



Acoustic Monitoring Report, Denali National Park and Preserve – 2007

Natural Resource Data Series NPS/CAKN/NRDS—2011/36



ON THE COVER

The National Park Service high altitude rescue helicopter above a sound monitoring station at Kahiltna Pass on Mt. McKinley's West Buttress climbing route.

NPS Photo by Jared Withers

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The National Park Service, Natural Resource Program Center publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

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All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established protocols and were analyzed and interpreted within the guidelines of the protocols.

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Executive Summary

Park staff deployed acoustic monitoring systems to ten locations in Denali National Park and Preserve in 2007. The purpose of this monitoring effort was to inventory the acoustic conditions and level of aircraft operations in as called for in the 2006 Denali Backcountry Management Plan. Data collected included existing ambient sound pressure levels, natural ambient sound pressure levels, percent time audible, and loud acoustic event statistics for intrinsic and extrinsic sound sources. Deployed systems were configured to log sound pressure levels every second and interval audio recordings once every five minutes, 24 hours per day. These data serve as a permanent record of existing acoustical conditions at these locations for the summer of 2007.

Table 1 shows summarized results of 2007 monitoring, including existing and natural ambient sound statistics in dBA (A-weighted decibels) and average percentage of time audible, number of events per day, and maximum sound pressure level (SPL) for aircraft sound sources, which are the most prominent extrinsic sound at these sites. Median existing ambient (L_{50}) describes the acoustical environment as is, including both natural and extrinsic sounds. Natural ambient (L_{nat}) estimates what the acoustical environment might sound like without the contribution of extrinsic sounds. This table also shows exceedence metrics L_{10} and L_{90} , which essentially mark the average maximum and minimum exceedence levels over the monitoring periods.

Table 1. Median natural sound, existing ambient sound, and mean aircraft statistics for all sites.*

Site Name	L_{nat}	L_{10}	L_{50}	L_{90}	% Aircraft	# Aircraft/Day	Aircraft Max SPL
	20.8						
Bear Creek	5	22.9	20.9	20.4	2.57	7.3	33.6
		25.4	22.4	21.4			
Blind Creek ¹	22.3	5	5	5	6.06	15.4	34.8
	39.2		39.3				
Cathedral Mountain	5	40.1	5	39.1	3.61	13.3	43.3
				28.0			
Chitsia Creek	29.4	32.2	29.4	5	1.75	6.2	41.8
		30.5	27.4	25.7			
Hidden River	27.3	5	5	5	6.81	20.0	36.3
		38.4	29.4	25.4			
Kahiltna Pass	29.1	5	5	5	8.35	29.2	55.6
		26.4		20.9			
Lower East Fork Toklat ¹	21.9	5	22	5	3.46	11.6	39.3
		27.7					
Lower Eldridge Glacier	24.6	5	24.7	23.5	3.98	16.3	41.1
	26.0		26.1				
McLeod Creek	5	28.3	5	24.7	5.05	13.6	36.4
	39.5		39.6				
Pica Glacier	5	41.0	5	38.3	5.03	21.4	57.4

* L_{nat} , L_{10} , L_{50} , L_{90} , and SPL in dBA

¹ winter season site

When interpreting sound pressure level data, it should be noted that the decibel scale is logarithmic. As such, a three decibel increase in sound pressure level is actually a doubling of sound energy. Overall, the acoustic conditions of these 2007 sites varied. The Bear Creek site was the quietest in both ambient and natural ambient sound. Very low levels of aircraft activity

were observed at Chitsia Creek. Ambient conditions at the winter monitoring locations were measured to be 7.4 dB quieter than the summer sites, on average.

Introduction

Natural sound is both a resource in its own right as well as an important aspect of Denali National Park and Preserve's (Denali's) wilderness resource values, and the influence of motorized noise on visitor experience is a key concern throughout the park. Denali's Backcountry Management Plan (BCMP), finalized in 2006, established indicators and standards for the natural sound environment and called for monitoring to evaluate whether the standards are being satisfied. Soundscape measurements are objective and employ methods for monitoring that are easily reviewed by the public, which will provide strong support for future management decisions. Without these data, the park will have little information to make management guidelines or support management decisions that may affect the quality of Denali's soundscape.

The initial push for Denali to begin soundscape inventories began with Director's Order 47 (DO-47). Robert Stanton issued the order in 2000 directing park managers to identify baseline soundscapes and related measures. DO-47 states that "natural sounds are intrinsic elements of the environment that are often associated with parks and park purposes... They are inherent components of 'the scenery and the natural and historic objects and the wild life' protected by the NPS Organic Act." DO-47 directed park managers to "(1) measure baseline acoustic conditions, (2) determine which existing or proposed human-made sounds are consistent with park purposes, (3) set acoustic management goals and objectives based on those purposes, and (4) determine which noise sources are impacting the park and need to be addressed by management." Furthermore, it requires park managers to "(1) evaluate and address self-generated noise, and (2) constructively engage with those responsible for other noise sources that impact parks to explore what can be done to better protect parks." (NPS 2000).

The primary purpose behind the Denali soundscape study has been to measure the level of influence overflight traffic and snowmachine traffic has on the Denali's soundscape. Understanding the natural soundscape is important to evaluate the level of impact human-generated sounds may have on this important resource. The natural soundscape is generally comprised of two main sound categories, physical and biological. Physical sounds are created by physical forces (wind, rock fall, rivers, etc.), whereas biological sounds are created by organisms (birds, frogs, plants, etc.). The presence and abundance of sounds from these two categories is used to characterize different habitats. (Dunholter et al. 1989) Different habitats have specific soundscape characteristics that are an important attribute of the natural system, with distinct impacts on the human perception of the environment. Impacts on the natural soundscape and on visitor experiences come from human-generated sounds.

Soundscape Planning Authorities

The National Park Service (NPS) 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." (NPS 1916) 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." (NPS 1978)

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

“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 Management Policy 8.2.3: Use of Motorized Equipment states “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 [acoustic resource] 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).

Sampling Plan

Denali’s soundscape sampling plan was designed using a coarse grid derived from the Long Term Ecological Monitoring (LTEM) grid (NPS 2006c). The number of points sampled in the coarse grid is driven by the number of acoustic monitoring stations available (five), and the length of time each station should be established at each location. To properly characterize the natural soundscape, stations should be established such that at least one month of continuous data is collected at each site during the field/tourist season (Ambrose and Burson 2004). To maximize the spatial coverage with only five stations it was decided to sample two locations through the entire field season, while rotating three stations over two sites each – two months as each site. Four of the two month-long sites would be established on the LTEM sampling grid, with two free to allow park managers to collect data at sites of specific interest which may not

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.

fall on a grid point. As such, six LTEM grid locations will be sampled each year, with 60 grid points to be sampled overall (Figure 1). In addition, opportunistic sampling may be attempted during the winter months as permitted by funding, personnel, and ease of access to provide some indication of acoustic conditions outside the field/tourist season.

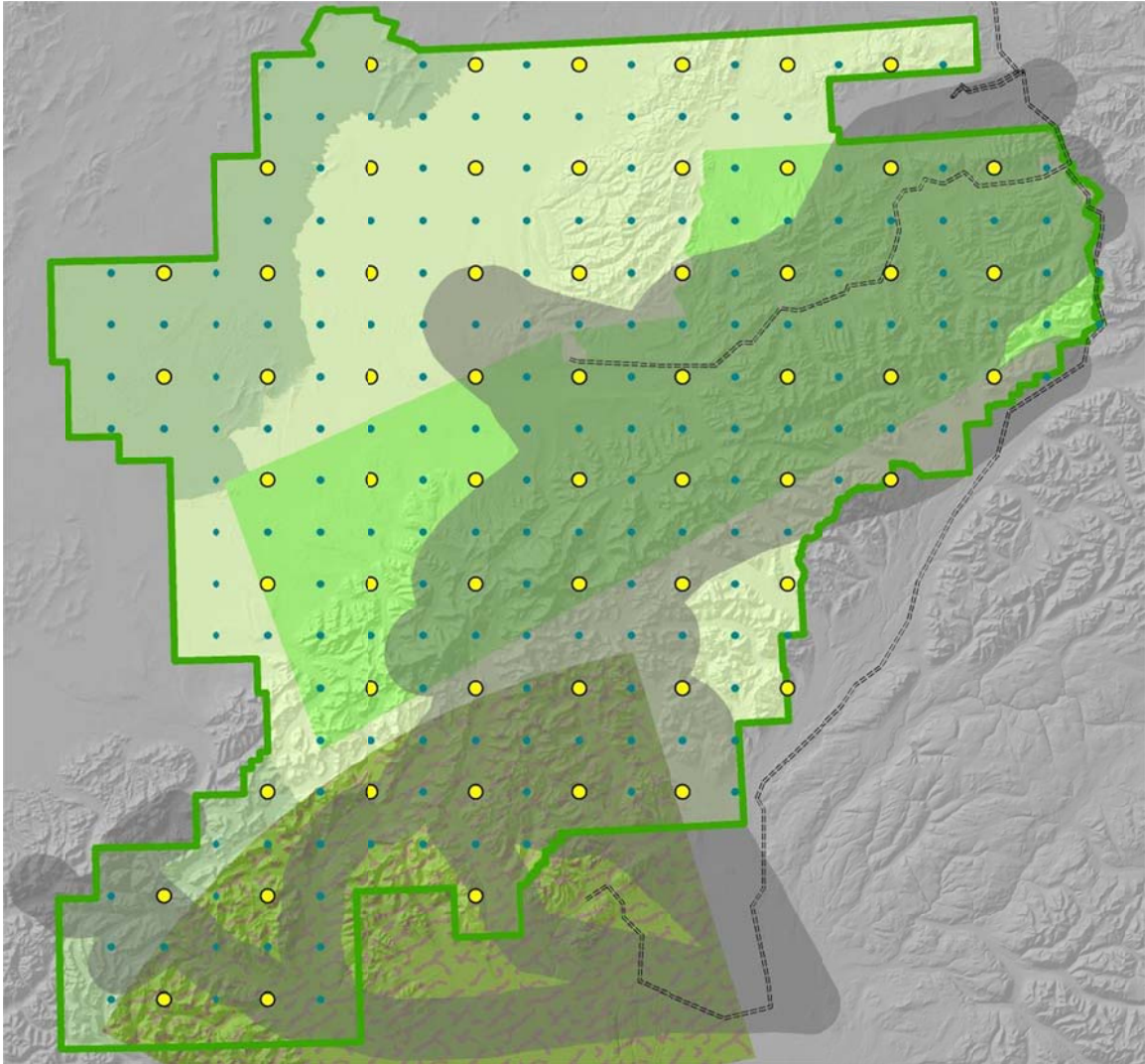


Figure 1. Map showing the coarse grid of sixty points to be sampled, marked by yellow dots.

Study Area

Park staff deployed acoustic monitoring systems to ten locations in Denali in 2007, as shown in Table 2 and Figure 2.

Table 2. Sites sampled in 2007.

Site Location	Elevation (meters)	Latitude	Longitude	Sampling Period*
Bear Creek	213	63.79082	-151.20482	Jun-13 to Sept-14
Blind Creek ¹	991	63.21919	-149.65857	Mar-28 to Jun-01
Cathedral Mountain	1202	63.57178	-149.60629	May-18 to Sept-15
Chitsia Creek	433	63.95127	-150.35603	Jun-01 to Jul-04
Hidden River	936	62.87249	-150.11368	Aug-16 to Sept-13
Kahiltna Pass	3080	63.07980	-151.17419	Jun-20 to Jul-04
Lower East Fork Toklat ¹	498	63.85641	-149.99731	Mar-20 to May-20
Lower Eldridge Glacier	893	63.05045	-150.07388	Jun-01 to Aug-01
McLeod Creek	543	63.43005	-151.23166	Jul-28 to Aug-17
Pica Glacier	1250	62.73740	-151.26781	Jul-28 to Aug-14

¹ winter season site

*One month of continuous data is the goal, but some sites do not achieve this goal due to equipment failure, animal tampering, insufficient solar radiation, and access scheduling. If a full month of data was not collected, an acoustic profile is compiled using the available data.

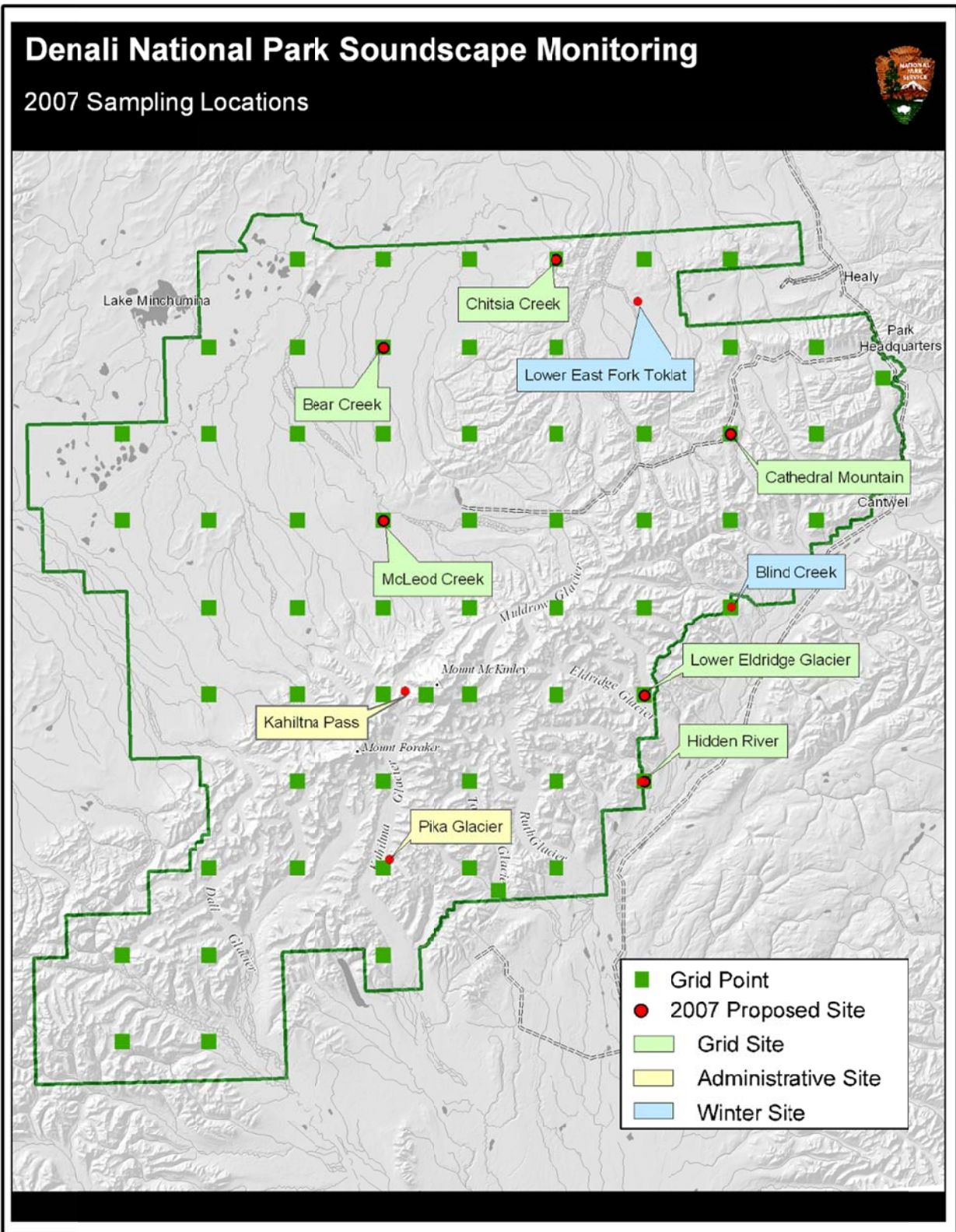


Figure 2. Acoustic monitoring sites in Denali National Park for 2007.

Methods

Automated Monitoring

The Larson Davis 824 sound level meter (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 connected laptop computer. These Larson Davis-based sites met American National Standards Institute (ANSI) Type 1 standards (ANSI 1992, 1968).

Each Larson Davis sampling station consisted of:

- Larson Davis 824 sound level meter
- G.R.A.S. 40AE microphone with environmental shroud and Rycote windscreen
- Larson Davis PRM901 Preamplifier
- Sennheiser ME62 microphone and M-Audio MobilePre (for audibility recordings)
- Panasonic Toughbook CF-45 laptop running gNat logging software
- Solar panel and batteries
- Anemometer (Bear Creek, Blind Creek, Lower East Fork Toklat, Lower Eldridge Glacier)

Each acoustic sampling station collected:

- Broadband, A-weighted sound pressure level (dBA) every second
- Interval digital audio recordings: 5 seconds every 5 minutes
- 1/3 octave band sound pressure level data, every second, ranging from 12.5 Hz – 20,000 Hz

Visual Analysis

For each monitoring site, staff visually analyzed thirty days of collected SPL samples in order to identify the frequency and durations of mechanized sound sources. See Appendix C for further information on visual analysis. Hourly time audible statistics are then used to calculate natural ambient sound level estimates (see Calculation of Metrics below).

Audibility Analysis

For each monitoring site, staff analyzed a subset of audio samples (every other day of the thirty days which were analyzed visually) to identify natural and quiet sound sources which are difficult to reliably identify through visual analysis. Listening headphones are calibrated with a 94dB, 1000Hz tone which was recorded at the time of data collection. This approximates a playback volume similar to what would be heard if the observer were actually listening at the sample site. This audibility data results in an estimate of total percent time audible and makeup of the natural components of the soundscape.

Calculation of Metrics

Several metrics are calculated in order to provide some detail about the characteristics of the acoustical environment. The current status of the acoustical environment can be characterized by

a number of measurements including sound levels across the 1/3 octave band spectrum (from 12.5 Hz to 20,000 Hz), overall sound levels, and percent time audible durations for various sound sources. Two fundamental descriptors of the acoustic environment are existing ambient and natural ambient sound levels which are presented as exceedence levels (L_x). They represent the dBA exceeded x percent of the time during the given measurement period. For example, measured in dBA, the existing ambient (L_{50}) is the sound level exceeded 50% of the time, or median sound level. It is the uncensored composite of all sounds at a site, both human caused and natural. The natural ambient (L_{nat}) estimates the acoustic environment without the contribution of anthropogenic sounds. L_{10} and L_{90} are also presented which describe the sound levels exceeded 10% and 90% of the time, respectively.

The differences between L_{50} and L_{nat} values allow NPS to answer the following questions:

1. What are the listening opportunities in the absence of human development and activities?
2. How are these listening opportunities compromised by increased sound levels due to noise?

To calculate L_{nat} , the following method is utilized:

- NPS staff calculate the percentage of all samples containing extrinsic sounds for each hour of the day (P_H) by either listening to samples, or visually analyzing daily spectrograms.
 - P_H is used to complete this formula for every hour: $x = \frac{1 - P_H}{2} + P_H$
 - Hourly x_H values are entered into a database of all octave band information.
 - Example: if extrinsic sounds are audible 50% of the time ($P_H=0.5$), then x_H is 0.75.
 - L_{nat} is computed as the sound level that is exceeded $100 \cdot x_H$ percent of the time.
- (In practice, L_{nat} is calculated by sorting the relevant sound level measurements and using x_H to extract the appropriate order statistic).

This procedure approximates the sound levels that would have been measured in the absence of extrinsic noise. The procedure is guaranteed to produce an estimate that is equal to or below the existing ambient sound levels, and the results of this calculation have produced consistent results at most backcountry sites analyzed by the NPS Natural Sounds Program (NPS 2008).

Results

Table 3 is a summary of 2007 data. Presented are the existing and natural ambient sound statistics in dBA and average percentage of time audible, number of events per day, and maximum sound pressure level (SPL) for aircraft sound sources, which are the most prominent extrinsic sound at these sites. Median existing ambient (L_{50}) describes the acoustical environment as is, including both natural and extrinsic sounds. Natural ambient (L_{nat}) estimates what the acoustical environment might sound like without the contribution of extrinsic sounds. This table also shows exceedence metrics L_{10} and L_{90} , which essentially mark the average maximum and minimum exceedence levels over the monitoring periods.

Table 3. Median natural and existing ambient sound* and mean aircraft statistics for all sites.

Site Name	L _{nat}	L ₁₀	L ₅₀	L ₉₀	% Aircraft	# Aircraft/Day	Aircraft Max SPL
Bear Creek	20.85	22.9	20.9	20.4	2.57	7.3	33.6
Blind Creek ¹	22.3	25.45	22.45	21.45	6.06	15.4	34.8
Cathedral Mountain	39.25	40.1	39.35	39.1	3.61	13.3	43.3
Chitsia Creek	29.4	32.2	29.4	28.05	1.75	6.2	41.8
Hidden River	27.3	30.55	27.45	25.75	6.81	20.0	36.3
Kahiltna Pass	29.1	38.45	29.45	25.45	8.35	29.2	55.6
Lower East Fork Toklat ¹	21.9	26.45	22	20.95	3.46	11.6	39.3
Lower Eldridge Glacier	24.6	27.75	24.7	23.5	3.98	16.3	41.1
McLeod Creek	26.05	28.3	26.15	24.7	5.05	13.6	36.4
Pica Glacier	39.55	41.0	39.65	38.3	5.03	21.4	57.4

*L_{nat}, L₁₀, L₅₀, L₉₀, and SPL in dBA

¹ winter season site

When interpreting sound pressure level data, it should be noted that the decibel scale is logarithmic. As such, a three decibel increase in sound pressure level is actually a doubling of sound energy. Overall, the acoustic conditions of these 2007 sites varied. The Bear Creek site was the quietest in both ambient and natural ambient sound. Very low levels of aircraft activity were observed at Chitsia Creek. Ambient conditions at the winter monitoring locations were measured to be 7.4 dB quieter than the summer sites, on average.

The following summaries and figures represent the reduced data for each of the 2007 sites. These include percent audibility for natural sounds and mechanized noise, hourly natural ambient and exceedence sound levels, and figures which speak directly to the soundscape indicators and standards outlined in Denali'sBCMP: percentage of time audible, number of events per day, and maximum sound pressure levels (NPS 2006c). A separate section is devoted to each site, and should be considered a comprehensive site profile for Denali purposes.

Bear Creek



Location Description: Bear Creek ~30 Km South of the Park Boundary.

Purpose/Project: Location randomly chosen from the LTEM grid as part of the long-term Denali Soundscape inventorying and monitoring sampling plan.

Coordinates: Lat. 63.79082, Long. 151.20482 Elevation: 213 meters

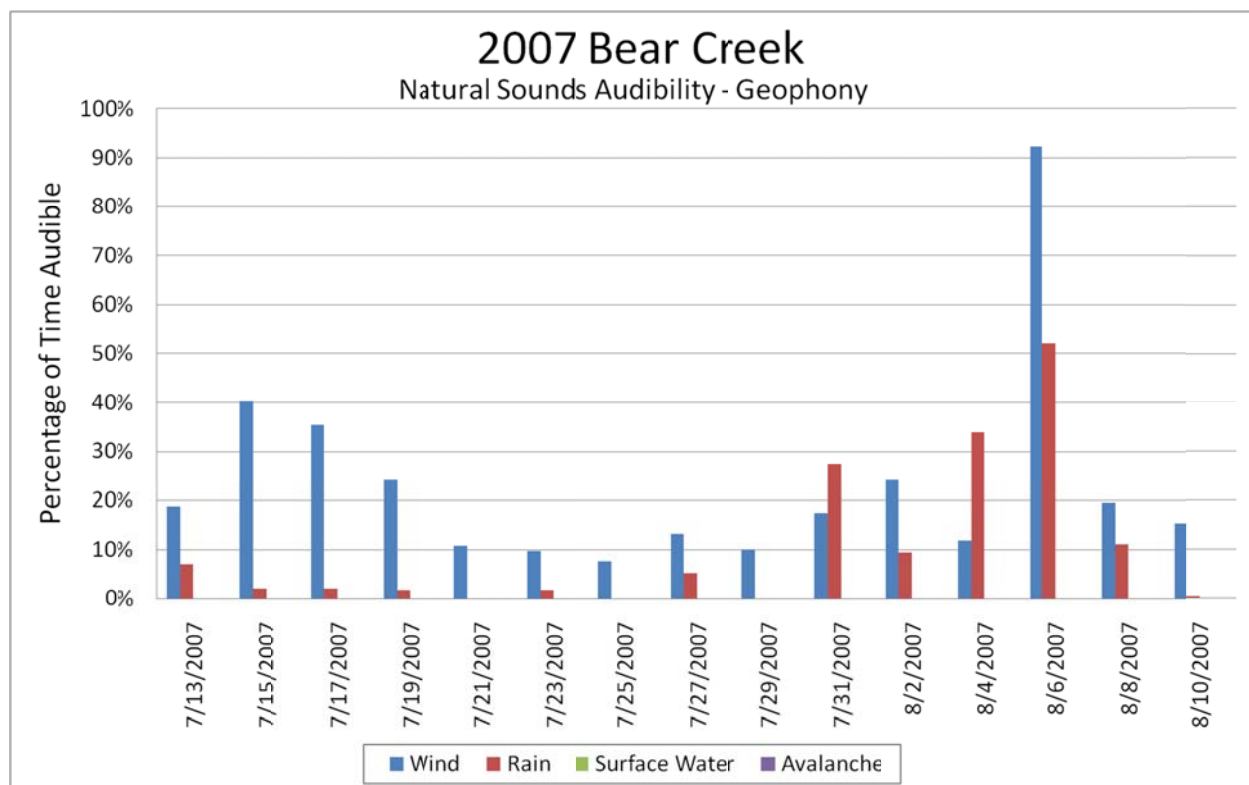
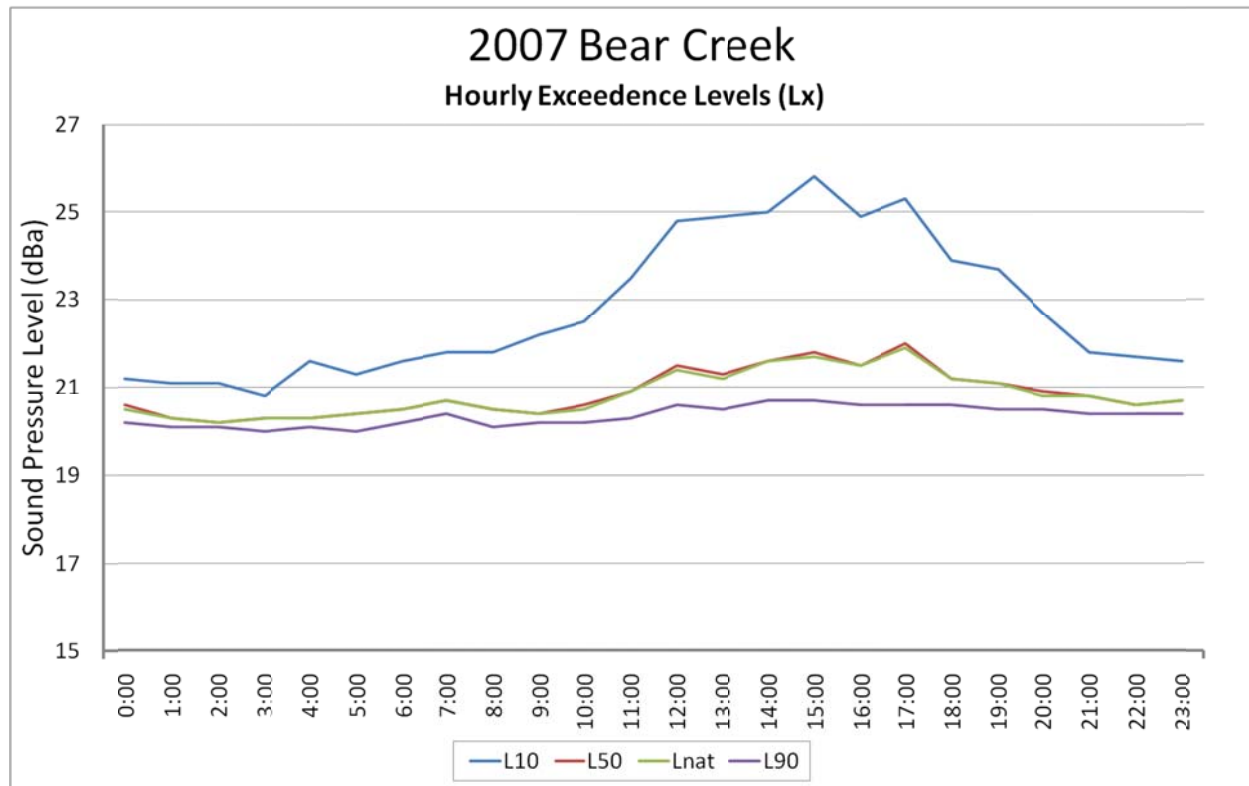
BCMP Management Zone: Low Park Ecoregion: Minchumina Basin Lowlands

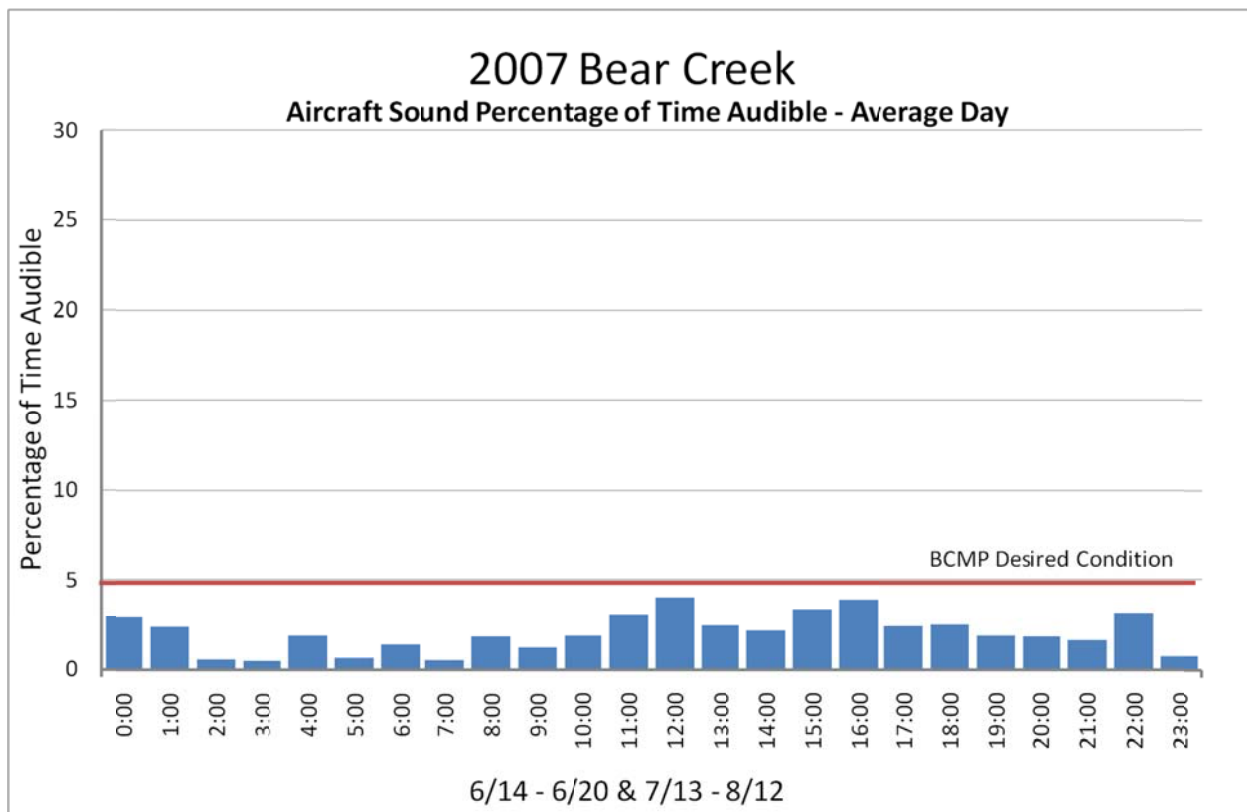
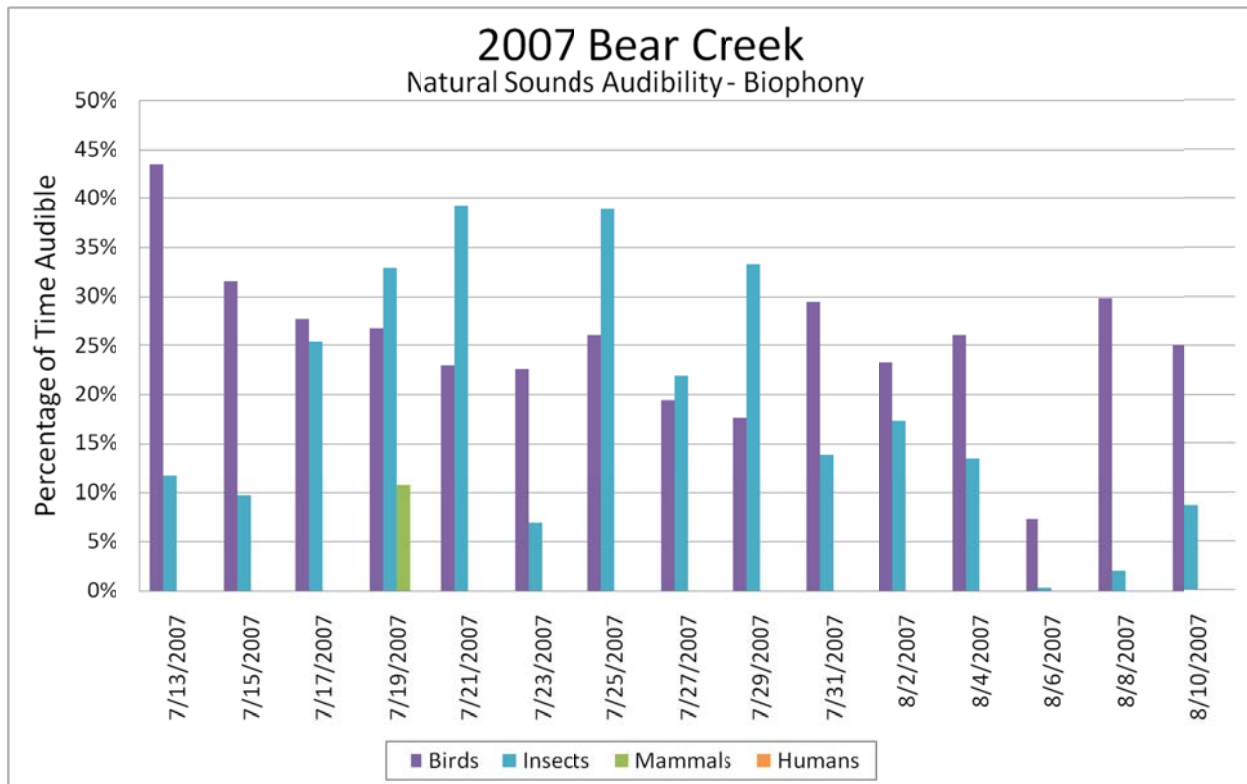
Time at Location: Jun-13 to Sept-14, 2007

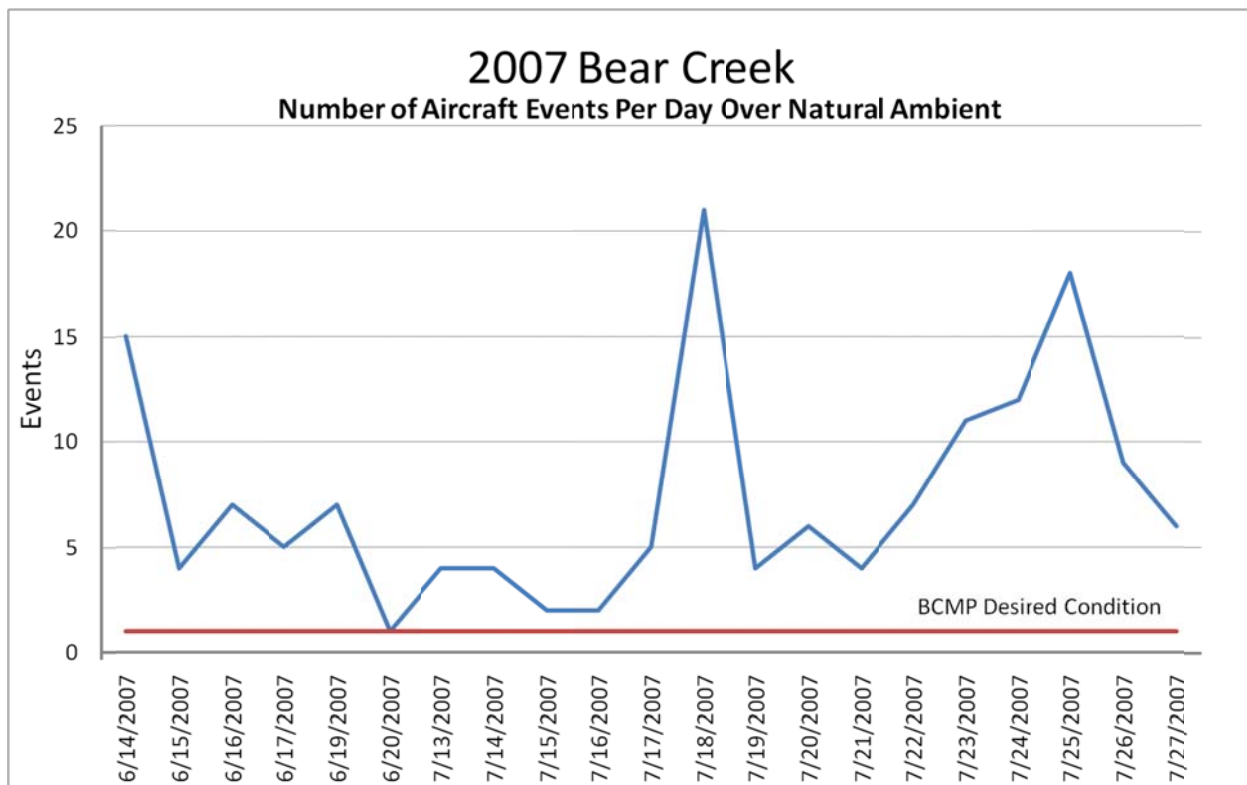
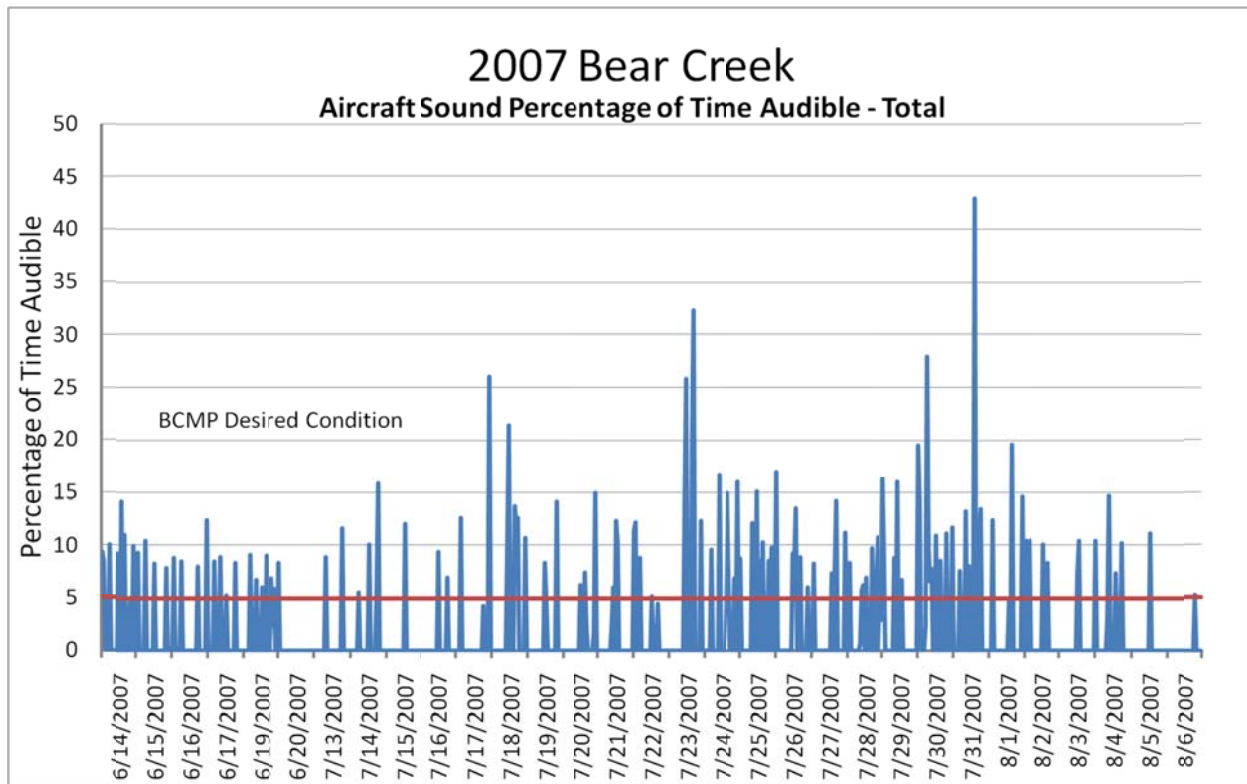
Access: Helicopter

