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Introduction

Introduction

This Working Paper, Working Paper Three, presents the background information on noise/methodology as well as existing and future baseline noise conditions. This working paper is the third in a series to be prepared for the General Mitchell International Airport FAR Part 150 Study. It must be remembered that the FAR Part 150 Study is a five-year planning study, with the future year being the fifth year after the date of submittal of the document. This Working Paper is intended for review and comment by the Committee, and should be considered a draft chapter of the final report.

Background Information on Noise/Methodology

Introduction to Background Information on Noise

Noise is perceived by, and consequently affects people in a variety of ways. This section presents background information on the characteristics of sound as a physical phenomenon and provides insight into the perception of noise by humans. This section will also provide a means by which to relate the sound made by aircraft operating to and from General Mitchell International Airport (MKE) to the noise perceived by people in the surrounding communities. The metrics (standards of measurement) and methodologies used in the Part 150 Noise and Land use Compatibility Study (Study) to measure and model the noise environment to provide an understanding of the assessment of noise experienced from aircraft operations. This section is divided into the following sub-sections:

- Characteristics of Sound - Presents properties of sound that are important for technically describing noise in the airport setting.
- Factors Influencing Human Response to Sound -Presents factors audible to the human ear that produce subjective perceptions and elicit a response.
- Health Effects of Noise - Summarizes the potential disturbances and health effects of noise to humans.
- Sound Rating Scales - Presents various sound rating scales and how these scales are applied to assessing noise from aircraft operations.
- Noise/Land Use Compatibility Guidelines - Summarizes the current guidelines and regulations used to control the use of land in areas affected by aircraft noise.
- Airport Noise Assessment Methodology - Describes computer modeling and on-site sound level measurements used to measure aircraft and other noise in the vicinity of airports.

Characteristics of Sound

<u>*Sound Level and Frequency.*</u> Sound is technically described in terms of the sound pressure (amplitude) and frequency (similar to pitch).

Sound pressure is a direct measure of magnitude of a sound without consideration for other factors that may influence its perception. The range of sound pressures that occur in the environment is so large that it is convenient to express them on a logarithmic scale. The standard unit of measurement of sound pressure is the Decibel (dB). One decibel is actually an exponent to the reference point of 20 micro Pascals or about .000000003 pounds per square inch. Thus, 65 decibels is that amount to the 65^{th} power. A logarithmic scale is used because of the difficulty in expressing such large numbers.

Therefore, on the logarithmic scale, a sound level of 70 dB has 10 times as much acoustic energy as a level of 60 dB while a sound level of 80 has 100 times as much acoustic energy as 60 dB. This differs from the human perception to noise, which typically judges a sound 10 dB higher than another to be twice as loud, 20 dB higher four times as loud, and so forth.

The frequency of a sound is expressed as Hertz (Hz) or cycles per second. The normal audible frequency range for young adults is 20 Hz to 20,000 Hz. The prominent frequency range for community noise, including aircraft and motor vehicles, is between 50 Hz and 5,000 Hz. The human ear is not equally sensitive to all frequencies, with some frequencies judged to be louder for a given signal than others. As a result, research studies have analyzed how individuals make relative judgments as to the "loudness" or "annoyance" to a sound. The most prominent of these scales include Loudness Level, Frequency-Weighted Contours (such as the A-weighted scale), and Perceived Noise Level. Noise metrics used in aircraft noise assessments are based upon these frequency weighting scales. Below is a glossary of noise metric terminologies, which are discussed in the following paragraphs.

> *Loudness Level.* This scale has been devised to approximate the human subjective assessment to the "loudness" of a sound. Loudness is the subjective judgment of an individual as to how loud or quiet a particular sound is perceived. The human ear is not equally sensitive to all frequencies, with some frequencies judged to be louder for a given signal than others. This sensitivity difference also varies for different sound pressure levels.
>
> These data are obtained through group laboratory studies of human response to noise. To measure noise perception, a pure tone signal of 1,000 hertz is generally played, and followed by an elapsed interval, a second tone of a different frequency is played. The listener then adjusts the signal until the two tones are judged to be the same.

Frequency-Weighted Contours (dBA, dBB, and dBC). In order to simplify the measurement and computation of sound loudness levels, frequency-weighted networks have obtained wide acceptance. The equal loudness level contours for 40 dB, 70 dB, and 100 dB have been selected to represent human frequency response to low, medium, and loud sound levels. By inverting these equal loudness level contours, the A-weighted, B-weighted and C-weighted frequency weightings were developed. These frequency-weighted contours demonstrate different aspects of noise, and are presented in Figure C1.

The most common weighting is the A-weighted noise curve. The A-weighted decibel scale (dBA) describes frequencies in a manner approximating the sensitivity of the human ear. In the A-weighted decibel, everyday sounds normally range from 30 dBA (very quiet) to 100 dBA (very loud). Most community noise analyses are based upon the A-weighted decibel scale. Examples of various sound environments, expressed in dBA, are presented in Figure C2.

Some interest has developed in utilizing a noise curve that measures lower frequency noise sources. For example, the C-weighted curve is used for the analysis of the noise impacts from artillery noise. Other suggested applications are for the assessment of aircraft ground noise levels.

Perceived Noise Level. Perceived noisiness is another method of rating sound. It was originally developed for the assessment of aircraft noise. Perceived noisiness is defined as "the subjective impression of the unwantedness of a not unexpected, non-pain or fear-provoking sound as part of one's environment," (Kryter, 1970) "Noisiness" curves differ from "loudness curves" in that they have been developed to rate the noisiness or annoyance of a sound as opposed to the loudness of a sound.

As with loudness curves, noisiness curves have been developed from laboratory psychoacoustic surveys of individuals. However, in noisiness surveys, individuals are asked to judge in a laboratory setting when two sounds are equally noisy or disturbing if heard regularly in their own environment. These surveys are more complex and are therefore subject to greater variability. Aircraft certification data are based upon these types of noisiness scales (see Federal Aviation Regulation (FAR) 36 Regulations presented in the Noise and Land Use section of this chapter).

