Intended for

Kimley-Horn and Associates, Inc.

Date

August 6, 2026

Project Bluestem

Noise Memo

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Project Bluestem

Noise Memo

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Project name	**Project Bluestem**
Project no.	**1940115134**
Recipient	**Kimley Horn and Associates**
Version	**1.0**
Date	**2026-08-06**
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Description	Memo summarizing work performed related to environmental sound emissions.

This work was undertaken in accordance with the contract between Ramboll Americas Engineering Solutions, Inc. and Kimley-Horn and Associates, Inc.

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Introduction

Ramboll has completed the sound and vibration technical due diligence for the proposed data center facility adjacent to the City of Tonganoxie and in Leavenworth County, Kansas. The assessment identified applicable noise and vibration requirements and evaluated the potential impact from project-related noise sources.

An ambient noise survey and environmental acoustical assessment was completed to identify and assess potential sound emissions associated with the proposed site. The assessment was conducted in general accordance with applicable provisions specified in relevant industry standards including ANSI S12.9 and ISO 9613.

The associated report provides a summary of the site, the relevant regulations, and Ramboll's findings based on work performed to-date. Appendix A contains basic sound definitions, metrics, and subjective descriptions of common sound sources for reference. Common topics are included such as Low Frequency (LF) sound, Infrasound, and Ground-borne vibration.

Regulatory Requirements

There are no applicable noise regulations pertaining to the State of Kansas. Regulations for Leavenworth County prohibit sound levels at the property boundary exceeding 60 dBA or the average local traffic noise. This requirement is generally consistent with the City of Tonganoxie regulations. However, the County does not define parameters for "average traffic noise" and based on this, a sound level survey was conducted to establish baseline conditions, including contributions from local traffic at the site boundaries. Ramboll used the measured ambient sound levels (LA_{EQ}) to determine the basis for the average traffic noise levels. The sound level limit for the site boundary will be 60 dBA, or the level of traffic noise, presumably whichever is lower, although Ramboll recommends clarifying with Leavenworth County. Whether the limit would apply to the emergency operation of generators during a site-wide power outage should also be clarified. Sound level limits near specified property boundary locations and adjusted per measured average traffic noise are summarized below in Table 1:

Table 1. Maximum Permissible Sound Pressure Levels Summary

Time of Day	Maximum Sound Pressure Levels (dBA)				
	West Property Boundary	East Property Boundary	Northeast Property Boundary	Southeast Property Boundary	Northwest Property Boundary
Daytime (7AM-10PM)	60	56	49	59	52
Nighttime (10PM-7AM)	60	49	45	51	54

Tonal Noise Evaluation

Ramboll has reviewed the ambient level data for tonal noise. Evaluation was conducted using the ANSI/ASA S12.9 Annex C, Sound with Tonal Content assessment criteria for evidence of tonal noise. A prominent discrete tone is identified when the sound pressure level of a certain band exceeds the adjacent bands by the applicable threshold shown in Table 2.

Table 2.ASA/ANSI 12.9 Part 4 – Tonal Noise Content Analysis

ASA/ANSI Annex C. Sounds with Tonal Content Analysis Summary		
Frequency Range	**1/3 Octave Bands**	**Required Difference Above Adjacent Bands**
Low-frequency bands	25 Hz – 125 Hz	15 dB
Mid-frequency bands	160 Hz – 400 Hz	8 dB
High-frequency bands	500 Hz – 10,000 Hz	5 dB

Ramboll reviewed the measured one-third octave-band sound pressure levels during the ambient sound survey. Sound monitoring location one (SLM 1) was used as a reference point for the tonal analysis for was on 5/15/26 from 12:00 AM to 12:10 AM. The measured data did not identify any one-third octave band that exceeded both adjacent bands by the applicable ANSI/ASA tonal threshold.

