



Vicksburg National Military Park

Acoustic Monitoring Report

Natural Resource Technical Report NPS/NRSS/NRTR—2013/789



ON THE COVER

Acoustic monitoring equipment at living history embrasures, Vicksburg National Military Park
Photograph by: NSNSD staff

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Natural Resource Technical Report NPS/NRSS/NRTR—2013/789

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Natural Sounds and Night Skies Division
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Executive Summary

The objectives of this report are to quantify existing acoustical conditions in Vicksburg National Military Park (VICK) and provide results that can be used for park management and planning. Multiple external sound sources currently impact the soundscape of VICK, including Interstate 20, U.S. Highway 61, Kansas City Southern Railroad, Yazoo Diversion Canal (shipping traffic), and a harbor industrial complex. Inside the park, buses, RVs, motorcycles, and cars create noise along the 16-mile tour road and especially at the Visitor Center and U.S.S. Cairo parking areas. Mississippi Department of Transportation (MDOT) is planning to widen a section of I-20 immediately adjacent to the park's southeast border. MDOT has contracted out the noise analysis for this construction project to Neel-Schaffer, Inc. The company uses 15-minute point measurements and TNM modeling to quantify impacts, but park staff requested more detailed sound monitoring by the Natural Sounds and Night Skies Division.

In determining the current conditions of an acoustical environment, it is important to examine how often sound pressure levels exceed certain values. Four values of interest to parks are listed in Table 1. Table 2 displays the percent of time that measured decibel levels were above four key values. Sound pressure levels above 35 dBA can negatively affect sleep, levels above 52 dBA can interfere with communication at a distance of 10 meters, and levels exceeding 60 dBA can cause speech interference at 1 meter. Exceeding these sound levels can negatively affect the visitor experience and the ability of park staff to communicate with visitors. Interpretive programs are likely impacted at both the Visitor Center and the National Cemetery, given that the 52 dB value was exceeded the majority of the time measured at those locations.

Table 1. Key sound level values.

Sound Levels (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)

Table 2. Percent time above metrics.

Site	Frequency (Hz)	% Time above sound level: 0800 to 1600				% Time above sound level: 1600 to 0800			
		35 dBA	45 dBA	52 dBA	60 dBA	35 dBA	45 dBA	52 dBA	60 dBA
VICK002	20-800	100.0	98.83	38.74	0.33	100.0	85.75	29.50	0.47
	12.5-20,000	100.0	100.0	79.18	1.06	100.0	100.0	97.20	6.10
Cemetery ¹	20-800	100.0	100.0	96.02	38.11				
	12.5-20,000	100.0	100.0	100.0	97.10				
Visitor Ctr ¹	20-800	100.0	100.0	95.88	13.49				
	12.5-20,000	100.0	100.0	86.73	54.26				

¹Metrics for Cemetery and Visitor Ctr sites represent only those hours during which equipment was deployed (approximately 1.5 hours each), whereas VICK002 metrics encompass 24 hours/day for 34 days.

As shown in Table 3 below, the percent time audible metrics indicate the amount of the 24 hour day that is affected by extrinsic and more specifically, aircraft and road vehicle sounds. Road vehicles, including automobiles and trucks, were the most frequently audible extrinsic sound sources. These results were produced by performing detailed analyses of two hours of on-site observations or samples from three days of audio recordings for the site.

The A-weighted median existing ambient statistics (also called L50) describe average sound levels for daytime and nighttime periods at each site. Existing ambient information was drawn from sound pressure level readings taken every second by calibrated, type-1 sound level meters. This metric was not available for VICK001 due to equipment failure at that site. VICK002 had a higher L50 at night than during the day. This is likely attributable to the continuous traffic noise combined with increased natural sounds (insects) in the dusk and dawn hours.

The A-weighted median natural ambient (also called L_{nat}) is an estimate of the remaining sound energy over a particular time period when all extrinsic or anthropogenic noises are removed from the existing ambient (L50). Due to the constant traffic noise at VICK002, L_{nat} could not be calculated for this site.

Table 3. Mean percent time audible for extrinsic, aircraft, and road vehicle sounds; existing and natural ambient sound levels.

Site Location	Mean % time audible ^a			Median A-Weighted Existing Ambient (L ₅₀) ^b		Median A-Weighted Natural Ambient (L _{nat}) ^d	
	Extrinsic sounds	Aircraft sounds	Road vehicle sounds	Day ^c	Night	Day	Night
VICK001: Boy Scout Trail							
On-site listening	99.56	32.24	90.10	-	-	-	-
Off-site analysis ^e							
VICK002: Indiana Monument							
On-site listening	-	-	-	-	-	-	-
Off-site analysis	99.93	5.58	99.93	-	-	-	-
	99.72	0.1	99.68	53.7	56.8	-	-

^a On-site: based on 2 hours of daytime listening; . Off-site: over a 24-hour period, based on three days of analysis.

^b For comparison, nighttime sound level in a typical residential area is about 40 dBA.

^c Day hours are 0800-1559; night hours are 1600-0759.

^d Natural ambient conditions could not be calculated due to nearly continuous extrinsic noise sources.

^e Equipment failure at VICK001 precluded off-site analysis.

Another metric that can be used to quantify existing acoustic conditions is the average noise free interval, or the period of time between extrinsic sound events. Table 4 compares the noise free interval (NFI) of each site, as calculated from on-site listening. On-site listening sessions represent conditions at the sites during the day, when field personnel were available to gather sound source data. Frequent road vehicle pass-by events account for the very short NFIs at both sites (see Table 8).

Table 4. Noise free interval statistics based on on-site listening

Site Location	Max Noise Free Interval (m:s)	Mean Noise Free Interval (m:s)
VICK001: Boy Scout Trail (n = 2h)	0:17	0:11
VICK002: Indiana Monument (n = 2h)	0:03	0:02

Introduction

A 1998 survey of the American public revealed that 72 percent of respondents thought that providing opportunities to experience natural quiet and the sounds of nature was a very important reason for having national parks, while another 23 percent thought that it was somewhat important (Haas & Wakefield 1998). In another survey specific to park visitors, 91 percent of respondents considered enjoyment of natural quiet and the sounds of nature as compelling reasons for visiting national parks (McDonald et. al 1995). Acoustical monitoring provides a scientific basis for assessing the current status of acoustical resources, identifying trends in resource conditions, quantifying impacts from other actions, assessing consistency with park management objectives and standards, and informing management decisions regarding desired future conditions.

National Park Service Natural Sounds and Night Skies Division

The NPS Natural Sounds Program (NSP) was established in 2000 to help parks manage sounds in a way that balances access to the park with the expectations of park visitors and the protection of park resources. As of fiscal year 2011, the program has been elevated to a division, the Natural Sounds and Night Skies Division (NSNSD) within the Natural Resource Stewardship and Science Directorate. The NSNSD addresses acoustical issues raised by Congress, NPS Management Policies, and NPS Directors Orders. An important element of this mission is working with the Federal Aviation Administration (FAA) to implement the National Parks Air Tour Management Act. Congress mandated that FAA and NPS jointly develop Air Tour Management Plans (ATMPs) for more than 106 parks where commercial air tours operate. The program also provides technical assistance to parks in the form of acoustical monitoring, data processing, park planning support, and comparative analyses of acoustical environments throughout the national park system.

Soundscape Planning Authorities

The National Park Service Organic Act of 1916 states that the purpose of national parks is "... to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." In addition to the NPS Organic Act, the Redwoods Act of 1978 affirmed that, "the protection, management, and administration of these areas shall be conducted in light of the high value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established, except as may have been or shall be directly and specifically provided by Congress."

Direction for management of natural soundscapes¹ is represented in 2006 Management Policy 4.9:

¹ The 2006 Management Policy 4.9 and related documents refer to "soundscapes" instead of "acoustic resources." When quoting from this authority, it is advisable to note that the term often refers to resources rather than visitor perceptions.

The Service will restore to the natural condition wherever possible those park soundscapes that have become degraded by unnatural sounds (noise), and will protect natural soundscapes from unacceptable impacts. Using appropriate management planning, superintendents will identify what levels and types of unnatural sound constitute acceptable impacts on park natural soundscapes. The frequencies, magnitudes, and durations of acceptable levels of unnatural sound will vary throughout a park, being generally greater in developed areas. In and adjacent to parks, the Service will monitor human activities that generate noise that adversely affects park soundscapes [acoustic resources], including noise caused by mechanical or electronic devices. The Service will take action to prevent or minimize all noise that through frequency, magnitude, or duration adversely affects the natural soundscape [acoustic resource] or other park resources or values, or that exceeds levels that have been identified through monitoring as being acceptable to or appropriate for visitor uses at the sites being monitored (NPS 2006a).

It should be noted that “the natural ambient sound level—that is, the environment of sound that exists in the absence of human-caused noise—is the baseline condition, and the standard against which current conditions in a soundscape [acoustical environment] will be measured and evaluated” (NPS 2006b). However, the desired acoustic condition may also depend upon the resources and the values of the park. For instance, “culturally appropriate sounds are important elements of the national park experience in many parks” (NPS 2006b). In this case, “the Service will preserve soundscape resources and values of the parks to the greatest extent possible to protect opportunities for appropriate transmission of cultural and historic sounds that are fundamental components of the purposes and values for which the parks were established” (NPS 2006b).

Study Area

During the summer of 2010, two long-term acoustical monitoring stations were deployed at VICK (Table 5). The two sites were selected to represent one of the quietest areas of the park and an area heavily impacted by external traffic noise. Short-term sound measurements were also taken at three locations in VICK (Table 6). Site VICK A was chosen to measure and record the cultural sounds of artillery fire during an interpretive program. Sites VICK B and C were selected to measure sound levels and determine whether noise might impact the visitor experience at the U.S.S. Cairo/National Cemetery and Visitor Center, respectively. See Figure 1-5 for site photos and Figure 6 for a park map indicating site locations.

