National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science
Natural Sounds and Night Skies Division

Noise Source Measurement Protocol

August 2011

Background Information:

In section 4.9 of the NPS Management Policies 2006, superintendents are directed to monitor noise caused by mechanical devices. In section 8.2.2, park managers are directed to identify levels and sounds that may hinder visitor enjoyment and specifically, to monitor mechanical noise that adversely affect opportunities to enjoy park soundscapes. Such efforts are important not only to understand how noise sources may affect a park unit's soundscape, but also to help park managers identify potential management actions which could reduce noise and thereby protect the acoustical environment. Such management actions could include limits on noise source operation or efforts to mitigate the noise at the source, i.e. noise control.

Noise source assessment may be done for various specific reasons. Noise measurements may be undertaken in order to provide data for noise propagation models, in order to characterize existing impacts, or in order to better understand how the noise can be controlled. When noise control is the ultimate goal, then it may be desirable to capture data on the amount of noise, the specific noise generation mechanisms, and their directivities, for example. In order to make accurate judgments about how the noise can be controlled, it is important to capture sufficient, accurate information. Insufficient data can be nearly as useless as no data at all.

Noise source assessment and control are related tasks. They are engineering disciplines that benefit from a knowledge of mechanics, electricity, thermodynamics, signal theory, power, construction, materials, machinery, and equipment operation. This document is intended to provide a general outline of the process and a checklist which should be followed for each noise source measurement. It is not intended to be comprehensive or specific enough to cover all relevant details for each noise source that may need to be measured.

Importance of Standards:

Measurement standards are generally intended to ensure that measurements are accurate and repeatable. They help to guarantee consistency and comparability of a given measurement with ones made by others. Standards also help to ensure broad support for a measurement procedure, since they are usually developed by consensus of experts. Finally, standards help the NPS to meet scientific integrity requirements from OMB and provisions of the Data Quality Act.

Measurement procedures are necessarily specific to the device under measurement and parameters such as the size, type, construction, mounting, power, operating condition, and other acoustically relevant considerations. Therefore, device-specific noise source measurement standards, measurement guidelines, and updates to those documents should always be researched before making any noise measurement. Sources for measurement requirements may be found in federal

regulations, agency guidelines, local noise codes, acoustical societies, and standards organizations such as ANSI/ ASA, ISO, IEC, SAE, ASHRAE, and ECMA[1]. Experienced noise control engineers may also be consulted in order to identify specific standards or procedures that may be relevant for a noise measurement.

SPECIFIC NOISE SOURCES AND STANDARDS

Examples:
The following are measurement standards for specific noise sources that might be encountered in or near national park units. In some cases, the measurement standard includes specific procedures that require site selection and preparation. Site selection for vehicle pass-by noise measurements can be very specific and demanding, requiring site visits and inspection for suitability. Other required preparation might include specific equipment such as anemometers, RPM sensors, and/or specially trained vehicle test drivers.

Wind turbine noise emission measurements:
International standard IEC 61400-11 is generally considered the most appropriate standard for measurement of wind turbine noise and calculation of sound power levels. IEC 61400-11 contains instructions on how to utilize a ground-based microphone mounting board, and on where the mounting board should be located with respect to the wind turbine hub. The use of a ground-based microphone mounting board has the benefit of reducing undesired extraneous noise due to wind turbulence around the microphone windscreen. Also included are instructions on how to calculate apparent sound power vs. wind speed, using regression.

Motorcycle (or other vehicle) pass-by source levels for highway noise modeling:
The federal guidelines in the Federal Highway Administration report FHWA-PD-96-046 "Measurement of Highway-Related Noise" are intended for Traffic Noise Model (TNM) use and may be more appropriate than other measurement standards. Among other things, FHWA-PD-96-046 includes recommended procedures for the measurement of existing highway noise, vehicle noise emissions, and barrier insertion loss. In addition to recommended site selection, microphone locations, vehicle logging, and measurement procedures, FHWA-PD-96-046 includes recommendations for event quality determination and equations for development of Reference Energy Mean Emission Levels (REMELs).

Motorcycle exhaust noise level measurements:
For exhaust muffler certification and compliance, the noise limits and measurement procedure in Environmental Protection Agency (EPA) regulation 40 CFR 205 may be most appropriate. The procedure in SAE F76a is equivalent to that in 40 CFR 205, Subpart D. However, the full throttle acceleration and RPM requirements in 40 CFR 205 can be difficult to achieve precisely. In some cases, SAE J47 or J331 may be appropriate. SAE J47 was intended in order to determine the maximum sound level potential for motorcycles, while SAE J331 was intended to capture noise under operating conditions similar to motorcycles accelerating rapidly up to cruising speed on an

[1] ANSI = American National Standards Institute; ASA = Acoustical Society of America; ISO = International Organization for Standardization; IEC = International Electrotechnical Commission; SAE = Society of Automotive Engineers; ASHRAE = American Society of Heating, Refrigerating and Air-Conditioning Engineers; ECMA = European Computer Manufacturers Association

expressway on-ramp. For ease of stationary motorcycle exhaust noise level measurement by law enforcement, SAE J1287 may be the best choice, however, as it was written to be usable for pass-fail enforcement testing. Because SAE J1287 specifies a close 0.5 m (20 in) measurement distance, the possibility of level contamination from other vehicles is minimized. Variations of these measurement procedures may be adopted according to applicable municipal, county, or state noise regulations.