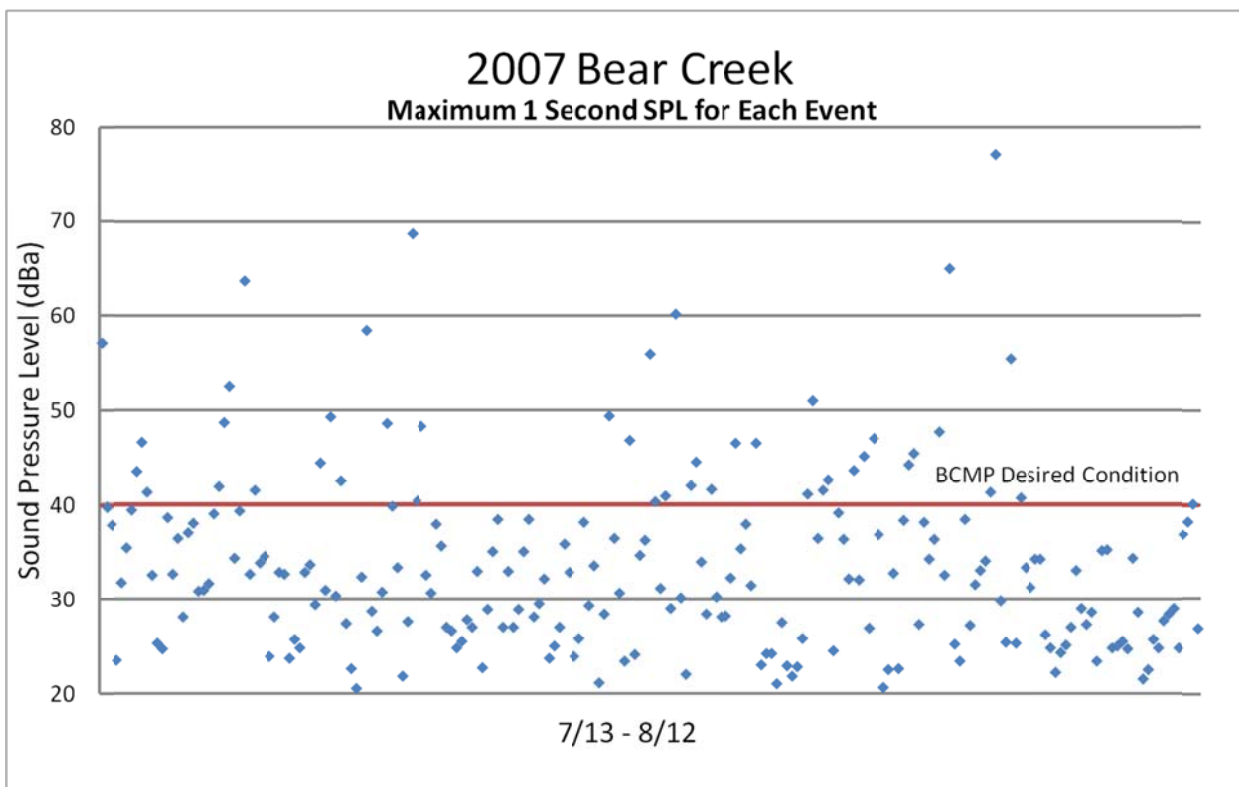
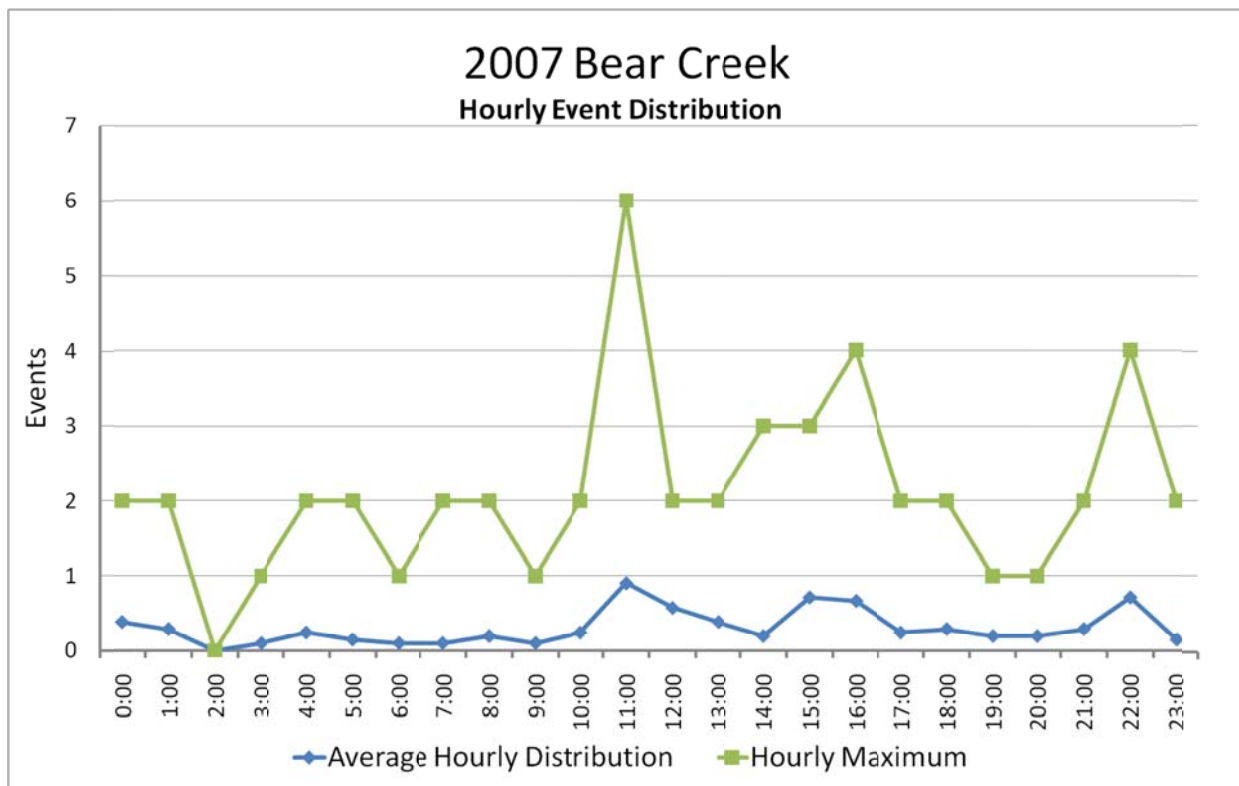
Summary/Notes: The purpose of the Bear Creek location was to collect data at one of the long-term ecological monitoring (LTEM) grid points, as outlined in the above sampling plan. LTEM grid point #223 was stratified as a New Park location and randomly selected from all locations requiring aircraft access.

The most commonly heard natural sounds at this site were birds (audible 25.3% of the time), wind (23.4%), insects (18.4%), and rain (10.3%). Mechanized sound was audible 2.6% of the time on average. Conditions exceeded the BCMP percent audible standard 19% of the time, number of events per day 95% of the time, and maximum SPL 28% of the time.









Blind Creek



Location Description: West of the Golden Zone Mine, inside the Park Boundary.

Purpose/Project: Location chosen from winter-accessible LTEM grid points as part of the long-term Denali Soundscape inventorying and monitoring sampling plan.

Coordinates: Lat. 63.21919, Long. 149.65857 Elevation: 991 Meters

Time at Location: Mar-28 to Jun-01, 2007

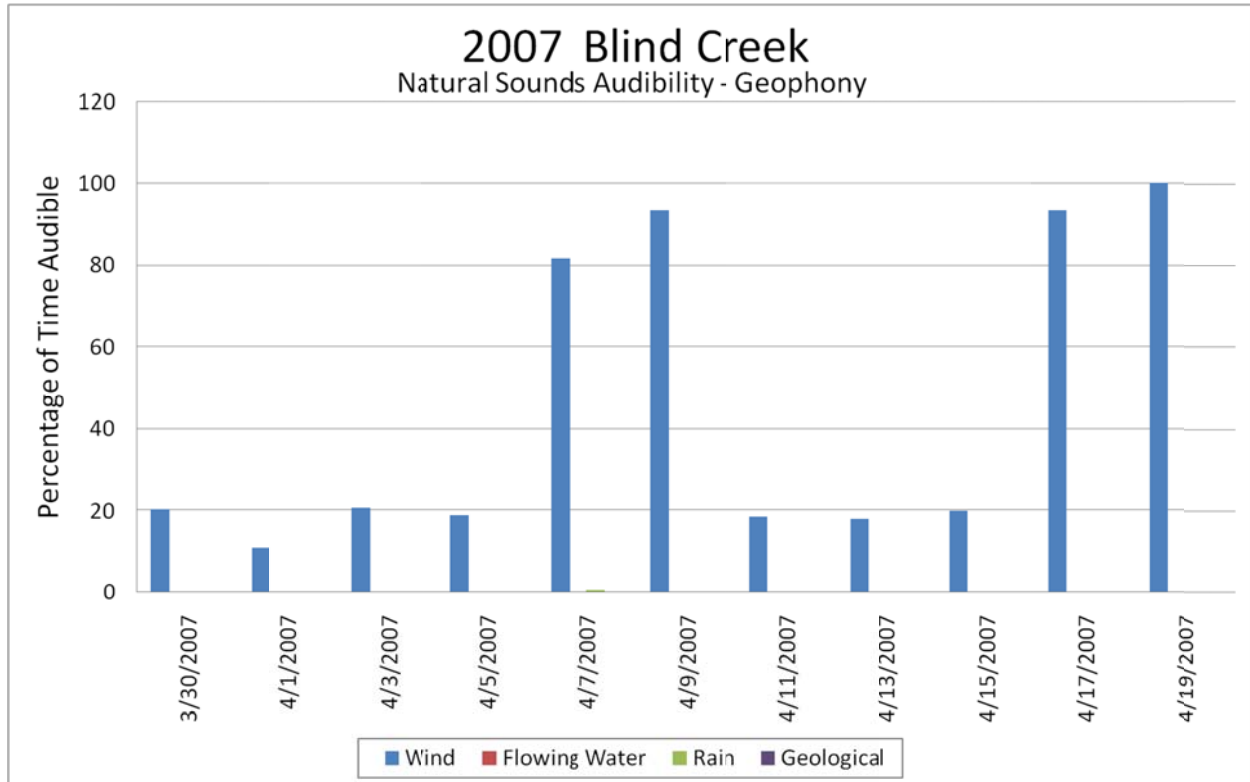
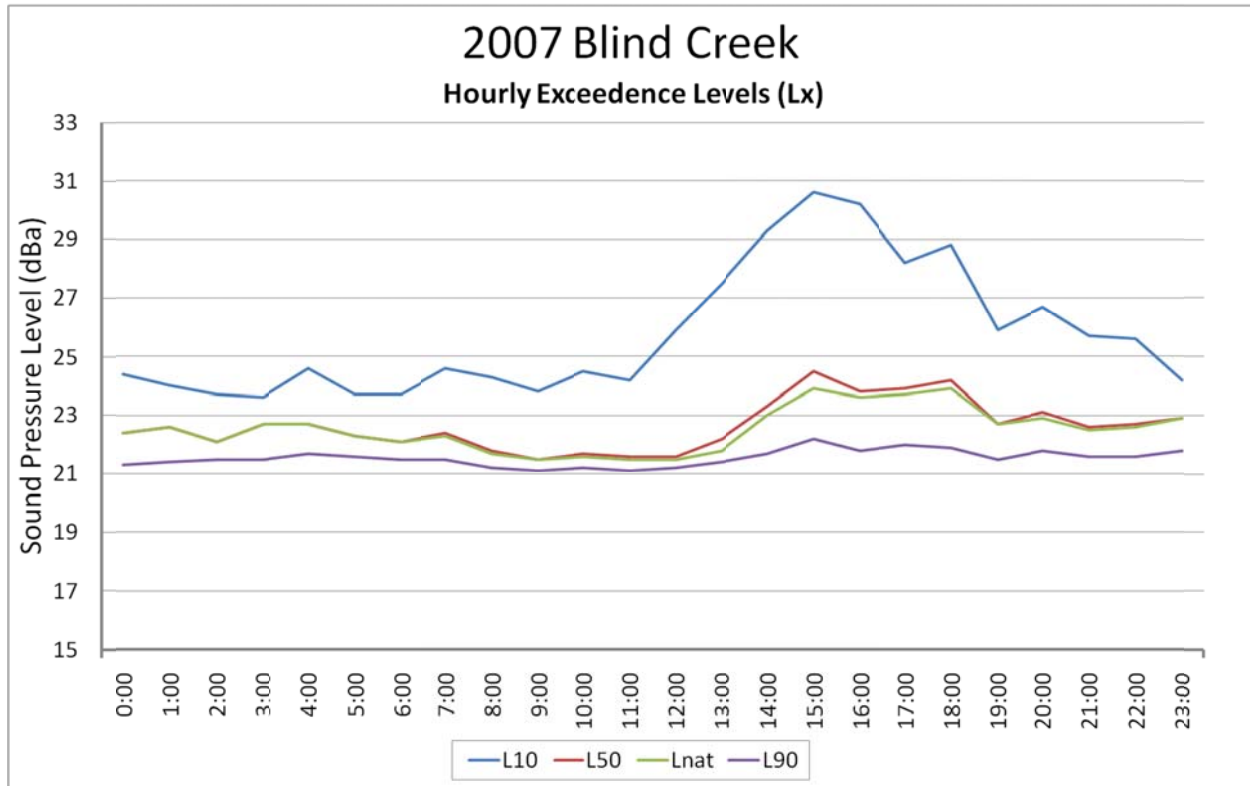
BCMP Management Zone: Medium

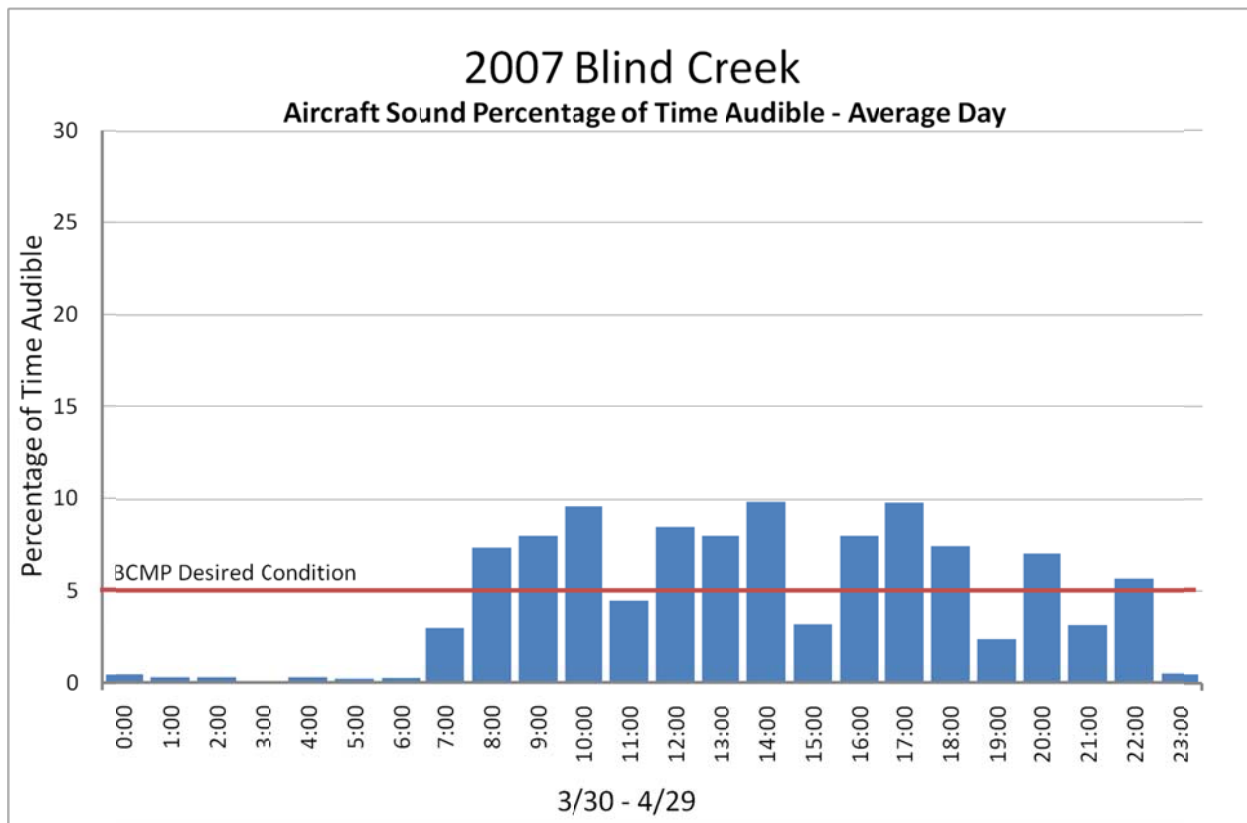
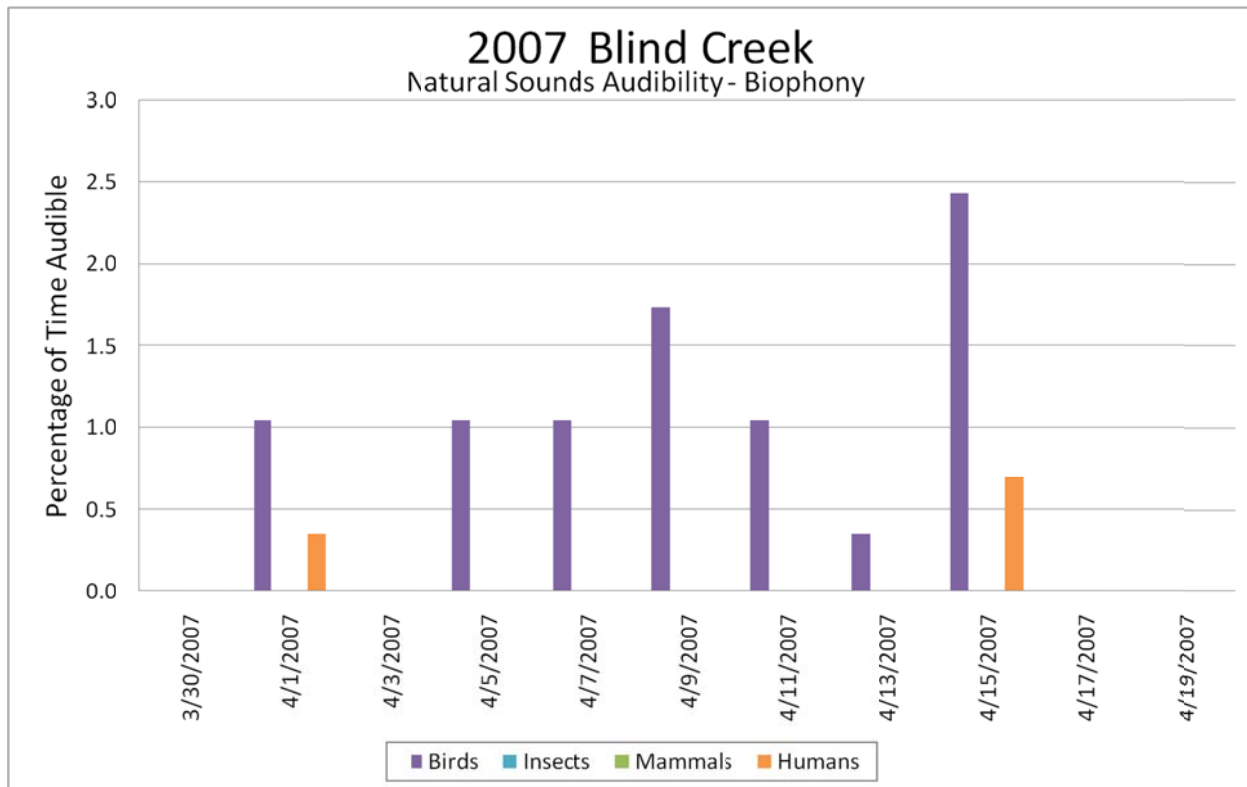
Park Ecoregion: Alpine Mountains

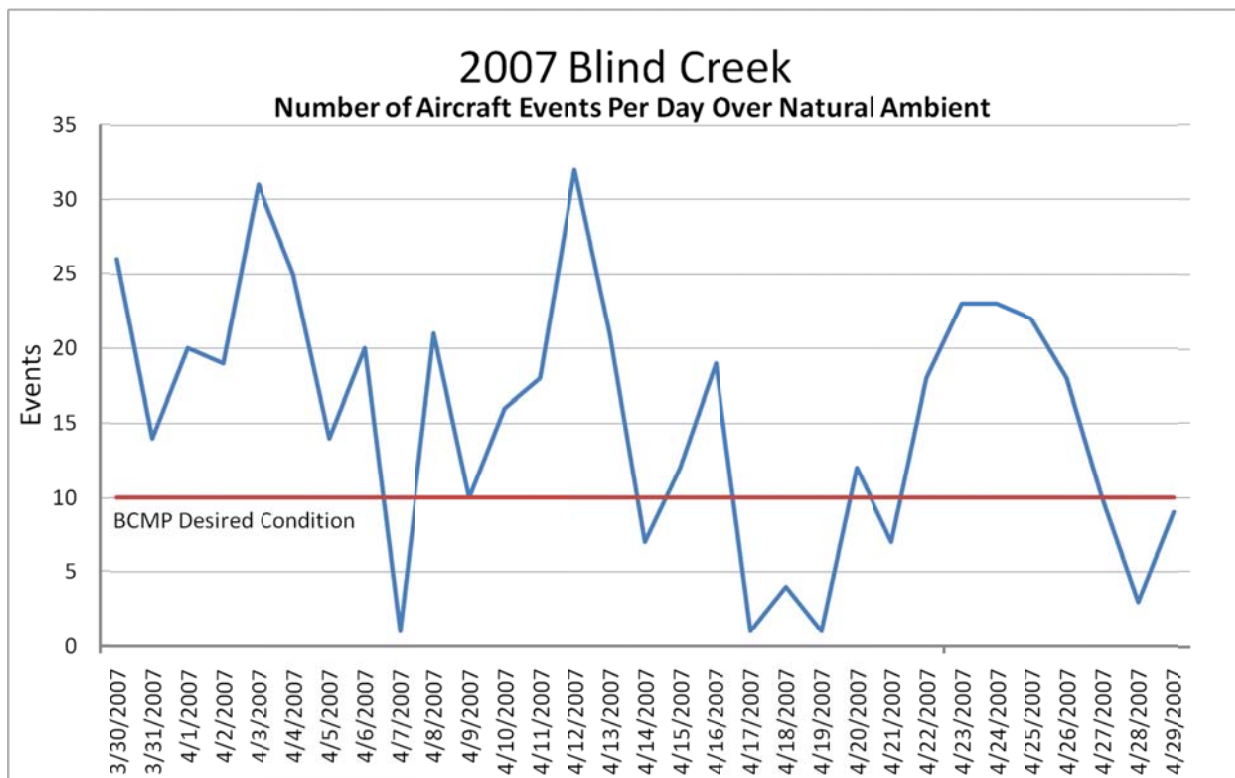
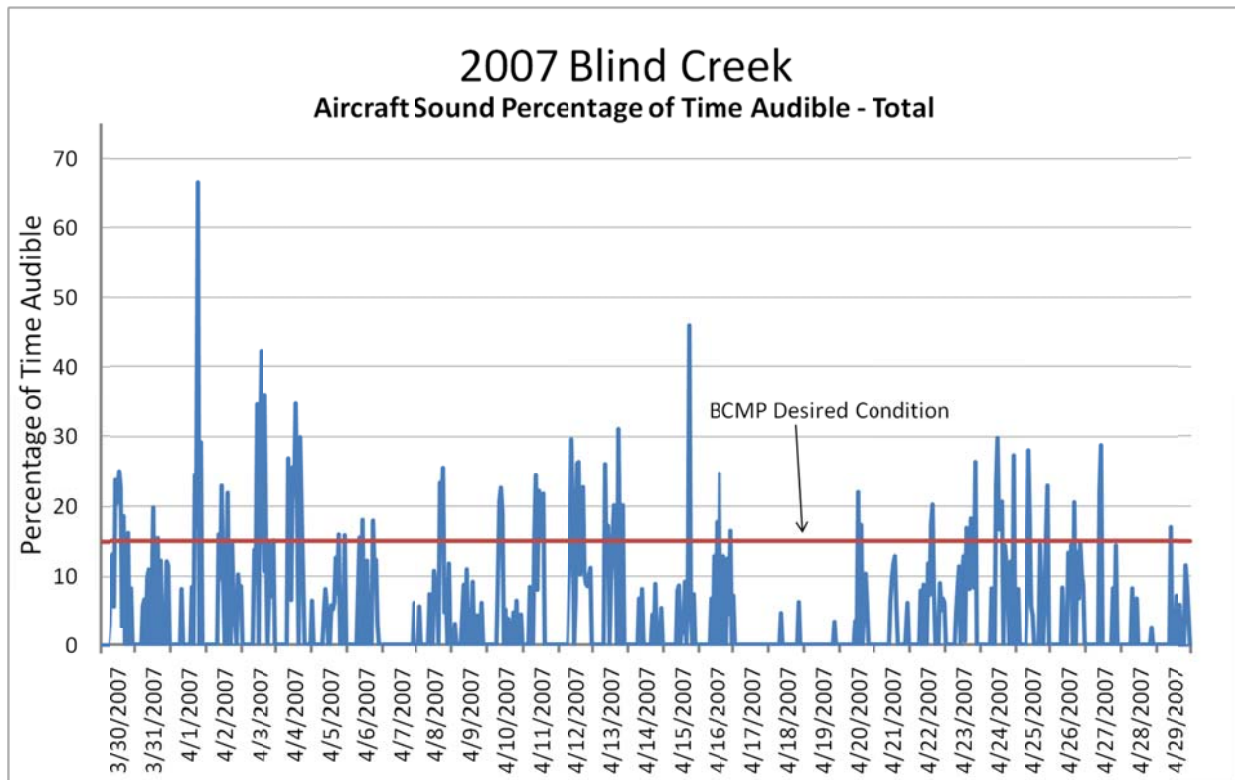
Access: Snowmobile

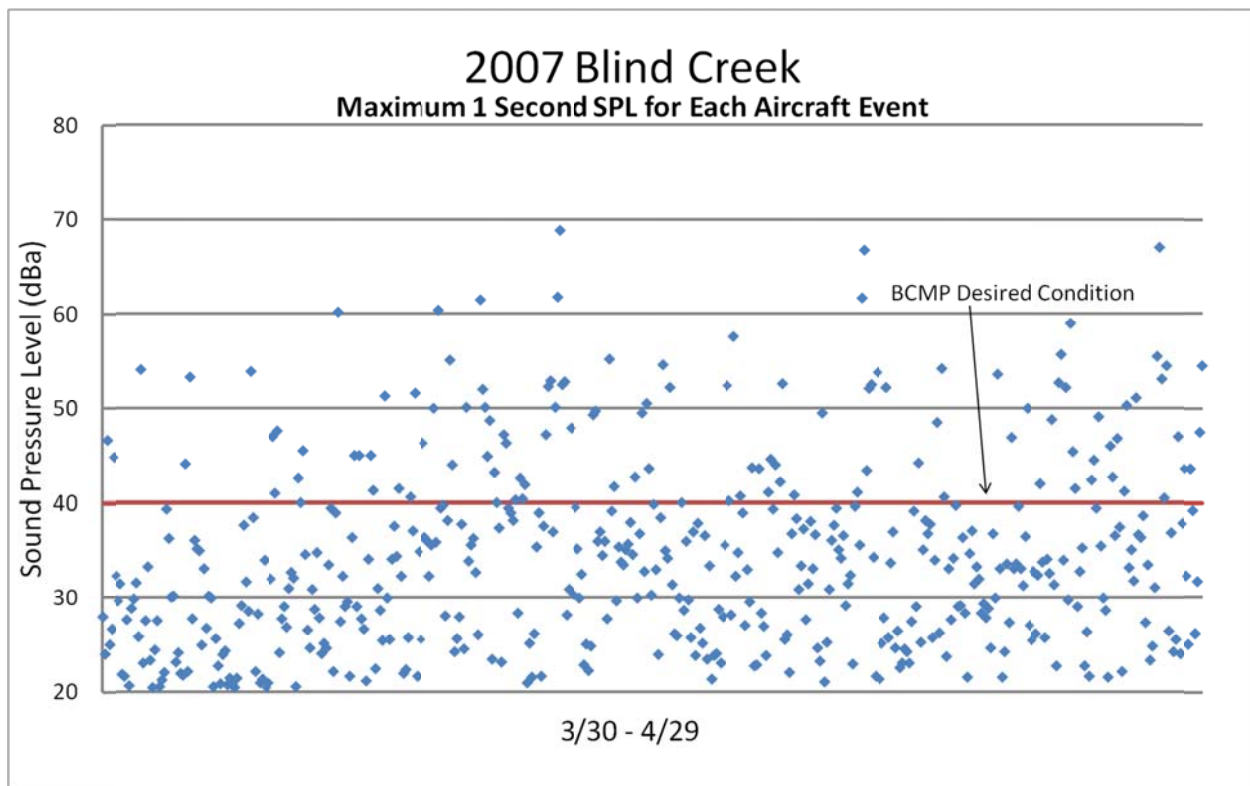
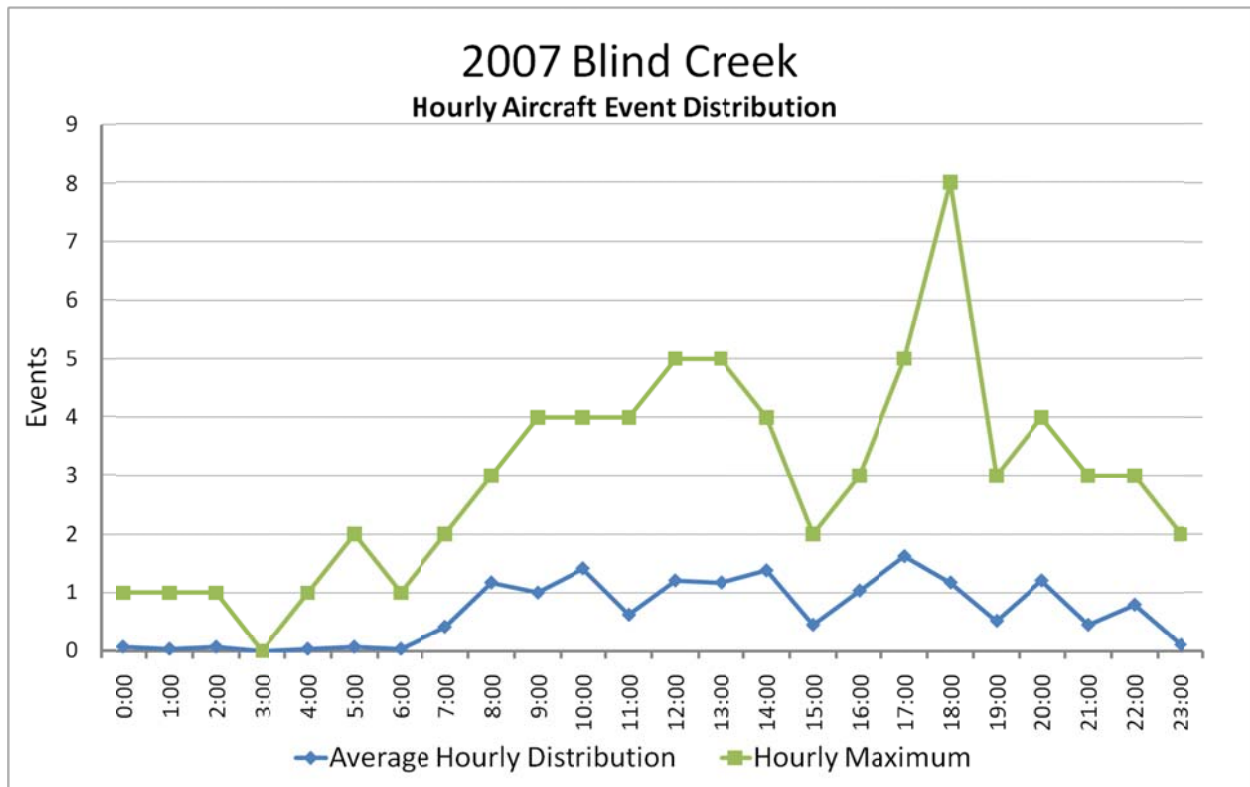
Summary: The purpose of the Blind Creek location was to collect data at a wintertime-accessible long-term ecological monitoring (LTEM) grid point, and provide an indication of levels of snowmobile noise. LTEM grid point #101 was stratified as a New Park location and selected from locations requiring snowmobile access.

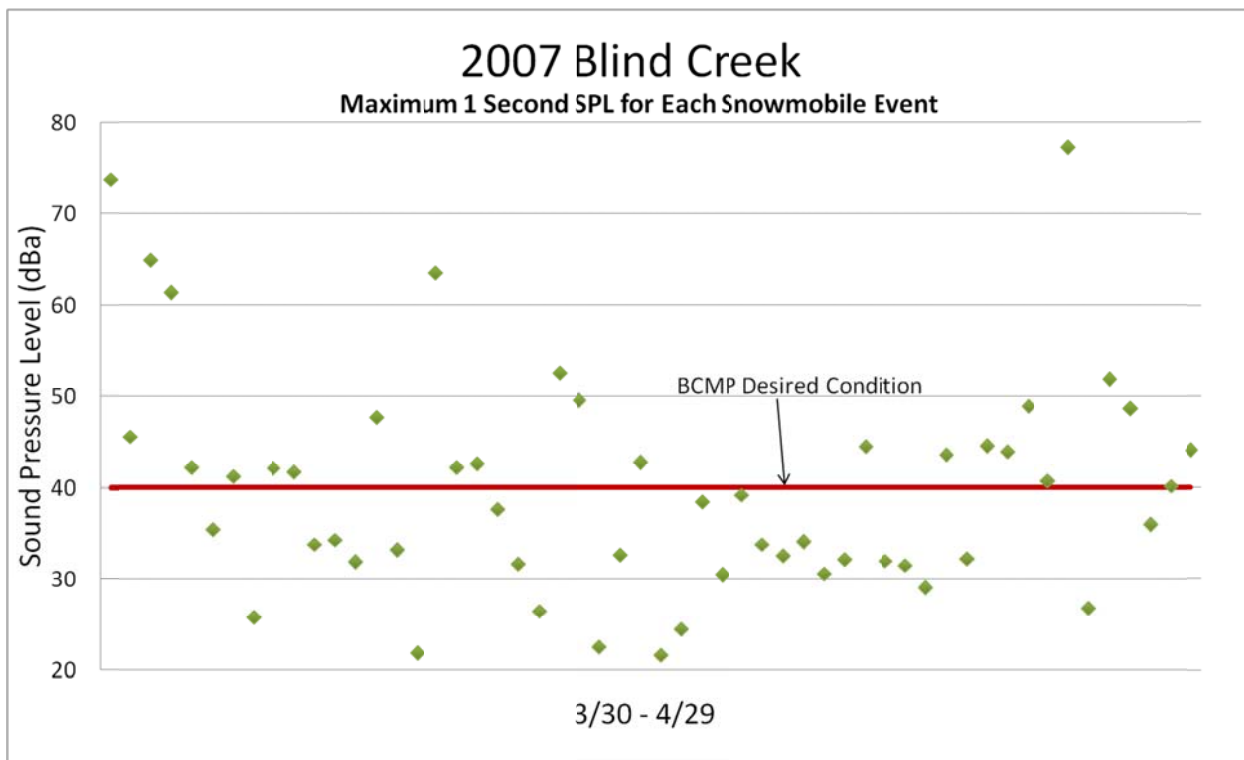
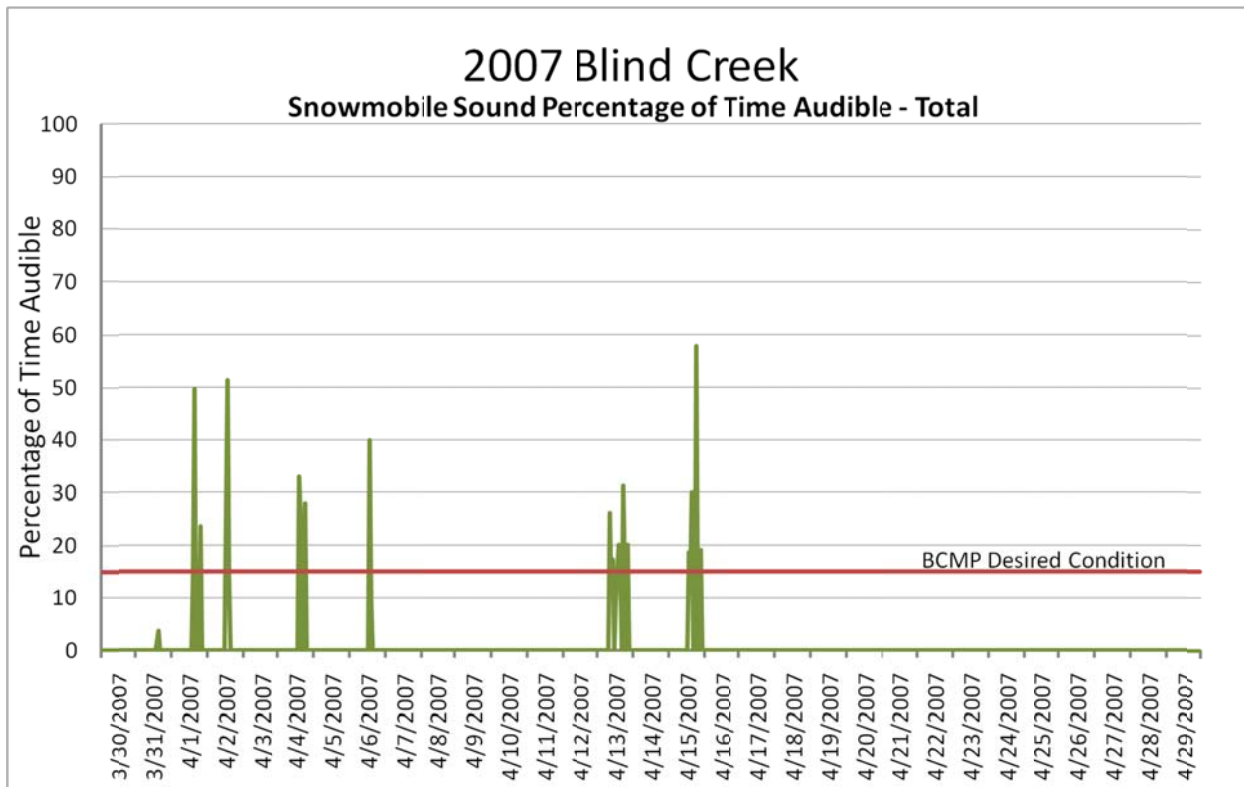
The most commonly heard natural sounds at this site were silence (audible 49.3% of the time) and wind (45.6%). Snowmobile sound was audible 0.9% of the time on average.