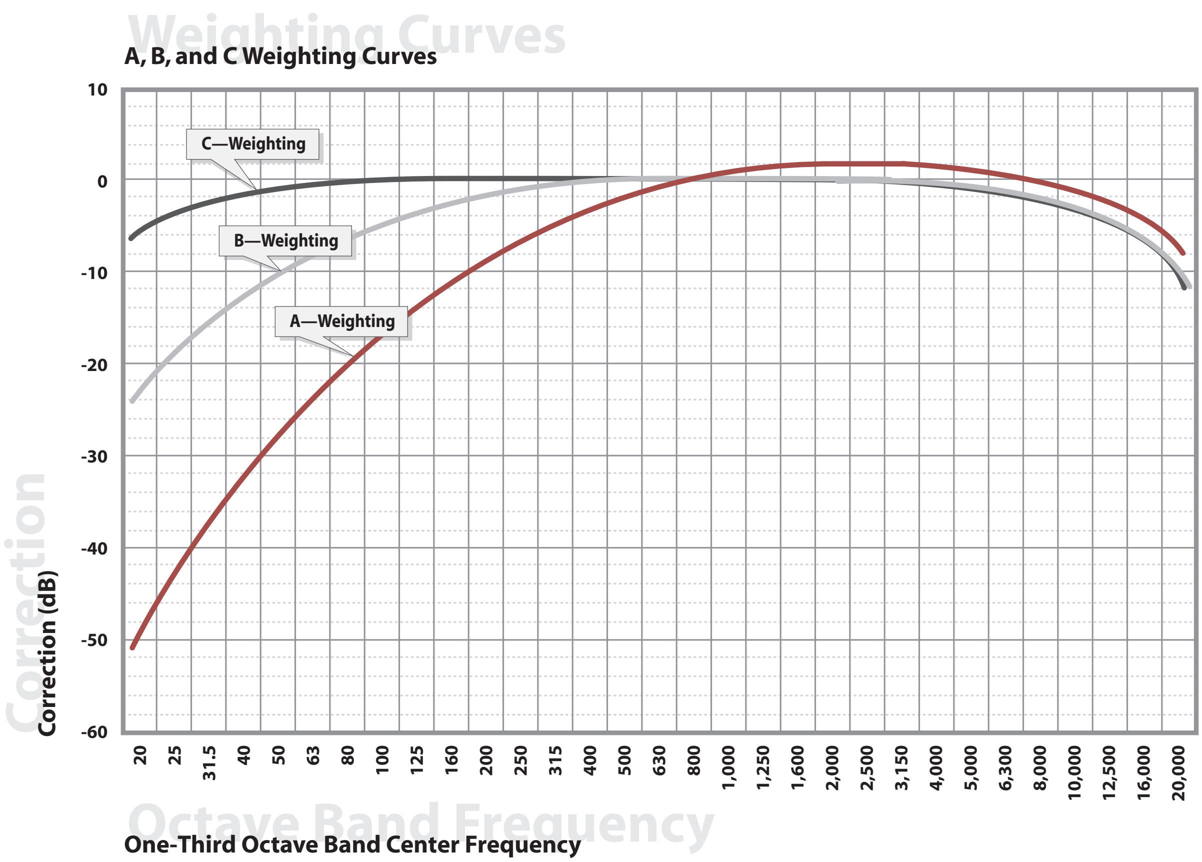

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Figure C1 **Frequency Weighted Contours (dBA, dBB, dBC)**

EXAMPLES OF VARIOUS A-WEIGHTED DECIBEL SOUND ENVIRONMENTS

dB(A)	OVER-ALL LEVEL Sound Pressure Level Approx. 0.0002 Microbar	COMMUNITY (Outdoor)	HOME or INDUSTRY	LOUDNESS Human Judgement of Different Sound Levels
130		Military Jet Aircraft Takeoff with Afterburner from Aircraft Carrier @ 50 ft. (130)	Oxygen Torch (121)	120 dB(A) 32 Times as Loud
120 110	UNCOMFORTABLY LOUD	Concorde Takeoff (113)	Riveting Machine (110) Rock and Roll Band (108-114)	110 dB(A) 16 Times as Loud
100		Boeing 747-200 Takeoff (101)		100 dB(A) 8 Times as Loud
90	VERY LOUD	Power Mower (96) DC-10-30 Takeoff (96)	Newspaper Press (97)	90 dB(A) 4 Times as Loud
80		Car Wash @ 20 ft. (89) Boeing 727 Hushkit Takeoff (89)	Food Blender (88) Milling Machine (85) Garbage Disposal (80)	80 dB(A) 2 Times as Loud
70	MODERATELY LOUD	High Urban Ambient Sound (80) Passenger Car, 65 mph @ 25 ft. (77) Boeing 757 Takeoff (76)	Living Room Music (76) TV-Audio, Vacumn Cleaner	70 dB(A)
60		Propeller Airplane Takeoff (67) Air Conditioning Unit @ 100 ft. (60)	Cash Register @ 10 ft. (65-70) Electric Typewriter @ 10 ft. (64) Conversation (60)	60 dB(A) 1/2 Times as Loud
50	QUIET	Large Transformers @ 100 ft. (50)		50 dB(A) 1/4 Times as Loud
40		Bird Calls (44) Low Urban Ambient Sound (40)		40 dB(A) 1/8 Times as Loud

"Aircraft takeoff noise measured 6,500 meters from beginning of takeoff roll
(Source: Advisory Circular AC-36-3G)"

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Figure C2 **Examples of Various Sound Environments**

Propagation of Noise. Outdoor sound levels decrease as a result of several factors, including increasing the distance from the sound source, atmospheric absorption (characteristics in the atmosphere that actually absorb sound), and ground attenuation (characteristics on the ground that absorb sound). If sound is radiated from a source in a homogeneous and undisturbed manner, the sound travels in spherical waves. As the sound wave travels away from the source, the sound energy is spread over a greater area dispersing the sound power of the wave.

