



Tuzigoot National Monument

Acoustical Monitoring 2010 and 2012

Natural Resource Report NPS/NRSS/NRR—2014/878



ON THE COVER

Tuzigoot National Monument, taken in 2010

Photograph courtesy Volpe Center

Tuzigoot National Monument

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13. ABSTRACT (Maximum 200 words) During the summer of 2010 (July - August) and winter of 2012 (March-April) baseline acoustical data were collected at Tuzigoot National Monument (TUZI) at a site deployed for approximately 30 days during each period. The baseline data collected during these periods will help park managers and planners estimate the effects of future noise impacts and will help to inform future park planning objectives such as creating soundscape management plans, as well as the development of an Air Tour Management Plan (ATMP), which provides for the regulation of commercial air tours. The sound sources of concern at TUZI include developments near park boundaries, air tours, commercial and private aircraft activities, and requests for special use permits for noisy activities. This document summarizes the results of the noise measurement study.			
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Executive Summary

The National Park Service (NPS) Natural Sounds and Night Skies Division (NSNSD) and the U.S. Department of Transportation, John A. Volpe National Transportation Systems Center (Volpe Center) performed acoustical monitoring during July-August 2010 and March-April of 2012 to characterize existing sound levels and estimate natural ambient sound levels representing summer and winter seasons, respectively, for Tuzigoot National Monument (TUZI). This monitoring effort also serves to identify audible sound sources in support of the potential development of an air tour management plan (ATMP). This report provides a summary of results of these measurements.

In determining the current conditions of an acoustical environment, the NPS examines how often sound pressure levels exceed certain decibel values that relate to human health and speech. The NPS uses these values for making comparisons; they should not be construed as thresholds of impact. Table 1 and Table 2 report the percent of time that measured levels were above four sound level values at the Tuzigoot measurement location for each season in dBA and dBT. The first value, 35 dBA, addresses the health effects of sleep interruption (Haralabidis, et. al., 2008). The second value is based on the World Health Organization’s recommendation that noise levels inside bedrooms remain below 45 dBA (Berglund, et. al., 1999). The third value, 52 dBA, is based on the Environmental Protection Agency’s speech interference threshold for speaking in a raised voice to an audience at 10 meters (Environmental Protection Agency, 1974). This value addresses the effects of sound on interpretive presentations in parks. The final value, 60 dBA, provides a basis for estimating impacts on normal voice communications at 1 m (3 ft.). Hikers and visitors in the park would likely be conducting such conversations.

Table 1. Percent Time Above Metrics (dBA).

Site ID	Site Name	% Time above sound level: Daytime (7 am to 7 pm)				% Time above sound level: Nighttime (7 pm to 7 am)			
		35 dBA	45 dBA	52 dBA	60 dBA	35 dBA	45 dBA	52 dBA	60 dBA
Summer season (2010)									
TUZI001	Tuzigoot	24.4	3.2	0.9	0.2	35.7	1.6	0.12	0.0
Winter season (2012)									
TUZI001	Tuzigoot	23.5	3.5	0.6	0.1	3.8	0.3	0.0	0.0

Table 2. Percent Time Above Metrics (truncated spectra dBT).

Site ID	Site Name	% Time above sound level: Daytime (7 am to 7 pm)				% Time above sound level: Nighttime (7 pm to 7 am)			
		35 dBT	45 dBT	52 dBT	60 dBT	35 dBT	45 dBT	52 dBT	60 dBT
Summer season (2010)									
TUZI001	Tuzigoot	19.6	2.9	0.8	0.2	2.9	0.2	0.0	0.0
Winter season (2012)									
TUZI001	Tuzigoot	21.1	2.4	0.5	0.1	2.5	0.2	0.0	0.0

Table 3 and Table 4 summarize the daytime and nighttime¹ acoustical observer log data (off-site listening and *in situ* logging combined) which provides an indication of the amount of time that certain sources are audible at each site. The *in situ* logging is performed during visits to the site itself; off-site listening is performed in an office environment using the audio files collected at each site.

Table 3. Summary of daytime acoustical observer log data (*in situ* and off-site listening combined).

Site ID	Site Name	% Time Audible: Daytime (7 am to 7 pm)			
		Fixed-Wing Aircraft and Helicopters	Other Aircraft Sounds	Other Human Sounds	Natural Sounds
Summer season (2010)					
TUZI001	Tuzigoot	23.1	20.7	39.5	16.8
Winter season (2012)					
TUZI001	Tuzigoot	23.0	19.4	31.1	26.6

Table 4. Summary of nighttime acoustical observer log data (off-site listening).

Site ID	Site Name	% Time Audible: Nighttime (7 pm to 7 am)			
		Fixed-Wing Aircraft and Helicopters	Other Aircraft Sounds	Other Human Sounds	Natural Sounds
Winter season (2012)					
TUZI001	Tuzigoot	2.7	10.2	64.8	22.3

¹ Nighttime acoustical observer logs are not available for the 2010 summer season.

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List of Terms

Acoustical Environment

The actual physical sound resources, regardless of audibility, at a particular location.

Amplitude

The instantaneous magnitude of an oscillating quantity such as sound pressure. The peak amplitude is the maximum value.

Audibility

The ability of animals with normal hearing, including humans, to hear a given sound. Audibility is affected by the hearing ability of the animal, the masking effects of other sound sources, and by the frequency content and amplitude of the sound.

dBA

A-weighted decibel. A-Weighted sum of sound energy across the range of human hearing. Humans do not hear well at very low or very high frequencies. Weighting adjusts for this.

Decibel

A logarithmic measure of acoustic or electrical signals. The formula for computing decibels is: $20 * (\text{Log}_{10}(\text{sound pressure}/\text{reference sound level}))$. 0 dB represents the lowest sound level that can be perceived by a human with healthy hearing. Conversational speech is about 65 dB.

Frequency

The number of times per second that the sine wave of sound repeats itself. It can be expressed in cycles per second, or Hertz (Hz). Frequency equals Speed of Sound/ Wavelength.

Hearing Range (frequency)

By convention, an average, healthy, young person is said to hear frequencies from approximately 20Hz to 20000 Hz.

Hertz

A measure of frequency, or the number of pressure variations per second. A person with normal hearing can hear between 20 Hz and 20,000 Hz.

Human-Caused Sound

Any sound that is attributable to a human source.

 L_{eq}

Energy Equivalent Sound Level. The level of a constant sound over a specific time period that has the same sound energy as the actual (unsteady) sound over the same period.

 L_x

A metric used to describe acoustical data. It represents the level of sound exceeded x percent of the time during the given measurement period.

Masking

The process by which the threshold of audibility for a sound is raised by the presence of another sound.

Noise-Free Interval

The period of time between noise events (not silence).

Noise

Sound which is unwanted, either because of its effects on humans, its effect on fatigue or malfunction of physical equipment, or its interference with the perception or detection of other sounds (Source: McGraw Hill Dictionary of Scientific and Technical Terms).

Off-site Listening

The systematic identification of sound sources using digital recordings previously collected in the field.

1. Introduction

An important part of the National Park Service (NPS) mission is to preserve and/or restore the resources of the parks, including the natural and cultural soundscapes associated with units of the national park system. The collection of ambient sound level data provides valuable information about a park's acoustical conditions for use in developing acoustic resource management plans.

Ambient data are also required to establish a baseline from which noise impacts can be assessed. The National Parks Air Tour Management Act of 2000 provides for the regulation of commercial air tour operations over units of the national park system through air tour management plans (ATMPs). The objective of the ATMPs is to develop acceptable and effective measures to mitigate or prevent significant adverse impacts, if any, of commercial air tour operations upon the natural and cultural resources of and visitor experiences in national park units as well as tribal lands (those included in or abutting a national park).

The U.S. Department of Transportation, John A. Volpe National Transportation Systems Center (Volpe Center) is supporting the Federal Aviation Administration (FAA), Western-Pacific Region (AWP) and NPS, Natural Sounds and Night Skies Division (NSNSD) in the development of ATMPs.

Ambient data were collected in Tuzigoot National Monument (TUZI) by Volpe personnel during July and August 2010 and by NPS, NSNSD personnel during March and April 2012. A map of the area surrounding Tuzigoot is shown in Figure 1. The purpose of this report is to provide a summary of the results of these measurements that will be used to represent TUZI's summer and winter seasons, respectively. Measurements representing TUZI's summer season were summarized in an earlier document (National Park Service, 2013a).

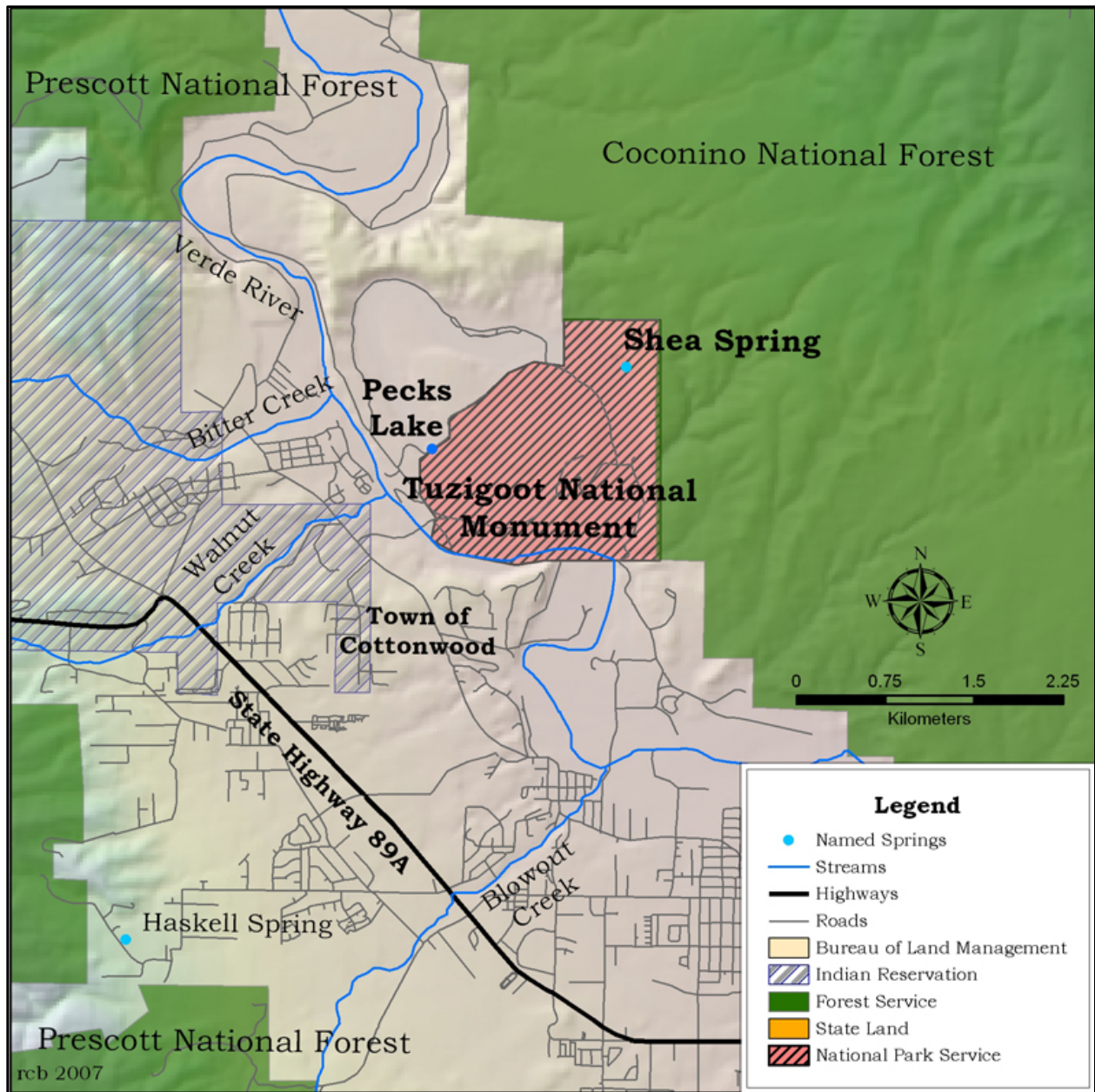


Figure 1. Map of area surrounding Tuzigoot National Monument (Northern Arizona University, 2011).

2. Study Area

Based on discussions between Volpe, NSNSD, and TUZI personnel, it was agreed that because TUZI is a relatively small park, 1 site was recommended. As such, one acoustical monitoring system was deployed during both summer and winter seasons (July and August 2010, March and April 2012) as shown in Table 5.

Table 5. Summary of measurement sites selected for Tuzigoot.

Site ID	Site Name	# of Days of Data	NLCD ² Classification	Coordinates (latitude/longitude in decimal degrees)	Elevation (m)
Summer season (2010)					
TUZI001	Tuzigoot	31 days	Scrub/Shrub	34.77491° 112.02496°	1,049 m (3,441 ft)
Winter season (2012)					
TUZI001	Tuzigoot	42 days	Scrub/Shrub	34.77493° 112.02490°	1,040 m (3,412 ft)

² With the goal of potentially facilitating future data transferability between parks, all baseline acoustical data collected for the ATMP program have been organized/classified in accordance with the National Land Cover Database (NLCD). Developed by the U.S. Geological Survey (USGS), the NLCD is the only nationally consistent land cover data set in existence and is comprised of twenty-one NLCD subclass categories for the entire U.S. (Homer, et. al., 2004).

3. Methods

3.1 Automatic Monitoring

A Larson Davis 831 sound level meter (SLM) was employed for continuous acoustical monitoring over the forty day monitoring period at Tuzigoot. The Larson Davis SLM is a hardware-based, real-time analyzer which constantly records one second sound pressure level (SPL) and one-third octave-band data, and exports these data to a portable storage device (thumb drive). The Larson Davis-based system meets American National Standards Institute (ANSI) Type 1 standards (American National Standards Institute 1990).