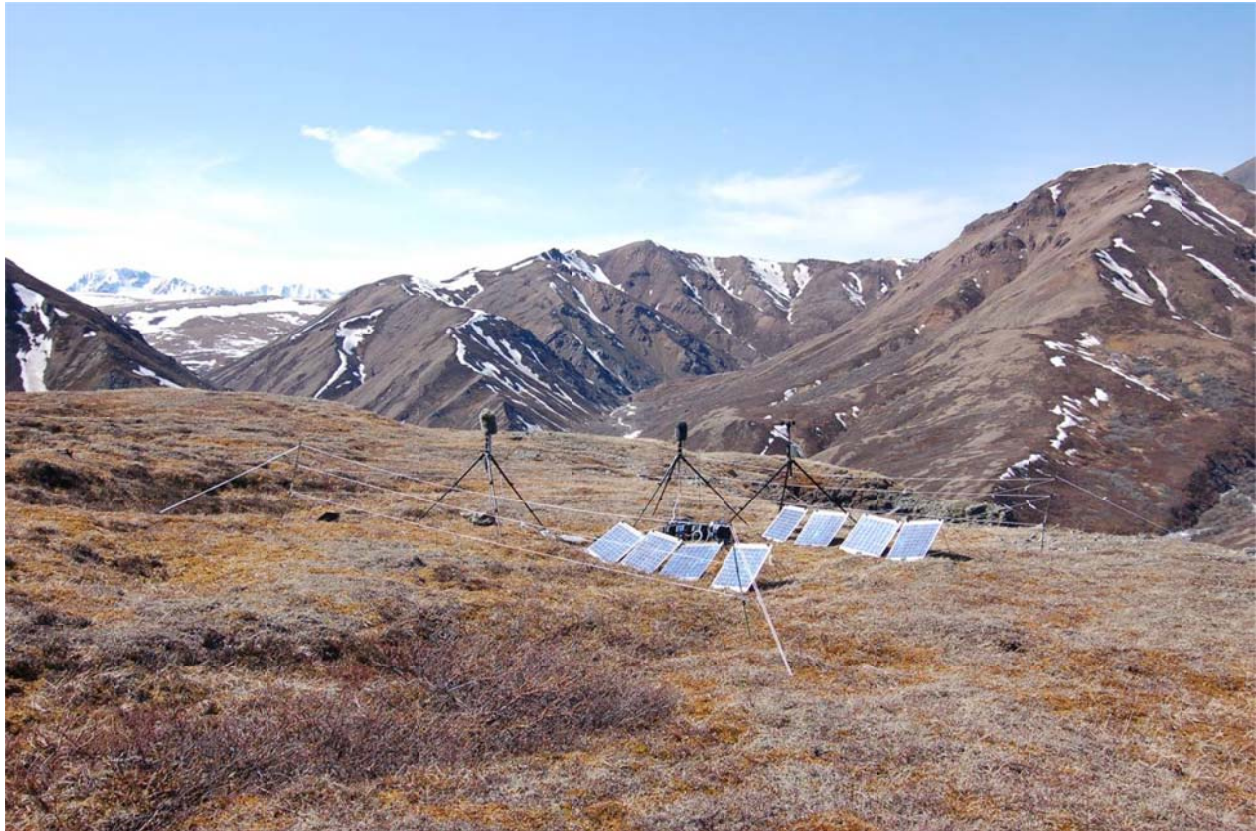








Cathedral Mountain



Location Description: Western slope of Cathedral Mountain, not visible from, but within earshot of the park road.

Purpose/Project: Location randomly chosen from the LTEM grid as part of the long-term Denali Soundscape inventorying and monitoring sampling plan.

Coordinates: Lat. 63.57178, Long. 149.60629 Elevation: 1202 Meters

Time at Location: May-18 to Sept-15, 2007

BCMP Management Zone: Low

Park Ecoregion: Alpine Mountains

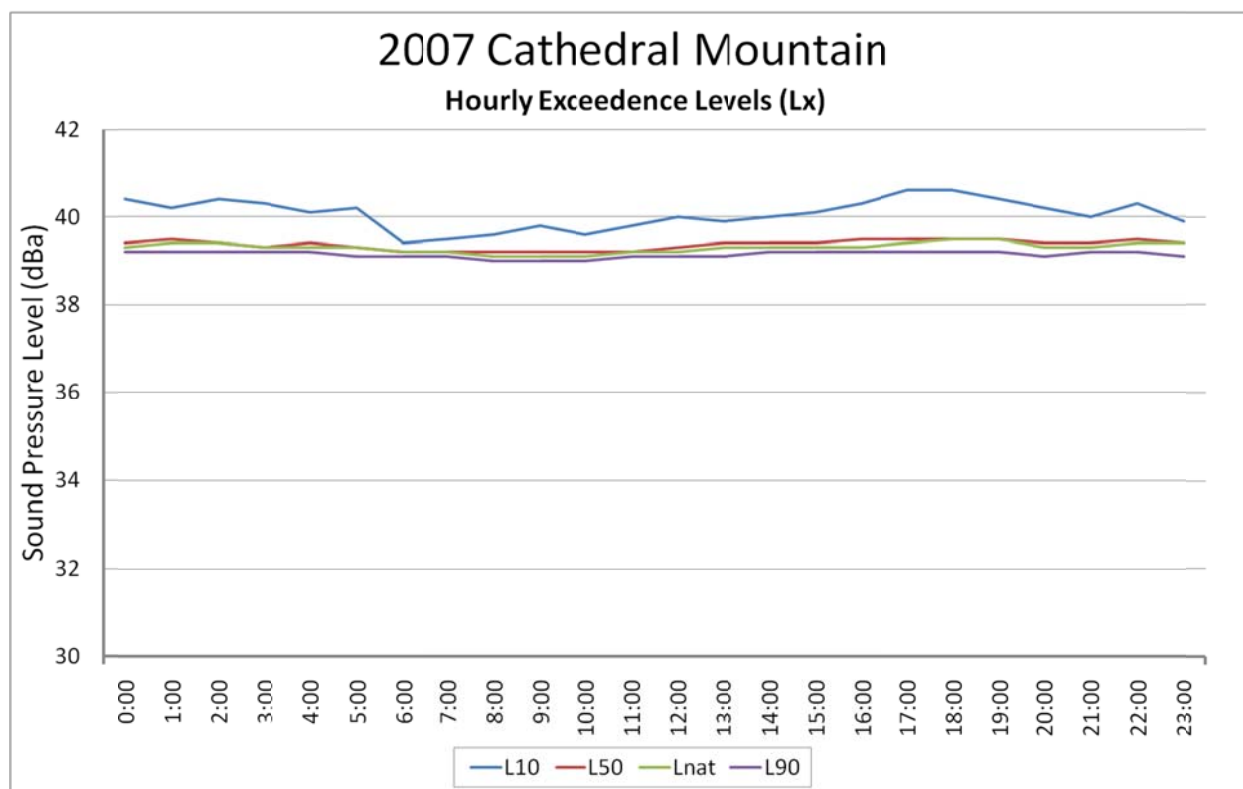
Access: Foot

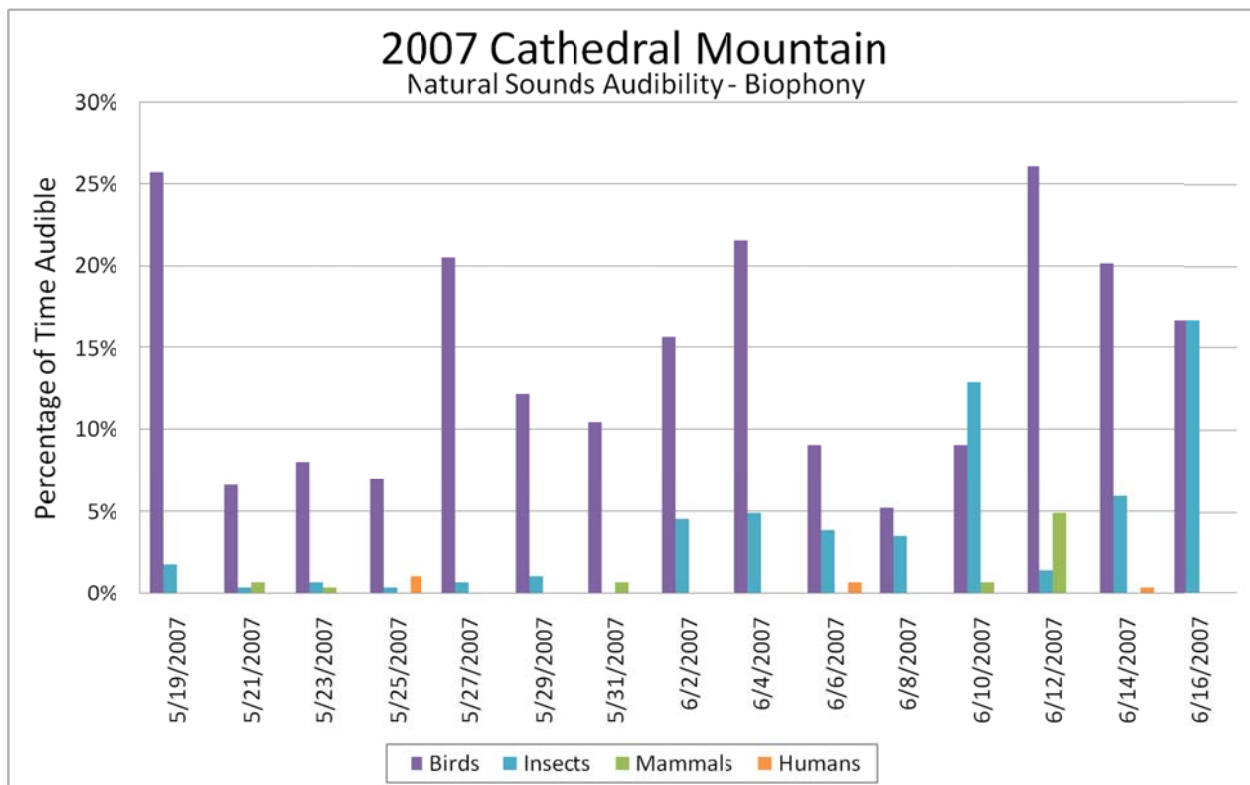
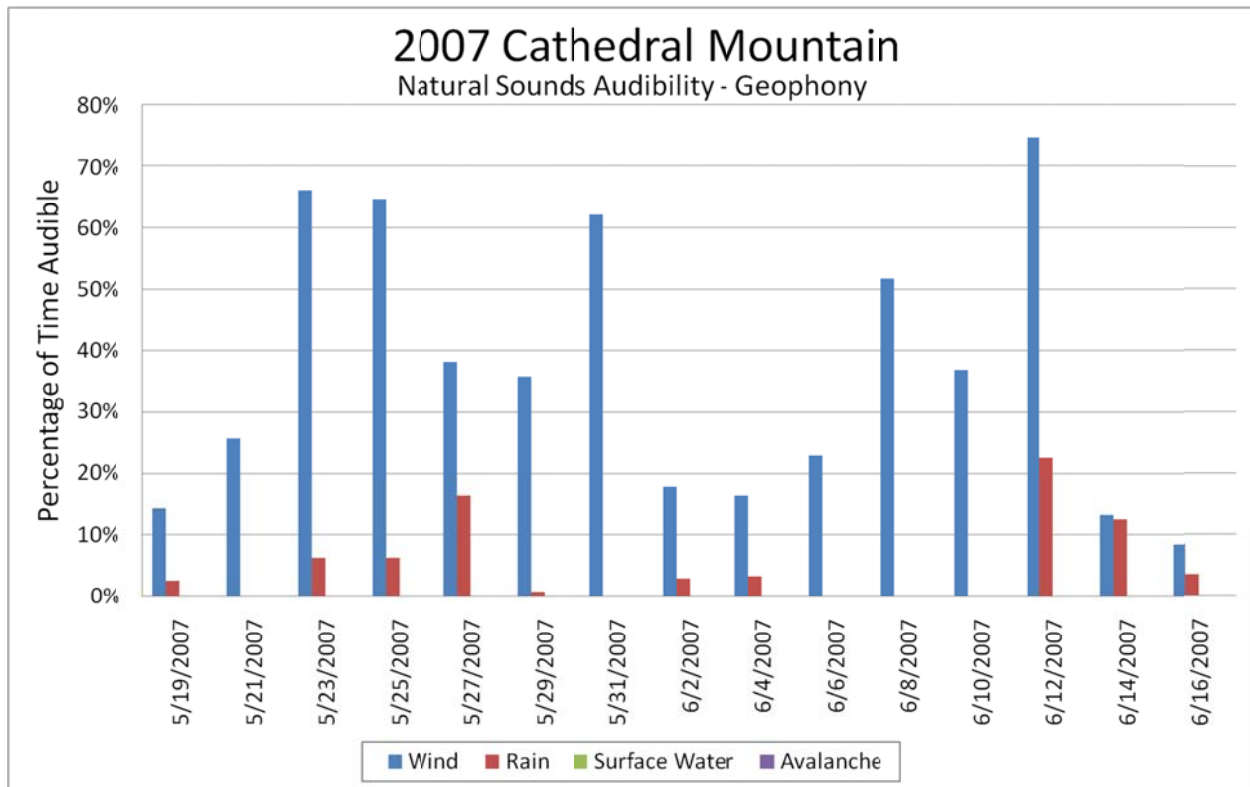
Summary: The purpose of the Cathedral Mountain location was to collect data at one of the long-term ecological monitoring (LTEM) grid points, as outlined in the above sampling plan. LTEM grid point #177 was stratified as an Old Park (Wilderness) location and randomly selected from all locations access which are accessible on foot. Traffic traveling the Denali Park Road was faintly audible at this sampling location, and these data provide an indication of the noise conditions that hikers in close proximity to the road (day hikers) may experience.

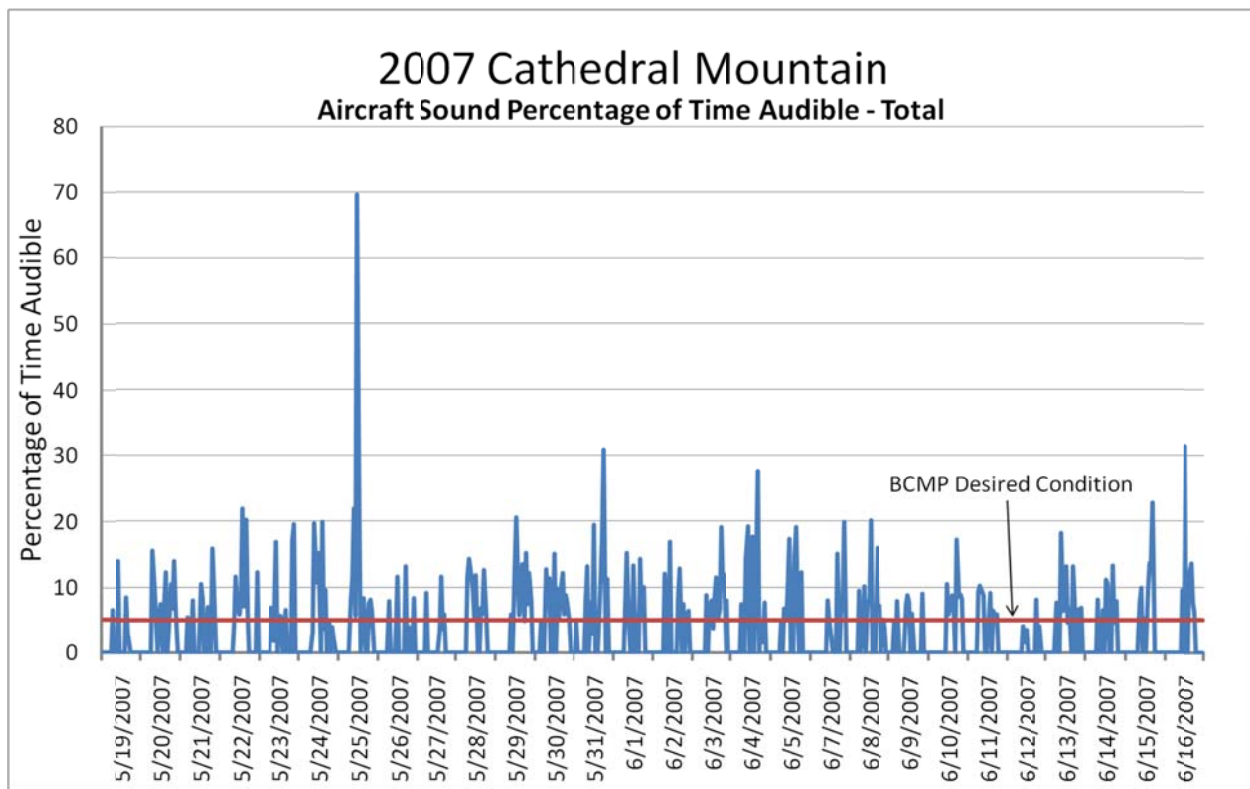
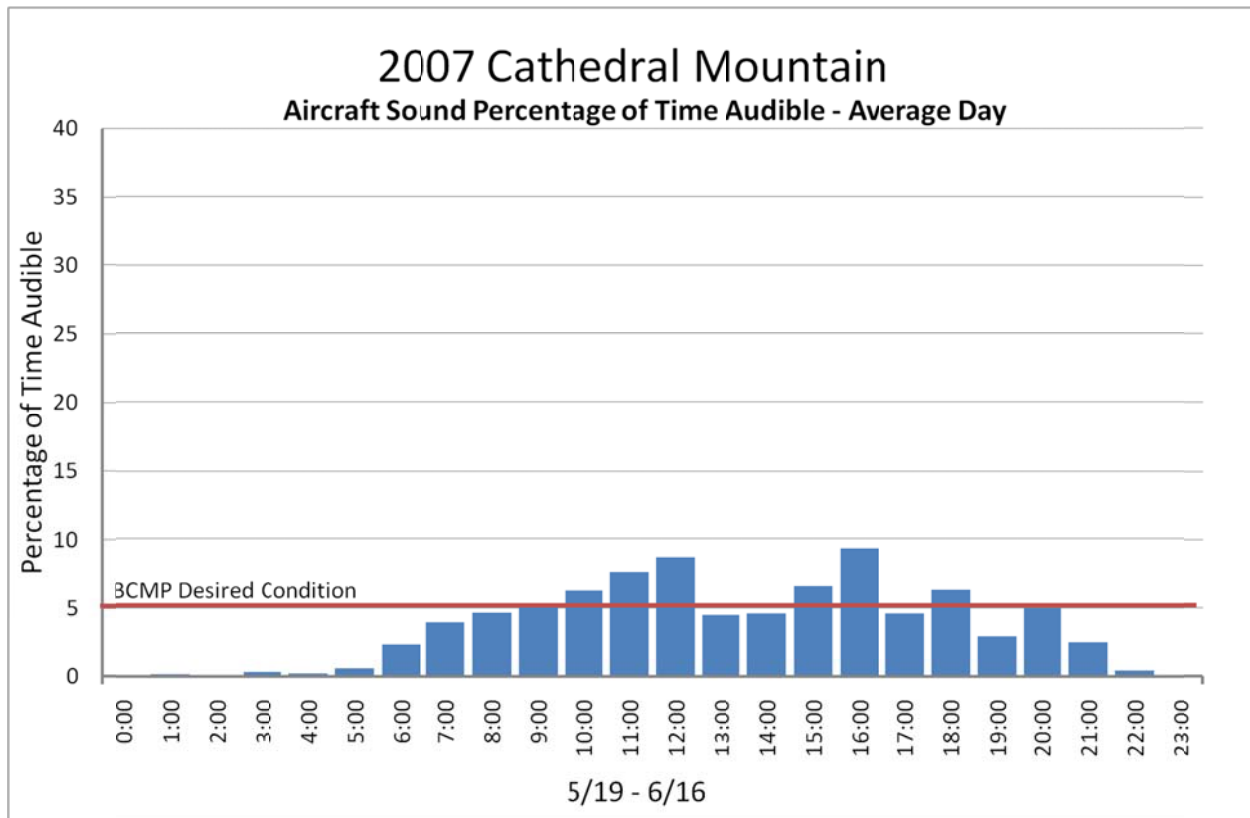
An attempt was made to collect data through the winter at this site, but was unsuccessful due to bugs in the early firmware versions of the Larson Davis 831. These glitches caused the unit to stop logging a small number of hours after setup. When cold weather reliability issues in the equipment are resolved, this Cathedral Mountain site would be a good candidate for winter

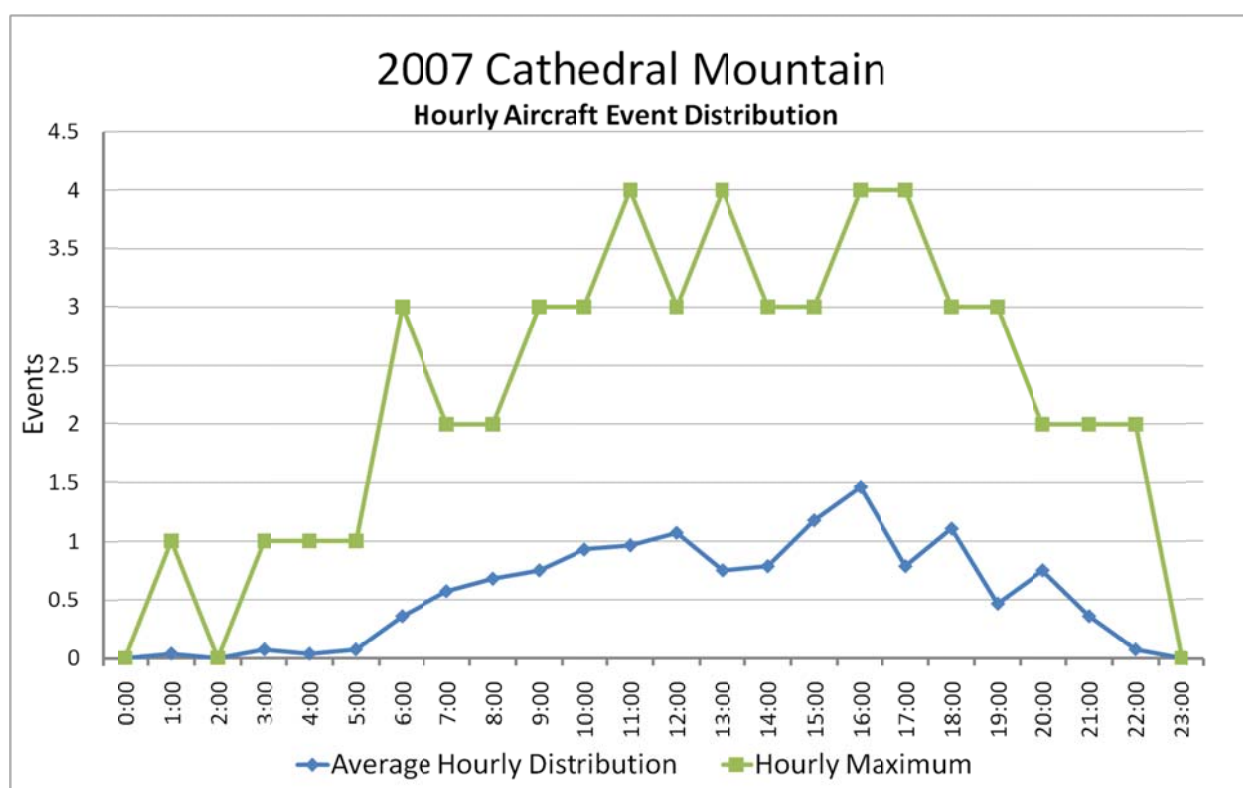
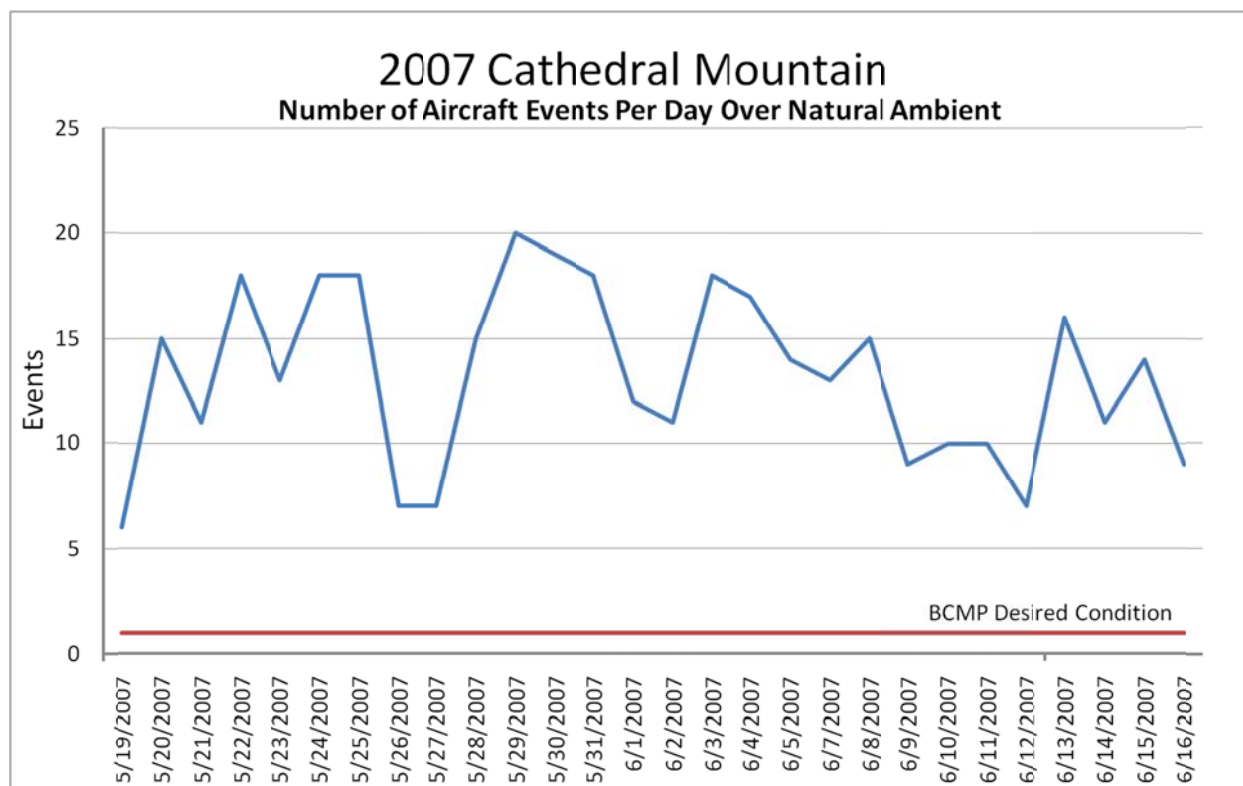
logging, and would be a good measure of winter sound conditions in Denali's Wilderness core. Access is feasible by skiing or dog team.

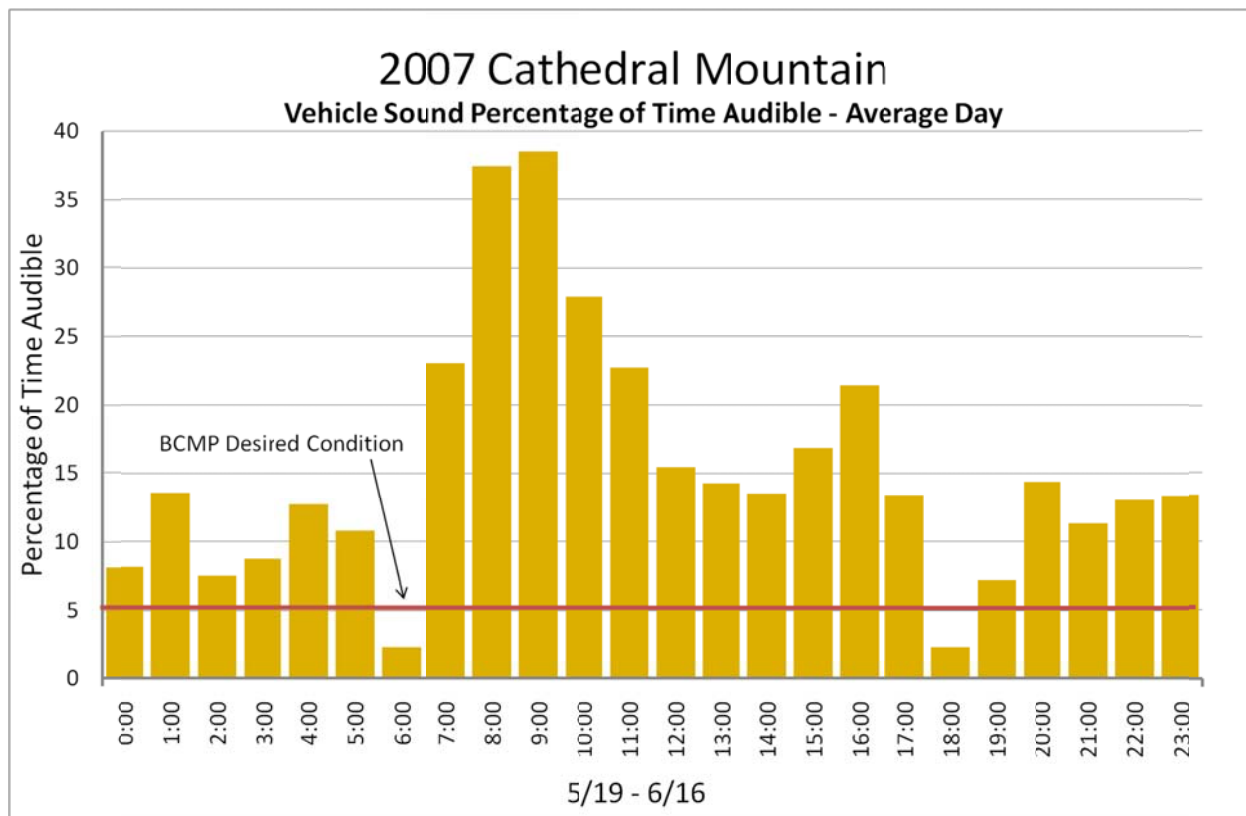
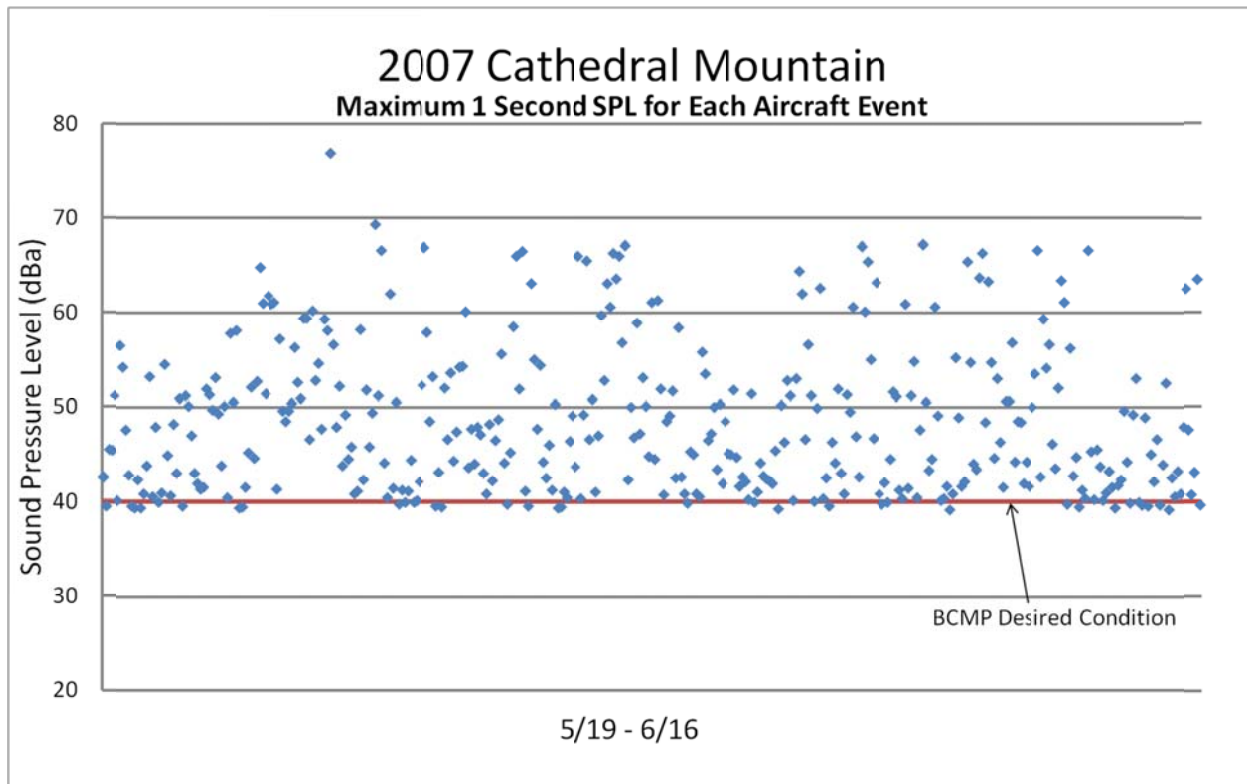
The most commonly heard natural sounds at this site were wind (audible 36.6% of the time), birds (14.2%), rain (5.1%), and insects (3.9%). Aircraft sound was audible 3.6% of the time on average, and on-road vehicles could be heard 11.7% of the time. It should be noted that a road construction project was occurring in the area during nighttime hours (7pm-5am), and added to this value considerably. Conditions (excluding road vehicle noise) exceeded the BCMP percent audible standard 32% of the time, number of events per day 100% of the time, and maximum SPL 91% of the time.

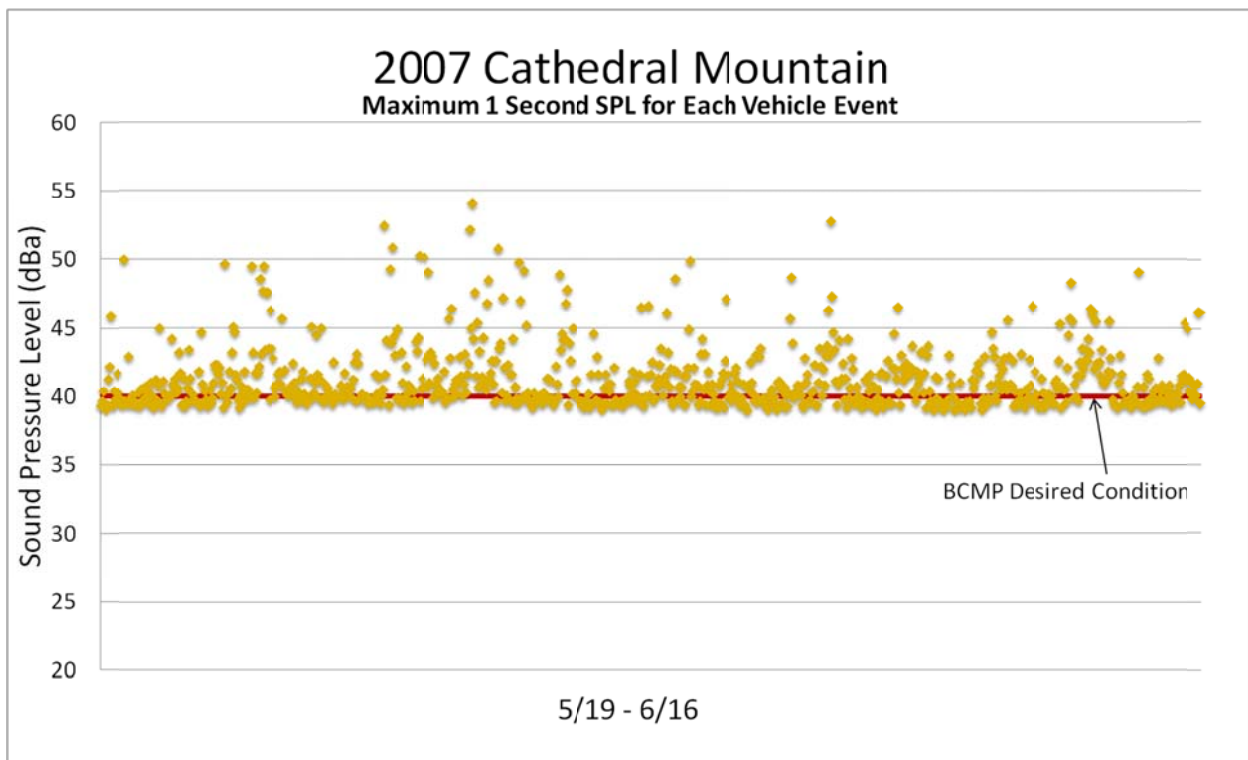
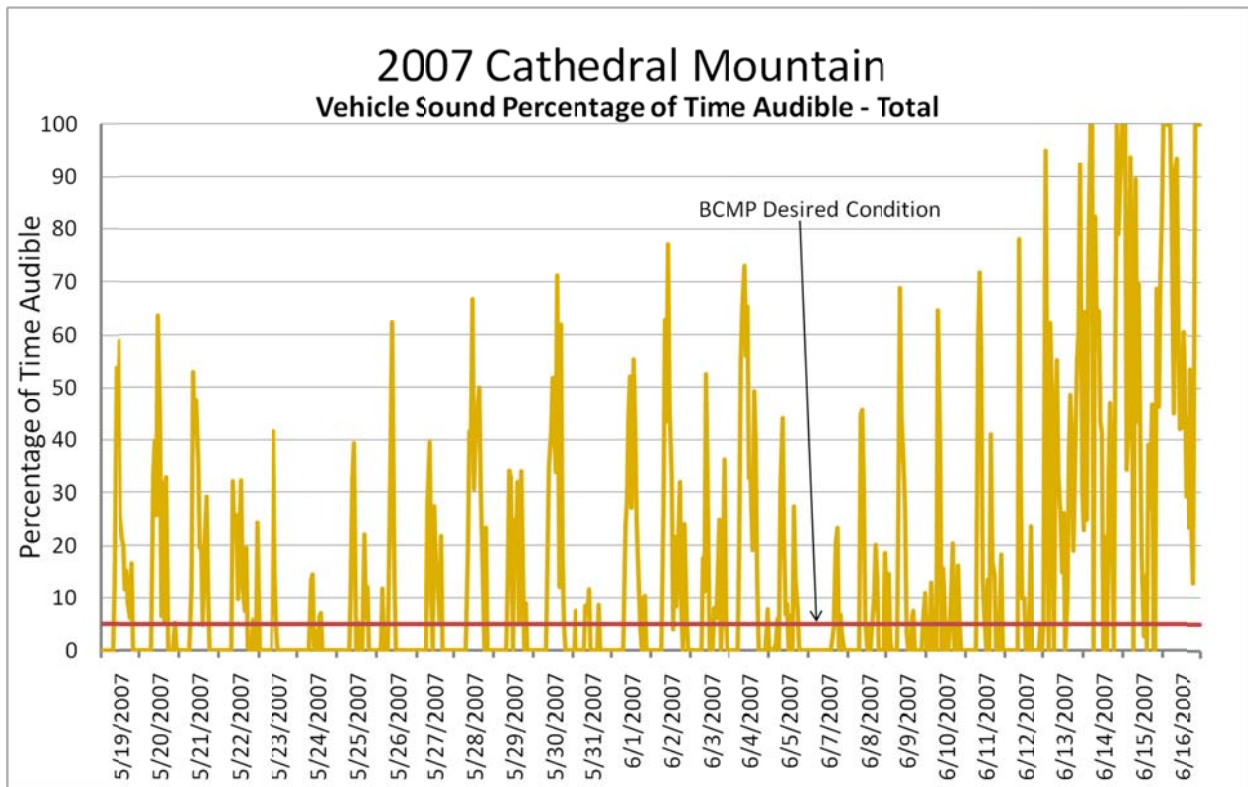












Chistia Creek



Location Description: On Chitsia Creek ~5Km South of the Park Boundary.

Purpose/Project: Location randomly chosen from the LTEM grid as part of the long-term Denali Soundscape inventorying and monitoring sampling plan.

