National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
Natural Sounds & Night Skies Division

Herbert Hoover National Historic Site
Acoustical Monitoring Snapshot

Summer 2013

Background Information

In 2013, the Natural Sounds & Night Skies Division received a request to collect baseline acoustical data at Herbert Hoover National Historic Site (HEHO). Beginning in May 2013, one acoustical monitoring system was deployed for 41 days.

The goal of the technical assistance request was to complete a baseline soundscape inventory for HEHO. The results of this inventory will be used to establish indicators and standards of soundscape quality that will support the park in developing a comprehensive approach to soundscape management planning. This project will assist the park in evaluating the potential effects of various man-made sound sources, including nearby community buildings, facilities, and highways. Additionally, results from this project will be included in the Heartland Network's Natural Resource Condition Assessment currently being drafted for the park.

This briefing is a preliminary snapshot of the acoustical conditions at the 2013 site. A full acoustical monitoring report will follow, pending further data analysis. The metrics presented in this snapshot are calculated solely from sound pressure level data, and do not distinguish between intrinsic and extrinsic sound sources. Sound source identification, an estimate of the natural ambient condition, and the summary of attended listening sessions will be included in the full report after analysis of the digital audio recordings is complete. Table 1 describes the location and characteristics of the monitoring site.

Table 1. Monitoring site – Summer 2013

Site	Site Name	Dates	Vegetation	Elevation	Latitude	Longitude
HEHO001	Gravesite Prairie	5/9/13- 6/19/13	Temperate Grasslands	223m	41.66827	091.35307

Data & Metrics

At each site, sound pressure level (SPL) measurements were taken, along with digital audio recordings and meteorological data. Natural Sounds Program equipment makes 33 SPL measurements each second for a set of frequency bands that span the range of human hearing (12.5 – 20,000 Hz). These 33 measurements approximate the capacity of human listeners to independently sense signals in different parts of the audible spectrum. The SPL is measured in decibels (dB), a logarithmic scale where 0 dB represents the threshold of human hearing at 1 kHz. Microphone measurements can be adjusted according to a weighted scale (A-weighting) such that they resemble the response of the human ear (Harris, 1998, p. 116).

The logarithmic dB scale can be difficult to interpret, and the functional effect of a seemingly small change in SPL can be greater than anticipated. When noise interferes with hearing natural sounds, the noise is said to *mask* the natural sounds, and this affects the extent of the listening area. For example, if the natural ambient SPL is 30 dB, and transportation noise raises the ambient to 33 dB (a 3 dB increase), the listening area for humans (and many birds and mammals) would be reduced by 50%. Increasing the ambient SPL an additional 3 dB (to 36 dB) would reduce the listening area by half again, to 25% of the initial area (see NSNSD Bridge Document). Note, however, that changes in SPL do not proportionately translate to changes in perceived loudness. It is commonly asserted that the perceived loudness of sounds doubles for every 10 dB increase in level, but this rule of thumb dramatically understates the growth in loudness for low frequency noise (< 1 kHz) in national park settings (Crocker, 1997, Figures 1, 4). Urban noise studies have shown that community annoyance tends to double with every 5.5 dB increase in A-weighted noise level (ANSI Standard 12.9-2005/Part 4, table F.1). Table 2 presents park sound sources and other common sound sources with their corresponding A-weighted decibel values (dBA).

Table 2. Sound pressure level examples

Park Sound Sources	Common Sound Sources	dBA
Volcano crater (HALE)	Human breathing at 3m	10
Leaves rustling (CANY)	Whispering	20
Crickets at 5m (ZION)	Residential area at night	40
Conversation at 5m (WHMI)	Busy restaurant	60
Snowcoach at 30m (YELL)	Curbside of busy street	80
Thunder (ARCH)	Jackhammer at 2m	100
Military jet at 100m AGL (YUCH)	Train horn at 1m	120

Table 3 summarizes sound pressure levels that relate to human health and speech, as documented in the scientific literature. Human responses can serve as a proxy for potential impacts to other vertebrates because humans have more sensitive hearing at low frequencies than most species (Dooling and Popper, 2007, p. 5). To help interpret the acoustic data collected within the park, and to better understand the implications of the data, it may be helpful to consider sound pressure levels in relation to the functional effects listed in Table 3.