In addition to the Larson Davis SLM, the acoustical sampling station consisted of:

- Microphone with environmental shroud
- Preamplifier
- Multiple 12V NiMH rechargeable battery packs
- Anemometer
- MP3 recorder
- Meteorological data logger
- Photo voltaic panels

Each acoustical sampling station collected:

- Sound level data in the form of A-weighted decibel readings (dBA) every second
- Continuous digital audio recordings
- One-third octave-band data every second ranging from 12.5 Hz – 20,000 Hz
- Meteorological data

3.2 Source Identification/Observer Logging

In characterizing natural and non-natural acoustical conditions in a park, knowledge of the intensity, duration, and distribution of the sound sources is essential. Thus, during sound-level data collection, FAA and NPS have agreed that periods of observer logging “*in situ*” (i.e., on site and in real-time) and/or off-site using high-quality digital recordings will be conducted in order to discern the type, timing, and duration of different sound sources. *In situ* observer logging takes full advantage of human binaural hearing capabilities, allows identification of sound source origin, simultaneous sound sources, and directionality, and closely matches the experience of park visitors. Off-site audio playback observer logging allows for sampling periodically throughout the entire measurement period (e.g., 10 seconds every 2 minutes) and repeated playback of the recordings (e.g. when the sound is difficult to identify). Bose Quiet Comfort Noise Canceling headphones were used for off-site audio playback to minimize limitations imposed by the office acoustical environment.

3.3 Calculation of Sound Level Descriptors

All sound-level data were analyzed in terms of the following metrics (also refer to the List of Terms section for definitions):

- L_{Aeq} : The equivalent sound level determined by the logarithmic average of sound levels of a specific time period;
- L_{50} : A statistical descriptor describing the sound level exceeded 50 percent of a specific time period (i.e., the median); and
- L_{90} : A statistical descriptor describing the sound level exceeded 90 percent of a specific time period.

For each descriptor, both the broadband A-weighted sound level is determined along with its associated one-third octave band un-weighted spectrum from 12.5 to 20,000 Hz. The process of computing the un-weighted one-third octave-band spectrum is virtually identical to the process for computing the broadband A-weighted sound level descriptors. The only difference is that the sound-level value is computed for un-weighted frequency-based sound levels rather than for broadband A-weighted sound levels. Specifically, the un-weighted sound level is computed individually for each one-third octave-band. The 33 un-weighted one-third octave-band sound levels (12.5 to 20,000 Hz) define the un-weighted sound level spectrum. This method of constructing the sound level spectrum means it is not an actual measured one-third octave band spectrum associated with a particular measurement sample, but a composite spectrum using the computed descriptor for each one-third octave-band.

3.4 Definitions of Ambient

The following four types of “ambient” characterizations are generally used and considered sufficient by the FAA and NPS in environmental analyses related to transportation noise (Fleming, et. al., 1999), (Fleming, et. al., 1998), (Plotkin, 2002).

- *Existing Ambient*: The composite, all-inclusive sound associated with a given environment, excluding only the analysis system’s electrical noise (i.e., aircraft-related sounds are included);
- *Existing Ambient Without Source of Interest*: The composite, all-inclusive sound associated with a given environment, excluding the analysis system’s electrical noise and the sound source of interest, in this case, commercial air tour aircraft (fixed-wing aircraft and helicopters);
- *Existing Ambient Without All Aircraft* (for use in assessing cumulative impacts): The composite, all-inclusive sound associated with a given environment, excluding the analysis system’s electrical noise and the sounds produced by the sound source of interest, in this case, all types of aircraft (i.e., commercial air tours, commercial jets, general aviation aircraft, military aircraft, and agricultural operations);³ and

³ The definition of Existing Ambient Without All Aircraft used in this report is consistent with FAA’s historical approach for cumulative impact analysis.

- *Natural Ambient*: The natural sound conditions found in a study area, including all sounds of nature (i.e., wind, streams, wildlife, etc.), and excluding all human and mechanical sounds.

If one considers the three sound level descriptors and the four types of ambient characterizations above, twelve ambient descriptors could potentially be computed as shown in Table 6.

Table 6. Matrix of twelve potential ambient descriptors.

Metric	Ambient Type			
	Existing	Existing Without Air Tours	Existing Without All Aircraft	Natural
L _{Aeq}	1	4	7	10
L ₅₀	2	5	8	11
L ₉₀	3	6	9	12

From the above twelve potential ambient descriptors, only the first three can be readily computed. The computation of ambient types other than Existing Ambient is more challenging because different sound sources often overlap in both frequency and amplitude; there is currently no practical method to separate out acoustic energy of different sound sources (i.e., human-caused sounds imbedded with natural sounds). The two ambient descriptors agreed upon for use in ATMP analyses are:

- L₅₀, Existing Ambient Without Source of Interest– Descriptor 5 from the table above; and
- L₅₀, Natural Ambient (L_{Nat})– Descriptor 11 from the table above.

3.5 Calculation of Ambients

Using the data in the acoustical observer logs, different characterizations of ambient can be estimated from the sound level data. This method was developed through detailed data analyses conducted by the Volpe Center, working closely with the NPS, comparing several approaches of estimating of the Natural Ambient and is comprised of the following steps: (Rapoza et. al., 2008)

- 1) From the short-term *in situ* and off-site logging, determine the percent time human-caused sounds are audible.
- 2) Sort, high-to-low, the A-weighted level data, derived from the short term, one-second, one-third octave-band data (regardless of acoustical state), and remove the loudest percentage (determined from the percent time audible of human-caused sounds in the short-term observer logs) of sound-level data. For example, if from Step 1 above, it is determined that at a particular site, the percent time audible of all human-caused sounds is 40 percent, then the loudest 40 percent of the A-weighted level data is removed. The L₅₀ computed from the remaining data is the estimated A-weighted natural ambient. This L₅₀, computed from the remaining data, can be mathematically expressed as an L_x of the entire dataset as follows (%TA is the percent of time human-caused sounds are audible in the short-term observer logs):

$$L_x, \text{ where } x = 50 + \frac{\%TA}{2}$$

For example, if non-natural sounds are audible for 40% of the time, L_0 to L_{40} corresponds to the loudest (generally non-natural) sounds, and L_{40} to L_{100} corresponds to the quietest (generally natural) sounds. The median of L_{40} to L_{100} data is L_{70} . Therefore, the A-weighted decibel value at L_{70} , the sound level exceeded 70 percent of the time, would be used for the entire dataset to characterize the natural ambient sound level.

- 3) The associated one-third octave-band un-weighted spectrum from 12.5 to 20,000 Hz is constructed similarly, except the L_{50} is computed from the remaining data for each one-third octave-band. As mentioned earlier, it is not an actual measured one-third octave-band spectrum associated with a particular measurement sample, but rather a composite spectrum derived from the L_x for each one-third octave-band.

This method for estimating the natural ambient is conceptually straightforward – as percent time audible approaches 0 percent, the L_x approaches L_{50} ; as it approaches 100 percent, the L_x approaches L_{100} . A concern with this approach is that sporadic, loud natural sounds, such as thunder, could be removed from the data before calculating natural ambient sound levels, and the resulting calculated natural ambient sound levels could be an under-estimate of natural ambient sound levels. Although this is a valid concern, such events are rare relative to the entire measurement period (>25 days). Therefore, removing these data should not likely have a significant impact on calculations of natural ambient sound levels. This method also eliminates the possibility of having an estimated natural ambient level that exceeds the existing ambient level.

Based on the concept of the above method, the computation of the other ambient types (Existing Without Air Tours, and Existing Ambient Without All Aircraft) is a similar process.

4. Results

This section summarizes the results of the study. Included are an overall summary of the final ambient sound levels for the measurement site, time above analysis, temporal trends, and the acoustical observer data logged at the measurement site.

4.1 Summary Results

The following figures and tables are presented to show overall season-to-season comparisons:

- Figure 2 presents a plot of the overall daytime⁴ L_{50} sound level computed for the site (a few points of interest outside the parks are also shown for comparison purposes only). The figure also shows a dark line above and below each plotting symbol, which indicate the 95% confidence interval on the results⁵;
- Table 7 contains a summary of the daytime and nighttime computed ambient; and
- Table 8 and Figure 4 through Figure 5 present the associated spectral data for these ambient maps.

⁴ For most parks, the majority of air tours occur during the day, the NPS and FAA have agreed that impact assessment will be conducted using ambient sound levels during the time that the air tour operations occur. Accordingly, all ATMP analysis are based on daytime ambient data. In general, daytime refers to time period of 7 am to 7 pm) unless otherwise specified by the NPS and FAA.

⁵ The confidence interval is a measure of how certain one is of the value shown. The length of each of the dark lines indicate the day-to-day variability of the measurement for a particular site - the longer the line, the larger the day-to-day variability.

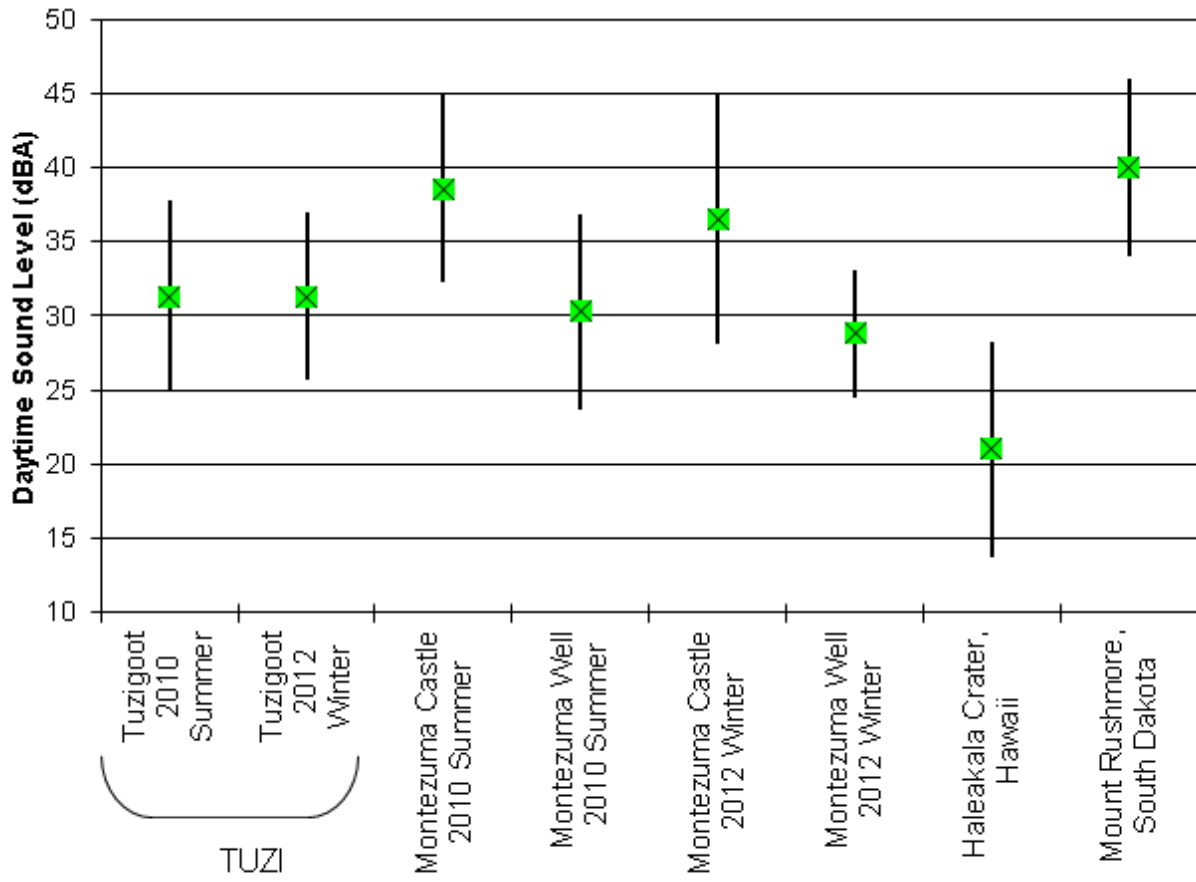


Figure 2. Comparison of overall daytime L50 sound levels.

Table 7. Summary of ambient sound level data. ⁶

Site ID	Site Name	Total # Days	Existing Ambient						Existing Ambient Without Air Tours (Daytime Data 7 am to 7 pm)	Existing Ambient Without All Aircraft (Daytime Data 7 am to 7 pm)	Natural Ambient (Daytime Data 7 am to 7 pm)
			Daytime Data Only: 7 am to 7 pm			Nighttime Data Only: 7 pm to 7 am					
			L _{Aeq} (dBA)	L ₅₀ (dBA)	L ₉₀ (dBA)	L _{Aeq} (dBA)	L ₅₀ (dBA)	L ₉₀ (dBA)			
Summer season (2010)											
TUZI001	Tuzigoot	31	41.5	31.3	25.7	40.7	32.8	28.1	29.7	28.4	25.7
Winter season (2012)											
TUZI001	Tuzigoot	42	41.3	30.9	26.3	31.9	24.3	18.9	29.3	28.2	26.6

⁶ As stated earlier, two ambient maps were agreed upon for use in ATMP analyses: the Existing Ambient Without Air Tours (L₅₀) and the Natural Ambient (L₅₀).