Table 5. VICK long-term acoustical monitoring sites

Site	Site Name	Dates Deployed	Vegetation	Elevation (m)	Latitude	Longitude
VICK001	Boy Scout Trail	7/26 – 8/25	In mowed clearing on trail, bottomland hardwood forest	104	32.37897	-90.84873
VICK002	Indiana Monument	7/26 – 8/25	On hill with monument, narrow wooded border between park and I-20	74	32.33262	-90.86265

Table 6. VICK short-term acoustical monitoring sites.

Site	Site Name	Date	Time	Location	Sound sources of interest
VICK A	Living History	7/27/10	1030-1120	Downhill from embrasures used in Living History programs	Cannon and musket fire
VICK B	U.S.S. Cairo-National Cemetery	7/27/10	1520-1700	Open area of cemetery in view of USS Cairo, parking lot, US-61, shipping canal, railroad tracks.	Road and canal traffic, train, industrial complex, landscaping equipment
VICK C	Visitor Center	7/28/10	0800-1030	At Living History embrasure, right next to parking lot and Visitor Center.	Park visitor traffic, I-20, MS-80



Figure 1. VICK001 (Boy Scout Trail long-term monitoring site).



Figure 2. VICK002 (Indiana Monument long-term monitoring site).



Figure 3. VICK A (Living History short-term monitoring site).



Figure 4. VICK B (National Cemetery/U.S.S. Cairo short-term monitoring site).



Figure 5. VICK C (Visitor Center short-term monitoring site [left] Living History embrasures with sound monitoring equipment and [right] view towards parking lot and Clay Street).

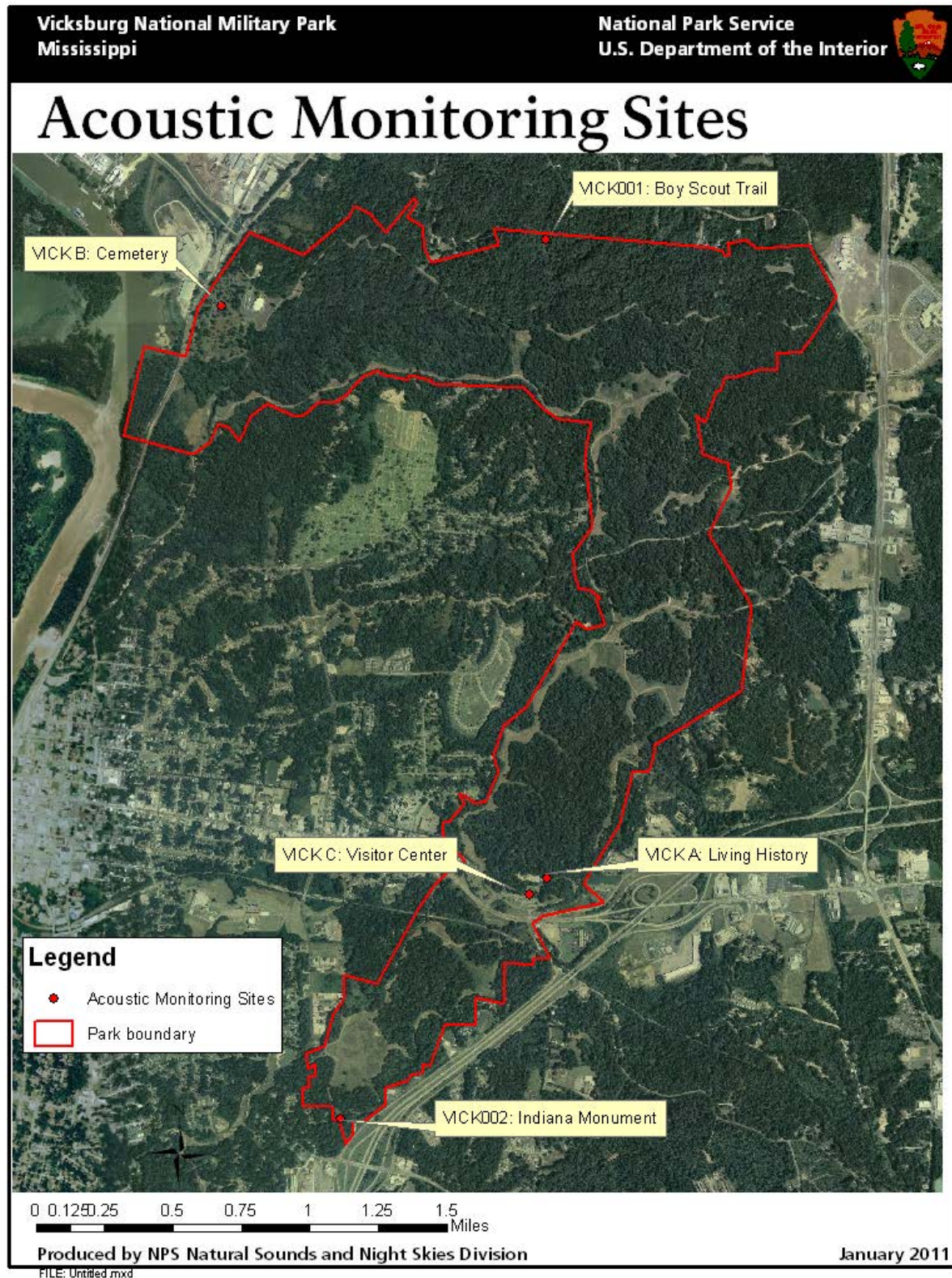


Figure 6. Locations of acoustical monitoring sites.

Methods

Automatic Monitoring

Larson Davis 831 sound level meters (SLM) were employed over the 34 monitoring period at VICK. The Larson Davis SLM is a hardware-based, real-time analyzer which constantly records one-second sound pressure level (SPL) and 1/3 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.

Each acoustical sampling station consisted of:

- Larson Davis 831 SLM
- Microphone with environmental shroud
- Preamplifier
- Anemometer
- MP3 recorder
- 12V LiFePO₄ batteries
- Photovoltaic panels

Each acoustical sampling station collected:

- SPL 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

Off-Site Listening

In 2005, the NPS drafted protocols for acoustic studies in National Parks, in cooperation with staff from the Volpe National Transportation Systems Center². When these acoustic monitoring protocols were developed, the amount of power it took to run recording devices, and storage limitations of these devices, were such that continuous recordings could not be made. As an alternative, recordings were made every 2 minutes for 10 seconds. This sampling scheme was designed to ensure that events of interest (namely aircraft and vehicles) would be recorded. Since that time, audio recorders have become much smaller and require less power. In addition, storage devices with larger capacities have become readily available. Therefore, continuous audio recordings were collected during the 2010 monitoring effort at VICK.

Per the 2005 protocol, a 25 day monitoring period is recommended for each site. During the monitoring period, investigators are instructed to conduct several hours of observer logging or recording playback (typically 16 hours per site) to determine the audible sources of noise. Continuous recording has allowed us the convenience of conducting these listening sessions in the office instead of in the field. Natural Sounds and Night Skies Division staff still listen to a subset of

² National Park Service. 2005. Acoustic and Soundscape Studies in National Parks DRAFT.

the audio data, using the 10 seconds per 2 minutes sampling scheme. When placed end-to-end, these 10 second samples constitute 2 hours of audio recordings. To reach an equivalent 16 hours of observer logging, we listen to 8 days of sub-sampled audio. These listening sessions provide the basis for the calculation of metrics such as natural ambient, as explained in detail in the section on “Calculation of Metrics” below. Noise canceling headphones were used for off-site listening playback to minimize limitations imposed by the office acoustic environment.

On-Site Listening

On-site listening is done by an observer near the acoustical monitoring station who listens for a designated period of time (in this case, one hour), identifying all sound sources and their durations and recording the data on a handheld PDA. On-site listening takes full advantage of human binaural hearing capabilities, and closely matches the experience of park visitors. Logistic constraints prevent comprehensive sampling by this technique, but selective samples of on-site listening provide a basis for relating the results of off-site listening to the probable auditory perception of events by park visitors and wildlife. On-site listening sessions are also an excellent screening tool for parks initiating acoustical environment studies. They produce an extensive inventory of sound sources, require little equipment or training, and can help educate park staff and volunteers.

Thus, periods of on-site listening were conducted in order to discern the type, timing, and duration during sound-level data collection at VICK. As recommended by NSNSD protocol (NPS 2005), these sessions generally began at the top of an hour and lasted for one hour. Staff recorded the beginning and ending times of all audible sound sources using custom-designed Personal Digital Assistant (PDA) software. These on-site listening sessions provided the basis for the calculation of metrics including the period of time between noise events (average noise free interval [NFI]), percent time each sound source was audible, and maximum, minimum, and mean length (in seconds) of sound source events (see Table 8 Table 9).

Calculation of Metrics

The current status of the acoustical environment can be characterized by spectral measurements, durations, and overall sound levels (intensities). The NSNSD uses descriptive figures and metrics to interpret these characteristics. Two fundamental descriptors are existing ambient (L_{50}) and natural ambient (L_{nat}) sound levels. These are both examples of exceedence levels, where each L_x value refers to the sound pressure level that is exceeded x percent of the time. The L_{50} represents the median sound pressure level, and is comprised of spectra (in dB) drawn from a full dataset (removing data with wind speed $> 5\text{m/s}$ to eliminate error from microphone distortion).

