



Coronado National Memorial

Acoustical Monitoring 2010

Natural Resource Report NPS/NRSS/NRR—2014/873



ON THE COVER

Coronado National Memorial, taken in 2010
Photograph courtesy Volpe Center

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Noah Schulz
Cynthia Lee
John MacDonald

U.S. Department of Transportation
Office of the Assistant Secretary for Research and Technology
John A. Volpe National Transportation Systems Center
Environmental Measurement and Modeling Division, RVT-41
Cambridge, MA 02142-1093

November 2014

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Please cite this publication as:

Schulz, N., C. Lee, and J. MacDonald. 2014. Coronado National Memorial: Acoustical monitoring 2010. Natural Resource Report NPS/NRSS/NRR—2014/873. National Park Service, Fort Collins, Colorado.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE April 2014	3. REPORT TYPE AND DATES COVERED Final Report	
4. TITLE AND SUBTITLE Coronado National Memorial: Acoustical Monitoring 2010		5. FUNDING NUMBERS VX-82 / JT022 VX-H2 / KL640	
6. AUTHOR(S) Noah Schulz, Cynthia Lee, and John MacDonald			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology John A. Volpe National Transportation Systems Center Environmental Measurement and Modeling Division, RVT-41 Cambridge, MA 02142-1093		8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Department of the Interior National Park Service Natural Resource Program Center Natural Sounds and Night Skies Division 1201 Oakridge Drive Fort Collins, CO 80525		10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES NPS Program Manager: Vicki Ward			
12a. DISTRIBUTION/AVAILABILITY STATEMENT		12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) During September - October 2010, The Volpe Center collected baseline acoustical data at Coronado National Memorial (CORO), at two sites deployed for approximately 30 days each. The baseline data collected during this period 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 acoustic resource 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 CORO 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.			
14. SUBJECT TERMS Aircraft noise, air tours, ambient, acoustic zones, noise impact, noise, Air Tour Management Plan, ATMP, National Park, soundscape		15. NUMBER OF PAGES 56	
		16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT

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Executive Summary

During September 2010, two acoustical monitoring systems were deployed in Coronado National Memorial (CORO) by Volpe National Transportation Systems Center (Volpe Center) personnel. The purpose of this monitoring effort was to characterize existing sound levels and estimate natural ambient sound levels in these areas, as well as identify audible sound sources. This report provides a summary of results of these measurements, representing CORO’s summer season.

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 each of the CORO measurement locations for the summer 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
CORO001	Coronado Uplands	16.4	5.3	2.5	0.2	83.4	70.2	14.9	0.0
CORO002	Border Grasslands	23.2	5.5	2.1	0.2	69.7	31.5	0.1	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
CORO001	Coronado Uplands	8.1	1.4	0.5	0.1	1.1	0.0	0.0	0.0
CORO002	Border Grasslands	7.7	3.5	0.8	0.2	0.5	0.1	0.0	0.0

Table 3 summarizes the 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
CORO001	Coronado Uplands	6.2	0.3	31.3	62.3
CORO002	Border Grasslands	11.4	0.0	27.9	60.8

Acknowledgments

The authors of this report wish to express their sincere gratitude to all who helped make this a successful study. The National Park Service (NPS), Natural Sounds and Night Skies Division, provided invaluable coordination and support. We would also like to thank Lelaina Marin, and the entire team at the southern Arizona Parks for their expertise and assistance during site selection and deployment. Finally, thanks to Robert “Skip” Ambrose (Computer Sciences Corporation) who also participated in the field measurement effort.

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.

dB(T)

Truncated decibel. A measure of sound energy in the range of frequencies where transportation noise is most often focused (20 - 1250 Hz). Transportation is often a major contributor of low frequency sound, but this range does not correspond to a specific vehicle or type of transportation.

Decibel

A logarithmic measure of acoustic or electrical signals. The formula for computing decibels is: $20 * (\text{Log}_{10}(\text{sound level}/\text{reference sound level}))$. 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 20 Hz to 20,000 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 natural resources of the parks, including the natural 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 the NPS, Natural Sounds and Night Skies Division (NSNSD) in the development of ATMPs.

Ambient data were collected by Volpe Center personnel in Coronado National Memorial (CORO) during September 2010. A map of the areas managed by CORO is shown in Figure 1. The purpose of this report is to provide a summary of the results of these measurements which will be used to represent CORO's summer season.

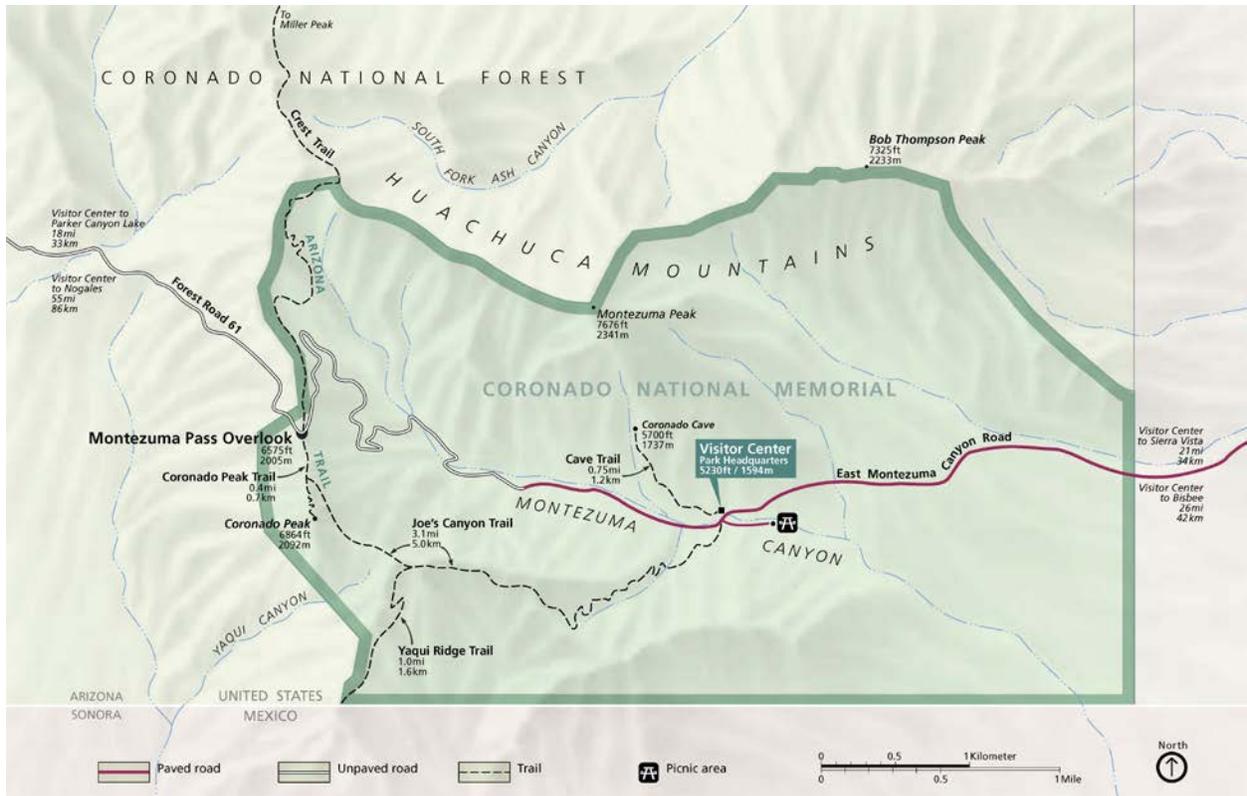


Figure 1. Map of area managed by Coronado National Memorial (National Park Service 2014a).

2. Study Area

Based on discussions between Volpe Center, NSNSD and CORO personnel, two acoustical monitoring systems were deployed during September 2010. The measurement sites selected reflect the two dominant land cover types within CORO and are shown in Table 4.

Table 4. Summary of measurement sites selected for Coronado National Memorial.

Site ID	Site Name	# Days of Data	NLCD ¹ Classification	Coordinates (latitude/longitude in decimal degrees)	Elevation (m)
CORO001	Coronado Uplands	29 days	Evergreen Forest	31.35233° / 110.27817°	1,780 m (5,841 ft)
CORO002	Border Grasslands	28 days	Grassland/Herbaceous	31.34217° / 110.22617°	1,501 m (4,926 ft)

¹ 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

Larson Davis 831 sound level meters (SLM) were employed over the thirty day monitoring periods at Coronado NM. 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). These Larson Davis-based sites met 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

The 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 are 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 and 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);² and

² 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 5.

