APPENDIX F

NOISE

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F.0 NOISE

F.1 NOISE ANALYSIS

Appendix F presents a detailed discussion of noise and its effects on people and the environment. An assessment of noise requires a general understanding of how sound is measured and how it affects people in the natural environment. The purpose of this appendix is to address public concerns regarding noise impacts.

Section F.1.1 is a general discussion on the properties of noise. Section F.1.2 summarizes the noise metrics discussed throughout this LEIS. Section F.1.3 provides federal land use compatibility guidelines that are used in analyzing noise impacts. Section F.2 addresses public concerns on potential impacts such as hearing loss, nonauditory health effects, annoyance, speech interference, sleep interference, and noise effects on domestic animals and wildlife. Section F.3 addresses impulsive noise assessment.

F.1.1 General

Noise, often defined as unwanted sound, is one of the most common environmental issues associated with military operations. Of course, aircraft overflight and the use of explosives are not the only sources of noise in an urban, suburban, or even rural environment. Interstate and local roadway traffic, rail, industrial, commercial activities, and neighborhood activities also are sources of noise and can intrude on the everyday quality of life. Nevertheless, noise resulting from military activities are often readily identifiable to those affected by it and are typically singled out for special attention and criticism.

Sound is a physical phenomenon consisting of minute vibrations which travel through a medium, such as air, and are sensed by the human ear. Whether that sound is interpreted as pleasant (for example, music) or unpleasant (for example, aircraft noise) depends largely on the listener's current activity, past experience, and attitude toward the source of that sound. It is often true that one person's music is another person's noise.

The measurement and human perception of sound involves two basic physical characteristics: intensity and frequency. Intensity is a measure of the acoustic energy of the sound vibrations and is expressed in terms of sound pressure. The higher the sound pressure, the more energy carried by the sound and the louder the perception of that sound. The second important physical characteristic is sound frequency which is the number of times per second the air vibrates or oscillates. Low-frequency sounds are characterized as rumbles or roars, while high-frequency sounds are typified by sirens or screeches.

The loudest sounds which can be detected comfortably by the human ear have intensities which are 1,000,000,000,000 times larger than those of sounds which can just be detected. Because of this vast range, any attempt to represent the intensity of sound using a linear scale becomes very unwieldy. As a result, a logarithmic unit known as the dB is used to represent the intensity of a sound. Such a representation is called a sound level.

A sound level of 0 dB is approximately the threshold of human hearing and is barely audible under extremely quiet listening conditions. Normal speech has a sound level of approximately 60 dB. Sound levels above about 120 dB begin to be felt inside the human ear as discomfort and eventually pain at still higher levels.

Because of the logarithmic nature of the decibel unit, sound levels cannot be added or subtracted directly and are somewhat cumbersome to handle mathematically. However, some simple rules of thumb are useful in dealing with sound levels. First, if a sound's intensity is doubled, the sound level increases by 3 dB, regardless of the initial sound level. Thus, for example:

60 dB + 60 dB = 63 dB, and

80 dB + 80 dB = 83 dB.

The total sound level produced by two sounds of different levels is usually only slightly more than the higher of the two. For example:

60.0 dB + 70.0 dB = 70.4 dB.

Because the addition of sound levels behaves differently than that of ordinary numbers, such addition is often referred to as "decibel addition" or "energy addition." The latter term arises from the fact that what we are really doing when we add decibel values is first converting each decibel value to its corresponding acoustic energy, then adding the energies using the normal rules of addition, and finally converting the total energy back to its decibel equivalent.

An important facet of decibel addition arises later when the concept of time-average sound levels is introduced to explain Day-Night Average Sound Level. Because of the logarithmic units, the time-average sound level is dominated by the louder levels which occur during the averaging period. As a simple example, consider a sound level which is 100 dB and lasts for 30 seconds, followed by a sound level of 50 dB which also lasts for 30 seconds. The time-average sound level over the total 60-second period is 97 dB, not 75 dB.