Calculation of diel L_x values

The Natural Sounds and Night Skies Division uses a custom program called “Hourly Metrics” to generate L_x values from long term acoustical monitoring data. All of the values reported are medians. The software aggregates L_x values (L_{50} , L_{nat} , L_{90}) for each hour monitored, based on one-second L_{eq} data. Then, hourly percentile values (L_{50} , L_{nat} , L_{90} etc.) are grouped by time category (daytime or

nighttime), and the median of each time category is reported. For instance, for daytime L_{90} , all L_{90} values between 0800h and 1600h are calculated and the median of this set is reported.

Calculation of L_{nat} values

The natural ambient (L_{nat}) is an estimate of what the ambient level for a site would be if all extrinsic or anthropogenic sources were removed. Unlike the existing ambient (L_{50}), the natural ambient is comprised of spectra drawn from a subset of the original data. For a given hour (or other specified time period), L_{nat} is calculated to be the decibel level exceeded x percent of the time, where x is defined by the equation

$$x = \frac{100 - P_H}{2} + P_H,$$

and P_H is the percentage of samples containing extrinsic or anthropogenic sounds for the hour. For example, if human caused sounds are present 30% of the hour, $x = 65$, and the L_{nat} is equal to the L_{65} , or the level exceeded 65% of the time.

It is standard practice for the Natural Sounds and Night Skies Division to calculate L_{nat} ; however, there are conditions under which this is not possible. If $P_H = 100$, then $x = 100$, and L_{nat} would be equal to the L_{100} , or the level exceeded 100% of the time. But because by definition these levels always include extrinsic or anthropogenic sounds, no estimate can be made of what the ambient level would be if they were absent. At VICK002, traffic noise was present 100% of the time. VICK001, which might have had some quiet intervals at night, experienced equipment failure. Therefore, L_{nat} is not reported for this park.

Results

Exceedence levels (L_x) are metrics used to describe acoustical data. They represent the dBA exceeded x percent of the time during the given measurement period (e.g., L₉₀ is the dBA that has been exceeded 90% of the time). The full frequency range of our recordings was 12.5-20,000 Hz. The range 20-800 Hz focuses on transportation sounds and crops out some of the more prevalent natural sounds, such as birds and insects.

VICK001 experienced equipment malfunction that prevented data recovery. VICK002 was so saturated with extrinsic noise that L_{nat} could not be calculated. Therefore, Table 7 reports the L₉₀, L₅₀, and L₁₀ values for the sites measured at VICK002.

Table 7. Exceedence levels for existing conditions

Site	Frequency (Hz)	Exceedence levels (dBA): 0800 to 1600				Exceedence levels (dBA): 1600 to 0800			
		L ₉₀	L _{nat}	L ₅₀	L ₁₀	L ₉₀	L _{nat}	L ₅₀	L ₁₀
VICK002	20-800	47.2	-	50.7	54.6	45.6	-	49.5	54.2
	12.5-20,000	50.9	-	53.7	56.9	55.3	-	56.8	58.6

¹The top value in each cell focuses on frequencies affected by transportation. This range does not correspond to a specific vehicle or type of transportation.

²The bottom value in each cell uses the full frequency spectrum.

Site VICK001: Boy Scout Trail

Due to equipment failure, no long-term data were recovered from VICK001. However, on-site listening results were available (Table 8). PA: Percentage of period audible; SD: standard deviation; Events reported as m:s.

Table 8. VICK001-Boy Scout Trail On-site listening. n = 2 hours.

Sound Source	PA	Max Event	Mean Event	Min Event	SD Event	Count
Aircraft	1.00	0:48	0:31	0:12	0:18	3
Jet	22.00	5:52	2:04	0:11	1:51	13
Aircraft, Propeller	9.00	2:40	1:29	0:28	0:51	7
Non-natural Other	3.00	1:04	0:30	0:12	0:20	6
Vehicle	90.00	58:56	7:43	0:27	15:19	14
Truck (6+ tires)	0.00	0:11	0:11	0:11	0:00	1
Wind	12.00	2:53	1:27	0:00	0:52	10
Rain/Fog Drip	6.00	3:59	2:26	0:34	1:44	3
Thunder	1.00	0:17	0:10	0:03	0:05	8
Squirrel	1.00	0:39	0:18	0:02	0:19	3
Bird	100.00	59:57	39:53	1:17	33:26	3
Amphibian	3.00	1:19	0:31	0:05	0:29	6
Insect	100.00	59:59	59:58	59:56	0:02	2
Train Rumble	1.00	0:30	0:22	0:16	0:07	3
Train Horn	0.00	0:20	0:18	0:16	0:03	2
Grounds Care	0.00	0:13	0:13	0:13		1
All Aircraft	32.24					
All Road Vehicles	90.10					
All Non-natural Sources	99.56					
All Natural Sources	99.93					
Noise Free Interval	0.44	0:17	0:11	0:07	0:06	3

Site VICK002: Indiana Monument

At VICK002, total extrinsic noise sources and road vehicles were audible at or near 100% of the time for all 24 hours within the 3 full days of off-site analysis. Only three hours (1200, 1900, 2000) had on average, less than 100% road vehicle noise audibility (98.9%, 94.4%, and 98.9%, respectively). This occurred when noises with similar frequencies (lawn mower, thunderstorm) briefly masked the audibility of highway vehicles. On-site listening results were also available (Table 9).

Table 9. VICK002-Indiana Monument On-site listening. n = 2 hours.

Sound Source	PA	Max Event	Mean Event	Min Event	SD Event	Count
Aircraft	4.00	1:18	0:27	0:01	0:24	10
Jet	1.00	0:49	0:32	0:16	0:23	2
Helicopter	1.00	0:54	0:35	0:16	0:27	2
Non-natural Other	10.00	2:13	0:46	0:05	0:45	16
Vehicle	100.00	59:58	59:58	59:57	0:01	2
Alarm, Horn	0.00	0:02	0:02	0:02		1
Brakes	0.00	0:02	0:02	0:02		1
Siren	4.00	2:13	2:11	2:09	0:03	2
Truck (6+ tires)	43.00	22:44	6:24	0:33	7:21	8
Rain/Fog Drip	33.00	40:05	40:05	40:05		1
Thunder	1.00	0:15	0:10	0:07	0:03	8
Squirrel	1.00	0:35	0:16	0:02	0:15	6
Bird	96.00	49:27	7:40	0:00	13:54	15
Insect	83.00	59:52	33:04	6:51	26:31	3
Train Horn	0.00	0:09	0:09	0:09		1
Grounds Care	16.00	3:27	0:46	0:06	0:52	25
Gunshot	0.00	0:06	0:06	0:06	0:24	1
All Aircraft	5.58					
All Road Vehicles	99.93					
All Non-natural Sources	99.93					
All Natural Sources	99.83					
Noise Free Interval	0.1	0:03	0:02	0:02		2

Figure 7 displays the percent time audible for various sound sources that were prominent during offsite listening. Both natural and non-natural sounds were audible 100% of the time, due to birds and insects (natural) and road vehicles (non-natural).

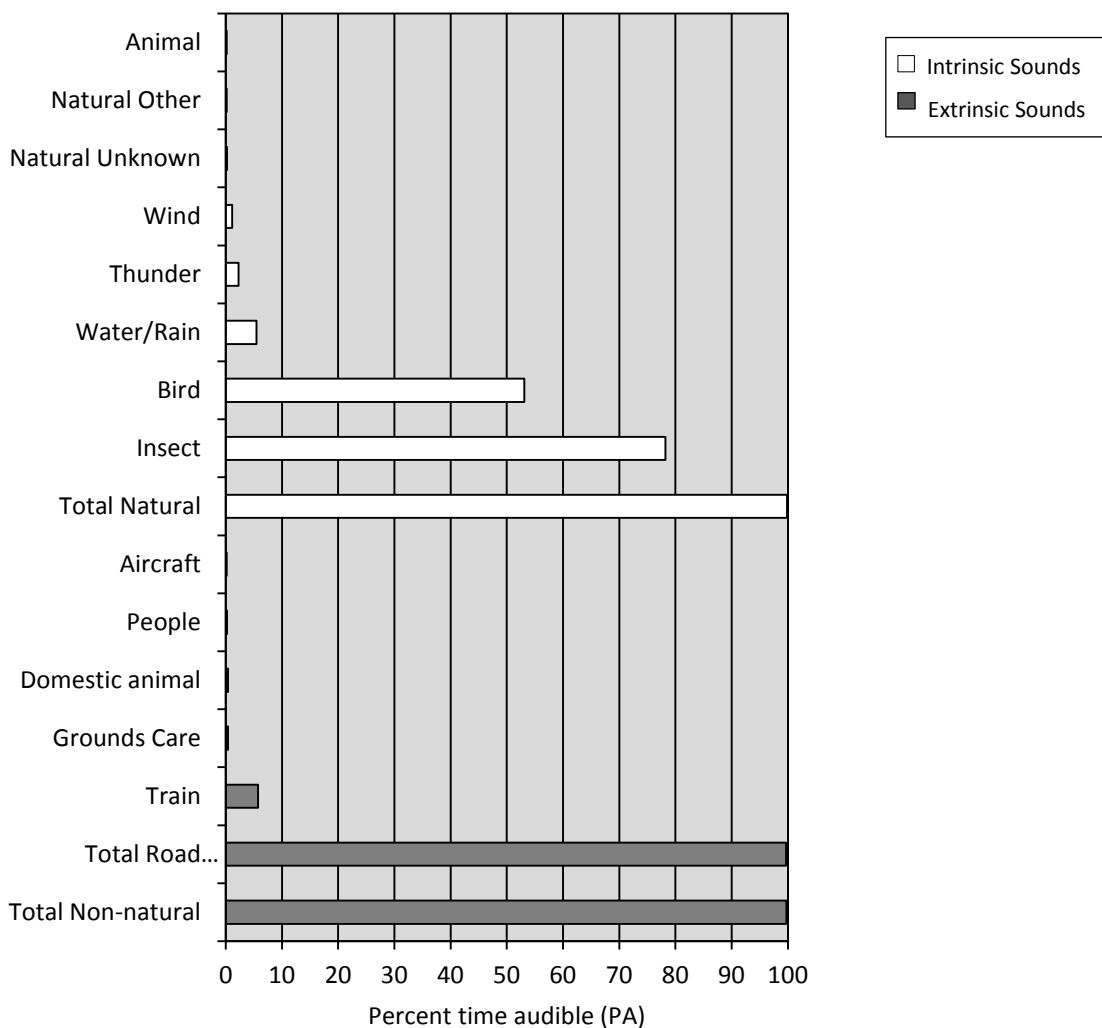


Figure 7. Percent time audible for sound sources during offsite listening sessions at VICK002 (Indiana Monument). N = 3 days.