Table 8. Summary of measured, daytime (7 am to 7 pm), ambient sound level spectral data. ⁷

Frequency (Hz)	Existing Ambient Without Air Tours L ₅₀ (dB)		Natural Ambient L ₅₀ (dB)	
	Summer season (2010)	Winter season (2012)	Summer season (2010)	Winter season (2012)
	TUZI001	TUZI001	TUZI001	TUZI001
12.5	39.3	48.1	35.0	40.2
16	38.8	45.8	34.8	40.4
20	36.7	41.9	33.9	37.2
25	36.1	39.9	33.2	36.0
31	36.0	39.2	33.4	36.0
40	36.0	39.2	32.8	35.4
50	35.3	38.1	32.4	35.0
63	35.5	37.8	33.0	35.1
80	35.4	37.2	32.3	34.4
100	34.2	35.7	31.0	32.8
125	34.4	33.2	31.4	30.5
160	28.4	30.0	24.8	27.1
200	24.7	27.2	21.3	24.4
250	22.4	25.4	17.9	22.1
315	17.9	23.8	13.8	20.2
400	16.3	22.1	13.3	18.7
500	15.4	21.1	12.2	18.0
630	13.4	17.7	11.4	15.7
800	12.3	15.4	10.3	13.6
1000	10.9	12.5	9.1	10.5
1250	9.1	9.3	7.5	7.8
1600	7.8	6.5	5.5	5.1
2000	7.4	5.5	5.2	4.0
2500	8.2	5.6	5.0	4.1
3150	9.3	5.7	5.4	4.3
4000	9.2	5.9	5.4	4.6
5000	10.7	5.4	7.7	4.9
6300	9.8	6.2	5.4	5.6
8000	8.6	5.7	5.8	5.5
10000	8.4	5.9	6.5	5.7
12500	7.4	5.2	6.2	5.0
16000	5.4	3.0	4.6	2.8
20000	7.4	0.8	6.6	0.4

⁷ As discussed in Section 3.5, the spectral data associated with the L₅₀ exceedence level is constructed by determining the L₅₀ from each one-third octave-band; therefore, it is not an actual measured one-third octave-band spectrum associated with a particular measurement sample.

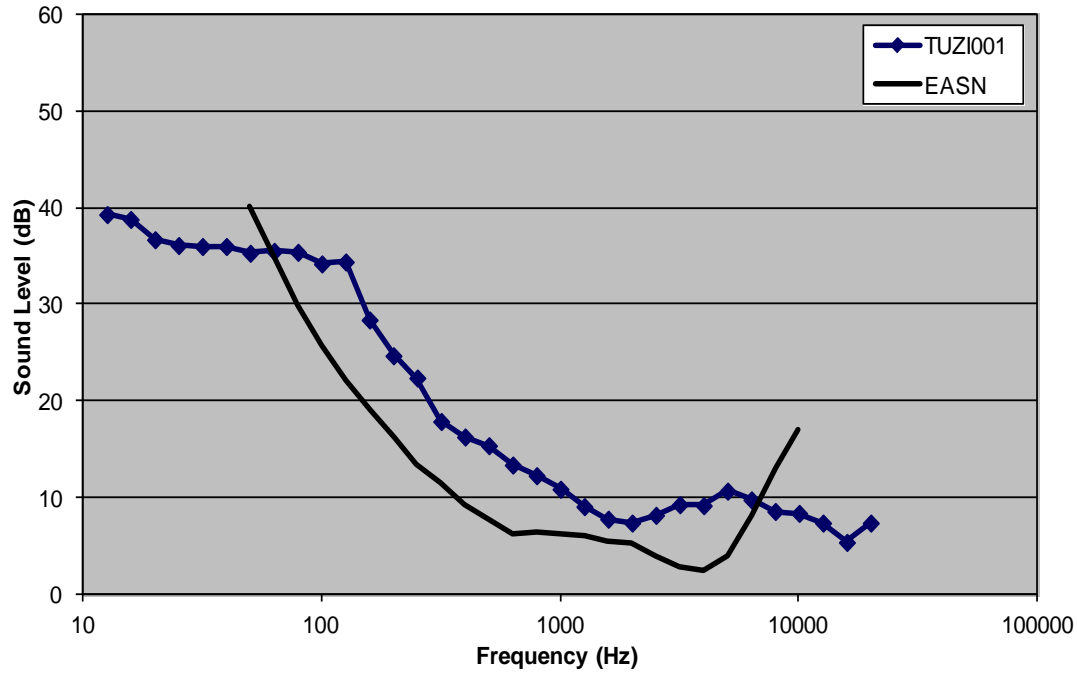


Figure 3. Daytime spectral data for the existing Ambient Without Air Tours (L_{50}), summer season (2010).⁸

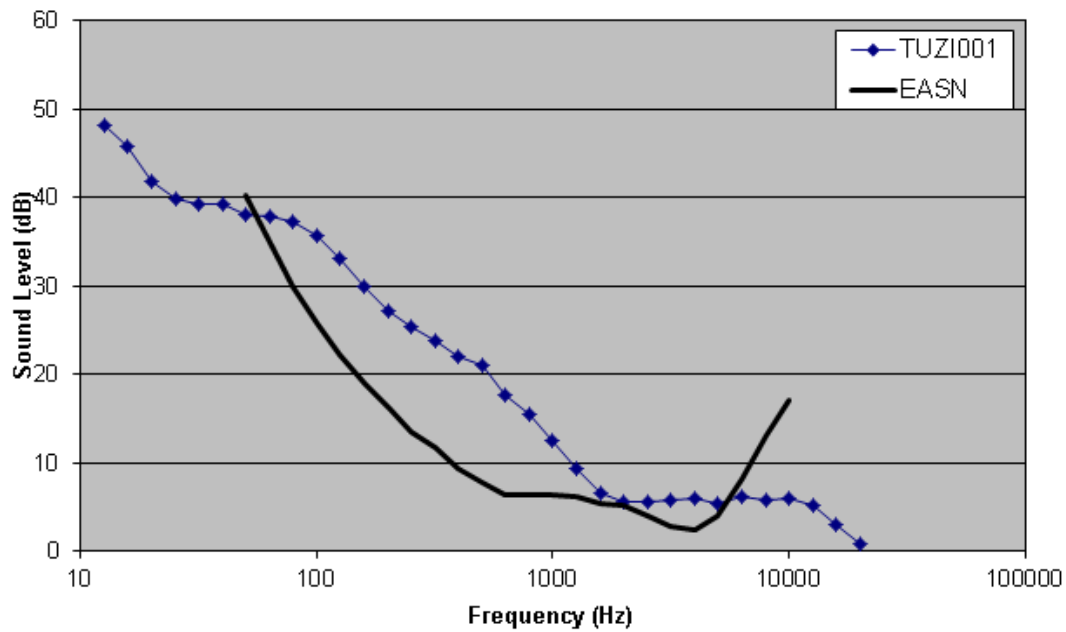


Figure 4. Daytime spectral data for the existing Ambient Without Air Tours (L_{50}), winter season (2012).⁸

⁸ Also shown in each figure is the Equivalent Auditory System Noise (EASN), which represents the threshold of human hearing for use in modeling audibility using one-third octave-band data.

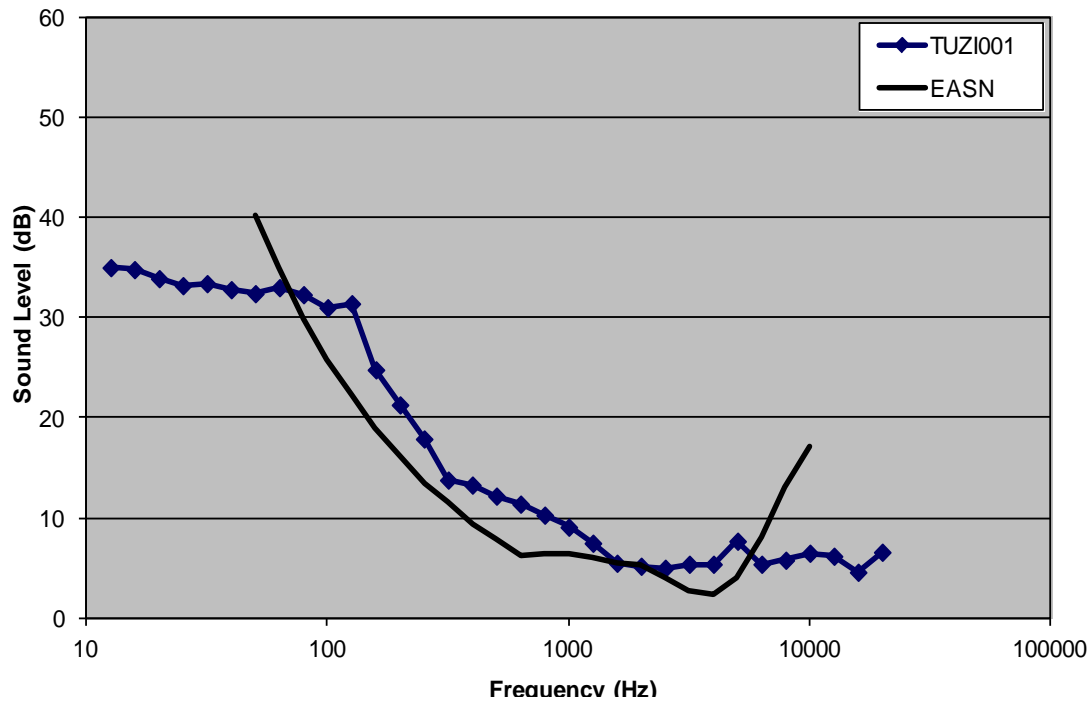


Figure 5. Daytime spectral data for the Natural Ambient (L_{50}), summer season (2010).⁹

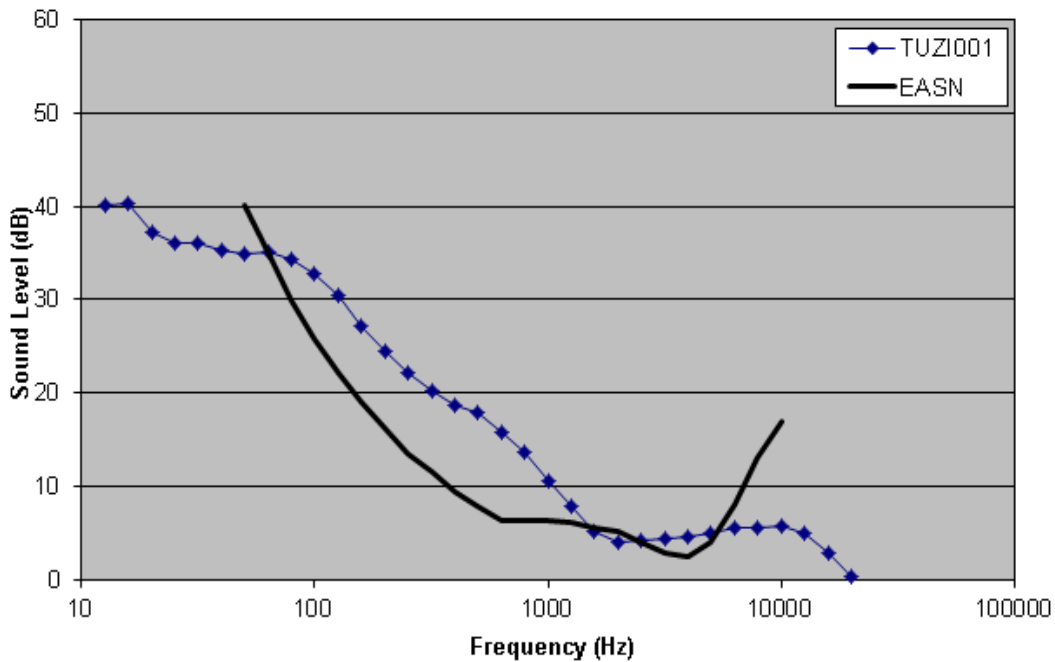


Figure 6. Daytime spectral data for the Natural Ambient (L_{50}), winter season (2012).⁹

⁹ Also shown in each figure is the Equivalent Auditory System Noise (EASN), which represents the threshold of human hearing for use in modeling audibility using $\frac{1}{3}$ -octave-band data.

4.2 Time Above Results

The Time Above metric indicates the amount of time that the sound level exceeds specified decibel values. In determining the current conditions of an acoustical environment, the NPS examines how often sound pressure levels exceed certain decibel values that relate to human health and speech. The NPS uses these values for making comparisons, but they should not be construed as thresholds of impact. Table 9 and Table 10 report the percent of time that measured levels were above four sound level values at the Tuzigoot measurement location. The first value, 35 dBA, addresses the health effects of sleep interruption (Haralabidis, et. al., 2008). The second value is based on the World Health Organization’s recommendation that noise levels inside bedrooms remain below 45 dBA (Berglund, et. al., 1999). The third value, 52 dBA, is based on the Environmental Protection Agency’s speech interference threshold for speaking in a raised voice to an audience at 10 meters (Environmental Protection Agency, 1974). This value addresses the effects of sound on interpretive presentations in parks. The final value, 60 dBA, provides a basis for estimating impacts on normal voice communications at 1 m (3 ft.). Hikers and visitors in the park would likely be conducting such conversations.

Table 9. Percent Time Above Metrics (dBA).

Site ID	Site Name	% Time above sound level: Daytime (7 am to 7 pm)				% Time above sound level: Nighttime (7 pm to 7 am)			
		35 dBA	45 dBA	52 dBA	60 dBA	35 dBA	45 dBA	52 dBA	60 dBA
Summer season (2010)									
TUZI001	Tuzigoot	24.4	3.2	0.9	0.2	35.7	1.6	0.12	0.0
Winter season (2012)									
TUZI001	Tuzigoot	23.5	3.5	0.6	0.1	3.8	0.3	0.0	0.0

Table 10. Percent Time Above Metrics (truncated spectra dBT).

Site ID	Site Name	% Time above sound level: Daytime (7 am to 7 pm)				% Time above sound level: Nighttime (7 pm to 7 am)			
		35 dBT	45 dBT	52 dBT	60 dBT	35 dBT	45 dBT	52 dBT	60 dBT
Summer season (2010)									
TUZI001	Tuzigoot	19.6	2.9	0.8	0.2	2.9	0.2	0.0	0.0
Winter season (2012)									
TUZI001	Tuzigoot	21.1	2.4	0.5	0.1	2.5	0.2	0.0	0.0

4.3 Temporal Trends

This section discusses the daily and diurnal trends of the data. Daily trends are shown on a 24-hour basis. Figure 7 presents the daily median Existing Ambient (i.e., the L_{50} with all sounds included). For the purpose of assessing daily trends in the data, sound level descriptors are computed for each individual hour; then the median from the 24 hours each day is determined. Dips and increases in daily sound levels are usually an indication of passing inclement weather and localized events. This data is useful in visually identifying potential anomalies in the data. Data anomalies would then be further examined from data recorded by the sound level meter and/or recorded audio samples.

