FREE STATE SOLAR PROJECT, LLC

ENVIRONMENTAL SOUND STUDY

KANSAS SKY ENERGY CENTER

PROJECT NO. 147658

REVISION 0

AUGUST 2023

CONTENTS

TABLES

List of Abbreviations

Abbreviation	Term/Phrase/Name
CadnaA	Computer Aided Noise Abatement
dB	Decibels
dBA	A-weighted decibels
Developer	Free State Solar Project, LLC
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
Hz	Hertz
HVAC	Heating ventilation and air conditioning
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization of Standardization
L_{eq}	Equivalent sound level
MW	Megawatt
MVA	Megavolt-ampere
NEMA	National Electrical Manufacturers Association
Project	Kansas Sky Energy Center
PV	Photovoltaic
PWL	Sound power level
SPL	Sound pressure level

1.0 Executive Summary

Burns & McDonnell conducted an environmental sound study for the Kansas Sky Energy Center located in Douglas County, Kansas (Project). The Project is being developed by Free State Solar Project, LLC (Developer), who plans to install a new 159-megawatt (MW) solar energy plant consisting of multiple arrays of photovoltaic (PV) panels, inverters, transformers, switchgear, and associated equipment.

The objectives of this sound study were to:

- Identify state and local sound level regulations that are applicable to the Project
- Develop a model to estimate Project-generated sound levels in the surrounding community
- Establish whether the Project will meet the identified noise requirements

There are no State of Kansas sound level limits applicable to the Project. However, there are local sound level limits for Douglas County specific to utility scale solar energy conversion systems. Douglas County limits the Project to 60 A-weighted decibels (dBA) at the property lines. Modeling results show that the Project as designed is predicted to meet the Douglas County sound level limits along the Project property lines. The following sections discuss the sound study methodology and modeling results in further detail.

2.0 Acoustical Terminology

The terms “noise level” and “sound level” are often used to describe two different sound characteristics: sound power and sound pressure. Every source that produces sound has a sound power level (PWL). The PWL is the acoustical energy emitted by a sound source and is an absolute number that is not affected by the surrounding environment. The acoustical energy produced by a source propagates through media as pressure fluctuations. These pressure fluctuations, also called sound pressure levels (SPL), are what human ears hear and microphones measure.

Sound is physically characterized by amplitude and frequency. The amplitude of sound is measured in decibels (dB) as the logarithmic ratio of a sound pressure to a reference sound pressure (20 micropascals). The reference sound pressure corresponds to the typical threshold of human hearing. To the average listener, a 3-dB change in a continuous broadband sound is generally considered “just barely perceptible”; a 5-dB change is generally considered “clearly noticeable”; and a 10-dB change is generally considered a doubling (or halving, if the sound is decreasing) of the apparent loudness.

Sound waves can occur at many different wavelengths, also known as the frequency. Frequency is measured in hertz (Hz) and is the number of wave cycles per second that occur. The typical human ear can hear frequencies ranging from approximately 20 to 20,000 Hz. Normally, the human ear is most sensitive to sounds in the middle frequencies (1,000 to 8,000 Hz) and is less sensitive to sounds in the lower and higher frequencies. As such, the A-weighting scale was developed to simulate the frequency response of the human ear to sounds at typical environmental levels. The A-weighting scale emphasizes sounds in the middle frequencies and de-emphasizes sounds in the low and high frequencies. Any sound level to which the A-weighting scale has been applied is expressed in A-weighted decibels, or dBA. The C-weighting scale (dBC) is commonly used for sources with a low-frequency component that would be de-emphasized by the A-weighted scale. For reference, the A-weighted sound pressure level and subjective loudness associated with some common sound sources are listed in Table 2-1.

Sound in the environment is constantly fluctuating, as when a car drives by, a dog barks, or a plane passes overhead. Therefore, sound metrics have been developed to quantify fluctuating environmental sound levels. These metrics include the exceedance sound level. The exceedance sound level is the sound level exceeded during “x” percent of the sampling period and is also referred to as a statistical sound level. Common exceedance sound level values are the 10-, 50-,90-percentile exceedance sound levels, denoted by L_{10}, L_{50}, and L_{90}. The equivalent-continuous sound level (L_{eq}) is the arithmetic average of the varying sound over a given time period and is the most common metric used to describe sound.