Temperature and humidity of the atmosphere also influence the sound levels received by the observer. The influence of the atmosphere and the resultant fluctuations increase with distance and become particularly important at distances greater than 1,000 feet. The degree of absorption depends on frequency of the sound as well as the humidity and air temperature. For example, when the air is cold and humid, and therefore denser, atmospheric absorption is lowest. Higher frequencies are more readily absorbed than the lower frequencies. Over large distances, lower frequency sounds become dominant as the higher frequencies are attenuated. Examples of the effects of temperature and humidity on the absorption effects of the atmosphere are presented in Figure C3.

This is particularly relevant to Milwaukee because winter weather often includes high humidity and cold overcast conditions that result in lowered noise attenuation causing noise levels to remain higher farther from a noise source than would occur under standard conditions. These conditions have a tendency to facilitate an atmospheric inversion, which also results in higher aircraft noise than when inversions are not present.

Duration of Sound. Duration of a noise event is an important factor in describing sound in a community setting. The longer the noise event, the more likely that the sound will be perceived as annoying. The "effective duration" of a sound starts when a sound rises above the background sound level and ends when it drops back below the background level. Psycho-acoustic studies have confirmed a relationship between duration and annoyance and established the amount a sound must be reduced to be judged equally annoying over an increased duration time.

This relationship between duration and noise level forms the basis of how the equivalent energy principal of sound exposure is measured. Reducing the acoustic energy of a sound by one-half results in a 3 dB reduction. Conversely, doubling the duration of the sound event increases the total energy of the event by 3 dB. This *equivalent energy principal* is based upon the premise that the potential for a noise to impact a person is dependent on the total acoustical energy content of the noise. Noise descriptors explained below (DNL, LEQ and SEL) are all based upon this equal energy principle.

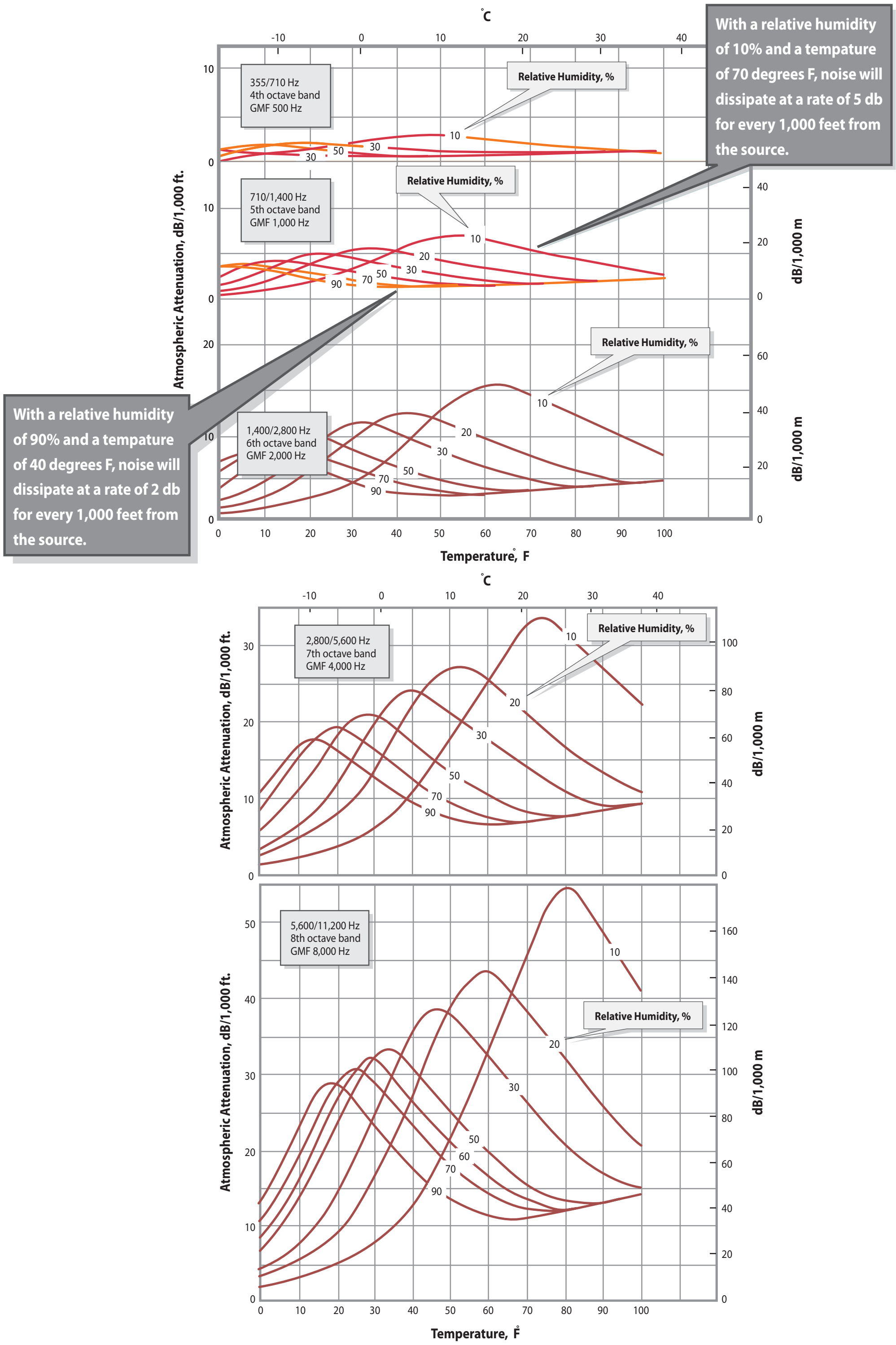

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Figure C3 **Atmospheric Attenuation Graphs**

Change in Noise Levels. The concept of change in sound levels is related to the reaction of the human ear to sound. The human ear detects relative differences between sound levels better than absolute values of levels. Under controlled laboratory conditions, a human listening to a steady unwavering pure tone sound can barely detect a change of approximately one decibel for sound levels in the mid-frequency region. However, when ordinary noises are heard, a young healthy ear can only detect changes of two to three decibels. A five-decibel change is noticeable while a 10-decibel change is judged by the majority of people as a doubling effect of the sound. Therefore it is typical in environmental noise studies to consider a 3 dB change as potentially discernible.