Diurnal trends are shown in Figure 8 on an hourly basis. Sites with a strong daytime diurnal pattern typically indicate the presence of human activity largely influencing the sound levels at those sites. Sites with a nighttime pattern typically indicate the presence of insect activity. Sites with little discernible pattern, e.g., somewhat constant across all hours, typically indicates a constant sound source. Examples of constant sound sources include nearby brook or river. This data is also useful in visually identifying potential anomalies in the data.

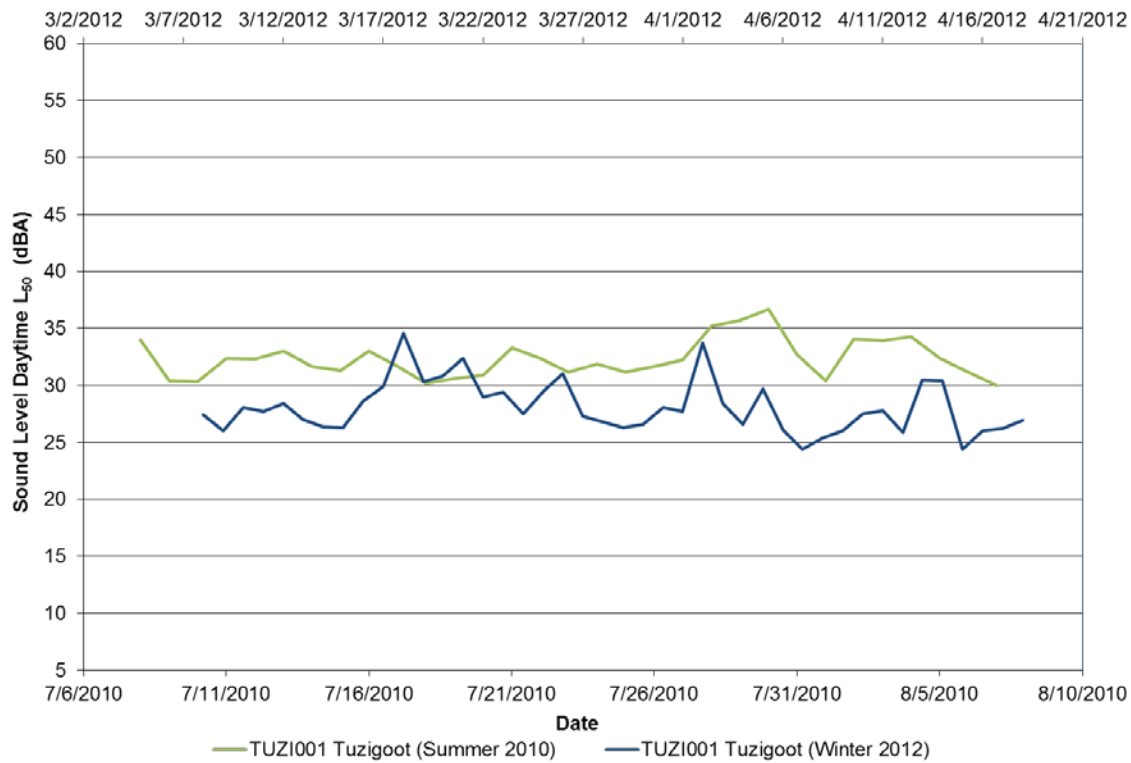


Figure 7. Comparison of daily L_{50} sound levels.

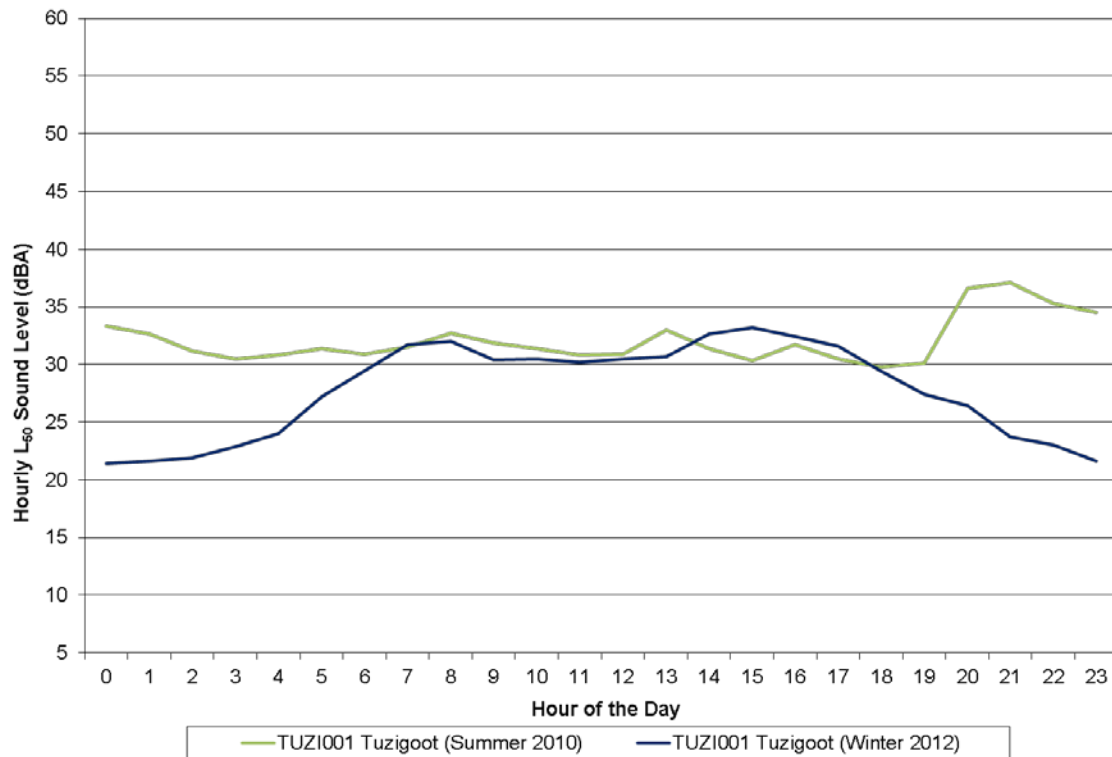


Figure 8. Comparison of hourly L_{50} sound levels.

4.4 Acoustical Observer Log Results

Table 11 and Table 12 summarize the daytime and nighttime¹⁰ combined listening results determined from both *in situ* and off-site sound source logs. This table provides an indication of the amount of time that certain sources are present at each site. *In situ* logging occurs on-site; an observer logs the source, time and duration of audible sounds. Typically a limited amount of *in situ* logging data is available due to measurement logistics. Off-site listening results are from a post-measurement review of the continuous audio files that were collected at each site. Continuous audio files were collected for the entire measurement and this allows a greater ability to listen and log sound sources for several days and any time period. *In situ* logging was performed in 2010, off-site listening in 2012. Table 12 summarizes the nighttime off-site listening results for the winter measurements.

Table 11. Summary of daytime acoustical observer log data (*in situ* and off-site listening combined).

Site ID	Site Name	% Time Audible: Daytime (7 am to 7 pm)			
		Fixed-Wing Aircraft and Helicopters	Other Aircraft Sounds	Other Human Sounds	Natural Sounds
Summer season (2010)					
TUZI001	Tuzigoot	23.1	20.7	39.5	16.8
Winter season (2012)					
TUZI001	Tuzigoot	23.0	19.4	31.1	26.6

Table 12. Summary of nighttime acoustical observer log data (off-site listening).

Site ID	Site Name	% Time Audible: Nighttime (7 pm to 7 am)			
		Fixed-Wing Aircraft and Helicopters	Other Aircraft Sounds	Other Human Sounds	Natural Sounds
Winter season (2012)					
TUZI001	Tuzigoot	2.7	10.2	64.8	22.3

¹⁰ Nighttime acoustical observer logs are not available for the 2010 summer season.

5. Ambient Mapping

Using the ambient data measured at the site, a comprehensive grid of ambient sound levels throughout the park (i.e., an ambient “map”) is developed. Ambient maps are useful to: (1) graphically characterize the ambient environment throughout an entire study area; and (2) to establish baseline, or background values in computer modeling. For ATMPs, the FAA’s Integrated Noise Model (INM)¹¹ will be used to model air tour aircraft activities and compute various noise-related descriptors (e.g., percentage of time aircraft sounds are above the ambient) and generate the sound-level contours that will be used in the assessment of potential noise impacts due to air tour operations.

The development of ambient maps is accomplished using Geographic Information System (GIS). In GIS, the following actions are performed:

- Define the input “objects”:
 - Define the park boundary in Universal Transverse Mercator (UTM)¹² coordinates to set the initial grid area boundary.¹³
 - Divide the park into a regular grid of points at a desired spacing using a Digital Elevation Model (DEM), which is a digital representation of a topographic surface typically used in GIS applications. Each point is assigned an elevation value and UTM coordinates from the DEM. Note: For Tuzigoot, a grid spacing of 100 ft (30.5 m) was used.
 - Define the acoustical zone boundaries in UTM coordinates.
 - Define the location of each measurement site.
- Assign a “measured” ambient sound level (and its associated one-third octave-band, unweighted spectrum), computed in Section 3.5, to each to each grid point within an acoustical zone.

For development of all ambient maps, except for Natural Ambient, three additional steps are performed:

- Define the location of localized noise sources, primarily vehicles on roads, but may also include brooks, waterfalls, and river rapids. The closest distance to each source is calculated and assigned to each grid point.

¹¹ For ATMPs, the FAA and NPS have agreed to use the INM. The INM is a computer program used by over 700 organizations in over 50 countries to assess changes in noise impact. Requirements for INM use are defined in FAA Order 1050.1E, Environmental Impacts: Policies and Procedures, and Federal Aviation Regulations (FAR) Part 150, Airport Noise Compatibility Planning. In accordance with the results of the Federal Interagency Committee on Aviation Noise (FICAN) review (“Findings and Recommendations on Tools for Modeling Aircraft Noise in National Parks”), INM Version 6.2 is the best-practice modeling methodology currently available for evaluating aircraft noise in national parks and will be the model used for ATMP development.

¹² The UTM system provides coordinates on a worldwide flat grid for easy manipulation in GIS applications.

¹³ Because the ATMP Act applies to all commercial air tour operations within the ½-mile outside the boundary of a national park, the park boundary included a ½-mile buffer.

- Assign an ambient sound level (and its associated one-third octave-band, un-weighted spectrum) for each roadway to each grid point using the drop-off rates determined by computer modeling discussed in Section 5.2.
- Compute a combined measured and roadway ambient (and spectra). This is performed by using energy-addition, i.e., sound levels in decibels were converted to energy prior to addition.

The final ambient maps are presented in Section 5.3.

5.1 Assignment of Measured Ambient Data to Acoustical Zones

Because it is neither economically nor expeditiously feasible to manually collect noise data under all possible conditions throughout an entire park, areas of like vegetation, topography, elevation, and climate were grouped into “acoustical zones,” with the assumption that similar wildlife, physical processes, and other sources of natural sounds occur in similar areas with similar attributes. The primary goal of the site selection process was to identify the minimum number of field measurement sites, which would allow for characterization of the baseline ambient sound levels throughout the entire park by assigning measured data stratified to these acoustical zones. The following considerations are used in the determination of acoustical zones:

- **Vegetation/Land Cover:** Sound propagates differently over different types of ground cover and through different types of vegetation. For example, sound propagates more freely over barren environments as compared with grasslands, and less freely through forest type environments. In addition, vegetation is typically dependent upon time-of-year, with foliage being sparser in the winter than other times in the year. Land cover can also affect wildlife activity.
- **Climate Conditions:** Climate conditions (temperature, humidity, precipitation, wind speed, wind direction, etc.) can also affect ambient sound levels. For example, higher elevation areas typically exhibit higher wind speeds resulting in higher ambient sound levels. Climate is also dependent upon daily and seasonal variations, which can affect ambient sound levels. For example, under conditions of a temperature inversion (temperature increasing with increasing height as in winter and at sundown), sound waves may be heard over larger distances; and winds tend to increase later in the day, and, as such, may be expected to contribute to higher ambient noise levels in the afternoon as compared with the morning.
- **Park Resources/Management Zones:** Park resources contribute, not only, to the multitude of sounds produced in certain areas of the park, but also to the serenity of other areas in the park. The way in which a park manages its resources can affect how potential impacts may be later assessed. It may also help identify where greater resource protection may be needed.

Based on the above considerations, Figure 9 presents the acoustical zones that were developed and the location of the measurement site for TUZI. The ATMP Act applies to all commercial air tour operations within the ½-mile outside the boundary of a national park. As noted in Section 2, based on discussions between Volpe, NSNSD, and TUZI personnel, it was agreed that because TUZI is a relatively small park, one site was recommended. Therefore data collected at this site were applied for all acoustical zones for this park.

