APPENDIX E

NOISE

ACRONYMS, ABBREVIATIONS, AND SYMBOLS

%N2	Percent RPM at Engine Compressor 2nd stage
%NC	Percent Core RPM
7SFG(A)	7th Special Forces Group (Airborne)
ADNL	A-weighted Day-Night Average Sound Level, as measured in decibels
AFB	Air Force Base
AFRL	Air Force Research Laboratory
AGL	Above Ground Level
ANSI	American National Standards Institute
ASA	Acoustical Society of America
CDNL or L_{Cdn}	C-weighted Day-Night Average Sound Level
CFR	Code of Federal Regulations
CHABA	Committee on Hearing, Bioacoustics and Biomechanics
CSEL	C-weighted Sound Exposure Level, as measured in decibels
CTIT	Centigrade Turbine Inlet Temperature
dB	Decibels
dBA or dB(A)	A-Weighted Decibels
dBC	C-Weighted Decibels
DNL	Day-Night Average Sound Level
DoD	Department of Defense
EIS	Environmental Impact Statement
ETR	Engine Thrust Request
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FICAN	Federal Interagency Committee on Aviation Noise
FICON	Federal Interagency Committee on Noise
FICUN	Federal Interagency Committee on Urban Noise
HE	High-Explosive
Hz	Hertz
kHz	Kilohertz
L_{Cdn}	C-weighted Day-Night Average Sound Level, as measured in decibels
L_{dn}	Day-Night Average Sound Level, as measured in decibels
L_{dnmr} or DNL_{mr}	Onset-Rate Adjusted Monthly Day-Night Average Sound Level
L_{eq}	Equivalent Sound Level
LFO load	Liftoff Loaded
L_{max}	Maximum Sound Level
L_{pk}	Peak Sound Level
m	Meter
mm	Millimeter
MOA	Military Operating Area
NIDCD	National Institute on Deafness and Other Communication Disorders
NLR	Noise Level Reduction
NRC/NAS	National Research Council/National Academy of Sciences
NZ I, II, or III	Noise Zone I, II, or III
PK_{15}(met)	Peak Noise Exceeded by 15 Percent of Firing Events
psf	Pounds Per Square Foot
RCNM	Roadway Construction Noise Model
RCW	Red-cockaded Woodpecker
RPM	Revolutions per Minute
SARNAM2	U.S. Army's Small Arms Range Noise Assessment Model
SEL	Sound Exposure Level
SEL_r	Onset-Rate Adjusted Sound Exposure Level
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
USEPA	U.S. Environmental Protection Agency

NOISE IMPACT ASSESSMENT METHODS

Noise impacts can be quantified based on objective effects (such as hearing loss or damage to structures) or subjective judgments (such as community annoyance). Thus, assessment of impacts requires a combination of physical measurement of noise as well as assessment of psycho-acoustic and socio-acoustic effects. Noise is defined subjectively as being any unwanted sound. The following sections discuss how noise is described, the potential effects that noise may have on its receivers, and the methods by which noise levels are predicted.

Characteristics of Sound

Sounds can be generally characterized based on three physical characteristics: amplitude, frequency, and duration. Amplitude is a measure of the strength of the sound and is directly measured in terms of the pressure of a sound wave. Frequency, which is perceived as "pitch," is the number of times per second sound causes air molecules to vibrate. Duration is simply how long the sound lasts. All three characteristics are critical to determining impacts of a particular sound source and are discussed in more detail below.

Amplitude. The loudest sounds that can be comfortably heard by humans have acoustic energy one trillion times the acoustic energy of the quietest sounds that humans detect. Because of this vast range in magnitude, attempts to represent sound amplitude by direct expression of sound pressure are unwieldy. In addition, human hearing is proportional rather than absolute (i.e., detecting whether one sound is twice as big as another rather than detecting whether one sound is a given number of pressure units bigger than another). Sound is, therefore, usually represented on a logarithmic scale, reflecting the way in which it is perceived, using a unit named the decibel (dB).

The threshold (level at which an effect starts) of human hearing is approximately 0 dB, and the threshold of discomfort is approximately 120 dB. Under laboratory conditions, differences in sound level of 1 dB can be detected by the human ear. In the community, the smallest change in average noise level that can be detected 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 quieter sounds. A decrease in sound level of 10 dB actually represents a 90 percent decrease in sound <u>intensity</u> but only a 50 percent decrease in perceived <u>loudness</u> because of the nonlinear response of the human ear.

Figure E-1 is a chart of A-weighted sound levels from typical sounds. Some sounds (air conditioner, vacuum cleaner) are continuous, and their levels are constant for some time. Other sounds (automobile, heavy truck) are the maximum sound during a vehicle

pass-by. Some sounds (urban daytime, urban nighttime) are averages over some extended period.

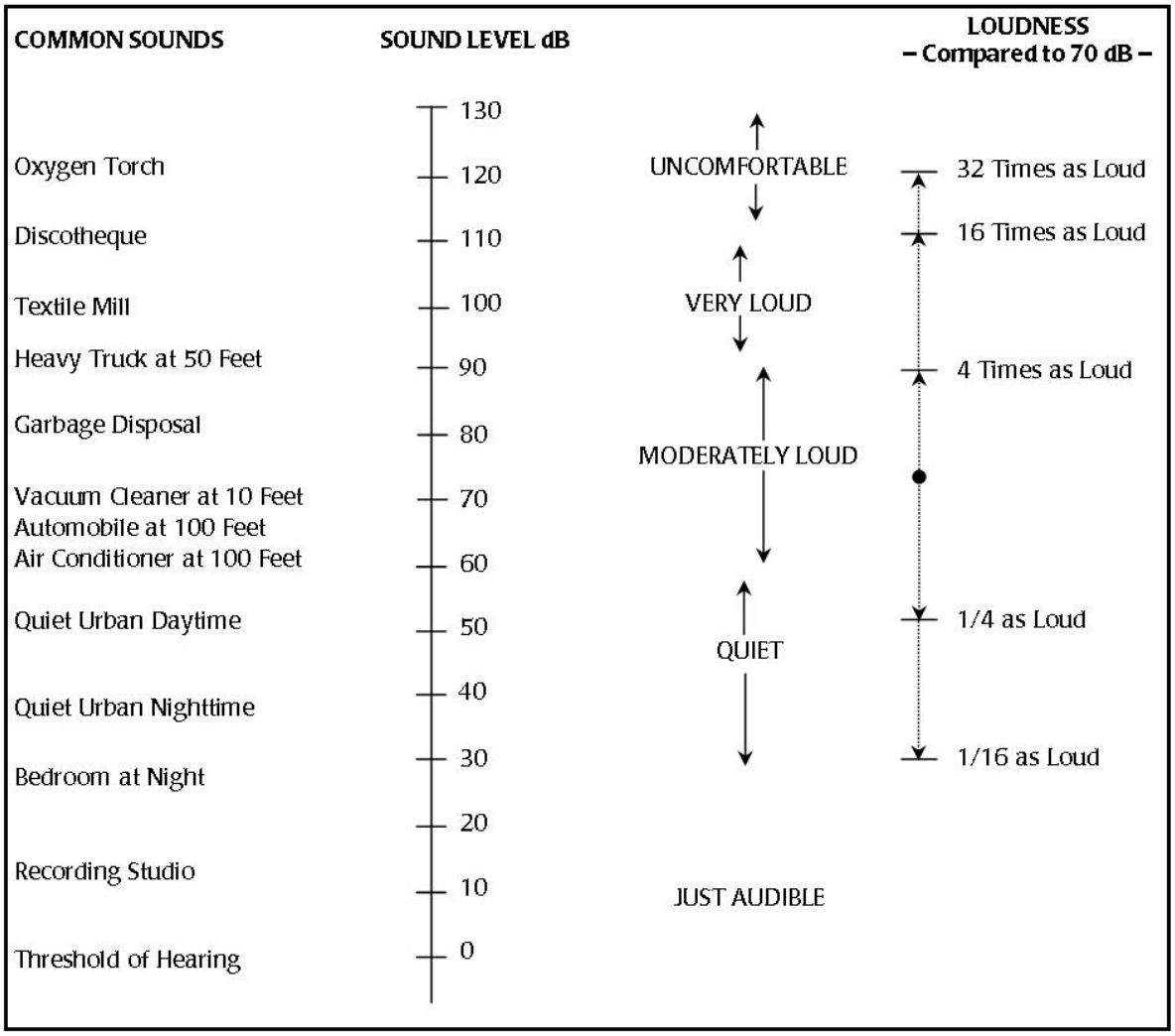

Figure E-1. Typical A-Weighted Sound Levels of Common Sounds

Because of the logarithmic nature of the decibel scale, sound levels do not add and subtract 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 only increases by 3 dB, regardless of the initial sound level. 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:

$$60.0\ dB + 70.0\ dB = 70.4\ dB.$$

Sound pressure of what is perceived as being continuous sound actually varies greatly over minute increments of time, so it is customary to deal with sound levels that represent averages over time. Levels presented as instantaneous (i.e., as might be read from the dial of a sound level meter) are based on averages of sound energy over either 1/8 second (fast) or 1 second (slow). This distinction becomes important when discussing sounds whose peak noise level lasts for only a short time, such as sonic booms.