The minimum change in the time-average sound level of individual events which an average human ear can detect is about 3 dB. A change in sound level of about 10 dB is usually perceived by the average person as a doubling (or halving) of the sound's loudness, and this relation holds true for loud sounds and for quieter sounds. A decrease in sound level of 10 dB actually represents a 90 percent decrease in sound intensity but only a 50 percent decrease in perceived loudness because of the nonlinear response of the human ear (similar to most human senses).

Sound frequency is measured in terms of cycles per second (cps), or Hz, which is the preferred scientific unit for cps. The normal human ear can detect sounds which range in frequency from about 20 Hz to about 15,000 Hz. All sounds in this wide range of frequencies, however, are not heard equally well by the human ear, which is most sensitive to frequencies in the 1,000 to 4,000 Hz range. In measuring community noise, this frequency dependence is taken into account by adjusting the very high and very low frequencies to approximate the human ear's generally lower sensitivity to those frequencies as well as the type, or characteristics of the noise. This is called "weighting" and is commonly used in measurements of environmental noise.

Sound levels do not represent instantaneous measurements but rather averages over short periods of time. Two measurement time periods are most common; one second and one-eighth of a second. A measured sound level averaged over one second is called a slow response sound level; one averaged over one-eighth of a second is called a fast response sound level. In general, noise resulting from transportation-type activities is termed "slow-response" type noise, and is measured on an "A-weighted" scale. Noise resulting from a phenomena such as an explosion is termed "fast-response," or impulsive noise, and is measured on a "C-weighted" scale.

F.1.2 Noise Metrics

A "metric" is defined as something "of, involving, or used in measurement." As used in environmental noise analyses, a metric refers to the unit or quantity which quantitatively measures the effect of noise on the environment. Noise studies have typically involved a confusing proliferation of noise metrics as individual researchers have attempted to understand and represent the effects of noise. As a result, past literature describing environmental noise or environmental noise abatement has included many different metrics. Recently, however, various federal agencies involved in environmental noise mitigation have agreed on common metrics for environmental impact analysis documents, and both the DoD and the FAA have specified those which should be used for federal aviation noise assessments. These metrics are as follows.

F.1.2.1 Maximum Sound Level

The highest A-weighted or C-weighted sound level measured during a single event in which the sound level changes value as time goes on is called the L_{max}. The maximum sound level is important in judging the interference caused by a noise event with conversation, TV or radio listening, sleep, or other common activities.

F.1.2.2 Sound Exposure Level

Individual time-varying noise events have two main characteristics; a sound level which changes throughout the event, and a period of time during which the event is heard. Although the L_{max}, described above, provides some measure of the intrusiveness of the event, it alone does not completely describe the total event. The period of time during which the sound is heard is also significant. The SEL combines both of these characteristics into a single metric.

SEL is a logarithmic measure of the total acoustic energy transmitted to the listener during the event. Mathematically, it represents the sound level of the constant sound that would, in one second, generate the same acoustic energy as did the actual time-varying noise event. Since A-weighted noise events (e.g., an aircraft overflight) usually last longer than one second, an A-weighted SEL is usually greater than the L_{max}. Conversely, since a C-weighted noise event (e.g., an explosion) usually lasts less than one second, a C-weighted SEL is usually somewhat less than the L_{max}.

SEL is a composite metric which represents both the intensity of a sound and its duration. It has been well-established in the scientific community that SEL measures noise impacts much more reliably than just L_{max}.

F.1.2.3 Day-Night Average Sound Level

Time-average sound levels are the measurements of sound levels which are averaged over a specified length of time. These levels provide a measure of the average sound energy during the measurement period.

For the evaluation of community noise effects, the Day-Night Average Sound Level (ADNL or CDNL) is used. These metrics average sound levels at a location over a complete 24-hour period, with a 10-dB adjustment added to those noise events which take place between 10:00 p.m. and 7:00 a.m. This 10-dB "penalty" represents the added intrusiveness of sounds which occur during normal sleeping hours, both because of the increased sensitivity to noise during those hours and because ambient sound levels during nighttime are typically about 10 dB lower than during daytime hours.

Ignoring the 10-dB nighttime adjustment for the moment, Day-Night Average Sound Level may be thought of as the continuous sound level which would be present if all of the variations in sound level which occur over a 24-hour period were smoothed out so as to contain the same total sound energy.