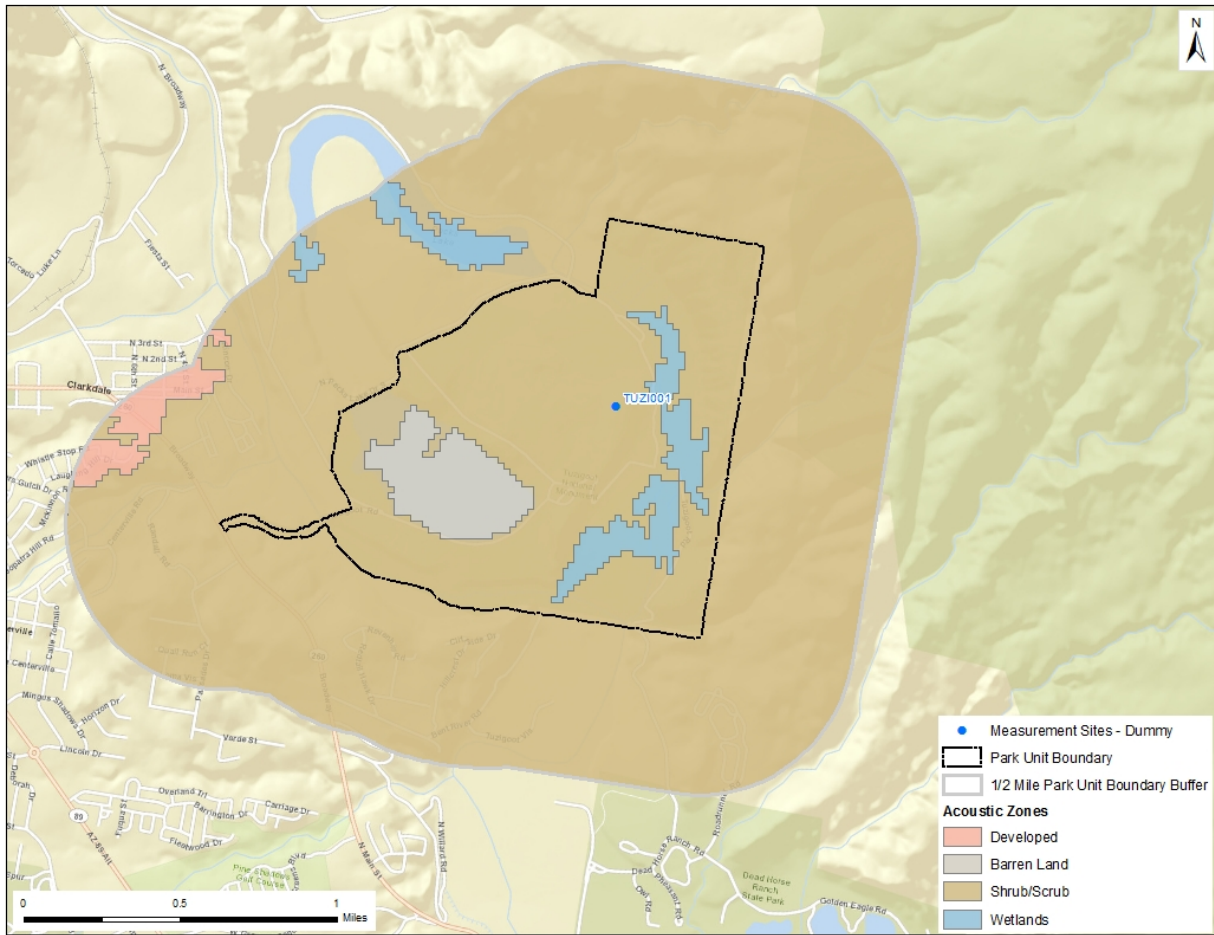


Figure 9. Acoustical zones and measurement sites for TUZI.

Table 13. Assignment of ambient data to acoustical zones.

Acoustical Zone	Site ID	Site Name
Developed	TUZI001	Tuzigoot
Barren Land	TUZI001	Tuzigoot
Shrub/Scrub	TUZI001	Tuzigoot
Wetlands	TUZI001	Tuzigoot

5.2 Ambient Mapping of Localized Sound Sources

The contributing of localized noise sources, primarily vehicles on roads, but may also include brooks, waterfalls, and river rapids, are typically modeled and combined with the measured sound levels to develop a composite, baseline, ambient “map” of a park for all ambient maps, except natural ambient (see Table 14). The combined (measured plus roadway, for example) ambient are computed by using energy-addition, i.e., sound levels in decibels were converted to energy prior to addition. Roadway

sound sources were modeled using the Federal Highway Administration’s Traffic Noise Model[®] (TNM) where the estimated drop-off rate, reflecting a continuous decrease in sound level as a function of increasing distance from each sound source, was computed (Lee, 2004). For a non-time-varying source, such as roadway noise, the TNM-computed L_{Aeq} sound level parameters may be conservatively assumed to be equivalent to the L_{50} and L_{90} and, thus, used interchangeably as the “roadway” ambient.

Table 14. Composite ambient maps.

Metric	Ambient Type			
	Existing	Existing Without Sound Source of Interest	Existing Without All Aircraft	Natural
L_{50}	Measured + Localized Noise Source(s)	Measured + Localized Noise Source(s)	Measured + Localized Noise Source(s)	Measured

In the vicinity of and within TUZI, there were a number of roadways. The following general assumptions were made in the modeling:

- Roadway Traffic Volumes - Annual traffic volume on each roadway was determined using data collected by the Arizona Department of Transportation (AZDOT) (Arizona Department of Transportation 2013). Where data are available for multiple years, the corresponding study year was chosen. The traffic volume for an average day during the peak winter month (February) and the peak summer month (May) were obtained by using monthly visitation data obtained from the NPS Public Use Statistics Office website (National Park Service 2013b) to apportion the AZDOT annual traffic. Hourly volume is estimated by dividing the month’s volume by the number of days in the month (28) and by 12 hours per day, which assumes the majority of traffic for TUZI occurs between 7:00 am and 7:00 pm – typical commute hours.
- Roadway Traffic Mix and Speeds –The traffic mix and speeds on a given roadway were based on two sources: (1) The NPS Monthly Usage information (National Park Service 2013b); and (2) observations by field personnel during previous site visits. In some cases, a specific speed limit was determined using Google Maps using the “street view” to view an actual speed limit sign. When multiple speed limit signs showed varying speeds over a single road segment, an average. In some specific cases, notations from the Volpe field notes en route to measurement site locations were used to determine speed limits over various segments. An average speed of 35 mph was assumed as the default within the park when another more specific speed limit could not be determined.
- Ground Impedance – An effective flow resistivity of 1000 cgs/rayls was used for Tuzigoot.

Table 15. Estimated hourly roadway traffic volume and speed.

Roadway			Estimated hourly volume				
#	Name	Average Speed (mph)	Autos	Medium Trucks	Heavy Trucks	Buses	Motorcycles
Summer season (2010)							
1	Tuzigoot Rd (Traffic entering the park)	25	11	0	0	0	0
2	SR 89A (Dundee Mine Rd. to Verde Valley Tower Rd./Turquoise)	35	301	12	7	0	10
3	SR 89A (Verde Valley Tower Rd./Turquoise to Old Hwy 89A)	35	493	20	11	1	16
4	SR 89A (Old Hwy 89A to Verde Heights Dr./Black Hills Dr)	35	1,049	42	24	1	34
5	SR 89A (Verde Heights Dr./Black Hills Dr. to 6th St)	35	1,642	66	38	2	54
6	SR 89A (6th St to Main St / Cottonwood St)	35	2,052	82	48	2	67
7	SR 89A (Cottonwood St to SR 260)	35	2,508	101	58	3	82
8	SR260 (SR 89A to Godard Rd)	45	1,916	77	44	2	63
9	SR 260(Godard to Prairie Ln)	45	2,144	86	50	3	70
10	Main St	35	456	18	11	1	15
11	SR 89A (SR260 to Cornville Rd/Forest 119 Rd)	35	1,779	71	41	2	58
12	SR 89A (Cornville Rd to page Springs Rd)	35	1,140	46	26	1	37
Winter season (2012)							
1	Tuzigoot Rd (Traffic entering the park)	25	8	0	0	0	0
2	SR 89A (Dundee Mine Rd. to Verde Valley Tower Rd./Turquoise)	35	241	10	6	0	8
3	SR 89A (Verde Valley Tower Rd/ Turquoise to Old Hwy 89A)	35	383	15	9	0	13
4	SR 89A (Old Hwy 89A to Verde Heights Dr./Black Hills Dr.)	35	850	34	20	1	28
5	SR 89A (Verde Heights Dr./Black Hills Dr. to 6th St.)	35	1,311	53	30	2	43
6	SR 89A (6th St to Main St. /Cottonwood St.)	35	1,630	65	38	2	53
7	SR 89A (Cottonwood St. to SR 260)	35	1,984	80	46	2	65
8	SR260 (SR 89A to Goddard Rd)	45	1,524	61	35	2	50
9	SR 260(Goddard Rd to Prairie Ln)	45	1,665	67	39	2	55
10	Main St.	35	354	14	8	0	12
11	SR 89A (SR260 to Cornville Rd/Forest 119 Rd)	35	1,382	55	32	2	45
12	SR 89A (Cornville Rd to Page Springs Rd)	35	886	36	21	1	29

5.3 Final Ambient Maps

The two ambient maps agreed upon for use in ATMP analyses are:

- Existing Ambient Without Air Tours (i.e., the Source of Interest); and
- Natural Ambient.

Figure 10 through Figure 13 present the ambient maps for the summer and winter seasons.

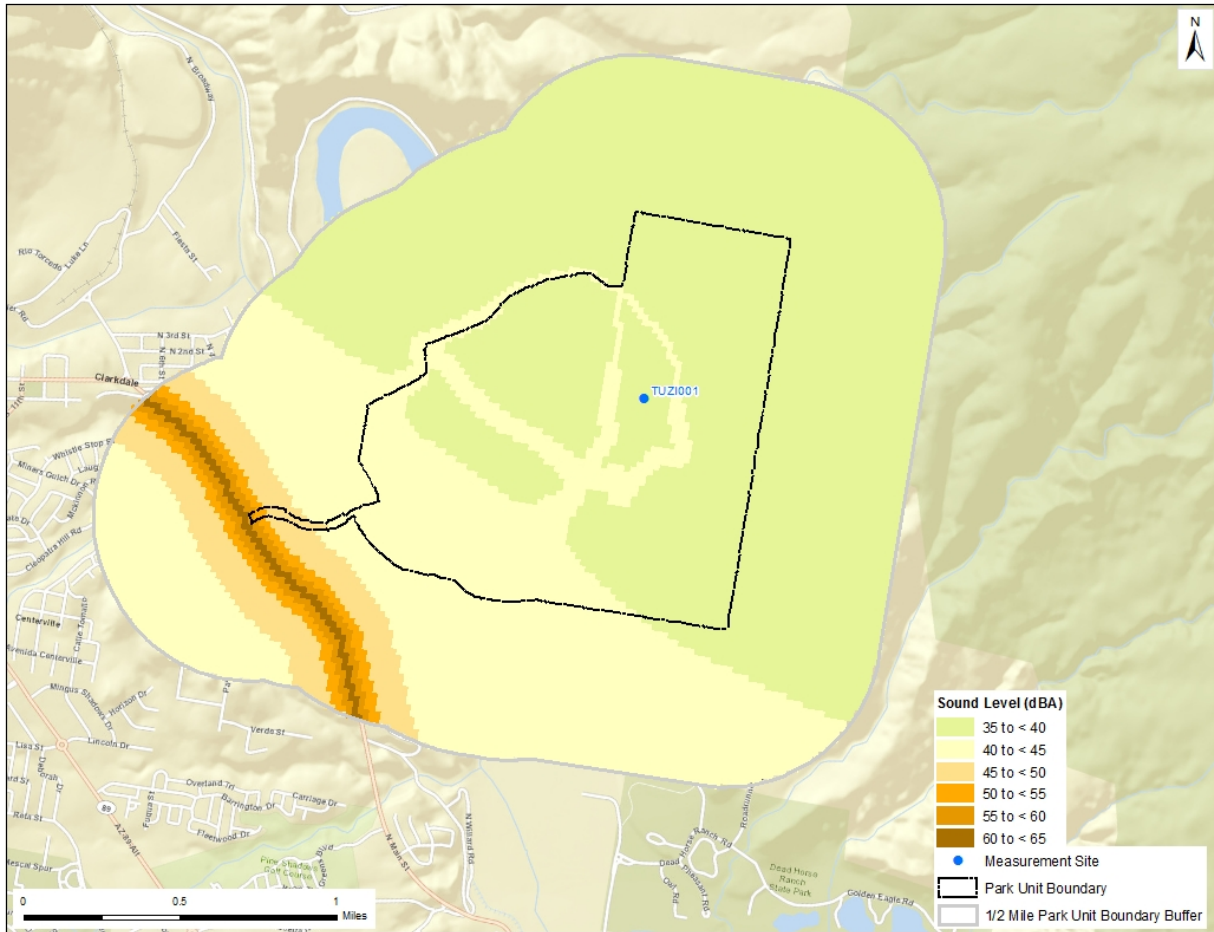


Figure 10. Baseline ambient map; Existing Ambient Without Air Tours (L₅₀) for the summer season (2010).

