ACOUSTICAL SAMPLING & ANALYSIS GUIDE

CHANGE HISTORY

Version numbers will be incremented by a whole number (e.g., Version 1.3 to Version 2.0) when a change is made that significantly affects requirements or procedures. Version numbers will be incremented by decimals (e.g., Version 1.6 to Version 1.7) when there are minor modifications that do not affect requirements or procedures included in the plan.

The following revisions have occurred to this plan since DAY MONTH, YEAR

Version #	Date	Revised by	Changes	Justification
1.0	12/02/2008	GRS/JB	Intro and change log	Track changes

1.0 INTRODUCTION

This acoustical protocol was developed for national parks, including those that may apply for Air Tour Management Plan (ATMP) acoustical monitoring and analysis via the NPS Servicewide Comprehensive Call (SCC) funding or their park contractors. To apply for such funding, a park must be on the current ATMP park list issued by the FAA. This guide meets the specifications of the FAA/NPS Implementation Plan for ATMP development.

To meet the needs of an ATMP or other park planning, park acoustical resources must be characterized in relation to desired future conditions and noise sources must be documented to support cumulative impact assessments. In addition to these necessities, park units may want to document specific elements of the natural, cultural, and/or historic soundscape that are deemed especially significant as park resources or as elements of visitor experience.

2.0 SITE SELECTION

2.1 Identification of Acoustical Sampling Areas

Areas of like vegetation, land cover, topography, elevation, and climate often possess similar acoustical characteristics, including sound sources, sound levels, propagation and attenuation properties. Most park units have identified and created digital maps of primary vegetation and topographic types; these should be reviewed in order to determine the potential number and types of different sampling areas in that park.

The acoustical sampling plan should allocate effort to document conditions and potential impacts to the largest fraction of the affected park environment that is feasible. Acoustical data will be analyzed by site and by sampling area. Inclusion of data from dissimilar ecosystems and acoustical environments within a unit of analysis should be avoided.

2.2 Monitoring Site Selection

Monitoring sites should be selected to ensure that at least one site is placed in each of the significant sampling areas of the park. The significance of a sampling area will be determined by the proportion of the park unit area that it covers, the importance of the resources it contains, and the role that it plays in visitor experience.

Secondary site selection considerations include, in rough order of priority:

- Park management zones, specific soundscape objectives for those zones, and associated need for baseline acoustical data;
- Specific sound-sensitive areas, such as endangered species habitat or sites of historical or cultural significance;
- Specific acoustical data needs, such as air tour aircraft and model verification and validation; a localized sound source such as a waterfall or river rapid);
- Visual considerations (security, solar exposure, visibility, etc.); and
- Measurement equipment availability, power requirements, and site access considerations.

Specific park management and soundscape objectives need to be discussed with local NPS personnel. The number of sites, site locations, and deployment schedules will be coordinated with NPS Natural Sounds Program and park staff through some combination of correspondence, teleconferences, and on-site meetings.

3.0 EQUIPMENT

The following are minimum standards for acoustical equipment. In situations where these standards are not followed, any deviation should be explicitly documented and justified.

Sound Level Meter
All sound level meters (SLMs) must meet or exceed requirements of ANSI S1.4-1983 (R2006) for Type 1 classification and IEC 61672:2003 for Class 1 performance. Each SLM should perform true numeric integration and averaging. In addition, all sound level meters

must meet or exceed the Class 1 requirements of ANSI S1.11-2004 and IEC 61260:1995 for one-third octave band spectra.

Calibrator
Use of a stable calibrator is required. All calibrators must meet minimum requirements of ANSI S1.4-1983 (R2006) and IEC 60942:2003 for Class 1 performance.

Digital Audio Recorder
A high quality, continuous digital audio recording system, such as the Edirol R-09 or Zoom H2, is required. The recording system should use an analog audio output from a Class 1 SLM and be capable of recording sounds with a dynamic range in excess of 90 dB. Recording instruments should have a signal-to-noise ratio greater than 90 dB (before compression). A quality audio recorder should provide accurate frequency response between 20 Hz and 20,000 Hz. However, atmospheric absorption substantially limits the long-distance propagation of high frequency sounds: absorption coefficients can exceed 20 dB per 100 m above 10 kHz. An upper frequency limit of 14 kHz may be acceptable for continuous recordings if there are no nearby sounds with high frequency content. If lossy audio compression is used to save storage space, the sampling plan should include explicit consideration of the performance characteristics of the selected compression algorithm and bitrate.

Equipment Calibration
All sound level meters, microphones, preamplifiers, and calibrators need to be calibrated annually by an ISO 17025 certified, NVLAP accredited, and/or other NIST-traceable acoustical calibration facility. All calibration documents must be up-to-date with copies provided to NPS as part of an acoustical report.