Table 5. 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 percent 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 each measurement site, time above analysis, temporal trends, and the acoustical observer data logged at each measurement site.

4.1 Summary Results

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

- Figure 2 presents a plot of the overall daytime³ L_{50} sound level computed with all days included for the summer season (a few points of interest outside the park 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 results;⁴
- Table 6 presents a tabular summary of the daytime and nighttime and computed ambient for the summer season;
- Table 7 contains a summary of overall ambient spectral data at each site; and
- Figure 3 and Figure 4 present the associated spectral data for these ambient maps.

³ For most parks, the majority of air tour operations occur during the day, the NPS and FAA have agreed that the impact assessment will be conducted using ambient sound levels during the time that the air tour operations occur. Accordingly, all ATMP analyses are based on daytime ambient data. In general, daytime refers to the time period of 7:00 am to 7:00 pm unless otherwise specified by the NPS and FAA.

⁴ 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.

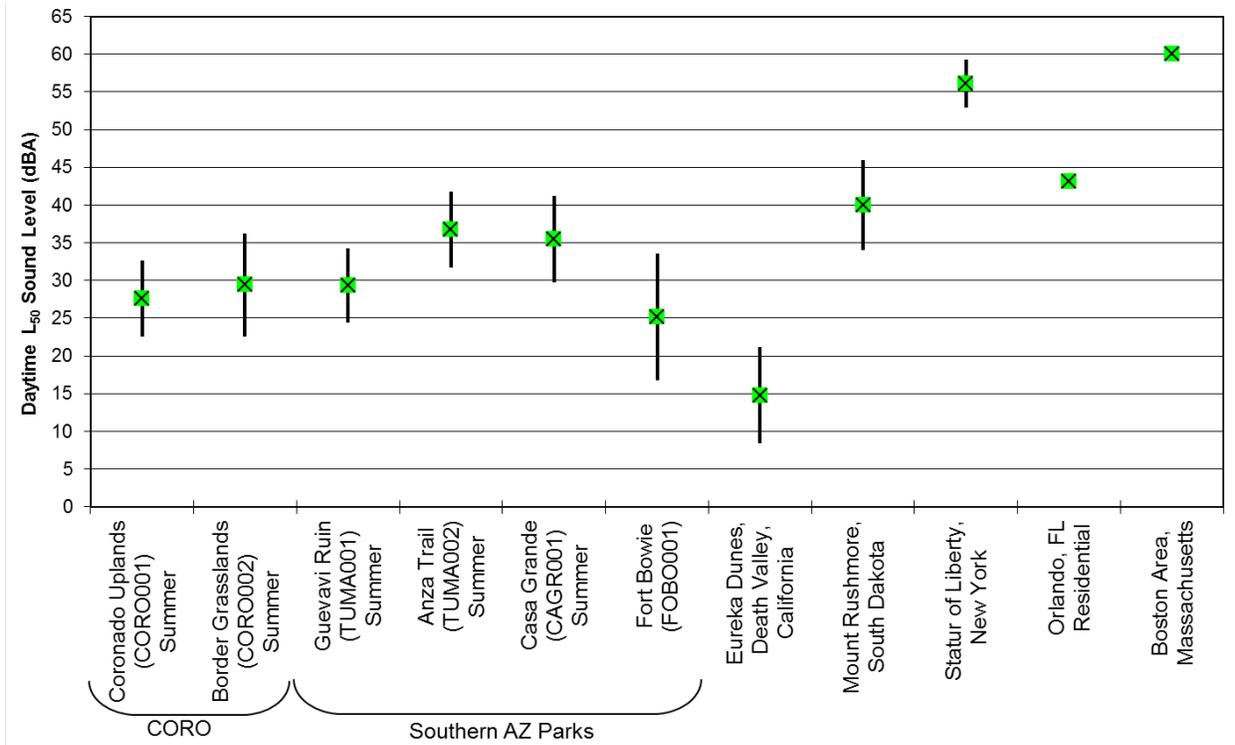


Figure 2. Comparison of overall daytime L₅₀ sound levels.⁵

⁵ Confidence intervals for Orlando and Boston are not shown due to the limited amount of data represented (2 days and 1 week, respectively). Ambient data at ATMP parks, such as Coronado NM, are typically measured for at least 25 days.

Table 6. Summary of ambient sound level data, summer season. ⁶

Site ID	Site Name	Total # Days	Existing Ambient						Existing Ambient Without Air Tours (Daytime Data 7:00 am to 7:00 pm)	Existing Ambient Without All Aircraft (Daytime Data 7:00 am to 7:00 pm)	Natural Ambient (Daytime Data 7:00 am to 7:00 pm)
			Daytime Data Only: 7:00 am to 7:00 pm			Nighttime Data Only: 7:00 pm to 7:00 am					
			L _{Aeq} (dBA)	L ₅₀ (dBA)	L ₉₀ (dBA)	L _{Aeq} (dBA)	L ₅₀ (dBA)	L ₉₀ (dBA)	L ₅₀ (dBA)	L ₅₀ (dBA)	L ₅₀ (dBA)
CORO001	Coronado Uplands	29	46.5	27.6	22.1	49.6	48.3	26.2	27.1	27.1	24.6
CORO002	Border Grasslands	28	43.3	29.4	23.7	43.8	39.1	23.1	28.7	28.7	27.0

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

Table 7. Summary of daytime (7:00 am to 7:00 pm) ambient sound level spectral data, summer season.⁷

Frequency (Hz)	Existing Ambient Without Air Tours L ₅₀ (dB)		Natural Ambient L ₅₀ (dB)	
	CORO001	CORO002	CORO001	CORO002
12.5	28.3	35.6	25.6	32.1
16	26.8	33.4	24.7	30.5
20	26.0	30.6	23.6	27.4
25	26.9	28.8	25.5	26.3
31	26.1	27.7	24.2	26.0
40	24.4	26.0	21.9	24.0
50	23.2	24.0	20.3	22.0
63	23.5	22.6	21.4	21.0
80	21.0	21.9	18.5	19.7
100	18.0	18.3	16.2	17.0
125	16.3	16.4	14.7	15.0
160	15.5	15.0	13.9	13.6
200	17.4	15.1	16.4	14.1
250	19.2	12.9	17.8	11.4
315	18.6	9.6	17.1	8.7
400	19.6	11.5	18.4	10.9
500	18.1	11.0	16.9	10.0
630	16.8	12.5	15.5	12.0
800	16.4	12.1	15.4	11.4
1000	16.0	11.9	14.9	11.3
1250	14.3	10.8	13.6	10.2
1600	12.4	9.6	11.5	9.1
2000	10.6	8.9	9.5	8.5
2500	9.5	8.7	8.3	8.4
3150	9.0	10.2	7.8	9.9
4000	9.1	12.4	8.0	11.6
5000	8.6	13.1	7.9	12.4
6300	8.8	14.5	8.2	13.5
8000	9.3	15.4	8.7	14.5
10000	9.7	18.4	9.2	17.8
12500	9.4	23.0	9.0	22.3
16000	8.4	26.7	8.3	26.1
20000	6.9	28.6	6.8	27.9

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.

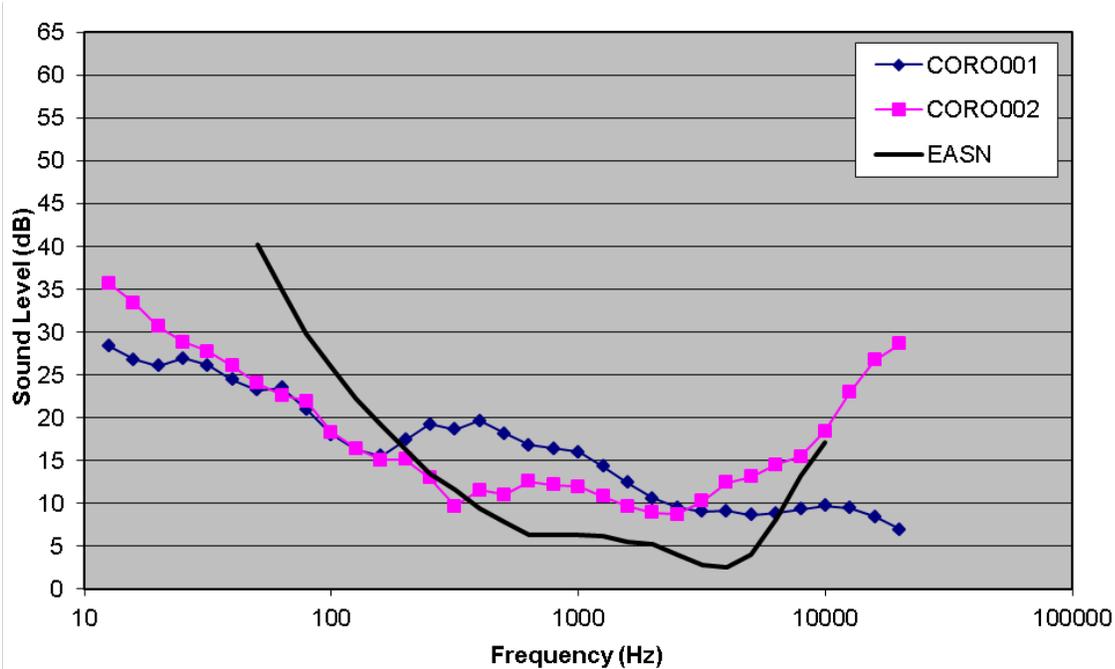


Figure 3. Spectral data for the Existing Ambient Without Air Tours (L_{50}), summer season.⁸