Hourly L_{eq} values represent the energy equivalent sound level for each hour of the day. Figure 8 shows these values for the full frequency spectrum of our measurements (12.5-20,000 Hz), while Figure 9 shows the truncated transportation frequencies (20-800 Hz). When high-frequency sounds, including birds and insects, are eliminated from consideration, the relative hourly L_{eq} values switch from higher at night to higher during the day (note different Y-axis scales). Neel-Schaffer, Inc., under contract to MDOT, reported peak hourly L_{eq} estimates for the peak local I-20 traffic hours of 4-6pm .

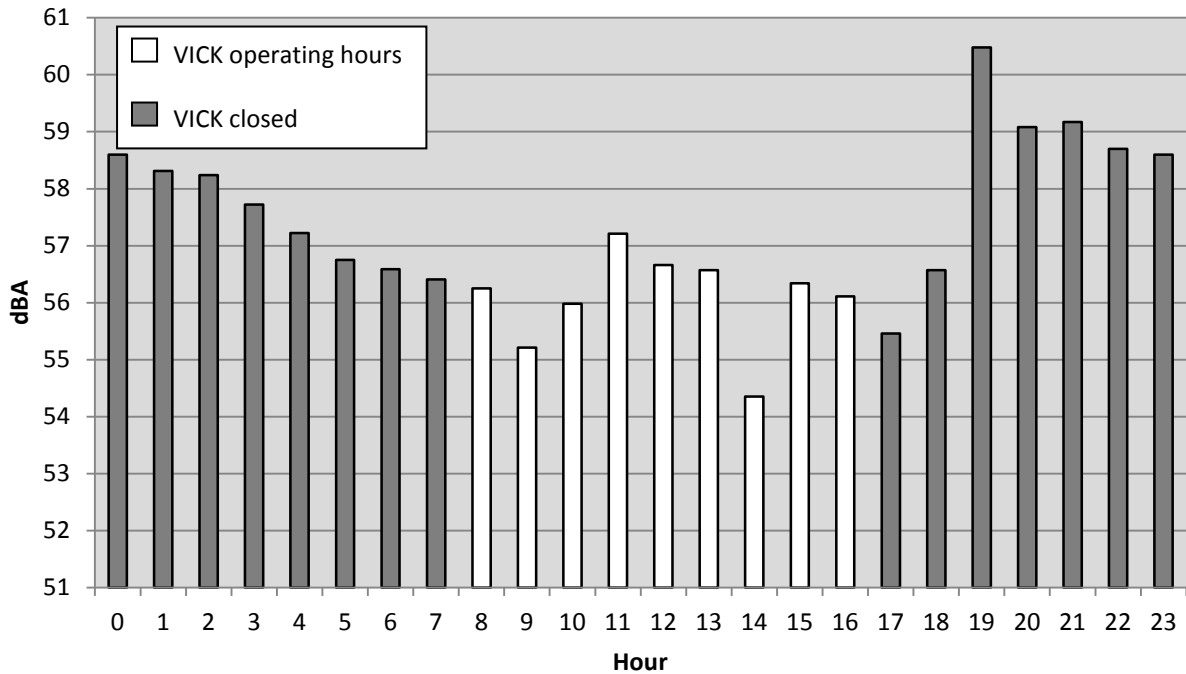


Figure 8. Mean hourly Leq over 34 days at VICK002 (Indiana Monument) for all measured frequencies (12.5-20,000 Hz). Hours 1600 and 1700 correspond to peak traffic as identified by Neel-Schaffer, Inc. (56.11 and 55.46 dBA, respectively. Mean = 55.8)

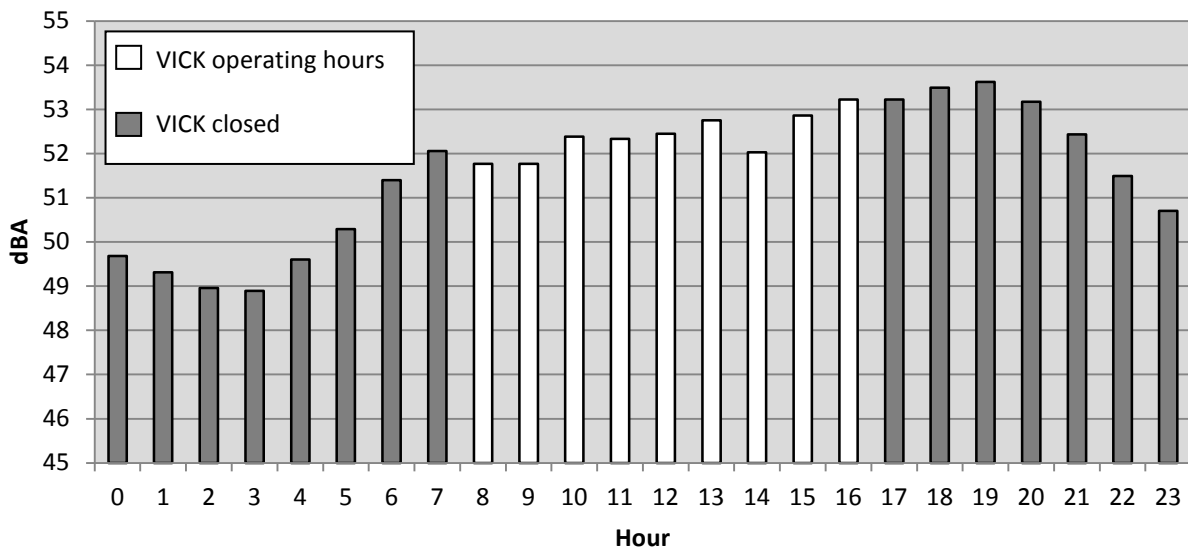


Figure 9. Mean hourly Leq over 34 days at VICK002 (Indiana Monument) for truncated frequencies corresponding to transportation sounds (20-800 Hz).

In order to determine the effects of extrinsic noise on the acoustical environment, it is useful to examine the median hourly exceedence metrics. In Figure 10 the dB levels for 33 one-third octave band frequencies over the day and night periods are shown for VICK002. Figures 15 and 16 provide the same information for the short term sites VICK B and C, but for only the hours during which measurements were taken. The grayed areas represent sound levels outside of the typical range of human hearing. The exceedence levels (L_x) are also shown for each one-third octave band. They represent the dB exceeded x percent of the time. For example, L_{90} is the dB that has been exceeded 90% of the time, and only the quietest 10% of the sample can be found below this point. On the other hand, the L_{10} is the dB that has been exceeded 10% of the time, and 90% of the measurements are quieter than the L_{10} .

L_{50} , L_{10} , and L_{90} essentially mark the median, maximum, and minimum sound pressure levels over the monitoring period. The typical frequency levels 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. It can be useful to review each one third octave band on these figures to adequately predict the audibility of one sound or the masking of another. For example, you will notice bird sounds and transportation noise are audible at different frequency spectrums. There may be times when transportation sounds were louder than the bird sounds; however, the bird sounds would not be masked because their song is audible at a different frequency. However, if two sounds are within similar or overlapping frequency ranges and one sound is louder than the other, you can begin to predict when sounds are going to be masked. As an example, vehicle noise, wind, and running water can mask distant aircraft in some cases.