Microphone Type
A random incidence microphone is recommended for acoustical measurements in most park settings. Microphones can be polarized or pre-polarized, but pre-polarized microphones are better suited for humid environments.

Microphone Simulator
A microphone simulator is required in order to establish the electronic noise floor of the measurement system absent the microphone.

Windscreen
In most park settings, a porous windscreen will be required. In exposed, windy locations, larger diameter windscreens may be required, possibly including a hairy fairing to further suppress turbulence around the windscreen.

Meteorological
An anemometer capable of logging wind speed and time stamps is required. In addition, logging of wind direction may be important when sounds are expected to be present along specific compass bearings.

Instrument Clocks
The SLMs, digital recorders, and meteorological equipment should be set up to enable synchronization such that events of interest can be unambiguously cross-referenced across data sets. This can be achieved either through the stability of the instrument clocks or provisions to track and compensate for clock drift. An authoritative time reference like GPS, WWV radio, or NIST Internet Time Service should be utilized to set system clocks.

4.0 DATA COLLECTION

Basic measures of park acoustical conditions are the existing ambient sound level and the natural ambient sound level that omits sound sources that are not intrinsic to the park's purpose. Section 8.2.3 of the NPS 2006 Management Policies specifies: "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 will be measured and evaluated." In addition to characterizing natural ambient sound levels, acoustical monitoring must document the different kinds of noise sources affecting the park, their sound levels and frequency content, and their patterns of occurrence.

4.1 Required Data

The types of data to be collected are discussed below, including specific formats, source identification, meteorological, measurement location, instrumentation, and observer logs.

Sound Level Data
Continuous, A-weighted sound levels and unweighted, one-third octave band spectra from at least 20 to 12,500 Hz must be collected at one second intervals (1-second L_{eq}), and the data stream must enable assignment of each record to a specific time. In order to maintain compliance with measurement standards for specific expected noise sources, if possible, an A-weighted sound level with "Fast" setting, representing a 125 ms exponential time constant, should also be sampled frequently enough to enable calculation of accurate hourly percentile levels. The intrinsic noise level of the system should be below 20 dBA, and systems with extremely low noise specifications may be required in some park units.

Meteorological Data
Continuous wind speed data must be collected, and the time of each measurement must be available in the data records. Wind direction, outside air temperature, and humidity may be useful for some purposes; they affect sound propagation as well as wildlife activity patterns.

Digital Audio Recording
High quality, continuous digital audio recordings are required. Some mechanism for assigning a time to each digital sample must be implemented. Audio recorders must meet the specifications of section 3.0.

Source Identification/Observer Logging
During sound level data collection, investigators with normal hearing should conduct observer logging for several hours (at least 2.5 percent of the measurement duration for that location). During that time, all sources of sound will be logged. When logging, observers should be located at least 50 ft (15 m) from the acoustical measurement system and in the same vegetation type (sampling area) as the system. Sound types to be logged should be obtained from the NPS Natural Sounds Program; logging software for Palm PDAs can be provided upon request.

Site Information
Characteristics of the site, such as GPS position, NLCD land cover type, the NatureServe Ecological Domain, Ecological Division, and Ecological System (if defined) must be documented. Noting the vegetation type as classified by the park will be useful as a cross-reference. Photographs documenting the site, the equipment setup, and its surroundings must be taken.

4.2 Equipment Setup Guidelines

The following are minimum required setup procedures. In situations where these protocols do not apply, any deviation should be documented and justified.

Site Selection
Acoustical monitoring equipment must be placed in a location representative of the sampling area (or specific acoustical issue) under study. Wherever possible, sites exposed to the wind should be avoided. If the sole purpose of the site is to document natural ambient sound levels, then the site should be as free from external noise influences as possible. Contamination of data due to equipment-generated sound should be avoided. For example, anemometer noise should be negligible at the measurement microphone, and all equipment wiring should be secured to prevent cable slap noise. Hard, flat equipment surfaces, such as solar panels, should be situated away from the microphone to reduce the potential reflection of sounds. For every measurement site, parameters of that site must be recorded, including latitude and longitude, elevation, vegetation type, land cover, exposure, distance to sound sources (natural and non-natural), and other appropriate descriptive information. Photographs of the site and surrounding area must be taken.