Table 3. Effects of sound pressure levels on humans

SPL (dBA)	Relevance
35	Blood pressure and heart rate increase in sleeping humans (Haralabidis et al., 2008)
45	World Health Organization's recommendation for maximum noise levels inside bedrooms (Berglund, Lindvall, and Schwela, 1999)
52	Speech interference for interpretive programs (U.S. Environmental Protection Agency, 1974)
60	Speech interruption for normal conversation (U.S. Environmental Protection Agency, 1974)

For a given frequency range, the *time above* metric indicates the amount of time that the SPL exceeds a specified decibel value. By comparing the amount of time that sound pressure levels are above certain values, variations in levels can be observed over time (or between sites). Table 4 reports the percent of time that measured levels were above the values in Table 3. These values are useful for making comparisons, but should not be construed as thresholds of impact. The top value in each split-cell of Table 4 reports the *percent time above* for the 20 – 1250 Hz range. It is useful to look at this low-frequency range because it includes transportation noise while excluding higher-frequency bird and insect sounds. Transportation is often a major contributor of

low frequency sound, but the 20 – 1250 Hz range does not correspond to a specific vehicle or type of transportation. Note that natural sources such as flowing water also produce low frequency sounds. The bottom *percent time above* value in each split-cell is calculated from the full 12.5 – 20,000 Hz range.

Table 4. Percent time above metrics

Site	Frequency (Hz)	% Time above sound level: 0700 to 1900				% Time above sound level: 1900 to 0700			
		35dBA	45dBA	52dBA	60dBA	35dBA	45dBA	52dBA	60dBA
HEHO001	20-1250	100.00	76.66	16.91	0.27	99.94	83.32	38.90	1.22
	12.5-20,000	100.00	91.11	27.44	0.78	99.99	88.22	49.38	2.10

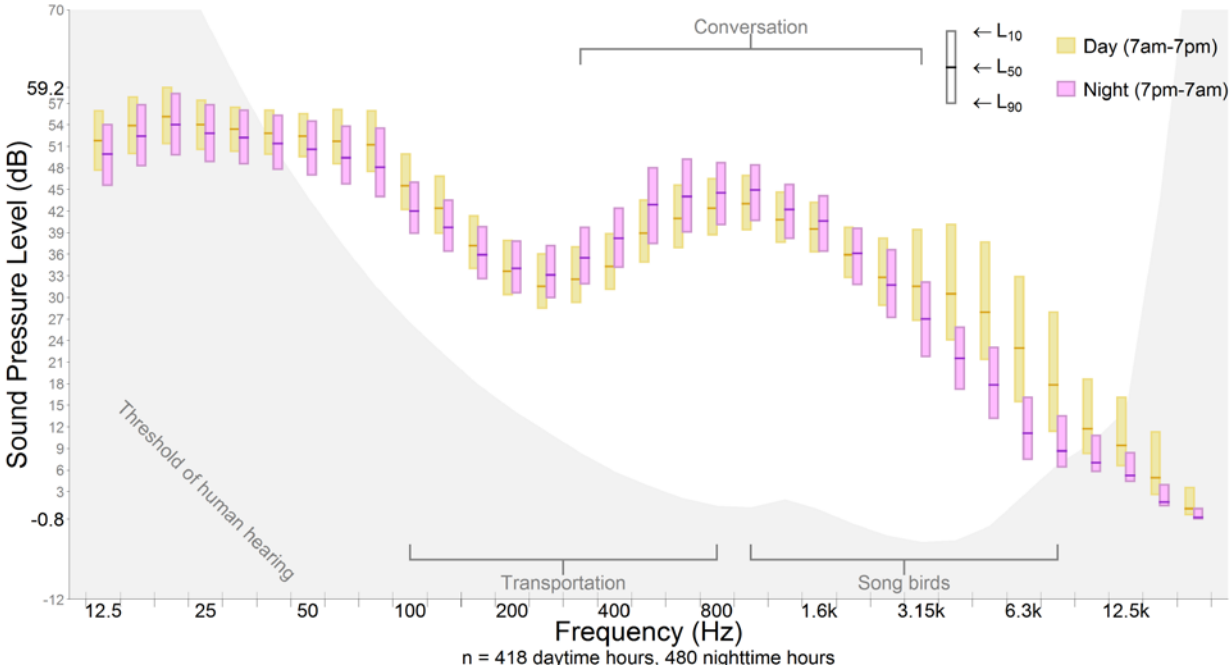
Exceedence levels (L_x) represent the sound pressure levels exceeded **x** percent during the given measurement period (e.g. L_{90} is the SPL that has been exceeded 90% of the time). Table 5 reports the L_{90}, L_{50}, and L_{10} values for the site. For each split-cell in Table 5, the top value reports the L_x for the 20 – 1250 Hz subset of the frequency range, and the bottom L_x value is calculated from the 12.5 – 20,000 Hz spectrum.

