Change in Noise. The human ear is a far better detector of relative differences in sound levels than absolute values of levels. For this reason, the human ear is much better at discerning changes between differing noise levels than determining absolute noise levels. Under controlled laboratory conditions, listening to a steady unwavering pure tone sound that can be changed to slightly different sound levels, a person can just barely detect a sound level change of approximately one decibel for sounds in the mid-frequency region. When ordinary noises are heard, a young healthy ear can detect changes of two to three decibels. A five decibel change is readily noticeable, while a ten decibel change is judged by most people as a doubling or a halving of the loudness of the sound.

Masking Effect. The ability of one sound to prevent or limit a listener from hearing another sound is known as the masking effect. The presence of one sound effectively raises the threshold of audibility for the hearing of a second sound. For a signal to be heard, it must exceed the threshold of hearing for that particular individual and exceed the masking threshold for the background noise.

The masking characteristics of sound depend on many factors including the spectral (frequency) characteristics of the two sounds, the sound pressure levels, and the relative start time of the sounds. Masking effect is greatest when the frequencies of the two sounds are similar or when low frequency sounds mask higher frequency sounds. High frequency sounds do not easily mask low frequency sounds.

2.3 FACTORS INLFLUENCING HUMAN RESPONSE TO SOUND

Many factors influence sound perception and annoyance. This includes not only physical characteristics of the sound but also secondary influences such as sociological and external factors. The *Handbook of Noise Control* [iii] describes human response to sound in terms of both acoustic and non-acoustic factors. These factors are summarized in Table 2-1.

Sound rating scales have been developed in reaction to the factors affecting human response to sound. Nearly all of these factors are relevant in describing how sounds are perceived in the community. Many non-acoustic parameters play a prominent role in affecting individual response to noise. Background sound, an additional acoustic factor not specifically listed, is also important in describing sound in rural settings. In the analysis of the effects of personal and situational variables on noise annoyance, a clear association of reported annoyance and various other individual perceptions or beliefs has been identified. Fields [iv], in his analysis of the effects of personal and situational variables on noise annoyance, has identified a clear association of reported annoyance and various other individual perceptions or beliefs. In particular, Fields stated:

> *"There is therefore firm evidence that noise annoyance is associated with: (1) the fear of an aircraft crashing or of danger from nearby surface transportation; (2) the belief that aircraft noise could be prevented or reduced by designers, pilots or authorities related to airlines; and (3) an expressed sensitivity to noise generally."*

Thus, it is important to recognize that non-acoustic factors such as the ones described above as well as acoustic factors contribute to human response to noise.

Table 2-1
FACTORS THAT AFFECT INDIVIDUAL ANNOYANCE TO NOISE

Primary Acoustic Factors
- Sound Level
- Frequency
- Duration

Secondary Acoustic Factors
- Spectral Complexity
- Fluctuations in Sound Level
- Fluctuations in Frequency
- Rise-time of the Noise
- Localization of Noise Source

Non-acoustic Factors
- Physiology
- Adaptation and Past Experience
- How the Listener's Activity Affects Annoyance
- Predictability of When a Noise will Occur
- Is the Noise Necessary?
- Individual Differences and Personality

Source: C. Harris, 1979

2.4 SOUND RATING SCALES

The description, analysis, and reporting of community sound levels, such as aircraft noise, is made difficult by the complexity of human response to sound and myriad sound-rating scales and metrics developed to describe acoustic effects. Various rating scales approximate the human subjective assessment to the "loudness" or "noisiness" of a sound. Noise metrics have been developed to account for additional parameters such as duration and cumulative effect of multiple events.

Noise metrics are categorized as single event metrics and cumulative metrics. Single event metrics describe the noise from individual events, such as one aircraft flyover. Cumulative metrics describe the noise in terms of the total noise exposure throughout the day. Below are brief descriptions of different noise metrics:

Single Event Metrics

Frequency Weighted Metrics (dBA). To simplify the measurement and computation of sound loudness levels, frequency weighted networks have obtained wide acceptance. The A-weighting (dBA) scale has become the most prominent of these scales and is widely used in community noise analysis. Its advantages are that it has shown good correlation with public response and is easily measured. The metrics used in this study are all based upon the dBA scale.

Maximum Noise Level (Lmax). The highest noise level reached during a noise event is, not surprisingly, called the "Maximum Noise Level," or Lmax. For example, as an aircraft approaches, the sound of the aircraft begins to rise above ambient noise levels. The closer the aircraft gets the louder it is until the aircraft is at its closest point directly overhead. Then as the aircraft passes, the noise level decreases until the sound level again settles to ambient levels. Such a history of a flyover is plotted at the top of Figure 2-3. It is this metric to which people generally instantaneously respond when an aircraft flyover occurs.

Sound Exposure Level (SEL). Another metric that is reported for aircraft flyovers is the Sound Exposure Level (SEL). It is computed from dBA sound levels. Referring again to the top of Figure 2-3, the shaded area, or the area within 10 dB of the maximum noise level, is the area from which the SEL is computed. The SEL value is the integration of all the acoustic energy contained within the event. Speech and sleep interference research can be assessed relative to single event Sound Exposure Level data.

The SEL metric takes into account the maximum noise level of the event and the duration of the event. For aircraft flyovers, the SEL value is typically about 10 dBA higher than the maximum noise level. Single event metrics are a convenient method for describing noise from individual aircraft events. This metric is useful in that airport noise models contain aircraft noise curve data based upon the SEL metric. In addition, cumulative noise metrics such as LEQ and DNL can be computed from SEL data.

Cumulative Metrics

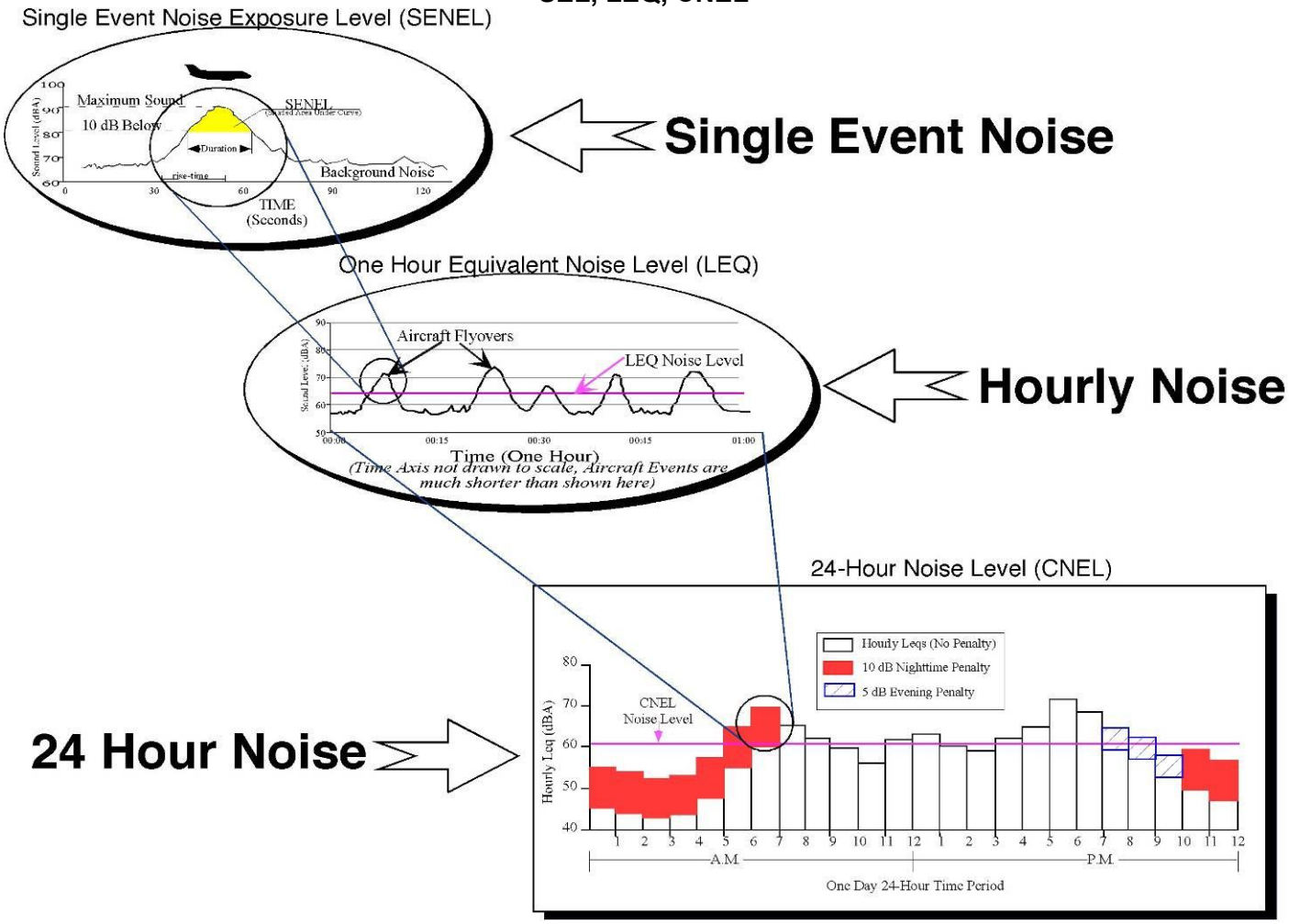
Cumulative noise metrics assess community response to noise by including the loudness of the noise, the duration of the noise, the total number of noise events and the time of day these events occur into one single number rating scale.