Recruitment of Loudness. Recruitment describes the perception of loudness in situations where masking elevates the threshold of hearing a sound from a background sound. A listener's judgment of the loudness of a sound will vary with different levels of background noise. In low level background situations that are near the threshold of hearing, the loudness level of a sound increases gradually. In these situations, a desired sound, such as music that is a level of 40 to 60 dB above the ambient or background, would be judged as comfortable. In loud background settings, a sound that is approximately 20 dB above background or ambient is perceived to be comfortable.

Masking Effect. One characteristic of sound is its ability to interfere with the listener's ability to hear another sound. This is defined as the masking effect. The presence of one sound effectively raises the threshold of audibility for the hearing of a second sound. For a sound 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 characteristic is dependent upon many factors, including the spectral (frequency) characteristics of the two sounds, the sound pressure levels and the relative start time of sound events. The masking effect is greatest when it is closest to the frequency of the signal. Low frequency sounds can mask higher frequency sounds; however, high frequency sounds do not easily mask low frequency sounds.

Ground Effects. This term describes the effects of vegetation on noise. As sound travels away from the source, some of it is absorbed by grass, plants, and trees. The amount of such ground attenuation (rate that noise level reduces at distances further from the noise source) depends on the structure and density of trees and foliage as well as the height of both the source and receiver and the frequency of the sound being absorbed. If the source and the receiver of the sound are both located below the average height of the intervening foliage, the ground covering will be most effective. If either the source or the receiver rises above the height of the ground covering, the excess attenuation will become less effective. Reflected sound, however, will still be reduced.

Factors Influencing Human Response to Sound

Many factors influence how a sound is perceived and whether or not it is considered annoying to the listener. This includes not only physical characteristics of the sound but also secondary influences such as sociological and external factors. Molino [2], in the "Handbook of Noise Control" describes human response to sound in terms of both acoustic and non-acoustic factors. These factors are summarized in Table C1.

Sound rating scales are developed to account for how humans respond to sound and how sounds are perceived in the community. Many non-acoustic parameters affect individual response to noise. Background sound, which is an additional acoustic factor, is important in describing sound in rural settings. Fields [3], in his analysis of the effects of personal and situational variables on noise annoyance, identified a clear association of reported annoyance and fear of an accident. In particular, Fields stated there is 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 pilots or authorities related to airlines; and (3) an expressed sensitivity to noise generally. Thus, it is important to recognize that such non-acoustic factors as well as acoustic factors, contribute to human response to noise.

Table C1
FACTORS THAT AFFECT INDIVIDUAL ANNOYANCE TO NOISE
General Mitchell International Airport FAR Part 150 Noise Compatibility Study

Primary Acoustic Factors	
	Sound Level
	Frequency
	Duration
Secondary Acoustic Factors	
	Spectral (Frequency) 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
	Whether the Noise is Necessary
	Individual Differences and Personality

Source: C. Harris, 1979

Health Effects of Noise

Noise is often described as unwanted sound and is known to have several adverse effects on people. From these effects, 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. Each of these potential noise impacts are briefly discussed in the following narrative:

- *Hearing Loss* is generally not a concern in community/aircraft noise situations, even close to a major airport or a freeway. The potential for noise induced hearing loss is more commonly associated with occupational noise exposures in heavy industry, very noisy work environments with long-term, sometimes close-proximity exposure, or certain very loud recreational activities such as target shooting, motorcycle or car 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, do not exceed this standard and are not sufficiently loud to cause hearing loss.

- *Communication Interference* is one of the primary concerns with aircraft noise. Communication interference includes interference with hearing, speech, or other forms of communication, such as watching television and talking on the telephone. Normal conversational speech produces sound levels in the range of 60 to 65 dBA and any noise in this range or louder may interfere with the ability of another individual to hear or understand what is spoken. There are specific methods for describing speech interference as a function of the distance between speaker, listener and voice level. Figure C4 shows the relationship between the quality of speech communication and various noise levels.

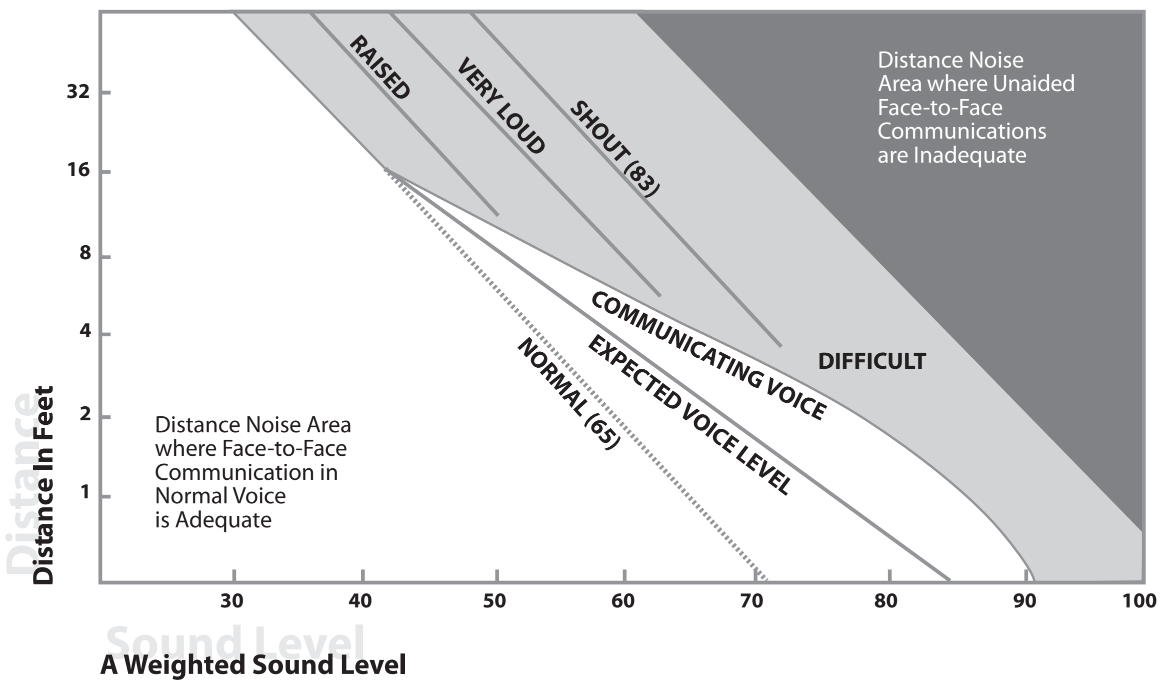

Figure C4 **Quality of SpeechCommunication In Relation To The Distance Between the Talker and the Listener**