Table 2-1: Typical Sound Pressure Levels Associated with Common Sound Sources

Sound Pressure Level (dBA)	Subjective Evaluation	Environment
140	Deafening	Jet aircraft at 75 feet
130	Threshold of pain	Jet aircraft during takeoff at a distance of 300 feet
120	Threshold of feeling	Elevated train
110	Very loud	Jet flyover at 1,000 feet
100		Motorcycle at 25 feet
90	Moderately loud	Propeller plane flyover at 1,000 feet
80		Diesel truck (40 mph) at 50 feet
70	Loud	B-757 cabin during flight
60	Moderate	Air-conditioner condenser at 15 feet
50	Quiet	Private Office
40		Farm field with light breeze, birdcalls
30	Very quiet	Quiet residential neighborhood
20		Rustling leaves
10	Just audible	--
0	Threshold of hearing	--

Sources:
(1) Adapted from *Architectural Acoustics, M. David Egan, 1988*
(2) *Architectural Graphic Standards*, Ramsey and Sleeper, 1994

3.0 Applicable Regulations

Burns & McDonnell reviewed Federal, State, and local level ordinance documentation to determine the noise requirements applicable to the Project. The Project is located in Douglas County, Kansas. The following sections include regulatory noise information that was found as part of the review and indication on its applicability to the Project.

3.1 Federal

The Noise Control Act of 1972 mandated a national policy "to promote an environment for all Americans free from noise that jeopardizes their health or welfare, to establish a means for effective coordination of federal research activities in noise control, to authorize the establishment of federal noise emission standards for products distributed in commerce, and to provide information to the public respecting the noise emission and noise reduction characteristics of such products." As required by the Act, the Environmental Protection Agency ("EPA") published *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety* in 1974. EPA phased out the Office of Noise Abatement and Control in 1982, transferring the primary responsibility of regulating noise to state and local governments. The Noise Control Act can be used as guidance, but is not an enforceable regulation. As a result, there are no applicable Federal sound level limits.

3.2 State of Kansas

The State of Kansas does not have state-wide noise limits applicable to this Project.

3.3 Douglas County, Kansas

The Douglas County Code of Ordinances, Chapter 12, Section 306-49.05(n)[1] limits noise from Commercial/Utility Scale Solar Energy Conversion System. The Code states, "the operational noise generated from the solar installation equipment, including inverters, battery energy storage systems, components, and associated ancillary equipment shall not exceed a noise level of 60 dBA as measured the property line or 500 feet from an existing residence." The design goal for the Project is to meet 60 dBA at all Project property lines that abut non-participating landowner properties.

[1] https://www.douglascountyks.org/sites/default/files/media/depts/administration/pdf/chapter-12-zoning-and-land-use-regulations.pdf (last accessed 6/13/2023).

4.0 Predictive Noise Modeling

The Project consists of noise emitting equipment in the form of inverters and transformers. To estimate future Project sound levels, the sound sources were input into a predictive model and sound levels generated by the Project were projected out to the property lines and surrounding community.

4.1 Methodology

Predictive noise modeling was performed using the industry-accepted sound modeling software CadnaA, version 2023. The software is a scaled, three-dimensional program, which considers air absorption, terrain, ground absorption, and reflections and shielding for each piece of noise-emitting equipment, and then predicts sound pressure levels at discrete locations and over a gridded area based on input source sound levels. The model calculates sound propagation based on International Organization for Standardization (ISO) 9613-2:1996, General Method of Calculation. ISO 9613-2 assesses the sound level propagation based on the octave band center-frequency range from 31.5 to 8,000 Hz.

The ISO standard considers sound propagation and directivity. The sound-modeling software calculates omnidirectional, downwind sound propagation using worst-case directivity factors, in tandem with user-specified directivities and propagation properties. Empirical studies accepted within the industry have demonstrated that modeling may over-predict sound levels in certain directions, and as a result, modeling results generally are considered a conservative measure of the Project's actual sound level.

The modeled atmospheric conditions were assumed to be calm, and the temperature and relative humidity were left at the program's default values. Reflections and shielding were considered for sound waves encountering physical structures. The area surrounding the Project has mild elevation changes, which scatter and absorb the sound waves. Thus, terrain was included to account for surface effects such as ground absorption. Farm fields are generally considered soft, absorptive ground, and would have a high ground absorption factor. To be conservative, only half the available absorption was considered, and the model's ground absorption factor was set to 0.5 for the Project and surrounding areas. The sound modeling parameters used in the model are outlined in Table 4-1.