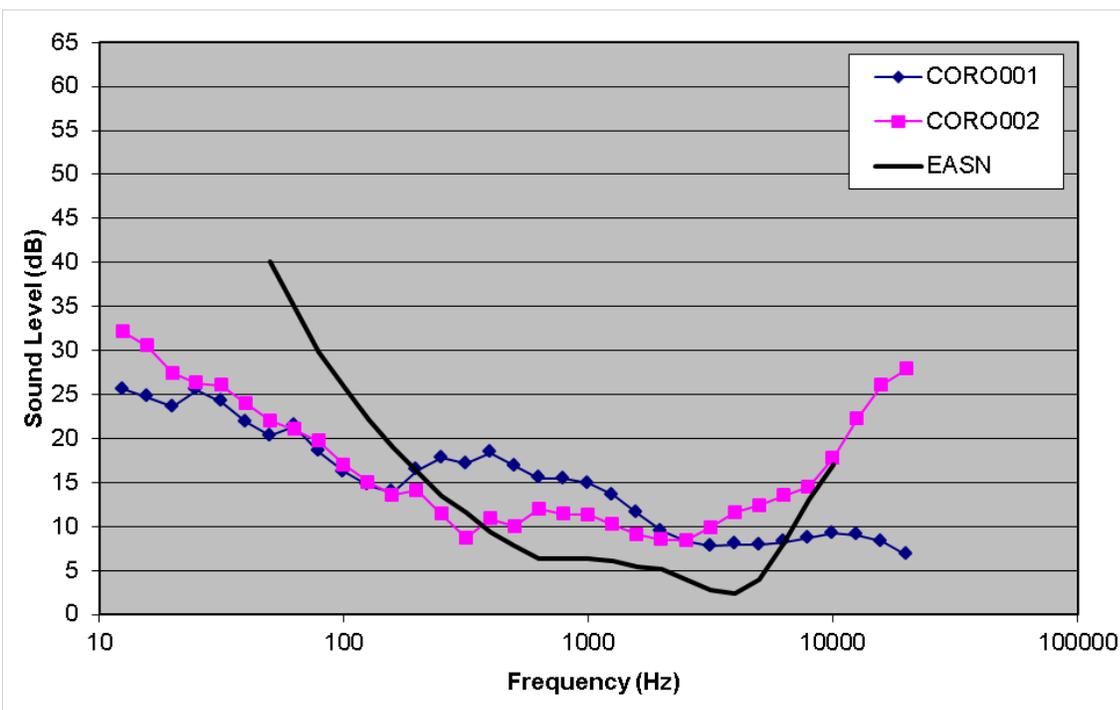


Figure 4. Spectral data for the Natural Ambient (L_{50}), summer season.⁸

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.

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 8 and Table 9 report the percent of time that measured levels were above four sound level values at each of the CORO measurement locations for the summer 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 8. Percent Time Above Metrics (dBA), summer season.

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
CORO001	Coronado Uplands	16.4	5.3	2.5	0.2	83.4	70.2	14.9	0.0
CORO002	Border Grasslands	23.2	5.5	2.1	0.2	69.7	31.5	0.1	0.0

Table 9. Percent Time Above Metrics (truncated spectra – dBT), summer season.

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
CORO001	Coronado Uplands	8.1	1.4	0.5	0.1	1.1	0.0	0.0	0.0
CORO002	Border Grasslands	7.7	3.5	0.8	0.2	0.5	0.1	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 5 presents the daily median Existing Ambient (i.e., the L₅₀ 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. These data is useful in visually identifying potential anomalies in the data. Data anomalies are further examined from data recorded by the sound level meter and/or recorded audio samples.

Diurnal trends are shown on an hourly basis in Figure 6. 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.

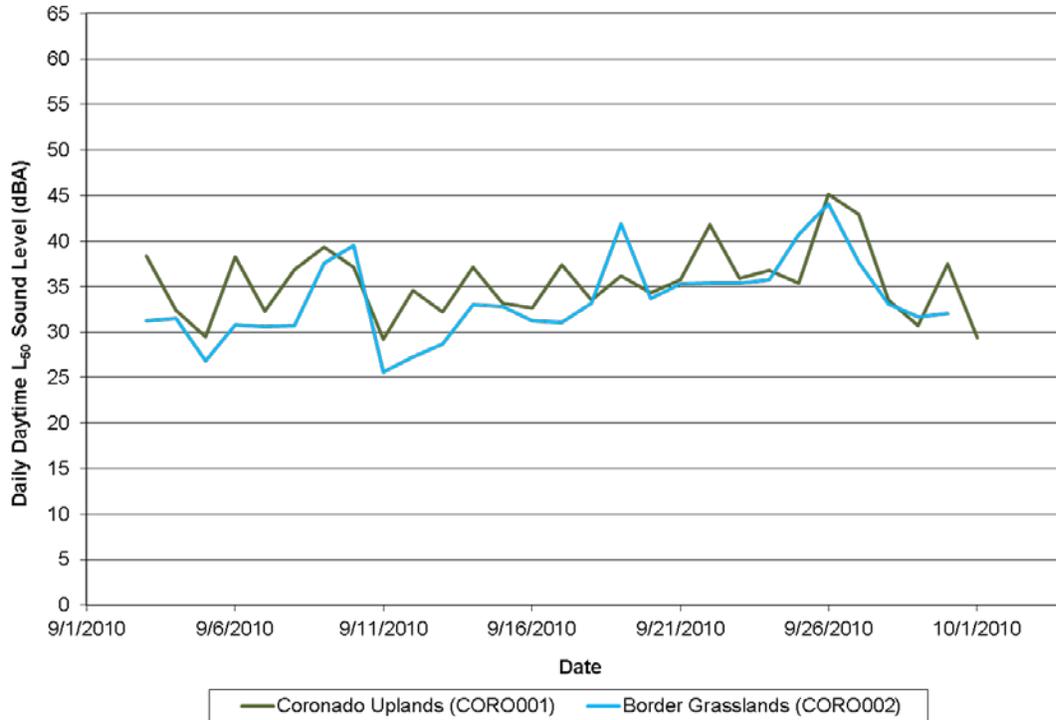


Figure 5. Comparison of daily L₅₀ sound levels.