Day-Night Average Sound Level provides a single measure of overall noise impact, but does not provide specific information on the number of noise events or the individual sound levels which occur during the day. For example, a Day-Night Average Sound Level of 65 dB could result from a very few noisy events, or a large number of quieter events.

As noted earlier for SEL, Day-Night Average Sound Levels do not represent the sound level heard at any particular time, but rather represent the total sound exposure. Scientific studies and social surveys which have been conducted to appraise community annoyance to all types of environmental noise have found the Day-Night Average Sound Level to be the best measure of that annoyance. Its use is endorsed by the scientific community (ANSI, 1980; ANSI, 1988; EPA, 1972; FICUN, 1980; FICON, 1992).

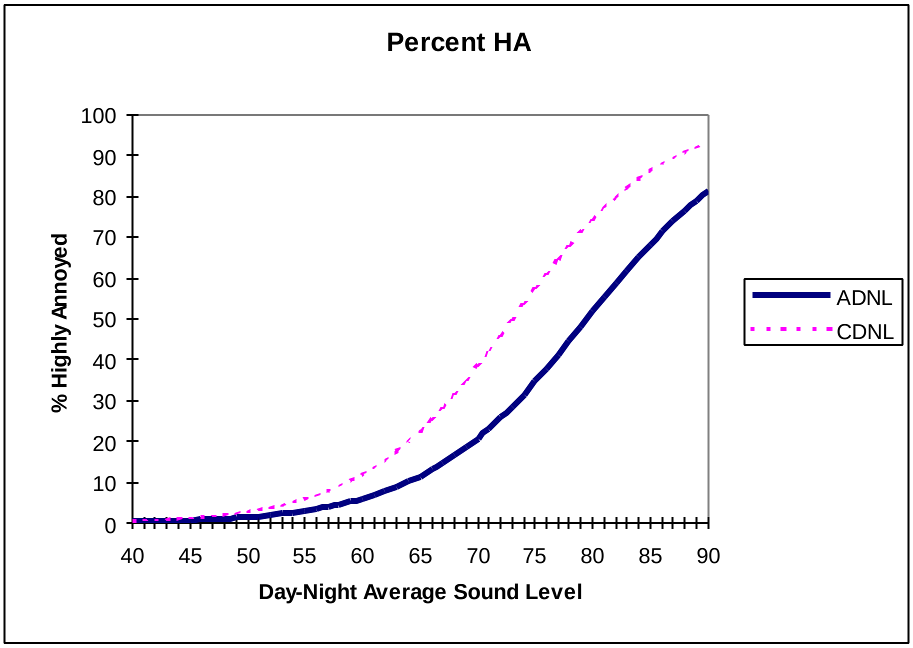
There is, in fact, a remarkable consistency in the results of attitudinal surveys about noise conducted in different countries to find the percentages of groups of people who express various degrees of annoyance when exposed to different levels of Day-Night Average Sound Level. Original studies on annoyance created by A-weighted noise were conducted by T. J. Schultz in 1978 (Schultz, 1978). More recent studies have reaffirmed this basic relationship (Fidell et al., 1991), and have resulted in the development of an updated form of the curve fit (Finegold et al., 1994). The updated fit, which does not differ substantially from the original, is the current preferred form. In general, correlation coefficients of 0.85 to 0.95 are found between the percentages of groups of people highly annoyed and the level of average noise exposure. The correlation coefficients for the annoyance of individuals are relatively low, however, on the order of 0.5 or less. This is not surprising, considering the varying personal factors which influence the manner in which individuals react to noise.

Similar attitudinal research has also been conducted on annoyance associated with C-weighted noise. Again, research has shown that Day-Night Average Sound Levels are the most reliable predictors of levels of community annoyance resulting from impulsive noise events (CHABA, 1981). Probably due to the differences in physical characteristics associated with A- and C-weighted noise, it was found that more people became annoyed at lower Day-Night Average Sound Levels of C-weighted noise as compared to A-weighted noise. Figure F-1 illustrates these differences.