Motorboat pass-by noise measurements:
For measurement of operational motorboat pass-by noise levels, NPS regulation 36 CFR 3.15 specifies a maximum level of 75 dBA and the measurement procedure in SAE J1970. SAE J1970 specifies a shoreline location but not a specific measurement distance. This offers the advantage that it protects park shorelines regardless of distance from the motorboat; however, it also offers the disadvantage that more distant motorboats are permitted to be louder. For measurement of stationary motorboat noise, NPS regulation 36 CFR 3.15 specifies a maximum level of 88 dBA utilizing the measurement procedure in SAE J2005. Similar to SAE J1287 for stationary motorcycle exhaust level measurement, SAE J2005 may be more practical for pass-fail enforcement testing of docked motorboats by park law enforcement. Some states such as Missouri specify other motorboat measurement procedures, such as SAE J34, which was also formerly utilized by NPS in regulation 36 CFR 3.7 that was superseded in 2007 by 36 CFR 3.15.

Snowmobile noise measurements:
NPS regulation 36 CFR 2.18 specifies a maximum pass-by noise level of 78 dBA for modern snowmobiles and higher levels for models of older manufacture. Unlike 36 CFR 2.18, however, SAE J192 offers a specific measurement procedure and is often utilized by NPS contractors or snowmobile manufacturers. SAE J192 specifies a full-throttle acceleration test as the basis for establishing maximum noise capabilities of a snowmobile.

Oversnow vehicle noise measurements:
For unique snow vehicles such as snow coaches, the measurement procedure in SAE J1161 has been utilized for NPS by organizations such as Volpe. SAE J1161 differs from SAE J192 in that SAE J1161 is intended to measure exterior operational sound levels such as could be encountered during actual vehicle operations, while SAE J192 produces only maximum sound levels, as explained above.

Choice of measurement procedure may depend not only on the local noise ordinance but also the skill level of the measurement operator, i.e. skill ranging from a licensed acoustician to a law enforcement officer. A combination of general and specific measurement standards may also apply. For example, noise source-specific measurement practices in standards such as SAE J34 may reference the general acoustical measurement standards in ANSI S1.1, S1.4, and S1.13.

GENERAL NOISE SOURCES

Measurement Considerations:
Before a general noise source is measured, the goal or purpose of the measurement must first be identified. As described for the specific noise sources above, if the goal is to assess compliance with some specification, regulatory limit, or standard, then the appropriate document(s) must first be consulted. However, if the goal is measurement of emission levels for noise source modeling,

appropriate standards may still need to be followed, but different procedures or adjustments may be required to accommodate the input needs of the noise modeling program. Examples will be provided below.

In addition to the goal for the measurement, key parameters such as the contributing noise source components, their size, locations, operating conditions, noise generation mechanisms, and all related variables should generally be adequately understood, as described below. If no published measurement standards are available for a given noise source, then the following general procedure may be followed. An experienced noise control engineer may also be consulted to determine whether there are other common applicable measurement practices that may meet the needs of accuracy, repeatability, and data quality.

Measurement Preparation:
Even in the cases where a standard, guideline, or common practice exists for measurement of a given noise source, the following measurement preparations are recommended and advisable.

Noise Source Parameters:
It is helpful to consider the basic parameters of the noise source before arriving on site and conducting the measurement. The basic parameters for a given noise source include size, location, and wavelength of the generated sound. In cases where the wavelength greatly exceeds the source size in any dimension, the source may be assumed to radiate more or less omnidirectionally, as a point source. When the source is located on a reflecting surface such as the ground, the effect of ground reflections should at least be considered. This can be done by considering the expected onsite ground surface, its expected impedance, e.g. soft or hard, and how it may affect the reflected component.

Noise Generation Mechanisms and Operating Conditions:
The noise generation mechanisms should be considered in order to anticipate how the noise may vary. As an example, vehicle engine noise may be expected to vary with throttle position, RPM, and load. Therefore, any site or operating conditions that may impact these parameters should be considered. A vehicle pass-by noise example will be considered in more detail below.

Keeping in mind the specific noise generation mechanisms for a given noise source, the noise source should also be operated at conditions which are considered to be representative for any noise impact assessment. This may include a normal and worst-case noise producing condition, such as may occur when all contributing noise sources operate concurrently under full load. Some advance research should be done on these conditions and what data could be measured, observed, or otherwise provided to document each operating condition.

As an example, for highway pass-by noise, speed should be monitored, and the average of many vehicle pass-bys levels should be used, as the noise level will depend on vehicle type, speed, throttle level, and load. Throttle position may be impacted by proximity to a curve or stop sign. Vehicle load will depend on a wide range of variables, including vehicle weight, road incline, rate of ascent, wind resistance, wheel rolling resistance, etc. Wind noise will be dependent on air speed and direction. The road noise component will be affected by vehicle speed, as well as road and tire condition. For a single power generator, the total noise level produced may vary with load, which will depend on the number of powered devices and the total current drawn by those devices.