Frequency. The normal human ear can hear frequencies from about 20 hertz (Hz) to about 20,000 Hz. It is most sensitive to sounds in the 1,000 to 4,000 Hz range. When measuring community response to noise, it is common to adjust the frequency content of the measured sound to correspond to the frequency sensitivity of the human ear. This adjustment is called A-weighting (American National Standards Institute [ANSI], 1988). Sound levels that have been so adjusted are referred to as A-weighted and may be denoted dBA or dB(A). However, because use of A-weighting to express sound level is so prevalent, it can normally be assumed that dB is equivalent to dBA or dB(A). In this study, sound levels are reported in dB and are A-weighted unless otherwise specified.

A-weighting is appropriate for sounds that are perceived by the ear. Impulsive sounds, such as sonic booms, thunder, and other sudden "booming" sounds, are perceived by more than just the ear; listeners may *feel* this type of sound as well as hearing it. When experienced indoors, this type of sound may cause rattling of the structure and its contents. Because A-weighting would de-emphasize the intrusive low-frequency component of this type of sound, C-weighting (ANSI, 1988) is applied, which only de-emphasizes frequencies that are outside the range of human hearing (about 20 Hz to 20,000 Hz). In this study, and in accordance with standard methodologies, C-weighted sound levels are used for the assessment of sonic booms, blasts from high explosives, and other impulsive sounds. C-weighting is specifically denoted as dBC whenever it is used in this study.

Duration. Sound varies over time at almost all locations. Sound can be classified into four basic categories that define its basic time pattern:

- Ambient. Ambient sound is the ever-present collection of background sounds at any given place. Ambient sound can be strictly natural, such as frogs and

cicadas in the deep woods; strictly mechanical, such as street noise in a busy city; or a combination of both, like sounds occurring in the suburbs. It is important to consider the existing ambient soundscape because what exists already has much to do with how annoying people will find a new sound. For example, the hum of a generator may be tolerated much better by those already living in an area with high mechanized ambient noise than those living in the far woods.

- Steady-state. Steady-state sound is of a consistent level and spectral content; examples are sounds originating from ventilation or mechanical systems that operate more or less continuously. From a military perspective, generators and aircraft run-up sounds are the most prominent steady-state sounds, and as a rule, the longer a steady-state sound persists, the more annoyed people will be.
- Transient Sound. Transient sound has a clearly defined beginning and end, rising above the background and then fading back into it. Transient sounds are typically associated with "moving" sound sources such an aircraft overflight or a single vehicle driving by, and they usually last for only a few minutes at the most. The annoyance caused by transient sounds is dependent upon both the maximum sound level and the duration.
- Impulsive Sound. Impulsive sound is of short duration (typically less than one second), high intensity, abrupt onset, rapid decay, and often a fast-changing spectral composition. It is characteristically associated with such sources as explosions, impacts, the discharge of firearms, the passage of supersonic aircraft (sonic booms), and many industrial processes. Impulsive sound can be particularly annoying because of the "startle factor" where the receiver has no warning that exposure to a loud sound is imminent.

Noise Metrics

To communicate sound levels, the Department of Defense (DoD) uses three general types of noise-measuring descriptors, or metrics: (1) measuring the highest sound level occurring during a noise event, (2) combining the maximum level of that single event with its duration, and (3) describing the noise environment based on the total noise energy received over a specified length of time. The metrics used in this environmental impact statement (EIS) are described below.

Maximum Sound Level. This metric, denoted as L_{max}, is the highest sound level measured (using time integration of either 1/8 second or 1 second) during a noise event. For a listener observing an aircraft overflight, the noise level starts at the ambient or background noise level, rises to the maximum level as the aircraft flies closest to the observer, and returns to the background level as the aircraft recedes into

the distance. L_{max} decreases as altitude or distance from the observer increases and varies according to the type of aircraft, airspeed, and power setting. Table E-1 lists the L_{max} sound levels for representative fighter aircraft at various distances from the listener.

Table E-1. Representative Maximum Sound Level (L_{max}) in Decibels under the Flight Track for Aircraft at Various Altitudes in a Military Operating Area

			Altitude in Feet Above Ground Level[1]						
Aircraft Type	**Airspeed**	**Power Setting[2]**	**300**	**500**	**1,000**	**2,000**	**5,000**	**10,000**	**20,000**
F-15C	520	81% NC	119	114	107	99	86	74	57
F-35	500	Est% ETR*	136	131	124	116	103	90	75
F-16C	450	87% NC	109	104	96	89	77	66	54
F-18E/F	360	83% N2	111	106	99	90	77	65	51
C-130H	170	970 CTIT	96	92	85	77	66	57	47
H-60	140	LFO load	91	86	79	72	61		

(1) Level flight, steady high-speed conditions. Used standard acoustical conditions (70°F and 59% relative humidity).
(2) Power setting metrics vary from engine to engine; ETR = engine thrust request, F-16 engine is PW-229; RPM = revolutions per minute, %NC = percent core RPM; %N2 = percent RPM at engine compressor stage #2; CTIT =Centigrade Turbine Inlet Temperature; LFO load = liftoff loaded, 140 knots indicated air speed.
* estimated data based on differential of F-16 on takeoff versus airspace conditions and ratioed to F-35 conditions

Peak Sound Level. For impulsive sounds, the true instantaneous peak sound pressure level, which lasts for only a fraction of a second, is important in determining impacts. For sonic booms, this is the peak pressure of the shock wave. This pressure is usually presented in physical units of pounds per square foot (psf). Peak sound levels are not frequency weighted. Sometimes it is represented on the decibel scale, with the symbol L_{pk}. Because the amount of sound energy that reaches a receiver from a given noise event varies so much with specific atmospheric conditions, a special metric is sometimes used to account for this variability. The PK_{15}(met) metric represents the peak sound level that will not be exceeded 85 percent of the time with a given noise event. This metric is useful for expressing, in general terms, how loud an area will get while a particular weapon is firing.

Sound Exposure Level. The Sound Exposure Level (SEL) metric is a single-number representation of a noise energy dose for an entire aircraft overflight. This measure takes into account the effect of both the duration and intensity of a noise event by summing the noise energy from each second in an event, which typically lasts several seconds into a single second. Table E-2 shows SEL and L_{max} noise levels for several aircraft types at various altitudes.

Table E-2. Representative A-Weighted SEL in Decibels under the Flight Track for the Aircraft at Various Altitudes in a Military Operating Area

			Altitude in Feet Above Ground Level[1]						
Aircraft Type	Airspeed	Power Setting[2]	300	500	1,000	2,000	5,000	10,000	20,000
F-15C	520	81% NC	116	112	107	101	90	80	65
F-35	500	Est% ETR*	133	129	121	112	99	87	74
F-16C	450	87% NC	109	105	100	94	84	76	65
F-18E/F	360	83% N2	113	110	104	97	86	76	65
C-130H	170	970 CTIT	100	97	91	86	77	70	61
H-60	140	LFO load	95	92	87	82	73	65	56

(1) Level flight, steady high-speed conditions. Used standard acoustical conditions (70°F and 59% relative humidity).
(2) Power setting metrics vary from engine to engine; ETR = engine thrust request, F-16 engine is PW-229; RPM = revolutions per minute, %NC = percent core RPM; %N2 = percent RPM at engine compressor stage #2; CTIT = _Centigrade Turbine Inlet Temperature; LFO load = Liftoff Loaded 140 knots indicated air speed.
* Estimated data based on differential of F-16 on takeoff versus airspace conditions and ratioed to F-35 conditions

SEL is useful for comparing aircraft that move at different speeds. As an example, fighter aircraft tend to create a high L_{max}, but their noise level tends to drop off quickly as the plane moves away from the listener at high speed. On the other hand, cargo-type aircraft tend to be quieter but generally take more time to move past the listener and out of earshot. It is important to remember that SEL does not directly represent the sound level heard at any given time, but rather, it provides a measure of the exposure of the entire acoustic event. SEL is useful for predicting several noise impacts, including sleep disturbance and animal escape response. SEL can be computed for C-weighted levels (appropriate for impulsive sounds), and the results denoted as CSEL. SEL for A-weighted sound is sometimes denoted as ASEL. Within this study, SEL is used for A-weighted sounds and CSEL for C-weighted.

Onset-rate Adjusted Sound Exposure Level. When an aircraft is flying fast and low to the ground, listeners may experience a very quick rise in noise as it flies overhead. To account for the resulting "surprise effect," a penalty of up to 11 dB is applied to the SEL value for the overflight. SEL values with this "onset-rate adjustment" are denoted as SEL_r.