Table 4-1: Sound Modeling Parameters

Model Input	Parameter Value
Ground Absorption	0.5
Number of Reflections	2
Foliage	None
Receptor Height	5 feet above grade
Terrain	USGS topographic land data
Temperature	50 °F
Humidity	70%

4.2 Project Equipment

Project transformers and inverters are the major sound sources associated with the Project. The Project transformers sound levels were derived from the use of historical transformer data and the National Electrical Manufacturers Association ("NEMA") *TR 1-2013: Transformers, Step Voltage Regulators and Reactors*. It is anticipated that transformers for this Project can be specified to a maximum 2nd stage of cooling average sound pressure level of 75 dBA. This sound pressure level, according to Institute of Electrical and Electronics Engineers ("IEEE") Standard C57.12.90, is an average of measurements along the equipment envelope, 6 feet from the cooling fans and 1 foot from the tank. Specific vendor data may demonstrate a transformer of the same specification that is considerably quieter (i.e., this analysis provides conservative modeling predictions).

The power conversion skids consist of the inverter, medium voltage transformer, and other associated equipment. The power conversion skids (SMA Sunny Central) were provided with acoustic test data. The average sound level measured on the sides of the unit is 67 dBA at 10 meters, as provided in the equipment specifications sheet. The modeled sound levels for the noise emitting equipment included in the Project are listed below in Table 4-2.

Table 4-2: Project Equipment Sound Levels

Source	Number of Sources	Sound Pressure Level per Source	Sound Level per Source[a]
PV Power Conversion Skid	41	67 dBA at 10 meters	98 dBA
Substation Transformer	2	75 dBA per NEMA	95 dBA

* dBA – A-weighted decibels, NEMA – National Electrical Manufacturers Association

(a) Sound power levels are estimated based on the sound pressure level and dimensions of the unit.

4.3 Sound Modeling Results

Project sound levels were modeled to show the noise propagation in the surrounding community from the Project. Transformers and power conversion skids were modeled based on general arrangement drawings provided by the Developer. As modeled, the Project includes 41 PV power conversion skids and two (2) substation transformers. The Project layout is depicted in Figure A-1 of Appendix A.

The maximum Project sound levels occur during solar inverters full load. A graphical representation of the model layout and sound level contours generated by the Project during the loudest operating scenario (i.e., all sources operating at maximum sound levels) is provided in Figure A-2 of Appendix A. The contours are shown in 5-dB sound level increments and represent the Project-generated sound levels only (i.e., no existing ambient sound levels). The maximum Project-generated sound level at the Project property line is below 60 dBA. Sound levels are predicted to be significantly less at property line locations farther from the Project sound sources. As can be seen in Figure A-2, the majority of Project property lines around the PV portion of the Project have sound level impacts below 45 dBA, which is significantly below the design goal of 60 dBA.

During nighttime hours, when the sun is no longer shining and the Project is not generating power, Project sound levels from the PV portion of the Project would be less than those shown in the figures in Appendix A. The substation transformers would remain energized during nighttime hours, but sound levels would generally be less than those emitted during peak power generation.

5.0 Construction Noise

Project construction will generate noise that may periodically be audible offsite. Construction of the proposed Project is expected to involve limited site clearing and solar panel erection, which each use various types of construction equipment. Although construction will intermittently generate the types and levels of sound common at large construction sites, it will not feature many of the most significant sound-generating activities common during construction of other facilities. The Project will not involve extensive excavation or other earth-moving work or, with the exception of the Substation, construction of large foundations. A solar plant only involves the installation of the mounting posts for the panel racks. Driving the mounting posts is essentially a small-scale pile driving operation that produces a repetitive, metallic pounding noise, may be audible offsite. The primary sources of construction noise will be associated with heavy-duty equipment operation.

Although numerous piles will be driven, they likely will be only driven to a shallow depth and the activity will be relatively brief at any particular location. This activity is short-lived and would proceed fairly quickly, only occurring for a period of days or a couple weeks at any one location. Blasting is not expected and any rock-breaking activities using conventional construction equipment are expected to be limited. In any event, such activities would be very limited in any particular location and of limited duration.

Pile-driving will be avoided during early and late hours and will involve smaller machines that repeatedly "tap" galvanized steel I-beams through about 10 feet of soil and earth. These are not the large pile drivers associated with major construction projects such as bridges and high-rise buildings that "drive" or "pound" large pilings, typically made of iron, deeply through earth and rock. The erection of structures and components will require almost exclusively standard construction vehicles and hand tools.