Coordinates: Lat. 63.95127, Long. 150.35603 Elevation: 433 Meters

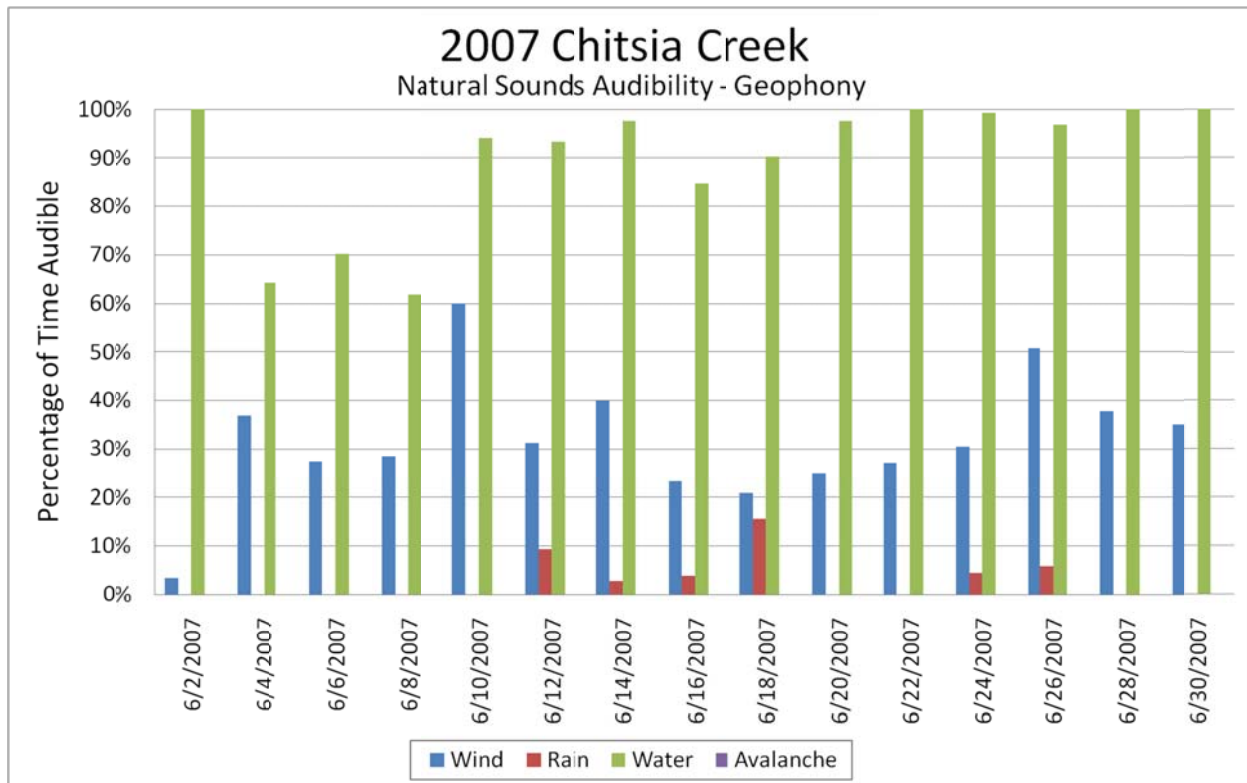
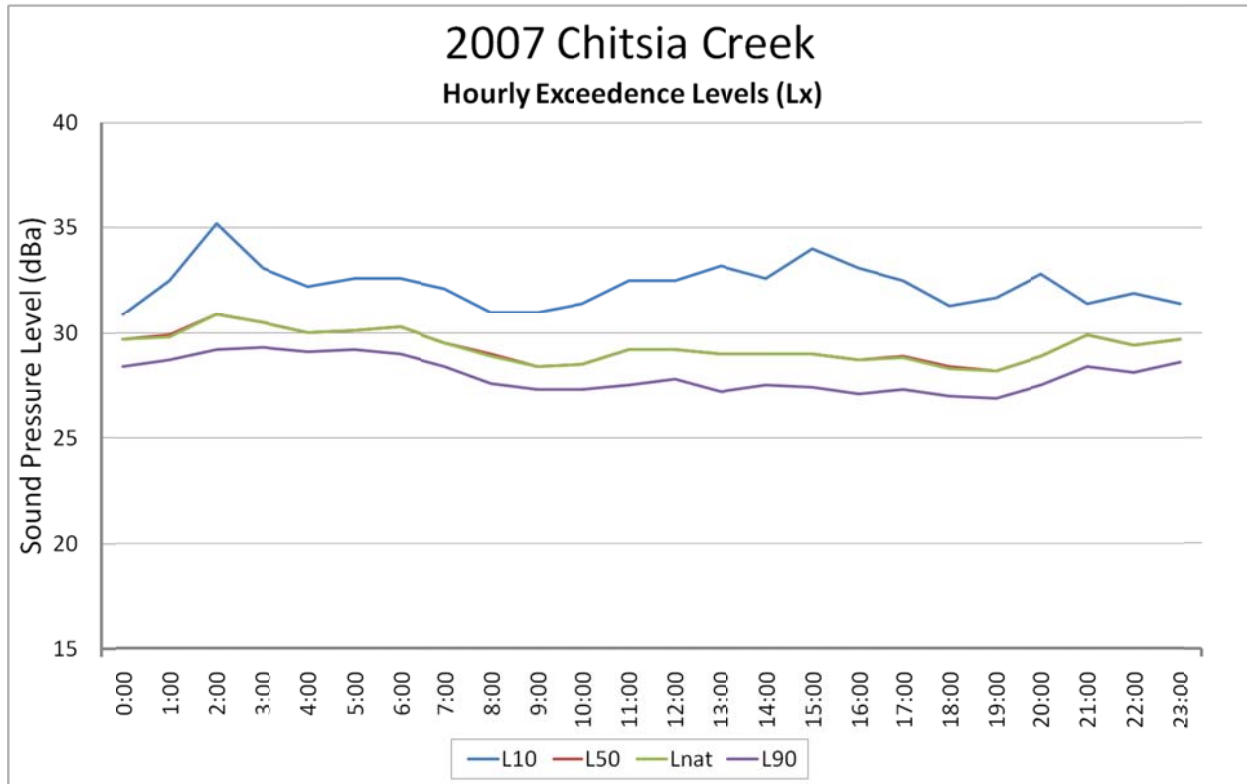
Time at Location: Jun-01 to Jul-04, 2007

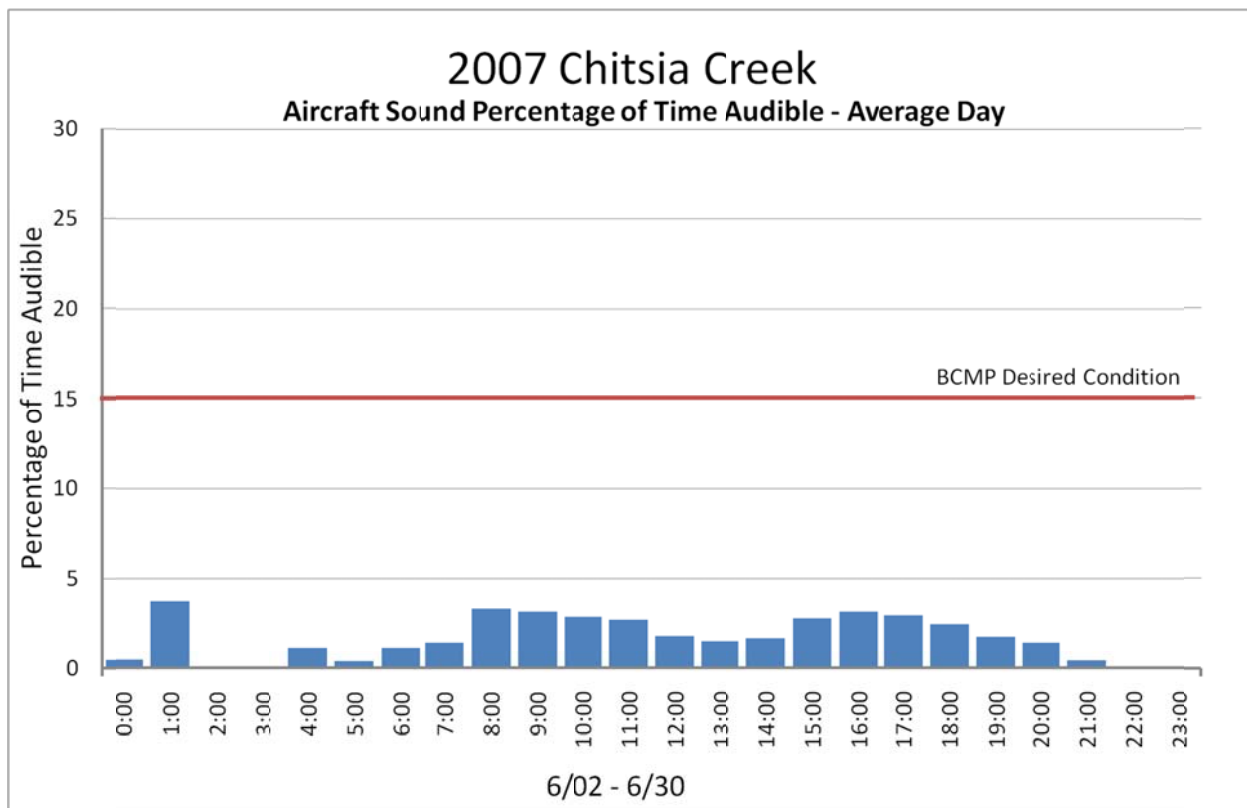
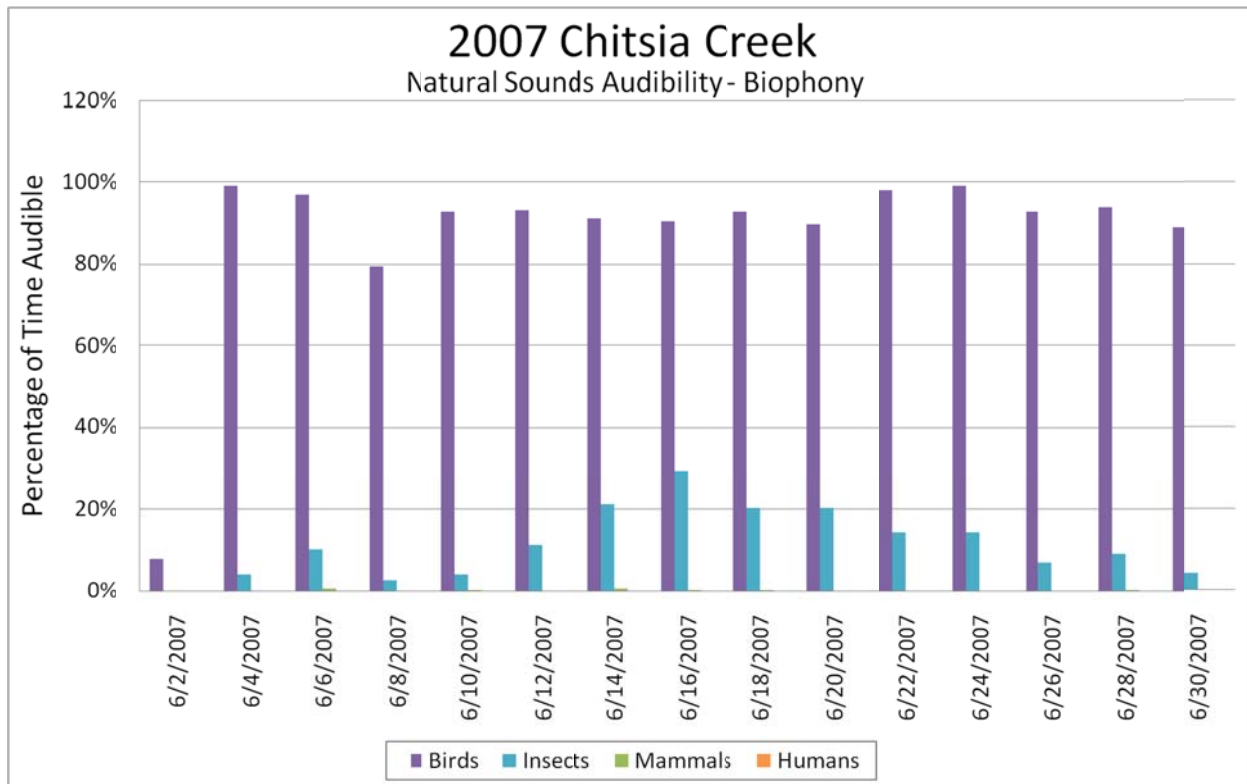
BCMP Management Zone: Medium Park Ecoregion: Boreal Outer Range

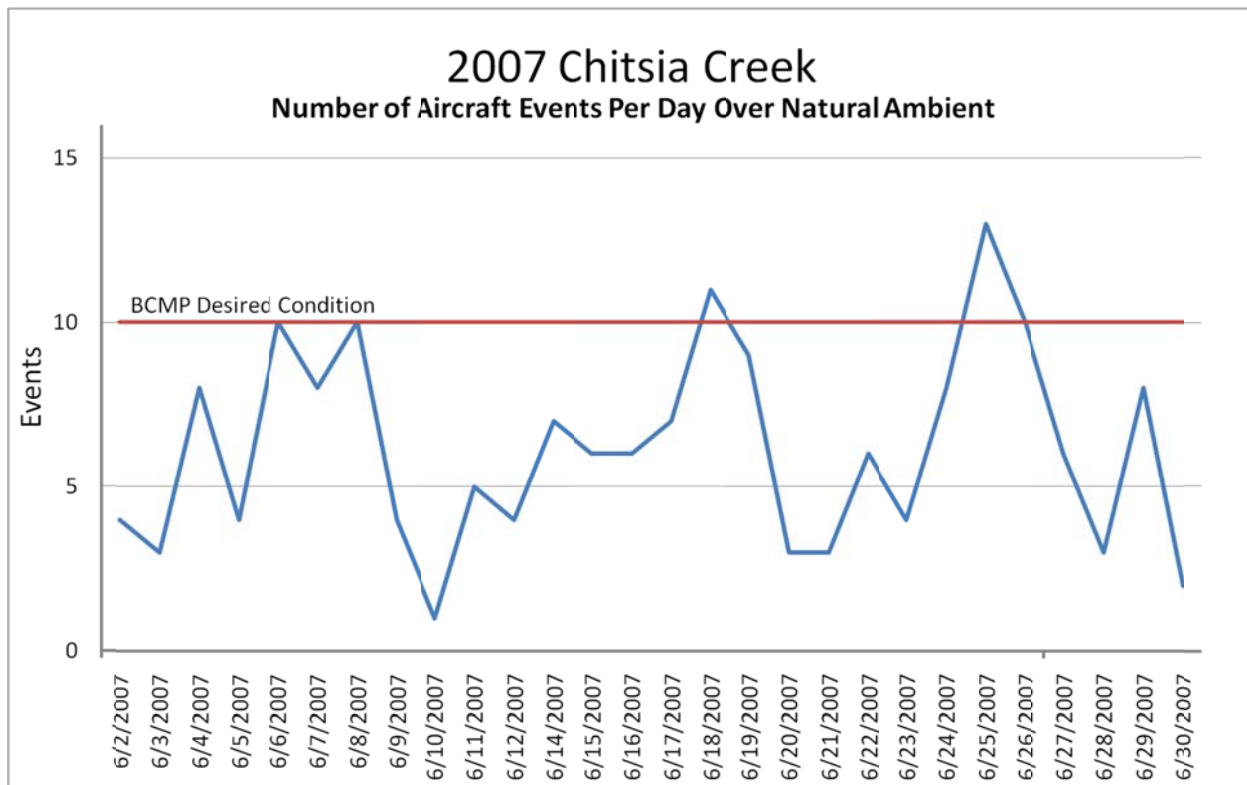
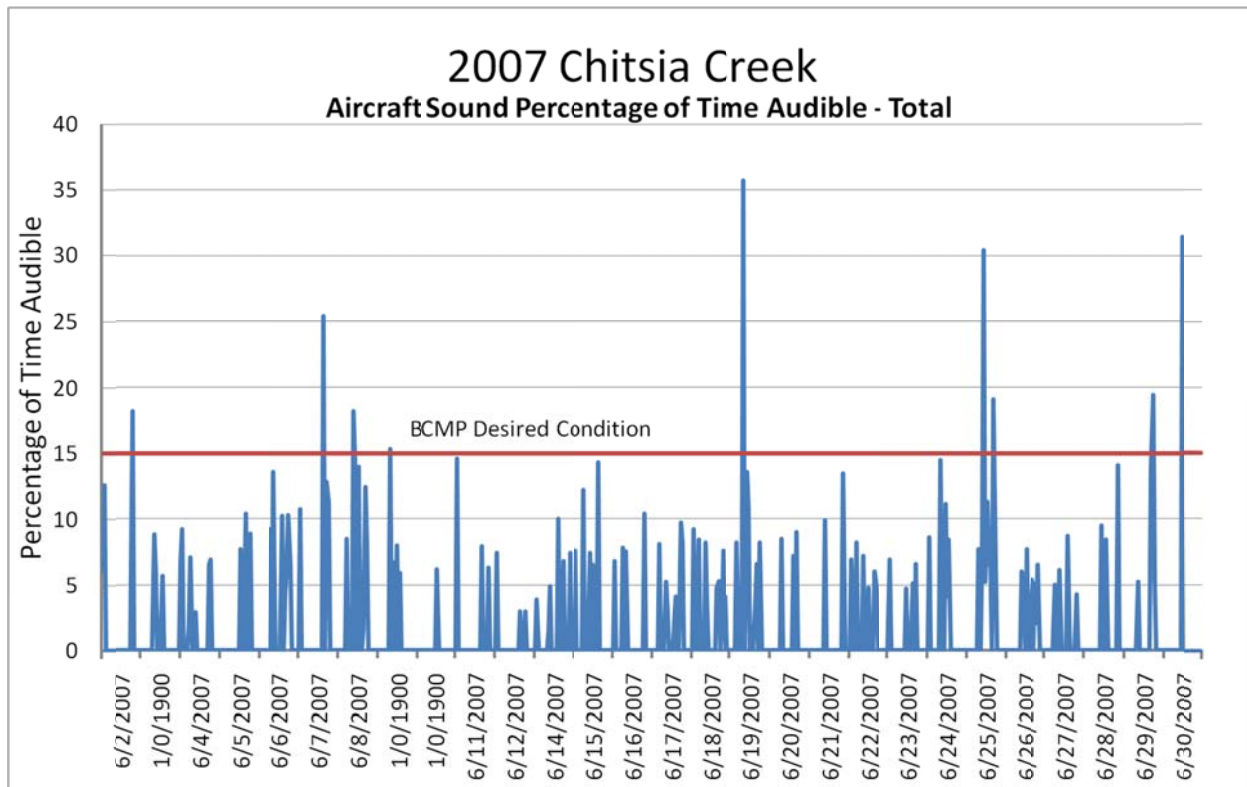
Access: Helicopter

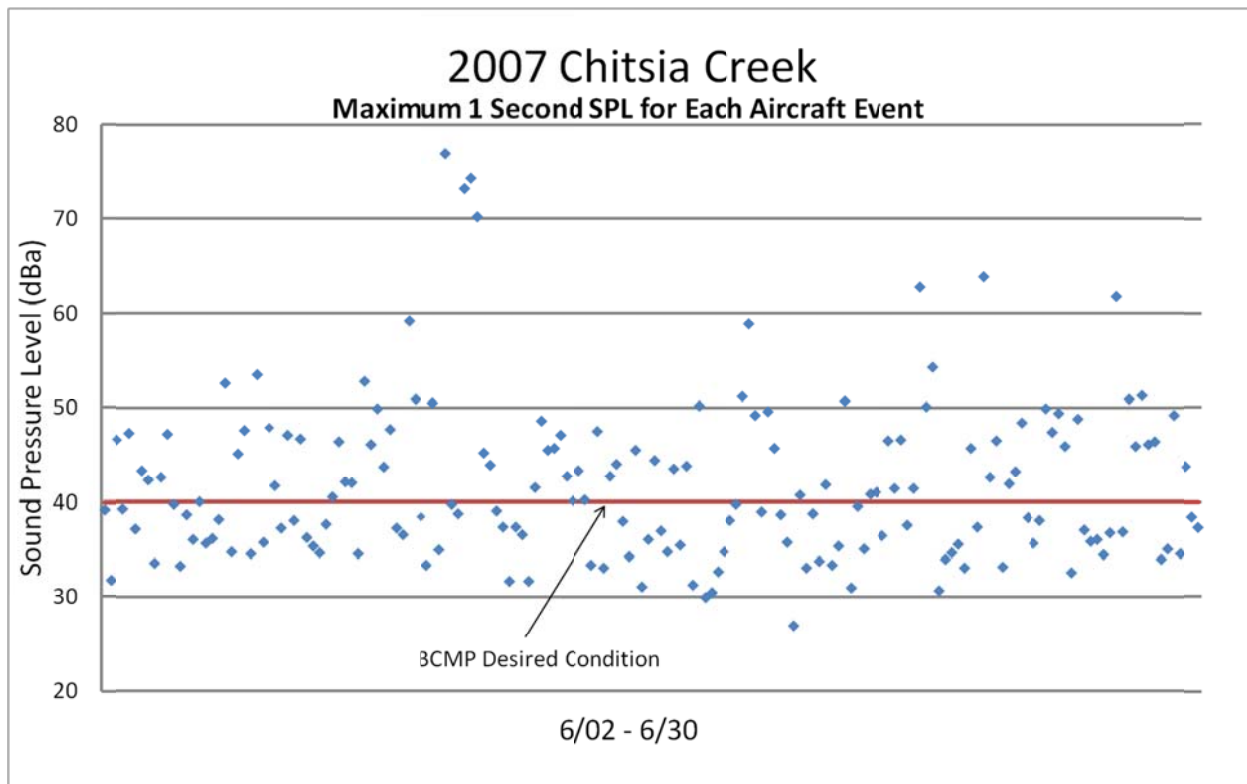
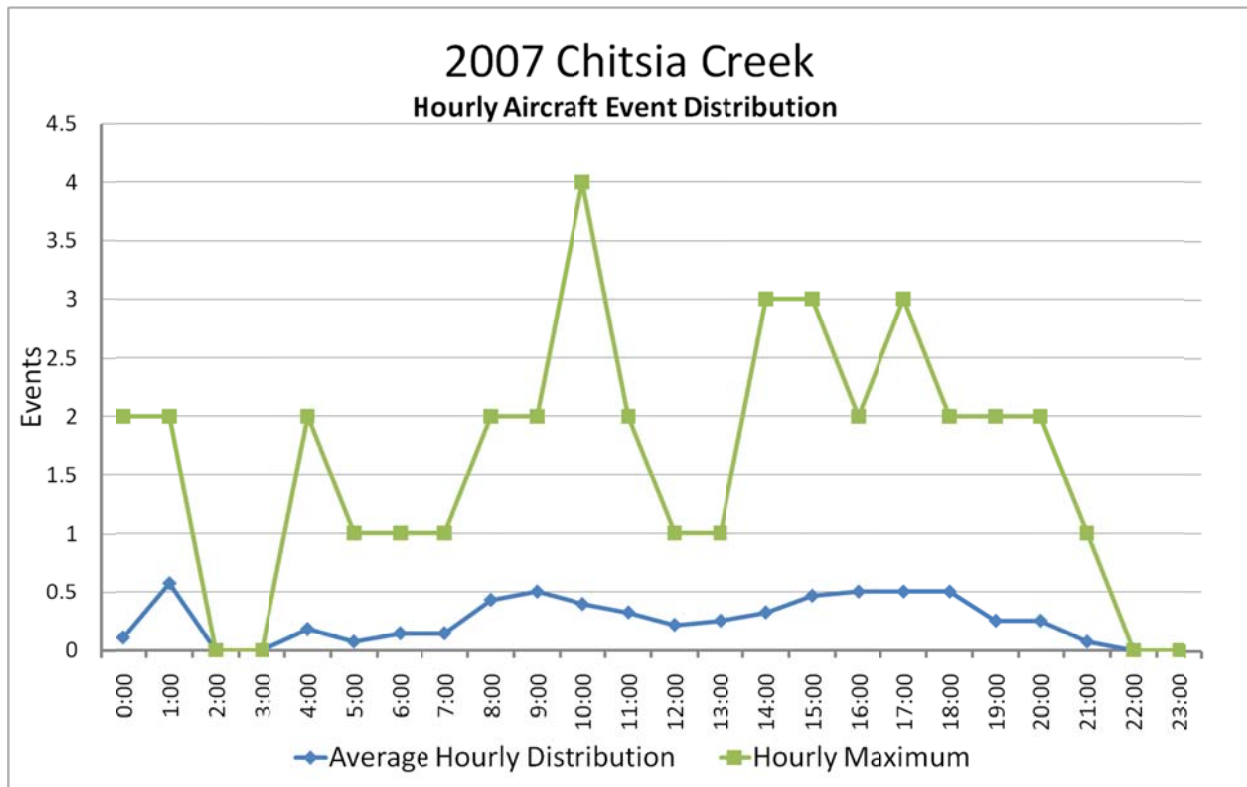
Summary: The purpose of the Chitsia Creek location was to collect data at one of the long-term ecological monitoring (LTEM) grid points, as outlined in the above sampling plan. LTEM grid point #245 was stratified as a New Park location and randomly selected from all locations requiring aircraft access.

The most commonly heard sounds at this site were running water (audible 90% of the time), birds (87%), wind (32%), and insects (12%). Mechanized sound was audible 1.75% of the time on average. Conditions exceeded the BCMP percent audible standard 2% of the time, number of events per day 10% of the time, and maximum SPL 47% of the time.









Hidden River



Location Description: On the foothills to the West of the Hidden River, just inside the Park Boundary.

Purpose/Project: Location randomly chosen from the LTEM grid as part of the long-term Denali Soundscape inventorying and monitoring sampling plan.

Coordinates: Lat. 62.87249, Long. 150.11368 Elevation: 956 Meters

Time at Location: Aug-16 to Sept-13, 2007

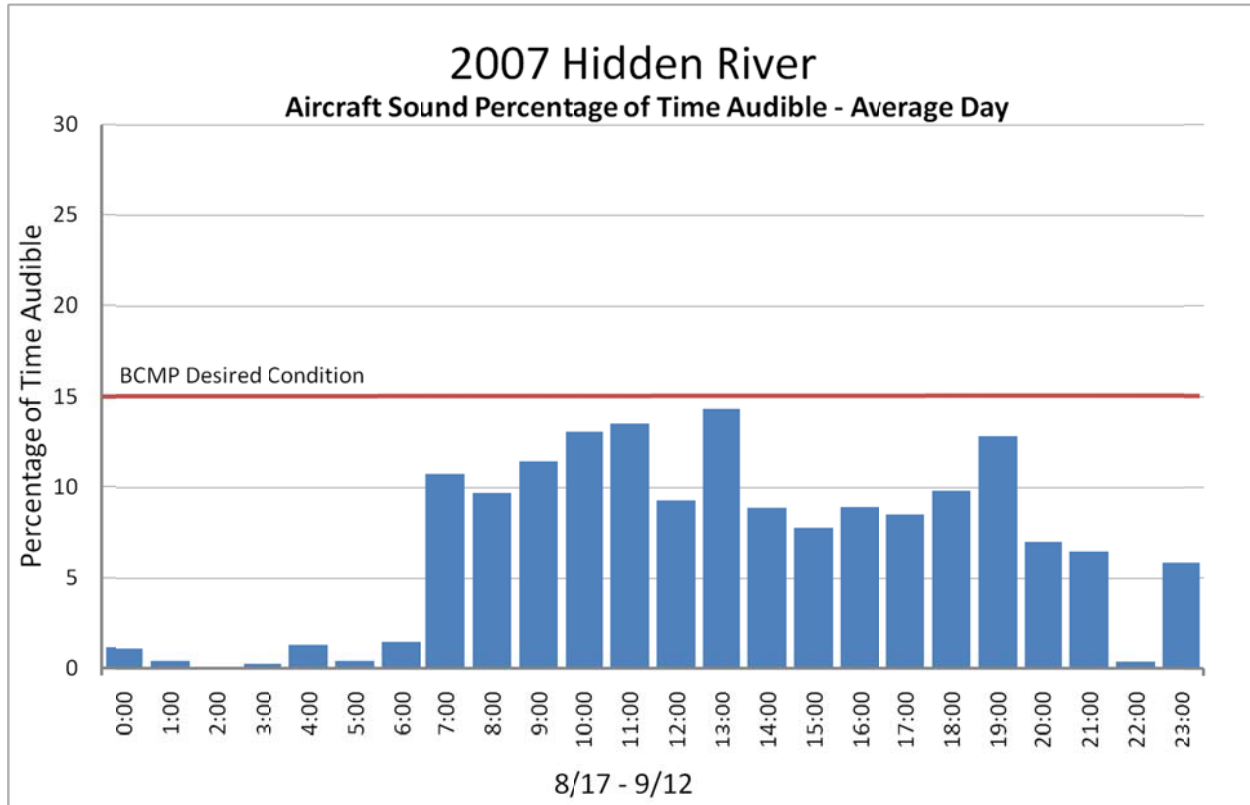
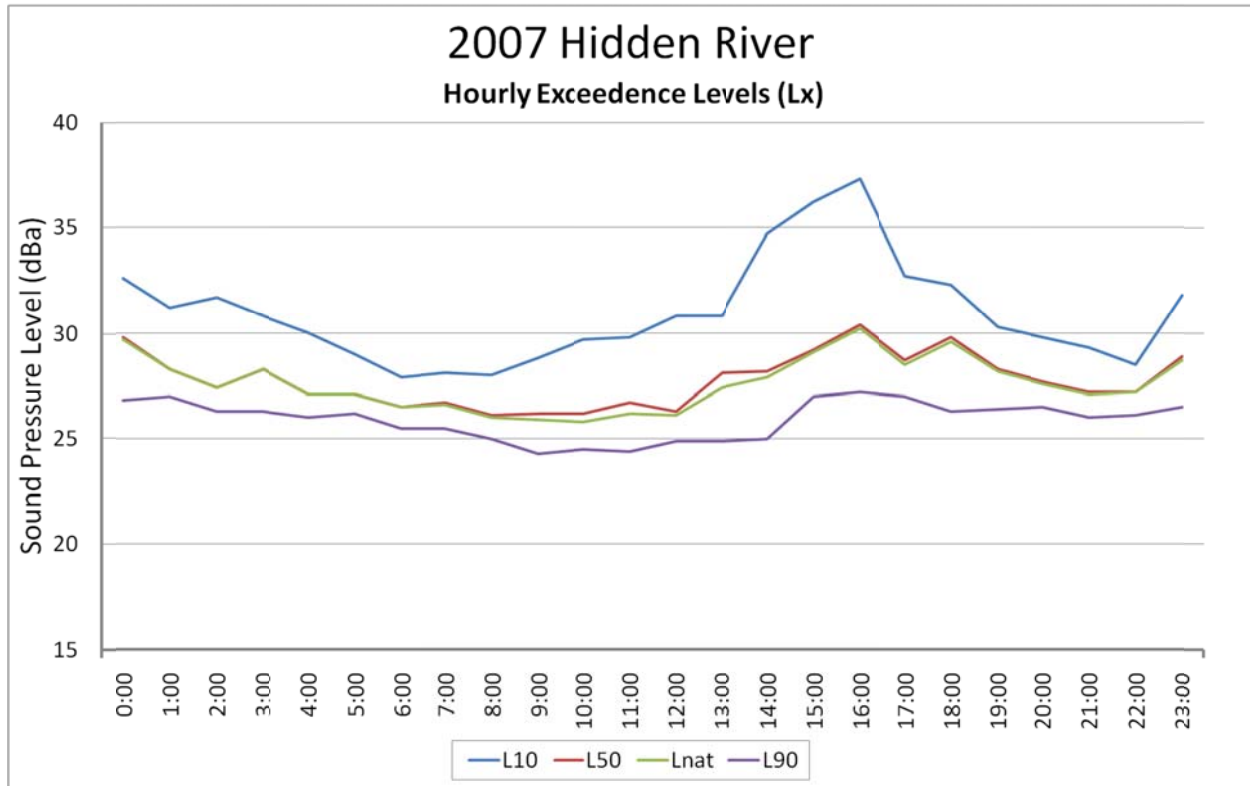
BCMP Management Zone: Medium Park Ecoregion: Alpine Mountains

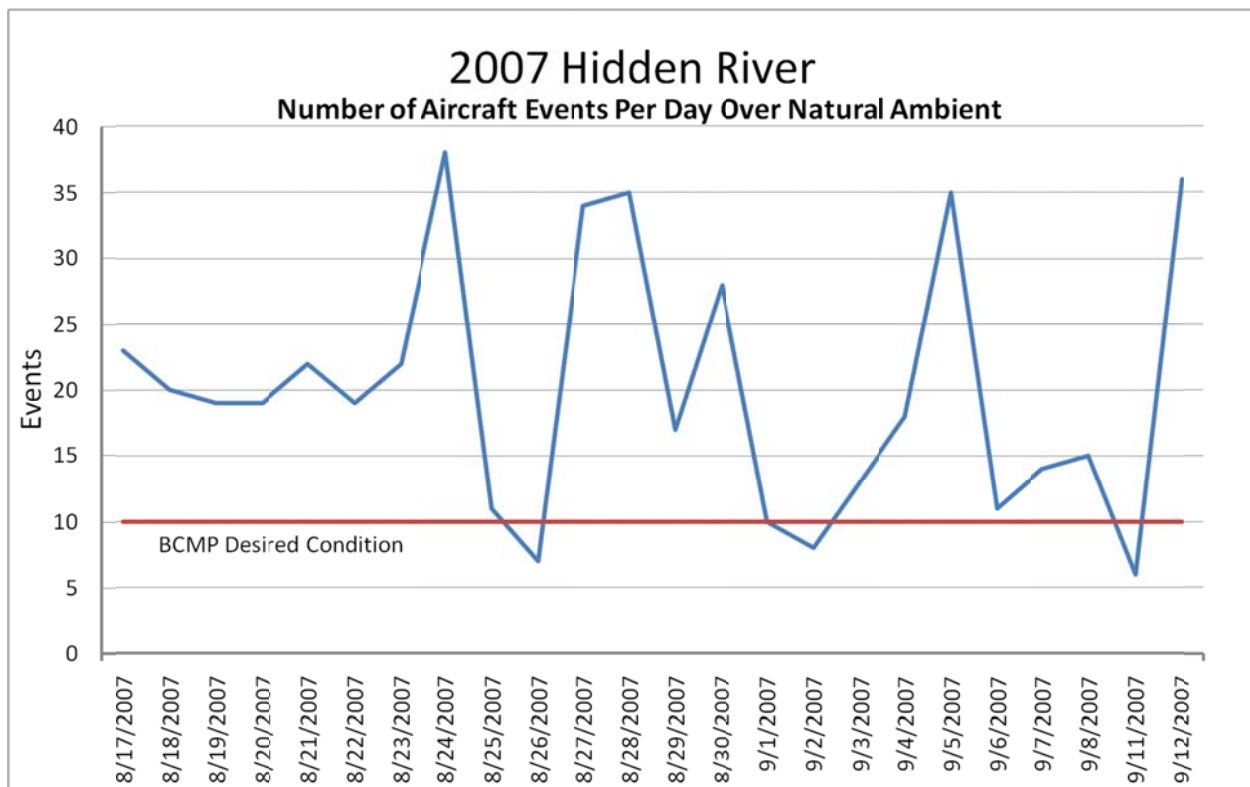
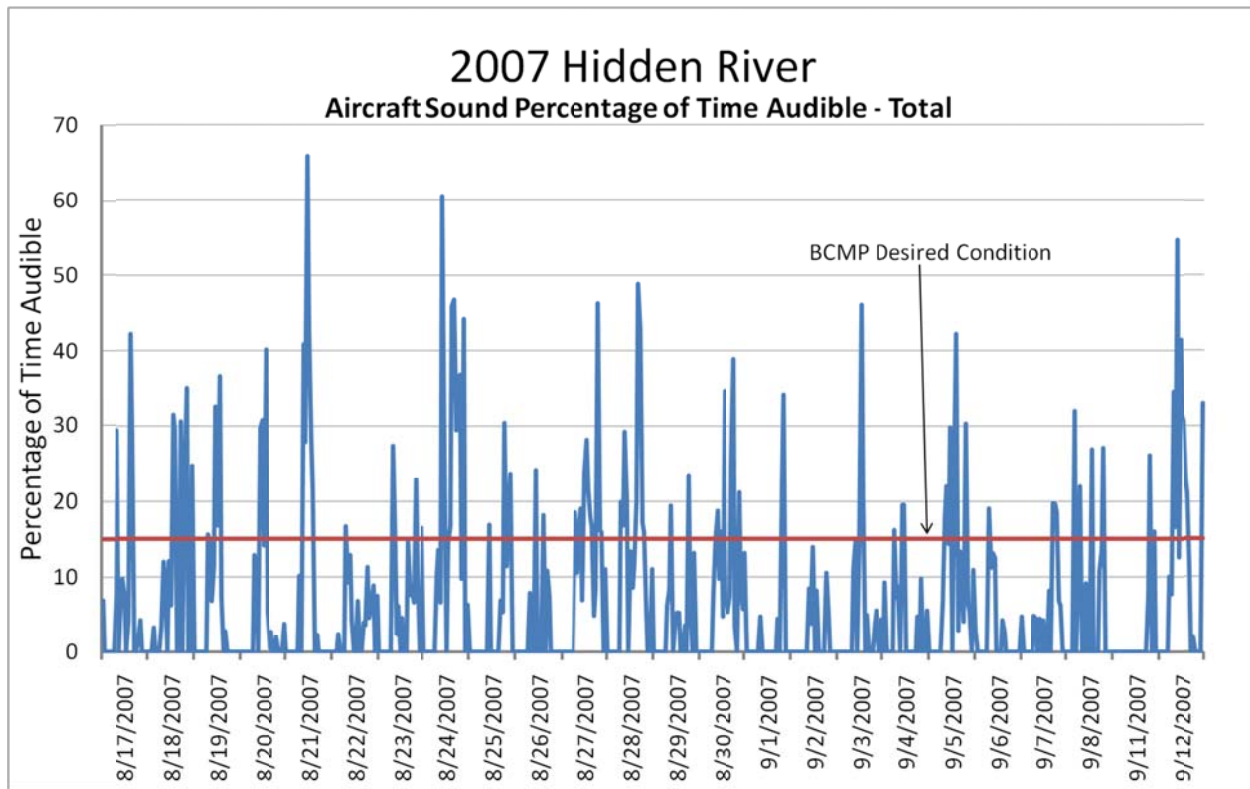
Access: Helicopter

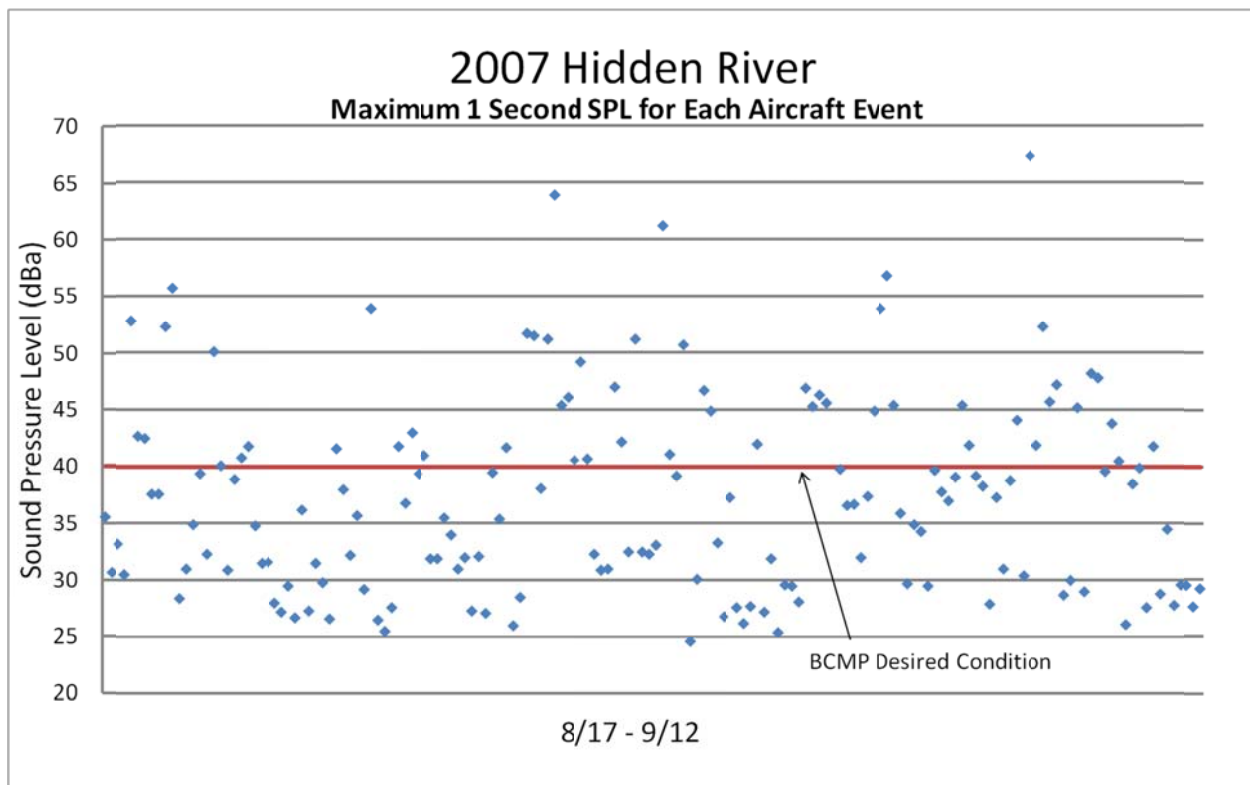
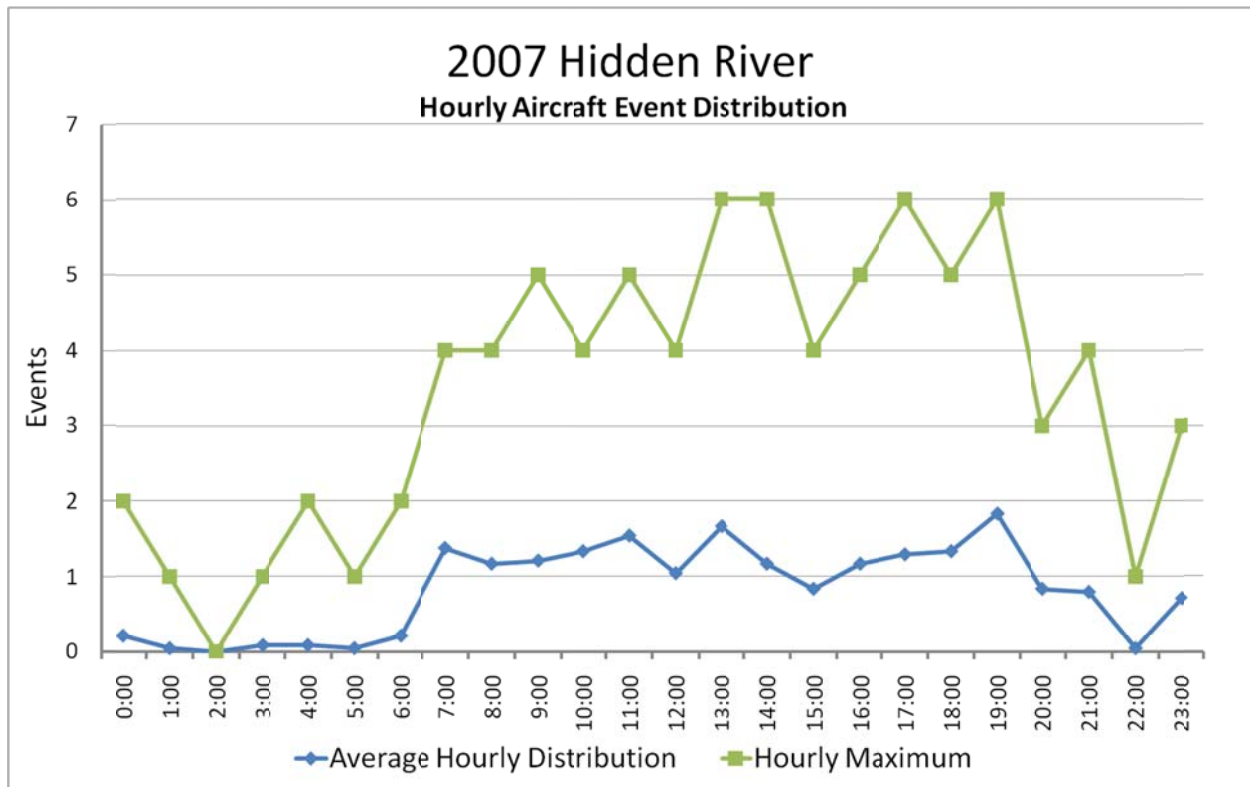
Summary: The purpose of the Hidden River location was to collect data at one of the long-term ecological monitoring (LTEM) grid points, as outlined in the above sampling plan. LTEM grid point #53 was stratified as a New Park location and randomly selected from all locations requiring aircraft access.