Equivalent Noise Level (Leq). Leq is the sound level corresponding to a steady-state A-weighted sound level containing the same total energy as several SEL events during a given sample period. Leq is the "energy" average noise level during the time period of the sample. It is based on the observation that the potential for noise annoyance is dependent on the total acoustical energy content of the noise. This is graphically illustrated in the middle graph of Figure 2-3. Leq can be measured for any time period, but is typically measured for 15 minutes, 1-hour, or 24-hours. .

Community Noise Equivalent Level (CNEL). CNEL is a 24-hour, time-weighted energy average noise level based on the A-weighted decibel. It is a measure of the overall noise experienced during an entire day. The term —time-weighted" refers to the penalties attached to noise events occurring during certain sensitive time periods. In the CNEL scale, noise occurring between the hours of 7 pm and 10 pm is penalized by approximately 5 dB. This penalty accounts for the greater potential for noise to cause communication interference during these hours, as well as typically lower ambient noise levels during these hours. Noise that takes place during the night (10 pm to 7 am) is penalized by 10 dB. This penalty was selected to attempt to account for the higher sensitivity to noise in the nighttime and the expected further decrease in background noise levels that typically occur in the nighttime.

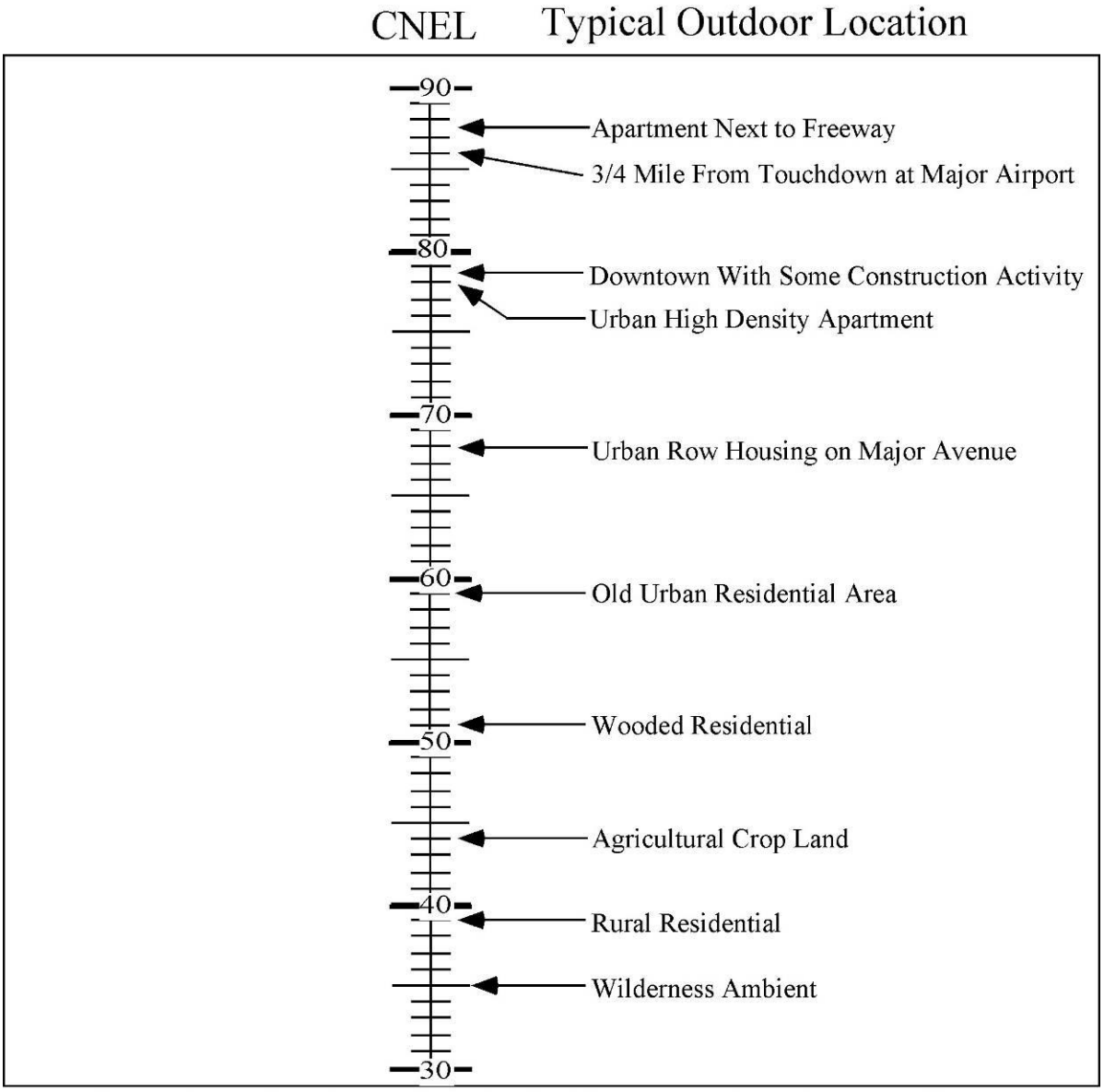
CNEL is graphically illustrated in the bottom of Figure 2-3. Examples of various noise environments in terms of CNEL are presented in Figure 2-4.

Figure 2-3
SEL, LEQ, CNEL



SOURCE: MGA/L&B (2011)

Figure 2-4
SOUND LEVELS IN TERMS OF CNEL



Source: Adapted from "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare With an Adequate Margin of Safety", EPA, 1974

2.5 EFFECTS OF NOISE ON HUMANS

Noise, often described as unwanted sound, is known to have several adverse effects on humans. From these known adverse effects of noise, criteria have been established to help protect the public health and safety and prevent disruption of certain human activities. These criteria are based on effects of noise on people such as hearing loss (not a factor with typical community noise), communication interference, sleep interference, physiological responses, and annoyance. Many of the impacts described in this section are described in greater detail in the *ACRP Synthesis 9, Effects of Aircraft Noise: Research Update on Selected Topics*[v], published in 2008. Each of these potential noise impacts on people are briefly discussed in the following narrative:

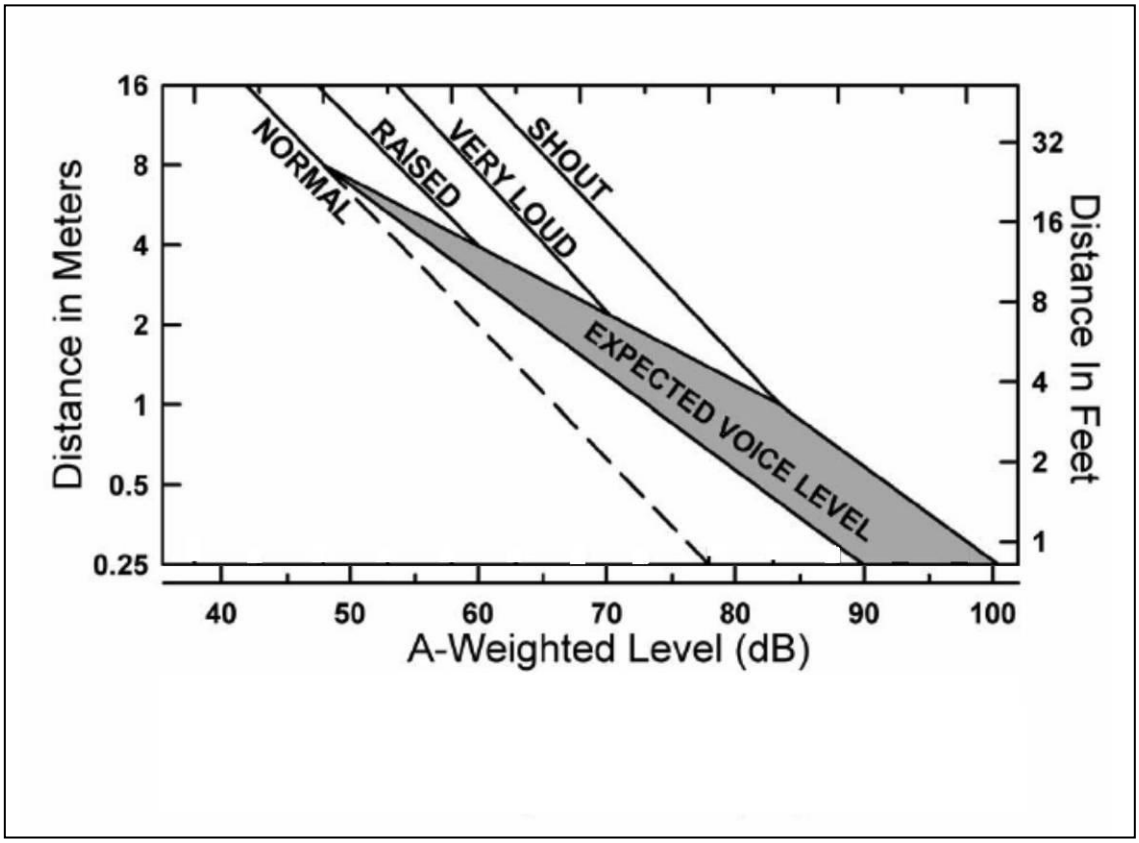
Hearing Loss is generally not a concern in community noise problems, even very near a major airport or a major freeway. Environmental noise does not have an effect on hearing threshold levels particularly due to the fact that environmental noise does not approximate occupational noise exposures in heavy industry, very noisy work environments with long-term exposure, or certain very loud recreational activities such as target shooting, motorcycle, or automobile racing, etc. The Occupational Safety and Health Administration (OSHA) identifies a noise exposure limit of 90 dBA for 8 hours per day to protect from hearing loss (higher limits are allowed for shorter duration exposures). Noise levels in neighborhoods, even in very noisy neighborhoods, are not sufficiently loud to cause hearing loss.

Communication Interference is one of the primary concerns in environmental noise problems. Communication interference includes speech interference and interference with activities such as watching television. Normal conversational speech is in the range of 60 to 65 dBA and any noise in this range or louder may interfere with speech. There are specific methods of describing speech interference as a function of distance between speaker and listener and voice level. Figure 2-5 shows the relation of quality of speech communication with respect to various noise levels.

Sleep Disturbance is a major noise concern in noise assessments and, of course, is most critical during nighttime hours. Sleep disturbance is one of the major causes of annoyance due to community noise. Noise can make it difficult to fall asleep, create momentary disturbances of natural sleep patterns by causing shifts from deep to lighter stages, and cause awakening. Noise may even cause awakening, which a person may or may not be able to recall.

Extensive research has been conducted on the effect of noise on sleep disturbance. Recommended values for desired sound levels in residential bedroom space range from 25 to 45 dBA with 35 to 40 dBA being the norm. Some years ago (1981), the National Association of Noise Control Officials[vi] published data on the probability of sleep disturbance with various single event noise levels. Based on laboratory experiments conducted in the 1970‘s, this data indicated noise exposure at 75 dBA interior noise level event could cause noise induced awakening in 30 percent of the cases.

Figure 2-5
SPEECH INTERFERENCE LEVELS

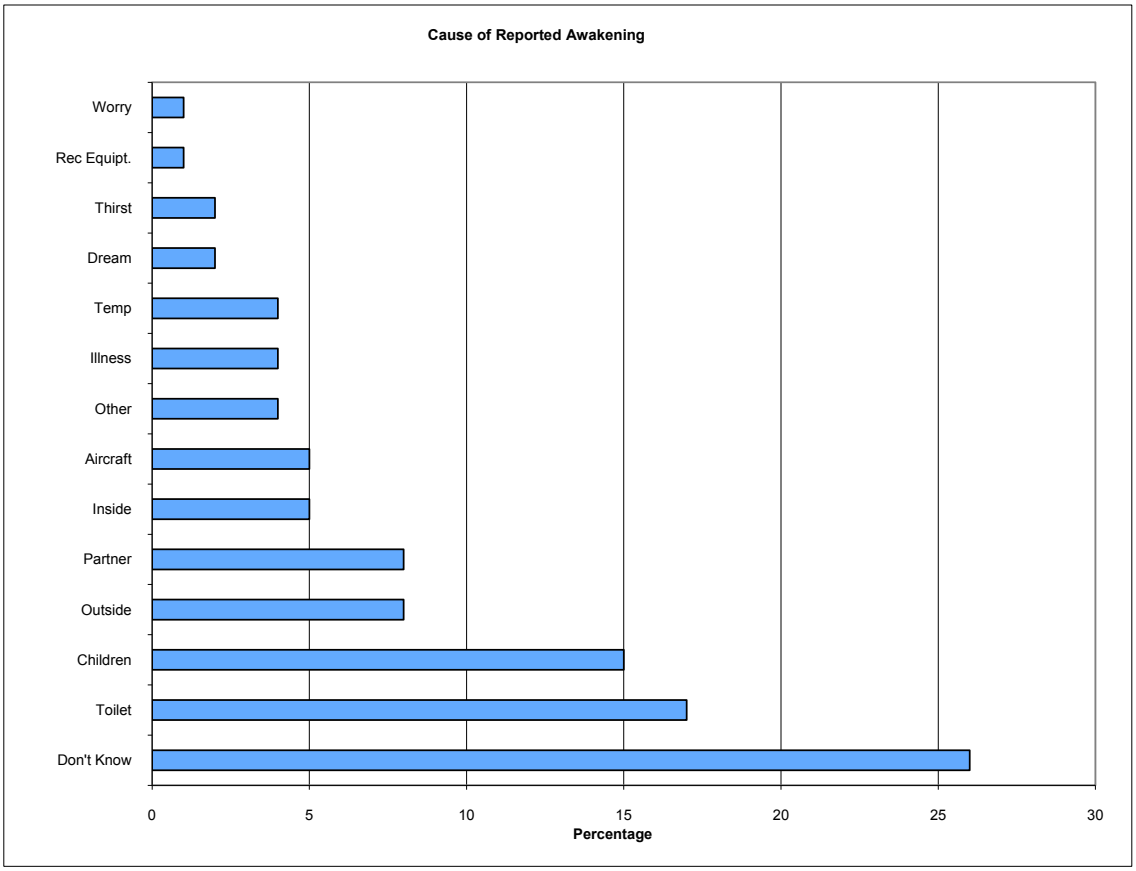


SOURCE: U.S. EPA (1973)

However, more recent research from England[vii] [viii] has shown that the probability for sleep disturbance is less than what had been reported in earlier research. These recent field studies were conducted during the 1990's and used more sophisticated data collection techniques. These field studies indicate that awakenings can be expected at a much lower rate than had been expected based on earlier laboratory studies. This research showed that once a person was asleep, it is much more unlikely that they will be awakened by a noise. The significant difference in the recent English study is the use of actual in-home sleep disturbance patterns as opposed to laboratory data that had been the historic basis for predicting sleep disturbance. Some of this research has been criticized because it was conducted in areas where subjects had become habituated to aircraft noise. On the other hand, some of the earlier laboratory sleep studies were criticized because of the extremely small sample sizes of most laboratory studies and because the laboratory was not necessarily a representative sleep environment. The 1994 British sleep study compared the various causes of sleep disturbance using in-home sleep studies. This field study assessed the effects of nighttime aircraft noise on sleep in 400 people (211 women and 189 men; 20-70 years of age; one per household) habitually living at eight sites adjacent to four U.K. airports, with different levels of night flying. The main finding was that only a minority of aircraft noise events affected sleep, and, for most subjects, that domestic and other non-aircraft factors had much greater effects. As shown in the Figure 2-6, aircraft noise was a minor contributor among a host of other factors that lead to awakening response.