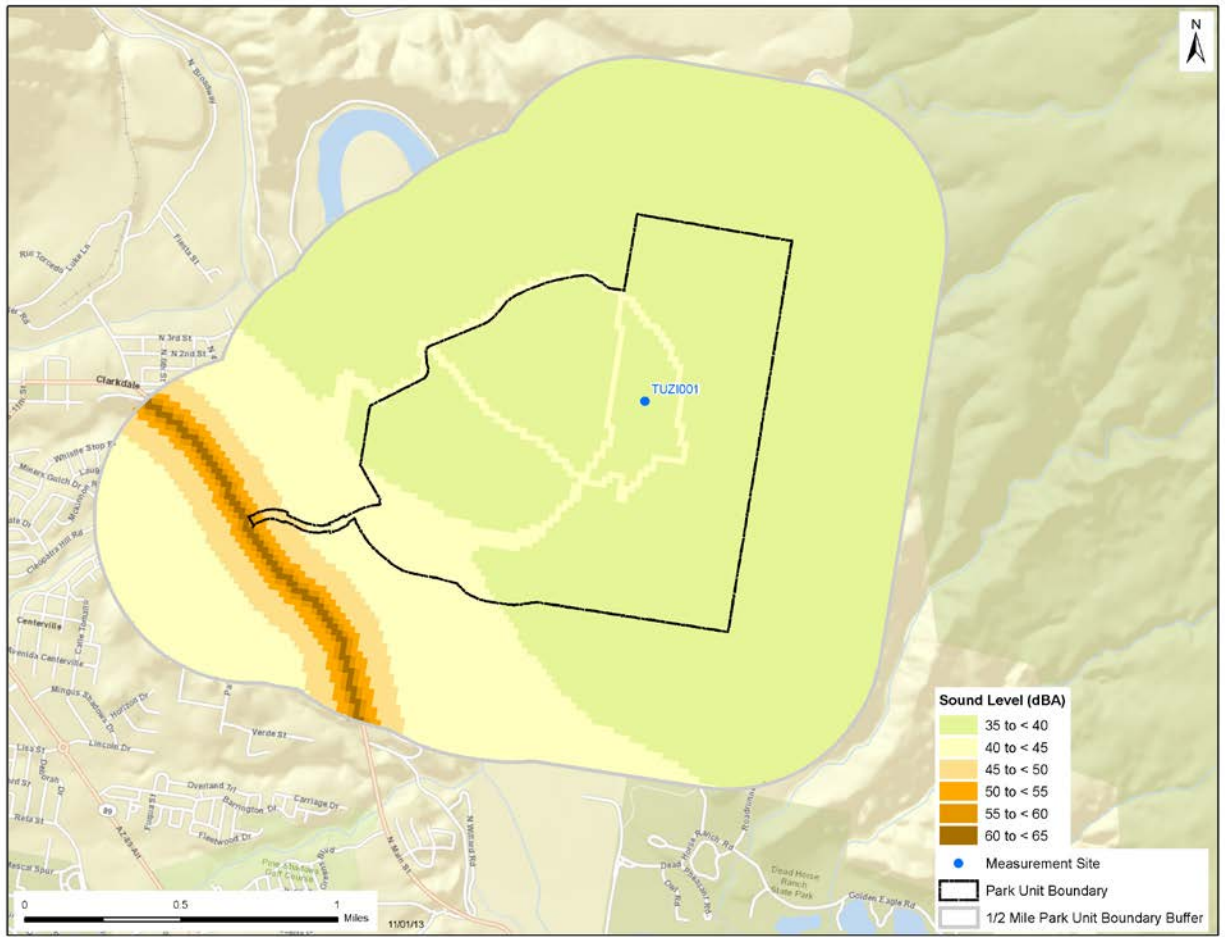


Figure 11. Baseline ambient map; Existing Ambient Without Air Tours (L_{50}) for the winter season (2012).

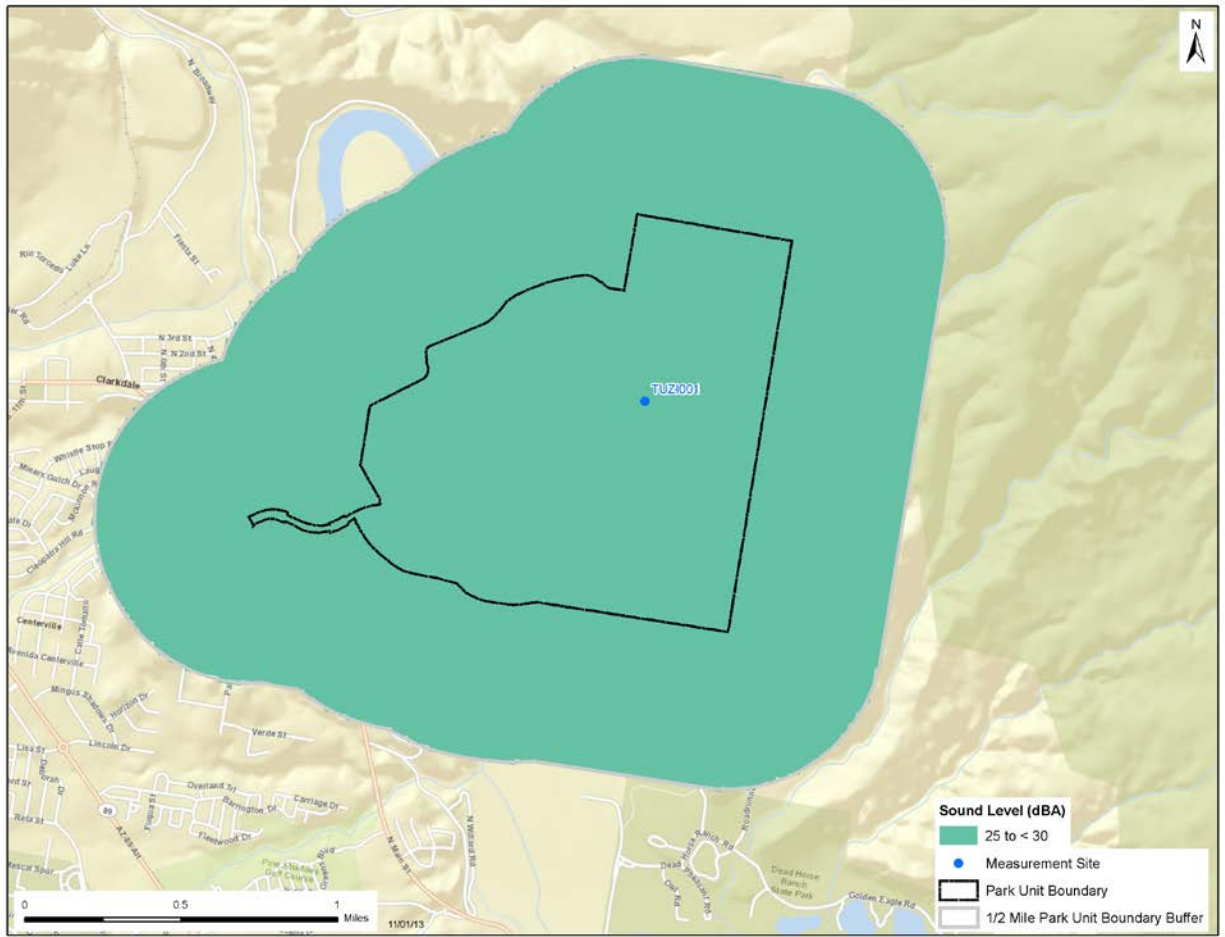


Figure 12. Baseline ambient map; Natural Ambient (L₅₀) for the summer season (2010).

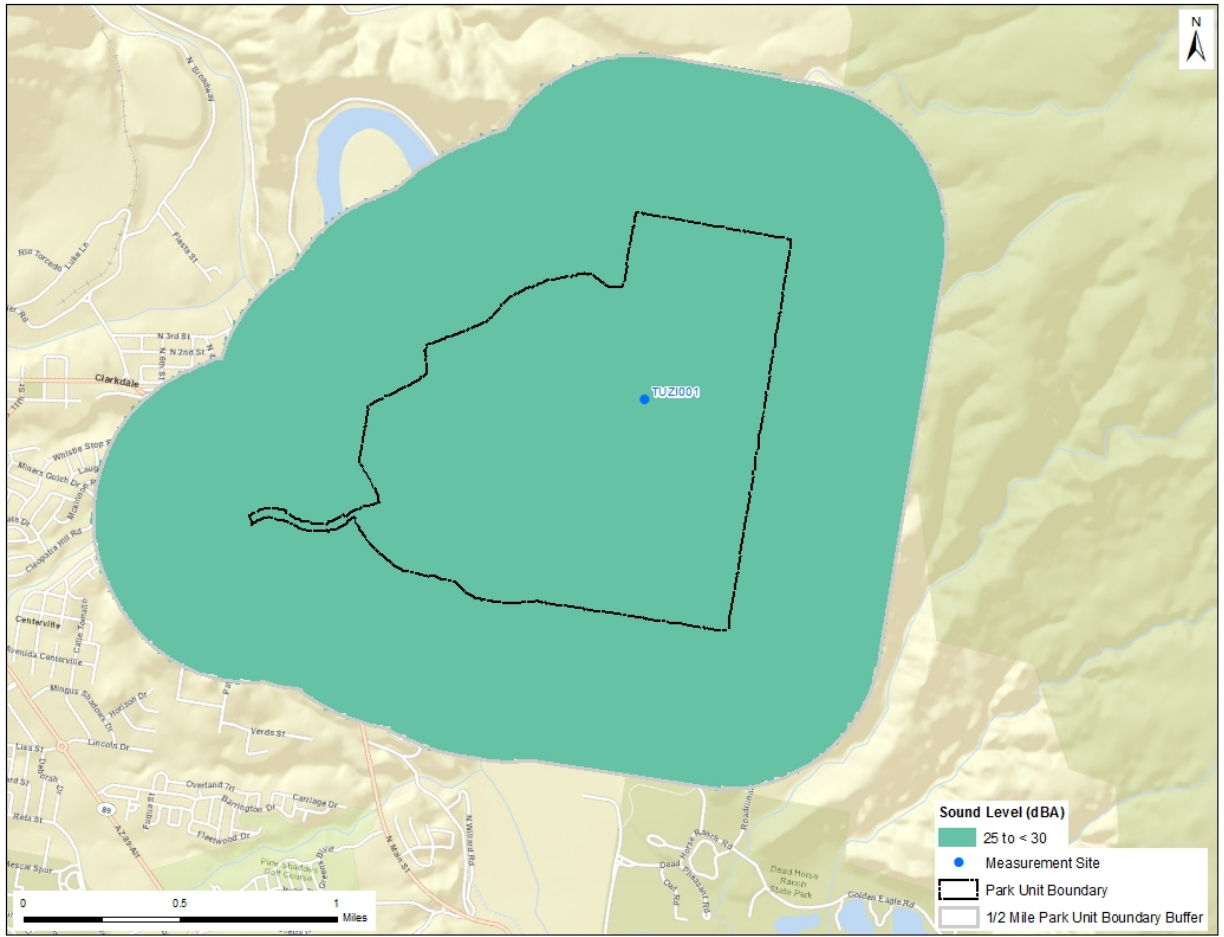


Figure 13. Baseline ambient map; Natural Ambient (L_{50}) for the winter season (2012).

6. Data for Individual Sites

This section provides more detailed information for each individual site. For each site, the following are included:

- Figure 14: A photograph of the measurement site and a brief discussion of preliminary observations;
- Figure 15, Figure 16: A pie chart presenting a comparison of types of sound sources that were audible during observer logging;
- Figure 17, Figure 18: A graphic presenting distribution plots of the number of 1-second samples of each sound pressure level measured during daytime and nighttime hours, and daytime/nighttime combined;
- Figure 19, Figure 20: A graphic presenting the daily sound levels using three hourly A-weighted metrics (L_{Aeq} , L_{50} , and L_{90} - refer to Terminology for definitions), as well as average daily wind speeds over the entire measurement period;
- Figure 21, Figure 22: A graphic presenting the hourly sound levels using three hourly A-weighted metrics (L_{Aeq} , L_{50} , and L_{90} - refer to Terminology for definitions), as well as average hourly wind speeds over the entire measurement period; and
- Figure 23, Figure 24: A graphic presenting the dB levels for each of the 33 one-third octave-band frequencies over the day and night periods using three hourly A-weighted metrics (L_{10} , L_{50} , and L_{90}). The L_{10} exceedence level represents the dB exceeded 10 percent of the time and 90 percent of the measurements are quieter than the L_{10} . Refer to Terminology for definitions of L_{50} and L_{90} . The grayed area represents sound levels outside of the typical range of human hearing.

6.1 Site TUZI001 – Tuzigoot



Figure 14. Photographs of Site TUZI001, summer 2010 (left) and winter 2012 (right).

The TUZI001 Tuzigoot site was located on the ridge overlooking the trail, approximately 3 miles from Cottonwood Airport, 2.1 miles from Highway 89A, and 1.7 miles from the Verde Canyon Railroad. The measurement system collected data from July 8, 2010 to August 7, 2010 for the summer season and from March 8, 2012 to April 18, 2012 to represent the winter season. The vegetation near the measurement system consisted of desert scrub at an altitude of 3,412 feet for the winter season and an altitude of 3,441 feet for the summer season. Daytime sources of sound included vehicle sounds, birds, insects, commercial jet aircraft, propeller aircraft, and wind related sounds.

The daytime on-site observations and off-site review of recorded audio data (Figure 15) show nearly identical aircraft audibility during daytime hours of the winter and summer seasons (42% and 44% respectively). Other human-related sounds were more prevalent during the summer (39% versus 31%), while noise-free time periods were more frequent during the winter season (27% versus 17%). Figure 16 summarizes the nighttime winter season off-site review of recorded audio data (off-site review was not performed for the summer season data). Aircraft were audible 13% of nighttime hours, other human-related sounds 65% of nighttime hours, while noise-free time periods accounted for 22% of nighttime hours. The majority of other human-related sounds during nighttime hours were due to vehicles on nearby roadways.

The overall median daytime sound level for this site was 31.4 dBA during the summer season and 31.2 dBA during the winter season. Daily (twenty-four hour) median sound levels (L_{50}) at the Tuzigoot site ranged from 30 to 37 dBA during the summer and 24 to 37 during the winter. Hourly median sound levels varied from 29 to 37 dBA during the summer and 21 to 33 dBA during the winter. Particularly loud days on August 3rd and 7th, 2010 were associated with thunderstorms and in the area. Nighttime sound levels were slightly louder than the overall daytime sound levels in the summer (due to insects), while the reverse occurred during the winter (due to wind).