Therefore, for a power generator, it may be helpful to assess the number of powered devices and monitor the total current drawn via an ammeter. These assessments are important to ensure representative operating conditions, data quality, and repeatability.

To the extent it is relevant for the amount of noise produced, some onsite data should be gathered on how often the measured noise source operates or is present. Duration of the noise source may be important to better understand noise impacts. This may consist of days/dates, times, and/or site specific counts per weekend/weekday hour. Hourly traffic counts by vehicle class are an example. In order to best understand how to gather this and the aforementioned operating condition data, some advance planning should be done, possibly including development of onsite data logging sheets (see Appendix below).

Noise Source Operation:
If the noise source requires special expertise to operate, permissions to access, or if safety controls are required, then the appropriate personnel/authorities should be contacted in advance of the measurement. It may be necessary to coordinate noise measurements with appropriate personnel and safety controls. For example, operation of power generators frequency requires trained onsite personnel familiar with the generator systems and the devices they power. Oil drilling or gas production areas might require hard hats. As another example, the specific engine RPM and throttle position is important for motorcycle exhaust level compliance testing, and therefore, special sensors and/or an experienced test driver may be required.

Measurement Procedure:
It is very rare that no standard, guideline, or common practice exists for measurement of a given noise source, but in those cases, the following measurement procedure should be used.

Measurement Setup:
Unless otherwise specified by regulation or standard, a microphone height of 1.5 m (5 ft) should generally be acceptable, as this is a standard ear height for an average person. If a free field microphone is chosen, it should be oriented toward the source. If a free field microphone is used, it should be oriented directly toward the noise source. If a random-incidence microphone is chosen, the microphone should be tilted at approximately a 70 degree angle to the noise source, in order to achieve a flat response at high frequencies.

If required by standard or if conditions warrant, a microphone windscreen should be used consistently for all measurements. Conditions that may warrant use of a windscreen include outdoor wind or indoor airflow near a supply duct air diffuser. The effect of the windscreen should be accounted for in the measurements.

Measurement Locations:
To the extent possible, noise source measurements should always be made at known distances and angles from the source. For stationary noise sources, it may be possible to utilize a limited number of measurements, depending on the directivity of the source. Source directivity may be investigated simply by moving around the source with an operating sound level meter. For a noise source radiating 360 degrees laterally on a ground plane, a minimum of four measurements should be made at equally spaced angles of 90 degrees. For a noise source radiating 180 degrees laterally from a wall, a minimum of two measurements should be made at 90 and 45 degrees, for example.

If the measured sound level at these locations varies no more than 1-2 dB for adjacent angular positions and equivalent distances, then a sufficient number of angles have likely been achieved. For moving noise sources such as automobiles where directivity may not be precisely known or may vary with operating condition, other rules of thumb apply (see below).

In general, the ideal location to measure a sound source is the closest distance at which free field conditions are met. Free field conditions are met for a single point source when spherical spreading occurs and the sound pressure level decays at a rate of 6 dB for every doubling of distance. These conditions are typically met when the measurement distance is at least five to ten times the largest dimension of the noise source. In general, if the 6 dB criterion cannot be verified, the measurement distance should be at least ten times the largest dimension of the source. For a line source such as a power line or busy highway, free field conditions are met when the sound pressure level decays at a rate of 3 dB for every doubling of distance.

The aforementioned rules of thumb also apply to multiple contributing noise sources. For example, if the primary noise sources from an enclosed generator are a ventilation duct and exhaust pipe that are 0.7 m apart, than it should be measured at a minimum distance of 7 meters from the primary noise source. As another example, if the sound source size from a moving vehicle center to the exhaust tailpipe is roughly 5 feet, then the maximum pass-by level should be measured at a lateral distance of 50 feet.

In the typical case that the source is located on a reflecting surface such as the ground, the effect of ground reflections should be considered. This can be done by inspecting the onsite ground surface and considering how its impedance may affect the reflected component. The effect of ground reflections can also be observed by moving the sound level meter forward and back and noting the variation in levels, particularly at specific low frequencies where wave addition or cancellation might be expected. The goal is to find a location where the level in each spectral band most accurately represents the source.

An exception to the aforementioned rules occurs when the measured noise source is obscured by walls, buildings, or other structure. In this case, the measurement should be made at a larger distance from the noise source, depending on the size and shape of the structure. Barriers, for example, result in attenuation similar to line sources. The goal is to find the closest distance at which reasonably consistent attenuation occurs with increasing distance. Depending on the size of the structure, its geometry, and the measurement location, attenuation may range from 3-6 dB per doubling of distance.