Equivalent Sound Level. To summarize noise levels over longer periods of time, total sound is represented by the equivalent sound level (L_{eq}). L_{eq} is the average sound level over some time period (often an hour or a day, but any explicit time span can be specified), with the averaging being done on the same energy basis as used for SEL. SEL and L_{eq} are closely related, differing by (1) whether they are applied over a specific time period or over an event, and (2) whether the duration of the event is included or divided out. Just as SEL has proven to be a good measure of the noise impact of a single event, L_{eq} has been established to be a good measure of the impact of a series of events during a given time period. Cumulative noise metrics, such as L_{eq}, are useful because they represent a complicated set of noise events with a single number.

Day-Night Average Sound Level (DNL or L_{dn}). Noise tends to be more intrusive at night than during the day. This effect is accounted for by applying a 10-dB penalty to events that occur after 10:00 PM and before 7:00 AM. DNL is similar to L_{eq} except DNL has a nighttime penalty added. DNL is the community noise metric recommended by the U.S. Environmental Protection Agency (USEPA) (USEPA, 1974) and has been adopted by most federal agencies (Federal Interagency Committee on Noise [FICON], 1992). It has been widely accepted that DNL correlates well with community response to noise (Schultz, 1978; Finegold et al., 1994). This correlation is presented below in the section titled "Noise Impacts on Humans." Furthermore, DNL has also been proven applicable to infrequent events (Fields and Powell, 1985) and to rural populations exposed to sporadic military aircraft noise (Stusnick et al., 1992, 1993).

It was noted earlier that, for impulsive sounds, C-weighting is more appropriate than A-weighting. The DNL can be computed for C-weighted noise and is denoted CDNL or L_{Cdn}. This procedure has been standardized, and impact interpretive criteria similar to those for DNL have been developed (Committee on Hearing, Bioacoustics and Biomechanics [CHABA], 1981).

Onset-rate Adjusted Monthly Day-Night Average Sound Level. Aircraft operations in military airspace (such as ranges, military operating areas [MOAs], and Warning Areas) generate a noise environment somewhat different from other community noise environments. Overflights are sporadic, occurring at random times and varying from day to day and week to week. This situation differs from most community noise environments, where noise tends to be continuous or patterned. Individual military overflight events also differ from typical community noise events in that noise from a low-altitude, high-airspeed flyover can have a sudden onset. To represent these differences, the conventional DNL metric is adjusted to account for the "surprise" effect of the sudden onset of aircraft noise events on humans (Plotkin et al., 1987; Stusnick et al., 1992, 1993). For aircraft exhibiting a rate of increase in sound level (called onset rate) of from 15 to 150 dB per second, an adjustment or penalty ranging from 0 to 11 dB is added to the normal SEL. Onset rates above 150 dB per second require an 11 dB penalty, while onset rates below 15 dB per second require no adjustment. In addition, because of the irregular occurrences of aircraft operations, the number of average daily operations is determined by using the calendar month with the highest number of operations. The Onset-Adjusted Monthly Day-Night Average Sound Level is denoted as L_{dnmr}.

Noise Impacts on Humans

Annoyance. The primary effect of aircraft noise on exposed communities is one of annoyance. Noise annoyance is defined by the USEPA as any negative subjective reaction on the part of an individual or group (USEPA, 1974).

Studies of community annoyance resulting from numerous types of environmental noise show that DNL correlates well with impact. Schultz (1978) showed a consistent relationship between DNL and percentage of the impacted population that was "highly annoyed" (9 or 10 on a scale of 1–10, with 10 being the most annoyed). A more recent study reaffirmed and updated this relationship (Finegold et al., 1994) (Table E-3). 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 that influence the manner in which individuals react to noise. Nevertheless, findings substantiate that, as a whole, communities' level of annoyance to aircraft noise is represented fairly reliably using DNL.

Table E-3. Relationship between Annoyance and DNL

Noise Exposure (DNL)	Percent of Population Highly Annoyed
<65	<12
65-70	12-21
70-75	22-36
75-80	37-53
80-85	54-70
>85	>71

Source: Finegold et al., 1994

It is important to note that DNL does not represent the sound level heard at any particular time, but rather, it represents a cumulative sound exposure. DNL accounts for the sound level of individual noise events, the duration of those events, and the number of events. Its use is endorsed by the scientific community and is recognized as the standard methodology by most federal agencies (ANSI, 1980, 1988; USEPA, 1974; Federal Interagency Committee on Urban Noise [FICUN], 1980; FICON, 1992).

There are several commonly recognized average noise level thresholds that are based on expected community reaction. The first is DNL of 65 dB. This is a level most commonly used for noise planning purposes and represents a compromise between community impact and the need for activities like aviation, which unavoidably result in noise. Areas exposed to DNL above 65 dB are generally not considered suitable for residential use. The second is DNL of 55 dB, which was identified by the USEPA as a level ". . . requisite to protect public health and welfare with an adequate margin of safety," (USEPA, 1974). 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 DNL of 65 dB as a criterion that protects those most impacted by noise, and that can often be achieved on a practical basis (FICON, 1992). This corresponds to about 12 percent of the exposed population

being highly annoyed. The third is DNL of 75 dB. This is the lowest level at which adverse health effects could be credible (USEPA, 1974).

Community annoyance from sonic booms, firing of heavy weaponry, and other impulsive noises is predicted using CDNL (C-weighted day-night average sound level). The correlation between CDNL and annoyance has been estimated, based on community reaction to impulsive sounds over several years (CHABA, 1981). Values of the C-weighted equivalent to the Schultz curve are different than that of the Schultz curve itself. Table E-4 shows the relationship between percentage of the population highly annoyed, DNL, and CDNL. If both continuous and impulsive noise occurs in the same area, impacts are assessed separately for each.

Table E-4. Relation Between Annoyance, DNL, and CDNL

CDNL	% Highly Annoyed	DNL
48	2	50
52	4	55
57	8	60
61	14	65
65	23	70
69	35	75

Source = CHABA, 1981

Speech Interference. Disruptions of speech by noise and other activities that require listening generally last a few seconds but are often found to be very annoying. It is difficult to predict speech intelligibility during an individual noise event, such as a flyover, because people automatically raise their voices as background noise increases. A study (Pearsons et al., 1977) suggests that people can communicate acceptably in background A-weighted noise levels of 80 dB, but that some speech interference occurs when background noise levels exceed 65 dB. Typical home insulation can reduce the noise levels experienced by 20 dB or more, thereby reducing speech interference. 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 SEL metric is a good predictor of speech interference, and that an SEL exceeding 65 dB will begin to interfere with speech communication.

Sleep Interference. Sleep interference is another source of annoyance associated with aircraft noise. This is especially true because of the intermittent nature and content of aircraft 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.

An analysis sponsored by the Air Force summarized 21 published studies concerning the effects of noise on sleep (Pearsons et al., 1989). The analysis concluded that a lack of reliable in-home studies, combined with large differences among the results from the various laboratory studies, did not permit development of an acceptably accurate assessment procedure. The noise events used in the laboratory studies and in contrived in-home studies were presented at much higher rates of occurrence than would normally be experienced. None of the laboratory studies were of sufficiently long duration to determine any effects of habituation (getting accustomed to the sound), such as that which would occur under normal community conditions. A follow-on study of sleep interference in people's own homes (Ollerhead, 1992) showed very little disturbance from aircraft noise.

A 1984 publication reviewed the probability of arousal or behavioral awakening in terms of SEL (Kryter, 1984). Figure E-2, extracted from Figure 10.37 of Kryter (1984), indicates that an indoor SEL of 65 dB or lower should awaken less than 5 percent of those exposed.

In 1997, the Federal Interagency Committee on Aviation Noise (FICAN) adopted an interim guideline for sleep awakening prediction. The new curve, based on studies in England (Ollerhead et al., 1992) and at two U.S. airports (Los Angeles International and Denver International), concluded that the incidence of sleep awakening from aircraft noise was less than identified in a 1992 study (FICON, 1992). Using indoor single-event noise levels represented by SELs, potential sleep awakening can be predicted using the curve presented in Figure E-3. Typically, homes in the United States provide 15 dB of sound attenuation with windows open and 25 dB with windows closed and air conditioning operating. Hence, the outdoor SEL of 107 dB would be 92 dB indoors with windows open and 82 dB indoors with windows closed and air conditioning operating.

Using Figure E-3, the potential sleep awakening would be 15 percent with windows open and 10 percent with windows closed in the above example. The results of these studies, depicted in Figure E-2 and Figure E-3, do not include any habituation over time by sleeping subjects. In a real-world scenario, habituation would reduce the number of awakenings caused by a given set of noise events over the long term. Nevertheless, this provides a reasonable guideline for assessing sleep interference and corresponds to similar guidance for speech interference, as noted above.