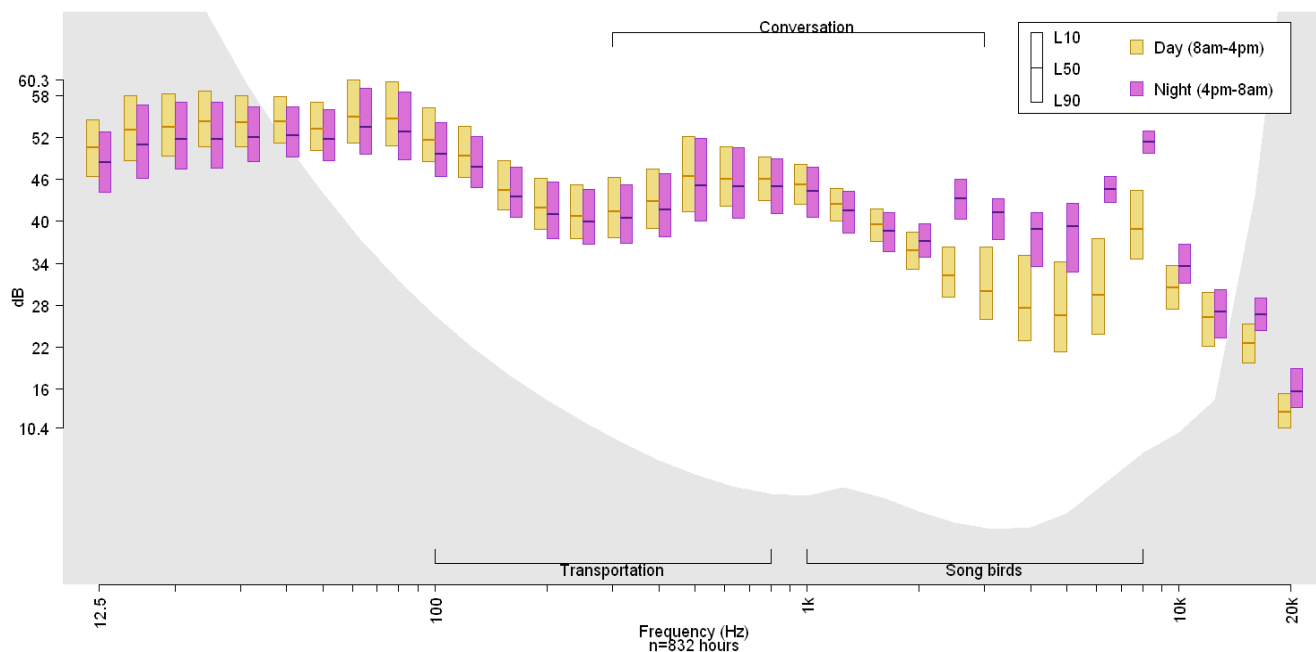


Figure 10. Day and night dB levels for 33 one-third octave bands at VICK002 (Indiana Monument).

Exceedence values (L_{10} , L_{50} , L_{90}) often vary throughout the day depending on sound sources. However, as seen in Figure 11, these values were fairly constant throughout the day and night at VICK002. This can be explained using Figure 11. Although low-frequency sound levels were slightly louder during the day (“transportation” frequency range), high-frequency sound levels increased at night due to cicadas.

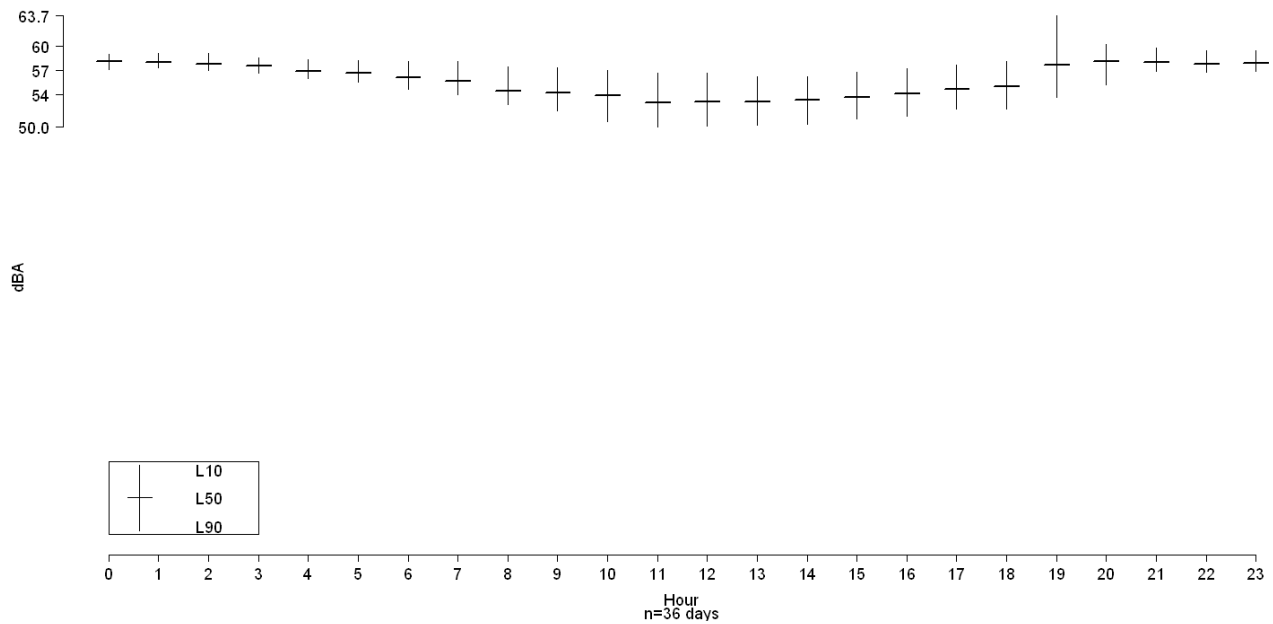


Figure 11. Exceedence values by hour at VICK002 (Indiana Monument).

Short-term sites

The measurements taken at VICK A (Living History) were designed to create a sound profile for the artillery fire used during interpretive programs. A common way to visually represent acoustic data is by using a spectrogram, a type of plot showing sound level as a function of time and frequency. Figures 12-14 are spectrograms of data collected during a living history interpretive program on July 27, 2010. Time is represented in seconds on the X axis, sound frequency in Hertz on the logarithmically scaled Y axis, and sound pressure level in decibels is indicated by color brightness (see legend below). The maximum levels recorded by our equipment at 154m from the sound sources were: **126.3** for the cannon, **112.6** for the single musket, and **120.6** for two muskets. See Table 10 for examples of dB levels for common sounds.

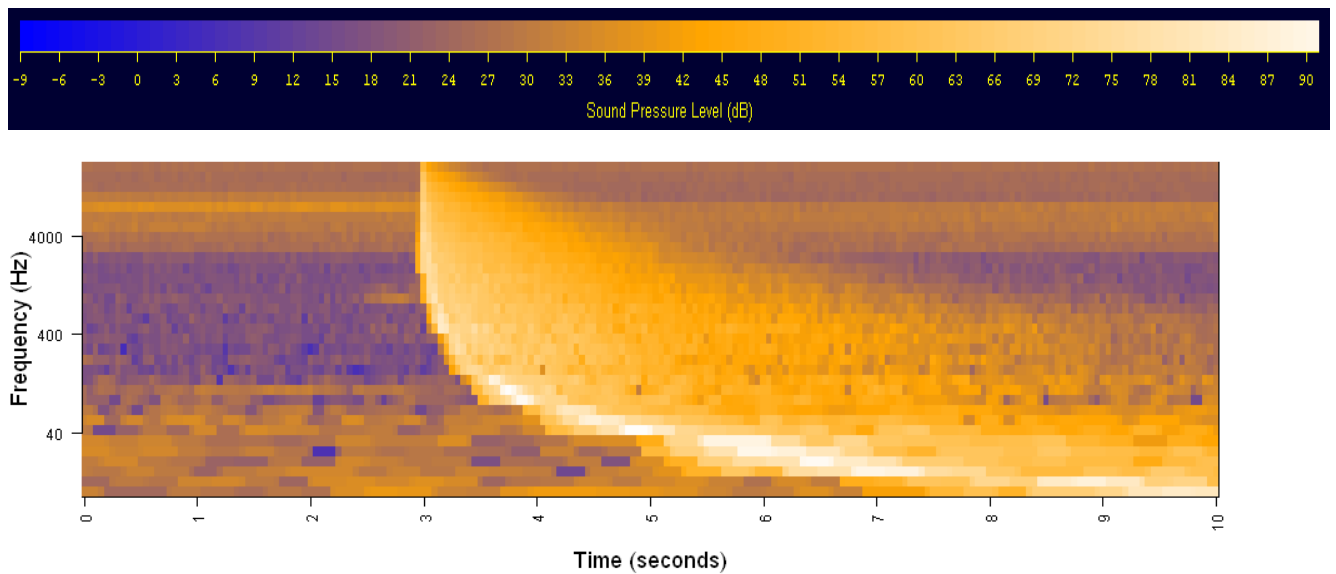


Figure 12. Spectrogram of cannon fire at 154m during Vicksburg NMP Living History Program.

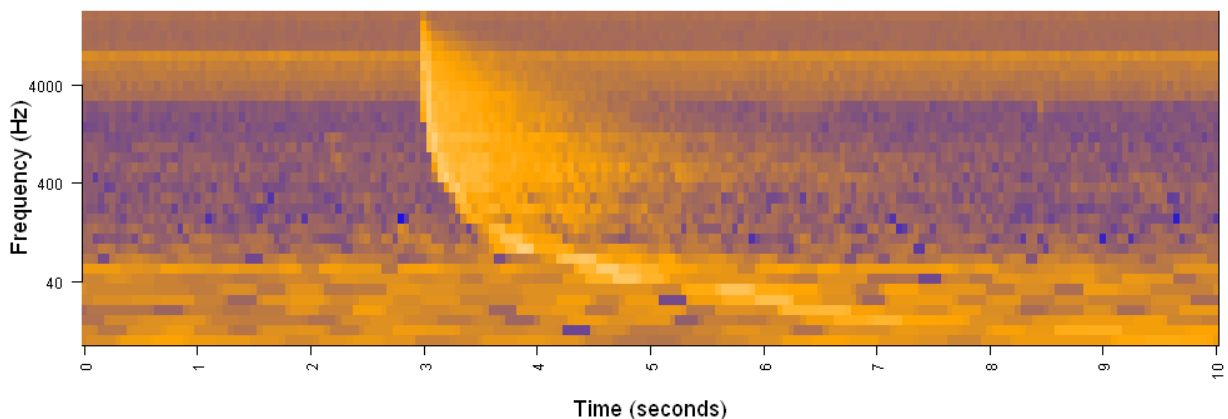


Figure 13. Spectrogram of musket fire at 154m during Vicksburg NMP Living History Program.