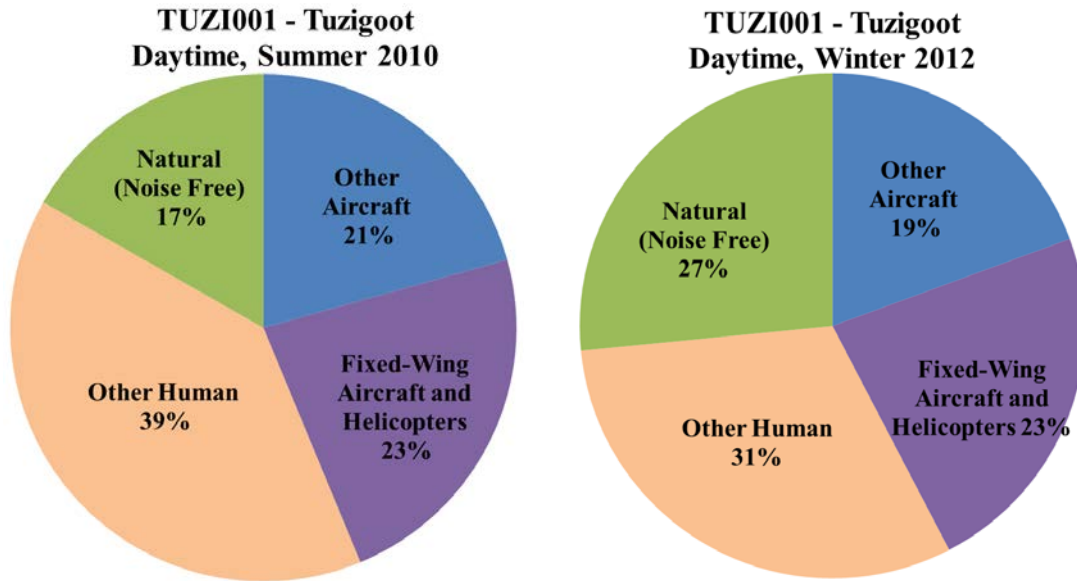


Figure 15. Distribution of daytime sound sources audible (*in situ* and off-site listening combined) for Site TUZI001, summer season (2010) (left) and winter season (2012) (right).

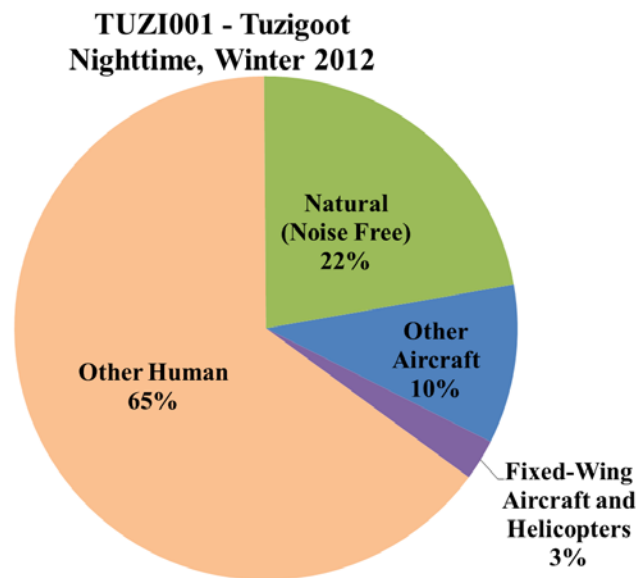


Figure 16. Distribution of nighttime sound sources audible (off-site listening) for Site TUZI001, winter season (2012) (summer season data unavailable).

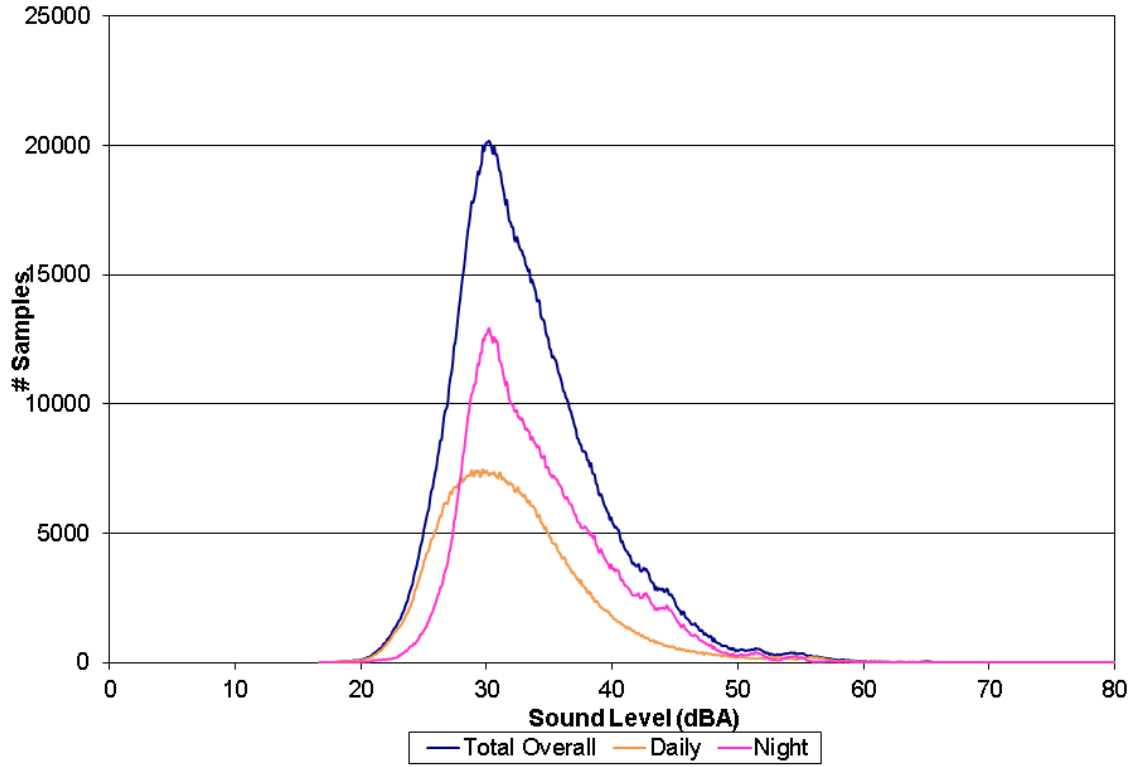


Figure 17. Distribution of sound level data for Site TUZI001, summer season (2010).

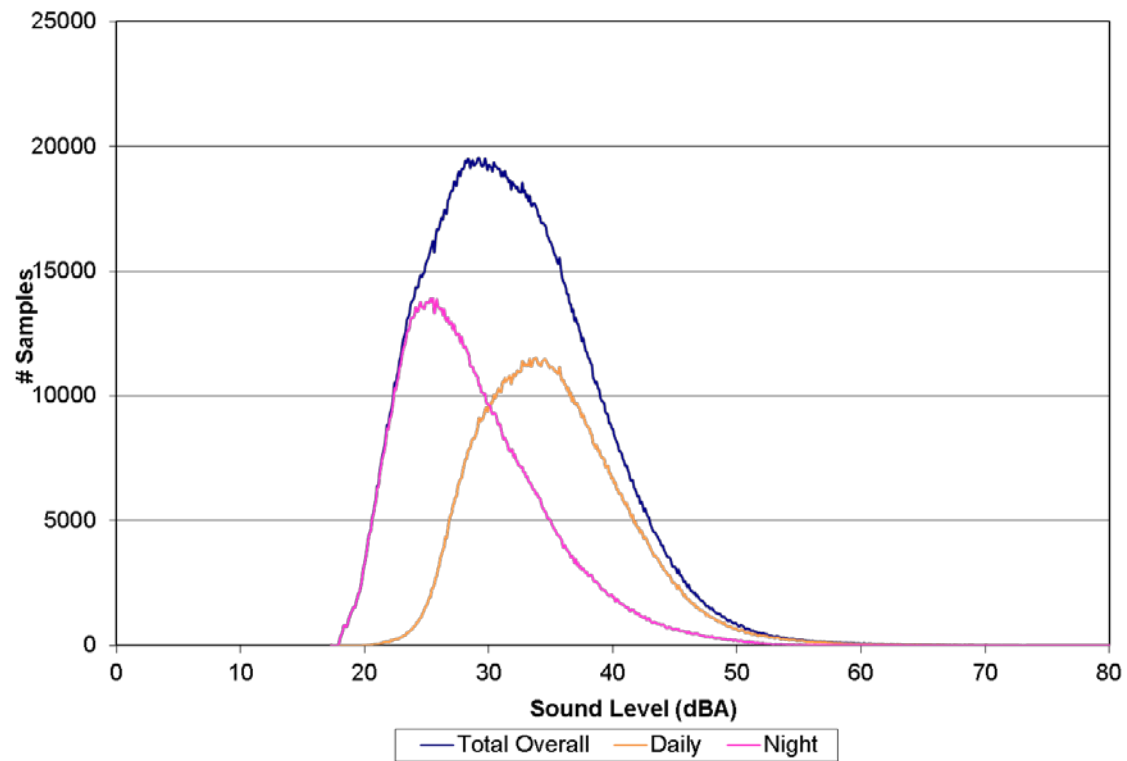


Figure 18. Distribution of sound level data for Site TUZI001, winter season (2012).

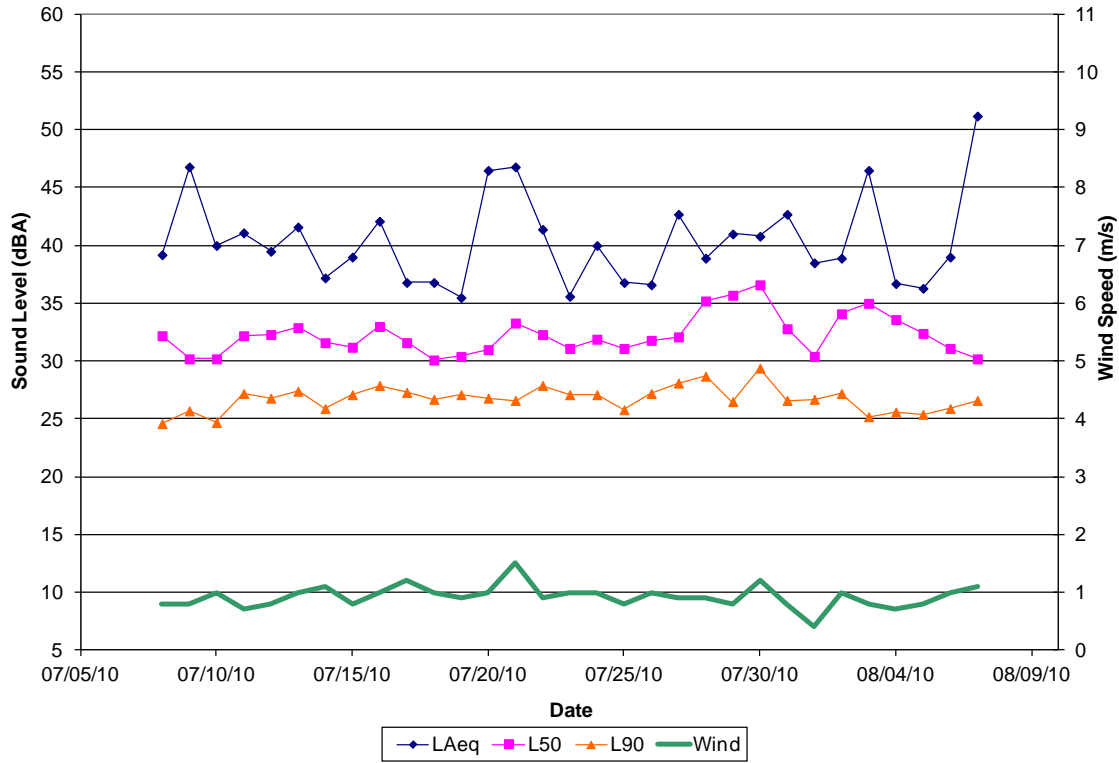


Figure 19. Daily sound levels and wind speeds for Site TUZI001, summer season (2010).

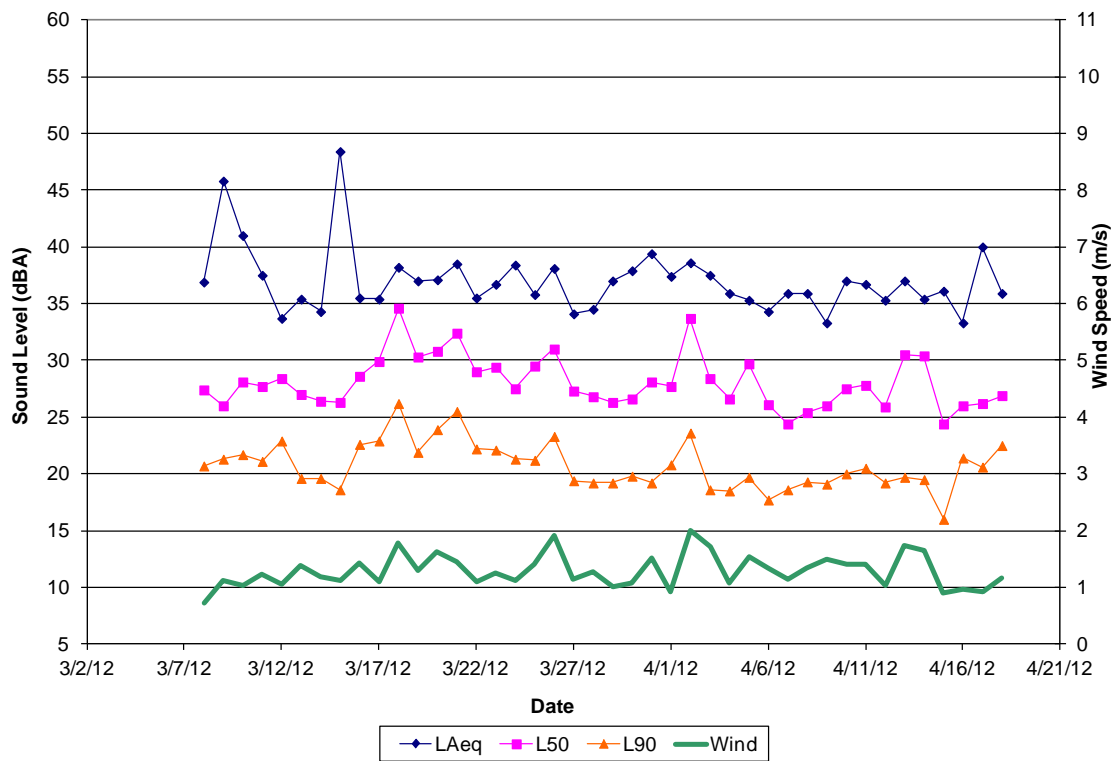


Figure 20. Daily sound levels and wind speeds for Site TUZI001, winter season (2012).