The use of Day-Night Average Sound Level has been criticized recently as not accurately representing community annoyance and land-use compatibility with noise. Much of that criticism stems from a lack of understanding of the basis for the measurement or calculation of ADNL and CDNL. One frequent criticism is based on the inherent feeling that people react more to single noise events and not as much to "meaningless" time-average sound levels.

In fact, a time-average noise metric takes into account both the noise levels of all individual events which occur during a 24-hour period and the number of times those events occur. As described briefly above, the logarithmic nature of the decibel unit causes the noise levels of the loudest events to control the 24-hour average.

As a simple example of this characteristic, consider a case in which only one noise event occurs in daytime during a 24-hour period, creating a sound level of 100 dB for 30 seconds. During the remaining 23 hours, 59 minutes, and 30 seconds of the day, the ambient sound level is 50 dB. The Day-Night



Calculated %HA Points											
DNL	40	45	50	55	60	65	70	75	80	85	90
ADNL	0.4	0.8	2	3	6	12	21	35	52	68	81
CDNL	0.6	1	3	6	12	23	39	57	74	86	93

ADNL % HA = 100/[1+exp(11.13 - 0.14*ADNL)]
CDNL % HA = 100/[1+exp(11.17 - 0.153 * CDNL)]

Figure F-1. Comparison of Persons Highly Annoyed by A- and C-Weighted Average Sound Levels.

Average Sound Level for this 24-hour period is 65.5 dB. Assume, as a second example, that ten such 30-second events occur in daytime hours during the next 24-hour period, with the same ambient sound level of 50 dB during the remaining 23 hours and 55 minutes of the day. The Day-Night Average Sound Level for this 24-hour period is 75.4 dB. Clearly, the averaging of noise over a 24-hour period does not ignore the louder single events and tends to emphasize both the sound levels and number of those events. This is the basic concept of a time-average sound metric, and specifically the Day-Night Average Sound Level.

F.1.3 Land Use Compatibility

As noted above, the inherent variability between individuals makes it impossible to predict accurately how any individual will react to a given noise event. Nevertheless, when a community is considered as a whole, its overall reaction to noise can be represented with a high degree of confidence. As described above, the best noise exposure metric for this correlation is the Day-Night Average Sound Level.

In June 1980, an *ad hoc* FICUN published guidelines (FICUN, 1980) relating Day-Night Average Sound Levels to compatible land uses. This committee was composed of representatives from the DoD, DOT, HUD, EPA, and the Veterans Administration. Since the issuance of these guidelines, federal agencies have generally adopted these guidelines for their noise analyses.

In 1990, a new FICON was formed to review the manner in which noise effects are assessed and presented. This group released its report in 1992 and reaffirmed the use of Day-Night Average Sound Level as the best metric for this purpose (FICON, 1992).

The general guidelines associated with these committee reports have been incorporated into the U.S. Army's Installation Compatible Use Zone (ICUZ) program. Standards are based on Day-Night Average Sound Levels, and thresholds where restrictions begin to be placed on land uses occur at ADNL 65 or CDNL 62.

F.2 NOISE EFFECTS

F.2.1 Hearing Loss

Noise-induced hearing loss is probably the best defined of the potential effects of human exposure to excessive noise. Federal workplace standards for protection from hearing loss allow a time-average level of 90 dB over an 8-hour work period, or 85 dB averaged over a 16-hour period. Even the most protective criterion (no measurable hearing loss for the most sensitive portion of the population at the ear's most sensitive frequency, 4,000 Hz, after a 40-year exposure) suggests a time-average sound level of 70 dB over a 24-hour period (EPA, 1972). Since it is unlikely that persons will be exposed to elevated noise levels 24 hours per day for extended periods of time, there is little possibility of hearing loss below a Day-Night Average Sound Level of 75 dB, and this level is extremely conservative.