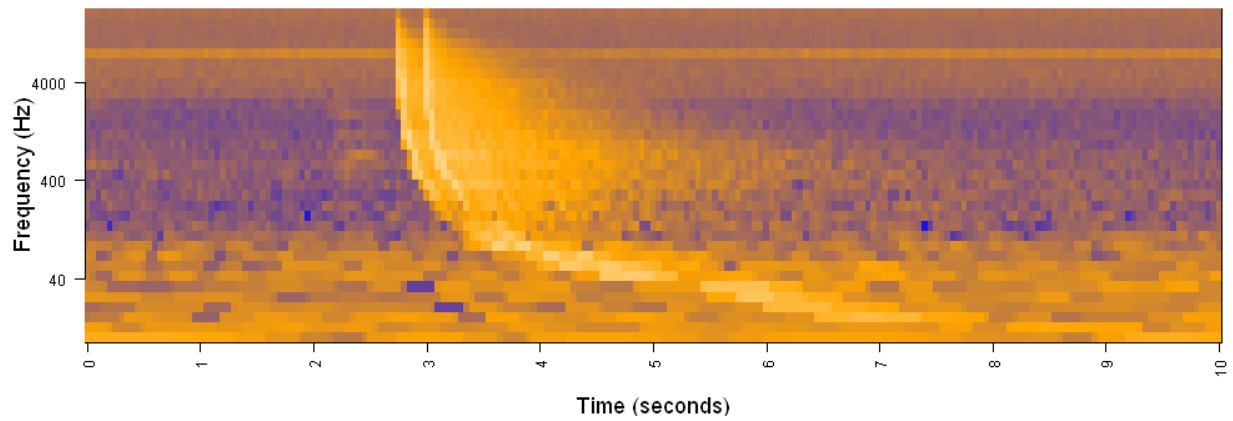


Figure 14. Spectrogram of two muskets fired simultaneously at 154m during Vicksburg NMP Living History Program.

Table 10. 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

Figure 15 and Figure 16 display the short term sound pressure levels for 33 one-third octave bands at VICK B (Cemetery) and VICK C (Visitor Center).

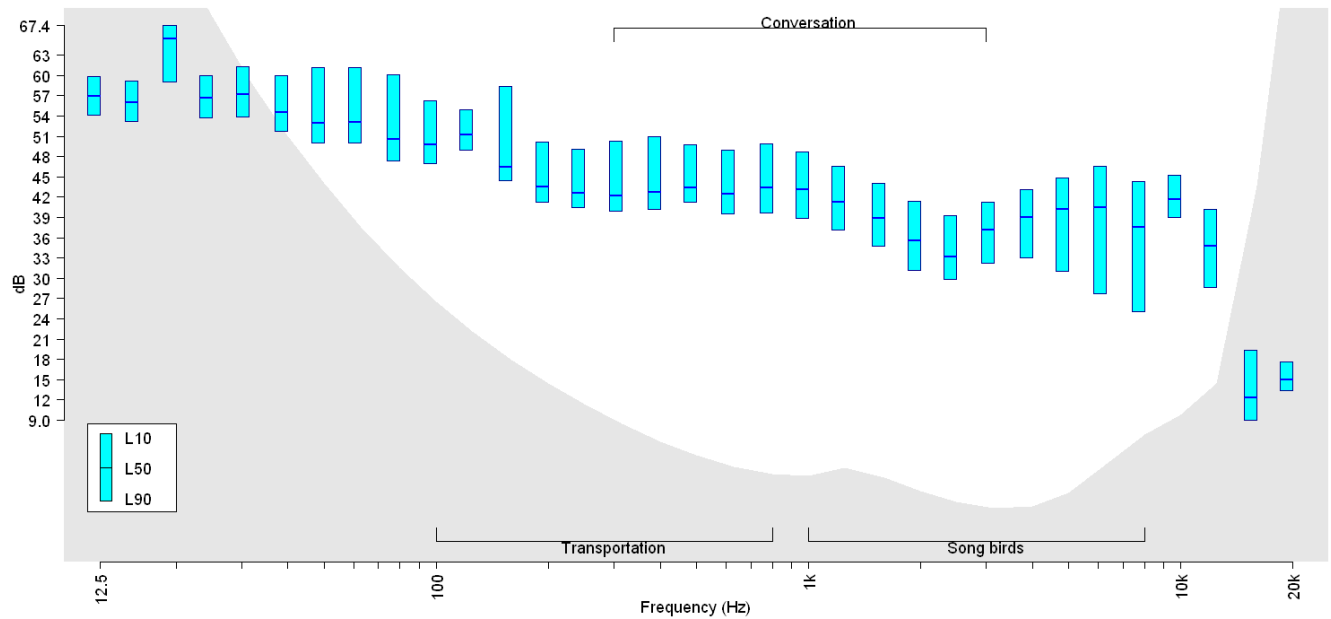


Figure 15. Short-term dB levels for 33 one-third octave bands at VICK B (Cemetery), July 27, 2010, 1520-1700.

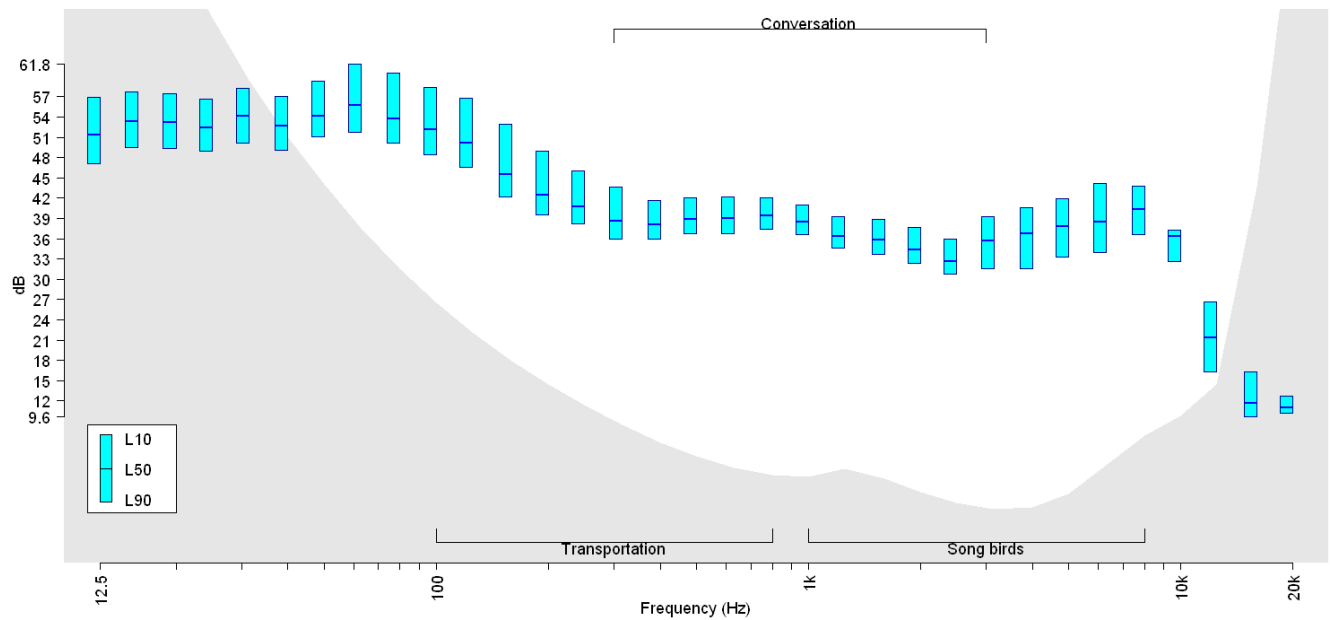


Figure 16. Short-term dB levels for 33 one-third octave bands at VICK C (Visitor Center), July 28, 2010, 0800-1030.

Discussion

Long-term sites

The purpose of this study was to conduct acoustical monitoring at Vicksburg National Military Park in order to determine current conditions. Monitoring results were intended to provide the park with baseline data about acoustical conditions and inform future management decisions. Sound pressure level, wind speed data, and continuous audio were collected. Data collected during this effort will be stored in the Natural Sounds and Night Skies Division (NSNSD) archive. The park can compare these data to the results of studies conducted by a private contractor for Mississippi Department of Transportation (see Appendices).

Due to equipment failure at VICK001 (Boy Scout Trail), the quieter site, NSNSD was unable to calculate the natural ambient sound level (L_{nat}) at that site. Based on the on-site listening data (Table 8), it is unlikely that L_{nat} could have been calculated from daytime recordings; however, if conditions were quieter at night this might have been possible. L_{nat} could not be calculated from VICK002 (Indiana Monument) due to nearly continuous I-20 traffic noise during all 24 hours at that site (Figure 7). However, given the urban setting of the park, L_{nat} is unlikely to be a useful metric for Vicksburg resource managers.