<u>Isolating Sources:</u>
If contributing noise sources are expected to operate independently, then it may be necessary to measure those noise sources independently, to the extent that the qualified engineers or technicians are able to make those sources operate independently. Some research may be required to determine how noise sources can be separated. For example, if a compressor is running, a chiller may operate when coolant temperature reaches a certain level, but the chiller might never operate if the compressor is not running. In order to assess the chiller noise level by itself, it might be important to identify the most ideal measurement location, measure the level before and after the chiller operates, and then use decibel (logarithmic) subtraction. If contributing noise sources cannot be operated independently, then it is the responsibility of the sound level meter operator to

use best judgment in order to determine and log the relative contributions of each noise source with reasonable accuracy. This is typically done by inspection, by moving the sound level meter back and forth to minimize undesired contributions and by using ones ears. The equation for decibel (logarithmic) subtraction is as follows:

$$L_{adj} = L_c - L_a$$

where Ladj = adjusted level
Lc = combined level, e.g. desired plus ambient
La = extraneous sound source, e.g. ambient

Ambient Influence:
In order to ensure measurement accuracy, the influence of the background ambient must be understood. Before and after noise source measurements are made, the ambient sound level should be measured and documented. The ambient can be measured when the noise source is not operating or by moving to a sufficient distance from the noise source where the ambient is expected to be the same as at the noise source location. If at any time, the ambient is observed to change significantly during measurements, it should be measured again.

In order to ensure that measured noise source levels are due to the noise source alone and not inflated by the ambient, overall sound levels measured with the noise source operating should be at least 10 dB higher than the measured ambient sound level with the noise source not operating. When Lc is precisely 10 dB higher than La in the aforementioned equation, then Ladj = 0.46 dB less than Lc, and the change can be rounded to zero. If noise source levels are not at least 10 dB higher than the ambient, then it may be necessary to move closer to the noise source or wait until the ambient sound level decreases sufficiently. If spectral data are desired, this 10 dB minimum increase criteria should also apply to as many measured one third octave bands as possible.

Site Documentation:
All measurement noise source locations, measurement distances, and times should be clearly documented in a site drawing sketch. If at some point during a measurement, the sound level is artificially influenced by some other unintended or unrelated noise source, the level and time should be documented and/or the measurement should be redone. This is very important as it can be extremely challenging, if not impossible, to separate sound sources that overlap closely in time and frequency. Meteorological data such as temperature, humidity, and wind speed should be logged if it could be reasonably expected to affect the measurement

All instrumentation, noise sources and operating conditions should be documented. The make, model, and serial number of the utilized instrumentation should be logged. For each noise source, relevant information, such as manufacturer, model number, power rating, and serial number, if available, should be documented. If a noise source comes in a package, such as a generator, the enclosure housing and engine model information should both be documented. Onsite data logging sheets are highly recommended (see Appendix below).

Instrument settings:
Unless otherwise specified by regulation or standard, the sound level meter should be set for A-weighting and fast response at a minimum rate of 20 samples per second. For stationary noise sources, a minimum 30 second measurement should be made at each location. For moving noise

sources, the maximum pass-by level should be captured. If possible, three repetitions of each measurement should be made. In addition, unweighted one-third octave spectral data should be acquired. These basic settings should provide adequate information for most purposes except for capture of very loud, impulsive sounds which may require impulse response and potentially, extended frequency response.

APPENDIX

The following examples of general noise sources include an RV power generator, an oil and gas drilling operation, and construction noise

CONSTRUCTION EQUIPMENT NOISE

Measurement Considerations:
The goal in this example case is supposed to be measurement of construction equipment emission levels for potential noise propagation modeling. A preliminary assessment reveals that construction site activity consists of several generic phases, including mobilization, clearing and grading, earthwork, foundations, bridge construction, base preparation, paving, and cleanup. Thus, any noise impact due to a construction site is actually composed of contributions from each of these phases.

Measurement Preparation:
Fortunately, a good measurement protocol exists for measurement of highway construction noise. It can be found in Section 7 of the Federal Highway Administration report FHWA-PD-96-046 "Measurement of Highway-Related Noise". The following recommendations follow from that report.

Noise Source Parameters:
Construction activity will consist of sources located on the ground. The expected ground impedance in most directions can be expected to be soft during the majority of post-grading phases of the construction activity.

Noise Generation Mechanisms and Operating Conditions:
As with other ground vehicles, construction equipment noise levels will vary with throttle position, RPM, and load. In the FHWA report, each type of construction equipment is characterized by up to four modes of operation: (1) STATIONARY-PASSIVE, e.g., a bulldozer at idle; (2) the STATIONARY-ACTIVE, e.g., a bulldozer lifting earth, debris, etc.; (3) MOBILE-PASSIVE, e.g. a bulldozer moving but not conducting project activities; and (4) MOBILE-ACTIVE, e.g., a bulldozer moving while pushing earth, debris, etc.

When it is not possible to capture each piece of equipment in each mode of operation, it may be possible to simplify the measurement by capturing a sufficiently long duration including all modes of operation, or alternatively, by capturing a single mode of operation that each vehicle remains in for more than 75% of its operating time.