Figure 2-6
CAUSES AND PREVALENCE OF ALL AWAKENINGS

(Total awakenings = 6,457. Each subject could have reported more than one awakening each night.)

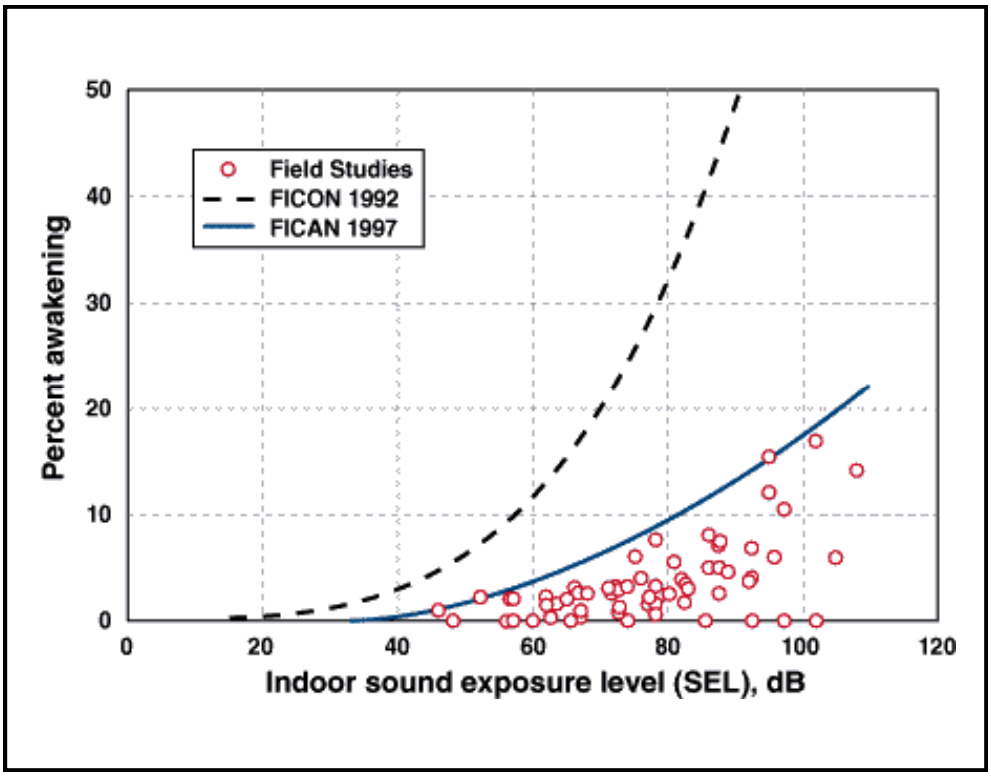


Source: Horne JA (1994)

The Federal Interagency Committee on Noise (FICON) in 1992 in a document entitled *Federal Interagency Review of Selected Airport Noise Analysis Issues* [ix] recommended an interim dose-response curve for sleep disturbance based on laboratory studies of sleep disturbance. In June of 1997, the Federal Interagency Committee on Aviation Noise (FICAN) updated the FICON recommendation with an updated curve based on the more recent in-home sleep disturbance studies which show lower rates of awakening compared to the laboratory studies.[x] The FICAN recommended a curve based on the upper limit of the data presented and, therefore, considers the curve to represent the —maximum percent of the exposed population expected to be behaviorally awakened," or the —maximum awakened." The FICAN recommendation is shown on Figure 2-7. This is a very conservative approach. A more common statistical curve for the data points reflected in Figure 2-7, for example, would indicate a 10% awakening rate at a level of approximately 100 dB SEL, while the —maximum awakened" curve reflected in Figure 2-7 shows the 10% awakening rate being reached at 80 dB SEL. (The full FICAN report can be found on the internet at www.fican.org.)

Figure 2-7

FICAN RECOMMENDED SLEEP DISTURBANCE CURVE



SOURCE: FICAN (1997)

- *Physiological Responses* are those measurable effects of noise on people that are realized as changes in pulse rate, blood pressure, etc. While such effects can be induced and observed, the extent is not known to which these physiological responses cause harm or are a sign of harm. Generally, physiological responses are a reaction to a loud short-term noise such as a rifle shot or a very loud jet over flight.

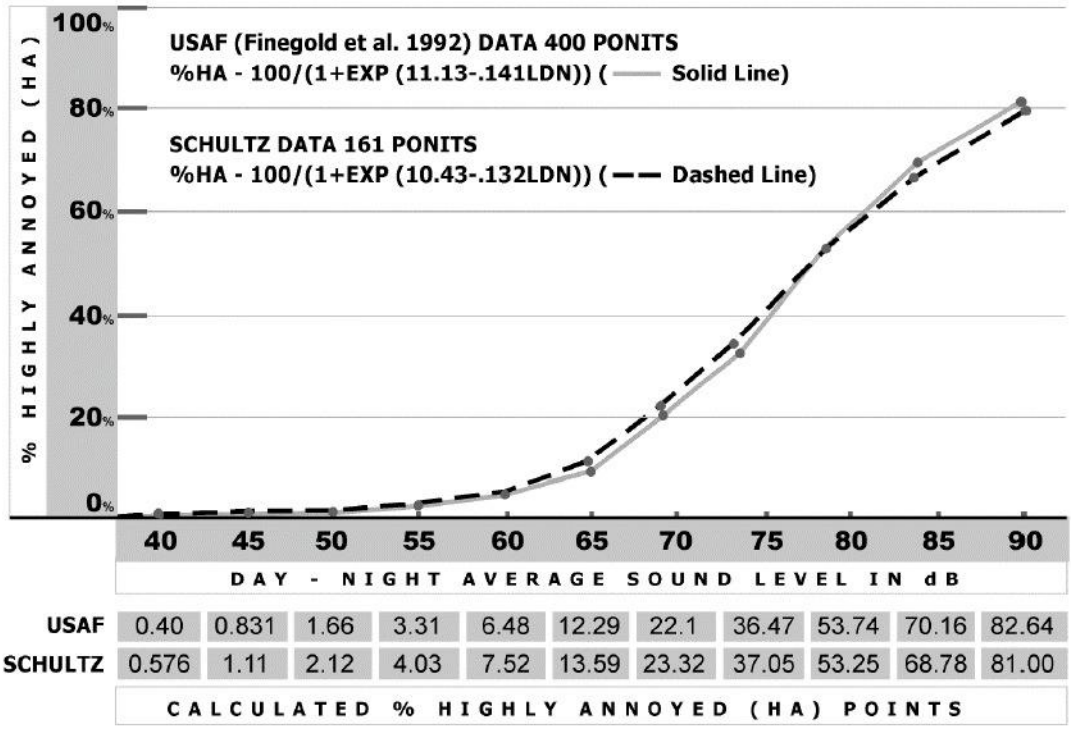
  Health effects from noise have been studied around the world for nearly thirty years. Scientists have attempted to determine whether high noise levels can adversely affect human health apart from auditory damage. These research efforts have covered a broad range of potential impacts from cardiovascular response from fetal weight to mortality. While a relationship between noise and health effects seems plausible, it has yet to be convincingly demonstrated—that is, shown in a manner that can be repeated by other researchers while yielding similar results.