The data from VICK002 indicate that road vehicle noise from I-20 is consistently audible at least in some locations of the park (Figure 7). Neel-Schaffer, Inc., in a preliminary report for MDOT, used an industry-standard Traffic Noise Model to estimate the average hourly L_{eq} during the peak local traffic hours of 4-6pm. For their closest points to VICK002, the values were 68.2, 66.6, and 58.3 dBA (see points 32, 48, and 53 in Appendix C). At VICK002, NPS Natural Sounds Program staff measured an average hourly L_{eq} of 55.8 for the 4-6pm hours. The fact that the measured sound level was lower can be explained in part by distance. The MDOT noise receptor locations were close to the road, with direct line of sight to I-20, while VICK002 is about 130 meters away. Sound levels at the site were also buffered by a narrow wooded border between the park and the highway which absorbs some sound energy. Depending on which alternative MDOT selects for I-20, they project an increase in estimated L_{eq} of 1.5-12.5 dBA at their noise receptor locations by 2040. In consultation with park staff, Neel-Schaffer, Inc. also modeled impacts at two sites inside the park. At the time of writing, precise locations of these are not known, but their current estimated average hourly L_{eq} values are 53.8 and 48.7 dBA (see points 117-118 in Appendix C). Point 117 is projected to be impacted in all of the possible alternatives; point 118 in none.

Short-term sites

The short-term data collected at the Cemetery and Visitor Center were designed to examine the functional effects of sound levels at those locations. According to the EPA, 52dBA is the threshold for speech interference for interpretive programs; 60dBA is the threshold for speech interruption for normal conversation (U.S. Environmental Protection Agency, 1974). During the hours that equipment was deployed, both sites exceeded these two metrics for the majority of the time (Table 2).

Cultural and Natural sounds

A secondary objective of this study was to record living history program sounds. Both cannon and musket fire were recorded and analyzed. In order to obtain high-quality audio recordings, the equipment was placed 154m away from the sound source at the embrasures. Even at this distance, peak sound levels approached or exceeded 120dB, the threshold of pain for human ears, and would be even louder near the source, where the volunteers and visitors stand. The current practice of using ear protection is therefore commended.

During analysis, NSNSD staff noted interesting natural sounds at VICK. Loud cicadas were recorded, along with a variety of bird species, including Great Horned Owl, Downy Woodpecker, Eastern Wood-pewee, White-eyed Vireo, Blue Jay, Carolina Chickadee, Eastern Tufted Titmouse, Carolina Wren, and Northern Cardinal. Impressive thunderstorms were also recorded. All audio recordings are available to the park upon request.

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Appendix A: Glossary of Acoustical Terms

Acoustical Environment

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

Alerting distance

The maximum distance at which a signal can be perceived. Alerting distance is pertinent in biological contexts where sounds are monitored to detect potential threats.

Amplitude

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

Atmospheric absorption

The part of transmission loss caused by conversion of acoustic energy into other forms of energy. Absorption coefficients increase with increasing frequency, and range from a few dB to hundreds of dB per kilometer within the spectrum of human audibility.

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.

A-weighted sound pressure level in decibels (dB(A) or dBA)

A frequency-based methodology used to account for changes in human hearing sensitivity as a function of frequency. The A-weighting network de-emphasizes the high (6.3 kHz and above) and low (below 1 kHz) frequencies, and emphasizes the frequencies between 1 and 6.3 kHz, in an effort to simulate the relative response of the human ear. Technically speaking, A-weighted decibels are defined as ten times the logarithm to the base ten of the ratio of A-weighted squared sound pressure to the squared reference sound pressure of 20 μ Pa, the squared sound pressure being obtained with fast (F) (125-ms) exponentially weighted time averaging. Alternatively, slow (S) (1000-ms) exponentially weighted time averaging may be specified.

Decibel

Decibel is abbreviated dB, and is a logarithmic unit of sound-pressure-squared level; it is common practice, however, to shorten this to sound pressure level, when no ambiguity results from so doing. 0 dB represents the lowest sound level that can be perceived by a human with healthy hearing. The formula for computing decibels is:

$$L_{dB} = 10 \log_{10} \left(\frac{P_1}{P_0} \right)$$

Diel

A 24-hour period usually consisting of a day and the adjoining night.

Extrinsic Sound

Any sound not forming an essential part of the park unit, or a sound originating from outside the park boundary (also see Intrinsic Sound).

Frequency

Frequency equals the speed of sound divided by wavelength, and can be expressed in cycles per second, or Hertz (Hz). For a function periodic in time, the frequency is the reciprocal of the period, where the period is the smallest increment of an independent variable for which a function repeats itself (also see Hertz).

Ground attenuation

The part of transmission loss caused by interaction of the propagating sound with the ground.

Hearing Range (frequency)

By convention, an average, healthy, young person is said to hear frequencies from approximately 20Hz to 20,000 Hz.

Hertz (Hz)

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. Kilohertz (kHz) equals 1000 Hz.

Intrinsic sound

A sound which belongs to a park by its very nature, based on the park unit purposes, values, and establishing legislation. The term “intrinsic sounds” has replaced “natural sounds” in order to incorporate both cultural and historic sounds as part of the acoustic environment of a park (also see Extrinsic Sound).

Listening area

The area of a circle whose radius is the alerting distance. Listening area is the same as the ‘active space’ of a vocalization, with a listener replacing the signaler as the focus, and is pertinent for organisms that are searching for sounds.

Listening Horizon

The range or limit of one’s hearing capabilities. Just as smog limits the visual horizon, so noise limits the acoustic horizon.

 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 (Percentile –Exceeded Sound Level)

The A-weighted sound level equal to or exceeded by a fluctuating sound level x percent of a stated time period. For example, the symbol L_{10} represents that sound level which is exceeded 10 percent of the stated time period.³

Masking (of a sound)

Interference with the detection of a sound due to the presence of another sound. More specifically, the number of decibels (dB) by which the intensity level of sound A must be raised above its

³ Hobbs & Downing 2003. Wyle Report WR 03-08.

threshold of audibility to be heard in the presence of a second sound, B. Sound A and sound B may be identical or may differ in frequency, complexity, or time.

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.⁴

Noticeable

A signal that attracts the attention of an organism whose focus is elsewhere.

Off-site Listening

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

Percent Time Audible (PA)

The percent of time that a time-varying sound level may be detected in the presence of ambient sound as audible by the human ear.

Spectrum, power spectrum and spectral profile

The distribution of acoustic energy in relation to frequency. In graphical presentations, the spectrum is often plotted as sound intensity against sound frequency.

1/3 octave spectrum

Acoustic intensity measurements in a sequence of spectral bands that span 1/3 octave. The International Standards Organization defines 1/3rd octave bands used by most sound level meters (ISO 266, 1975). 1/3rd octave frequency bands approximate the auditory filter widths of the human peripheral auditory system.

Sound pressure level Ten times the logarithm to the base ten of the ratio of the time-mean-square pressure of a sound, in a stated frequency band, to the square of the reference sound pressure in gases

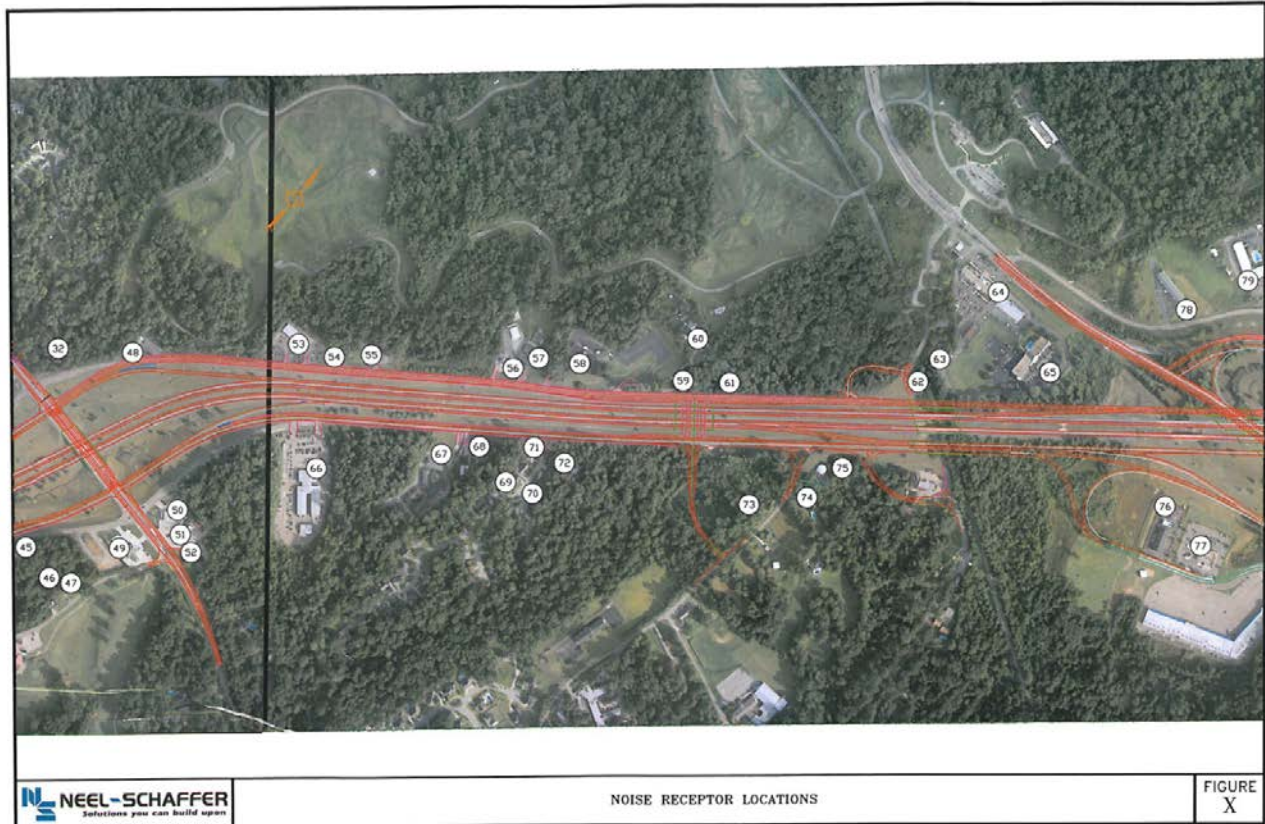
⁴ McGraw Hill Dictionary of Scientific and Technical Terms, online

<http://www.accessscience.com/index.aspx>

of $20\ \mu\text{Pa}$, the threshold of human hearing. $\text{SPL} = 10\text{Log}_{10}(p^2/p_{\text{ref}}^2)$, where p^2 = time-mean-square sound pressure and p_{ref}^2 = squared reference sound pressure of $20\ \mu\text{Pa}$.