Collection of audibility data at this site was not successful, so no audibility analysis is possible. However, SPL data was collected, so a visual analysis of human-caused noise and BCMP indicator analysis was performed.

Mechanized sound was audible 6.81% of the time on average. Conditions exceeded the BCMP percent audible standard 18% of the time, number of events per day 83% of the time, and maximum SPL 28% of the time.







Kahiltna Pass



Location Description: Kahiltna Pass, along the West Buttress climbing route.

Purpose/Project: Location chosen on the request of the Southside climbing rangers. The rangers are concerned about the increasing traffic around the summit. Kahiltna Pass was suggested by Dave Kreutzer as a test location to work out the bugs of placing a sound station at such a high elevation. This location is also a popular flightseeing tour path for tours that go around Mt. McKinley.

Coordinates: Lat. 63.07980, Long. 151.17419 Elevation: 3080 Meters

Time at Location: Jun-20 to Jul-04, 2007

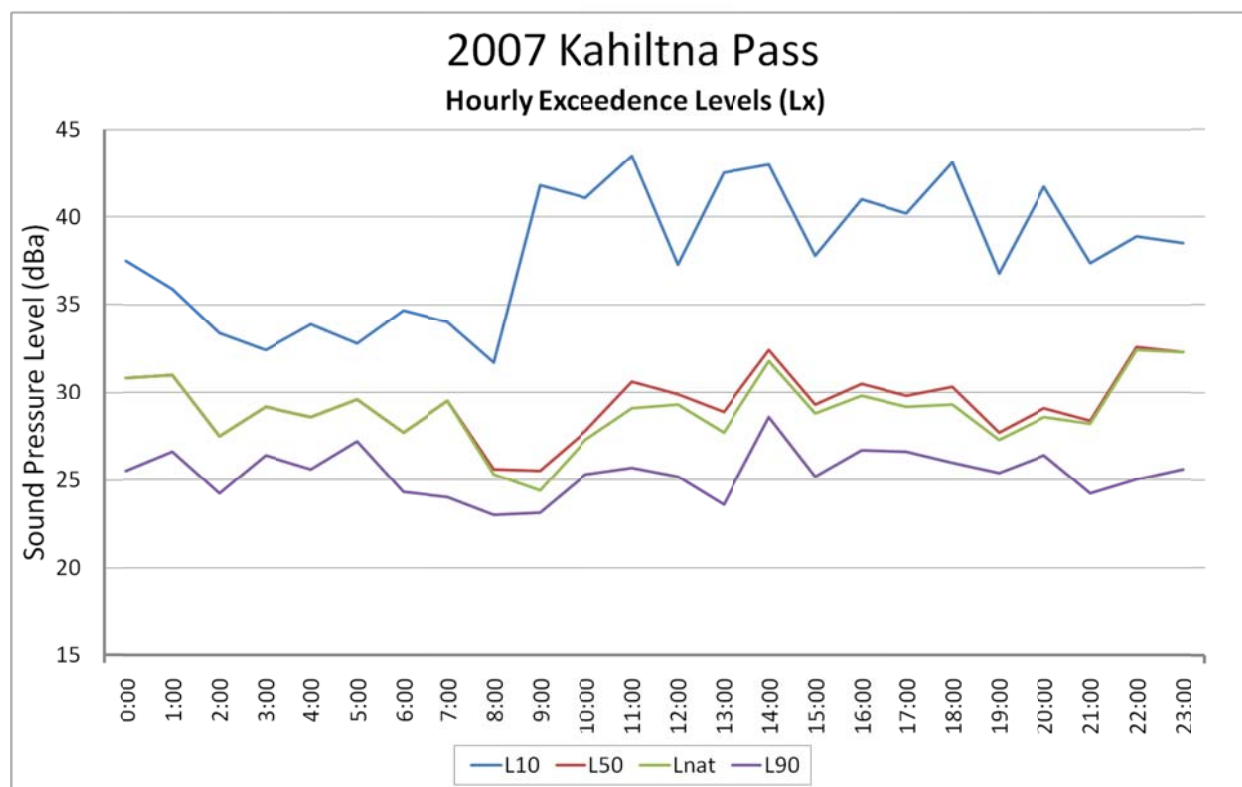
BCMP Management Zone: Low Park Ecoregion: Nonvegetated Alpine Mountains

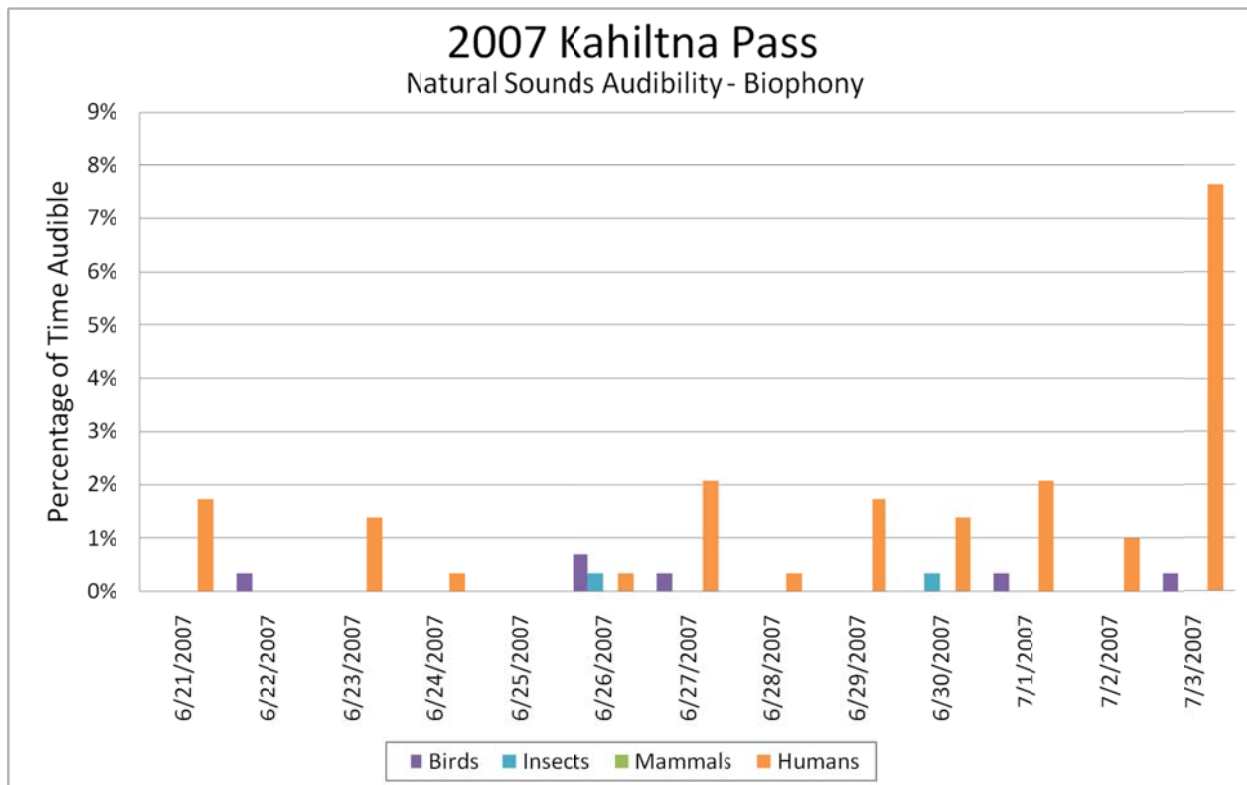
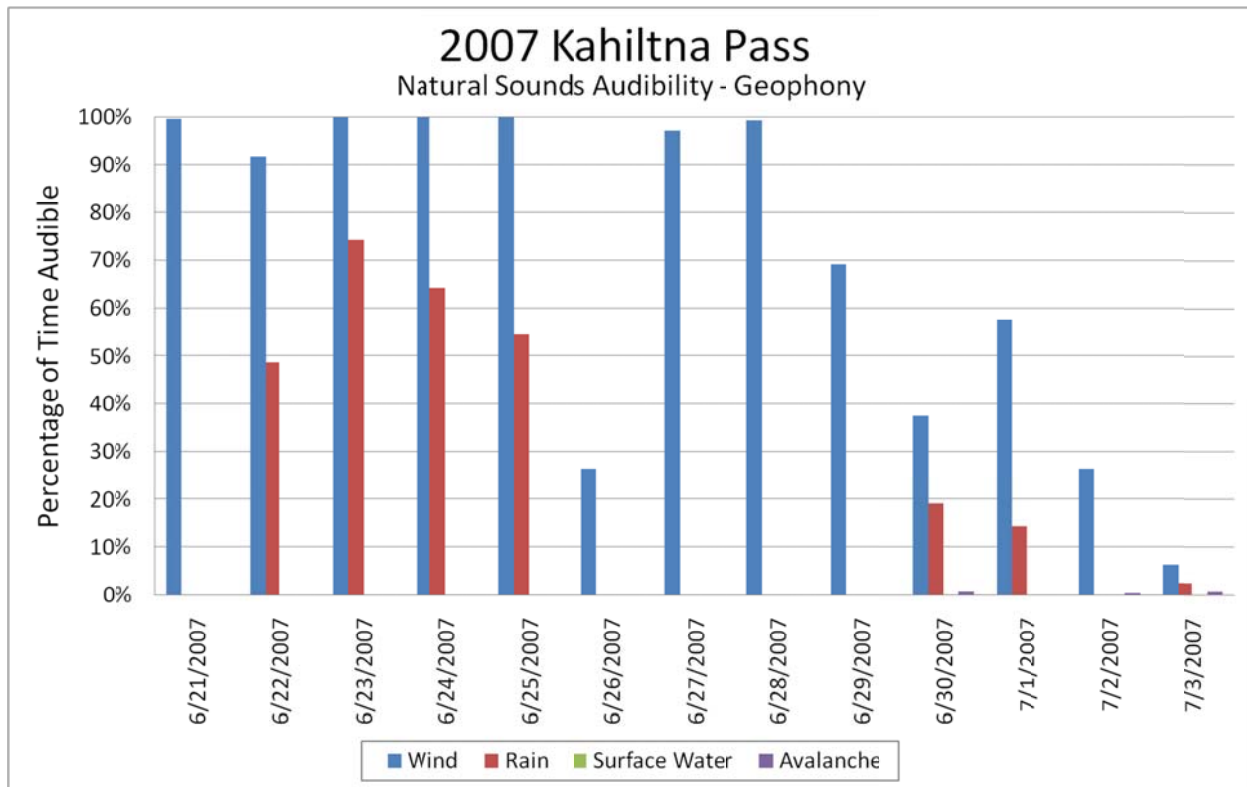
Access: Helicopter

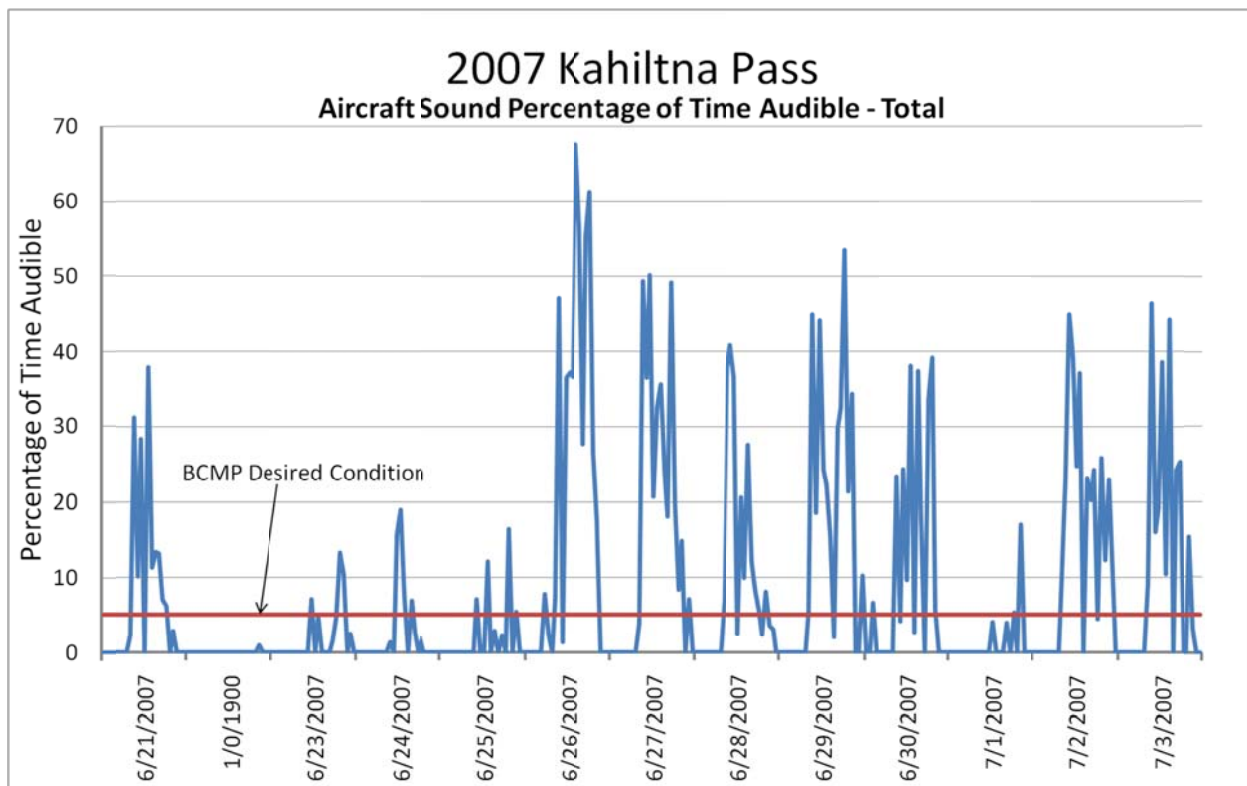
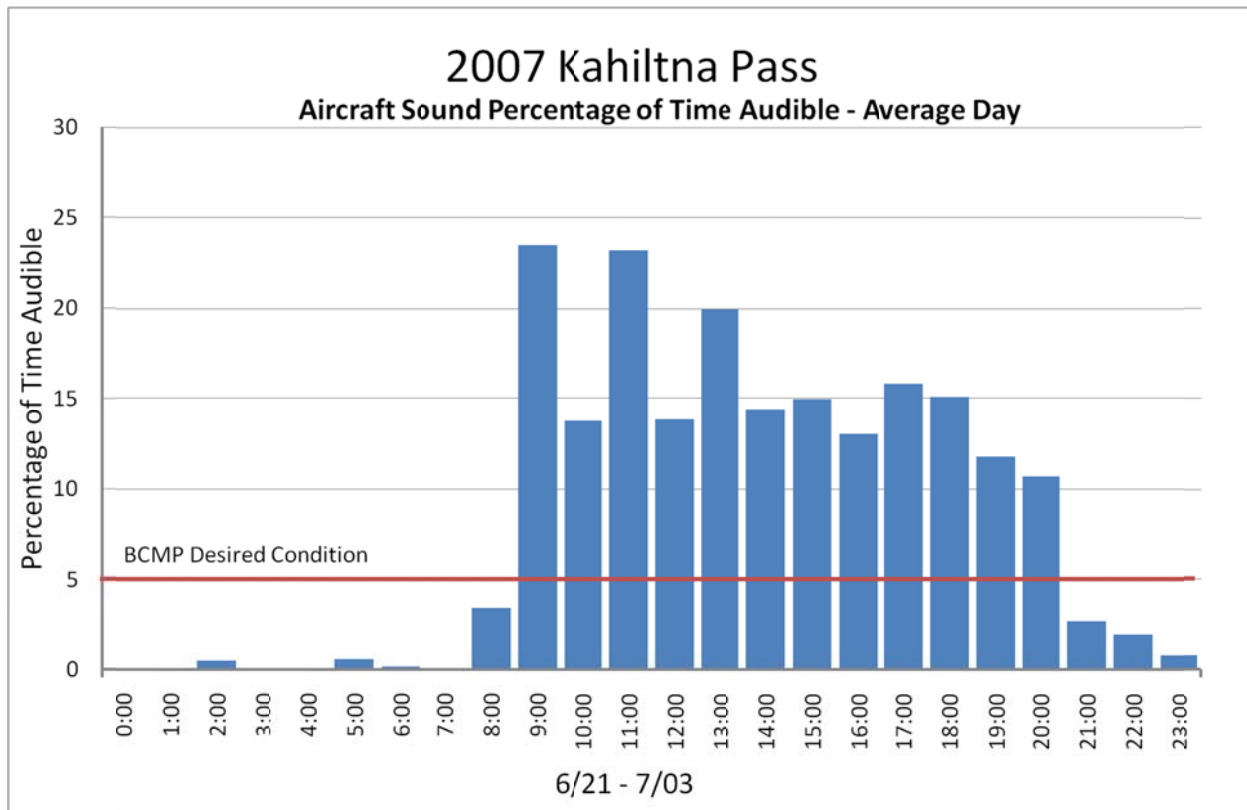
Summary: The purpose of the Kahiltna Pass location was to collect acoustic data a location along the popular West Buttress climbing route on Mt. McKinley. This would provide a measurement of the levels of aircraft noise mountaineers on the route are being exposed to. It also provided a chance to learn whether a remote sound monitoring station could be operated reliably under the extreme climactic conditions which occur at high elevations in the Alaska Range. Kahiltna Pass is an Old Park (designated Wilderness) location.

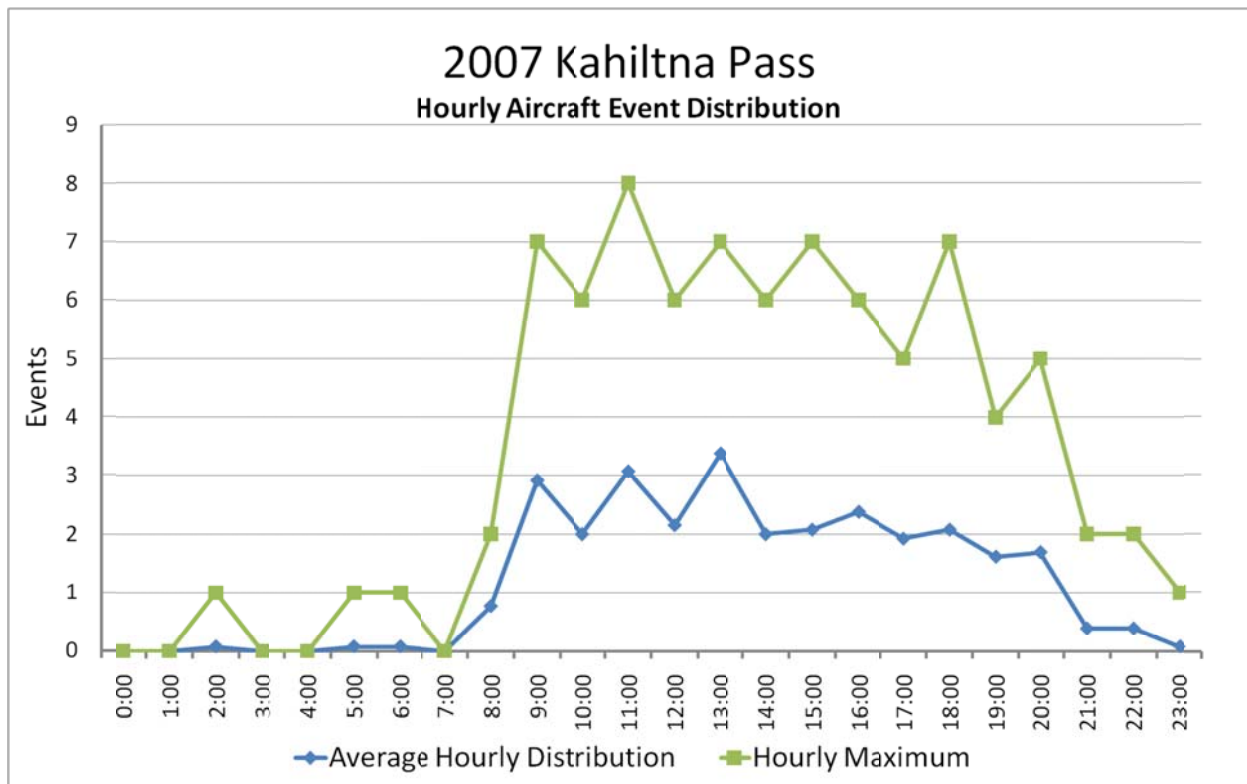
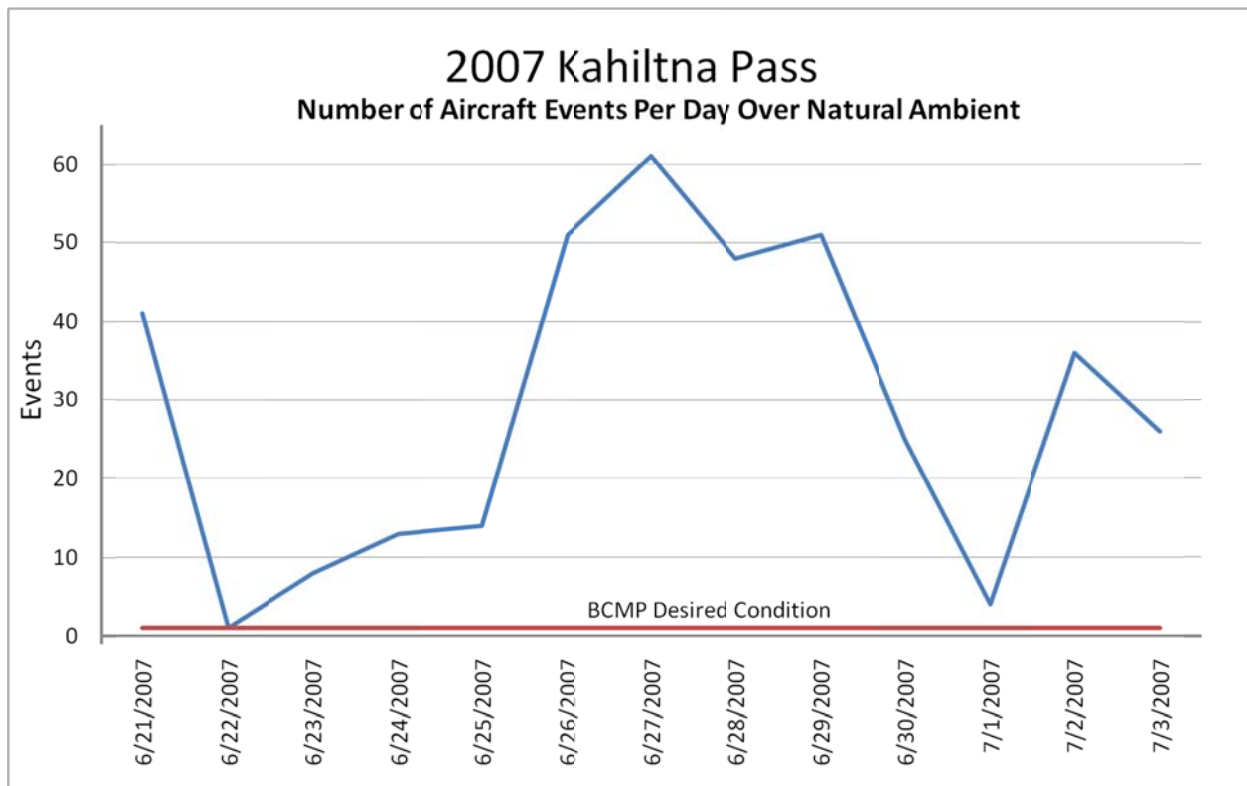
Park staff accessed the site via the Lama mountain rescue helicopter and installed the equipment on June 20th. Because of cost of access and generally unpredictable weather patterns in the region, it was decided that there would be no maintenance trips to the site. It would be allowed to run unattended until park mountaineering staff removed their base camp installations in mid July. The station collected 13 days of good data before a software or hardware glitch disabled it, and it was hauled out with base camp extraction on July 18th.

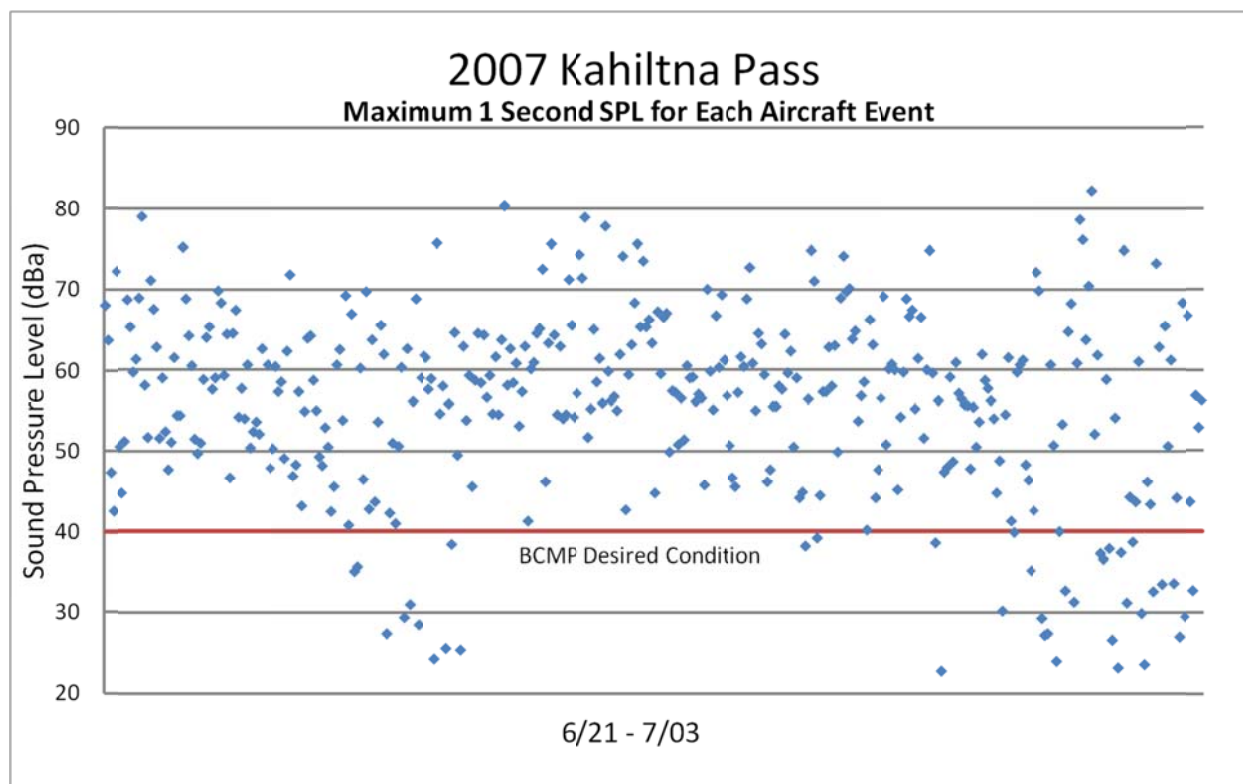
The most commonly heard sounds at this site were wind (audible 70% of the time), precipitation (21%), and mountaineers (3%). Mechanized sound was audible 8.35% of the time on average. Conditions exceeded the BCMP percent audible standard 37% of the time, number of events per day 92% of the time, and maximum SPL 89% of the time.











Lower East Fork Toklat River



Location Description: At the East Fork Toklat River and Stampede Trail.

Purpose/Project: Location chosen from winter-accessible LTEM grid points as part of the long-term Denali Soundscape inventorying and monitoring sampling plan.

Coordinates: Lat. 63.85641, Long. 149.99731 Elevation: 498 Meters

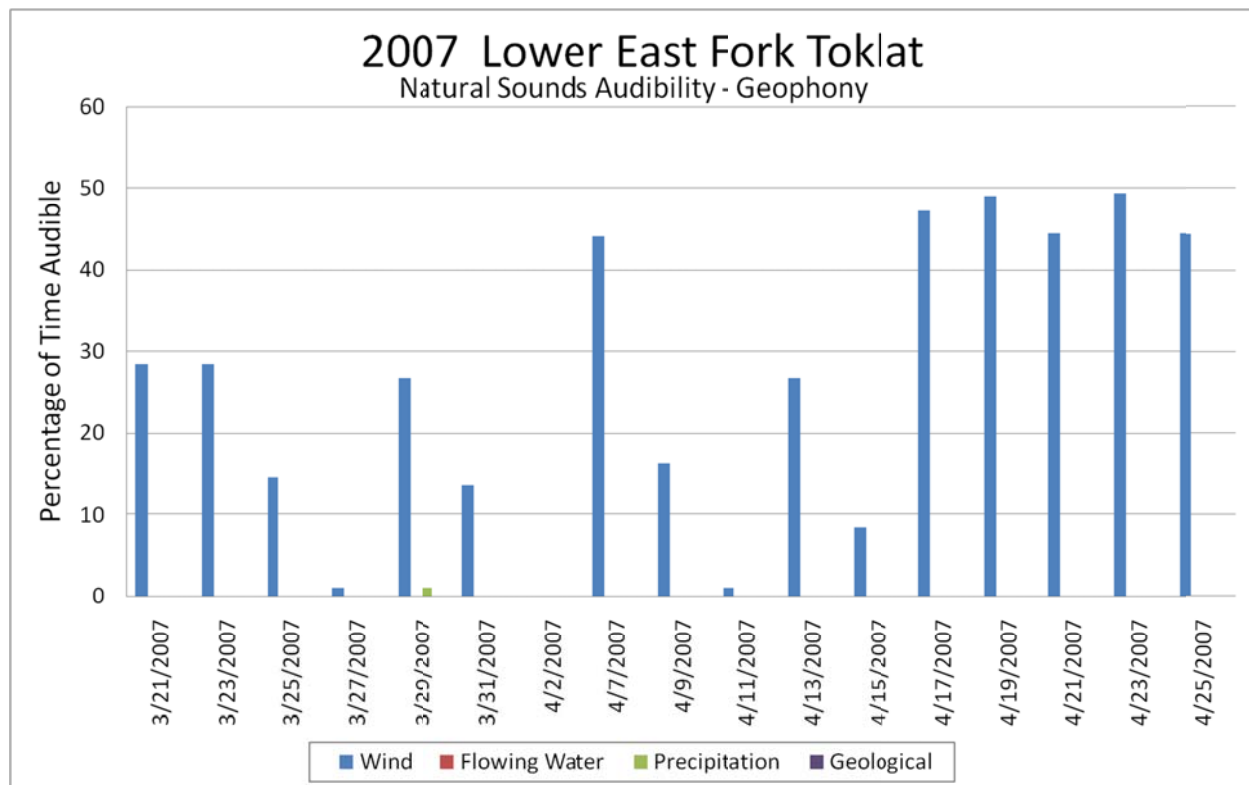
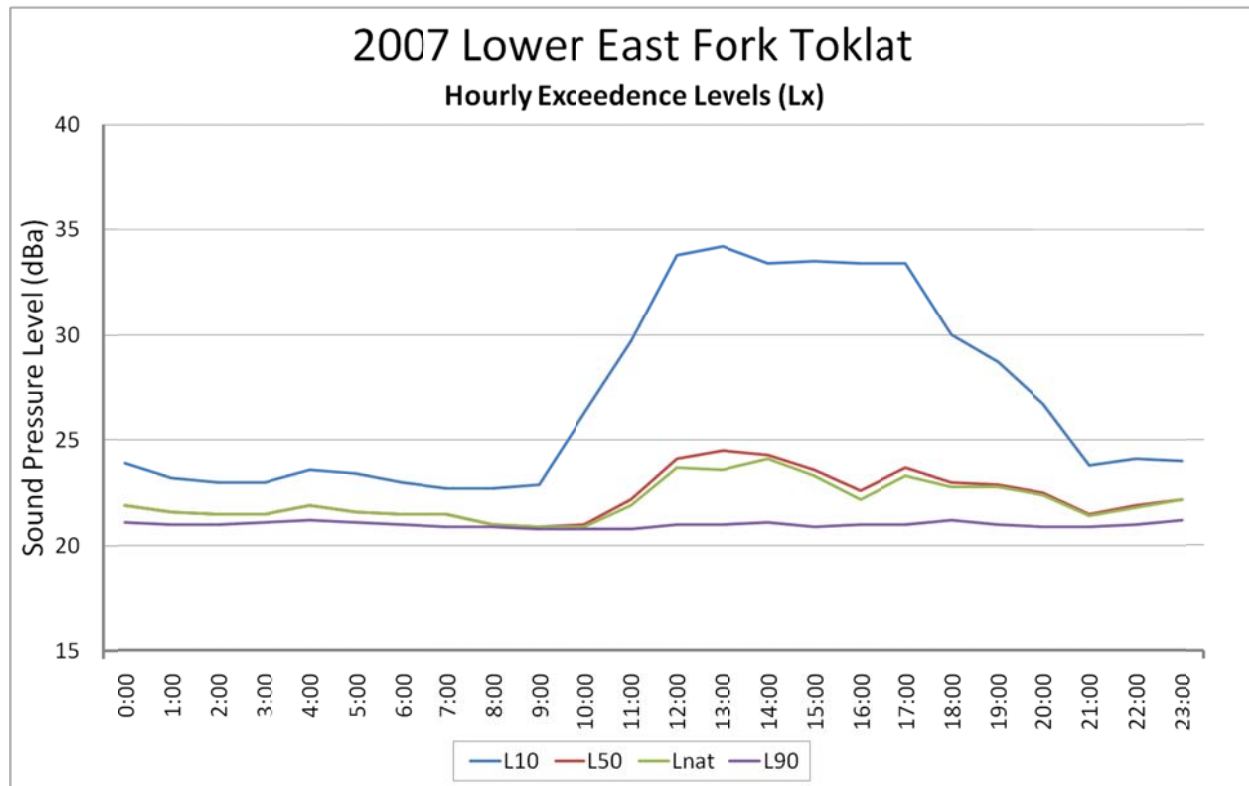
Time at Location: Mar-20 to May-20, 2007