- *Sleep Interference,* particularly during nighttime hours, is one of the major causes of annoyance due to noise. Noise may make it difficult to fall asleep, create momentary disturbances of natural sleep patterns by causing shifts from deep to lighter stages and may cause awakenings that a person may not be able to recall.

  This research showed that once a person was asleep in their own home, it is much more unlikely that they will be awakened by a noise. Some of this research has been criticized because it was conducted in areas where subjects had become accustomed to aircraft noise. On the other hand, some of the earlier laboratory sleep studies had been criticized because of the extremely small sample sizes of most laboratory studies and because the laboratory was not necessarily a representative sleep environment.

  This English *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) 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 C5 aircraft noise was a minor contributor among a host of other factors that lead to awakening response.

  Likewise, the Federal Interagency Committee On Noise (FICON) in an earlier 1992 document entitled Federal Interagency Review of Selected Airport Noise Analysis Issues recommended an interim dose-response curve for sleep disturbance based on laboratory studies of sleep disturbance. This was updated in June of 1997, when the Federal Interagency Committee on Aviation Noise (FICAN) replaced the FICON recommendation with an updated curve based on the more recent in-home sleep disturbance studies. 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 C6. This is a very conservative approach. A more common statistical curve for the data points is also reflected in Figure C6. The differences indicate, for example, a 10% awakening rate at a level of approximately 100 dB SEL, while the "maximum awakened" curve prescribed by FICAN 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.) Sleep interference continues to be a major concern to the public and an area of debate among researchers.