Noise Source Operation:
Construction equipment requires special expertise to operate and safety gear is often required. Consequently, the appropriate personnel/authorities should be contacted in advance, and the noise measurements will likely need to be coordinated with those personnel and safety controls. Experienced drivers are very likely required.

Measurement Procedure:
The site selection and measurement procedure in Section 7 of the report FHWA-PD-96-046 "Measurement of Highway-Related Noise" should be used.

Measurement Setup:
As is frequently specified for highway pass-by noise measurements, section 7.1.2 specifies a microphone height of 1.5 m (5 ft) above ground level. A microphone windscreen is specified for all measurements. Section 7.1.1 states that a flat open space, free of large reflecting surfaces, should be used. The ground must be noted as acoustically hard or soft, and there should be unobscured line of sight from the microphone to the measurement site.

Measurement Locations:
Section 7.1.2 also specifies that a microphone distance of 15 m (50 ft) should be used. As mentioned in the procedure above, a minimum of four measurements should be made at equally spaced angles of 90 degrees for stationary noise sources. For moving noise sources, measurements should be made at 15 m (50 ft) with equipment moving in both a left-to-right and right-to-left direction.

Ambient Influence:
Section 7.1.1 requires that the ambient sound level at the measurement site must be low enough to enable the measurement of uncontaminated vehicle noise levels. In order to ensure this is the case, the difference between the lowest anticipated construction equipment noise level and the A-weighted ambient at the measurement microphone must be at least 10 dB. If noise source levels are not at least 10 dB higher than the ambient, then it may be necessary to move temporarily closer to the noise source or wait until the ambient sound level decreases sufficiently. If spectral data are desired, this 10 dB minimum increase criteria should also apply to as many measured one third octave bands as possible.

Site Documentation:
All measurement noise source locations, measurement distances, and times should be clearly documented in a site drawing sketch. Relevant information, such as manufacturer, model number, power rating, and serial number, if available, should be documented for each noise source. Onsite data logging sheets are highly recommended (see examples below).

Instrument settings:
Unless otherwise specified by regulation or standard, the sound level meter should be set for A-weighting and fast response at a minimum rate of 20 samples per second. In addition, unweighted one-third octave spectral data should be acquired. These basic settings should provide adequate information for most purposes except for capture of very loud, impulsive sounds which may require impulse response and potentially, extended frequency response.

RV GENERATOR NOISE

Measurement Considerations:
The goal in this example case is supposed to be measurement of RV generator or generators such as may be found in national park unit campgrounds. Park campgrounds vary widely in size, shape, and operational rules; therefore some preliminary site investigation may be helpful. Some measurement parameters will depend on whether a single or multiple generators are intended for noise measurement.

Measurement Preparation:
A measurement procedure for RV generator noise is presumed to be unknown. However, there is a difficult-to-find measurement procedure from the former Diesel Engine Manufacturers Association entitled "TEST CODE FOR THE MEASUREMENT OF SOUND FROM HEAVY-DUTY RECIPROCATING ENGINES". In the case of RV generators in NPS campgrounds though, the NPS audio disturbances prohibitions in 36 CFR 2.12 could be applicable. It prohibits "operating motorized equipment of machinery such as an electrical generating plant,… in a manner: (i) that exceeds a noise level of 60 decibels measured on the A-weighted scale at 50 feet; or if below that level, nevertheless; (ii) makes noise which is unreasonable…"

Noise Source Parameters:
RV generators are usually contained in fully enclosed packages that vary in size and are installed on the lower side of an RV. A common size is approximately 30" x 20" x 16". Therefore, in absence of any SPL data, the minimum measurement distance should be at least 4 to 7.5 meters (15 to 25 feet) from a single noise source.

Noise Generation Mechanisms and Operating Conditions:
RV generator noise can be expected to vary primarily with load, which will depend on the number of powered devices and the total current drawn by those devices. Therefore, for a single generator, it may be helpful to make inquiries and create an estimate of the total load.

Noise Source Operation:
RV generator operation will depend primarily on the discretion of the vehicle owner and the need to power electrical devices such as lights, appliances, air conditioners, heaters, fans, and pumps.

Measurement Procedure:
If compliance with NPS regulation 36 CFR 2.12 is of interest, then measurements of single generators should be made at the prescribed distance of 50 feet.

Measurement Setup:
A microphone height of 1.5 m (5 ft) above ground level is advisable. A microphone windscreen may also be advisable if wind is present. For a single generator, the measurement site should be free of large reflecting surfaces, with line of sight from the microphone to the RV generator and /or its exhaust.

Measurement Locations:
Source directivity of the RV generator should be investigated by moving around the source with an operating sound level meter. Because a single RV generator may be characterized as a noise

source radiating 180 degrees laterally from a wall, a minimum of two measurements should be made at 90 and 45 degrees from the exposed side of a single generator. If the measured sound level varies more than 1-2 dB for adjacent angular positions, then more positions should be investigated.

In line with the above recommendations, free field measurement conditions should be checked at 25 and 50 foot distances. If the sound pressure level decays at the expected rate of 6 dB at the larger of these two distances, free field conditions have likely been met. If there are nearby RVs, walls, buildings, or other structures, then the measurement location may need to be adjusted. For example, if there is such an object within 4 to 7.5 meters (15 to 25 feet of the measurement position for a single generator, then the measurement angle or distance should likely be changed.