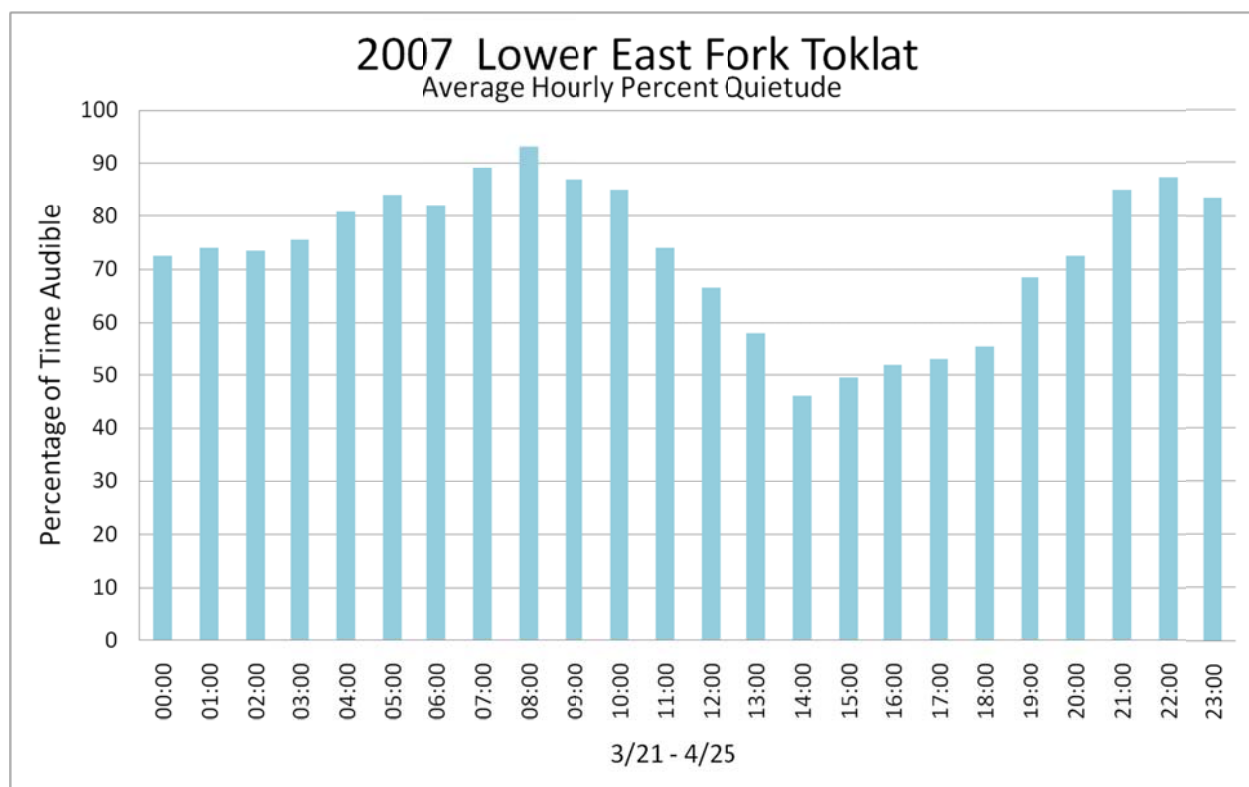
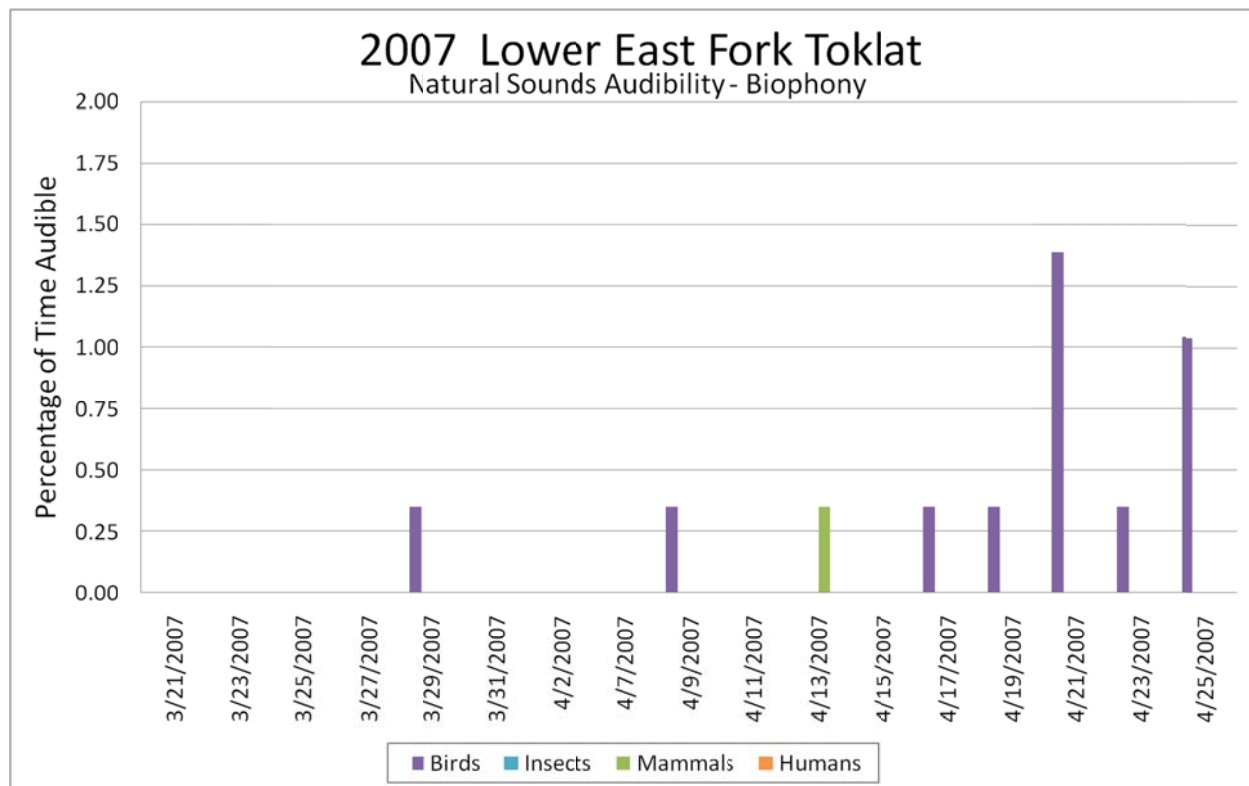
BCMP Management Zone: Medium Park Ecoregion: Toklat Basin Lowlands

Access: Snomobile/Dog Sled/Helicopter

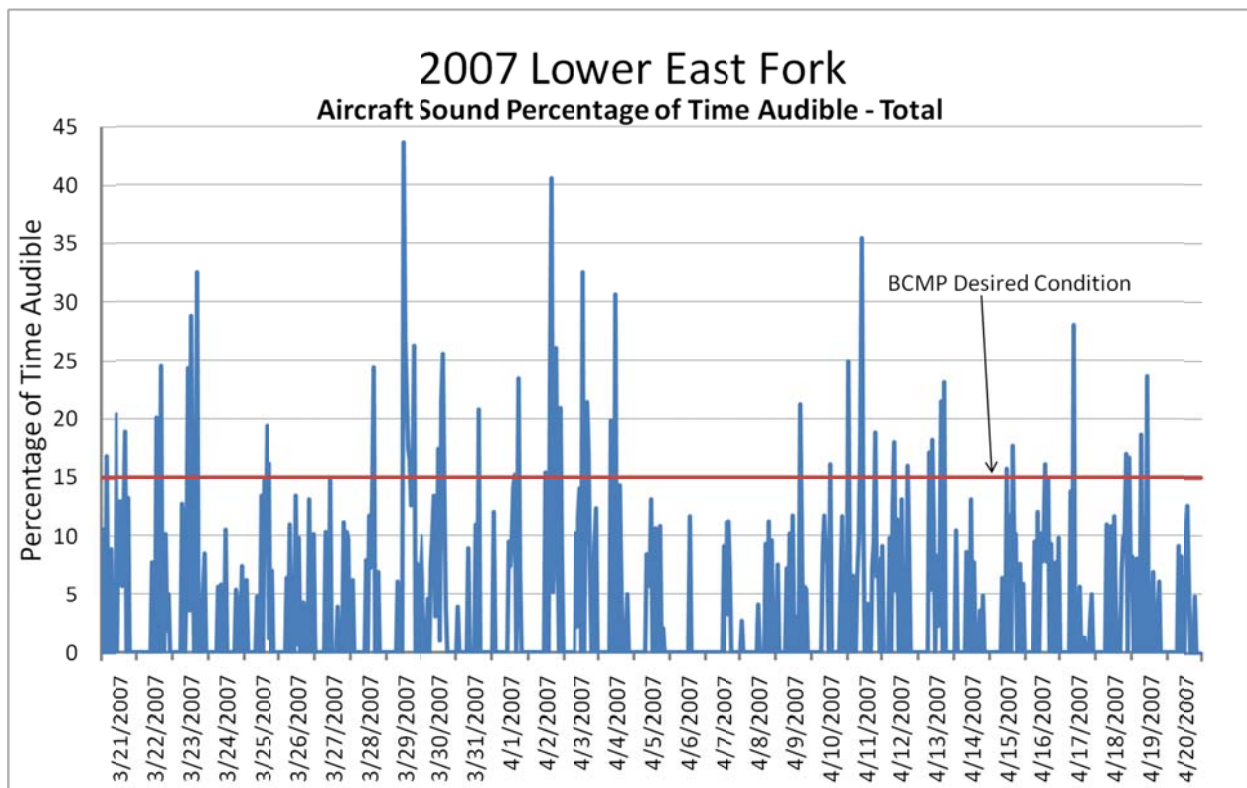
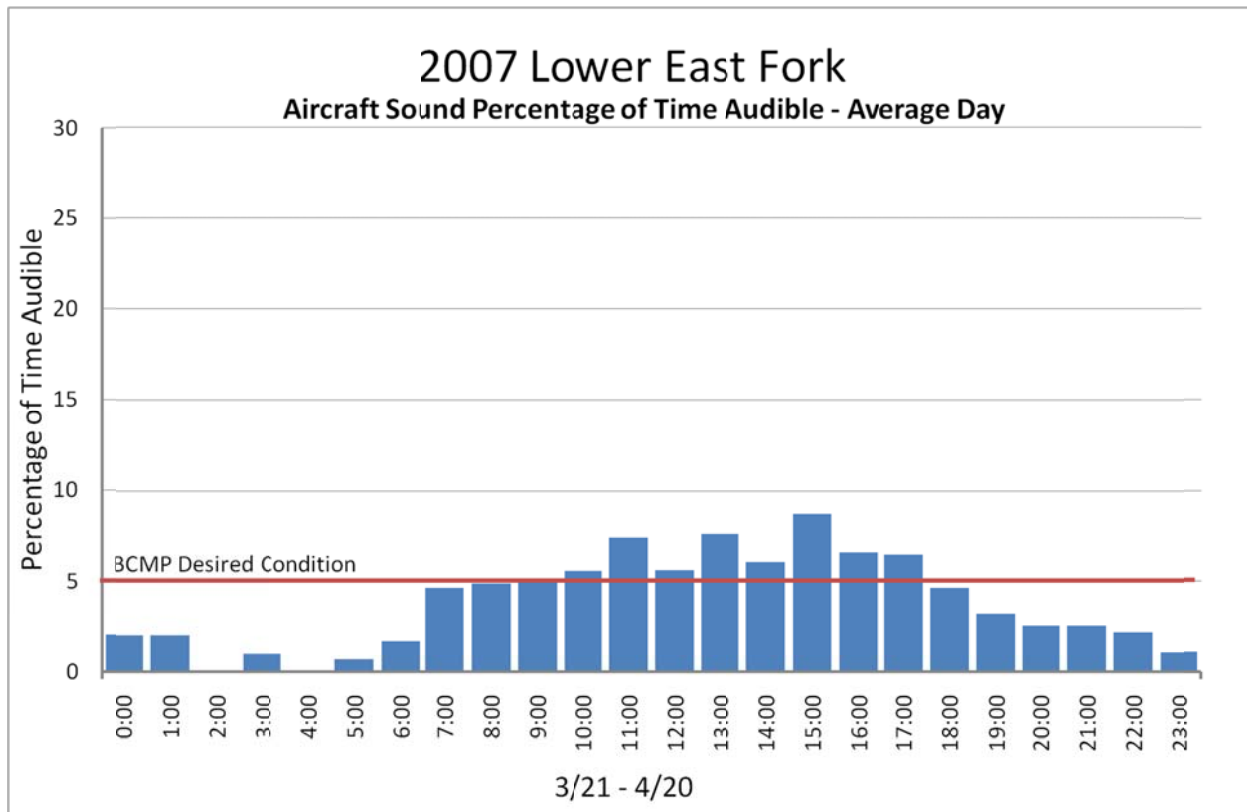
Summary: The purpose of the toe of the Lower East Fork Toklat location was to collect acoustic data at a wintertime-accessible location, and to provide an indication of levels of snowmobile noise along the Stampede Road corridor. This location was stratified as a New Park location and selected from locations requiring snowmobile access.

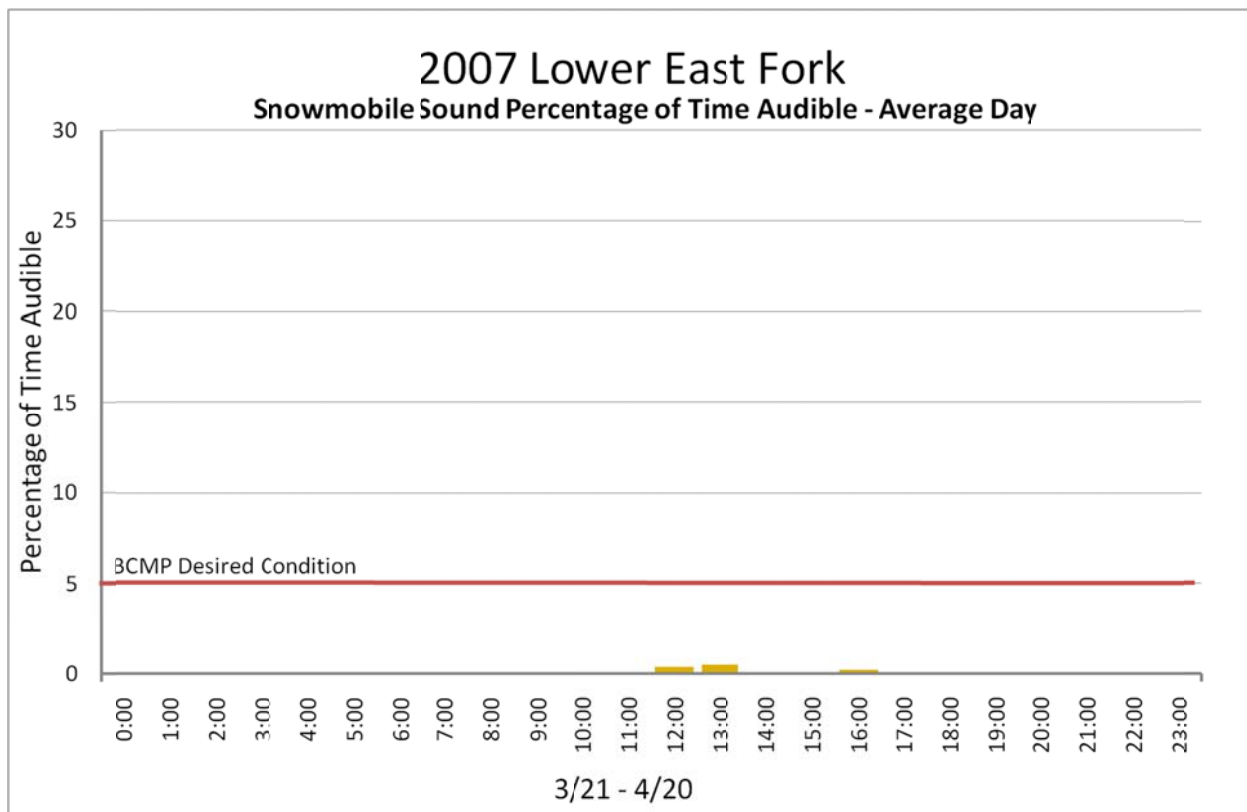
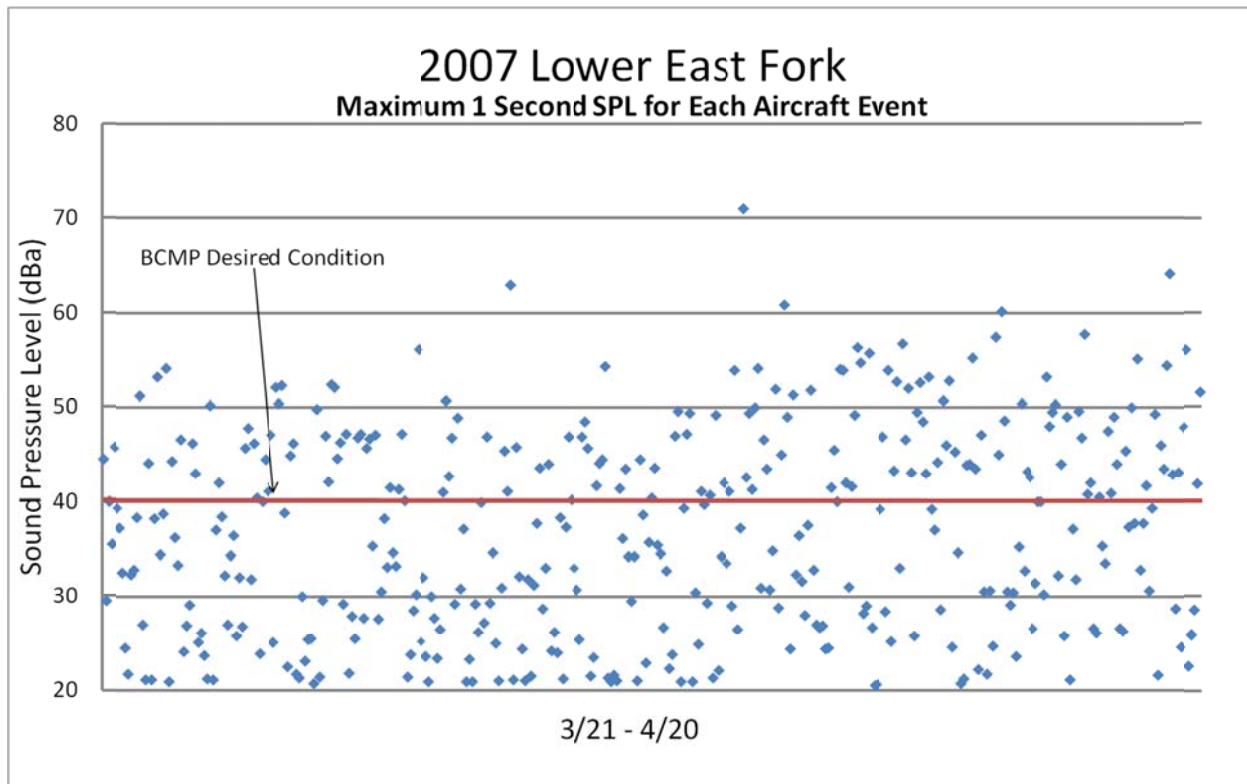
The most commonly heard natural sounds at this site were silence (audible 73% of the time) and wind (26%). Only 5 snowmobile events were detected over the month of April, amounting to an audibility of 0.5% of the time on average.

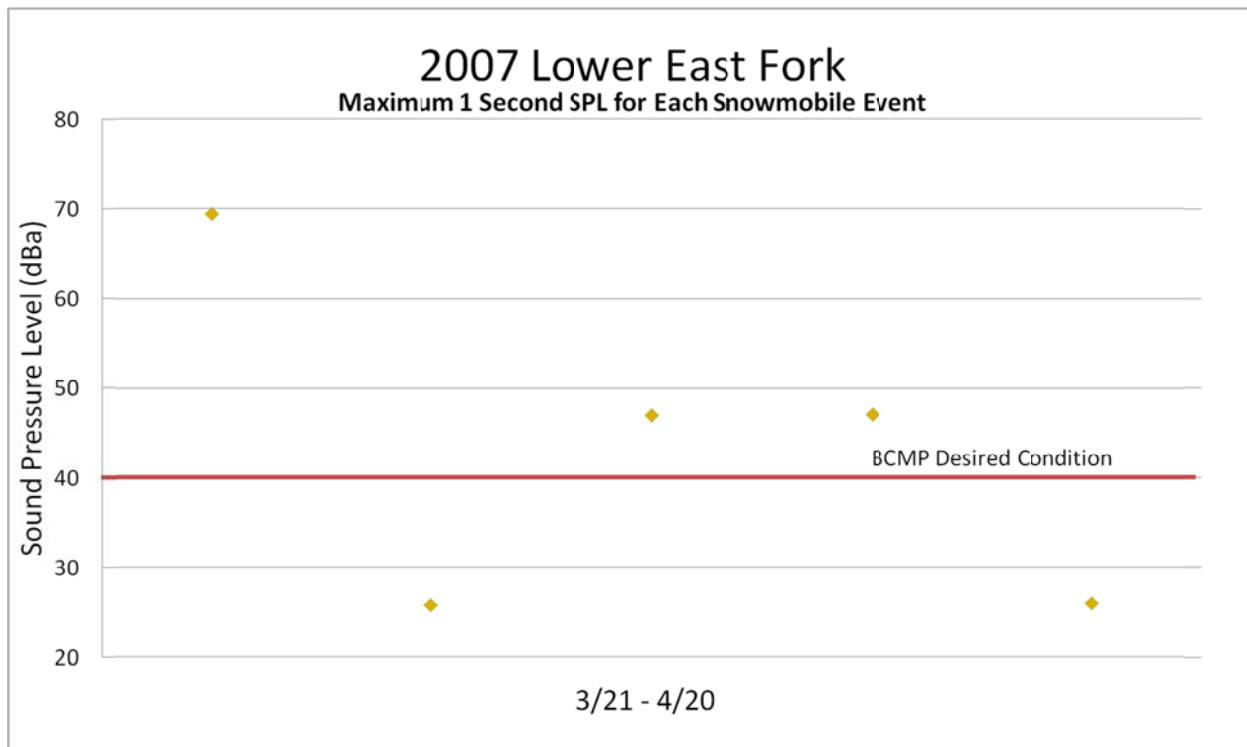
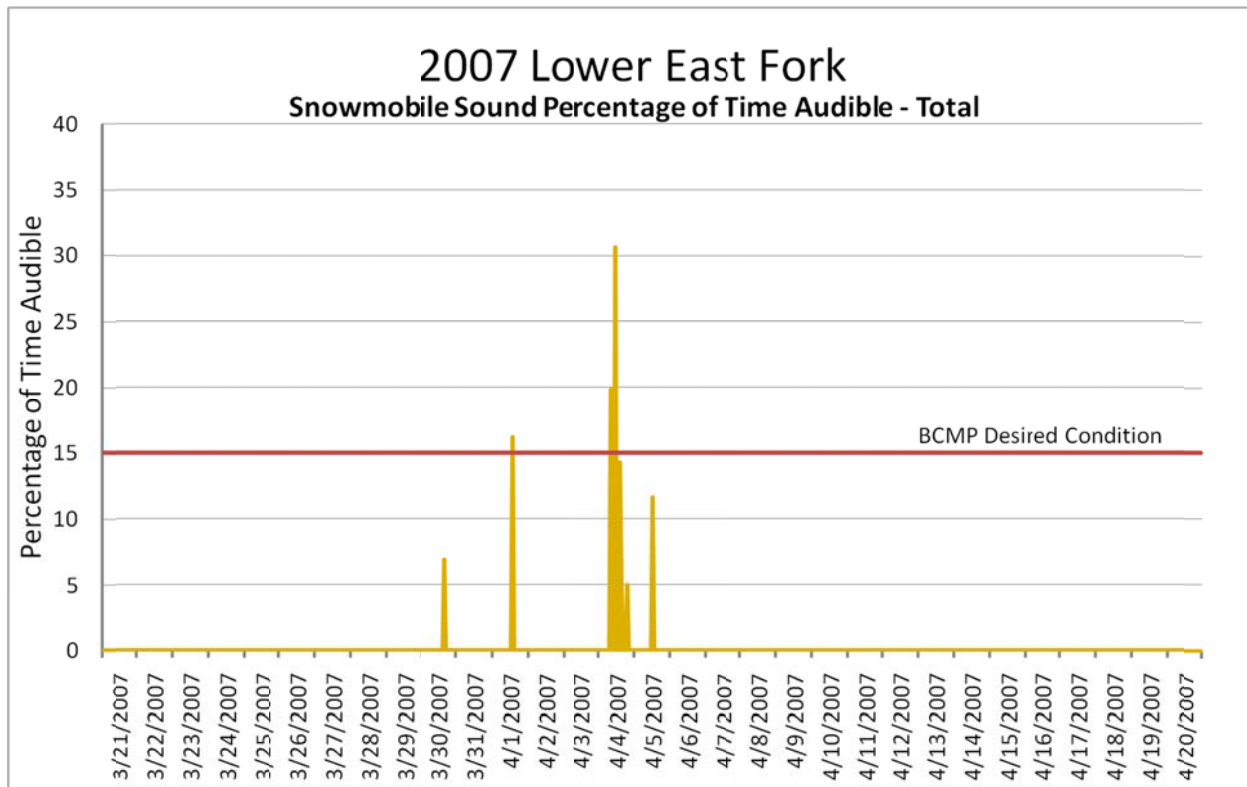




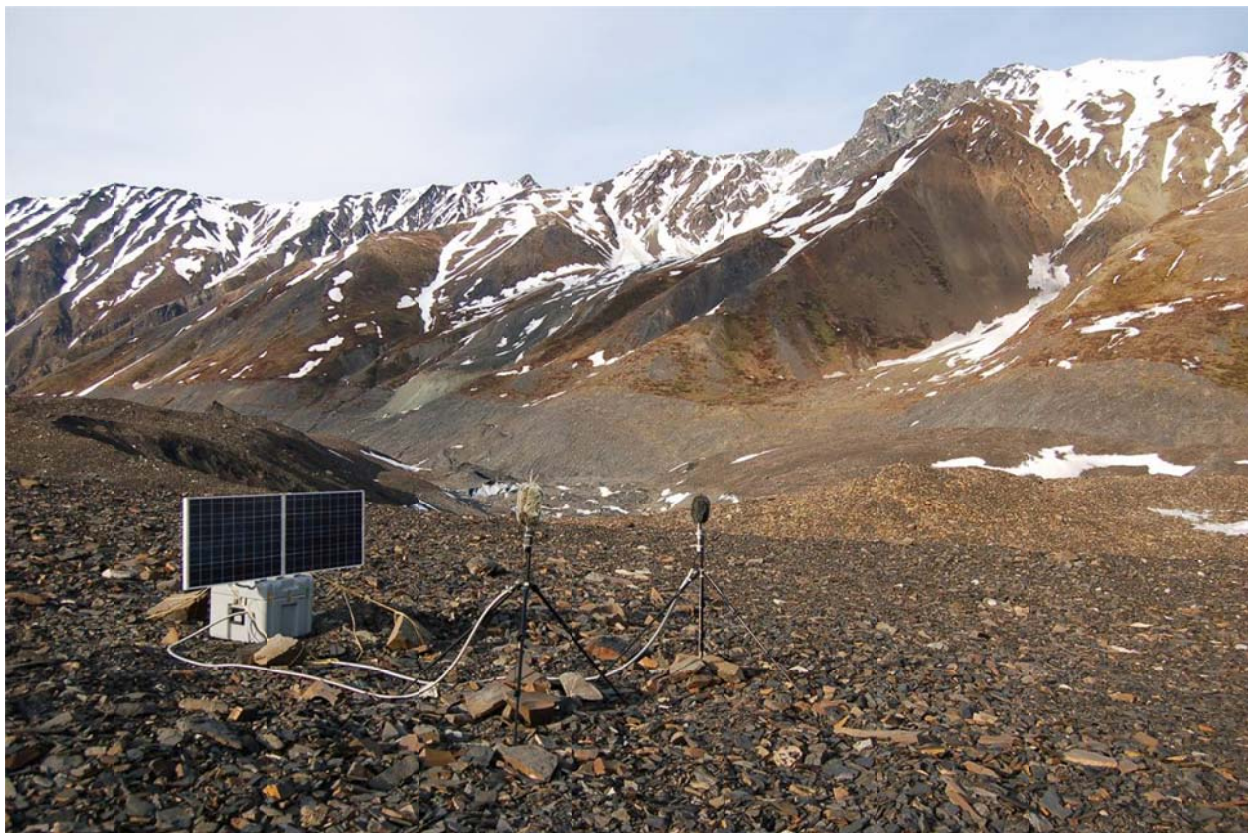
East







Lower Eldridge Glacier



Location Description: At the confluence of the Eldridge and an unnamed glacier ~2 Km West of the Park Boundary.

Purpose/Project: Location randomly chosen from the LTEM grid as part of the long-term Denali Soundscape inventorying and monitoring sampling plan.

Coordinates: Lat. 63.05045, Long. 150.07388 Elevation: 893 Meters

Time at Location: Jun-01 to Aug-01, 2007

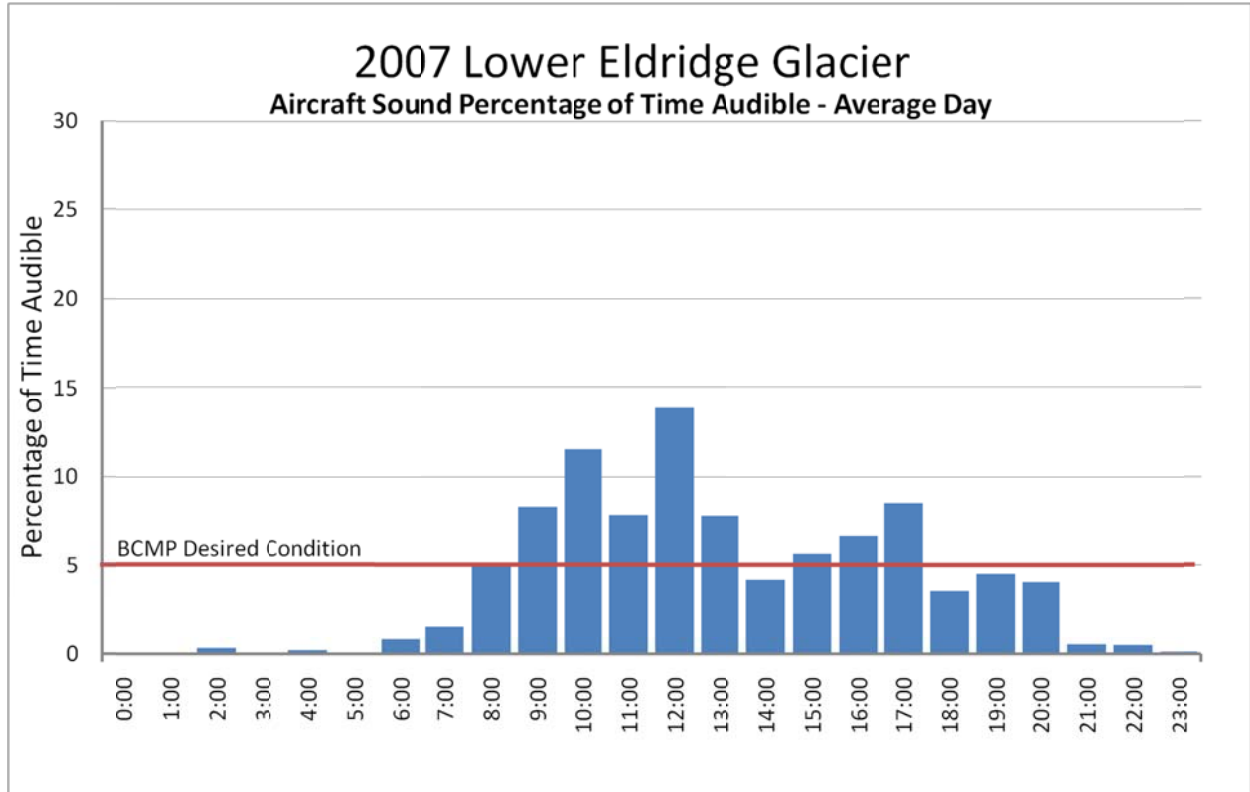
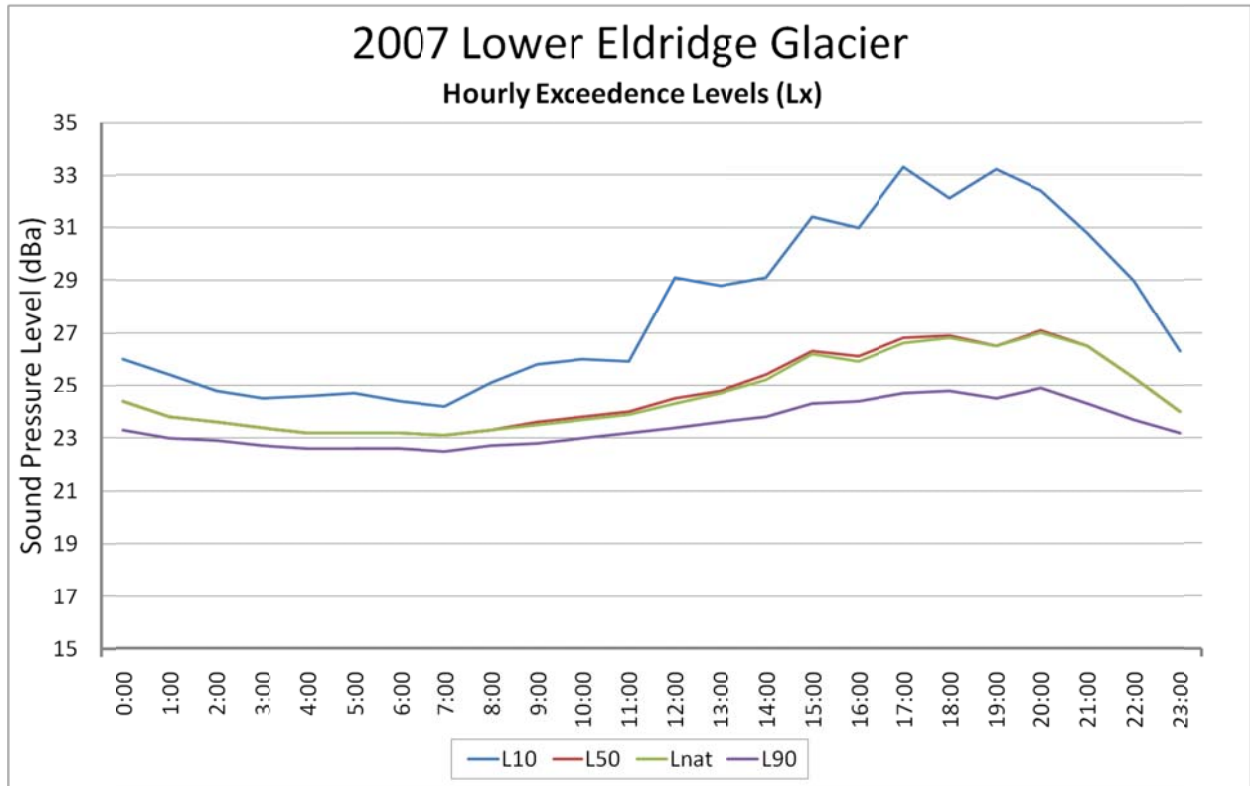
BCMP Management Zone: Medium Park Ecoregion: Nonvegetated Alpine Mountains

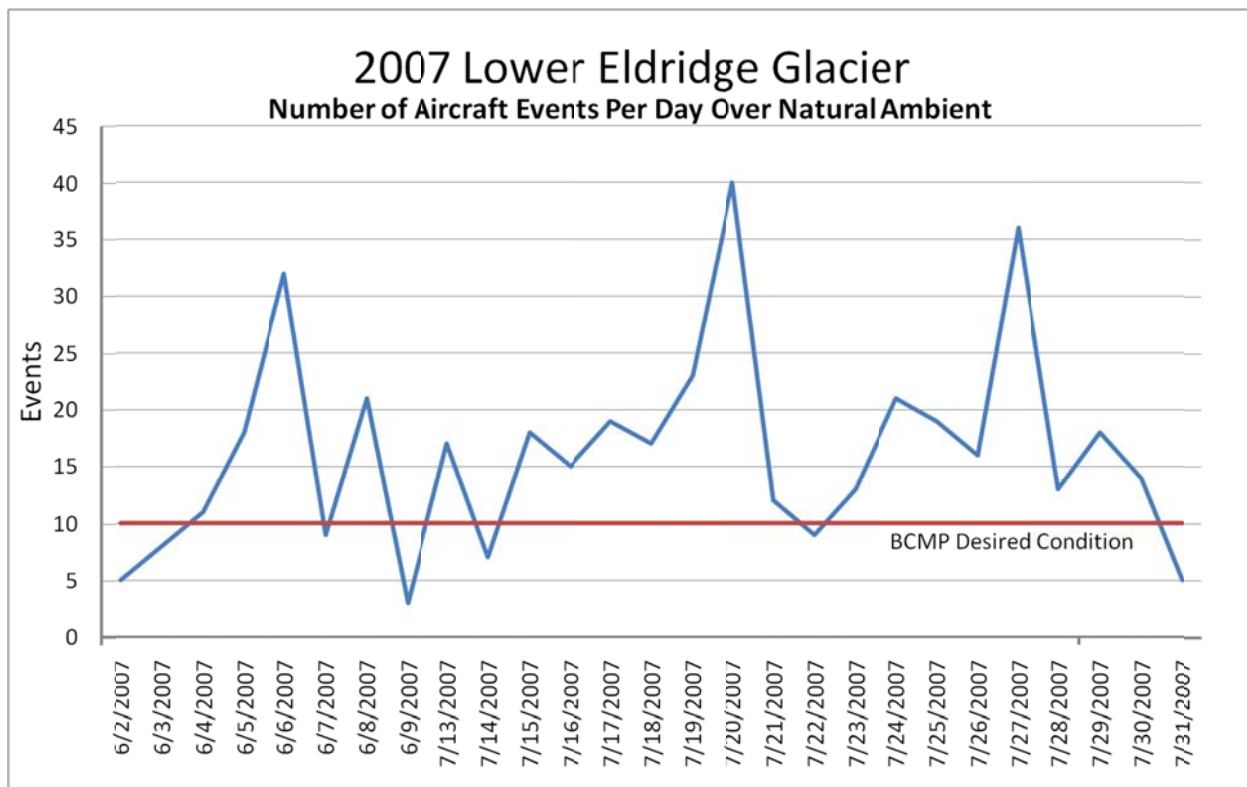
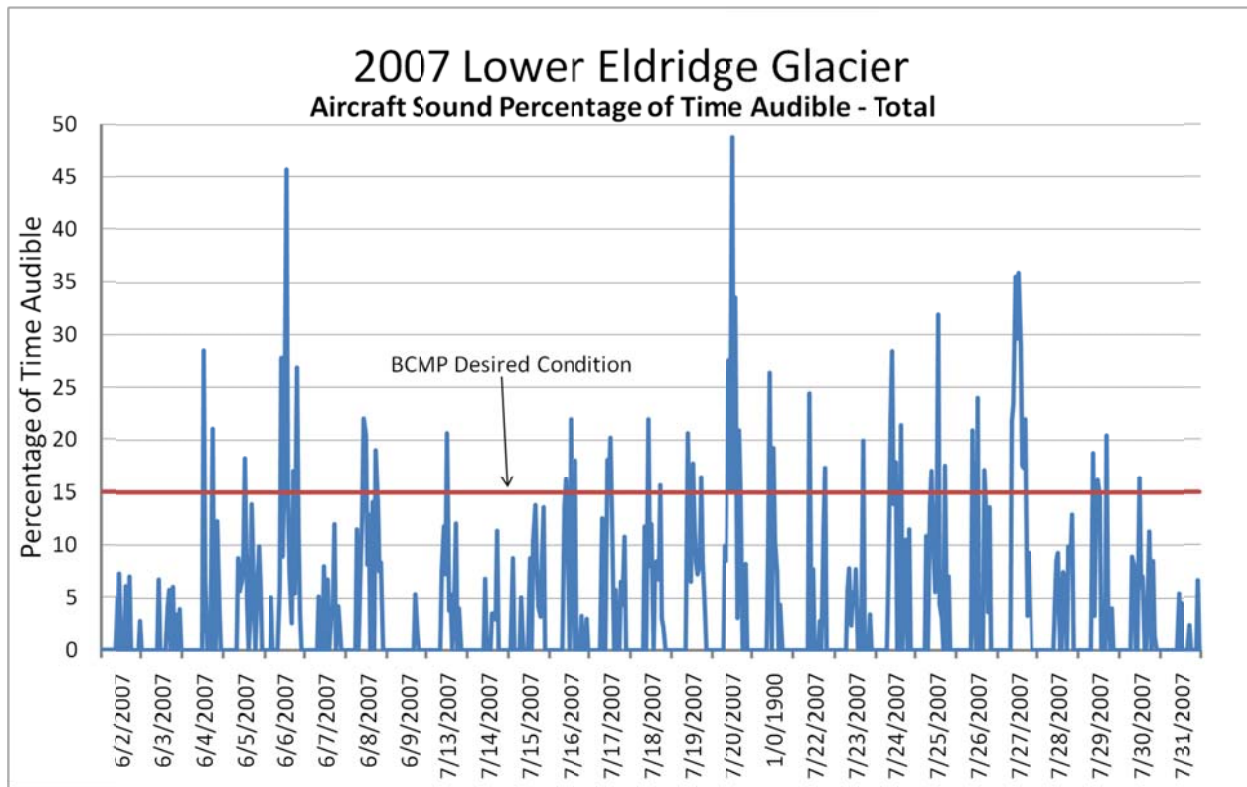
Access: Helicopter

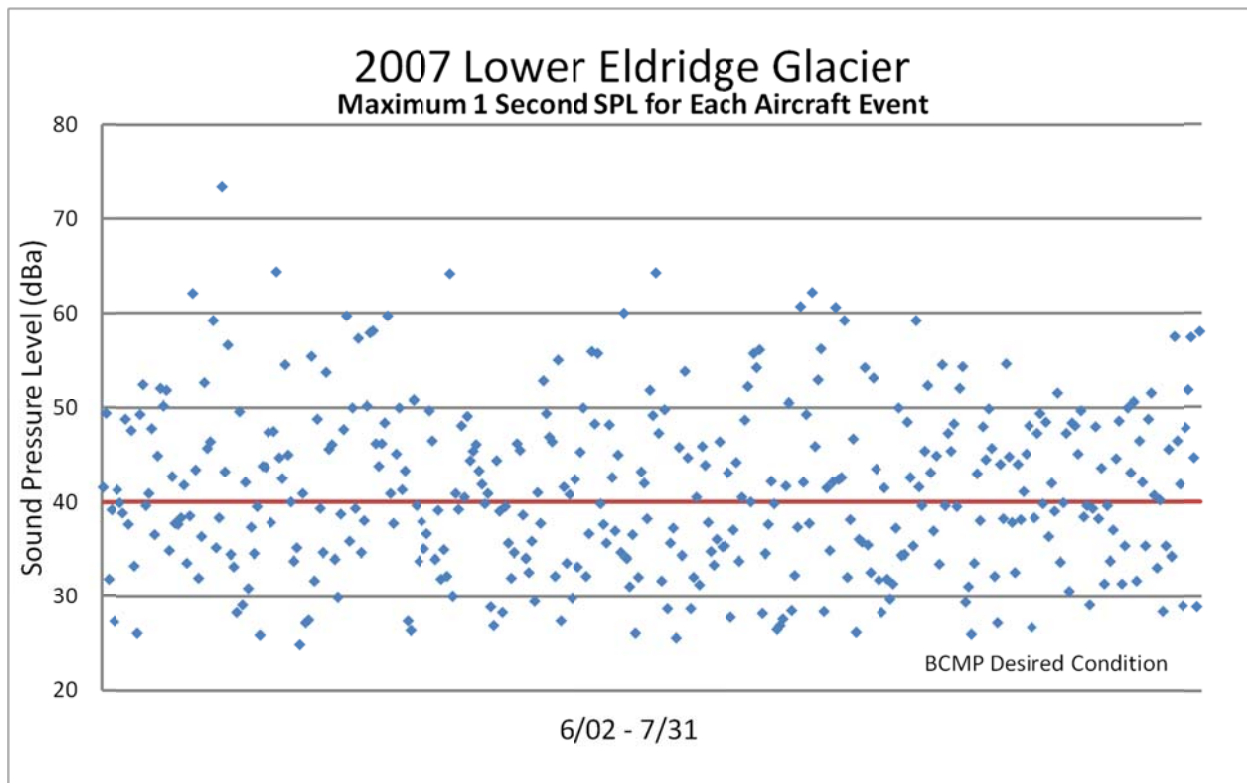
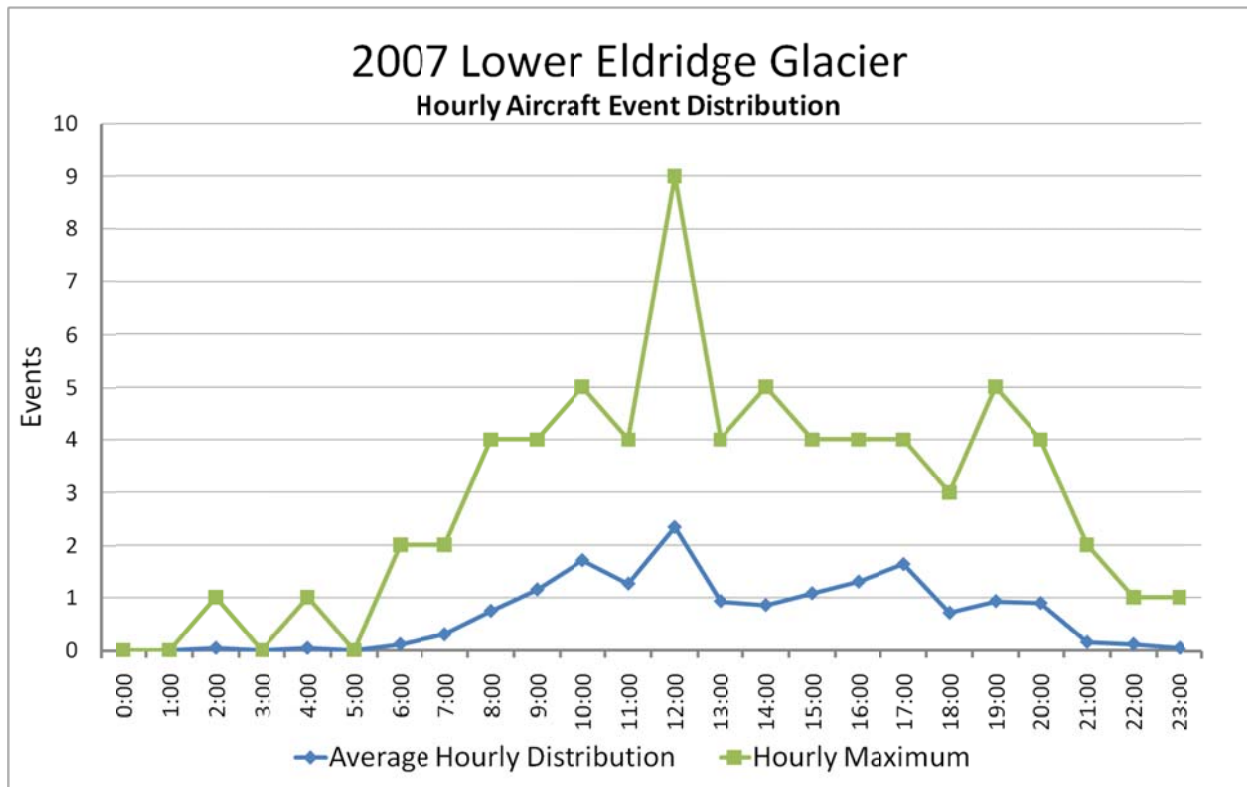
Summary: The purpose of the Lower Eldridge Glacier location was to collect data at one of the long-term ecological monitoring (LTEM) grid points, as outlined in the above sampling plan. LTEM grid point #76 was stratified as a New Park location and randomly selected from all locations requiring aircraft access.