There is some controversy associated with the recent studies, so a conservative approach should be taken in judging sleep interference. Based on older data, the USEPA identified an indoor DNL of 45 dB as necessary to protect against most sleep

interference (USEPA, 1974). Assuming a very conservative structural noise insulation of 20 dB for typical dwelling units, this corresponds to an outdoor DNL of 65 dB or less as a goal for residences, which also corresponds well to the general guideline for assessing speech interference. Annoyance that may result from sleep disturbance is accounted for in the calculation of DNL, which includes a 10-dB penalty for each sortie occurring after 10:00 PM or before 7:00 AM.

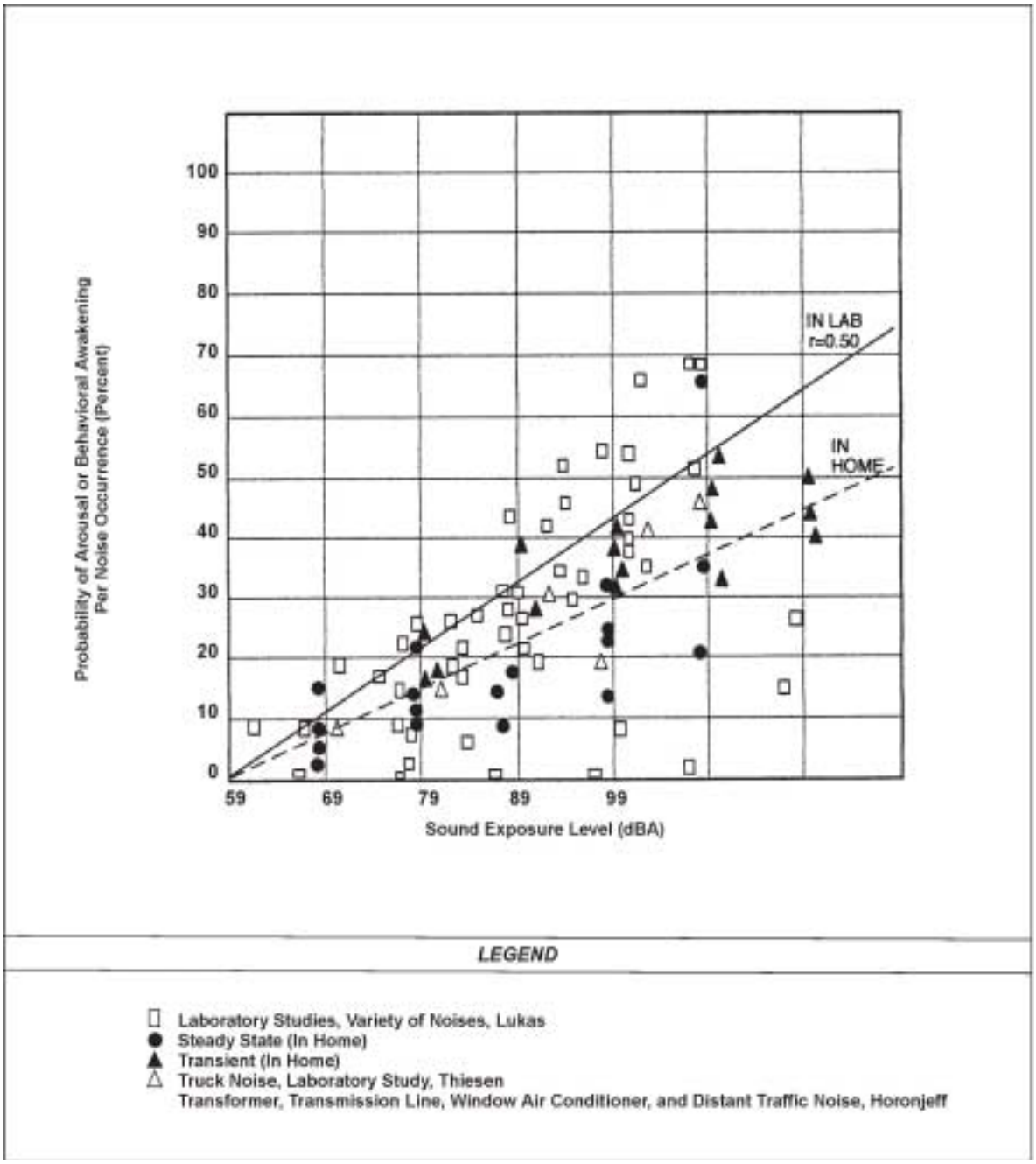

Figure E-2. Probability of Arousal or Behavioral Awakening in Terms of Sound Exposure Level

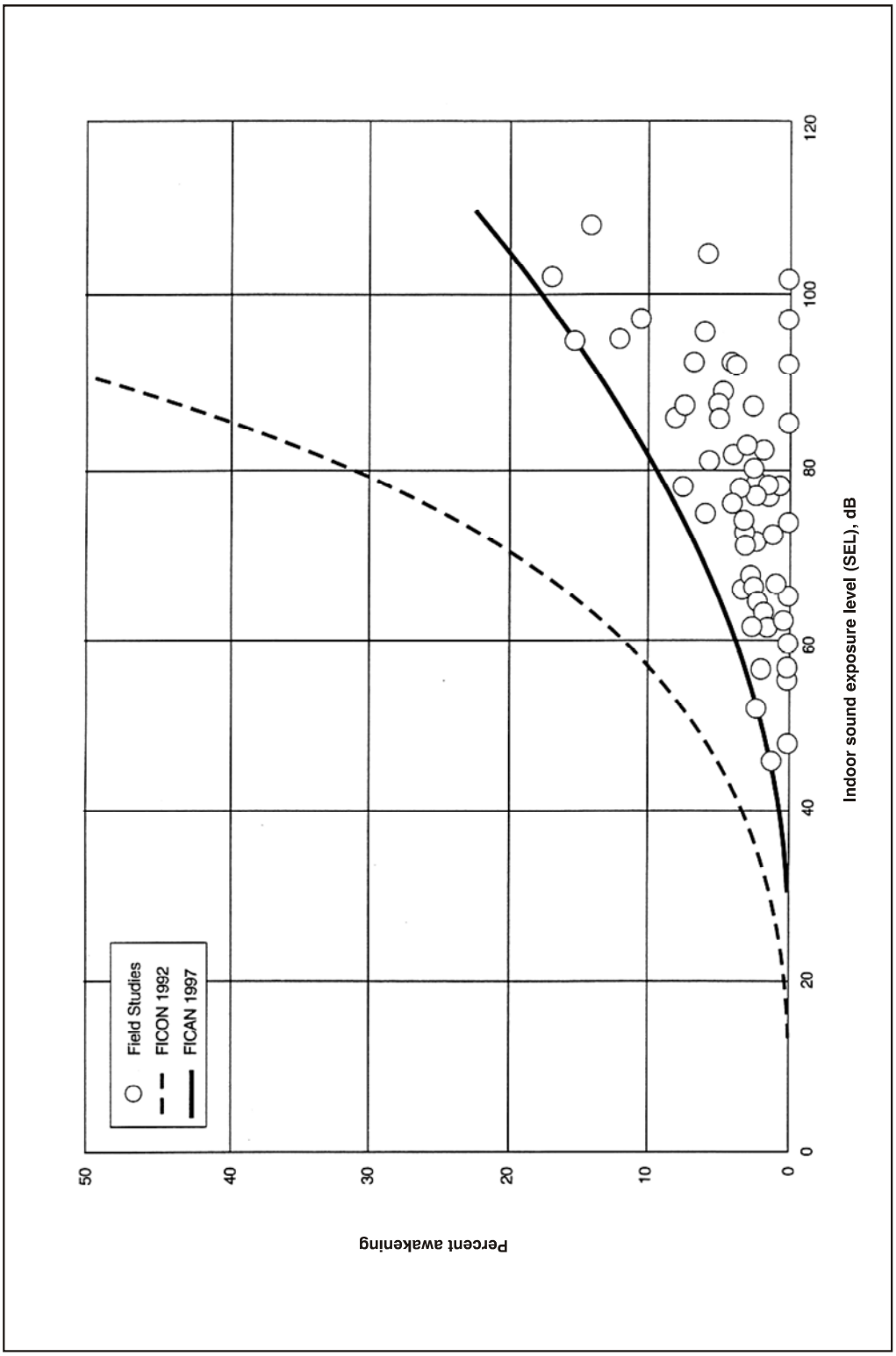

Figure E-3. Recommended Sleep Disturbance Dose-Response Relationship

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 DNL or L_{dnmr} for military overflights. Impulsive noise can be assessed by relating CDNL to an "equivalent annoyance" DNL.

In June 1980, the ad hoc Federal Interagency Committee on Urban Noise (FICUN) published guidelines (FICUN, 1980) relating DNL to compatible land uses. This committee was composed of representatives from the DoD; Transportation, Housing and Urban Development; USEPA; and the Veterans Administration. Since issuance of the FICUN guidelines, federal agencies have generally adopted the guidelines for their noise analyses. These guidelines are reprinted in Table E-5. The designations contained in the table do not constitute a federal determination that any use of land covered by the program is acceptable or unacceptable under federal, state, or local law. The responsibility for determining the acceptable and permissible land uses, and the relationship between specific properties and specific noise contours, rests with the local authorities. The Federal Aviation Administration (FAA) determinations under Part 150 are not intended to substitute federally determined land uses for those determined to be appropriate by local authorities in response to locally determined needs and values in achieving noise-compatible land uses.