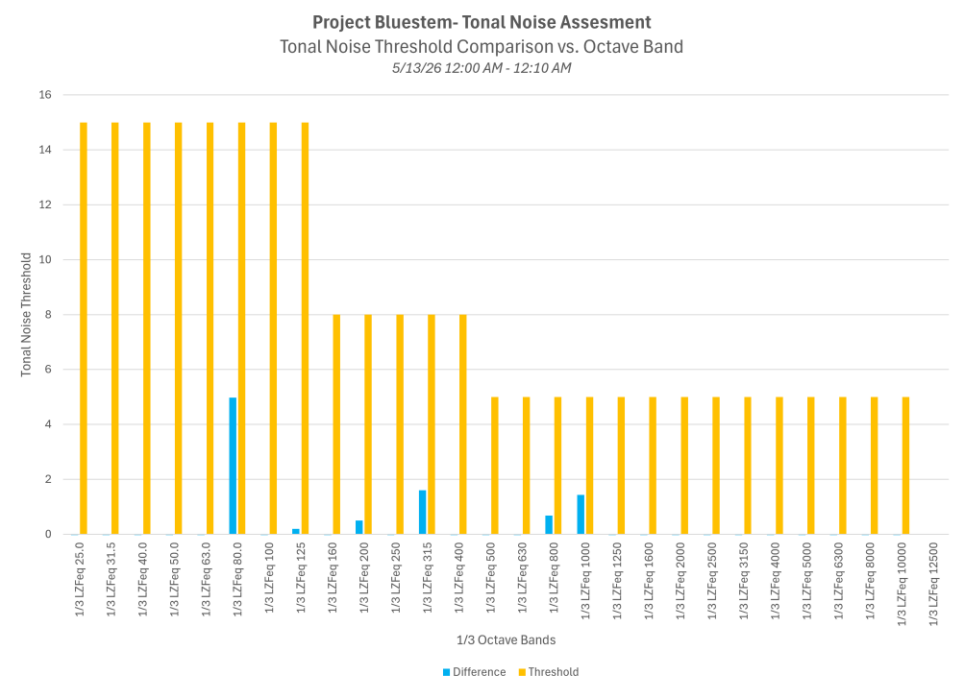


Figure 1. Tonal Noise Assessment

Tonal Noise Summary

Based on Ramboll's review of the measured ambient sound levels one-third octave band data, there is no indication of prominent tonal noise near the project site. The existing ambient noise measured is reflective of a generally rural environment influenced by road traffic as well as general wildlife.

Appendix A

Basics of Sound

Sound is the transmission of energy in the form of fluctuating pressure waves from a vibrating source through an elastic medium, such as air, that is detectable by the human ear. The pressure fluctuates above and below atmospheric pressure. The amplitude of the pressure fluctuation is typically described in terms of decibels (dB), while the rate of fluctuation per unit time (frequency) is described in hertz (Hz).

The decibel is a logarithmic ratio of a given sound pressure to a reference sound pressure. A logarithmic ratio is used for decibels since human hearing is roughly logarithmic, rather than linear. The reference sound pressure is roughly equal to the threshold of human hearing. Sound pressure levels below the human threshold of hearing are less than 0 dB, while levels above the human threshold of hearing are greater than 0 dB. Differences in sound level are also described in decibels. A 3-dB difference is considered "just noticeable", a 5-dB difference is considered "clearly noticeable", while a 10-dB difference is perceived as a doubling (or halving) in loudness. Table A-1 provides a list of common sound sources, their sound level, and their subjective loudness.

The range of frequencies a healthy human ear can hear is approximately 20 Hz to 20,000 Hz. The human ear is not equally sensitive to all frequencies across the audible frequency spectrum. The human ear is most sensitive to mid frequencies (the frequency range associated with speech) and is less sensitive at low frequencies and very high frequencies. To account for this, frequency weighting networks have been developed to approximate the human ear's frequency response at different sound pressure levels. The A-weighting network is used to approximate the frequency response of the human ear at normal sound levels. Measurements using the A-weighting network are described in terms of A-weighted decibels, often abbreviated colloquially as dBA or dB(A).

Common Sound Level Metrics

Sound level metrics are often employed to characterize changes in sound levels over time. The following is a summary of some of the more common metrics.

- The equivalent-continuous sound level, L_{EQ}, is the steady-state sound level over a given time period that has the same total sound energy as the time-varying sound level measured over that same time period.
- The exceedance sound level, L_x, is the sound level exceeded for *x* percent of a measurement period. For example, L_{50} is the sound pressure level exceeded for 50% of the measurement period. The L_{50} of a measurement is often considered the median sound level. L_{10} is the sound pressure level exceeded for 10% of the measurement period and is often referred to as the intrusive sound level. Exceedance sound levels are considered statistical sound levels.
- The Day-Night Level, abbreviated as either DNL or L_{DN}, is an equivalent-continuous sound pressure level for a 24-hour period that includes a 10-dB penalty from 10:00 PM to 7:00 AM to reflect people's increased sensitivity to sound at night.