If a measurement of a large group of RV generators is desired, then the following procedure should be used: A minimum of two measurements should be made. One measurement should be made at a central location that offers a representative level experienced by most occupants of the campground. The representative location may be found by walking around with an operating sound level meter and choosing the location that appears to offer an apparent average noise level. The second measurement should be made at an outside location, where the farthest operating generator is between 2 to 3 times distant from the closest operating generator. In both cases, however, the distances to the closest generators should be noted, the total number of operating generators should be estimated along with any other prominent noise sources, and a site drawing should be made.

Isolating Sources:

In the case of RV generators, it may be important to ensure that other operating noise sources are not influencing the generator noise measurement. For example, if an air conditioner (A/C) or pump is running concurrently, it may not be trivial to measure the RV generator noise by itself. In order to assess the generator noise level by itself, it may be necessary to wait until the A/C compressor stops or to use decibel (logarithmic) subtraction.

Ambient Influence:

In order to ensure that the RV generator measurement is not unduly influenced by the background ambient sound level, the ambient should be measured and documented before and after noise source measurements are made. Ideally, the ambient should be captured at the desired RV generator measurement location when the noise source is not operating, but if this is not possible, one should move a sufficient distance from the noise source where the ambient is expected to be the same as at the noise source location. In all cases, noise source measurements should be checked to ensure that overall sound levels with the noise source operating are at least 10 dB higher than the measured ambient sound level with the noise source not operating. To the extent feasible, this should apply to as many measured one third octave bands as possible.

Site Documentation:

All measurement noise source locations, measurement distances, and times should be clearly documented in a site drawing sketch. Relevant information, such as generator manufacturer, model number, power rating, and serial number, if readily available, should be documented for each noise source. If the generator make and model cannot be documented, then the RV brand,

model and year, should be noted; however, because generators may change with model year or more frequently, the RV make and model may not be reliable documentation for determining the generator specifications. Onsite data logging sheets are highly recommended.

Instrument settings:

Unless otherwise specified by regulation or standard, the sound level meter should be set for A-weighting and fast response at a minimum rate of 20 samples per second. In addition, unweighted one-third octave spectral data should be acquired. These basic settings should provide adequate information for typical RV generator measurements.

OIL AND GAS OPERATION NOISE

Measurement Considerations:
The goal in this example case is proposed to be measurement of oil and gas drilling noise in Colorado and specifically, such as may be found near national park units such as the Great Sand Dunes National Park and Preserve.

Measurement Preparation:
A basic noise measurement procedure for oil and gas operations is included in Section 802 Noise Abatement of the Colorado Aesthetic and Noise Control Regulations. The goal of the rule is to identify noise sources related to oil and gas operations that impact surrounding landowners and implement mitigation measures that bring the oil and gas facilities into compliance.

Noise Source Parameters:
A preliminary assessment reveals that oil and gas operations can consist of multiple phases, including exploration, drilling/development, production, and decommissioning/reclamation. Thus, a noise impact due to oil and gas operations could be composed of varying contributions from each of these phases.

Noise Generation Mechanisms and Operating Conditions:
The total noise from an oil and gas operation will depend on the operating phase and the number/type of noise sources present during that phase. The drilling/development phase is widely considered to be one of the most dynamic. Development may involve the construction of well pads, access roads, gathering pipelines, wellhead compressors, separators, dehydrators, storage tanks, reserve pits, flare pits, and the drilling and completion of wells. Noise sources may include large power generators, pumps, compressors, separators, and dehydrators.

Noise Source Operation:
With oil and gas drilling, many noise sources will require special expertise to operate, permission to access, and safety controls. The appropriate personnel/authorities should be contacted in advance of the measurement.

Measurement Procedure:
Due to the diversity of noise sources, Section 802 Noise Abatement of the Colorado Aesthetic and Noise Control Regulations includes language on representative conditions in Section 802 (c)(4).

Measurement Setup:
A microphone height of 4 feet is specified. A microphone windscreen is required. Sound level measurements over minimum 15 minute sample durations are required. The sampling periods should be continuous or spaced out over a day to capture noise data during both daytime and nighttime periods.

Measurement Locations:
Source directivity of an oil and gas drilling operation should be investigated by moving around the site with an operating sound level meter. A minimum of four measurements should be made at equally spaced angles of 90 degrees. If the measured sound level varies more than 1-2 dB for adjacent angular positions, then more positions should be investigated.

According to per Section 802 (c)(1) of the Noise Abatement of the Colorado Aesthetic and Noise Control Regulations, measurements should be made at a distance of 350 feet from the primary noise sources. However, the ambient should also be considered per per Section 802 (c)(5). If the measured noise levels are not a minimum of 10 dB higher than the ambient per the Ambient Influence section below, then they should be made at a closer distance per Section 802 (c)(1).