  While annoyance and sleep/speech interference have been acknowledged, health effects, if they exist, are associated with a wide variety of other environmental stressors. Isolating the effects of aircraft noise alone as a source of long-term physiological change has proved to be nearly impossible. In a review of 30 studies conducted worldwide between 1993 and 1998,[xi] a team of international researchers concluded that, while some findings suggest that noise can affect health, improved research concepts and methods are needed to verify or discredit such a relationship. They called for more study of the numerous environmental and behavioral factors than can confound, mediate, or moderate survey findings. Until science refines the research process, a direct link between aircraft noise exposure and non-auditory health effects remains to be demonstrated. Recent studies by Eriksson (2007) and Jarup (2007 HYENA study) have reported higher rates of hypertension with increasing aircraft noise levels. The Hyena study identified the effect occurred only for nighttime aircraft noise.

- *Annoyance* is the most difficult of all noise responses to describe. Annoyance is an individual characteristic and can vary widely from person to person. What one person considers tolerable can be quite unbearable to another of equal hearing capability. The level of annoyance, of course, depends on the characteristics of the noise (i.e.; loudness, frequency, time, and duration), and how much activity interference (e.g. speech interference and sleep interference) results from the noise. However, the level of annoyance is also a function of the attitude of the receiver. Personal sensitivity to noise varies widely. It has been estimated that two to ten percent of the population is highly susceptible to annoyance from any noise not of their own making, while approximately twenty percent are unaffected by noise. Attitudes are affected by the relationship between the person and the noise source (Is it our dog barking or the neighbor's dog?). Whether we believe that someone is trying to abate the noise will also affect our level of annoyance.

  There is no current research to suggest that there is a better metric than DNL to relate to annoyance. Figure 2-8 relates DNL noise levels to community response from two of these surveys. One of the survey curves presented in Figure 2-8 is the well-known Schultz Curve. It displays the percent of a populace that can be expected to be annoyed by various DNL values for residential land use with outdoor activity areas. At 65 DNL, the Schultz Curve predicts approximately 14% of the exposed population reporting themselves to be —highly annoyed." At 60 DNL, this decreases to approximately 8% of the population.

Figure 2-8
SCHULTZ CURVE



USAF	0.40	0.831	1.66	3.31	6.48	12.29	22.1	36.47	53.74	70.16	82.64
SCHULTZ	0.576	1.11	2.12	4.03	7.52	13.59	23.32	37.05	53.25	68.78	81.00

CALCULATED % HIGHLY ANNOYED (HA) POINTS

SOURCE: FICON (1992)

The Schultz Curve and recent updates include data having a very wide range of scatter with communities near some airports reporting much higher percentages of population highly annoyed at these noise exposure levels. For example, under contract to the FAA, Bolt Beranek & Newman conducted community attitude surveys in the residential areas south of John Wayne Airport in Orange County in 1981 as part of a study of possible —power cutback" departure procedures. That study concluded that the surveyed population had more highly annoyed individuals at various noise levels than would be predicted by the Schultz Curve. When plotted similar to the Schultz Curve, this survey, indicated the populations in these areas were approximately 5 dB more sensitive to noise than the average population predicted by the Schultz Curve. While the precise reasons for this increased noise sensitivity were not identified, it is possible that non-acoustic factors, including political or the socio-economic status of the surveyed population may have played an important role in increasing the sensitivity of this community during the period of the survey. Annoyance levels have never been correlated statistically to single event noise exposure levels in airport related studies.

- *School Classroom Effects*. Interference with classroom activities and learning due to aircraft noise is an important consideration and has been the subject of much recent research. Studies from around the world indicate that vehicular traffic, railroad, and aircraft noise can have adverse effects on reading ability, concentration, motivation, and long-term learning retention. A complicating factor in this research is the extent of background noise from within the classroom itself. The studies indicating the most adverse effects examine

cumulative noise levels equivalent to 65 DNL or higher and single event maximum noise levels ranging from 85 to 95 dBA. In other studies, the level of noise is unstated or ambiguous. According to these studies, a variety of adverse school room effects can be expected from *interior* noise levels equal to or exceeding 65 DNL and or 85 dBA SEL.

Some interference with classroom activities can be expected with noise events that interfere with speech. As discussed in other sections of this report, speech interference begins at 65 dBA, which is the level of normal conversation. Typical construction attenuates outdoor noise by 20 dBA with windows closed and 12 dBA with windows open. Thus some interference of classroom activities can be expected at outdoor levels of 75 to 85 dBA. These levels are included in the Time Above analysis performed as part of this study. No studies have been identified where observations of student activity were compared to aircraft noise levels during aircraft flyovers. There is a clear need for additional research on the effects of aviation noise on schools and these studies need to include in classroom noise measurements and observation of student responses to aircraft activity.

2.6 AIRCRAFT NOISE POLICY CONTEXT

Noise metrics provide a means for quantifying public or community response to various noise exposure levels. The public reaction to different noise levels has been estimated from extensive research on human responses to exposure of different levels of aircraft noise. Noise standards generally are expressed in terms of the DNL (CNEL in California) 24-hour averaging scale based on the A-weighted decibel. Utilizing these metrics and surveys, agencies have developed guidelines for assessing the compatibility of various land uses with the noise environment. There are no single event noise based noise/land use compatibility criteria that have been adopted by the federal, state, or local governments.

This section presents information regarding noise and land use criteria useful in the evaluation of noise impacts. The Federal Aviation Administration has a long history of publishing noise/land use assessment criteria for airports. These laws and regulations provide the basis for local development of airport plans, analyses of airport impacts, and the enactment of compatibility policies. Other agencies including the EPA and the Department of Defense have developed noise/land use compatibility criteria. A summary of some of the more pertinent regulations and guidelines are presented in the following paragraphs.

Federal Aviation Administration

- **Federal Aviation Regulations, Part 36, "Noise Standards: Aircraft Type and Airworthiness Certification".**

Originally adopted in 1960, FAR Part 36 prescribes noise standards for issuance of new aircraft type certificates. Part 36 prescribes limiting noise levels for certification of new types of propeller-driven, small airplanes as well as for transport category, large airplanes. Subsequent amendments extended the standards to certain newly produced aircraft of older type designs. Other amendments have at various times extended the required compliance dates. Aircraft may be certificated as Stage 1, Stage 2, Stage 3, or Stage 4 aircraft based on their noise level, weight, number of engines, and in some cases, number of passengers. Higher Stage number certifications require quieter engines. All Stage 1 aircraft and Stage 2 aircraft weighing greater than 75,000 pounds are no longer permitted to operate in the U.S. Although aircraft meeting Part 36 standards are noticeably quieter than many of the older aircraft, the regulations make no determination that such aircraft are acceptably quiet for operation at any given airport or operation. The Stage 4 standard is intended to provide uniform noise certification standards for aircraft built in the U.S. to meet recent Civil Aviation Organization Annex 16 Chapter 4 noise standards.

- **U.S. Department of Transportation/FAA Aviation Noise Abatement Policy.**

This policy, adopted in 1976, sets forth the noise abatement authorities and responsibilities of the Federal Government, airport proprietors, state and local governments, the air carriers, air travelers and shippers, and airport area residents and prospective residents. The basic thought of the policy is that the FAA's role is primarily one of regulating noise at its source (the aircraft) plus supporting local efforts to develop airport noise abatement plans. The FAA will give high priority to projects designed to ensure compatible use of land near airports, but it is the role of state and local governments and airport proprietors to undertake the land use and operational

actions necessary to promote compatibility. In July 2000, the FAA proposed a draft-revised policy that has yet to be finalized. The draft can be found on the FAA's web site at: http://www.aee.faa.gov/noise/aee100_files/fr_anap.pdf

- **Federal Aviation Regulations, Part 150, "Airport Noise Compatibility Planning".**

As a means of implementing the Aviation Safety and Noise Abatement Act, the FAA adopted Regulations on Airport Noise Compatibility Planning Programs. These regulations are spelled out in FAR Part 150. As part of the FAR Part 150 Noise Control program, the FAA published noise and land use compatibility charts to be used for land use planning with respect to aircraft noise. An expanded version of this chart appears in Aviation Circular 150/5020-1 (dated August 5, 1983) and is reproduced in Figure 2-9.