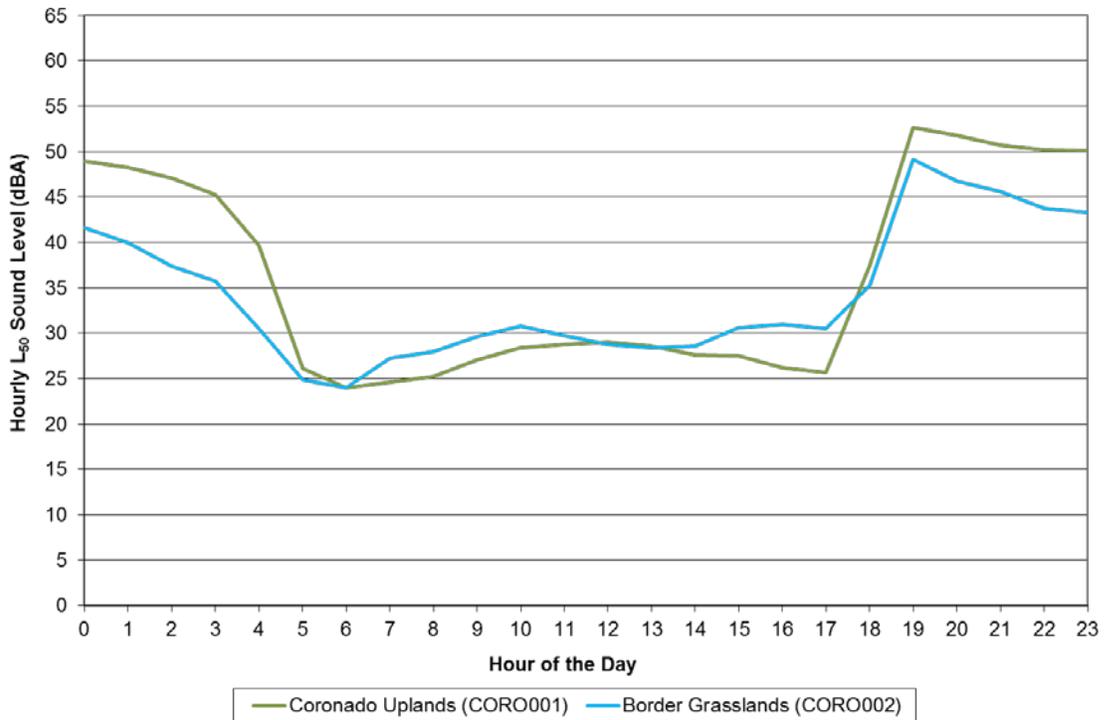


Figure 6. Comparison of hourly L₅₀ sound levels.

4.4 Acoustical Observer Log Results

Table 10 summarizes the 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.

Table 10. Summary of daytime acoustical observer log data (*in situ* and off-site listening combined), summer season.

Site ID	Site Name	% Time Audible			
		Fixed-Wing Aircraft and Helicopters	Other Aircraft Sounds	Other Human Sounds	Natural Sounds
CORO001	Coronado Uplands	6.2	0.3	31.3	62.3
CORO002	Border Grasslands	11.4	0.0	27.9	60.8

5. Ambient Mapping

Using the ambient data measured at each 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)⁹ 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)¹⁰ coordinates to set the initial grid area boundary.¹¹
 - 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 CORO, a grid spacing of 500 ft. (152.4 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, un-weighted spectrum), computed in Section 3.5, to each grid point within an acoustical zone.

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

⁹ 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.

¹⁰ The UTM system provides coordinates on a worldwide flat grid for easy manipulation in GIS applications.

¹¹ 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.

- 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.
- 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 resultant 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 7 presents the acoustical zones that were developed and the location of the measurement sites for CORO. The acoustical zones developed reflect the two dominant land cover types within CORO. The ATMP Act applies to all commercial air tour

operations within the ½-mile outside the boundary of a national park. Table 11 presents which measurement site data were applied to each acoustical zone.

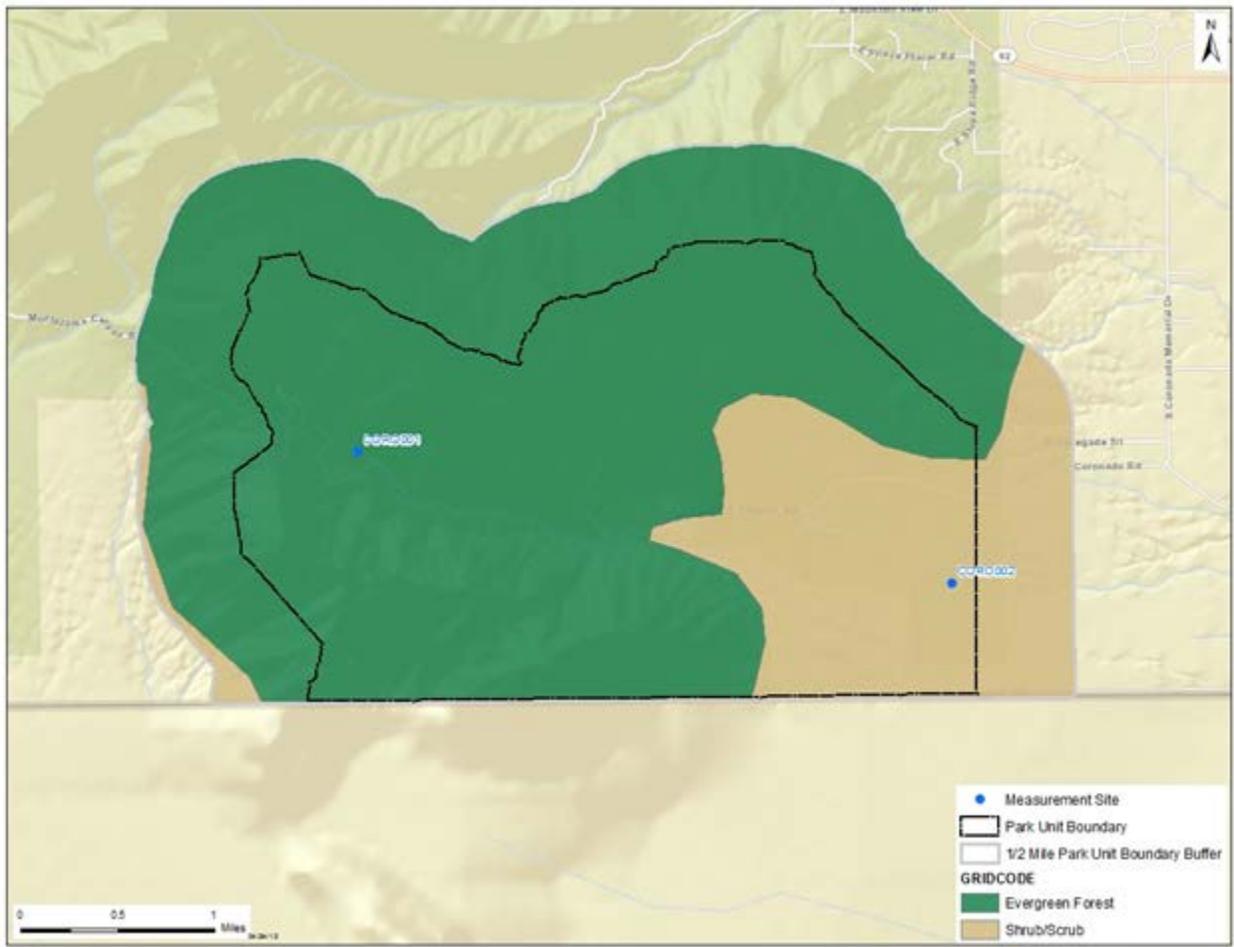


Figure 7. Acoustical zones and measurement sites for Coronado NM.

Table 11. Assignment of ambient data to acoustical zones.

Acoustical Zone	Site ID	Site Name
Evergreen Forest	CORO001	Coronado Uplands
Shrub/Scrub	CORO002	Border Grasslands

5.2 Ambient Mapping of Localized Sound Sources

The contributing effect of localized noise sources, primarily vehicles on roads, but may also include trains, 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 12). 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 12. Composite ambient maps.

Metric	Ambient Type			
	Existing	Existing Without Air Tours	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 CORO, there were a number of roadways. The following general assumptions were made in the modeling:

- **Roadway Traffic Volumes** – Hourly roadway traffic volume is based on the estimated volume of traffic during the month of peak visitation during the summer season at CORO. The Average Annual Daily Traffic (AADT) volume on each roadway was determined using data collected by the Arizona Department of Transportation (AZDOT) (Arizona Department of Transportation 2012). Where data are available for multiple years, the most current year was chosen. The AZDOT AADT was apportioned to reflect peak month daily volume using the ratio of park visitation for the peak summer month (August) to the average month. Monthly visitation data were obtained from the NPS Public Use Statistics Office website (National Park Service 2014b). Hourly volume is estimated by dividing the month’s volume by the number of days in the month (31) and by 12 hours per day, which assumes the majority of traffic for CORO 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 2014b); and (2) observations by field personnel during 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 was used. In some specific cases, notations from the 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 CORO.

Table 13. Estimated hourly roadway traffic volume and speed.

Roadway			Estimated Hourly Volume				
#	Name	Average Speed (mph)	Autos	Medium Trucks	Heavy Trucks	Buses	Motor-cycles
1	W. Montezuma Canyon Rd	35	7	0	0	0	0
2	SR 92 N of E Hererford Road	55	786	37	21	2	25
3	SR 92 Hererford to Palominas Road	55	315	15	8	1	10
4	Montezuma Canyon Road	45	2	0	0	0	0
5	Monson Road (Hereford to Ramsey Road)	45	220	10	6	1	7
6	Hereford Road (SR-92 to Moson Road)	45	338	16	9	1	11
7	Hereford Road (Moson Road to Palominas Road)	45	135	6	4	0	4

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 8 and Figure 9 present the ambient maps for the summer season.