Isolating Sources:
In the case of oil and gas operation, the specific operating noise sources must be known in order to ensure they are representative per Section 802 (c)(4) and so that the extent to which each may be influencing the overall measurement is adequately understood. For example, if an air conditioner (A/C) or pump is running concurrently, it may not be trivial to measure the RV generator noise by itself. In order to assess the generator noise level by itself, it may be necessary to wait until the A/C compressor stops or to use decibel (logarithmic) subtraction.

Ambient Influence:
In order to ensure that the oil and gas operation measurement is not unduly influenced by the background ambient sound level, the ambient should be measured and documented before and after noise source measurements are made. Ideally, the ambient should be captured at the oil and gas site measurement location when the noise sources are not operating, but if this is not possible, one should move a sufficient distance from the noise source where the ambient is expected to be the same as at the noise source location. In all cases, noise source measurements should be checked to ensure that overall sound levels with the noise source operating are at least 10 dB higher than the measured ambient sound level with the noise source not operating. To the extent feasible, this should also apply to as many measured one third octave bands as possible.

Site Documentation:
All measurement noise source locations, measurement distances, and times should be clearly documented in a site drawing sketch. Relevant information, such as noise source type, manufacturer, model number, power rating, and serial number, if readily available, should be documented for each noise source. If the generator make and model cannot be documented, then the RV brand, model and year, should be noted; however, because generators may change with model year or more frequently, the RV make and model may not be reliable documentation for determining the generator specifications. Onsite data logging sheets are highly recommended.

Instrument settings:
Unless otherwise specified by regulation or standard, the sound level meter should be set for A-weighting and fast response at a minimum rate of 20 samples per second. In addition, unweighted one-third octave spectral data should be acquired. These basic settings should provide adequate information for most purposes except for capture of very loud, impulsive sounds which may require impulse response and potentially, extended frequency response.

Noise Source Measurement Checklist:

- ☐ Write statement of purpose, including expectation of intended data use, i.e. informative, model predictive, regulatory, or enforcement-related. What metrics are required?

  _____
  _____
  _____

- ☐ What federal, state, county, municipal, or other local noise regulations exist?

  _____
  _____
  _____

- ☐ What measurement standards are specified by or are of highest relevance per regulations?

  _____
  _____
  _____

- ☐ What are the contributing noise sources and their general directivities/characteristics?

  _____
  _____
  _____

- ☐ What are the operating conditions and modes of concern? How do the operating conditions affect the relative intensity and characteristics of each noise source?

  _____
  _____
  _____

- ☐ Are the identified measurement standards or practices compatible with existing site characteristics, and are they capable of adequately addressing the unique operating conditions and characteristics of the noise source(s) to be measured? Do they adequately capture the needed metric(s)? Identify any deviations from the measurement standard procedure that may be required for the site, operating conditions, or desired metrics.

  _____
  _____
  _____

- ☐ Whether or not post-processing or other metric analysis is required after data acquisition is performed, what supporting data needs to noted and/or logged during the measurement? How detailed should the site drawing be? If necessary, create a logging sheet (see example below) which can facilitate capture of important supporting data such as measurement location, distance, noise source identification data (e.g. make/model), relevant operating conditions (e.g. throttle, speed, and/or load), event times, and noise source counts.