F.2.2 Nonauditory Health Effects

Nonauditory health effects of long-term noise exposure, where noise may act as a risk factor, have never been found to occur at levels below those protective against noise-induced hearing loss, described above. Most studies attempting to clarify such health effects have found that noise exposure levels established for hearing protection will also protect against any potential nonauditory health effects, at least in workplace conditions. The best scientific summary of these findings is contained in the lead paper at the National Institutes of Health Conference on Noise and Hearing Loss, held on January 22 to 24, 1990 in Washington, D.C., which states the following:

> The nonauditory effects of chronic noise exposure, when noise is suspected to act as one of the risk factors in the development of hypertension, cardiovascular disease, and other nervous disorders, have never been proven to occur as chronic manifestations at levels below these criteria (an average of 75 dBA for complete protection against hearing loss for an 8-hour day). At the recent (1988) International Congress on Noise as a Public Health Problem, most studies attempting to clarify such health effects did not find them

> at levels below the criteria protective of noise-induced hearing loss, and even above these criteria, results regarding such health effects were ambiguous. Consequently, one comes to the conclusion that establishing and enforcing exposure levels protecting against noise-induced hearing loss would not only solve the noise-induced hearing loss problem but also any potential nonauditory health effects in the work place (von Gierke, 1990 [parenthetical wording added for clarification.])

Although these findings were directed specifically at noise effects in the workplace, they are equally applicable to noise effects in the community environment. Research studies regarding the nonauditory health effects of noise are ambiguous, at best, and often contradictory. Yet, even those studies which purport to find such health effects use time-average noise levels of 75 dB and higher for their research.

In summary, there is no scientific basis for a claim that potential health effects exist for aircraft time-average sound levels below 75 dB.

F.2.3 Annoyance

The primary effect of noise on exposed communities is one of annoyance. Noise annoyance is defined by the EPA as any negative subjective reaction on the part of an individual or group (EPA, 1972). As noted in the discussion of Day-Night Average Sound Level above, community annoyance is best measured by that metric.

Because the EPA Levels Document (EPA, 1972) identified a DNL of 55 dB as ". . .requisite to protect public health and welfare with an adequate margin of safety," it is commonly assumed that 55 dB should be adopted as a criterion for community noise analysis. From a noise exposure perspective, that would be an ideal selection. However, financial and technical resources are generally not available to achieve that goal. Most agencies have identified ADNL 64 and CDNL 62 as a criterion which protects those most impacted by noise, and which can often be achieved on a practical basis.

F.2.4 Speech Interference

Speech interference associated with noise is a primary cause of annoyance to individuals on the ground. The disruption of routine activities such as radio or television listening, telephone use, or family conversation gives rise to frustration and irritation. The quality of speech communication is also important in classrooms, offices, and industrial settings and can cause fatigue and vocal strain in those who attempt to communicate over the noise. Research has shown that the use of the SEL metric will measure speech interference successfully, and that a SEL exceeding 65 dB will begin to interfere with speech communication.

F.2.5 Sleep Interference

Sleep interference is another source of annoyance associated with noise. This is especially true because of the intermittent nature and content of transportation and impulsive noise, which is more disturbing than continuous noise of equal energy and neutral meaning.

Sleep interference may be measured in either of two ways. "Arousal" represents actual awakening from sleep, while a change in "sleep stage" represents a shift from one of four sleep stages to another stage of lighter sleep without actual awakening. In general, arousal requires a somewhat higher noise level than does a change in sleep stage.

Some guidance is available in judging sleep interference. The EPA identified an indoor Day-Night Average Sound Level of 45 dB as necessary to protect against sleep interference (EPA, 1972). Assuming a very conservative structural noise insulation of 20 dB for typical dwelling units, this corresponds to an outdoor Day-Night Average Sound Level of 65 dB as minimizing sleep interference.

F.2.6 Noise Effects on Domestic Animals and Wildlife

Animal species differ greatly in their responses to noise. Each species has adapted, physically and behaviorally, to fill its ecological role in nature, and its hearing ability usually reflects that role. Animals rely on their hearing to avoid predators, obtain food, and communicate with and attract other members of their species. Noise may mask or interfere with these functions. Secondary effects may include nonauditory effects similar to those exhibited by humans—stress, hypertension, and other nervous disorders. Tertiary effects may include interference with mating and resultant population declines.