Noise levels resulting from construction equipment are dependent on several factors, including the number and type of equipment operating, the level of operation, and the distance between sources and receptors. The impacts that various construction-related activities might have will vary considerably based on the proximity to the Project boundary. Construction noise levels associated with the Project could be greater than ambient conditions for some receptors close to the Project.

During a typical day, equipment would not be operated continuously at peak levels. While the average noise levels would represent a noticeable temporary increase over the ambient noise levels near the construction sites, the noise would attenuate with increasing distance, fading into ambient noise background levels at greater distances from the loudest equipment. Generic sound data ranges are available for various types of equipment at certain distances. Table 5-1 lists generic activities and their minimum and maximum instantaneous sound levels at 50 feet as provided in the Federal Highway Administration (FHWA), Highway Construction Noise handbook and the Federal Transit Administration (FTA), Transit Noise and Vibration Impact Assessment Manual. It should be noted that the FHWA and FTA describe noise from large pile drivers that are significantly louder than the smaller pile drivers used for this Project. The Project pile drivers are expected to operate at or below the provided minimum noise level at 50 feet, for pile drivers provided in the table.

Table 5-1: Range of Typical Construction Equipment Noise Levels

Generic Construction Equipment	Minimum Noise at 50 feet (dBA)	Maximum Noise at 50 feet (dBA)
Backhoes	74	92
Concrete Mixers	76	88
Cranes (movable)	70	94
Front Loaders	77	96
Graders	72	91
Pile Driver[a]	96	101
Scrapers	76	95
Trucks	83	96

Source: Values taken from FHWA Highway Construction Noise handbook and the Federal Transit Administration, Transit Noise and Vibration Impact Assessment Manual, 2006
(a) Pile driver sound levels provided are associated with larger pile drivers than those typically used in solar panel erection.

Sound levels are expected to be lower in areas where activities are occurring at distances greater than 50 feet from the construction zone. The types of equipment listed in the table above may be used at various times and for various periods of time. Typically, construction equipment has a usage factor ranging between 15 and 50 percent of the day, according to the FHWA roadway construction noise handbook. However, the actual amount of use for each type of equipment would vary day to day.

5.1 Construction Noise Mitigation

Noise from construction equipment will be temporary during construction of the Project. The construction contractor selected is expected to implement, where appropriate, construction methods that limit construction noise levels to the extent practicable. Construction is anticipated to occur during typical work hours. There may be times that work needs to be accomplished in part outside of typical working hours. Such work generally consists of activities that must occur continuously once begun (e.g., a concrete pour or transformer oil filling).

Additionally, most construction activities will not occur simultaneously at any location. Construction noise will mostly be audible near the construction activities. Construction noise mitigation measures that could be implemented include the following actions:

1. Limit construction activities to daytime hours;
2. Maintain construction-related vehicles in proper working condition;
3. Utilize construction equipment with proper mufflers;
4. Turn off idling equipment when not in use; and
5. Work with the local community to advise residents of those periods when sustained construction activity is expected to take place in proximity to their homes.

The construction phase of a solar energy facility is fairly short and the activities that generate any significant noise are few. Due to the temporary nature of the construction activities, and best practices with regards to controlling construction noise in the directions of noise sensitive areas, no adverse impacts with respect to construction noise are anticipated.

6.0 Conclusions

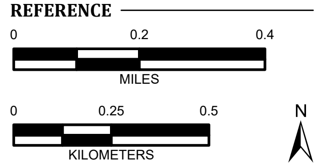
Burns & McDonnell conducted an environmental sound study of the Kansas Sky Energy Center proposed to be located in Douglas County, Kansas. The Project will consist of multiple arrays of PV panels, power conversion skids, transformers, and associated equipment. The proposed Project sound levels were modeled using industry-accepted sound modeling software to predict future sound levels at the property lines and in the surrounding community. Project transformers and power conversion skids are expected to be the significant sound-emitting sources associated with the Project. Sources were modeled based on Developer-provided general arrangement drawings. Modeling results show that the Project sound levels are predicted to meet the Douglas County sound level limits for solar energy conversion systems of 60 dBA along the Project property lines.