Table A-1. Sound Pressure Level of Common Sound Sources (Hansen, 2003) (Raichel, 2006)

Sound Pressure Level of Common Sound Sources		
Sound Pressure Level (dBA)	**Subjective Evaluation**	**Descriptions of Example Sound Sources**
140	Deafening	Jet aircraft at 75 feet (ft)
130	Threshold of pain	Jet aircraft during takeoff at a distance of 300 ft
120	Threshold of feeling	-
110	Extremely Loud	Jet flyover at 1000 ft
100	Very Loud	auto horn at 10 ft
90		jackhammer at 50 ft
80	Loud	Diesel truck (40 miles per hour (mph)) at 50 ft, noisy urban street
70	Moderately Loud	Busy highway at 100 ft
60	Moderate	-
50	Quiet	Small town
40		
30	Very quiet	-
20		Rustling leaves
10	Just audible	-
0	Threshold of hearing	-

Common Topics on Data Center Sound

Data Centers

Environmental sound associated with data centers is primarily generated by mechanical cooling systems, electrical equipment, and backup power systems, rather than the computing equipment itself. Mechanical cooling equipment often represents the dominant continuous sound source, particularly where large arrays of equipment operate simultaneously. Transformers can contribute steady, low-frequency sound, while emergency generators may produce higher sound levels during testing or emergency operation.

It is important to note that none of the above sound sources are unique to data centers. All equipment components are used in other types of commercial and industrial facilities, but a data center development will often require a relatively higher quantity of units needed for cooling and backup power generation.

Common Topics

In addition to overall sound levels, certain acoustical characteristics may influence how data center sound is perceived. The following acoustical phenomena are often cited in conversations around data center sound emissions and are evaluated as applicable.

- Low-Frequency Sound

Low-frequency sound is commonly associated with large mechanical equipment (e.g., cooling systems and transformers). It can propagate over longer distances and may be less effectively attenuated than higher-frequency sound.

In some regulatory frameworks, C-weighted sound level (dBC) limits are established relative to A-weighted sound level (dBA) limits, often on the order of approximately 15 to 20 dB above the corresponding dBA

limit. A better approach to controlling low frequency noise is to assess low frequency octave-band sound levels against standard criteria designed to minimize annoyance, such as those found in ANSI.

- Tonal Sound

Tonal sound is characterized by distinct frequencies (e.g., fan or electrical hum). These sounds can be more noticeable than broadband sounds and are often evaluated through frequency-based analysis. In some cases, regulatory frameworks apply adjustments where tonal characteristics are present.

- Infrasound

Infrasound refers to sound below the range of human hearing (<20 Hz). While certain equipment may produce low-frequency components, infrasound is typically not a primary consideration for standard data center developments.

- Ground-borne Vibration

Ground-borne vibration from data center equipment is generally minimal. Mechanical systems are typically designed with isolation to protect sensitive computing equipment and resulting vibration levels at off-site locations are typically well below perceptible thresholds.

Mitigation

Sound mitigation is generally most effective when addressed at the source, such as with OEM low-noise options, enclosures, attenuators, or by substituting quieter models at the design stage. Beyond that, disrupting the transmission path of the sound is possible using barrier walls, earthen berms, or by physical shielding from buildings and other features. These are typically most effective when located as-close to the source(s) as possible. Lastly, the least-effective mitigation approach is addressing the receiver, such as screen walls or fencing near the property line or receiver location.

Human Response

Human response to sound varies widely between individuals and is influenced by both acoustical and non-acoustical factors. The most common community response to environmental sound is annoyance. Above approximately 40 to 45 dBA, annoyance generally increases as sound levels increase. However, additional factors can significantly influence perception, including:

- Existing baseline sound levels
- Sound characteristics (e.g., tonal, impulsive, or intermittent)
- Variability over time
- Time of day (greater sensitivity at night)
- Predictability of the sound source
- Individual sensitivity and attitudes toward the source

As a result, responses to the same sound source can range from “not noticeable” to “highly annoying” depending on the listener and context.