  _____
  _____
  _____

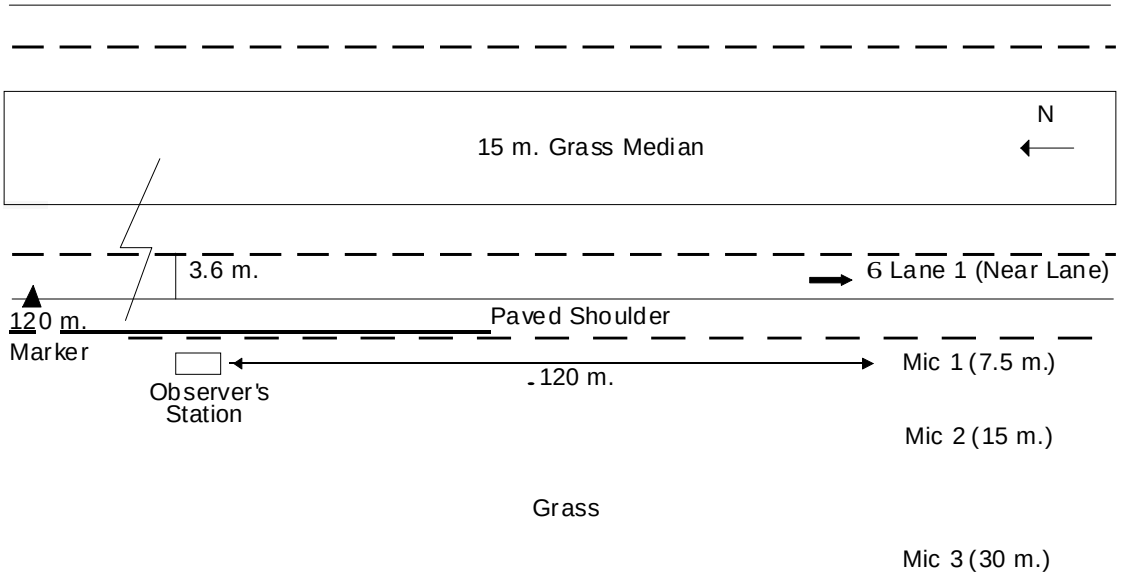
Sample instrumentation log

Site #: 1	Date: 5/1/96	Location: I-95 S	
Item #:	Quantity:	Instrument Type:	Serial #:
1	1	Brüel & Kjær 4155 Microphone	43515
2	1	Brüel & Kjær 4155 Microphone	43516
3	1	Larson Davis 820 Sound Level Meter	33768
4	1	Larson Davis 820 Sound Level Meter	33769
5	1	Cetec Ivie Random Noise Generator	501
6	2	Microphone Simulators	N/A
7	3	Brüel & Kjær 0237 Windscreens	N/A
8	1	Wind-Cup Anemometer	N/A
9	1	Sling Psychrometer	N/A
10	1	100-Ft Tape Measure	N/A
11	10	9-Volt Batteries	N/A
12	1	Flashlight	N/A
13	10	D-Cell Batteries	N/A

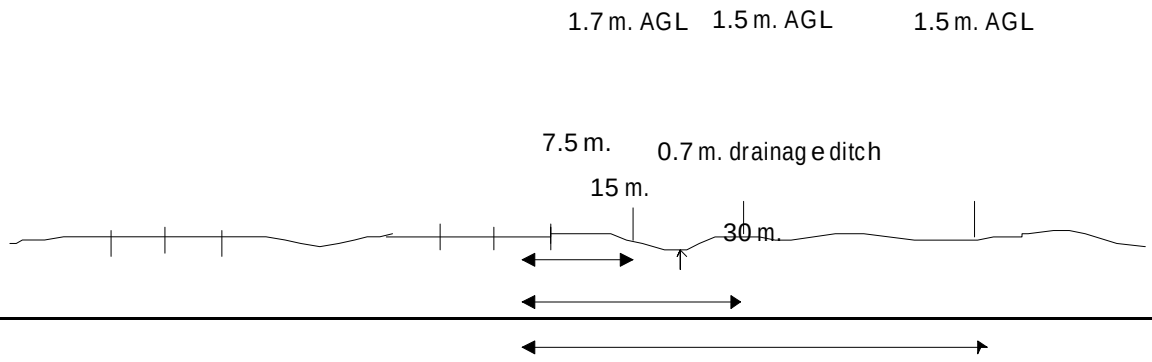
Sample site drawing

Site #: 1	Date: 5/1/96	Location: I-95 S	Observer: Joe
Lane Dir: South	Site Surface: Soft	Nearby Landmark: I-495 Junction	
Grade: 0%	Pavement Type: Concrete	Distance to Landmark: 0.25 km	

Plan View:



Elevation View:



Sample meteorological data log

Site #: 1	Date: 5/1/96	Location: I-95 S		Observer: Joe		
Time:	Temperature, °C (dry bulb):	Temperature, °C (wet bulb):*	Relative Humidity (%):	Wind Speed (km/h):	Wind Dir	Cloud Cover Class
8:00	15	13	89.8	5	W-E	2
8:15	16	13	86.6	5	W-E	2
8:30	16	14	86.7	5-7	W-E	2
8:45	16	14	86.7	5-7	W-E	2
9:00	16	14	86.7	5	W-E	3
9:15	16	15	91.5	5	W-E	3
9:30	17	15	89.9	0	N/A	3
9:45	17	16	89.9	0	N/A	3
10:00	18	16	83.9	0-5	W-E	3
10:15	19	16	83.3	0-5	W-E	3
10:30	19	16	83.3	0-5	W-E	3
10:45	19	16	83.3	4	W-E	3
11:00	20	16	79.7	4	W-E	3
11:15	20	16	79.7	4	W-E	3

Construction equipment noise measurements
Sample acoustic data log

Site #: 1	Date: 5/1/96	Location/Construction Phase: I-95 S /Earthwork				Observer: Joe	
Operating Mode (Check one):	Stationary-Passive	Stationary-Active	Mobile-Passive	Mobile-Active	Equipment Type: Bulldozer	Mic #: 1	Mic Location: 15 m. offset
			T				
Event #:	Time:	Duration (sec):	Sound Level (dB):	Equipment Speed (km/h):	Gain Setting:	Comments:	
PreCal	8:00:31	25.0	N/A	N/A	0		
Cal	8:05:24	20.125	N/A	N/A		Reset SLM	
Dummy	8:09:01	30.125	N/A	N/A			
Pink	8:15:00	31.625	N/A	N/A			
PreCal	9:15:23	22.0	N/A	N/A			
Cal	9:20:15	20.25	N/A	N/A			
1	10:00:07	8.0	56.4	5	+20		
2	10:05:15	10.875	65.7	6			
3	10:09:56	18.9	79.0	5			
4	10:14:37	4.375	58.9	7		No good - dogs barking	
5	10:21:21	7.25	65.0	5			