There are available many scientific studies regarding the effects of noise on wildlife and some anecdotal reports of wildlife "flight" due to noise. Few of these studies or reports include any reliable measures of the actual noise levels involved. However, in the absence of definitive data on the effect of noise on animals, the Committee on Hearing, Bioacoustics, and Biomechanics of the National Research Council has proposed that protective noise criteria for animals be taken to be the same as for humans (National Research Council, 1977).

F.2.7 Noise Effects on Structures

Normally, the most sensitive components of a structure to noise are the windows and, infrequently, the plastered walls and ceilings. An evaluation of the peak sound pressures impinging on the structure is normally sufficient to determine the possibility of damage. In general, at sound levels above 130 dB, there is the possibility of the excitation of structural component resonances. While certain frequencies (such as 30 Hz for window breakage) may be of more concern than other frequencies, conservatively, only sounds lasting more than one second above a sound level of 130 dB are potentially damaging to structural components (National Research Council, 1977).

A recent study, directed specifically at low-altitude, high-speed aircraft showed that there is little probability of structural damage from such operations (Sutherland, 1989). One finding in that study is that sound levels at damaging frequencies (e.g., 30 Hz for window breakage or 15 to 25 Hz for whole-house response) are rarely above 130 dB.

Noise-induced structural vibration may also cause annoyance to dwelling occupants because of induced secondary vibrations, or "rattle," of objects within the dwelling—hanging pictures, dishes, plaques, and bric-a-brac. Window panes may also vibrate noticeably when exposed to high levels of noise, causing homeowners to fear breakage. In general, such noise-induced vibrations occur at sound levels above those considered normally incompatible with residential land use. Thus, assessments of noise exposure levels for compatible land use should also be protective of noise-induced secondary vibrations.

F.2.8 Noise Effects on Historical and Archaeological Sites

Because of the potential for increased fragility of structural components of historical buildings and other historical sites, noise may affect such sites more severely than newer, modern structures. Again, there are few scientific studies of such effects to provide guidance for their assessment.

One study involved the measurements of sound levels and structural vibration levels in a superbly restored plantation house, originally built in 1795, and now situated approximately 1,500 feet from the centerline at the departure end of Runway 19L at Washington Dulles International Airport. These measurements were made in connection with the proposed scheduled operation of the supersonic Concorde airplane at Dulles (Wesler, 1977). There was special concern for the building's windows, since roughly half of the 324 panes were original. No instances of structural damage were found. Interestingly, despite the high levels of noise during Concorde takeoffs, the induced structural vibration levels were actually less than those induced by touring groups and vacuum cleaning within the building itself.

F.3 IMPULSIVE NOISE ASSOCIATED WITH THE DETONATION OF HIGH EXPLOSIVES

McGregor Range supports the delivery of live ordnance. This section of this appendix discusses the methodology used to quantify these acoustic effects, and develop capacity assessments which indicate the levels of ordnance use that can be supported without creating environmental acoustic impacts outside the boundaries of the range.

The noise associated with the detonation of high explosives is impulsive in nature, and its main components emphasize very low frequencies, often equal to or less than 100 cps (Hz). Since the noise is impulsive, it is measured on the "C-weighted" scale.

The noise model used for this impact assessment is the NAPS developed for the U.S. Army's Atmospheric Sciences Laboratory, WSMR, New Mexico. The NAPS model is a single-event model that generates sound intensity contours based on meteorological conditions that influence the speed of sound and the propagation of sound. NAPS calculates SPL in dBP based on the amount of explosive material normalized to an equivalent weight of trinitrotoluene (TNT). The model uses a ray trace approach that takes into account spherical spreading, atmospheric absorption, and refraction (Smith et al., 1991).

SPLs spread spherically in the absence of wind. This spreading is normally calculated so that for each doubling of distance from the noise source, the SPL decreases by 6 dB (U.S. Army, 1995h).

The atmosphere absorbs sound energy. However, this absorption is not a significant factor for sounds with frequencies of 500 Hz or less. For example, at 10 Hz, approximately 0.04 dB is lost to atmospheric absorption over a 10 kilometer (km) distance, and for a sound at 100 Hz, about 3.5 dB is attenuated over the same distance. Conversely, for a sound at 1,000 Hz, approximately 100 dB would be lost over the same 10 km. What is important is that when sound created by the detonation of high explosives is considered, since these sounds normally occur in the 5 to 10 Hz range or less, atmospheric absorption has little effect (U.S. Army, 1995h).

