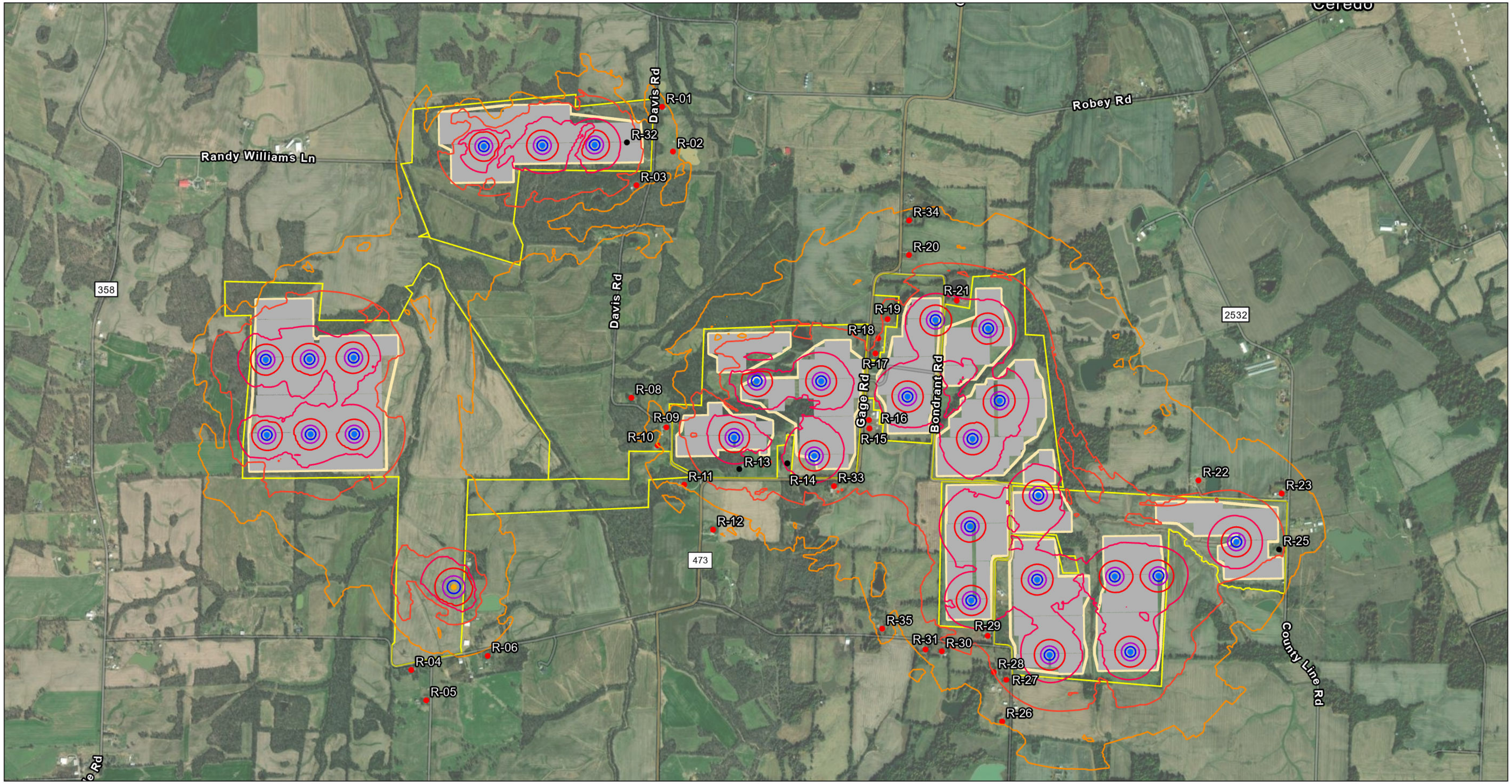
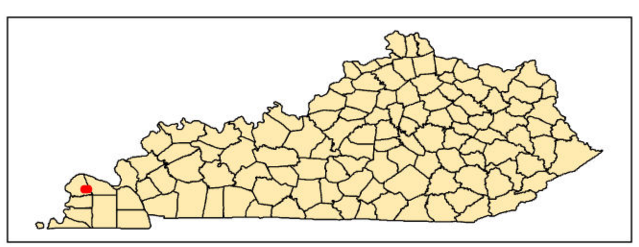
Figure 4

Operational Sound Modeling Results





Legend

Operational Daytime Sound Level Contours

- 35 dBA
- 40 dBA
- 45 dBA
- 50 dBA
- 55 dBA
- 60 dBA

- Noise Sensitive Receptors
- Participating Structures
- Potential PV Layout
- Potential Inverter Locations
- Potential Substation Location
- Potential Fence Line
- Project Boundary

0 3,000 6,000 Feet

N

(At original document size of 8.5x11)
1:22,000

Notes
1. Coordinate System: GCS WGS 1984
2. Data Sources: ESRI, Stantec, Song Sparrow Solar
3. Background: Hybrid Reference Layer: Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, US Census Bureau, USDA
World Imagery: Maxar

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Figure No.
4

Title
Estimated Operational Sound Level Contours

Figure 4

Appendix A

Receptor Locations (UTM 16 Coordinates) and Operational Sound Model Results

Table A.1. Receptor Locations and Operational Sound Model Results

Receptor ID	Sound Level (dBA Leq)	Distance to inverter (ft)	Distance to substation (ft)	Distance to panel tracking system (ft)	Distance to fence (ft)	X, UTM 16 (m)	Y, UTM 16 (m)	Z (m)
R-01	36	1324	8949	479	453	330944.5	4100792	143
R-02	36	1343	8335	544	524	331000.9	4100560	144
R-03	39	993	7546	417	397	330811.1	4100384	143
R-04	33	4148	1594	3482	3453	329638.9	4097862	139
R-05	31	4719	1998	4041	4009	329717.2	4097702	144
R-06	34	4425	1312	3679	3625	330036.7	4097935	141
R-08	33	1883	4437	972	952	330784.7	4099278	133
R-09	39	1172	4544	256	226	330966.2	4099124	142
R-10	36	1314	4242	349	329	330920.9	4099030	134
R-11	37	1172	4310	511	491	331059.6	4098826	134
R-12	34	1614	4540	1287	1267	331209.7	4098592	139
R-15	43	848	7605	277	257	332023.1	4099118	144
R-16	44	769	7651	271	245	332020.7	4099163	145
R-17	41	920	8240	257	228	332054.3	4099509	144
R-18	40	1026	8411	266	240	332069.4	4099588	143
R-19	42	819	8716	302	270	332117.4	4099688	144
R-20	39	1199	9632	773	753	332228.8	4100021	140
R-21	46	492	9895	301	281	332477.2	4099784	137
R-22	39	1234	12860	403	371	333734.9	4098848	145
R-23	38	1131	14243	280	254	334168	4098780	146
R-26	35	1400	9655	1209	946	332714	4097592	145
R-27	41	855	9578	289	258	332735	4097810	146
R-28	40	997	9346	409	379	332670.3	4097850	146
R-29	44	665	9164	308	288	332638.2	4098040	147
R-30	39	1004	8415	575	552	332399.7	4097959	146
R-31	36	1147	8134	663	635	332314.7	4097968	142
R-33	43	614	6715	321	301	331839.0	4098819	142
R-34	36	1758	9979	1363	1345	332229.6	4100201	140
R-35	36	1595	7347	1145	1123	332089.5	4098077	142