Collection of audibility data at this site was not successful, so no audibility analysis is possible. However, SPL data was collected, so a visual analysis of human-caused noise and BCMP indicator analysis was performed.

Mechanized sound was audible 3.98% of the time on average. Conditions exceeded the BCMP percent audible standard 10% of the time, number of events per day 74% of the time, and maximum SPL 51% of the time.

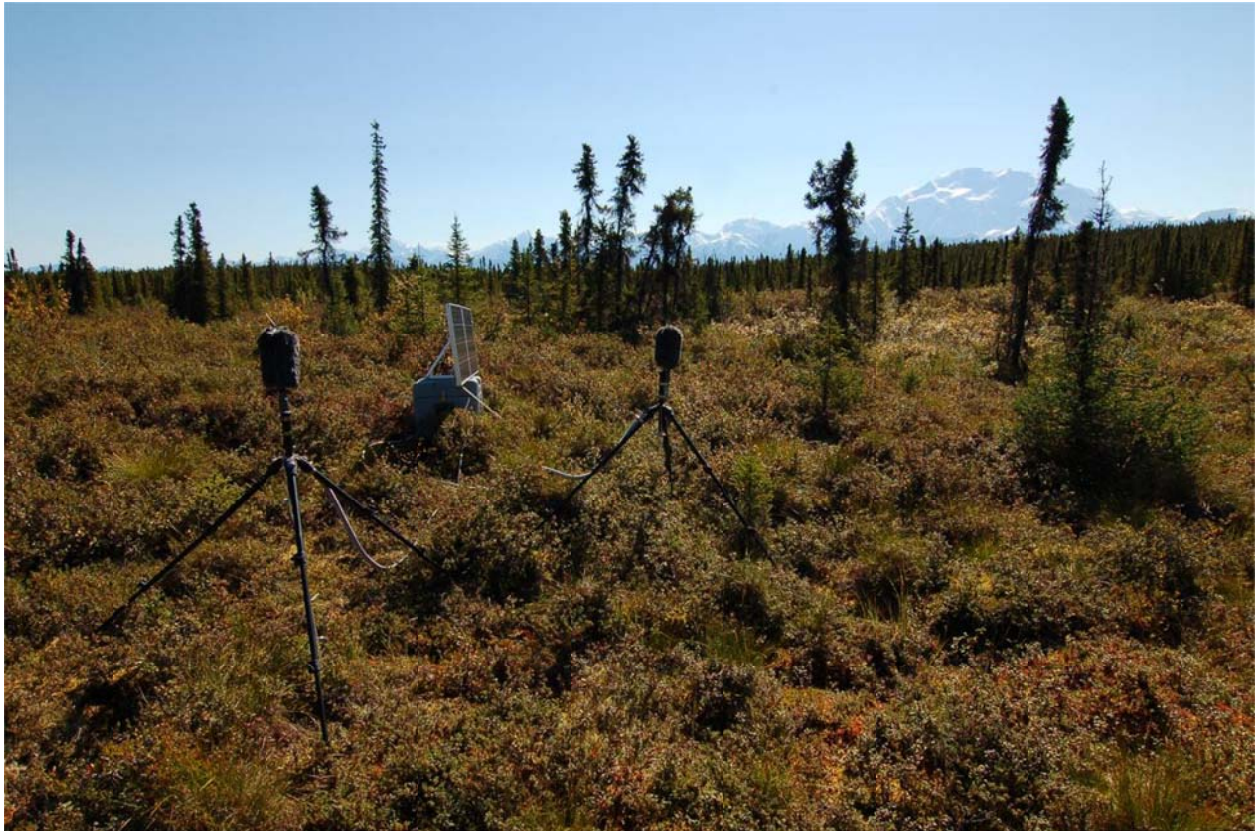






er.

McLeod Creek



Location Description: On McLeod Creek, just south of the Wilderness Boundary.

Purpose/Project: Location randomly chosen from the LTEM grid as part of the long-term Denali Soundscape inventorying and monitoring sampling plan.

Coordinates: Lat. 63.43005, Long. 151.23166 Elevation: 543 Meters

Time at Location: Jul-28 to Aug-17, 2007

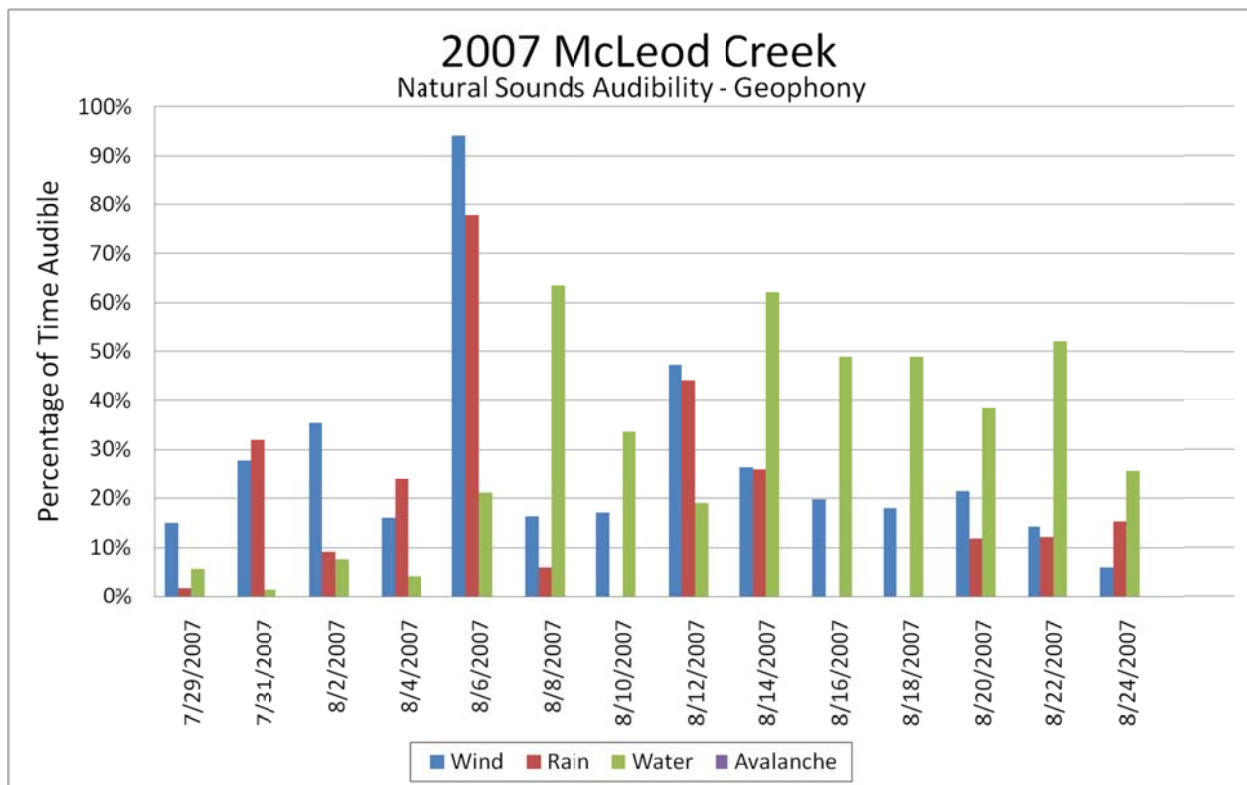
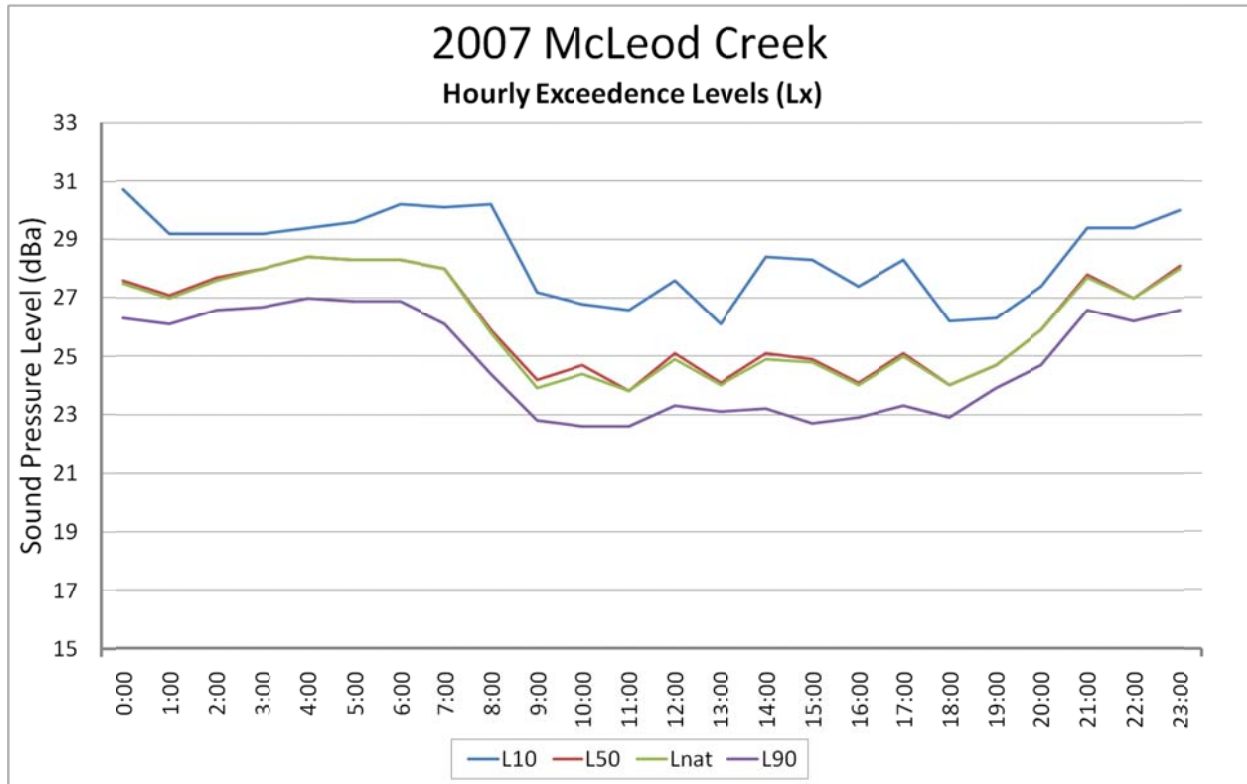
BCMP Management Zone: Low

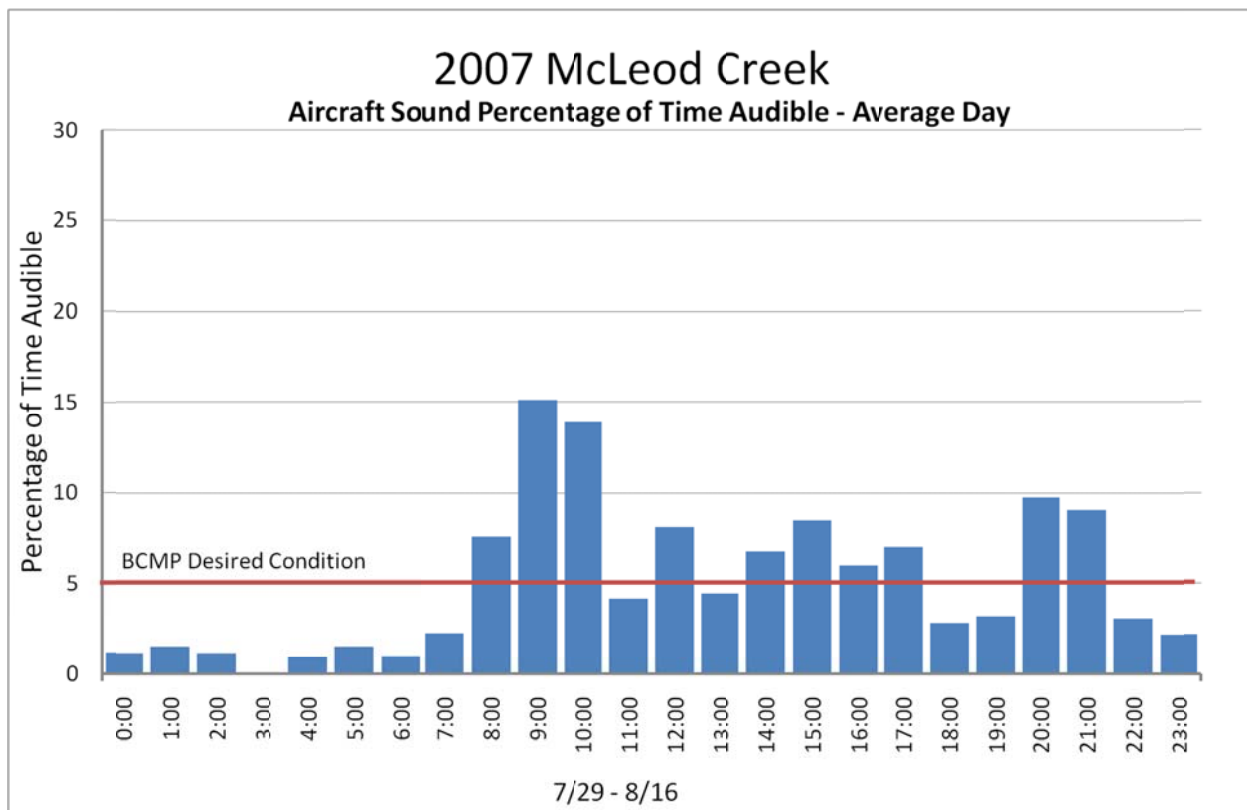
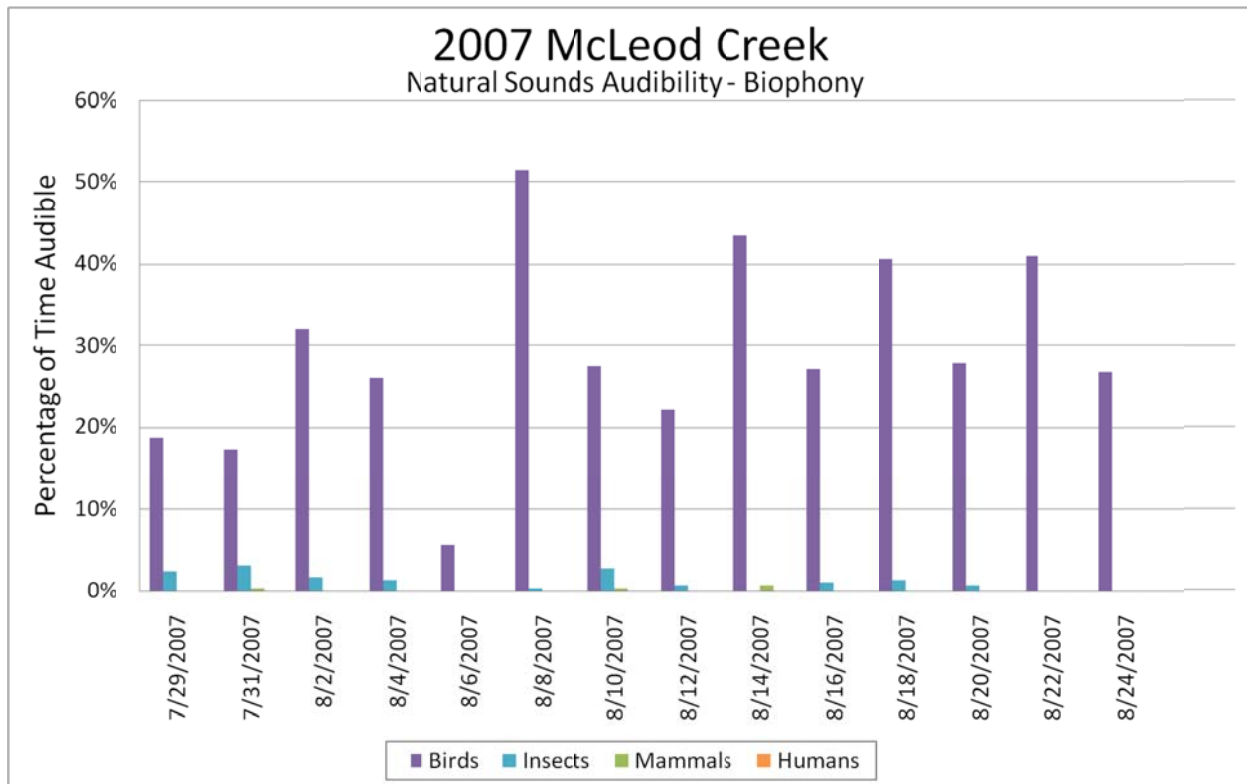
Park Ecoregion: Glaciated Uplands

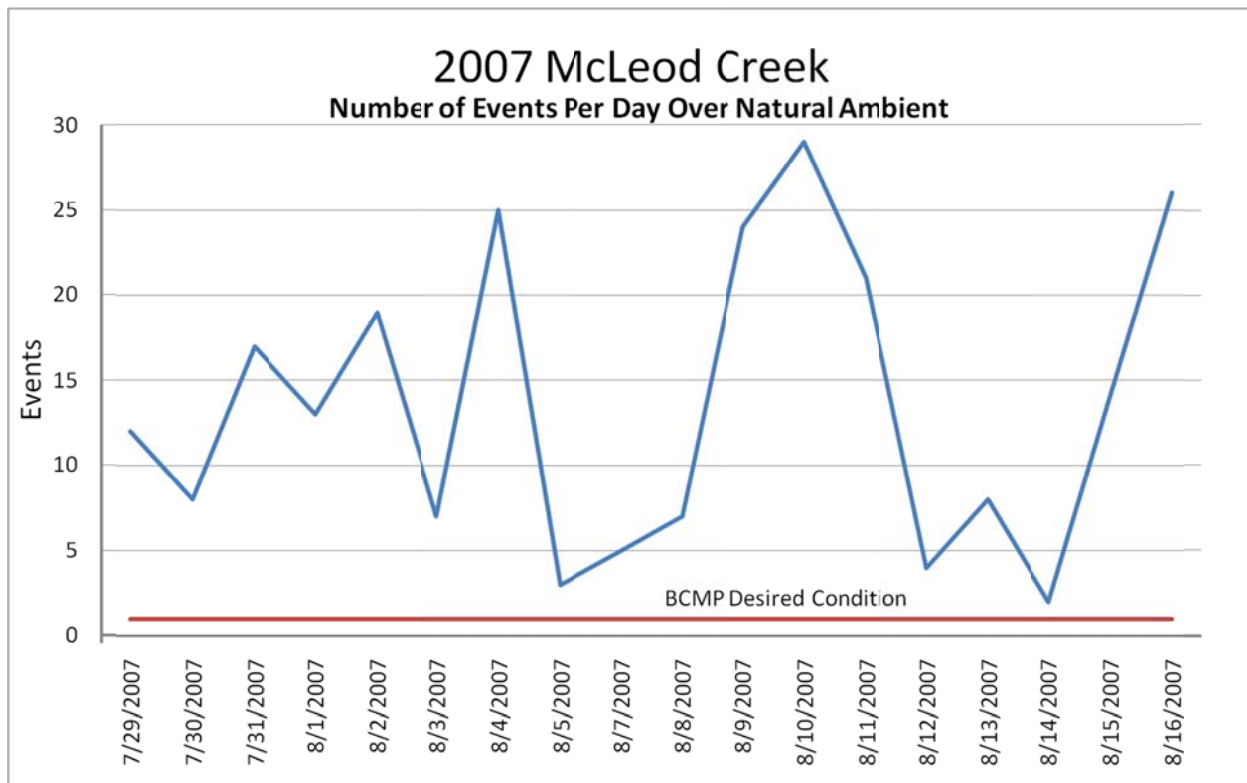
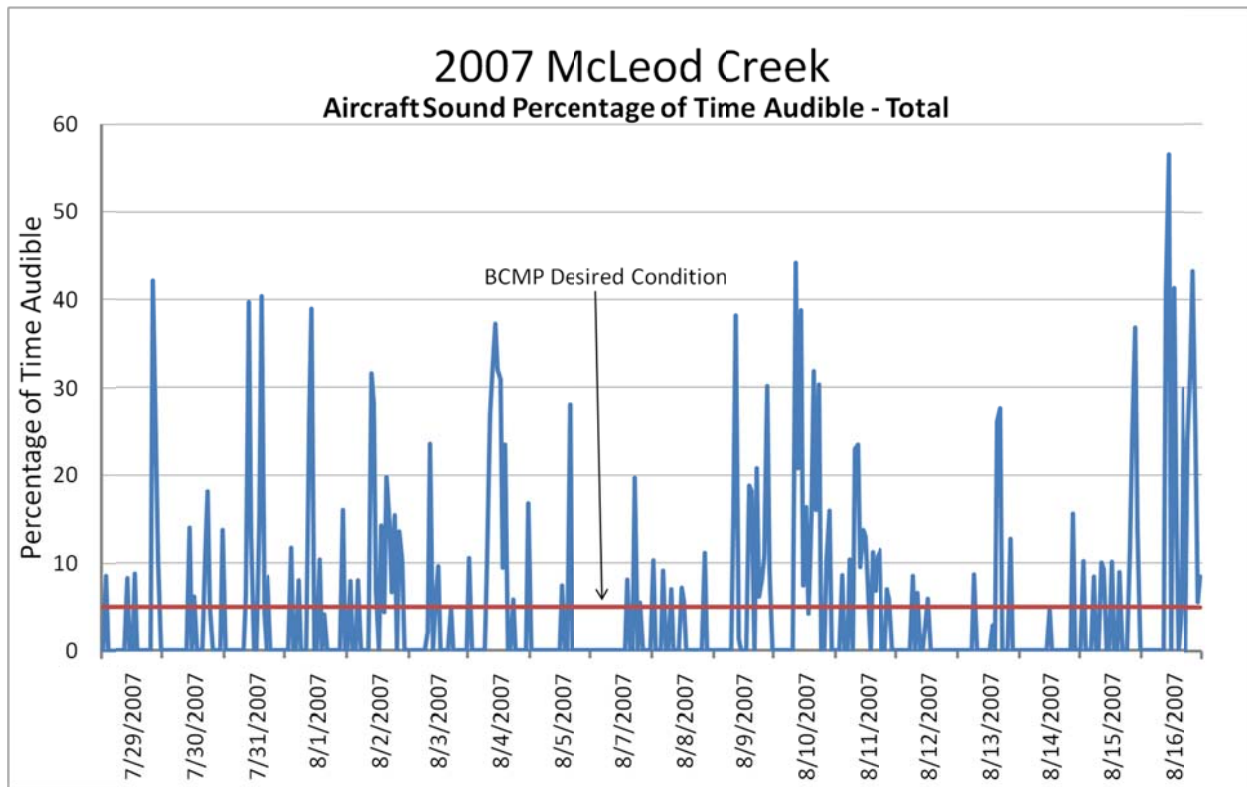
Access: Helicopter

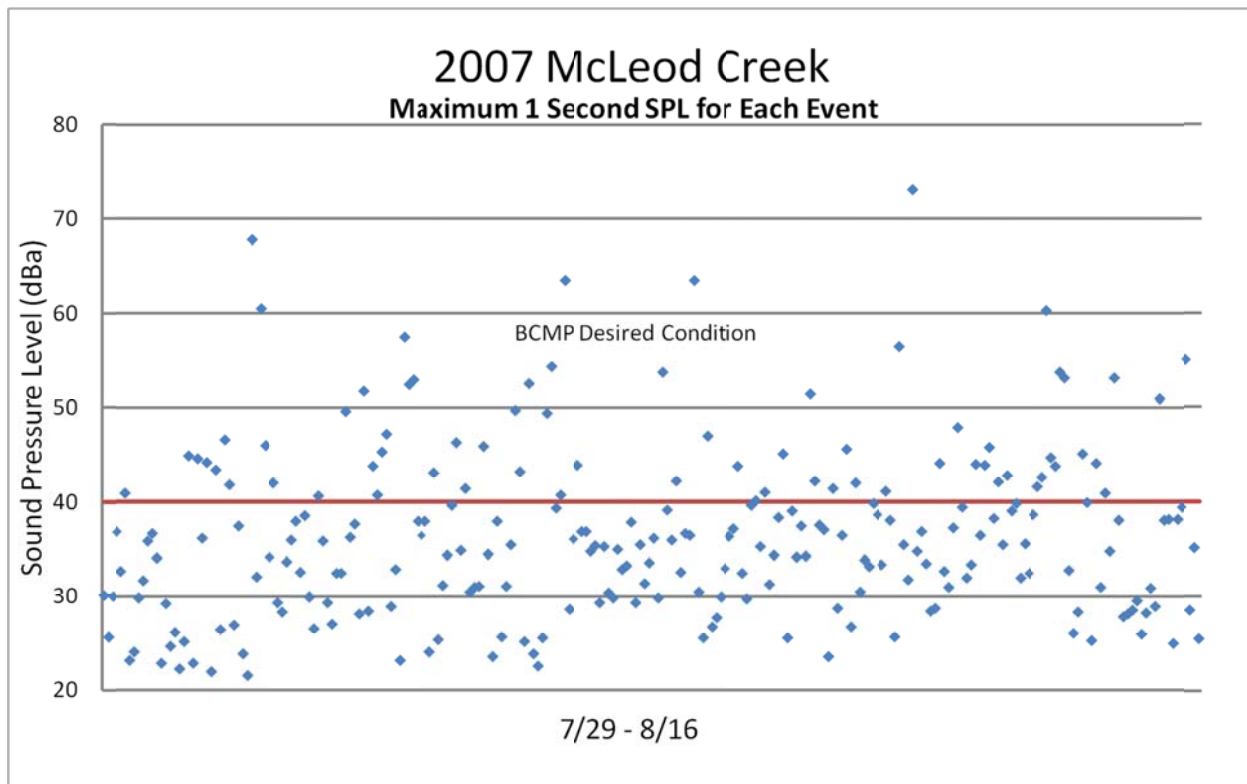
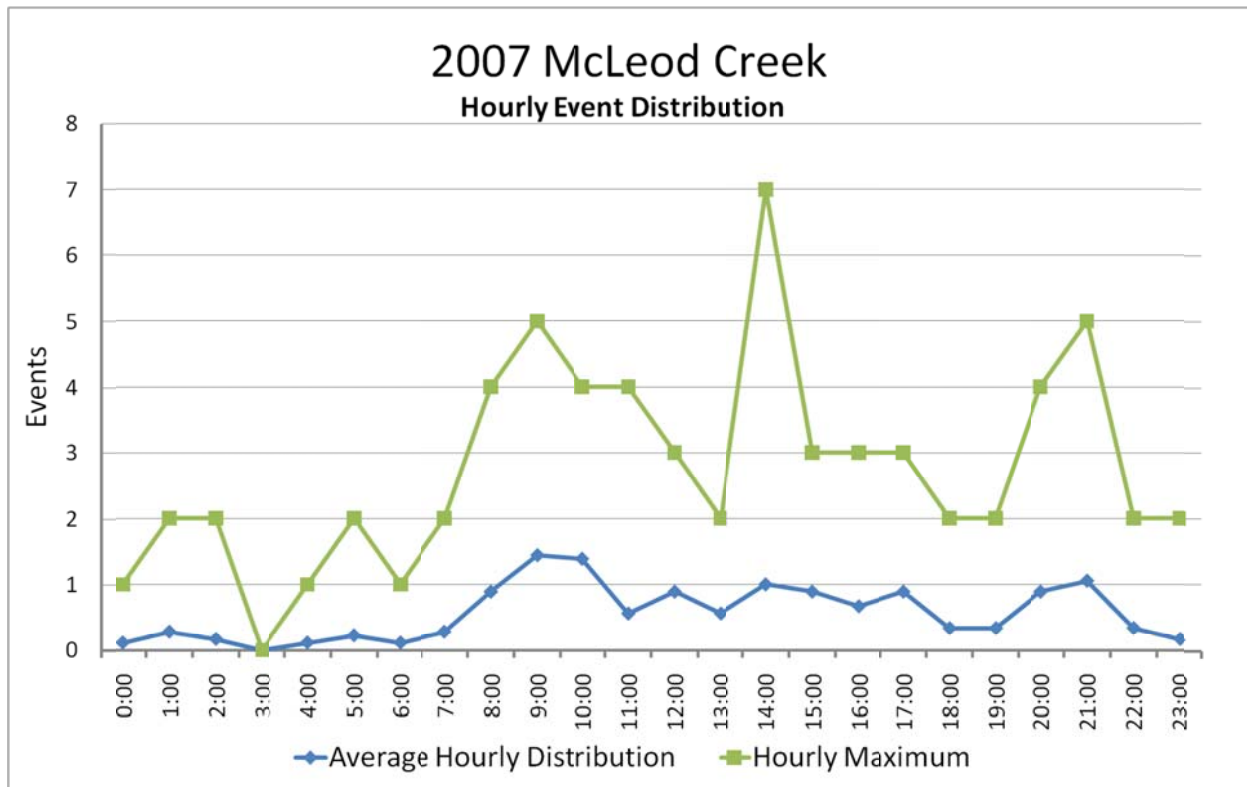
Summary: The purpose of the McLeod Creek location was to collect acoustic data at one of the long-term ecological monitoring (LTEM) grid points, as outlined in the above sampling plan. LTEM grid point #144 was stratified as an Old Park (designated Wilderness) location and randomly selected from all locations requiring aircraft access.

The most commonly heard sounds at this site were running water (audible 32% of the time), birds (29%), wind (27%), and rain (19%). Mechanized sound was audible 5.05% of the time on average. Conditions exceeded the BCMP percent audible standard 30% of the time, number of events per day 100% of the time, and maximum SPL 28% of the time.









Pica Glacier



Location Description: Pica Glacier at its confluence with the Kahiltna Glacier.

Purpose/Project: Location chosen at the request of park managers in order to inventory the current level of scenic and airtaxi traffic near the Pica Glacier landing area.