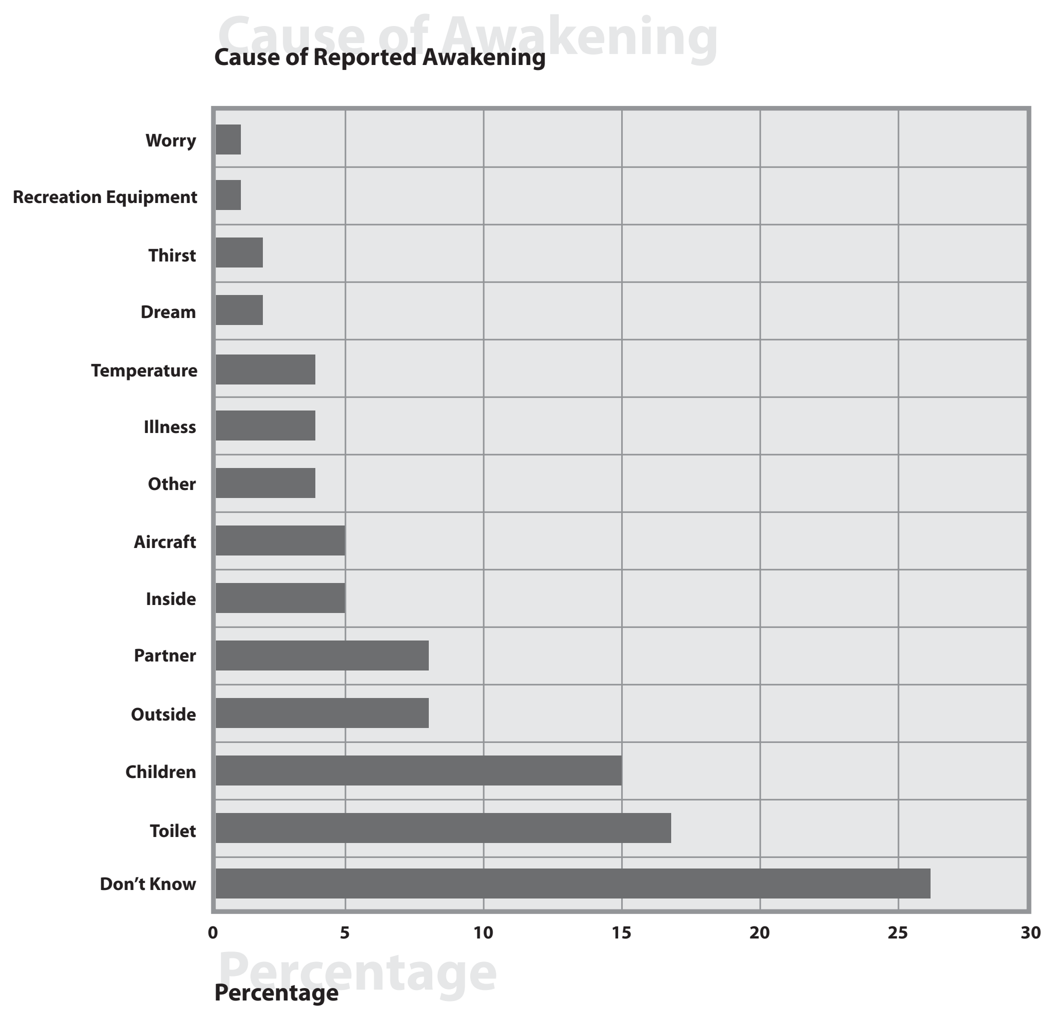

Figure C5 **Causes of Reported Awakenings**

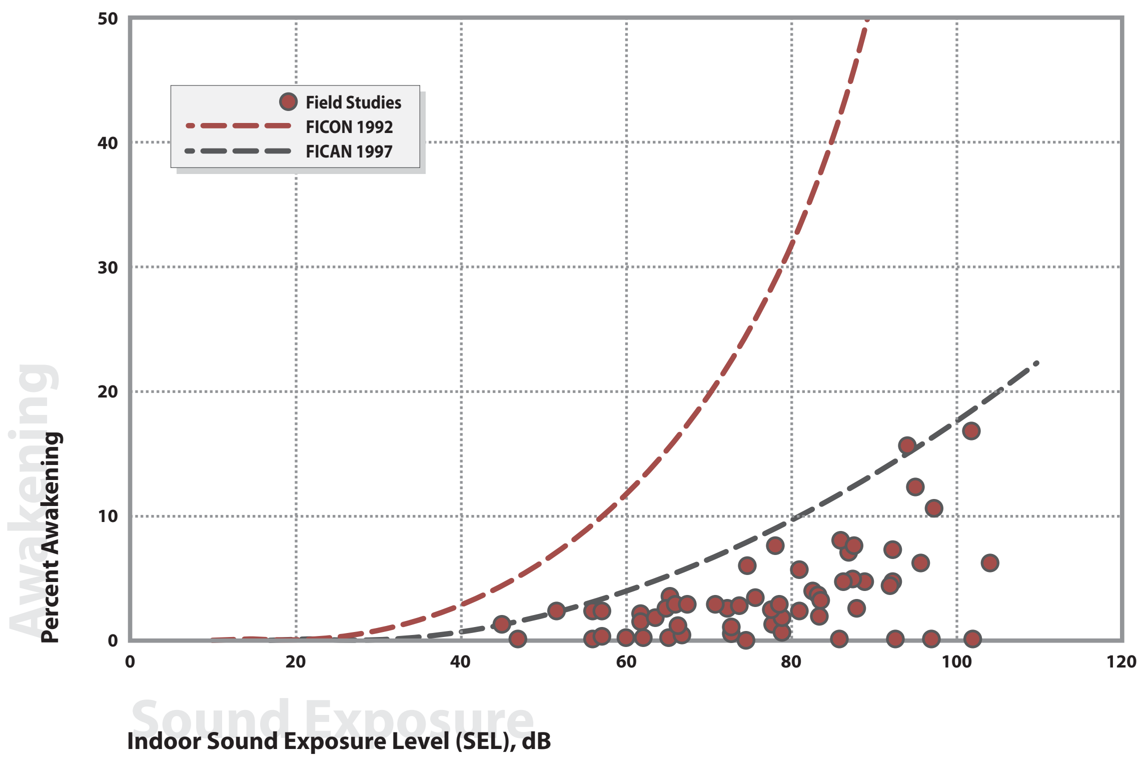

Figure C6 **Speech Interference with Different Background Noise**

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

- *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 may be unbearable to another of equal hearing capability. The level of annoyance also 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 2 to 10 percent of the population is highly susceptible to annoyance from noise not of their own making, while approximately 20 percent are unaffected by noise. Attitudes are affected by the relationship between the listener 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.

Sound Rating Scales

The description, analysis, and reporting of community sound levels is made difficult by the complexity of human response to sound, and the myriad of sound-rating scales and metrics that have been developed for describing acoustic effects. Various rating scales have been devised to approximate the human subjective assessment of "loudness" or "noisiness" of a sound.

Noise metrics can be categorized as single event metrics and cumulative metrics. Single event metrics describe the noise from individual events, such as an aircraft flyover. Cumulative metrics describe the noise in terms of the total noise exposure throughout the day. The noise metrics used in this study are summarized below:

Single Event Metrics

- *Frequency Weighted Metrics (dBA*). In order 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. This metric has shown good correlation with community response and may be easily measured. The metrics used in this study are all based upon the dBA scale.

- *Maximum Noise Level*. The highest noise level reached during a noise event is 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. As the aircraft passes, the noise level decreases until the sound level settles to ambient levels. This is plotted at the top of Figure C7. It is this metric to which people generally respond when an aircraft flyover occurs.

- *Sound Exposure Level (SEL)*. The duration of a noise event, or an aircraft flyover, is an important factor in assessing annoyance and is measured most typically as SEL. The effective duration of a sound starts when a sound rises above the background sound level and ends when it drops back below the background level. An SEL is calculated by summing the dB level at each second during a noise event (referring again to the shaded area at the top of Figure C7) and compressing that noise into one second. It is the level the noise would be if it all occurred in one second. The SEL value is the integration of all the acoustic energy contained within the event. This metric takes into account the maximum noise level of the event and the duration of the event. For aircraft flyovers, the SEL value is numerically about 10 dBA higher than the maximum noise level. Single event metrics are a convenient method for describing noise from individual aircraft events. 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 (these metrics are described in the next paragraphs). The SEL metric will be used as a supplemental metric in the General Mitchell International Airport Part 150 Noise Compatibility Study.

Cumulative Metrics

Cumulative noise metrics have been developed to assess community response to noise. They are useful because these scales attempt to include the loudness and duration of the noise, the total number of noise events and the time of day these events occur into one rating scale. They are designed to account for the known health effects of noise on people described earlier.

- *Equivalent Noise Level (LEQ)*. LEQ is the sound level corresponding to a steady-state A-weighted sound level containing the same total energy as a time-varying signal (noise that constantly changes over time) over a given sample period. LEQ is the "energy" average taken from the sum of all the sound that occurs during a certain time period; however, it is based on the observation that the potential for a noise to impact people is dependent on the total acoustical energy content. This is graphically illustrated in the middle graph of Figure C7. LEQ can be measured for any time period, but is typically measured for 15 minutes, 1 hour or 24-hours. LEQ for one hour is used to develop the Day Night Noise Level (DNL) values for aircraft operations.