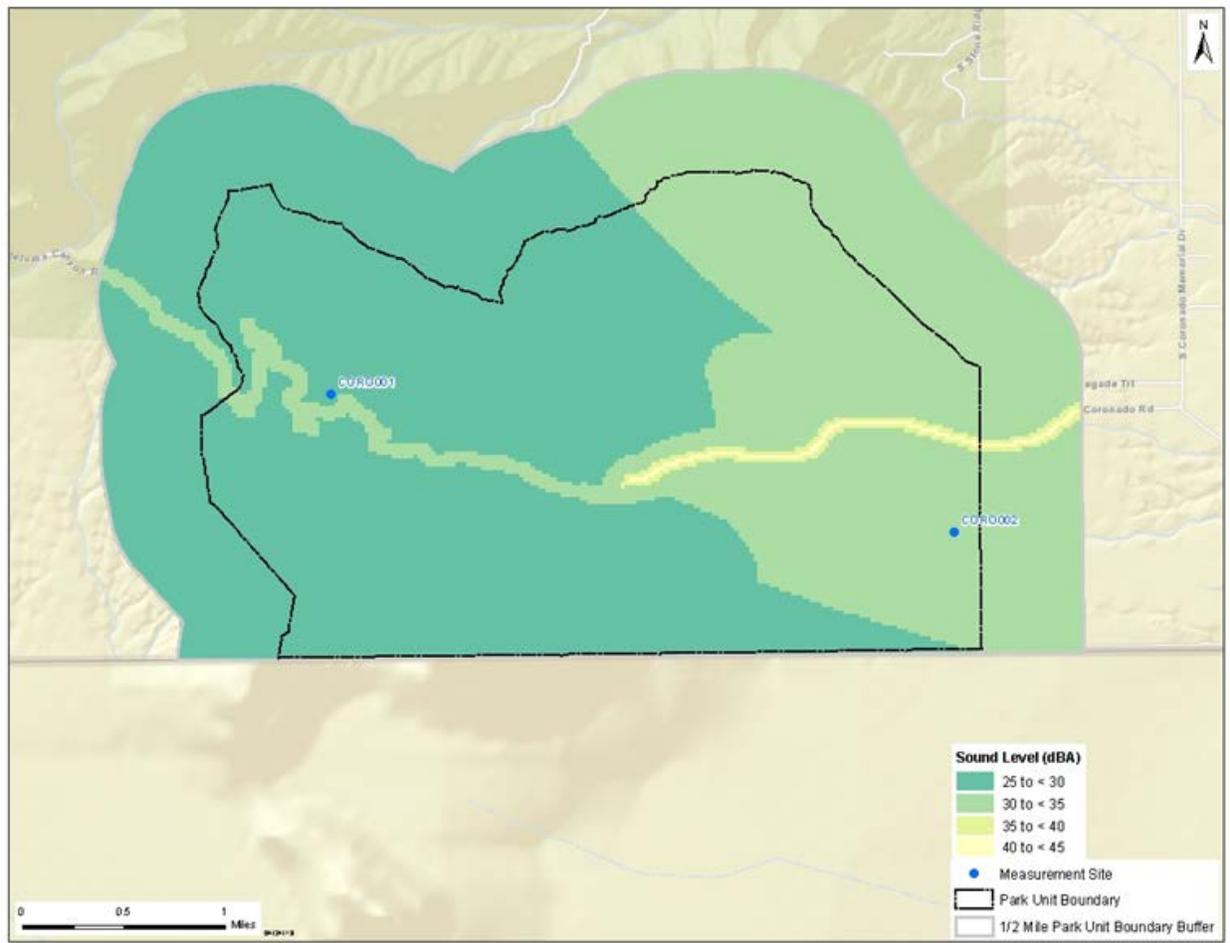


Figure 8. Baseline ambient map: Existing Ambient Without Air Tours (L₅₀), summer season.

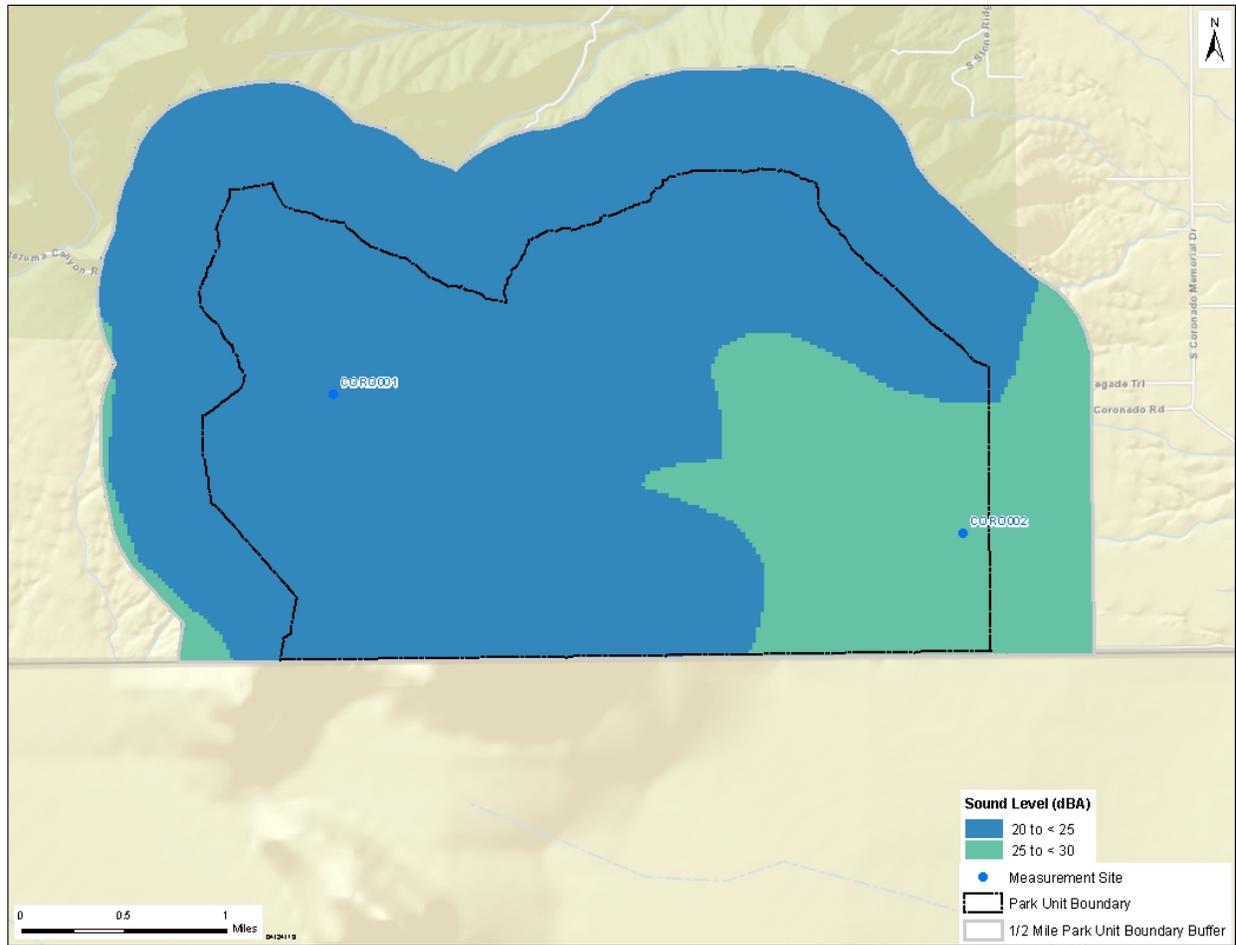


Figure 9. Baseline ambient map: Natural Ambient (L₅₀), summer season.

6. Data for Individual Sites

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

- Figure 10, Figure 16: A photograph of the measurement site and a brief discussion of preliminary observations;
- Figure 11, Figure 17: A pie chart presenting a comparison of types of sound sources that were audible during observer logging;
- Figure 12, 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 13, Figure 19: 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 14, Figure 20: 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 15, Figure 21: A graphic presenting the dB levels for each of 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 CORO001 – Coronado Uplands



Figure 10. Photograph of site CORO001.

The CORO001 measurement location was positioned off the Montezuma Canyon Road, at an elevation of 5841 ft. The measurement system was located in a mixed forest area with a rocky ground surface that contained grasses and forest debris. Due to the site's proximity to Montezuma Pass Road, vehicle events on the road were audible at this location. Helicopter activity related to mining operations within the Memorial was also audible at this site.