Table 5. Exceedence levels for existing conditions

Site	Frequency (Hz)	Exceedence levels (dBA): 0700 to 1900			Exceedence levels (dBA): 1900 to 0700		
		L_{90}	L_{50}	L_{10}	L_{90}	L_{50}	L_{10}
HEHO001	20-1250	45.2	48.6	52.3	46.4	50.7	54.3
	12.5-20,000	47.1	50.4	53.9	47.6	51.6	55.3

High frequency sounds (e.g. a cricket chirping) and low frequency sounds (e.g. transportation noise) often occur simultaneously, and do not always occur constantly throughout the day. Figure 1 illustrates these concepts by dividing the full frequency spectrum into 33 smaller frequency bands (each encompassing a one-third octave range), and by plotting the daytime and nighttime SPL range for each band. The grayed area in the background of the graph represents sound pressure levels outside of the typical range of human hearing. The typical frequency ranges for transportation, conversation, and songbirds are presented on the figure as examples for interpretation of the data. These ranges are estimates and are not vehicle-, species-, or habitat-specific.

Figure 1. Day and night dB levels for 33 one-third octave bands at HEHO001



Literature Cited

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Crocker, M. J. (1997). *Encyclopedia of Acoustics*. John Wiley and Sons, New York.

Dooling, R., & Popper, A. (2007). *The effects of highway noise on birds*. Rockville, MD: Environmental BioAcoustics LLC.

Haralabidis, A, Dimakopoulou, K., Vigna-Taglianti, F., Giampaolo, M., Borgini, A., Dudley, M., Pershagen, G., Bluhm, G., Houthuis, D., Babisch, & others. 2008. Acute effects of night-time noise exposure on blood pressure in populations living near airports. European Heart Journal **29**:658-664.

Harris, C. M. (1998). *Handbook of Acoustical Measurements and Noise Control*, 3rd ed. McGraw-Hill, New York.

U.S. Environmental Protection Agency (EPA). 1974. Information on levels of environmental noise requisite to protect public health and welfare with an adequate margin of safety. EPA, Washington, D.C.

Note: *This is a preliminary snapshot designed to get salient acoustical information back to the park as quickly as possible. This does not replace a full acoustical report, which will follow, pending further data analysis. If there are any questions or concerns about the information in this document, please contact the Natural Sounds Program. Thank you for your interest and participation in acoustical resource monitoring.*

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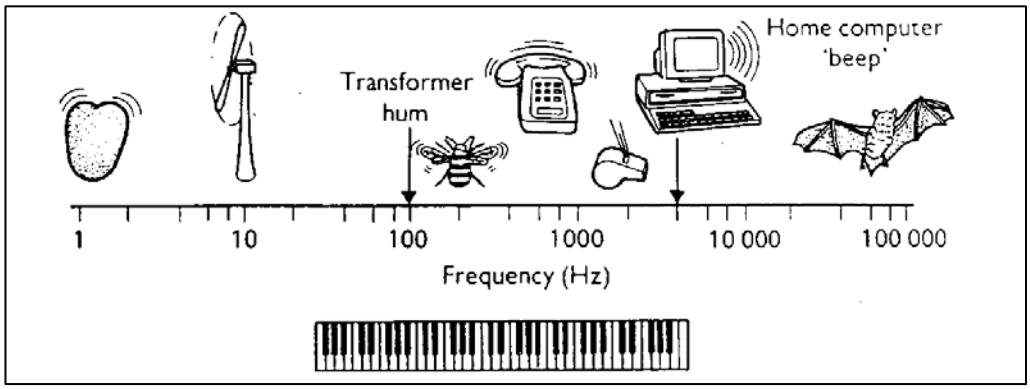
Things to Consider When Reading the Acoustical Monitoring Report