- *Day Night Noise Level (DNL)*. The DNL index measures the overall noise experienced during an entire (24-hour) day. DNL calculations account for the SEL of aircraft, the number of aircraft operations and a penalty for nighttime operations. In the DNL scale, noise occurring between the hours of 10 p.m. to 7 a.m. is penalized by 10 dB. This penalty was selected to account for the higher sensitivity to noise in the nighttime and the expected further decrease in background noise levels that typically occur at night. DNL is specified by the FAA in Federal Aviation Regulation Part 150 to be used for community and airport noise assessment. In addition, it is used by other federal agencies including the Environmental Protection Agency (EPA), the Department of Defense (DOD) and the Department of Housing and Urban Development (HUD). DNL is graphically illustrated in the bottom of Figure C7. Examples of various noise environments in terms of DNL are presented in Figure C8.

Supplemental Metrics

- *Time Above (TA)*. The FAA developed the Time Above metric as a second metric for assessing impacts of aircraft noise around airports. The Time Above metric refers to the total time in seconds or minutes that aircraft noise exceeds certain dBA noise levels in a 24-hour period. It is typically expressed as Time Above 65, 75 and 85 dBA sound levels which can be used to illustrate various degrees of noise interference. While this metric is not widely used, it may be used by the FAA in environmental evaluation of airport development projects that show a significant increase in noise levels. There are no noise/land use standards related to the Time Above index.

  The Time Above levels can be used to illustrate the time that noise is above potential thresholds of disturbance. One such threshold is the Time Above 65 dBA, which generally represents the time when noise is above the level for which outdoor speech interference starts to occur. This metric will be used as a supplemental metric in the General Mitchell International Airport Part 150 Noise Compatibility Study.

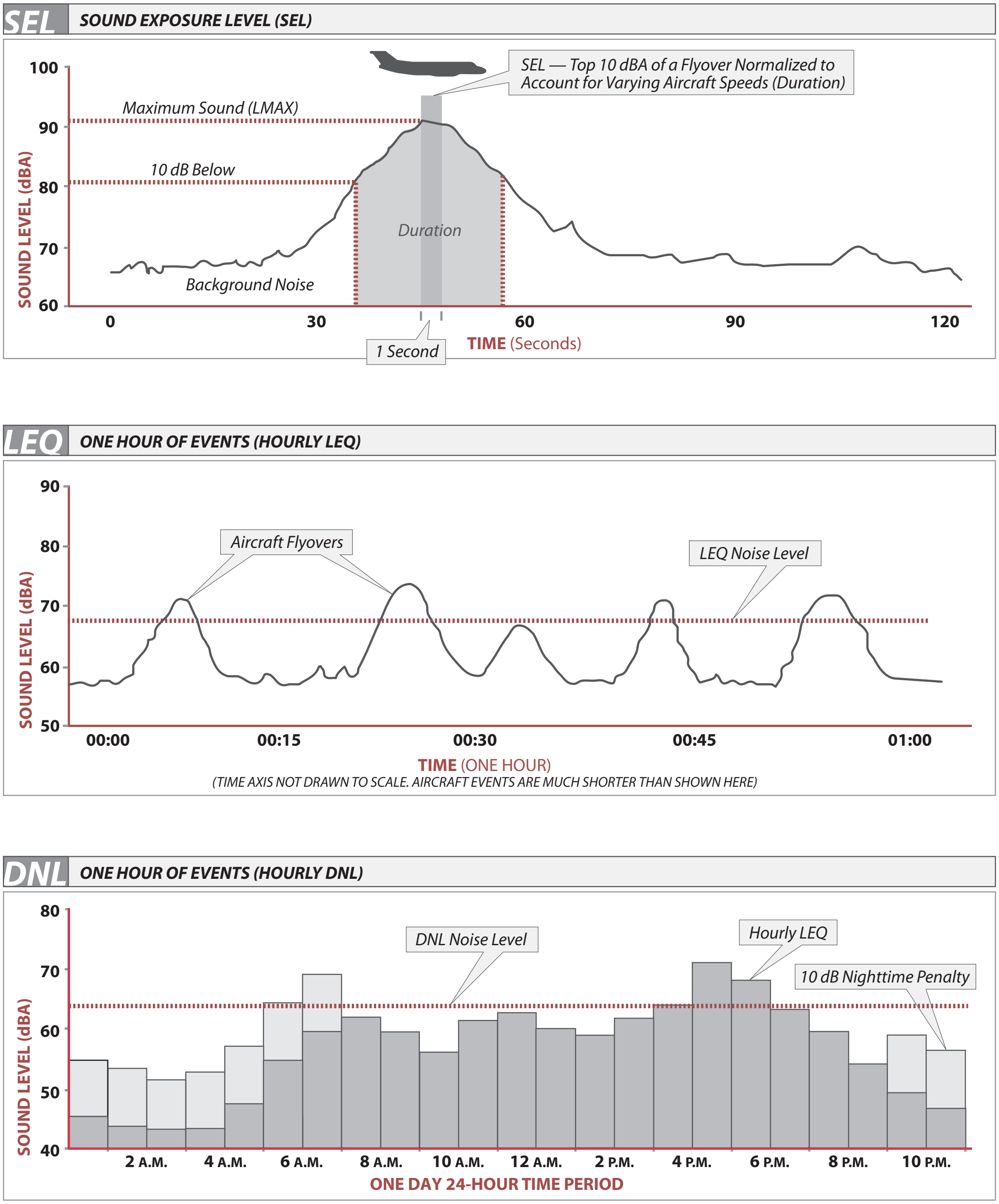

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Figure C7 **Examples of Lmax, SEL, LEQ, and DNL Noise Levels**