On-site observations and off-site review of recorded audio data concluded that aircraft were audible at the CORO001 location for 7.1% of the daytime hours. The aforementioned mining-related helicopter operations were audible 6.7% of the daytime hours. Total human-related sounds were audible 38% of the time. The period of time where no human sounds were audible is called the "Noise-free" component of the soundscape. Noise-free time periods accounted for 62% of the daytime hours. Daytime natural sounds audible at this site, which may have coincided with human-related sounds, were wind-related sounds, birds, water, and animal- and insect-related sounds.

The overall median daytime sound level for this site was 27.6 dBA. Daily (twenty-four hour) median sound levels (L_{50}) varied from 29 to 45 dBA, with louder days corresponding to days with higher winds. Hourly median sound levels ranged from 24 to 53 dBA with significantly louder levels in the evening and nighttime hours corresponding to increased insect activity.

CORO001 - Coronado Uplands

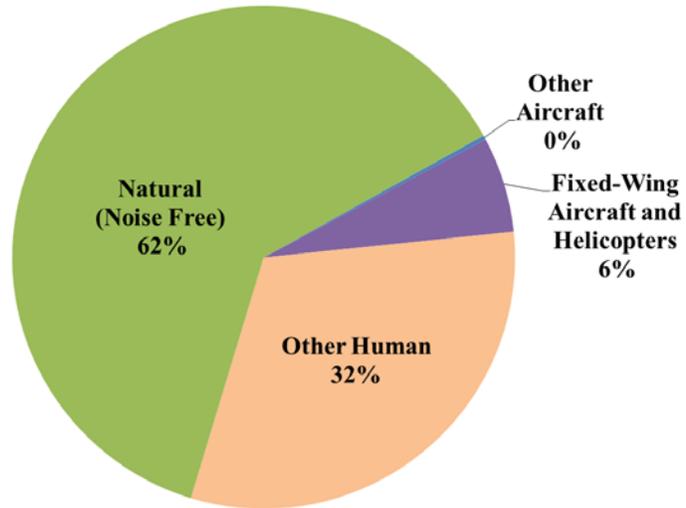


Figure 11. Distribution of daytime sound sources audible (*in situ* and off-site listening combined) for site CORO001.

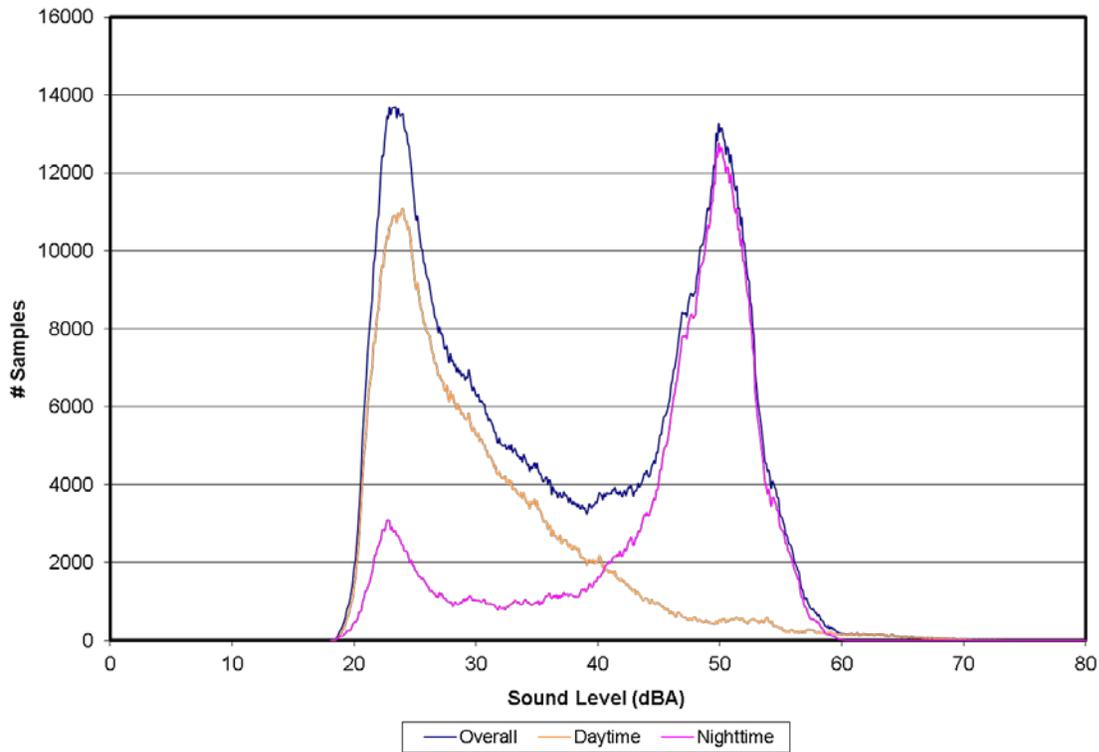


Figure 12. Distribution of sound level data for site CORO001.

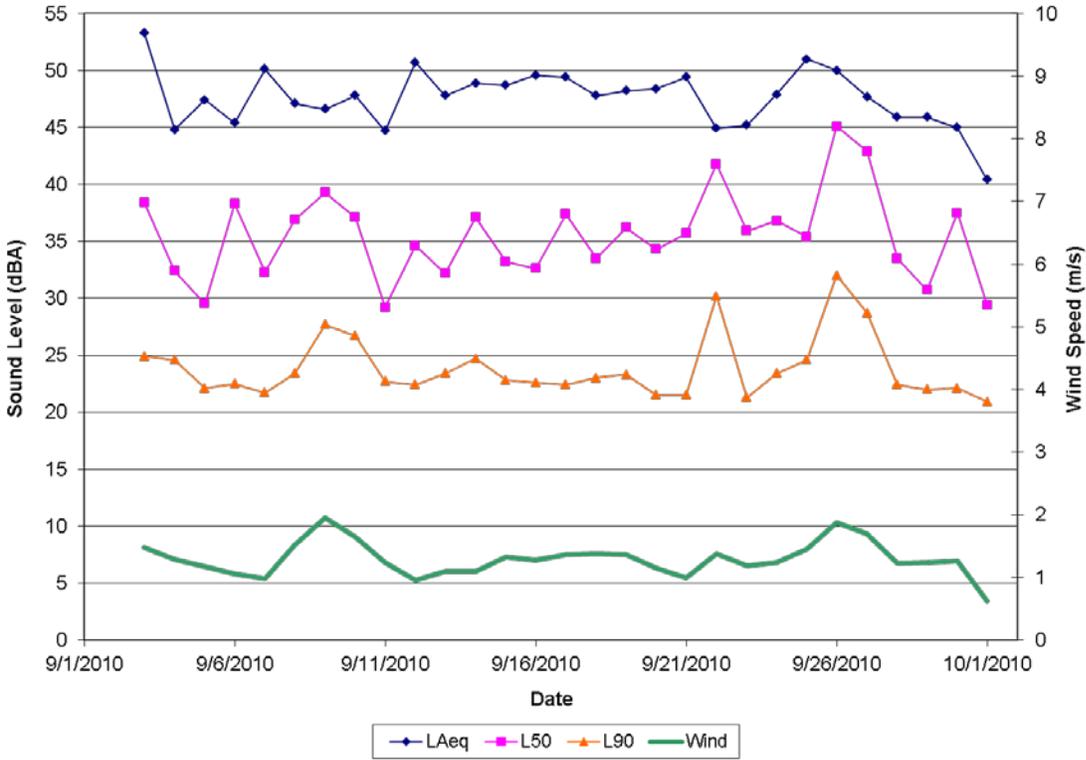


Figure 13. Daily sound levels and wind speeds for site CORO001.