It is important to note that the guidelines presented in Table E-5 are recommendations, and compliance with them is not mandatory.

Table E-5. Land Use Compatibility with Yearly Day-Night Average Sound Levels

Land Use	Yearly Day-Night Average Sound Level (DNL) in Decibels					
	Below 65	65–70	70–75	75–80	80–85	Over 85
Residential Use						
Residential, other than mobile and transient lodgings	Y	N[1]	N[1]	N	N	N
Mobile home parks	Y	N	N	N	N	N
Transient lodgings	Y	N[1]	N[1]	N[1]	N	N
Public Use						
Schools	Y	N[1]	N[1]	N	N	N
Hospitals and nursing homes	Y	25	30	N	N	N
Churches, auditoriums, and concert halls	Y	25	30	N	N	N
Government services	Y	Y	25	30	N	N
Transportation	Y	Y	Y[2]	N[3]	Y[4]	Y[4]
Parking	Y	Y	Y[2]	Y[3]	Y[4]	N

Continued on the next page…

Table E-5. Land Use Compatibility with Yearly Day-Night Average Sound Levels, Cont'd

Land Use	Yearly Day-Night Average Sound Level (DNL) in Decibels					
	Below 65	65–70	70–75	75–80	80–85	Over 85
Commercial Use						
Offices—business and professional	Y	Y	25	30	N	N
Wholesale and retail—building materials, hardware, and farm equipment	Y	Y	Y[2]	Y[3]	Y[4]	N
Retail trade—general	Y	Y	25	30	N	N
Utilities	Y	Y	Y[2]	Y[3]	Y[4]	N
Communication	Y	Y	25	30	N	N
Manufacturing and Production						
Manufacturing—general	Y	Y	Y[2]	Y[3]	Y[4]	N
Photographic and optical	Y	Y	25	30	N	N
Agriculture (except livestock) and forestry	Y	Y[6]	Y[7]	Y[8]	Y[8]	Y[8]
Livestock farming and breeding	Y	Y[6]	Y[7]	N	N	N
Mining and fishing, resource production and extraction	Y	Y	Y	Y	Y	Y
Recreational						
Outdoor sports arenas and spectator sports	Y	Y[5]	Y5[6]	N	N	N
Outdoor music shells, amphitheaters	Y	N	N	N	N	N
Nature exhibits and zoos	Y	Y	N	N	N	N
Amusements, parks, resorts, and camps	Y	Y	Y	N	N	N
Golf courses, riding stables, and water recreation	Y	Y	25	30	N	N

Data for this table were taken from the Standard Land-Use Coding Manual.
Y (YES) = land use and related structures compatible without restrictions.
N (No) = land use and related structures are not compatible and should be prohibited.
NLR = Noise Level Reduction (outdoor to indoor) to be achieved through incorporation of noise attenuation into the design and construction of the structure.
25, 30, or 35 dB = land use and related structures generally compatible; measures to achieve NLR of 25, 30, or 35 dB must be incorporated into design and construction of structures.

(1) Where the community determines that residential or school uses must be allowed, measures to achieve outdoor-to-indoor NLR of at least 25 dB and 30 dB should be incorporated into building codes and be considered in individual approvals. Normal residential construction can be expected to provide an NLR of 20 dB; thus, the reduction requirements are often stated as 5, 10, or 15 dB over standard construction and normally assume mechanical ventilation and closed windows year-round. However, the use of NLR criteria will not eliminate outdoor noise problems.
(2) Measures to achieve NLR 25 dB must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise-sensitive areas, or where the normal noise level is low.
(3) Measures to achieve NLR 30 dB must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise-sensitive areas, or where the normal noise level is low.
(4) Measures to achieve NLR 35 dB must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise-sensitive areas, or where the normal noise level is low.
(5) Land use compatible provided special sound reinforcement systems are installed.
(6) Residential buildings require an NLR of 25.
(7) Residential buildings require an NLR of 30.
(8) Residential buildings not permitted.

Hearing Loss. Noise-induced hearing loss is probably the best defined of the potential effects of human exposure to excessive noise, and a considerable amount of data on hearing loss has been collected and analyzed. It has been well-established that continuous exposure to high noise levels, with no hearing protection in place, will damage human hearing (USEPA, 1974). Hearing loss is generally interpreted as the shifting to a higher sound level of the lowest sound level that can be heard (i.e., sound must be louder to be heard). This change can be either temporary or permanent.

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 (29 Code of Federal Regulations [CFR] 1910.95). The USEPA has stated that a time-average sound level of 70 dB L_{eq} over a 24-hour period is safe (USEPA, 1974). At that noise level, less than a 5 dB noise-induced permanent threshold shift can be expected for the most sensitive portion of the population at 4,000 Hz (the ear's most sensitive frequency) after 40 years of exposure. Since it is unlikely that airport neighbors will remain outside their homes 24 hours per day for extended periods of time, there is little possibility of hearing loss below a DNL of 75 dB, and this threshold is extremely conservative.

Studies on community hearing loss from exposure to aircraft flyovers near airports showed that there is no danger, under normal circumstances, of hearing loss due to aircraft noise (Newman and Beattie, 1985). Hearing loss is considered to be extremely unlikely when instantaneous noise levels do not exceed 80 dB (National Institute on Deafness and Other Communication Disorders [NIDCD], 2002) Commercial airport traffic is commonly much more continuous and frequent than at military airfields. Air traffic at commercial/civilian airports is also substantially more frequent and generally lower in altitude than in MOAs or Warning Areas. In MOAs and Warning Areas, military aircraft fly at varied altitudes, rarely fly over the same point on the ground repeatedly during a short period, and operations occur sporadically over a day. These factors make it unlikely that an increase in hearing loss would occur (Thompson, 1997). The conclusion of no risk to hearing loss as a result of even low-altitude flight noise is also supported by a 1992 laboratory study that measured changes in human hearing from noise representative of low-flying aircraft on military training routes (Nixon et al., 1993). In this study, participants were first subjected to four overflight noise exposures at A-weighted levels of 115 dB to 130 dB. One-half of the subjects showed no change in hearing levels, one-fourth had a temporary 5-dB *increase* in sensitivity (the people could hear a 5-dB wider range of sound than before exposure), and one-fourth had a temporary 5-dB *decrease* in sensitivity (the people could hear a 5-dB narrower range of sound than before exposure). In the next phase, participants were subjected to a single overflight at a maximum level of 130 dB for eight successive exposures, separated by 90 seconds or until a temporary shift in hearing was observed. The temporary hearing threshold shifts resulted in the participants hearing a wider range of sound but within 10 dB of their original range.

Effects on Children. The effect of aircraft noise on children is a controversial area. Certain studies indicate that, in certain situations, children are potentially more sensitive to noise compared to adults. For example, adults average roughly 10 percent better than young children on speech intelligibility tests in high noise environments (Acoustical Society of America [ASA], 2000). Some studies indicate that noise negatively impacts classroom learning (e.g., Shield and Dockrell, 2008).

In response to noise-specific and other environmental studies, Executive Order 13045, *Protection of Children from Environmental Health Risks and Safety Risks* (1997), requires federal agencies to ensure that their policies, programs, and activities address environmental health and safety risks and to identify any disproportionate risks to children. While the issue of noise impacts on children's learning is not fully settled, in June 2002 ANSI released a new classroom acoustics standard entitled "Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools" (ANSI S12.60-2002). At present, complying with the standard is voluntary in most locations. Essentially, the criteria states that when the noisiest hour is dominated by noise from such sources as aircraft, the limits for most classrooms are an hourly average A-weighted sound level of 40 dB, and the A-weighted sound level must not exceed 40 dB for more than 10 percent of the hour. For schools located near airfields, indoor noise levels would have to be lowered by 35–45 dBA relative to outdoor levels (ANSI, 2002).

Non-auditory Health Effects. Non-auditory health effects of long-term noise exposure, where noise may act as a risk factor, have not been found to occur at levels below those protective against noise-induced hearing loss (as 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 non-auditory health effects, at least in workplace conditions. The lead paper at the National Institutes of Health Conference on Noise and Hearing Loss, held on 22–24 January 1990 in Washington, DC, stated the following: "The non-auditory 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 eight-hour day)." At the 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, it can be concluded that establishing and enforcing exposure levels to protect against noise-induced hearing loss would not only solve the noise-induced hearing loss problem but also any potential non-auditory health effects in the work place (von Gierke, 1990).

Although these findings were directed specifically at noise effects in the work place, they are equally applicable to aircraft noise effects in the community environment.