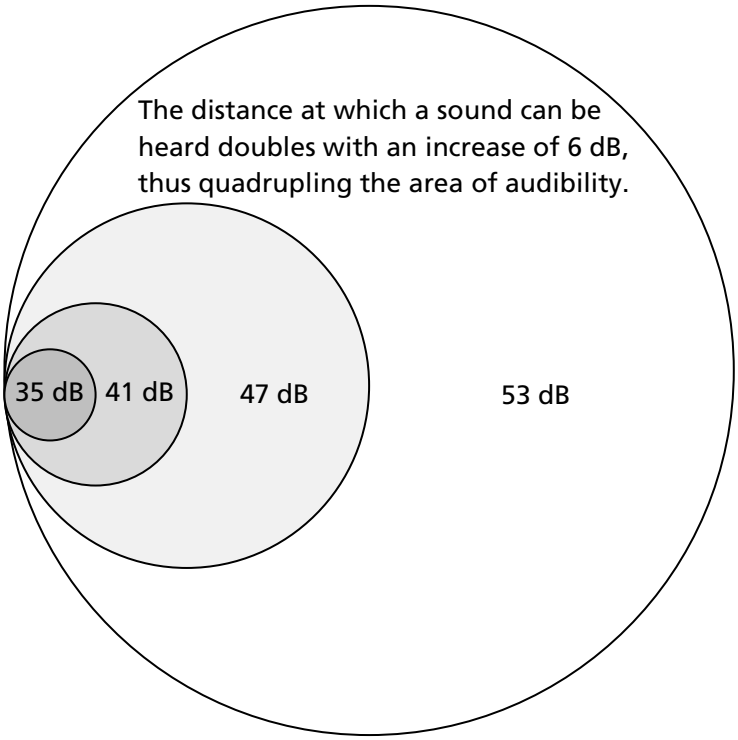
- **Please note that this report does not include management considerations or specific information about how to incorporate acoustical data into park plans.** Please contact a NSNSD planner, who will work with you to interpret this information in relation to park management priorities and provide guidance on incorporating these data into park plans.
- This report is an authoritative scientific reference describing acoustical conditions in your park and provides the foundation you need to develop soundscape management policy and plans.
  It has been peer-reviewed as required by law and policy (Data Quality Act, 2001; OMB Information Quality Bulletin, Dec. 2004, NPS Interim Peer Review, Information Quality Correction Guide and Ethics Statement, January 31, 2008).
- If you flip through the report to tables and figures, please read the preceding paragraphs for their description, definitions of terms, and explanation of abbreviations.
- All times listed in the report are in military time (0000 to 2359).

SOUND SCIENCE 101

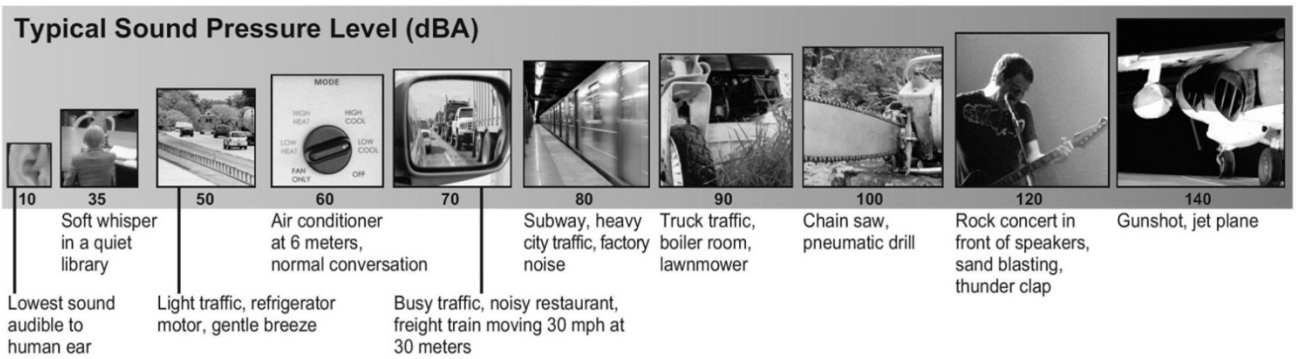
- In air or water, sound is a pressure wave moving through the medium. Sound moves almost five times faster through water than air.
- How do we quantify sounds?
  Frequency: This measures the cycles per second of a sound wave and is perceived as pitch. Frequency is measured in Hertz (Hz). 440 Hz is near the middle of a piano keyboard. Humans with normal hearing can hear sounds between 20 Hz and 20,000 Hz, and are most sensitive to frequencies between 1,000 Hz and 6,000 Hz.