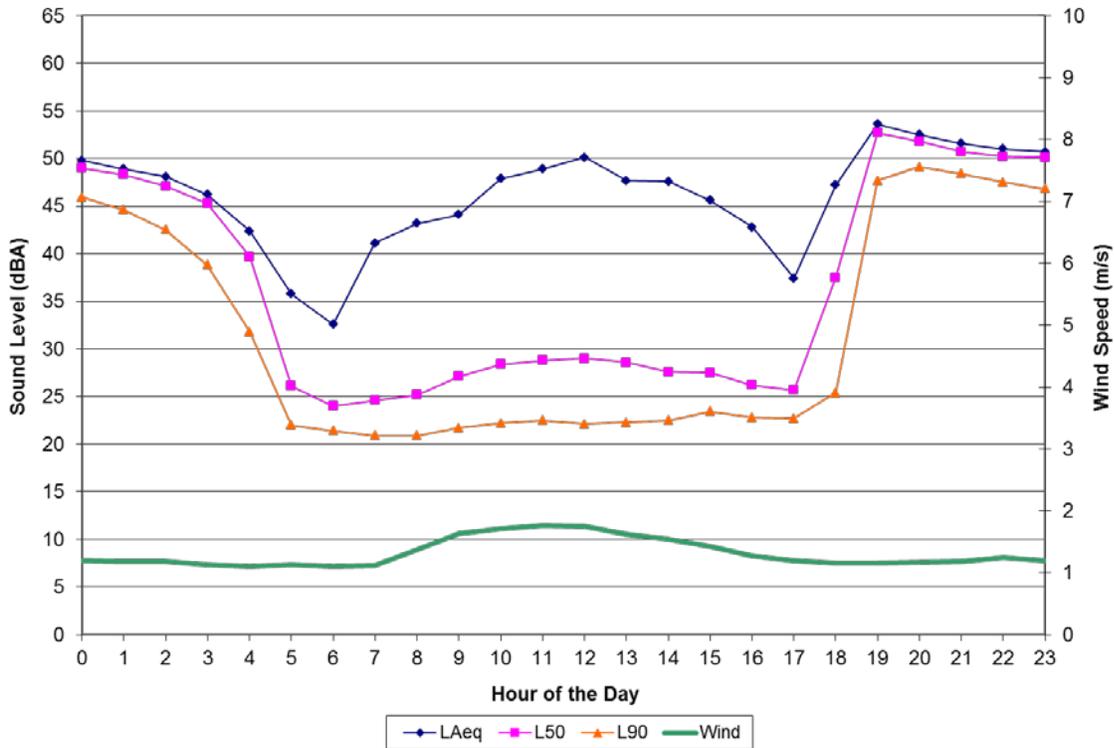


Figure 14. Hourly sound levels and wind speeds for site CORO001.

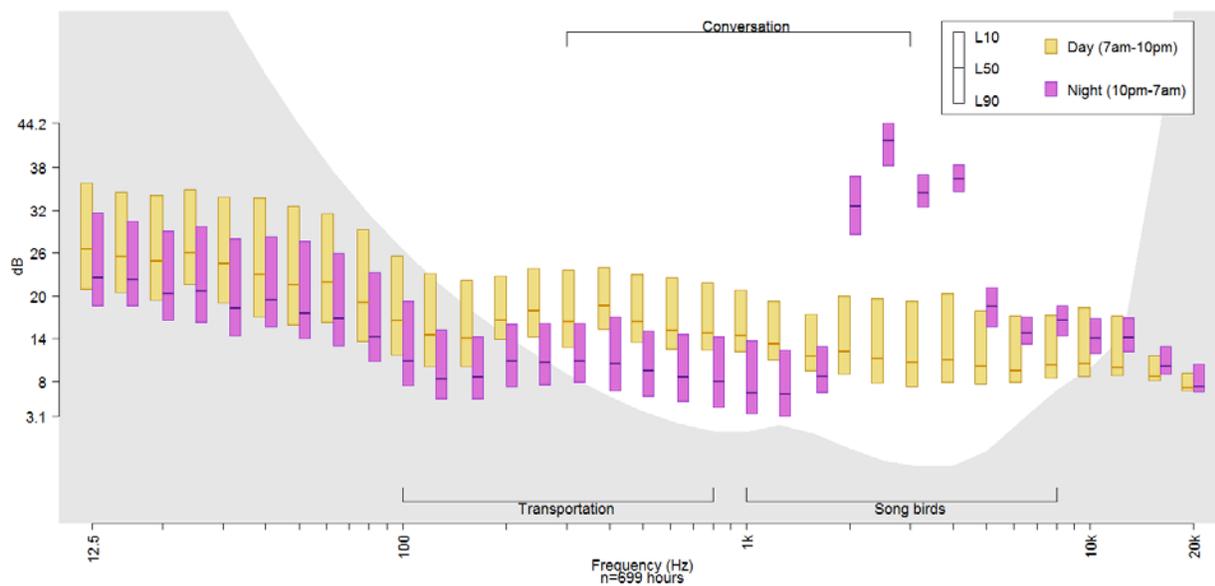


Figure 15. Sound spectrum for site CORO001.

6.2 Site CORO002 – Border Grasslands



Figure 16. Photograph of Site CORO002.

The CORO002 measurement system was located in a large, exposed grassy area near the U.S./Mexico international border at an elevation of 4,926 ft. Due to the exposed nature of the site, winds were often prevalent and may have masked other sounds during some of the sample periods.

On-site observations and off-site review of recorded audio data concluded that aircraft were audible 11% of the daytime hours; other human sounds were audible 28% of the time. The mining helicopter's staging area was nearby to this site, and its operations account for a majority of the aircraft audibility at CORO002. The period of time where no human sounds were audible is called the "Noise-free" component of the soundscape. Noise-free time periods accounted for 61% of the daytime hours. Daytime natural sounds audible at this site, which may have coincided with human-related sounds, were wind related sounds, birds, water, and insects.

The overall median daytime sound level for this site was 29.7 dBA. Twenty-four hour L_{50} sound levels range from 28 dBA to 44 dBA with the louder days occurring during windy conditions. The hourly sound levels ranged from 24 dBA to 49 dBA with the loudest levels in the evening due to increased insect activity.

CORO002 - Border Grasslands

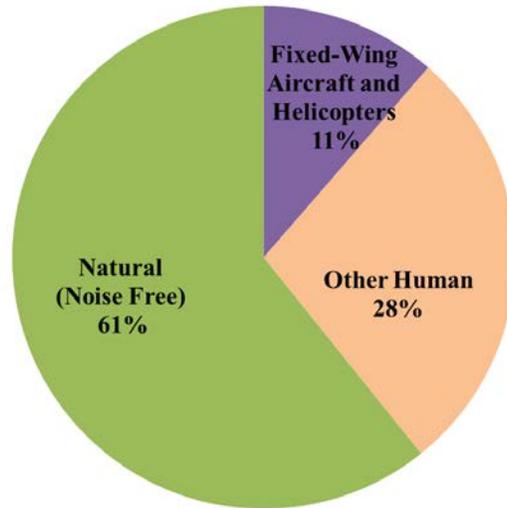


Figure 17. Distribution of sound sources audible (*in situ* and off-site listening combined) for site CORO002.

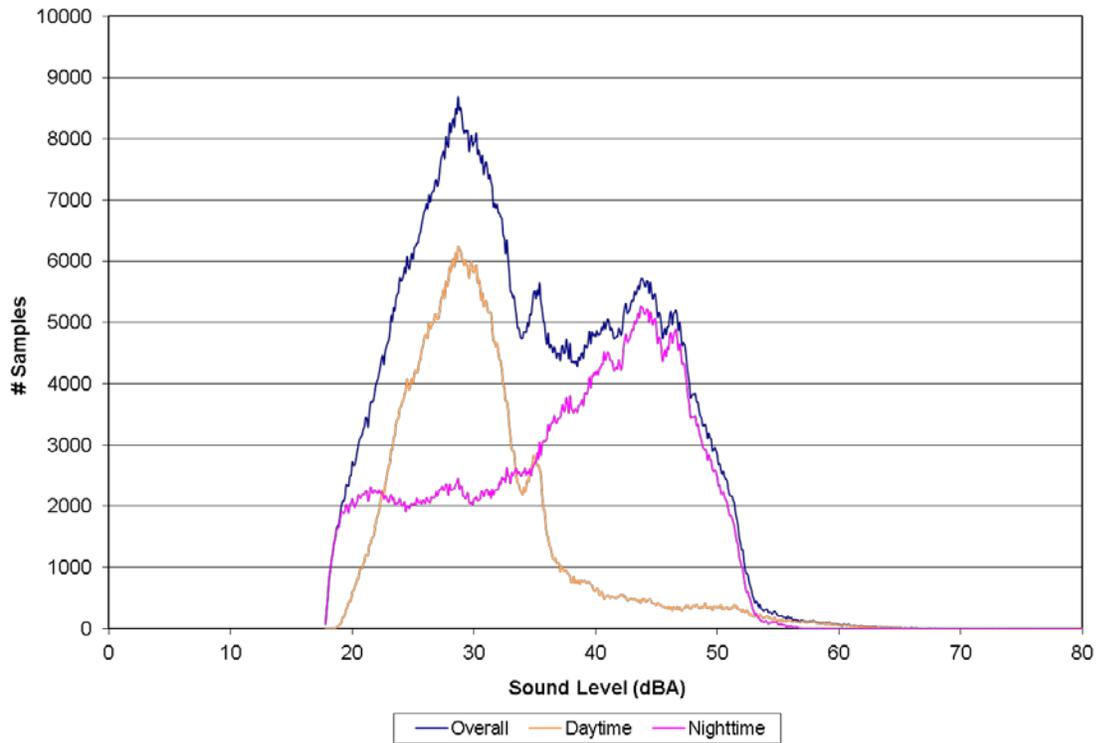


Figure 18. Distribution of sound level data for site CORO002.