Research studies regarding the non-auditory health effects of aircraft noise are ambiguous, at best, and often contradictory. Yet, even those studies that purport to find such health effects use time-average noise levels of 75 dB and higher for their research.

The potential for noise to affect physiological health, such as the cardiovascular system, has been speculated; however, no unequivocal evidence exists to support such claims (Harris, 1997). Conclusions drawn from a review of health effect studies involving military low-altitude flight noise, with its unusually high maximum levels and rapid rise in sound level, have shown no correlation to cardiovascular disease (Schwartze and Thompson, 1993). Since the F-35 would fly predominantly at high altitudes, even less concern exists for such health effects. Additional unsupported claims include flyover noise that produces increased mortality rates, adverse effects on the learning ability of middle- and low-aptitude students, aggravation of post-traumatic stress syndrome, increased stress, increase in admissions to mental hospitals, and adverse effects on pregnant women and the unborn fetus (Harris, 1997). Harris' comments are based on a report by The Health Council of The Netherlands (1996). That study discusses two epidemiological studies that looked at the hearing abilities of children whose mothers had been exposed to occupational noise during pregnancy. The results were conditionally qualified by the committee concluding "…that equivalent sounds levels of 85 dB(A) or higher during an 8-hour working day appear to be detrimental to the hearing of the unborn child," but then they also recommended that further research be undertaken to verify that conclusion.

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

Aircraft Noise Effects on Structures. Normally, the most sensitive components of a structure to airborne 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 resonance. 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 (CHABA, 1977).

One study, directed specifically at low-altitude, high-speed aircraft, showed that there is little probability of structural damage from such operations (Sutherland, 1989). Sound levels at damaging frequencies (e.g., 30 Hz for window breakage or 15 to 25 Hz for whole-house response) produced by most military aircraft 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 (such as hanging pictures,

dishes, plaques, and bric-a-brac) within the dwelling. Window panes may also vibrate noticeably when exposed to high levels of airborne noise, causing homeowners to fear breakage. In general, such noise-induced vibrations occur at sound levels above those considered normally compatible with residential land use. Thus, assessments of noise exposure levels for compatible land use should also be protective of noise-induced secondary vibrations.

Sonic Boom Effects on Structures. Sonic booms are commonly associated with structural damage. Most damage claims are for window panes, glass and plaster. Table E-6 summarizes the threshold of damage that might be expected at various overpressures. There is a large degree of variability in damage experience, and much of the damage depends on the pre-existing condition of a structure. Breakage data for glass, for example, spans a range of two to three orders of magnitude at a given overpressure. While glass can suffer damage at low overpressures, as shown in Table E-6, laboratory tests of glass (White, 1972) have shown that properly installed window glass will not break at overpressures below 10 pounds psf, even when subjected to repeated booms. In general, structural damage from sonic booms should be expected only for overpressures above 10 psf.

Table E-6. Possible Damage to Structures from Sonic Booms

Sonic Boom Overpressure Nominal (psf)	Type of Damage	Item Affected
0.5 - 2	Plaster	Fine cracks; extension of existing cracks, with more in ceilings, over door frames, between some plaster boards.
	Glass	Rarely shattered, either partial or extension of existing.
	Roof	Slippage of existing loose tiles/slates; sometimes new cracking of old slates at nail hole.
	Damage to outside walls	Existing cracks in stucco extended.
	Bric-a-brac	Items carefully balanced or on edges can fall; fine glass, such as large goblets, can fall and break.
	Other	Dust falls in chimneys.
2 - 4	Glass, plaster, roofs, ceilings	Failures would have been difficult to forecast in terms of their existing, localized condition. Nominally in good condition.
4 - 10	Glass	Regular failures within a population of well-installed glass; industrial as well as domestic greenhouses.
	Plaster	Partial ceiling collapse of good plaster; complete collapse of very new, incompletely cured, or very old plaster.
	Roofs	High probability rate of failure in nominally good state, slurry-wash; some chance of failures in tiles on modern roofs; light roofs (bungalow) or large area can move bodily.
	Walls (out)	Old, free standing, but in fairly good condition, can collapse.
	Walls (in)	Inside ("party") walls known to move at 10 psf.

Continued on the next page…

Table E-6. Possible Damage to Structures from Sonic Booms, Cont'd

Sonic Boom Overpressure Nominal (psf)	Type of Damage	Item Affected
Greater than 10	Glass	Some good glass will fail regularly to sonic booms from the same direction. Glass with existing faults could shatter and fly. Large window frames move.
	Plaster	Most plaster affected.
	Ceilings	Plaster boards displaced by nail popping.
	Roofs	Most slate/slurry roofs affected, some badly; large roofs having good tile can be affected; some roofs bodily displaced causing gale-end and will-plate cracks; domestic chimneys dislodged if not in good condition.
	Walls	Internal party walls can move even if carrying fittings such as hand basins or taps; secondary damage due to water leakage.
	Bric-a-brac	Some nominally secure items can fall; e.g., large pictures, especially if fixed to party walls.

Source: Haber and Nakaki, 1989

Noise Effects on Historical and Archaeological Sites. Aircraft noise may affect historical sites more severely than newer modern structures because of the potential for increased fragility of structural components of historical buildings and other historical sites. There are limited scientific studies of such effects to provide guidance for their assessment.

One study involved the measurement 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.

As noted above for the effects of noise-induced vibrations of normal structures, assessments of noise exposure levels for normally compatible land uses should also be protective of historic and archaeological sites.

NOISE IMPACTS MODELING

Aircraft Noise

Subsonic Aircraft Noise. An aircraft in subsonic flight emits noise from two sources: the engines and flow noise around the airframe. To estimate noise impacts on the ground, the DoD first measures noise from each aircraft in several flight configurations in straight and level flight at a reference altitude above an array of microphones. These measurements are stored in the NOISEFILE database. Next, this information on aircraft source noise is applied to a computer model to show how aircraft noise can be expected to propagate in real-world conditions. The algorithms at the core of these models account for spherical spreading, atmospheric absorption, and lateral attenuation. Spherical spreading is, in essence, the reduction in noise due to the spreading of sound energy away from its source. Sound energy decreases by approximately 6 dB every time the distance between the source and receiver is doubled. Daily and hourly variations in atmospheric conditions (such as humidity and clouds) can alter the amount of sound energy at a given location. The noise models use monthly average temperature and humidity conditions to derive acoustically average atmospheric absorption coefficients for each given location. Lateral attenuation, or the loss of sound energy due to reflection of sound by the ground, depends upon the altitude of the aircraft and the distance to the receiver.

The Air Force has developed a series of computer models to handle modeling of aircraft noise in various situations. To describe airfield noise in the vicinity of an installation, the model NOISEMAP (Version 7.0) was used. NOISEMAP extracts data (speed and power setting of the aircraft) from the NOISEFILE database. The noise from each segment of each flight track from each aircraft is then summed to generate a map of average noise levels on the ground, which are typically expressed using the DNL metric. The model accounts for all operations, including both based and transient aircraft (Moulton, 1992).

Supporting routines from NOISEMAP were used to calculate SEL and L_{max} for various flight altitudes and lateral offsets from a ground receiver position.

MR_NMAP was used to compute noise levels in the MOAs and Warning Areas (Lucas and Calamia, 1994). The primary noise metric computed by MR_NMAP is L_{dnmr} averaged over each airspace. MR_NMAP also uses data from the NOISEFILE database based on aircraft speed and power setting, but it spreads the noise energy throughout specified volumes of airspace. Both models calculate the noise levels based on aircraft operations data obtained from aircrews and airspace managers. These data include airspeed, duration of flight, altitudes of flight, distribution of aircraft in the airspace, and frequency of flight activities.

Noise levels for the pre-production F-35A aircraft were measured for limited conditions by Lockheed-Martin during initial testing in 2001 and then re-measured by the U.S. Air Force in 2007. The Air Force Research Laboratory (AFRL) incorporated the 2007 data into the NOISEFILE database, which was then used as the source for noise analysis in this document. Those data collected have been compared with noise levels associated with other comparable fighter aircraft and are shown in Table E-7.

At military takeoff power, noise from the F-35 is about 9 dB higher (or twice as loud) than an F-15C at military takeoff power.

During approach, noise from the F-35 is about 19 dB higher than noise from an F-15C. This corresponds to the F-35 being about four times as loud as the F-15C. However, noise at approach power is always less than that for takeoff. Depending on particular power and speed, noise levels on arrival are approximately one-third to one-half as loud as noise levels on departure.

Table E-7 shows SELs derived from NOISEFILE for the F-35 and three other aircraft for a military takeoff, cruise and approach condition (F-35 airspace condition power was estimated). Noise levels are SEL at a distance of 1,000 feet, and the speed for each condition is shown.