Ground impedance is a measurement of the extent to which an acoustic wave traveling through the atmosphere would be absorbed into the ground upon contact, or reflected back into the atmosphere. Soft sands, such as those found on beaches, and fresh, powdery snow are examples of ground with low impedance, where most of the acoustic energy is absorbed, and little is reflected. Medium impedance surfaces reflect a majority of the acoustic energy, and most lands within the United States are classified as medium impedance surfaces for sounds of 200 Hz or less. Surfaces such as water, concrete, and mountains with rock outcroppings are illustrative of high impedance surfaces which will reflect all, or almost all of the acoustic energy (U.S. Army, 1995h).

As previously discussed, actual SPLs are usually "weighted" to more closely approximate the response of the human ear to the sound. The most commonly used metrics for characterizing impulsive noise are based on the "C-weighting" protocol, which represses SPLs under 100 and over 3,000 Hz. Field measurements suggest that unweighted SPLs are 22 to 25 dB higher than C-weighted SPLs for high explosive events (Kerry and Ford, 1994).

The dBP metric utilized by the NAPS model does not reflect the cumulative effects from multiple noise events over time. The preferred metric for assessing the annoyance level associated with multiple impulsive noise events associated with use of high explosives in the CDNL. CDNL is calculated:

$$CDNL = CSEL + (10 Log_{10}(N_D + 10 N_N)) - 49.4$$

Equation 1

Where:

CSEL = C-weighted Sound Exposure Level for a single event.
ND = Number of events per 24-hour period occurring between 7:00 a.m. and 10:00 p.m. (daytime).
NN = Number of events per 24-hour period occurring between 10:01 p.m. and 6:59 a.m. (nighttime).
Multiplying the events by 10 assigns a 10 dB penalty for noise events at night.
49.4 = 10 Log 10 times 86,400 (the number of seconds in a 24-hour period).

Source: U.S Army, CERL, 1986.

Further, the relationship between dBP and CSEL is given by the following:

$$CSEL \cong dBP - 25$$

Equation 2

Source: Kerry and Ford, 1994.

Therefore, a dBP-dependent equation for CDNL may be written as follows, and, based on substitution:

$$CDNL \cong dBP - 25 + (10 Log_{10}(N_D + 10 N_N)) - 49.4$$

Equation 3a

and

$$CDNL \cong dBP + (10 Log_{10}(N_D + 10 N_N)) - 74.4$$

Equation 3b

For land use planning purposes, CDNL 62 is generally considered to be equivalent to ADNL 65. That is, residential development is normally compatible with noise levels below CDNL 62.

Although the NAPS model outputs contours in unweighted SPL, this output can be used to represent CDNL values. As shown above, if one noise event occurred during daytime in a 24-hour period, then the CDNL value would be 74.4 dB lower than the NAPS calculated SPL (Equations 3a and 3b). Therefore:

$$CDNL\,62 = 136.4dBP$$

Equation 4

As the number of events from the same source increase above one per 24-hour period, the value of:

$$10Log_{10}\left(N_D + 10N_N\right)$$

may be subtracted from 136.4 to obtain the SPL contour value from NAPS that is equivalent to CDNL 62. For multiple sources contributing different sound levels at given distances, source-specific CDNL values would be summed logarithmically to obtain total cumulative CDNL.

Alternatively, if it is desired to keep exposure of a given location at or below a specific CDNL value, and the unweighted SPL value is known for that location, the number of permissible day-equivalent events that can occur may be calculated by:

$$AntiLog_{10}\left(\frac{136.4 - SPL}{10}\right) = N_{DE}$$

Equation 5

As indicated, Equation 5 provides the number of day-equivalent events. Dividing the result by 10 would provide the number of night-permissible events. Mixed day and night events may be determined using a ratio of one night event to ten day events. For example, 30 day events would equal 3 night events, or 10 day events and 2 night events.