These guidelines represent recommendations to local authorities for determining acceptability and permissibility of land uses. The guidelines recommend a maximum amount of noise exposure (in terms of the cumulative noise metric DNL) that might be considered acceptable or compatible to people in living and working areas. These noise levels are derived from case histories involving aircraft noise problems at civilian and military airports and the resultant community response. Note that residential land use is deemed acceptable for noise exposures up to 65 DNL. Recreational areas are also considered acceptable for noise levels above 65 DNL (with certain exceptions for amphitheaters). However the FAA guidelines indicate that ultimately "the responsibility for determining the acceptability and permissible land uses remains with the local authorities."

- **Federal Aviation Order 5050.4B, "Airport Environmental Handbook" and Order 1050.1E, "Environmental Impacts: Policies and Procedures"**

The FAA has developed guidelines for conducting environmental studies to meet the requirements of the National Environmental Policy Act (NEPA). Included in the FAA orders is the requirement to evaluate aircraft noise using the DNL metric, as well as to present the impact of proposed airport actions, such as proposed airport development, in terms of the 65 DNL, 70 DNL, and 75 DNL noise contours. Further, these orders also indicate the threshold of project-related significant impacts. Federal requirements dictate that increases in noise levels caused by a federal action in noise sensitive land uses of over 1.5 DNL within 65 DNL are considered significant. A noise sensitive area includes residential, educational, health, and religious structures and sites, and parks, recreational areas (including areas with wilderness characteristics), wildlife refuges, and cultural and historical sites.

FAA Order 1050.1E states "Analysis within the DNL 60-65 dB contours to identify noise sensitive areas where noise will increase by DNL 3 dB, only when DNL 1.5 dB increases are documented within the DNL 65 dB contour." It is important to note that the 3 DNL increase is not a threshold of significance, but rather a disclosure of impact. A Desk Reference was published in 2007 that summarizes applicable special purpose laws to conveniently integrate all environmental review procedures that should be ran concurrently rather than consecutively.

- **Airport Noise and Capacity Act of 1990 (ANCA)**

The Airport Noise and Capacity Act of 1990 (PL 101-508, 104 Stat. 1388), also known as ANCA or the Noise Act, established two broad directives to the FAA: (1) Establish a method to review aircraft noise, airport use or airport access restrictions, imposed by airport proprietors; and (2)

institute a program to phase-out Stage 2 aircraft over 75,000 pounds by December 31, 1999. Stage 2 aircraft are older, noisier aircraft (B-737-200, B-727 and DC-9); Stage 3 aircraft are newer, quieter aircraft (B-737-300, B-757, MD80/90). To implement ANCA, FAA amended Part 91 and issued a new Part 161 of the Federal Aviation Regulations. Part 91 addresses the phase-out of large Stage 2 aircraft and the phase-in of Stage 3 aircraft. Part 161 establishes a stringent review and approval process for implementing use or access restrictions by airport proprietors.

Part 91 generally states that all Stage 2 aircraft, over 75,000 pounds, were to be out of the domestic fleet by December 31, 1999. For the most part, only Stage 3 aircraft greater than 75,000 pounds are currently in the domestic fleet.

Part 161 sets out the requirements and procedures for implementing new airport use and access restrictions by airport proprietors. Proprietors must use the DNL metric to measure noise effects and the Part 150 land use guideline table, including 65 DNL, as the threshold contour to determine compatibility, unless there is a locally adopted standard more stringent.

The regulation identifies three types of use restrictions and treats each one differently: (1) negotiated restrictions, (2) Stage 2 aircraft restrictions and (3) Stage 3 aircraft restrictions. Generally speaking, any use restriction affecting the number or times of aircraft operations will be considered an access restriction. Even though the Part 91 phase-out does not apply to aircraft under 75,000 pounds, FAA has determined that Part 161 limitations on proprietors' authority applies as well to the smaller aircraft.

Figure 2-9

FAA PART 150 LAND USE COMPATIBILITY GUIDELINES

Land Use	Yearly day-night average sound level (Ldn) in decibels					
	Below 65	65-70	70-75	75-80	80-85	Over 85
RESIDENTIAL						
Residential, other than mobile homes and transient lodging	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)	Y(3)	Y(4)	Y(4)
Parking	Y	Y	Y(2)	Y(3)	Y(4)	N
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)	Y(5)	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

Numbers in parenthesis refer to notes.

*The designations contained in this 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. 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.

Key to Table 1

SLUCM 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 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 structure.

Notes for Table 1

(1) Where the community determines that residential or school uses must be allowed, measures to achieve outdoor to indoor Noise Level Reduction (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 a 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 of 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 of 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 of 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.

Source: FAR Part 150

Negotiated restrictions are more favorable from the FAA's standpoint, but still require unwieldy procedures for approval and implementation. In order to be effective the agreements normally must be agreed to by all airlines using an airport.

Stage 2 restrictions are more difficult, because one of the major reasons for ANCA was to discourage local restrictions more stringent than 1999 phase-out already contained in ANCA. To comply with the regulation and institute a new Stage 2 restriction, the proprietor must generally do two things. It must prepare a cost/benefit analysis of the proposed restriction and give proper notice. The cost/benefit analysis is extensive and entails considerable evaluation. Stage 2 restrictions primarily apply to Stage 2 aircraft weighing less that 75,000 pounds. These restrictions do not require approval by the FAA.

Stage 3 restrictions are even more difficult to implement. A Stage 3 restriction involves considerable additional analysis, justification, evaluation and financial discussion. In addition, a Stage 3 restriction must result in a decrease in noise exposure of the 65 dB DNL to noise sensitive land uses (residences, schools, churches, parks, and other uses deemed noise sensitive by the local juristiction). The regulation requires both public notice and FAA approval.

Environmental Protection Agency

- **Environmental Protection Agency, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety".**

In March 1974, in response to a federal statutory mandate, the EPA published this document[1] (EPA 550/9-74-004) describing 55 DNL as the requisite level with an adequate margin of safety for areas with outdoor uses, including residences and recreational areas. This document does not constitute EPA regulations or standards. Rather, it is intended to "provide State and Local governments as well as the Federal Government and the private sector with an informational point of departure for the purpose of decision-making". Note that these levels were developed for suburban type uses. In some urban settings, the noise levels will be significantly above this level, while in some wilderness settings, the noise levels will be well below this level. The EPA "levels document" does not constitute a standard, specification or regulation, but identifies safe levels of environmental noise exposure without consideration for achieving these levels or other potentially relevant considerations.

Federal Interagency Committee on Noise (FICON) Report of 1992

The use of the CNEL or DNL metric and the 65 dB CNEL criteria has been reviewed by various interest groups concerning its usefulness in assessing aircraft noise impacts. At the direction of the EPA and the FAA, the Federal Interagency Committee On Noise (FICON) was formed to review specific elements of the assessment of airport noise impacts and to make recommendations regarding potential improvements. FICON includes representatives from the Departments of Transportation, Defense, Justice, Veterans Affairs, Housing and Urban Development, the Environmental Protection Agency, and the Council on Environmental Quality.

FICON was formed to review Federal policies used to assess airport noise impacts and on the manner in which noise impacts are determined. This included whether aircraft noise impacts are fundamentally different from other transportation noise impacts; the manner in which noise

impacts are described; and the extent to which impacts outside of DNL 65 should be reviewed in federal environmental impact statements.

The committee determined that there are no new descriptors or metrics of sufficient scientific standing to substitute for DNL. The DNL noise exposure metric and the dose-response relationships used to determine noise impact were determined to be proper for assessing noise from civil and military aviation in the general vicinity of airports. The report supported agency discretion in the use of supplemental noise analysis. The report recommended improvement in public understanding of the DNL, supplemental methodologies and aircraft noise impacts.

The report endorsed and expanded traditional FAA environmental screening criteria for potential airport noise impacts. FICON recommended that if screening analysis determines noise-sensitive areas at or above DNL 65 dB show an increase of DNL 1.5 dB or more, then further analysis should be conducted of noise sensitive areas between DNL 60-65 dB having an increase of DNL 3 dB or more. The most recent FAA environmental guidelines, Order 1050.1E, incorporates these FICON recommendations.

State of California

The Aeronautics Division of the California State Department of Transportation (Caltrans) enforces the California Airport Noise Regulations. These regulations establish 65 dB CNEL as a noise impact boundary within which there shall be no incompatible land uses. This requirement is based, in part, upon the determination in the Caltrans regulations that 65 dB CNEL is the level of noise which should be acceptable to "a reasonable man residing in the vicinity of an airport." Airports are responsible for achieving compliance with these regulations. Compliance can be achieved through noise abatement alternatives, land acquisition, land use conversion, land use restrictions, or sound insulation of structures. Airports not in compliance can operate under variance procedures established within the regulations.