Microphone Placement
Generally, to attain symmetrical frequency response in the horizontal plane, the microphone diaphragm should be oriented vertically (microphone grid facing the sky). The microphone is usually placed at 5 ft (1.5 m) above the ground surface, to mimic a typical ear height for a human listener. However, in very windy locations it may be advisable to mount the microphone much closer to the ground. For winter deployments, snow surface height can vary considerably and it may be appropriate to place a microphone higher than 5 ft above the ground. Microphone height and placement must be documented via onsite pictures and GPS coordinates.

Windscreen Use
In most park settings, a porous windscreen should be used to cover the microphone and minimize the measurement artifacts of wind blowing past the microphone. The effect of the windscreen on sound level measurements should be known and reported to within ± 0.5 dB in each one-third octave-band. When windscreen attenuation exceeds 0.5 dB in any frequency band, the data should be adjusted to correct for this attenuation. A bird spike should be used to prevent the windscreen from being used as a perch.

Field Calibration
Field calibration is required at the beginning and end of each site deployment, and it is recommended for every site visit. Calibrator readings should account for all manufacturer-recommended adjustments, e.g. atmospheric pressure, coupler volume corrections, etc. Any required corrections should be made and the changes noted. This information must be provided to NPS along with measurement data.

Noise Floor
A microphone simulator must be used to establish the electronic noise floor of the entire electrical system absent of the microphone. A log must be kept that documents calibration and noise measurement. A copy of this log must be provided to NPS.

SLM Time Response
The SLM time response should be set to enable logging of 1-second L_{eq} data and maintain compliance with noise standards where possible. If possible, an A-weighted sound level with “Fast” setting, representing a 125 ms exponential time constant, should also be sampled. However, when measuring brief impulsive sound events such as sonic booms, a faster time response setting and more frequent data (many readings per second) may be necessary.

Digital Audio Setup
Digital audio recordings must be continuous and high quality, using a Class 1 SLM output. If lossy audio compression is used, the performance characteristics of the compression algorithm and the selected bitrate should be specified (especially frequency response).

Clock Synchronization
Provision must be made to synchronize data collected by different instruments at the monitoring station. The accuracy of synchronization must be adequate to permit unambiguous identification of events of interest across all devices. It is recommended that system clocks be set using an authoritative time reference, like GPS or WWV. Interim and end of deployment time differences can be noted to document clock drift among the instruments.

Site Visits
At the start of data collection, each system deployed at a site will be checked to ensure all components are functioning properly. In addition, visits to each site (approximately once per week or as weather permits) are recommended to ensure the system is running, perform observer logging, download data, recalibrate the system, and check clock synchronization.

4.3 Temporal Measurement Considerations (Daily, Seasonal, Duration)

Temporal sampling must span times of probable acoustical variation, such as diel and seasonal cycles, a representative sample of weather conditions, and possibly changes related to local phenology. To the extent possible, the acoustical sampling plan must take into consideration these sources of variability in the sampling areas.

Time of Day
Ambient sound levels can be expected to vary as a function of time-of-day according to wind, rain, temperature profiles, visitor activity, and biological factors.

Season
Ambient sound levels may differ by season due to weather, visitor activity, and biological factors. Acoustical data should be collected during a representative seasonal month when air tours occur, typically between May-August for summer, and between November-February for winter. The NPS Natural Sounds Program should be consulted on a park-by-park basis to discuss seasonal sampling options.

Duration

In order to limit measurement uncertainty, ambient sound levels should be sampled for at least 25 days in winter and 25 days in summer. In some situations, shorter or longer monitoring periods may be indicated. Like all other aspects of the acoustical sampling plan, monitoring periods should be designed using the best available information and discussions with park unit staff.

Margin of Error
The goal is to collect data so that there will be no more than a ± 3 dB difference between the average (or expected) ambient sound level and the ambient sound level measured from the sample period.

4.4 Data Formats

As per its interpretation of the Museum Properties Act of 1955, the National Park Service requires that copies of all data, pictures, and reports that are generated as a result of research activities occurring in National Parks remain the property of the National Park Service. All raw data described in sections 4.1 and 4.2 must be provided to NPS in a convenient, computer readable format. For large data sets, an external hard disk drive will often offer the simplest mode of transport.

Sound Level Data
Continuous A-weighted sound levels and unweighted one-third octave band sound levels at one second intervals (1-second L_{eq}) must be provided in a convenient, computer-readable format. In addition, other data, such "Fast" A-weighted sound levels, should also be provided. An acceptable format protocol will be provided upon request from the NPS Natural Sounds Program. If 1/3 octave band data are acquired using a Larson Davis 824 or 831, the NSP

office is able to offer useful utilities for converting and viewing the data. A-weighted sound levels may be collected in the field, or computed from the one-third octave data.