Coordinates: Lat. 62.73740, Long. 151.26781 Elevation: 1250 Meters

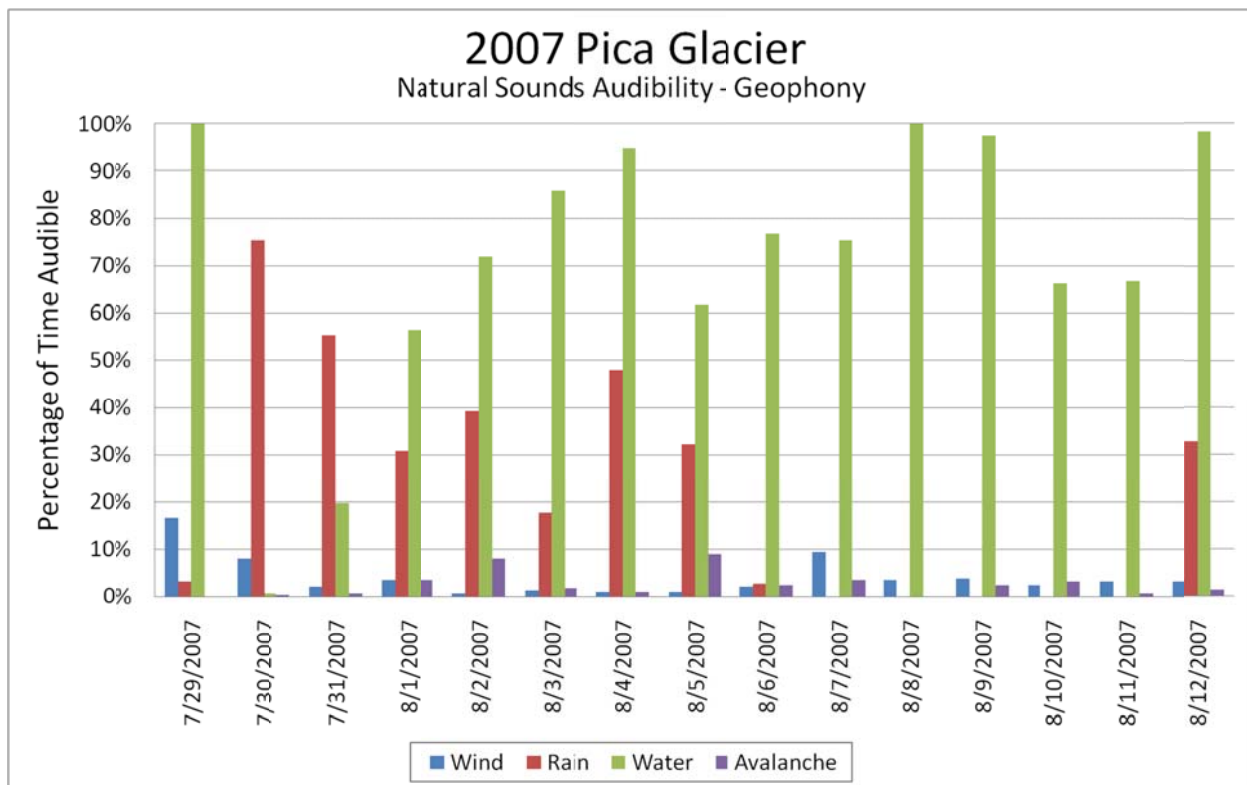
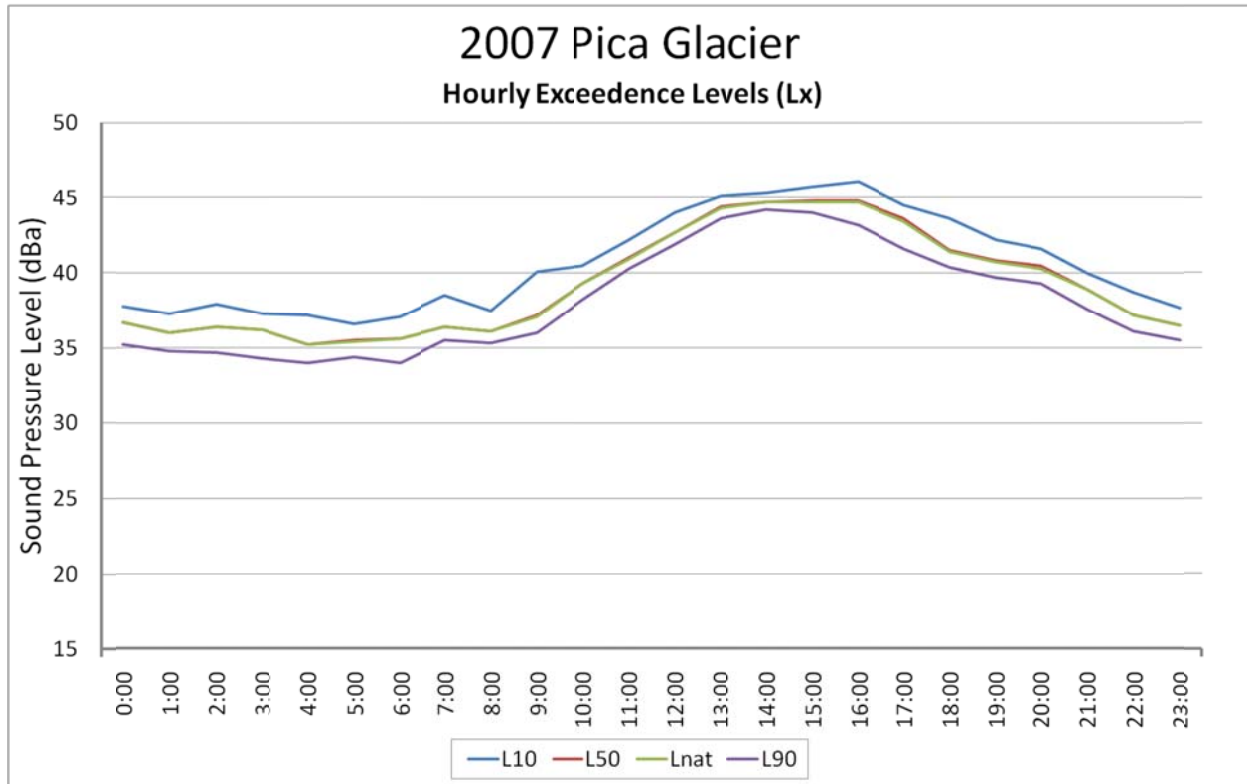
Time at Location: Jul-28 to Aug-14, 2007

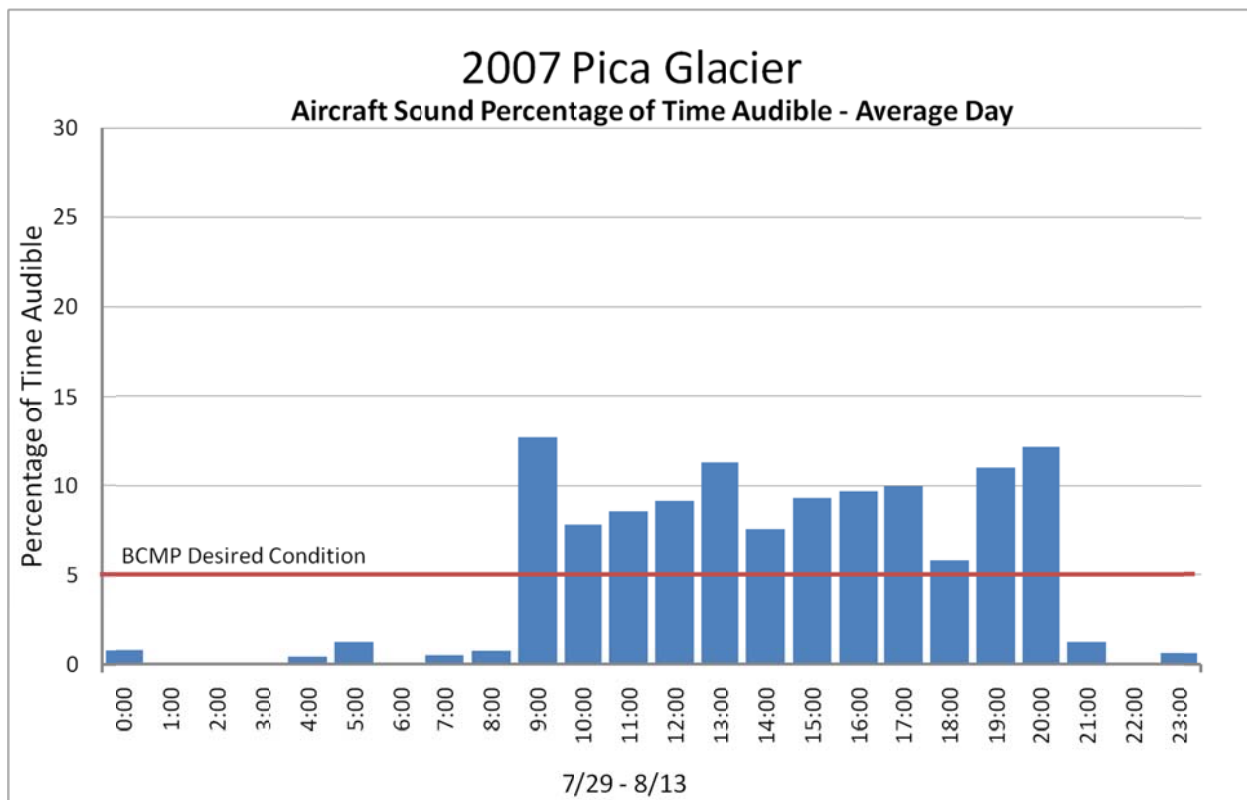
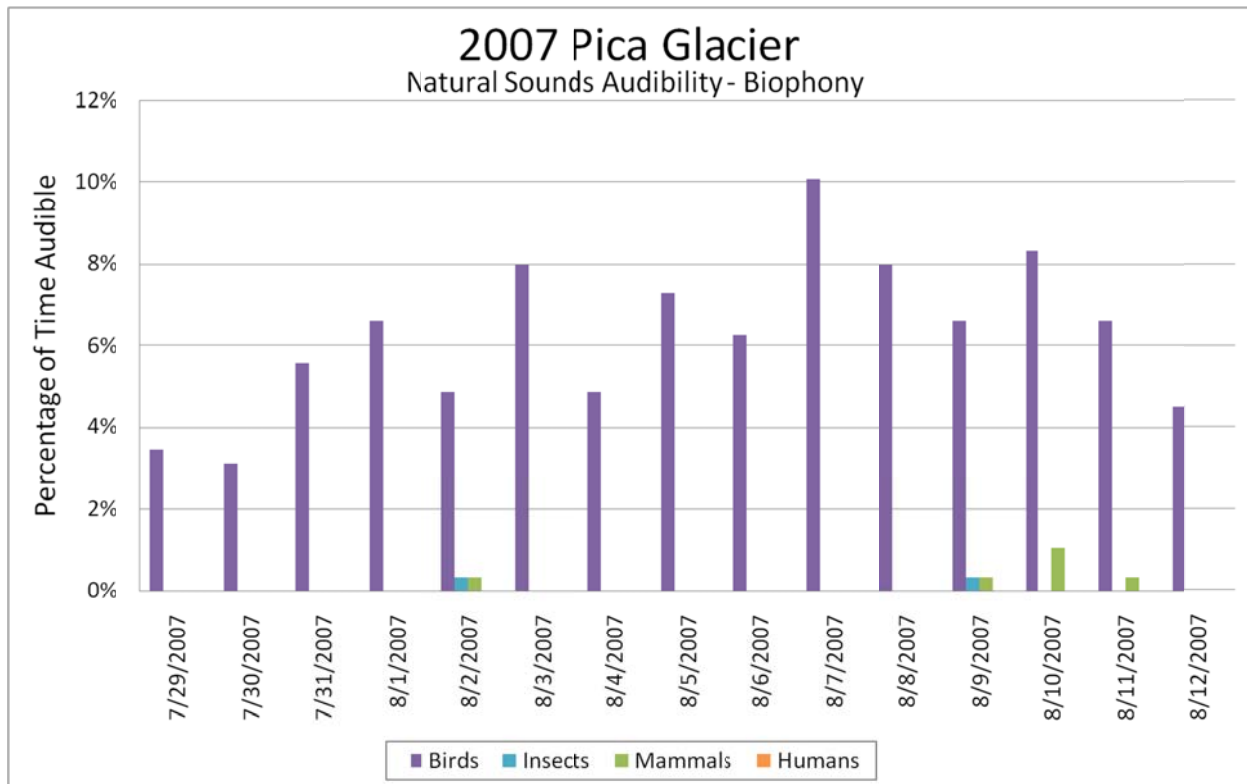
BCMP Management Zone: Medium Park Ecoregion: Nonvegetated Alpine Mountains

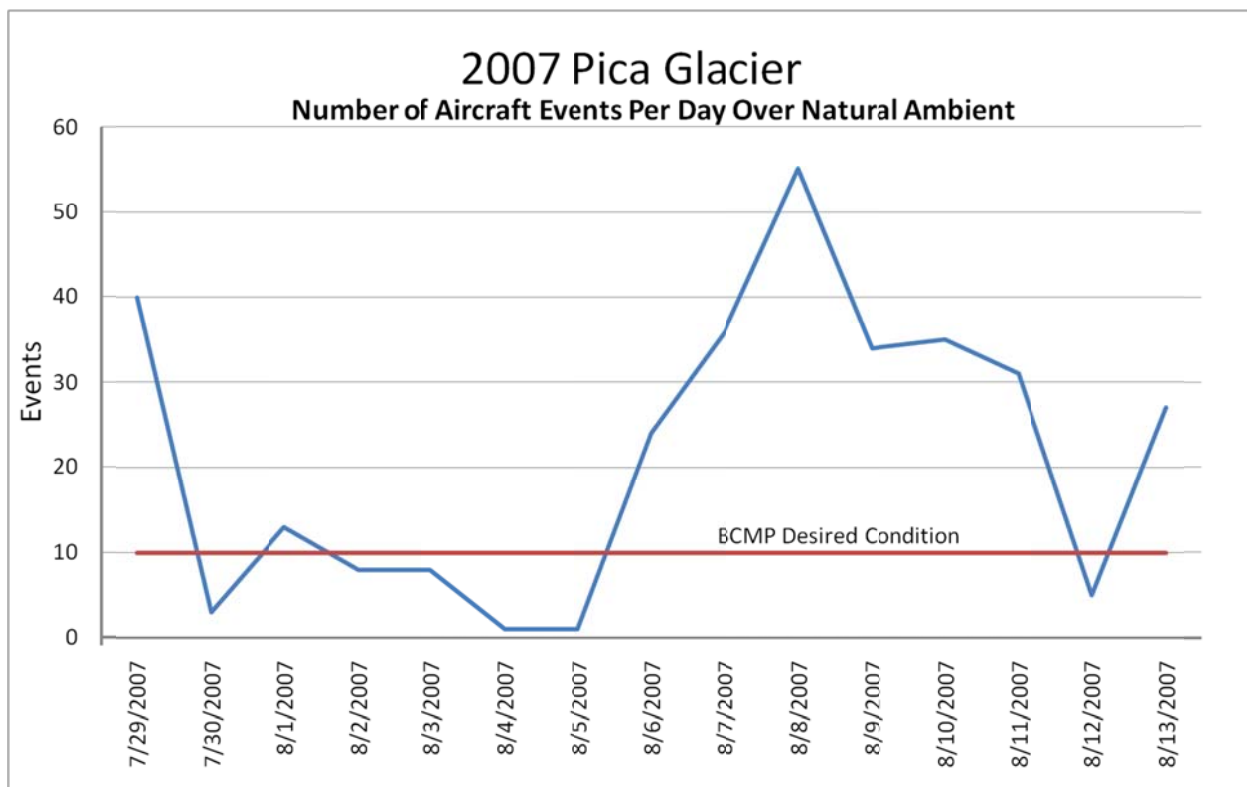
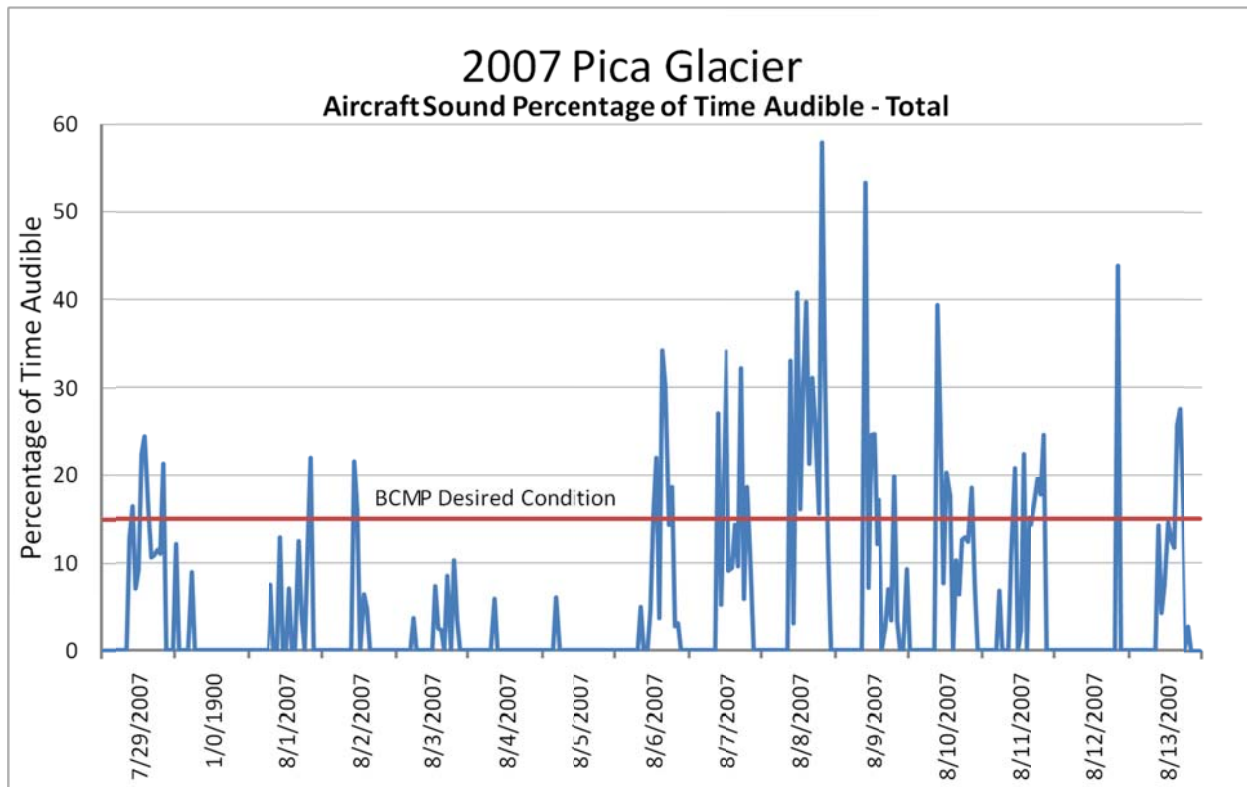
Access: Helicopter

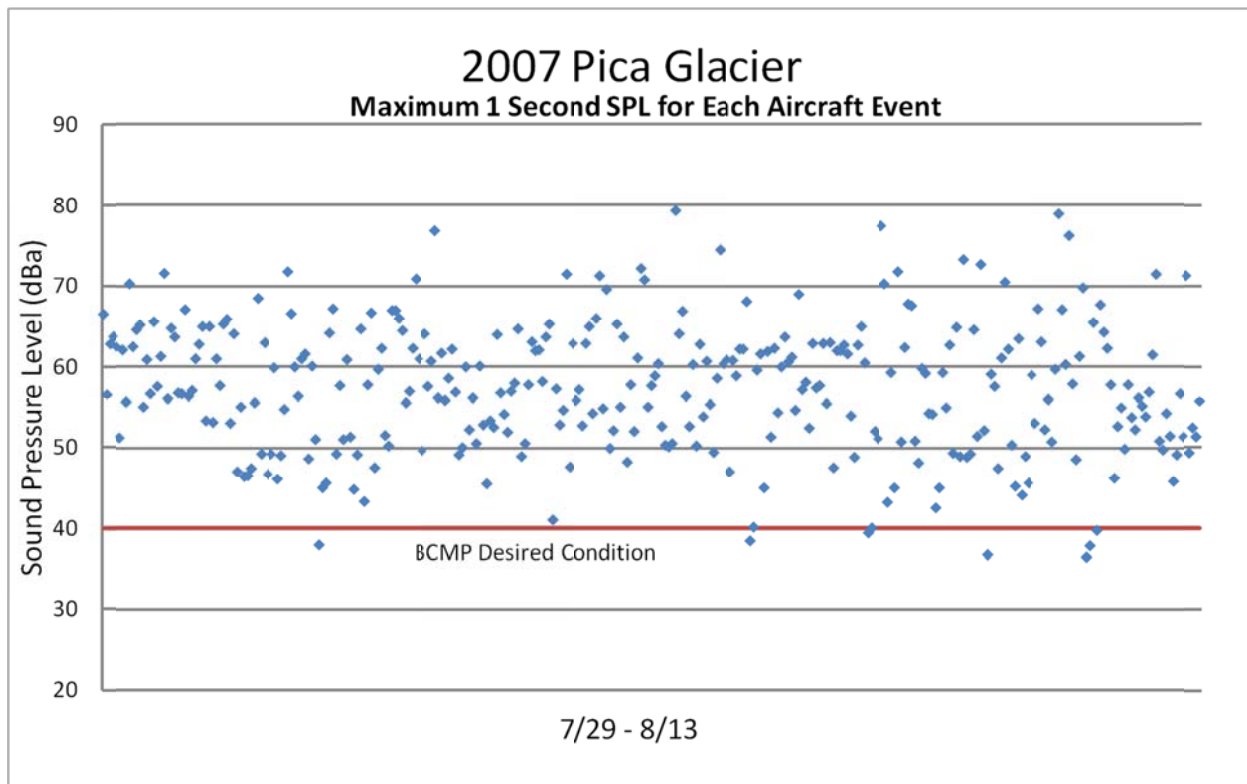
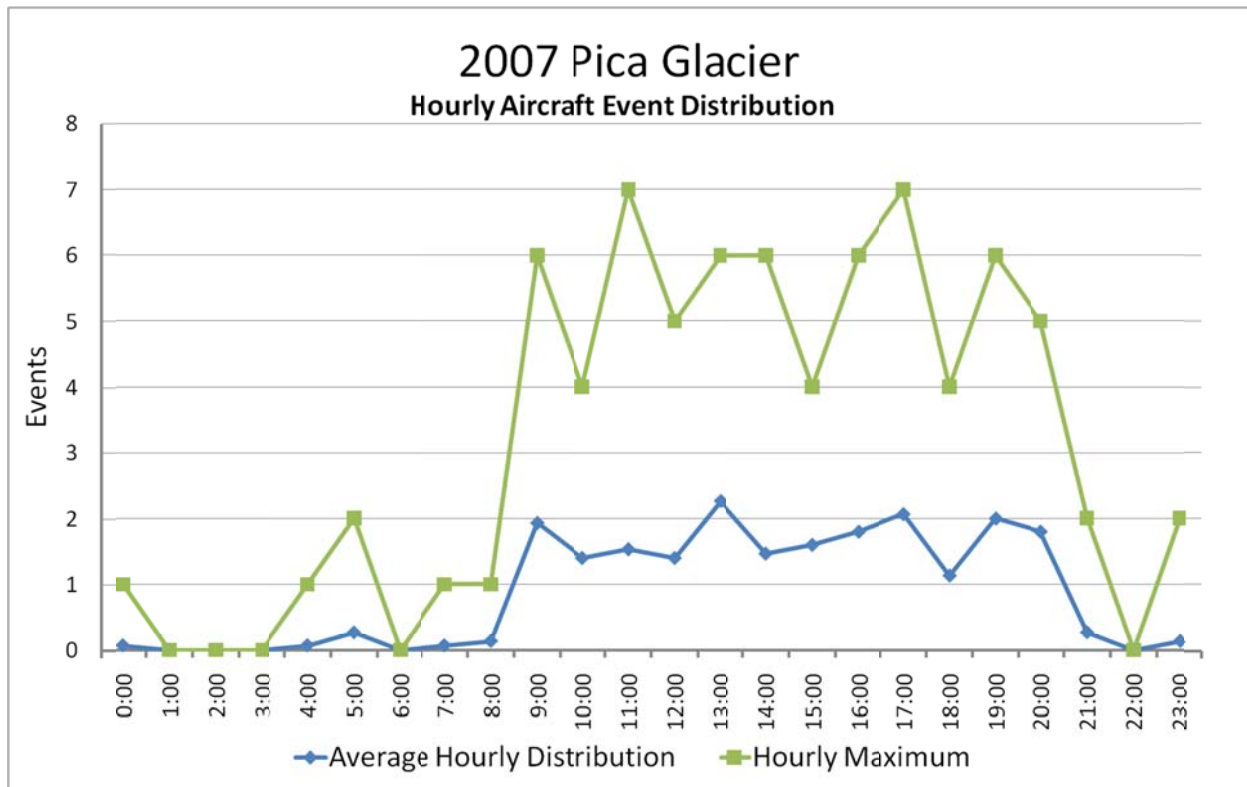
Summary: The purpose of the Pica Glacier (Little Switzerland) location was to collect acoustic data at this popular climbing and scenic glacier landing tour destination. Park managers were concerned at the possibility that mountaineers camped or climbing in the area may be experiencing high levels of aircraft noise exposure.

The most commonly heard sounds at this site were running water (audible 72% of the time), rain (23%), birds (6%), and wind (4%). Mechanized sound was audible 5.03% of the time on average. Conditions exceeded the BCMP percent audible standard 15% of the time, number of events per day 60% of the time, and maximum SPL 98% of the time.









Conclusion

The second year of the Denali Soundscape Inventory was intended to provide baseline natural sounds and current overflight data at an additional ten sites in Denali. It builds on previous work conducted 2001-2006, which collected similar data at other locations.

The acoustic monitoring systems collected detailed records of ambient sound pressure levels. The existing ambient (L_{50}) level is the median sound level, and is the composite of all sounds at a site, both human-caused and natural. Most locations sampled experienced relatively low ambient sound levels, averaging an L_{50} of less than 30dBA. Exceptions were the Cathedral Mountain site, which was located on a high canyon bluff exposed to persistent wind, and measured 39.4dBA on average. Also, the Pica Glacier site measured 39.7dBA on average due to the sound of water flowing over the surface of the glacier near to the measurement equipment. All sites exhibited some level of exceedence of the BCMP standards as shown in Table 4. These findings have been added to the parkwide BCMP compliance maps which can be found in Appendix B.

Table 4. Percentage of samples exceeding BCMP sound standards.

Site Name	Hourly Motorized Noise Audibility	Motorized Noise Events/Day	Motorized Max SPL (dBA)
Bear Creek	19	95	28
Blind Creek ¹	*	*	*
Cathedral Mountain	32	100	91
Chitsia Creek	2	10	47
Hidden River	18	83	28
Kahiltna Pass	37	92	89
Lower East Fork Toklat ¹	*	*	*
Lower Eldridge Glacier	10	74	51
McLeod Creek	30	100	28
Pica Glacier	15	60	98

¹ winter season site

* Due to large seasonal variability in aircraft activity, BCMP exceedances for winter monitoring sites are not comparable to summer, and therefore are not computed.

As it stands today, Denali has one of the most extensive acoustical monitoring datasets in the National Park system. The data included in this report may be used to inform a Soundscape Management Plan, General Management Plan, Resource Stewardship Strategy, Natural Resource Conditions Assessment, other park plans, or NEPA documents that include soundscapes.

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Appendix A. Glossary of Acoustic Terms

Acoustical Environment

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

Amplitude

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

Audibility

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

dBA

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

Decibel (dB)

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

Extrinsic Sound

Any sound not forming an essential part of the park unit, or a sound originating from outside the park boundary.

Frequency

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

Hearing Range (frequency)

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

Hertz (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.

Human-Caused Sound

Any sound that is attributable to a human source.

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.

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

A metric used to describe acoustic data. It represents the level of sound exceeded x percent of the time during the given measurement period. Thus, L_{50} is the level exceeded 50% of the time (it is also referred to as existing ambient).

 L_{nat}

An estimate of what the acoustical environment might sound like without the contribution of extrinsic (anthropogenic) sounds.

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.

Sound

Variations in local pressure that propagate through a medium (e.g. the atmosphere) in space and time.

Soundscape

Human perception of the acoustical environment.

Sound Pressure

The difference between instantaneous pressure and local barometric pressure. Measured in Pascals (Pa), Newtons per square meter, which is the metric equivalent of pounds per square inch.

Sound Pressure Level (SPL)

A calibrated measure of sound level, expressed in decibels, and referred to an atmospheric standard of 20 micro Pascals.

Time Audible

The amount of time that a sound source is audible to a human with normal hearing.

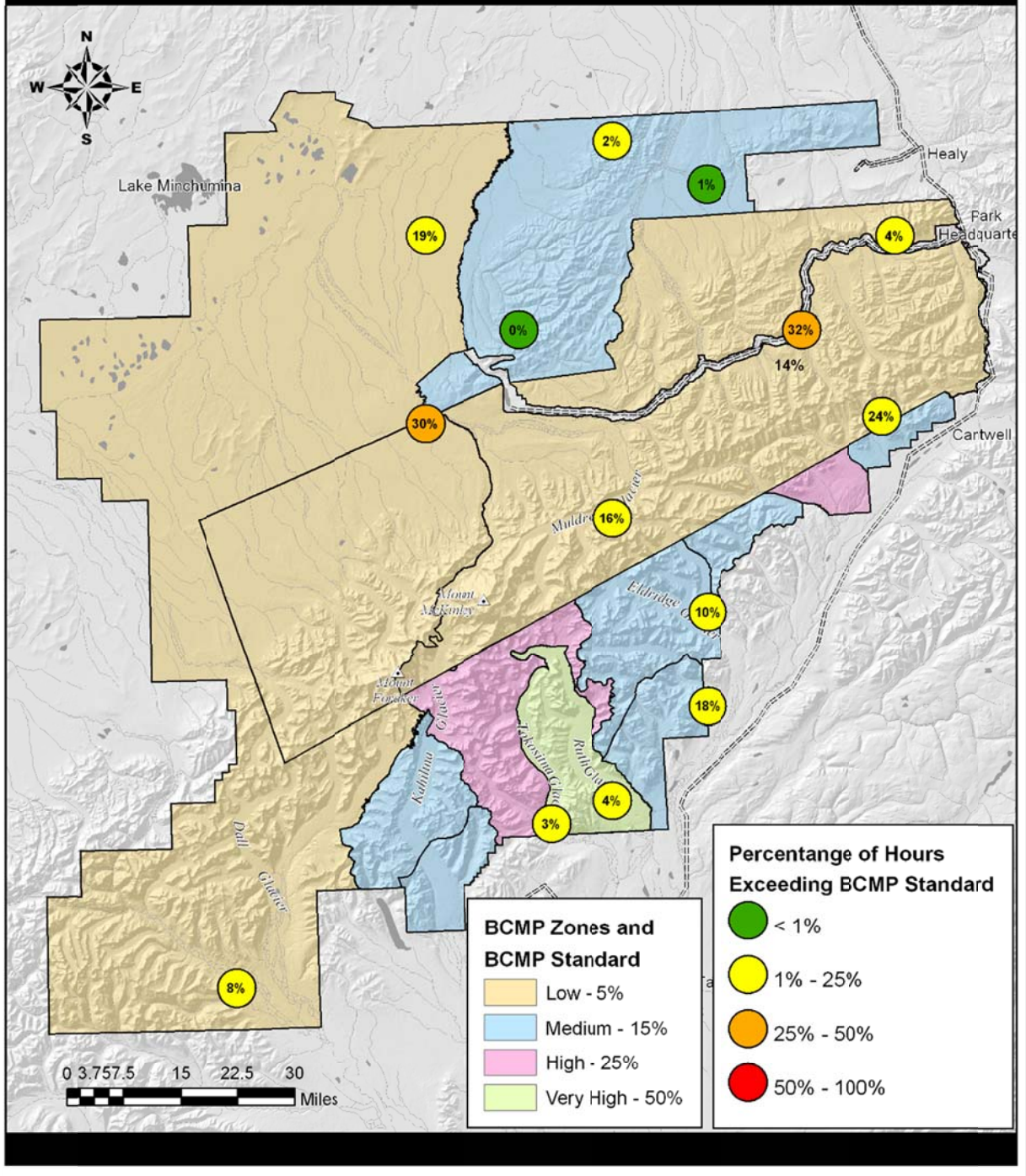
Appendix B. BCMP Exceedence Maps

The following three maps are compiled to provide a parkwide look at the acoustic measurements made to date, and indicate the current level compliance with BCMP acoustic standards. There is one map for each BCMP standard, and each sampling point is annotated with the percentage of time that standard was exceeded during the measurement period. Data from previous years is from Hults 2005 and Withers and Hults 2006.

Denali National Park Soundscape Monitoring 2005-2007

BCMP Standard #1: Portion of Any Hour Which Motorized Noise is Audible

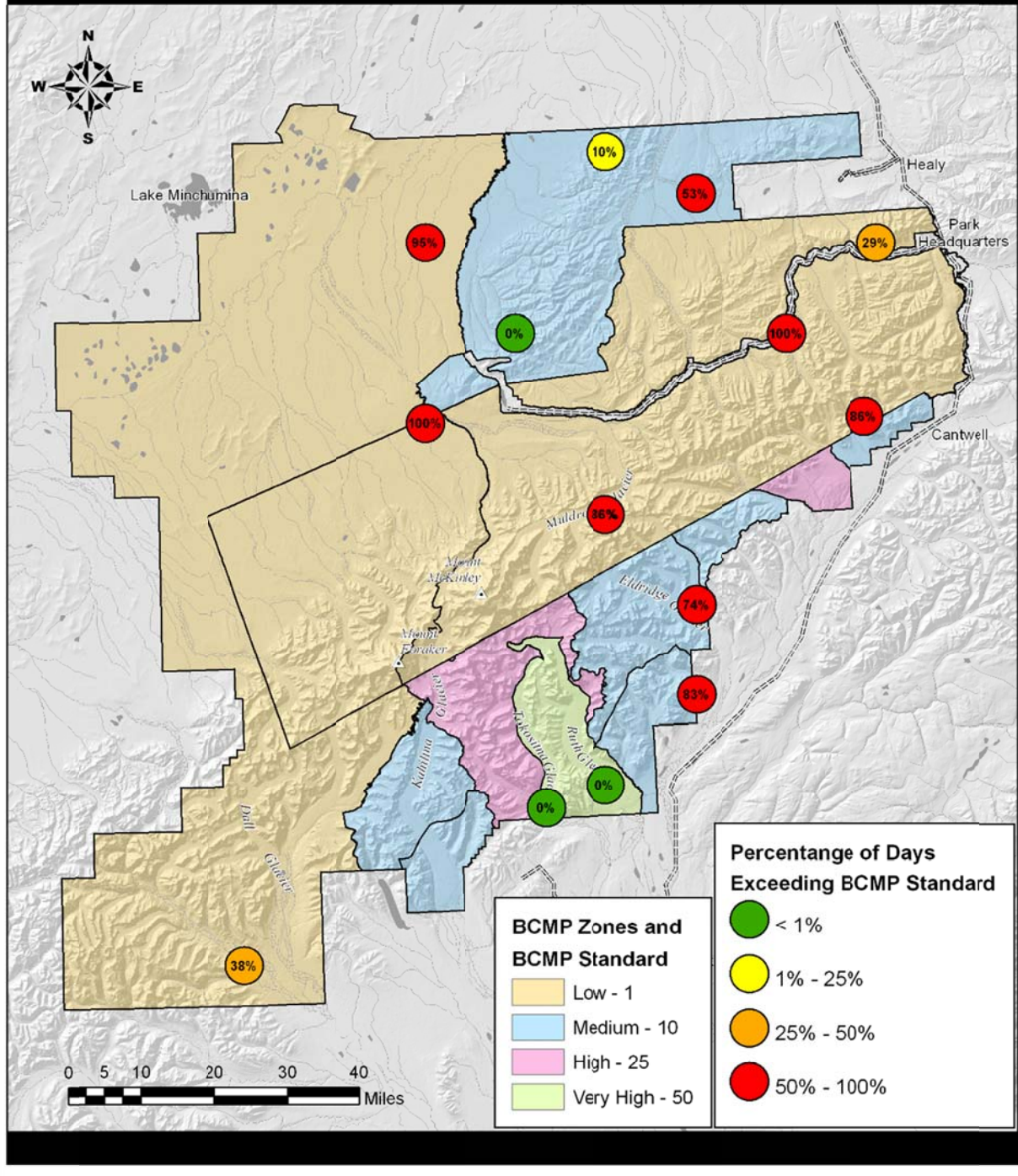
Percentage of Sampled Hours Exceeding Standard (Aircraft Only)



Denali National Park Soundscape Monitoring 2005-2007

BCMP Standard #2: Number of Motorized Events Per Day Greater than Natural Ambient

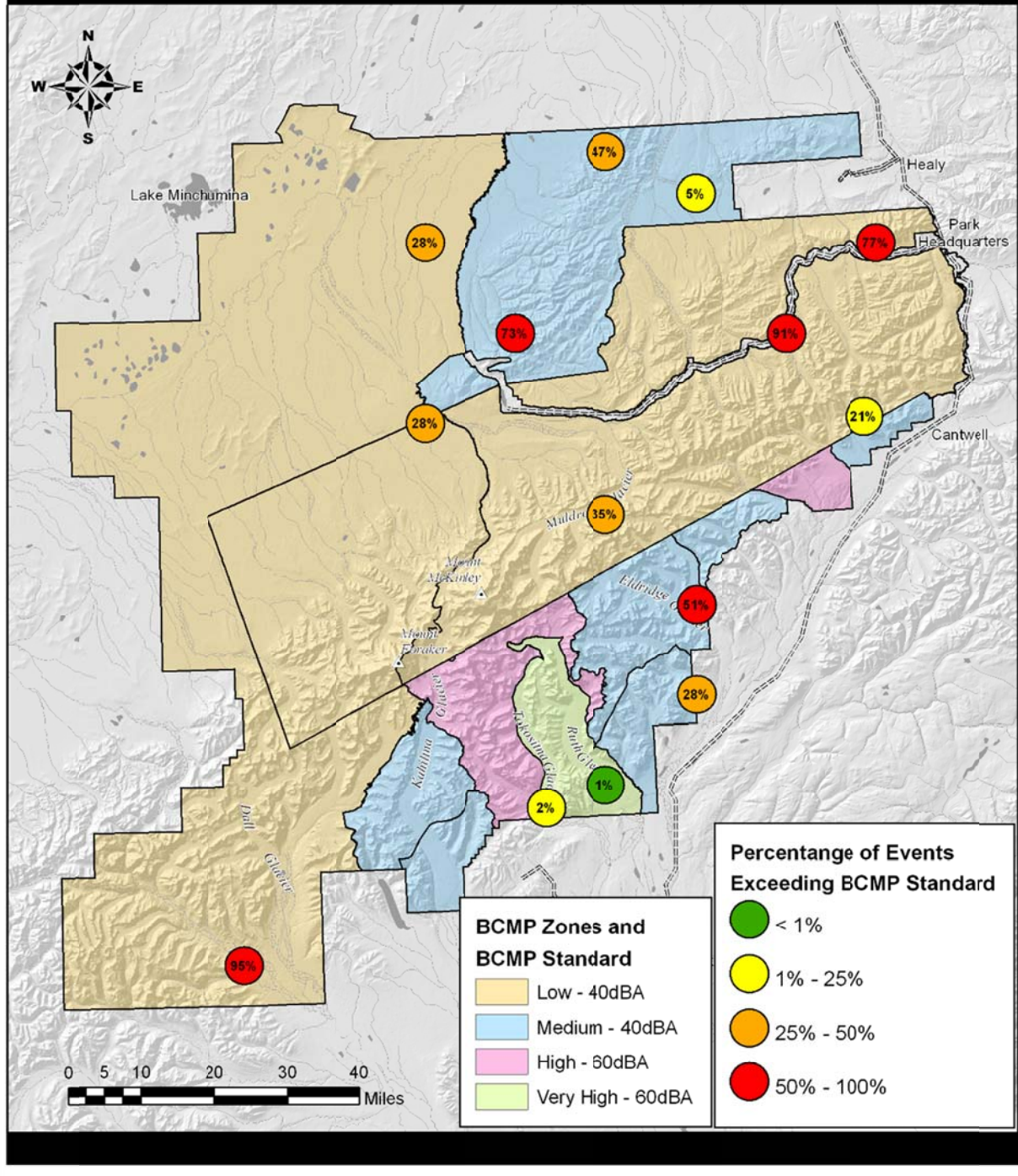
Percentage of Sampled Days Exceeding Standard (Aircraft Only)



Denali National Park Soundscape Monitoring 2005-2007

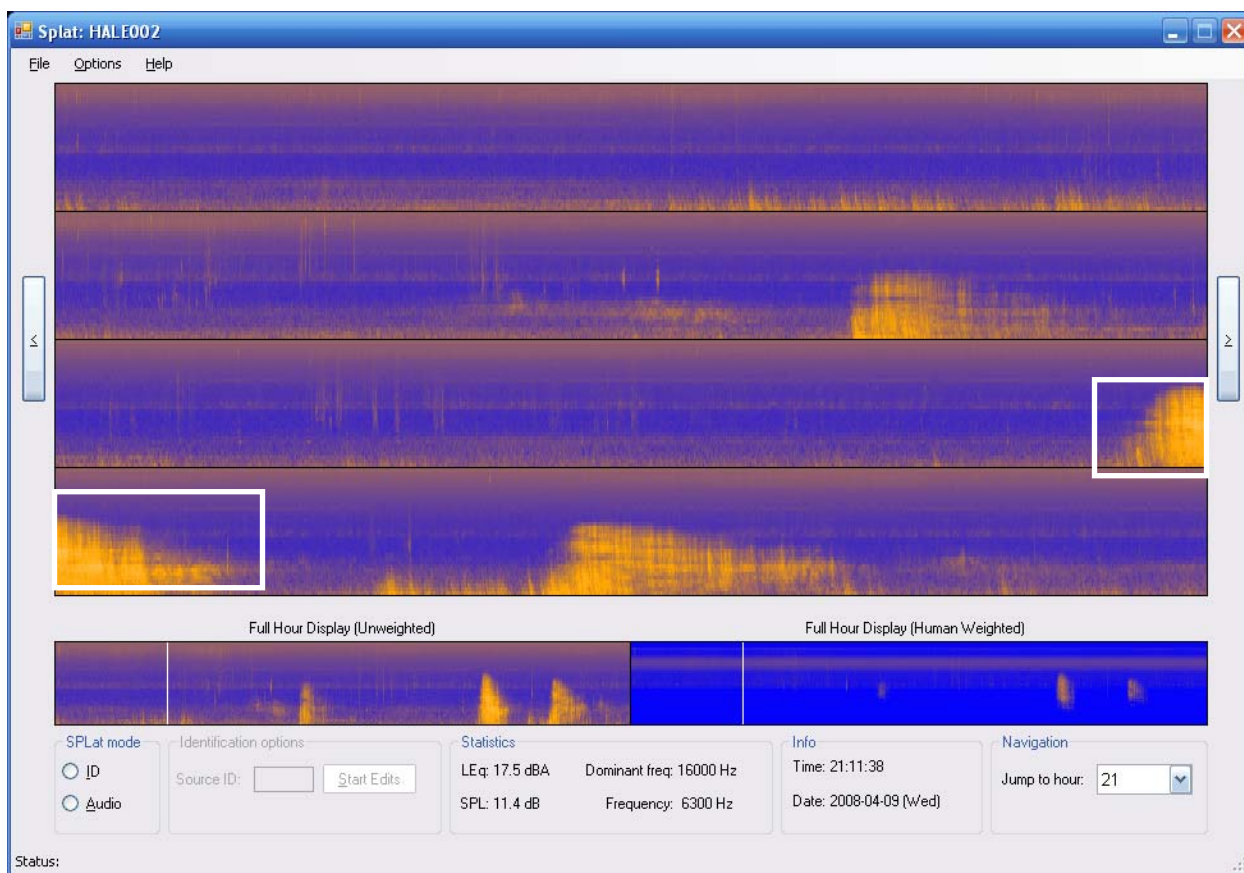
BCMP Standard #3: Maximum Motorized Sound Pressure Level

Percentage of Sampled Events Exceeding Standard (Aircraft Only)



Appendix C. Analyzing audio with visual tools

Sound pressure levels (SPL) from one hour at an acoustic monitoring site at Haleakala National Park are shown below (Lee et al 2006). One hour of SPL data is displayed over four rows. Each row shows SPL values from low frequency (12.5 Hz, bottom of line) to high frequency (20 kHz, top of line). Values are represented with a color scale, where dark blue is quiet and yellow/white is loud. Thus, individual events stand out against the blue background, appearing as yellow areas.



Acoustic events can be visually identified (by drawing a box around the event) and annotated. For each identified event, time, duration, maximum SPL, and spectral information are cataloged. For example, the white boxes above mark the occurrence of a high altitude jet overflight. Two other jet events are also visible.