Table E-7. Sound Exposure Level (SEL) in dB for F-35 and Other Fighter Aircraft

	F-35A			F-15C			F/A-18A/B/C/D			F/A-18E/F		
Condition	**Power**	**Speed**	**SEL**	**Power**	**Speed**	**SEL**	**Power**	**Speed**	**SEL**	**Power**	**Speed**	**SEL**
Takeoff/ Mil	100 % ETR	300	121	90% NC	300	112	96.5% NC	300	116	96% N2	300	116
Cruise	55 % ETR	350	107	90% NC	350	98	85% NC	300	96	84% N2	300	95
Approach	50 % ETR	170	108	75% NC	150	89	88% NC	135	109	85% N2	130	113
Airspace	Est*	500	121	81% NC	520	107	92% NC	500	108	–	–	NA

* estimated data based on differential of F-16 on takeoff versus airspace conditions and ratioed to F-35 conditions

Supersonic Aircraft Noise. Aircraft exceeding Mach 1 (the speed of sound) always create a sonic boom; however, not all supersonic flight activities will cause a boom that can be heard at ground level. As altitude increases, air temperature decreases, and the resulting layers of temperature change cause booms to be turned upward as they travel toward the ground. Depending on the altitude of the aircraft and the Mach number, many sonic booms are turned upward sufficiently that they never reach the ground. This same phenomenon, referred to as "cutoff," also acts to limit the width (area covered) of the sonic booms that reach the ground (Plotkin et al., 1989).

The computer program BOOMAP was used to model sonic booms associated with the proposed F-35 training. BOOMAP predicts CDNL beneath military airspace units based on variables such as airspace geometry and number of operations. The model accounts for altitude distribution, maneuver characteristics, variation in operations numbers, and atmosphere effects. The current version of BOOMAP was developed based on extensive field measurements of sonic booms (Frampton and Lucas, 1993).

Construction Noise

Construction noise was modeled using the Roadway Construction Noise Model (RCNM) version 1.00, the Federal Highway Administration's (FHWA's) standard model for the prediction of construction noise (FHWA, 2006). The RCNM has the capability to model the types of construction equipment that are expected to be the dominant noise sources during construction associated with this action. The program uses a database of construction equipment source noise taken at a standard distance of 50 feet. Information on the noise level of each piece of equipment involved in construction is combined with data on what percentage of the time each piece of equipment would be running and the length of the workday to produce an equivalent noise level for the work site. The model adjusts for sound barriers that may reduce impact of the sound as well as a sound's being impulsive (banging), which increases the intrusiveness of the sound. The model yields L_{eq} and L_{max} at various distances and/or receptor locations.

Munitions Noise

Noise resulting from the use of the 7th Special Forces Group (Airborne), or 7SFG(A), small-arms ranges was assessed using the U.S. Army's Small Arms Range Noise Assessment Model (SARNAM2). SARNAM2 is an accepted program for small-arms ranges at which .50 caliber and smaller ammunitions are used. This model incorporates the latest available information on weapons noise source models (including directivity and spectrum), sound propagation, effects of noise mitigation and safety structures (such as walls, berms, and ricochet barriers) in generation of noise contours. It includes an extensive selection of weapons in the source library and can handle multiple ranges of various types.

The program BNoise2 was used to assess blast noise associated with expenditure of large-caliber munitions on the range. This program estimates CDNL based on type of weapon and ammunition, number of rounds fired, time-of-day of rounds fired, range attributes, and weather. The software also accounts for spectrum and directivity of both muzzle blast and projectile sonic boom. Source noise levels are based on field measurements of weapons noise.

Both BNoise2 and SARNM2 are capable of producing both single-event and average noise levels. The day-night average sound level has been endorsed by the scientific community and several governmental agencies (ANSI 1980, 1988; USEPA, 1974; FICUN, 1980; FICON, 1992) for use in assessing transportation and other types of noise. However, the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) has concluded that the use of average noise levels over a protracted time period generally does not adequately assess the probability of community noise complaints from weapons firing. Therefore, modeling and analysis of munitions noise in this EIS were performed for both DNL and PK_{15}(met) metrics.

To assess noise effects, the USACHPPM has defined three noise zones to be considered in land use planning. The zones are described by the noise levels to which they are exposed, and based on sociological considerations, compatible land uses are recommended.

Noise Zone I (NZ I) includes all areas in which the PK_{15}(met) decibel level is less than 87 dB (for small-arms), the A-weighted Day-Night Average Sound Level (ADNL) is less than 65 dB (for aircraft), and the CDNL is less than 62 dB (for large arms and explosions). NZ I is usually the furthest zone from the noise source, and it basically includes all areas not in either of the next two zones. As a rule, this area is suitable for all types of land use.

Noise Zone II (NZ II) is the next furthest area away from the noise source where the PK_{15}(met) decibel level is between 87 and 104 dB, the ADNL is between 65 and 75 dB, or the CDNL is between 62 and 70 dB. The noise exposure here is considered significant, and the use of land in this zone should generally be limited to activities such as manufacturing, warehousing, transportation, and resource protection. Residential use is strongly discouraged; however, if the community determines that this land must be used for houses, there should be a requirement that Noise Level Reduction (NLR) features be integrated into the design and construction of houses. Further details of NLR ideas and strategies are available from USACHPPM.

Noise Zone III (NZ III) is the area closest to the source of the noise where the PK_{15}(met) decibel level is greater than 104 dB, the ADNL is greater than 75 dB, or the CDNL is greater than 70 dB. The noise level is so severe that no noise-sensitive uses should be considered in this area.

One final zone is the more informal Land Use Planning Zone. This zone is at the upper end of NZ I and is defined by a CDNL of 57–62 dB or an ADNL of 60–65 dB. It accounts for the fact that some installations have seasonal variability in their operations (or several unusually busy days during certain times of the year), and that averaging those

busier days over the course of a year (as with the DNL) effectively dilutes their impact. Showing this extra zone creates one more added buffer layer to encroachment, and it signals to planners that encroachment into this area is the beginning of where complaints may become an issue. It also signals that extra care should be taken when approving plans. Table E-8 shows all of the noise zones by the respective noise levels.

Table E-8. Noise Zone Levels

Zone	Noise Limits Small Arms in PK_{15}(met)	Noise Limit Aviation ADNL in A-Weighted dB	Noise Limit Impulsive CDNL in C-Weighted dB
Land Use Planning Zone	N/A	60-65	57-62
Noise Zone I	< 87	< 65	< 62
Noise Zone II	87-104	65-75	62-70
Noise Zone III	> 104	> 75	> 70

Source: *Operational Noise Management* (USACHPPM, 2005)

ADNL = A-Weighted Day-Night Average Sound Levels; CDNL = C-Weighted Day-Night Average Sound Levels; PK_{15}(met) = Single Event Peak Level exceeded by 15% of events; < = less than; > = greater then; N/A = Not Applicable

(a) Although local conditions regarding the need for housing may require noise-sensitive land uses in Noise Zone II, on or off base, this type of land use is strongly discouraged. The absence of viable alternative development options should be determined, and an evaluation should be conducted locally prior to local approvals, indicating that a demonstrated community need for the noise-sensitive land use would not be met if development were prohibited in Noise Zone II.

(b) Where the community determines that these uses must be allowed, measures to achieve an outdoor-to-indoor NLR of at least 25 to 30 dB in Noise Zone II, from small-arms and aviation noise, should be incorporated into building codes and contained in individual approvals. The NLR for communities subjected to large-caliber weapons and the weapons system noise is lacking scientific studies to accomplish the recommended NLR. For this reason, it is strongly discouraged that noise-sensitive land uses be allowed in Noise Zone II where large-caliber weapons use occurs.

(c) Normal permanent construction can be expected to provide a NLR of 20 dB for aircraft and small-arms; thus, the reduction requirements are often stated as 5, 10, or 15 dB over standard construction, and they normally assume mechanical ventilation, upgraded Sound Transmission Class ratings in windows and doors, and closed windows year-round. Additional consideration should be given to modifying NLR levels based on peak noise levels or vibrations.

(d) NLR criteria will not eliminate outdoor noise problems. However, building location and site planning and the design and use of berms and barriers can help mitigate outdoor noise exposure NLR, particularly from ground-level aircraft sources. Barriers are generally not effective in noise reduction for large arms such as artillery and armor or large explosions.

Representative Noise-Sensitive Receptors Point Analysis

As part of the noise analysis, a detailed acoustical analysis was performed for a series of locations, which are listed in Table E-9 and shown in Figure E-4, Figure E-5 and

Figure E-6. Figure E-4 shows locations near the city of Fort Walton Beach. Figure E-5 depicts locations on and in the vicinity of Eglin AFB. Figure E-6 shows locations near the city of Valparaiso.