Digital Audio Recordings
High quality, continuous digital audio recordings must be provided in a computer-readable digital audio format. Acceptable formats include WAV, MP3, or WMA. The NPS Natural Sounds Program may be contacted for utilities intended for viewing one-third octave band spectra while listening to digital audio recordings.

5.0 DATA ANALYSIS

5.1 Data Processing

Several quality assurance checks must be applied to the acoustical data prior to data reduction to ensure that any questionable data is identified and that "good" data can be analyzed for a minimum of 25 total days. The following checks should be used; any data with the following characteristics should be considered questionable and discarded:

- Data taken when battery readings were less than the minimum recommended voltage;
- Data taken when internal temperature readings exceeded the equipment manufacturer's maximum operating temperature limit;
- Data taken when 1-second average wind speeds indicate an anemometer error;
- Data with 1-second sound levels that exceed the manufacturer's recommended maximum level for a given gain setting;
- Data which indicates a problem with the sound-level sample;
- Data that were contaminated by field personnel (e.g., operator noise);
- Data taken when 1-second average wind speeds were greater than 11 mph (5 m/s), the maximum acceptable wind speed threshold;
- Data in any given hour, for which greater than 25 percent of the samples are lost due to the above factors. Any hour with $\geq$ 75 percent "good" data is acceptable for data analysis.

Acoustical data adjustments are discouraged, but may be necessary in some circumstances. The following is a list of adjustments which may be applied to the data:

- Gain adjustments, if any;
- Calibration adjustments to account for calibration drift as measured at the start and end of a data collection period;
- Microphone frequency response adjustments as recommended by a microphone calibration facility (these adjustments must be documented in detail);
- Windscreen frequency response adjustments as recommended by the manufacturer; these adjustments must be explicitly documented.

5.2 Data Analysis

The most laborious component of the analysis is measuring the fraction of the data in which noise sources are detectable. Historically, this was done by listening to samples of audio recordings. For example, ten seconds of digital audio data were recorded every two minutes in some equipment packages. Analysts attentively listened to a randomly selected sample of eight days of these data. Attentive listening is often aided by simultaneous visual review of spectrograms using software like Adobe Audition. The Natural Sounds Program also uses a macro-enabled Excel spreadsheet to expedite this mode of data analysis. Attentive listening yields the most detailed information regarding the number and identities of noise sources. In quiet, backcountry environments, noise events may be rare and recognizable, so that a more rapid assessment may be realized using software to mark events in spectrograms made from the 1/3rd octave spectral or digital audio data. This form of analysis can be ten times more rapid than attentive listening.

Existing Ambient Sound Level ($L_{Existing}$)

Existing ambient sounds are all sounds in a given area (includes all natural sounds as well as all mechanical, electrical and other human-caused sounds). The existing ambient sound level should be calculated on the "good" data sample after data processing as described in sections 5.1 and 5.2. The summary statistic is the median sound level ($L_{50,}$ applied to each 1/3rd octave spectral band.

Natural Ambient Sound Level ($L_{Natural}$)

Natural ambient comprises all sounds intrinsic to the park unit's purpose, excluding extrinsic noise (*e. g.* transportation noise, infrastructure noise, possibly noise from visitors). Note that some human-caused sounds may be intrinsic to a cultural or historic park unit's purpose. In order to calculate natural ambient sound levels for each hour of the day, sound data must be analyzed to determine the percent time audible for extrinsic noise. If A is the percent time audible, then the $L_{Natural}$ estimate will be $L_{50+A/2}$. Thus, if noise is audible 16% of the time, then:

$L_{Natural} = L_{50+16/2} = L_{58}$. Note that L_{58} is the 42nd percentile order statistic (smaller than the median; see the next section).

Existing Ambient Sound Level without Air Tours ($L_{Existing\ w/o\ AirTours}$)

The existing ambient without source of interest (air tour aircraft noise) is calculated in a manner similar to natural ambient, but the percent time audible of the source of interest is used in the calculation.

5.3 Metrics

The following metrics should be used to describe the ambient and sound levels as defined in section 5.2. The NPS Natural Sounds Program can provide software that expedites calculation of these metrics. It is important to note that NPS focuses on one-third octave spectra, rather than A-weighted sound levels that integrate energy across the audio spectrum. A-weighted metrics are widely used to characterize transportation noise, in which most of the sound energy is concentrated at low frequencies (often below 1000 Hz). If a park unit wishes to compute A-weighted summary statistics for natural environments, to be compared with transportation noise sources, it is crucial that the environmental A-weighted metrics be bandlimited to the same range of frequencies in which the transportation noise is concentrated. Otherwise, sound energy far outside the noise spectrum – sounds from birds, insects, and other high frequency sources – will inappropriately inflate the environmental A-weighted sound levels.