California Noise Insulation Standards[xii] apply to all multi-family dwellings built in the State. Single-family residences are exempt from these regulations. With respect to community noise sources, the regulations require that all multi-family dwellings with exterior noise exposures greater that 60 dB CNEL must be sound insulated such that the interior noise level will not exceed 45 dB CNEL. These requirements apply to all roadway, rail, and airport noise sources.

The State of California requires that all municipal General Plans contain a Noise Element [xiii]. The requirements for the Noise element of the General Plan include describing the noise environment quantitatively using a cumulative noise metric such as CNEL or DNL, establishing noise/land use compatibility criteria, and establishing programs for achieving and/or maintaining compatibility. Noise elements shall address all major noise sources in the community including mobile and stationary sources.

Airport Land Use Commissions were created by State Law[xiv] for the purpose of establishing a regional level of land use compatibility between airports and their surrounding environs. The Sonoma County Airport Land Use Commission has adopted a Comprehensive Airport Land Use Plan (CALUP) for Sonoma County Airport. All residential, uses are unacceptable with noise above 65 dB CNEL. Residences are conditionally acceptable between 55 and 65 dB CNEL, subject to an outdoor-to-indoor noise level reduction of at least 25 to 30 dB[xv].

Sonoma County

Sonoma County has adopted land use and noise compatibility policies to address existing and potential noise impacts. Three primary documents that include these policies are as follows:

Sonoma County General Plan – Noise Element

The Noise Element describes policies that identify acceptable land uses relative to existing and projected noise levels. Policy NE-1a designates areas exposed to existing or projected exterior noise levels that exceed 60 dB CNEL as noise impacted areas. Policy NE-1b states to avoid noise sensitive land use development in noise impacted areas unless noise levels can be reduced to 60 dB CNEL or less. A maximum exterior noise level of 65 dB CNEL is allowed given that the interior noise level does not exceed 45 dB CNEL[xvi].

Sonoma County General Plan – Air Transportation Element

The Air Transportation Element supports and guides the future growth and development of the air transportation services within Sonoma County in a manner that is consistent and reinforces the policies stated in other elements of the General Plan. The goal of this Element is to maintain the land uses adjacent to the Airport compatible with existing and future Airport operations. Policy AT-1a states that proposed development within a noise environment in excess of 55 dBA CNEL shall comply with the Sonoma County Comprehensive Airport Land Use Plan.

Sonoma County Comprehensive Airport Land Use Plan (CALUP)

The CALUP describes the noise compatibility standards of the six public use airports within Sonoma County. All residential uses are unacceptable with noise above 65 dBA CNEL. Residences are conditionally acceptable between 55 and 60 dBA CNEL, subject to an outdoor-to-indoor noise level reduction of at least 25 decibels, and between 60 and 65 dBA CNEL, subject to an outdoor-to indoor noise level reduction of at least 30 decibels. Schools, libraries, hospitals, and nursing homes are unacceptable in areas exposed to noise above 60 dBA CNEL and are conditionally acceptable between 55 and 60 dBA CNEL subject to a noise level reduction of 25 decibels. Churches, auditoriums, and concert halls are unacceptable at noise levels above 65 dBA and are required to provide for noise level reductions of 25 to 30 decibels if they are located between 55 and 65 dBA CNEL.

It is common to assume that a home with typical construction will provide 20 dB outdoor-to-indoor noise reduction with windows and doors closed. This assumption dates back to the 1960's and is based on typical Southern California wood frame construction. This is the value assumed in the California Airport Noise Regulations (California Code of Regulations, Title 21, Division of Aeronautics, Chapter 6). This assumption is conservative, as homes built since the mid 1970's, when the building code was enhanced to improve energy insulation, and in areas where cooler winters and warmer summers are prevalent homes are more likely to provide sound insulation more in the range of 25 dB or higher as a result of better construction or home improvements to reduce energy costs. The key factors are how well the windows and doors seal in their frame, and the window area. For the homes around the Airport, and in particular those that will not be acquired, 25 dB is a good assumption for the noise reduction with windows and doors closed. Of course, this is an assumption that could vary with the house. A poorly maintained home with broken or cracked windows, or windows that are jammed in an open or partially open position won't even achieve a 20 dB noise reduction. However, this is not the case for some homes in Sonoma County where a 15 dB noise reduction is the standard. Therefore, homes located between Proposed Project 55 and 60 dB CNEL meet the Sonoma

County Noise Compatibility Standards. Homes located between 60 and 65 dB CNEL and above 65 dB CNEL do not meet the standards.

The noise compatibility standards are listed on Table 3-1 below:

Table 3-1

SONOMA COUNTY CALUP NOISE COMPATIBILITY STANDARDS

	CNEL, dBA				
LAND USE CATEGORY	**less than 55**	**55-60**	**60-65**	**65-70**	**more than 70**
RESIDENTIAL					
Rural (less than 1 dwelling unit/acre)	A	C[a]	C[b]	U	U
Urban - low density (1-4 units/acre)	A	C[a]	C[b]	U	U
Urban - medium to high density (more than 4 units/acre)	A	C[a]	C[b]	U	U
Transient lodging, except hotels and motels	A	C[a]	C[b]	U	U
Mobile home parks	A	C[a]	C[b]	U	U
PUBLIC					
Schools, libraries, hospitals, and nursing homes	A	C[c]	U	U	U
Churches, auditoriums, and concert halls	A	C[c]	C[d]	U	U
Transportation, parking, and cemeteries	A	A	A	A	C[c]
COMMERCIAL AND INDUSTRIAL					
Hotels and motels	A	A	C[c]	C[d]	U
Offices and retail trade	A	A	C[c]	C[d]	U
Service commercial, wholesale trade, warehousing, and light industrial	A	A	A	C[c]	C[d]
General manufacturing, utilities, and extractive industry	A	A	A	A	A
AGRICULTURAL AND					

RECREATIONAL					
Cropland	A	A	A	A	A
Livestock breeding and zoos	A	A	A	A	U
Parks and playgrounds	A	A	A	A	C[c]
Golf courses, riding stables, and water recreation	A	A	A	A	C[c]
Outdoor spectator sports	A	A	A	C[e]	U
Amphitheaters	A	U	U	U	U

NOTES:

A = Acceptable land use.

C = Land use is conditionally acceptable upon meeting compatibility criteria. (See notes below.)

U = Unacceptable land use. Land use is not permitted.

[a] An NLR* of at least 25 decibels disclosure covenant shall also b

[b] An NLR* of at least 30 decibels disclosure covenant shall also b

[c] Measures to achieve an NLR* c is received, office areas, or slee

[d] Measures to achieve an NLR* c is received, office areas, or slee

[e] Sound reinforcement system is

*NLR Outdoor-to-indoor noise level re

Table 5-1 continued

NOTES:

A = Acceptable land use.

C = Land use is conditionally acceptable upon meeting compatibility criteria. (See notes below.)

U = Unacceptable land use. Land use is not permitted.

[a]	An NLR* of at least 25 decibels is required. The granting of an avigation easement to the airport operator shall be required. The recording of a fair disclosure covenant shall also be required.
[b]	An NLR* of at least 30 decibels is required. The granting of an avigation easement to the airport operator shall be required. The recording of a fair disclosure covenant shall also be required.
[c]	Measures to achieve an NLR* of 25 decibels shall be incorporated into the design and construction of portions of these buildings where the public is received, office areas, or sleeping areas.
[d]	Measures to achieve an NLR* of 30 decibels shall be incorporated into the design and construction of portions of these buildings where the public is received, office areas, or sleeping areas.
[e]	Sound reinforcement system is required.
*NLR	Outdoor-to-indoor noise level reduction in A-weighted decibels assuming doors and windows are closed.

SOURCE: SONOMA COUNTY GENERAL PLAN (2008)

3.1 METHODOLOGY

The methods used here for describing baseline noise and forecasting the future noise environment rely extensively on computer noise modeling. The noise environment is commonly depicted in terms of lines of equal noise levels, or noise contours. These noise contours are supplemented here with specific noise data for selected points on the ground.