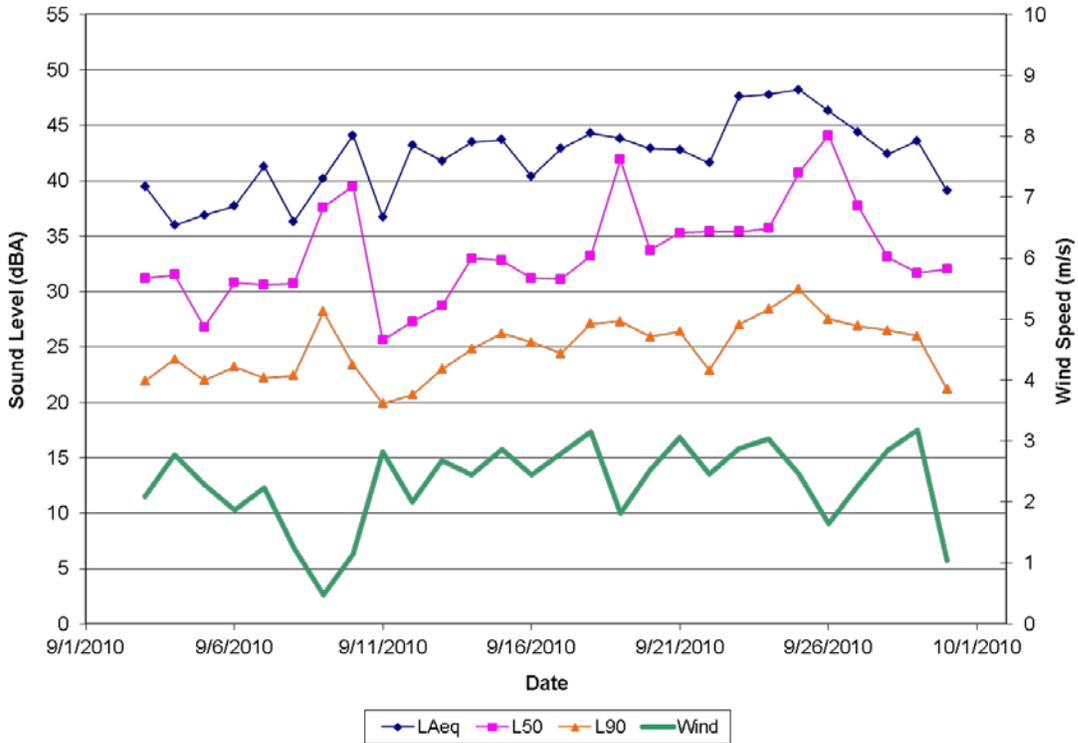


Figure 19. Daily sound levels and wind speeds for site CORO002.

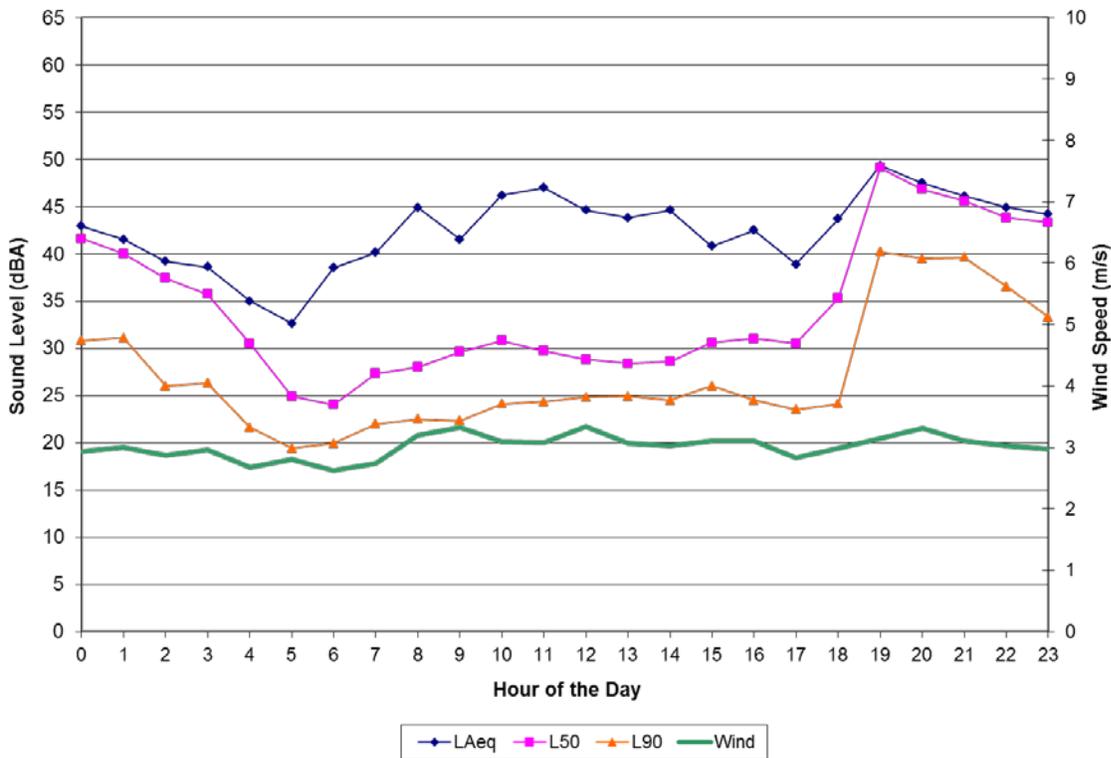


Figure 20. Hourly sound levels and wind speeds for site CORO002.

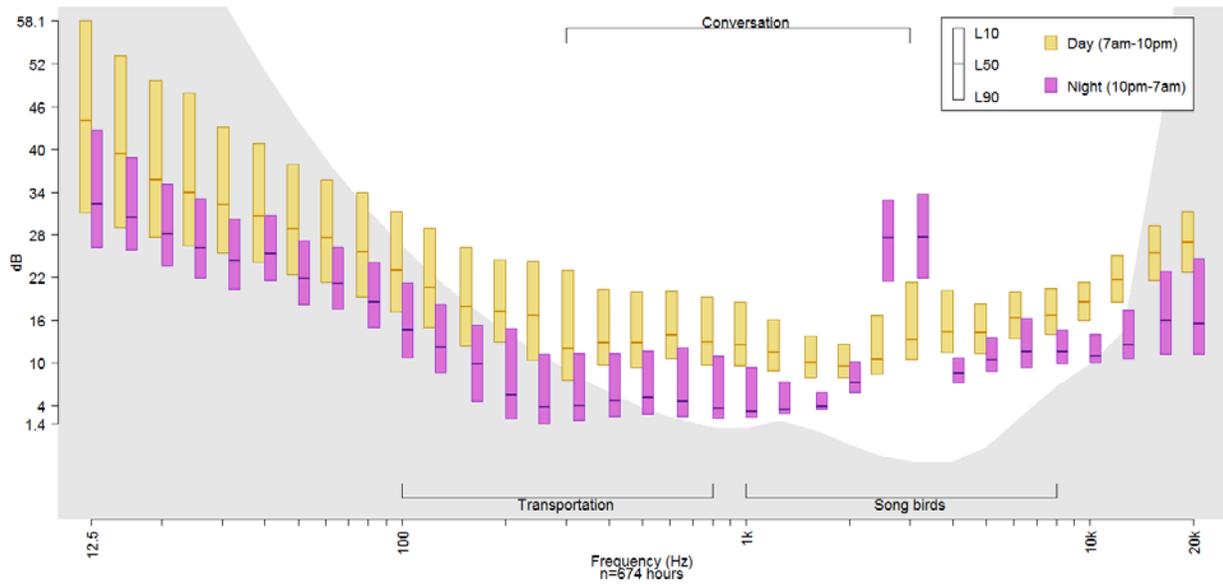


Figure 21. Sound spectra for site CORO002.

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The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 401/127124, November 2014

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1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

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