Equivalent Continuous Sound Level (L_{eq})
The equivalent continuous sound level is the level of a steady sound that would have the same time-mean-square sound pressure as the time-varying sound under measurement in a given time period. For example, the hourly L_{eq} is a logarithmic measure related to the average sound energy (not the average sound level) observed over a one hour measurement period.

Percentile Level (L_{10} , L_{50} , L_{90})
The *x*-percentile-exceeded sound level is the sound level that is exceeded *x* percent of the measurement period. For example, the hourly L_{10} is the sound level that is exceeded 10 percent of a measurement hour. The hourly L_{50} is the sound level that is exceeded 50 percent of the measurement hour. The L_{50} is also known as the median sound level. Similarly, the hourly L_{90} is the sound level that is exceeded 90 percent of a given measurement hour.

Source Identification Data
After listener judgments are used to identify and categorize audible sounds, the resulting data should be used to create a table of sound sources and statistics summarizing their occurrence.

Noise Free Interval (NFI)
This metric is the length of the continuous time period during which only natural sounds are audible.

Number of Events Per Hour (NEH)
This metric will be applied to the number of air tour operations audible within a specified time period, generally each hour during the day.

Time Above Ambient (%TAA) – (un-weighted spectra)
This is the percentage of time that aircraft sound levels exceed the baseline ambient sound spectrum levels in a given area during a given time period. This will be calculated for each un-weighted one-third octave band from 20 to 20,000 Hz.

5.4 Modeling

The latest version of FAA's Integrated Noise Model (INM) will be used for ATMP modeling of the acoustical environment within the park. Ambient maps will be developed using measured data as the base layer. At minimum, ambient maps will be developed for the natural ambient sound level and the existing ambient sound level without air tours as described in section 5.2.

Ambient maps should be created using Geographic Information System (GIS) data and software developed by the Volpe Center. Specific software requests can be made to the NPS Natural Sounds Program.

The two primary input parameters required in the INM modeling effort are the baseline ambient sound level maps and aircraft type, route, and schedule data, which can be obtained from the park or NSP office. These data are utilized by INM to compute appropriate metrics (1) as contours; (2) as points located on a regular grid spaced at consistent intervals apart; and/or (3) at user-specified sensitive locations, such as an endangered species habitat. An average day of air tour operations during the peak seasonal month (PMAD) will be used for modeling purposes.

INM's output data, presented in a series of graphics and tables, will be used in the modeling the existing environment, as well as aircraft impacts and changes resulting from the various alternatives being considered. Modeling will also allow assessment of changes in operating conditions, including the number and frequency of operations, routes, altitudes, and aircraft technologies, as well as geographic and/or temporal restrictions. The following descriptors will be calculated for use in aircraft noise assessment.

- *Time Audible (%TA)* – The percentage of time that aircraft sound levels are audible, including the percentage of the park area within which aircraft are audible. This metric will be modeled twice, once for Existing Ambient without Air Tours and once for Natural Ambient;

- *Time Above Ambient (%TAA) – (A-weighted)* The percentage time that aircraft sound levels (in A-weighted decibels) exceed than baseline ambient sound levels in a given area during a given time period. This metric will be modeled twice, once for Existing Ambient without Air Tours and once for Natural Ambient;

- *Equivalent Continuous A-Weighted Sound Level* (L_{Aeq}) – The A-weighted level of a steady sound that would have the same time-mean-square A-weighted sound pressure as the time-varying sound under measurement in a given time period. For example, the hourly L_{Aeq} is a logarithmic measure related to the average A-weighted sound energy (not the average A-weighted sound level) observed over a one hour measurement period;

- *Change in Exposure* (ΔL) – The algebraic difference (in A-weighted decibels) between aircraft sound levels and baseline ambient sound levels during a given time period. This metric will be modeled twice, once for Existing Ambient without Source of Interest and once for Natural Ambient;

- *Maximum Sound Level* (L_{max}) – The maximum sound level (in A-weighted decibels) associated with the loudest aircraft event occurring during a modeling assessment. Note: The FAA and NPS have agreed to compute this metric at user-specified sensitive locations, such as an endangered species habitat.

6.0 INDICATORS & STANDARDS

Indicators and standards will generally be identified by the NPS Natural Sounds Program and park staff. Natural Sounds Program contacts include Frank Turina, Vicki McCusker, and Lelaina Marin.

7.0 IMPACT ASSESSMENT

Impact assessment will typically be accomplished via collaboration between NPS Natural Sounds Program and park staff. Natural Sounds Program contacts include Frank Turina, Vicki McCusker, and Lelaina Marin.