APPENDIX A – FIGURES

LEGEND

- Project Area
- Project Layout

REFERENCE



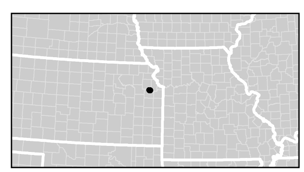


Figure A-1
Project Layout

LOCATION:	Douglas County, KS
CLIENT:	Free State Solar Project, LLC
PROJ. NO.:	147658
CREATED:	07/26/2023

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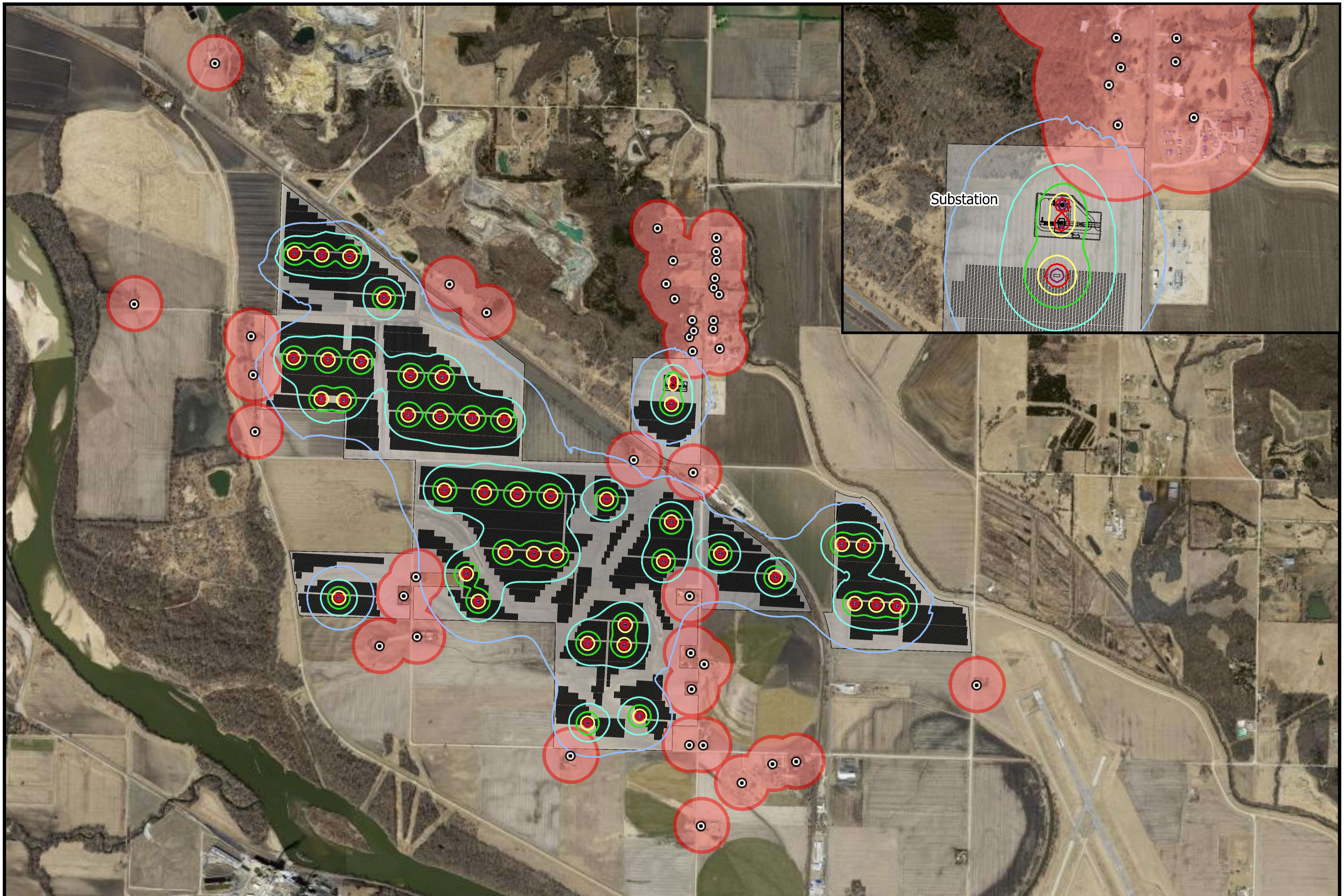

LEGEND

- 40 dBA
- 45 dBA
- 50 dBA
- 55 dBA
- 60 dBA
- 65 dBA
- Project Layout
- Project Area
- 500 ft Residential Buffer
- Residential Receptor

REFERENCE

0 0.5 1
MILES

0 0.75 1.5
KILOMETERS

N

Figure A-2
Sound Level Contours

LOCATION: Douglas County, KS
CLIENT: Free State Solar Project, LLC
PROJ. NO.: 147658
CREATED: 08/09/2023

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