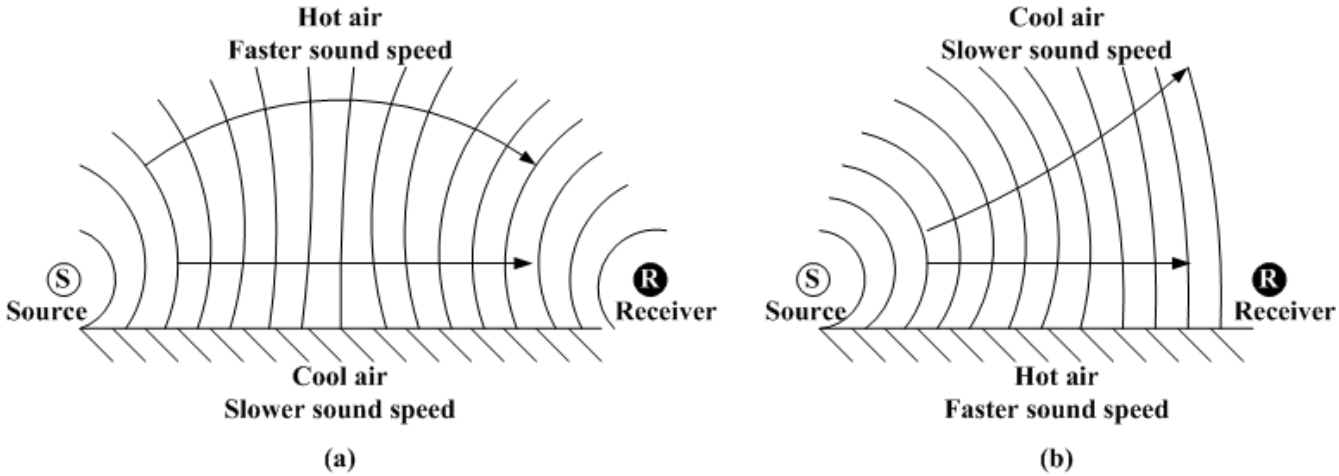
Sound pressure level (SPL): We perceive SPL as loudness. SPL is measured in decibels (dB). The decibel scale is logarithmic, which means that every 10 dB increase in SPL represents a tenfold increase in sound energy. It also means that small variations in sound pressure level can have a significant effect on a soundscape. A 6 dB increase in a noise source will double the distance at which it can be heard, increasing the affected area by a factor of four.



A-weighted sound pressure level (dBA): This is the most common summary measurement of sound level across all audible frequencies. It significantly discounts sounds below 1,000 Hz and above 6,000 Hz, to approximate the variation in human hearing sensitivity.



- What affects how sound travels?



Climatic factors: Atmospheric absorption of sound varies with temperature and humidity. The speed of sound increases with increasing temperature and humidity. Vertical temperature profiles dramatically affect sound propagation due to refraction. Sounds will be heard at much greater distances during a temperature inversion in the early morning (a) than on a hot summer afternoon (b).

Ground cover: Very hard surfaces like bare rock, water, or ice reflect sound and allow it to travel great distances. Soft surfaces like leaf litter or duff tend to absorb sound.

Frequency: High frequency sounds are more readily absorbed by the atmosphere or scattered by obstructions than low frequency sounds. Low frequency sounds diffract more effectively around obstructions. Therefore, low frequency sounds travel farther.

- When two sounds overlap in time and frequency, the louder sound may obscure, or "mask," the quieter. For mammalian listeners, low-frequency sounds can also mask high-frequency sounds, but not the reverse.
- Noise modeling software can be used to account for topography, atmospheric conditions, and vegetation.

- Some tables report metrics for two frequency ranges: 12.5–20,000 Hz and 20–1,250 Hz. The larger range encompasses all sounds, natural and human-caused, that were recorded. Many loud natural sounds, including insects and birds, are higher in pitch, while most human-caused noise is confined to lower frequencies. Therefore, the truncated, lower-frequency range is more appropriate for identifying noise levels in parks.
- Exceedence levels (L_x) represent the sound pressure levels exceeded **x** percent of the time during the measurement period. The report refers to:
  - L_{90} – 90% of the time it's louder than this level; an estimate of the background against which individual sounds are heard.
  - L_{50} – 50% of the time it's louder than this level; an estimate of the median condition.
  - L_{10} – 10% of the time it's louder than this level; an estimate of loud conditions that regularly occur.
  - L_{nat} – natural ambient; an estimate of the L_{50} that would occur in the absence of human-caused noise.
- The report refers to % Time Above 35, 45, 52, and 60 dBA. These levels coincide with particular effects on humans. You might consider these metrics useful as management indicators.

SPL (dBA)	Relevance
35	Blood pressure and heart rate increase in sleeping humans
45	Recommended maximum noise level inside bedrooms
52	Speech interference for interpretive programs
60	Speech interruption for normal conversation

- **If you have any questions don't hesitate to contact the Natural Sounds and Night Skies Division (NSNSD).**