The FAA's Integrated Noise Model (INM) Version 7.0b[xvii] was used to model aviation operations for the Airport for purposes of identifying the extent of aircraft noise exposure. The original INM was released in 1977. The latest version, INM Version 7.0b, was released for use in 2009, and is the state-of-the-art in airport noise modeling. The INM is a large computer program developed to plot noise contours for airports. The program is provided with standard aircraft noise and performance data for over 100 civilian aircraft types that can be tailored to the characteristics of an airport, as well as a database of military aircraft types. Version 7.0b includes an updated database that includes some newer aircraft, the ability to include run-ups in the computations, the ability to include topography in the computations, and the increased differentiation between different types of aircraft (civil, military, and helicopter). Noise contour files from the INM were loaded into the ArcView Geographic Information System (GIS) software for plotting and land use analysis. Mestre Greve Associates developed all of the CNEL noise contours presented in the report.

The INM program requires the input of the physical and operational characteristics of an airport. Physical characteristics include runway coordinates, airport altitude, and temperature and optionally, topographical data. Operational characteristics include various types of aircraft data. This includes not only the aircraft types and flight tracks, but also departure procedures, arrival procedures, and stage lengths (flight distance) that are specific to the operations at an airport. Aircraft data needed to generate noise contours include:

- Number of aircraft operations by type
- Types of aircraft
- Day/Night time distribution by type
- Flight tracks
- Flight track and runway utilization by type
- Flight profiles
- Typical operational procedures
- Average Meteorological Conditions

The following sections describe the data used in generating existing and future aircraft noise exposure contours.

4.1 BASELINE NOISE CONDITIONS — BACKGROUND

The purpose of this section is to document the analysis of the base year noise environment at the Airport. For purposes of noise analysis and comparison, operations data for the calendar year 2009 were analyzed as the baseline conditions for this study. At the time of preparation of this report, this period was the latest twelve-month period for which reliable operations information was available. This period serves as the baseline noise environment and provides a reference point from which changes to the noise environment may be assessed. For purposes of identification, this period will be referenced as Baseline 2009.

4.2 BASELINE 2009 OPERATIONS AND FLEET MIX

The Airport serves scheduled commercial passenger airline operations, general aviation operations, and military (US Coast Guard) operations. The operations for the year 2009 are summarized below in Table 4-1.

Table 4-1
BASELINE AIRCRAFT OPERATIONS

Category	Baseline 2009 Operations
Air Carrier	3,510
Air Taxi	5,118
General Aviation	50,399
Military	227
Touch & Go (General Aviation)	31,348
Touch & Go (Military)	58
Total Operations	**90,660**

SOURCE: FAA, MGA/L&B (2011)

Table 4-1 shows that 3,510 or 3.8% of total operations were conducted by Air Carrier (Turbo-prop) aircraft. Air Taxi operations include small single engine aircraft as well jet-powered aircraft.

Aircraft operations and fleet mix are important components of this analysis as cumulative noise levels in the environs of the Airport are a function of the loudness of the aircraft and the number of aircraft operations. Of the 90,660 total operations occurring at the Airport during the baseline year, an estimated 6,120, or 6.8%, were business jet operations.

Detailed operations data are maintained for Air Carrier operations. However, information regarding specific aircraft types within the Air Taxi, General Aviation and Military categories was estimated with the assistance of the Airport Air Traffic Control Tower (ATCT) personnel and the use of FAA radar data. A summary of the Airport Baseline 2009 operations for each aircraft type is shown in Table 4-2. These data were input into the INM for development of the Baseline 2009 noise contours.

Table 4-2
AIRCRAFT OPERATIONS BY AIRCRAFT TYPE – BASELINE 2009

INM Category/Aircraft	Aircraft Description	Baseline 2009
Jet		
737700	Boeing Business Jet	30
CIT3	Citation III	374
CL600	Challenger 600	625
CNA500	Citation I	700
CNA510	Citation Mustang	105
CNA750	Citation X	523
EMB120	Embraer 120	13
EMB145	Embraer 145	30
DO328	Dornier 328	26
FAL20	Falcon 20	268
GII	Gulfstream II	17
GIIB	Gulfstream III	145
GIV	Gulfstream IV	304
GV	Gulfstream V	88
IA1125	Westwind Astra	281
LEAR25	Lear 25	49
LEAR35	Lear 35	668
MU3001	Beechjet 400	1,874
SUBTOTAL		**6,120**
Propeller		
BEC58P	Beech Baron	13,605
CNA172	Cessna 172	5,339
CNA182	Cessna 182	2,912
CNA206	Cessna 206	7,077
CNA208	Cessna 208	1,676
CNA20T	Cessna 206 Turbo	2,462
CNA441	Cessna Conquest	1,851
DHC6	Dash 6	3,883
GASEPF	Single Engine Piston-Fixed Pitch	21,922
GASEPV	Single Engine Piston-Variable Pitch	12,737
PA30	Piper Twin Comanche	72
PA31	Piper Navajo	359
SD330	Shorts 330 (Piaggio P190)	2,457

Table 4-2 continued

INM Category/Aircraft	Aircraft Description	Baseline 2009
DHC830(Q400)	Bombardier Q400	3,510
C130	C130 Hercules	50
OV10A	Rockwell Bronco	742
SUBTOTAL		**80,654**
Helicopter		
A109	Augusta 109	924
B407	Bell 407	866
B222	Bell 222	43
R44	Robinson 44	1,938
EC130	Eurocopter 130	43
S70	Sikorsky Blackhawk	72
SUBTOTAL		**3,886**
TOTAL OPERATIONS		**90,660**

SOURCE: FAA, MGA/L&B (2011)

4.3 RUNWAYS AND FLIGHT TRACKS

Flight tracks refer to the actual tracks projected over the ground used by aircraft for arrival or departure to/from the Airport. Flight tracks are related to runway utilization and are a large factor in determining the shape of the noise contours. These data are critical to the noise analysis as cumulative noise metrics such as CNEL are based upon the total noise exposure occurring during a 24-hour period. Safety considerations, airport layout, aircraft performance, runway length requirements, direction of destination and meteorological conditions influence the runway utilization at the Airport. These considerations are discussed in detail in the following paragraphs.

Runway Utilization

Runway utilization refers to the percentage of total arrival or departure operations occurring on a specific runway. Runway utilization is determined by several factors including runway length, proximity to the terminal, and meteorological conditions as well as the performance capabilities of specific aircraft.

Runway utilization is greatly influenced by meteorological conditions. For safety reasons, aircraft take off and land into the prevailing wind. This practice results in reduced groundspeed and greater safety margins for each of these operations. The wind direction at the Airport changes frequently, but allows utilization to be divided amongst all runways. However, there are minimal departures from Runway 01 due to the relatively long taxi to the beginning of the runway.

The physical characteristics of the airport layout are another important factor influencing runway utilization. These characteristics include the length and orientation of the runways and terminal

location with respect to the runways. The runway layout for the Airport is shown in Figure 4-1. Runways are identified by reference to the direction of heading referenced to magnetic north rounded to the nearest 10 degrees. For example, an aircraft taking off or landing on Runway 29 have a magnetic heading of approximately 290 degrees.

The runways at the Airport are similar in length. Runway 01/19 is 5,002 feet in length. Runway 14/32 is 5,115 feet in length. Additionally, helicopters use helipads located near the terminal building.

Pilots generally prefer to use the longer runways for safety considerations and aircraft performance capabilities and meteorological conditions may dictate the use of a specific runway. Air Carrier operations for example, primarily use the longest runway (Runway 14/32). Terminal proximity and direction of arrival or departure are secondary considerations that influence runway utilization. Assuming safety considerations are met, pilots prefer to use the most expeditious runway and route of flight. At the Airport, these considerations favor the use of Runway 14/32 for Air Carrier, Air Taxi, and General Aviation jet operations. Touch and Go operations, which are normally training flights that fly over the runway or land on the runway momentarily before departing, predominantly take place on Runway 14/32. Touch and Go operations also take place on Runway 01/19, which is used predominantly by General Aviation propeller aircraft.

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