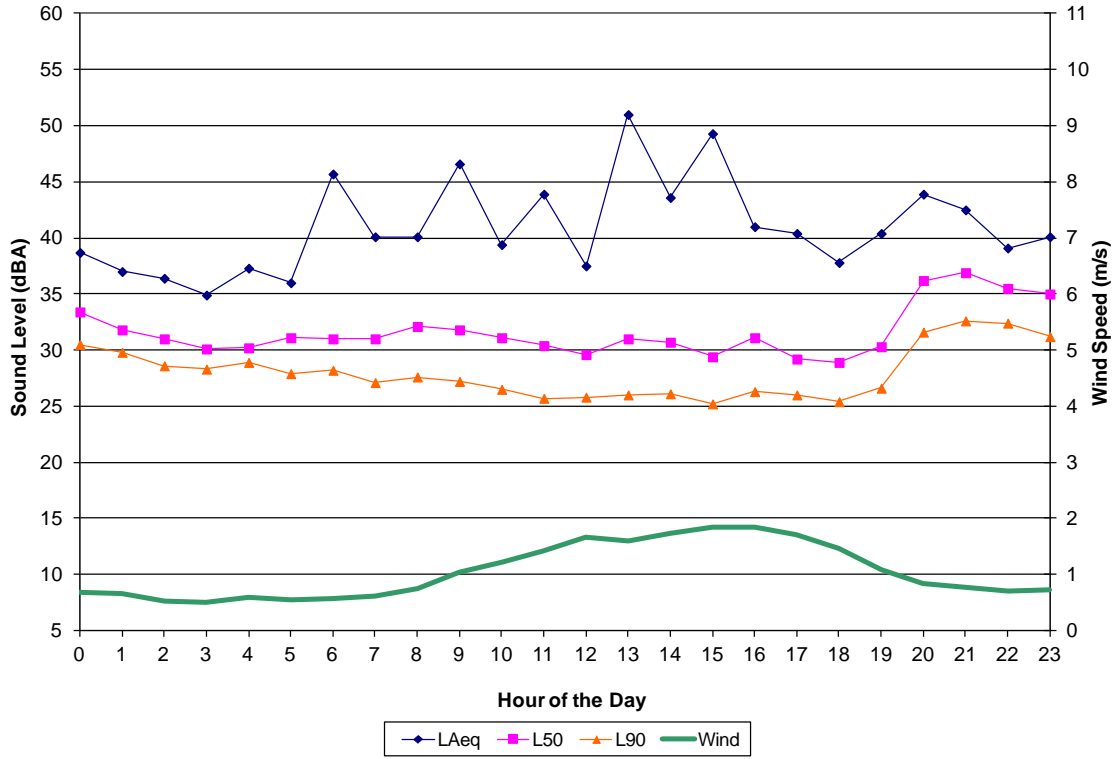


Figure 21. Hourly sound levels and wind speeds for Site TUZI001, summer season (2010).

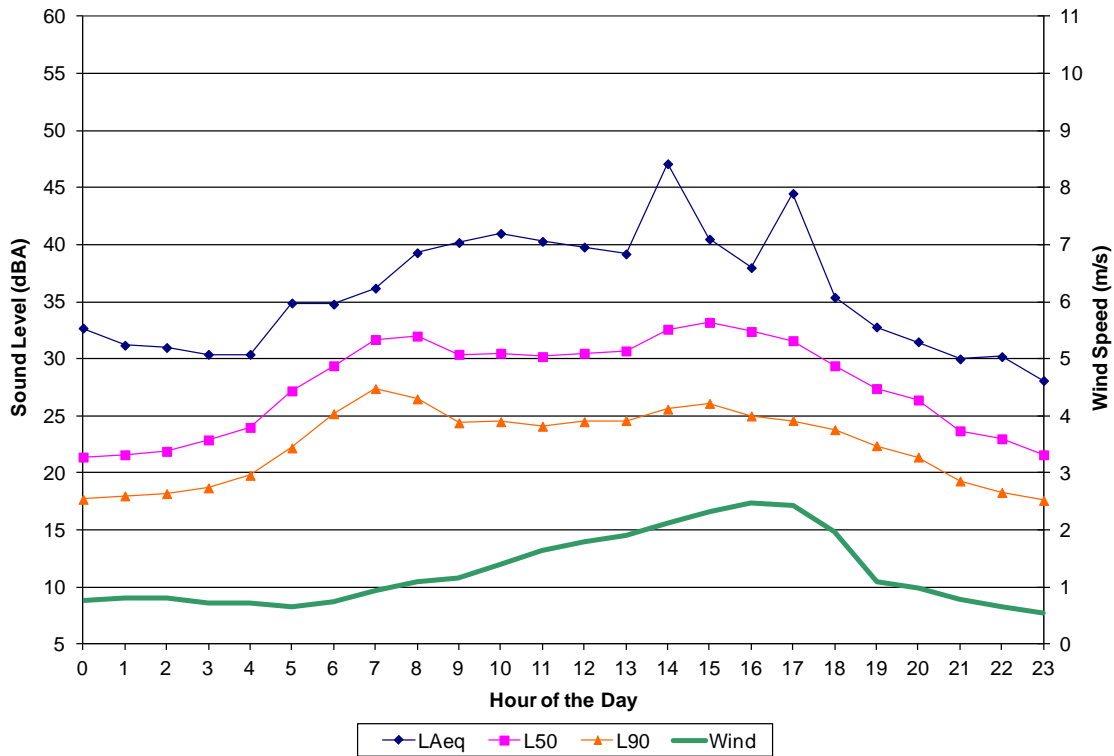


Figure 22. Hourly sound levels and wind speeds for Site TUZI001, winter season (2012).

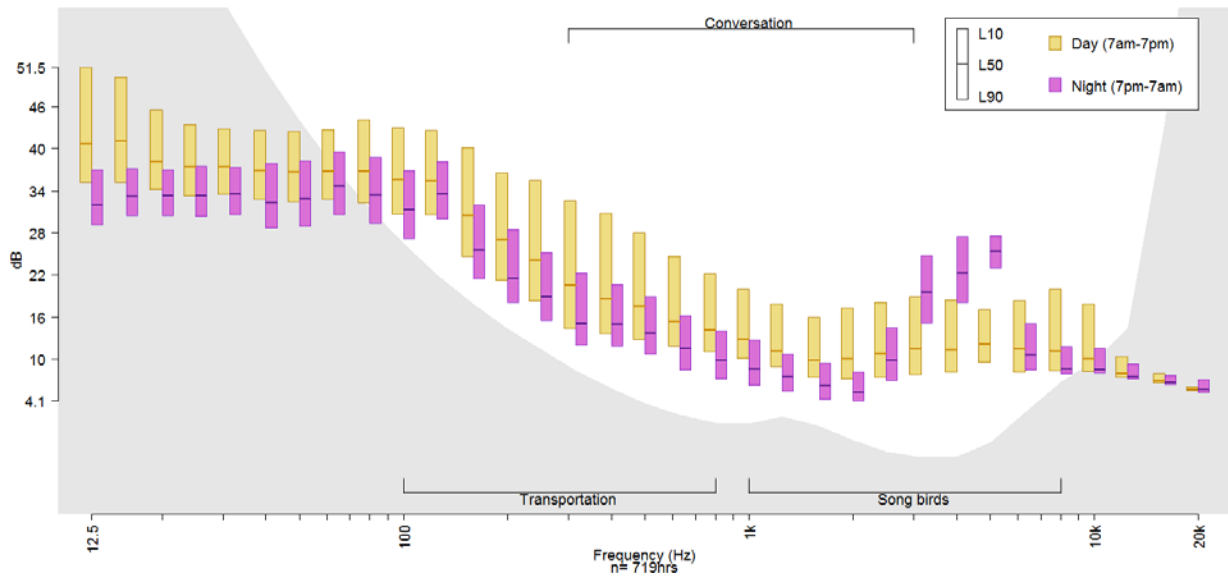


Figure 23. Sound spectrum for Site TUZI001, summer season (2010).

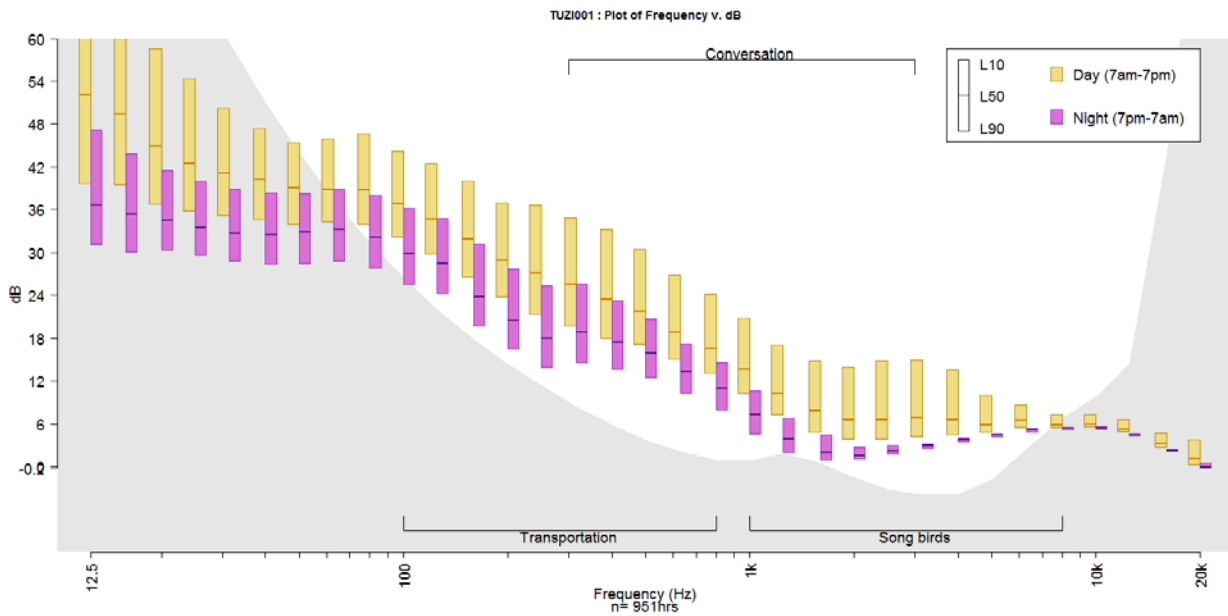


Figure 24. Sound spectrum for Site TUZI001, winter season (2012).

Literature Cited

- American National Standards Institute. 1990. Specification for Sound Level Meters. American National Standard, ANSI Standard S1.4-1983 (R 1990). American National Standards Institute, New York, New York.
- Arizona Department of Transportation. 2013. AZDOT Planning website. <http://mpd.azdot.gov/planning/data/aadt.asp> (accessed 10 October 2013).
- Berglund, B., Lindvall, T. and Schwela, D.H (Eds.). Guidelines for Community Noise, World Health Organization, Geneva: 1999.
- Environmental Protection Agency. Information on Levels of Noise Requisite to Protect the Public Health and Welfare with an Adequate Margin of Safety, March 1974. http://www.fican.org/pages/noise_speech.html (accessed 30 September 2013).
- Fleming, G., et. al., Ambient Sound Levels at Four Department of Interior Conservation Units in Support of Homestead Air Base Reuse Supplemental Environmental Impact Statement, Report Nos. DOT-VNTSC-FAA-99-3, FAA-AEE-99-02, Cambridge, MA: John A. Volpe National Transportation Systems Center, June 1999.
- Fleming, G., et. al., Development of Noise Dose/Visitor Response Relationships for the National Parks Overflight Rule: Bryce Canyon National Park Study, Report Nos. DOT-VNTSC-FAA-98-6, FAA-AEE-98-01, Cambridge, MA: John A. Volpe National Transportation Systems Center, July 1998.
- Haralabidis Alexandros S., et. al., “Acute effects of night-time noise exposure on blood pressure in populations living near airports” European Heart Journal Advance Access, Published online February 12, 2008.
- Homer, C. C. Huang, L. Yang, B. Wylie and M. Coan. “Development of a 2001 National Landcover Database for the United States” Photogrammetric Engineering and Remote Sensing, Vol. 70, No. 7, July 2004, pp. 829-840.
- Lee, et. al., FHWA Traffic Noise Model® (FHWA TNM®) User’s Guide Version 2.5 Addendum to the User’s Guide Version 1.0, Report No. FHWA-PD-96-009, Washington, D.C.: Federal Highway Administration, April 2004.
- National Park Service. 2013a. Tuzigoot National Monument: Acoustical Monitoring 2010. Natural Resource Technical Report NPS/NRSS/NRTR—2013/762. National Park Service, Fort Collins, Colorado.
- National Park Service. 2013b. National Park Service Visitor Use Statistics website. <https://irma.nps.gov/Stats/> (accessed 28 October 2013).

Northern Arizona University. 2011. Arizona Heritage Waters website.

<http://www.azheritagewaters.nau.edu/images/SheaSpringMap.jpg> (accessed 12 February 2014).

Plotkin, Kenneth J., Review of Technical Acoustical Issues Regarding Noise Measurements in National Parks, Draft Report WR 01-20, Arlington, VA: Wyle Laboratories, January 2002.

Rapoza, et. al., Development of Improved Ambient Computation Methods in Support of the National Parks Air Tour Management Act, Cambridge, MA: John A. Volpe National Transportation Systems Center, October 2008.

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