Appendix B: Neel-Schaffer, Inc. noise receptor locations for MDOT I-20 noise modeling

Note that points 32, 48, and 53 are closest to VICK002 (Indiana Monument).



Appendix C: Neel-Schaffer, Inc. noise levels

Table 2, Exterior Noise Levels, from Neel-Schaffer report to MDOT. Note that points 32, 48, and 53 are closest to VICK002 (Indiana Monument); points 117 and 118 are inside the park.

Noise Receiver	Category and 23 CFR 722 Noise Abatement Level (Leq) dBA	Traffic Noise Source(s)	Distance from Receiver to Existing Centerline	Distance from Receiver to Alternative B and Alternate C Centerline	Existing			2030 No Build		2030 Alternative B		2030 Alternative C	
					Measured Leq (dBA)	Estimated Leq (dBA)	Noise Impact	Estimated Leq (dBA)	Noise Impact	Estimated Leq (dBA)	Noise Impact	Estimated Leq (dBA)	Noise Impact
17	Commercial 72	I-20	255	255	68.8	70.8	No	73.4	Yes	70.9	No	70.7	No
18	Commercial 72	I-20	190	190	-	69.4	No	71.7	Yes	69.5	No	69.4	No
19	Residential 67	I-20	195	195	-	67.9	Yes	70.2	Yes	69.7	Yes	69.6	Yes
20	Residential 67	I-20	330	330	-	66.0	Yes	68.5	Yes	69.1	Yes	68.9	Yes
21	Commercial 72	I-20	170	170	-	72.6	Yes	75.1	Yes	74.5	Yes	74.6	Yes
22	Commercial 72	I-20	200	200	-	66.1	No	69.0	No	68.7	No	69.1	No
23	Commercial 72	I-20	185	185	-	72.4	Yes	75.4	Yes	76.2	Yes	76.1	Yes
24	Commercial 72	I-20	195	195	-	71.5	Yes	74.4	Yes	75.0	Yes	74.9	Yes
25	Commercial 72	I-20	210	210	-	70.8	No	73.8	Yes	74.7	Yes	74.6	Yes
26	Commercial 72	I-20	220	220	-	70.1	No	73.1	Yes	74.5	Yes	74.3	Yes
27	Commercial 72	I-20	185	185	-	71.5	Yes	74.5	Yes	75.4	Yes	75.5	Yes
28	Commercial 72	I-20	305	305	-	67.9	No	70.9	No	70.6	No	70.8	No
29	Commercial 72	I-20	310	310	-	66.6	No	69.5	No	69.4	No	70.2	No
30	Commercial 72	Indiana Ave.	155	155	-	55.8	No	58.2	No	58.7	No	58.6	No
31	Commercial 72	I-20	535	535	-	60.3	No	62.7	No	63.0	No	-	-
32	Residential 67	I-20	640	640	-	58.4	No	60.8	No	59.8	No	60.3	No

Noise Receiver	Category and 23 CFR 722 Noise Abatement Level (Leq) dBA	Traffic Noise Source(s)	Distance from Receiver to Existing Centerline	Distance from Receiver to Alternative B and Alternate C Centerline	Existing			2030 No Build		2030 Alternative B		2030 Alternative C	
					Measured Leq (dBA)	Estimated Leq (dBA)	Noise Impact	Estimated Leq (dBA)	Noise Impact	Estimated Leq (dBA)	Noise Impact	Estimated Leq (dBA)	Noise Impact
33	Commercial 72	I-20	180	180	-	70.3	No	73.2	Yes	72.4	Yes	72.5	Yes
34	Commercial 72	I-20	235	235	-	68.4	No	71.3	Yes	71.8	Yes	71.8	Yes
35	Commercial 72	I-20	215	215	-	63.5	No	66.3	No	69.2	No	69.4	No
36	Commercial 72	I-20	280	280	-	65.8	No	68.8	No	70.1	No	70.4	No
37	Commercial 72	I-20	260	260	-	68.3	No	71.3	Yes	72.5	Yes	72.5	Yes
38	Commercial 72	I-20	225	225	-	68.0	No	70.9	No	71.7	Yes	72.0	Yes
39	Commercial 72	I-20	425	425	-	60.4	No	63.3	No	63.3	No	63.4	No
40	Commercial 72	I-20	375	375	-	63.5	No	66.4	No	65.9	No	66.1	No
41	Commercial 72	I-20	415	415	-	65.9	No	68.8	No	68.6	No	69.2	No
42	Commercial 72	I-20	465	465	-	65.8	No	68.7	No	68.4	No	68.7	No
43	Commercial 72	I-20	475	475	-	63.0	No	66.0	No	66.0	No	65.7	No
44	Commercial 72	I-20	335	335	-	67.4	No	70.3	No	68.8	No	68.8	No
45	Commercial 72	I-20	405	405	-	65.9	No	68.5	No	67.6	No	68.0	No
46	Residential 67	I-20	645	645	-	63.7	No	66.6	Yes	66.9	Yes	67.3	Yes
47	Residential 67	I-20	700	700	-	62.7	No	65.6	No	65.8	No	66.2	Yes
48	Hotel 67	I-20	405	405	-	68.2	Yes	71.0	Yes	71.1	Yes	71.3	Yes
Noise Receiver	Category and 23 CFR 722 Noise Abatement Level (Leq) dBA	Traffic Noise Source(s)	Distance from Receiver to Existing Centerline	Distance from Receiver to Alternative B and Alternate C Centerline	Existing			2030 No Build		2030 Alternative B		2030 Alternative C	
					Measured Leq (dBA)	Estimated Leq (dBA)	Noise Impact	Estimated Leq (dBA)	Noise Impact	Estimated Leq (dBA)	Noise Impact	Estimated Leq (dBA)	Noise Impact
49	Commercial 72	I-20	670	670	-	62.5	No	65.2	No	65.4	No	-	-
50	Commercial 72	I-20	620	620	-	60.0	No	62.4	No	63.0	No	-	-
51	Commercial 72	Indiana Ave.	140	140	-	61.9	No	64.4	No	64.8	No	-	-
52	Commercial 72	Indiana Ave.	140	140	-	60.6	No	62.9	No	64.1	No	66.1	No
53	Commercial 72	I-20	290	290	-	66.6	No	69.5	No	69.4	No	70.3	No
54	Commercial 72	I-20	230	230	-	58.1	No	60.4	No	61.8	No	61.9	No
55	Commercial 72	I-20	265	265	-	62.4	No	65.2	No	68.8	No	70.9	No
56	Commercial 72	I-20	245	245	-	61.7	No	64.5	No	69.0	No	70.4	No
57	Commercial 72	I-20	320	320	-	62.0	No	65.0	No	69.2	No	71.9	Yes
58	Church 67	I-20	310	310	-	69.0	Yes	72.0	Yes	74.1	Yes	76.2	Yes
59	Residential 67	I-20	220	220	-	72.9	Yes	75.9	Yes	75.4	Yes	76.9	Yes
60	Residential 67	I-20	495	495	-	64.4	No	67.4	Yes	69.3	Yes	70.6	Yes
61	Residential 67	I-20	215	215	-	73.0	Yes	76.0	Yes	75.2	Yes	75.9	Yes
62	Commercial 72	I-20	250	250	-	69.1	No	71.9	Yes	68.4	No	68.8	No
63	Commercial 72	I-20	400	400	-	65.3	No	68.2	No	66.0	No	66.1	No
64	Hotel 67	Clay St.	155	155	-	59.2	No	61.7	No	61.3	No	61.4	No

Noise Receiver	Category and 23 CFR 722 Noise Abatement Level (Leq) dBA	Traffic Noise Source(s)	Distance from Receiver to Existing Centerline	Distance from Receiver to Alternative B and Alternate C Centerline	Existing			2030 No Build		2030 Alternative B		2030 Alternative C	
					Measured Leq (dBA)	Estimated Leq (dBA)	Noise Impact	Estimated Leq (dBA)	Noise Impact	Estimated Leq (dBA)	Noise Impact	Estimated Leq (dBA)	Noise Impact
113	Church 67	US 61 N.	150	150	67.6	65.0	Yes	67.4	Yes	67.4	Yes	67.4	Yes
114	Commercial 72	US 61 N.	170	170	-	63.9	No	66.5	No	66.5	No	66.5	No
115	Commercial 72	US 61 N.	160	160	-	65.3	No	68.0	No	68.1	No	68.1	No
116	Commercial 72	US 61 N.	160	160	-	65.9	No	68.5	No	68.5	No	68.5	No
117	National Park 57	I-20	770	770	-	53.8	No	56.8	Yes	56.3	Yes	57.6	Yes
118	National Park 57	I-20	1500	1500	-	48.7	No	51.6	No	52.1	No	53.2	No
Note: The Mississippi Department of Transportation has defined 1 dBA below the 23 CFR 722 Noise Abatement Level as approaching, and thus results exceeding 1 dBA below the stated noise abatement level are considered as impacts.													

Source: Neel-Schaffer, Inc.

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.

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National Park Service
U.S. Department of the Interior



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