Table E-9. Noise-Sensitive Receptors In the Vicinity of Affected Airfields

Location ID	General Description	Latitude (WGS84)	Longitude (WGS84)
SP1	Eglin Housing (Capehart)	N 30º 27.7260′	W 86º 32.0602′
SP2	Eglin Housing (Ben's Lake)	N 30º 27.9786′	W 86º 32.6446′
SP3	Chapel 2 - Building 2574	N 30º 28.0545′	W 86º 32.9153′
SP4	Cherokee Elem. School	N 30º 28.0592′	W 86º 32.7230′
SP5	Child Development Center	N 30º 28.0726′	W 86º 32.3707′
SP6	Oakhill School	N 30º 28.2399′	W 86º 32.1440′
SP7	Eglin Hospital	N 30º 27.7062′	W 86º 33.3051′
SP8	Eglin VAQ and Dorms	N 30º 29.1113′	W 86º 30.0943′
SP9	Eglin Chapel 1	N 30º 29.8260′	W 86º 07.9653′
SP10	JSF ITC	N 30º 28.6894′	W 86º 32.9662′
SP11	Lewis Middle School	N 30º 29.5813′	W 86º 07.9653′
SP12	Valparaiso Elementary School	N 30º 30.1947′	W 86º 07.9653′
SP13	First Assembly of God (Valparaiso)	N 30º 30.6765′	W 86º 30.3143′
SP14	New Hope Baptist (Valparaiso)	N 30º 30.7426′	W 86º 30.2948′
SP15	Sovereign Grace Church (Valparaiso)	N 30º 30.6563′	W 86º 30.0692′
SP16	First Baptist Church (Valparaiso)	N 30º30.6200′	W 86º 29.9500′
SP17	Unitarian Church (Valparaiso)	N 30º 30.8172′	W 86º 29.6067′
SP18	Housing (Valparaiso)	N 30º 30.5187′	W 86º30.3225′
SP19	Housing (Valparaiso)	N 30º 30.9077′	W 86º 30.3376′
SP20	Edge Elementary School	N 30º 31.6322′	W 86º 29.6852′
SP21	Twin Cities Medical Center	N 30º 32.0156′	W 86º 29.7390′
SP22	Niceville Community Church	N 30º 31.2748′	W 86º 30.3176′
SP23	Private School (Niceville)	N 30º 30.9844′	W 86º 30.4512′
SP24	Private School (Ft Walton)	N 30º 28.2321′	W 86º 36.4212′
SP25	Okaloosa Walton College	N 30º 28.1460′	W 86º 36.8792′
SP26	Kenwood Elementary	N 30º 27.5359′	W 86º 36.4608′
SP27	Pryor Middle School	N 30º 26.7376′	W 86º 36.6058′
SP28	Housing (Ft Walton)	N 30º 28.0831′	W 86º 36.4028

Figure E-4. Representative Noise-Sensitive Receptors in Fort Walton Beach

Figure E-5. Representative Noise-Sensitive Receptors in Eglin Main Base

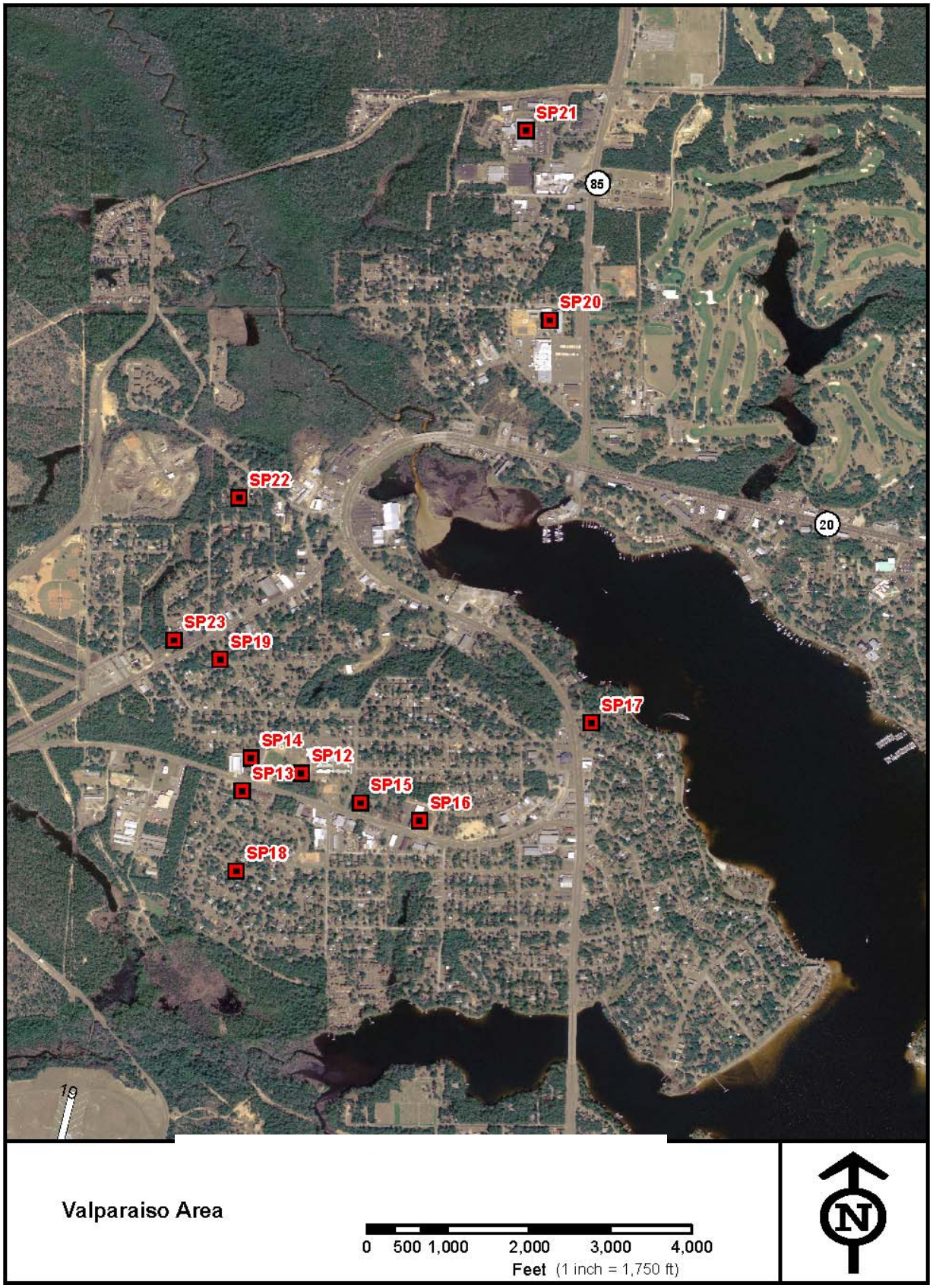

Figure E-6. Representative Noise-Sensitive Receptors in Valparaiso

Table E-10 lists noise levels at representative noise-sensitive facilities under baseline conditions, each of the action alternatives, and the No Action Alternative. Noise impacts at these locations are described in the EIS and earlier in this Appendix.

Table E-10. Noise Levels at Representative Noise-Sensitive Facilities Under Baseline Conditions, Action Alternatives, and the No Action Alternative

Location ID	General Description	Baseline DNL	Alt 1 DNL	Alt 2 DNL	No Action DNL
SP1	Eglin Housing (Capehart)	67	77	78	65
SP2	Eglin Housing (Ben's Lake)	64	76	76	62
SP3	Chapel 2 - Building 2574	63	76	75	60
SP4	Cherokee Elem. School	64	77	76	61
SP5	Child Development Center	68	78	80	64
SP6	Oakhill School	72	82	83	67
SP7	Eglin Hospital	57	69	69	55
SP8	Eglin VAQ and Dorms	67	75	79	66
SP9	Eglin Chapel 1	63	72	76	62
SP10	JSF ITC	71	83	82	66
SP11	Lewis Middle School	60	68	73	58
SP12	Valparaiso Elementary School	68	79	80	66
SP13	First Assembly of God (Valparaiso)	71	83	83	69
SP14	New Hope Baptist (Valparaiso)	70	83	83	69
SP15	Sovereign Grace Church (Valparaiso)	65	76	77	64
SP16	First Baptist Church (Valparaiso)	63	73	75	62
SP17	Unitarian Church (Valparaiso)	59	68	71	57
SP18	Housing (Valparaiso)	70	82	83	69

Continued on the next page…

Table E-10. Noise Levels at Representative Noise-Sensitive Facilities Under Baseline Conditions, Action Alternatives, and the No Action Alternative, Cont'd

Location ID	General Description	Baseline DNL	Alt 1 DNL	Alt 2 DNL	No Action DNL
SP19	Housing (Valparaiso)	72	88	87	72
SP20	Edge Elementary School	60	70	71	59
SP21	Twin Cities Medical Center	62	72	73	61
SP22	Niceville Community Church	71	90	88	74
SP23	Private School (Niceville)	75	91	90	77
SP24	Private School (Ft Walton)	55	60	61	53
SP25	Okaloosa Walton College	52	57	58	50
SP26	Kenwood Elementary	53	56	57	52
SP27	Pryor Middle School	52	54	54	50
SP28	Housing (Ft Walton)	55	59	60	53

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