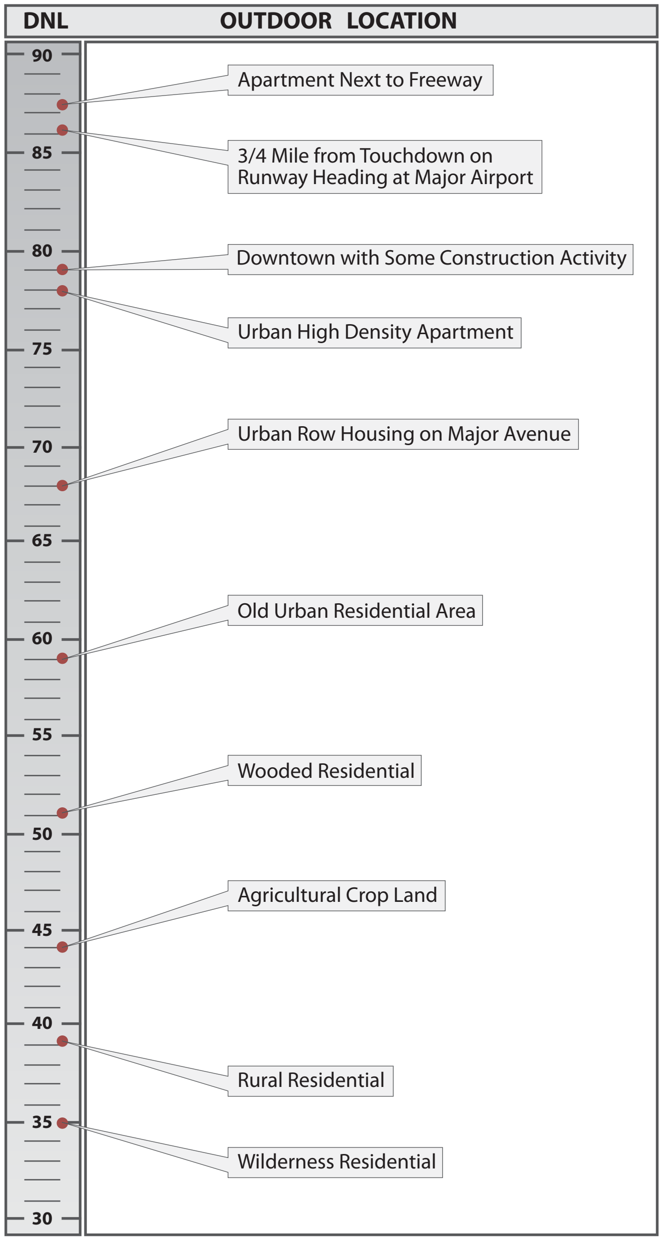

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Figure C8 **Typical Outdoor Noise Environments in Terms of DNL**

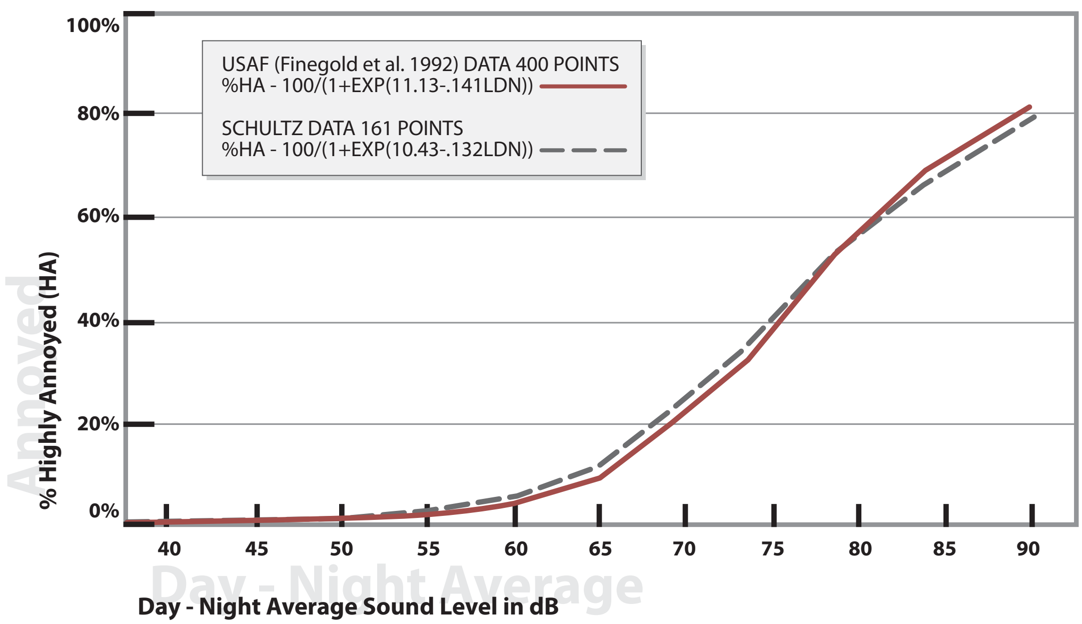
Percent Noise Level (Ln). The Ln characterizes intermittent or fluctuating noise by showing the noise level that is exceeded n% of the time during the measurement period. It is usually measured in the A-weighted decibel, but can be an expression of any noise rating scale. Percent Noise Levels often are used to characterize ambient noise where, for example, L90 is the noise level exceeded 90 percent of the time, L50 is the level exceeded 50 percent of the time, and L10 is the level exceeded 10 percent of the time. L90 represents the background or minimum noise level; L50 represents the median noise level, and L10 the peak or intrusive noise levels. Percent noise level is commonly used in community noise ordinances that regulate noise from mechanical equipment, entertainment noise sources, and the like.

The Percent Noise Level is often used to represent the ambient noise environment. The L90 noise level is commonly used to illustrate the ambient or background noise when other noise sources are not present. In the middle graphic of Figure C7, the L90 is the lower noise level that is present in between the aircraft noise events. For the General Mitchell International Airport Part 150 Noise Compatibility Study, the L90 is used to represent the background or ambient noise environment.

Noise/Land Use Compatibility Standards and Guidelines

Noise metrics help describe and predict community response to various noise exposure levels. The public reaction to different noise levels has been estimated based upon extensive research on human responses to exposure of different levels of aircraft noise. Figure C8 relates DNL noise levels to community response from one of these surveys. Community noise guidelines are derived from tradeoffs between community response surveys, such as this, and economic considerations for achieving these levels. These guidelines are generally defined in terms of the DNL 24-hour averaging scale that is based upon 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.

Several agencies mentioned earlier have utilized such research on the human response to aircraft noise and developed guidelines for land use within certain areas exposed to aircraft noise. With respect to airports, the FAA has a long history of publishing noise/land use assessment criteria. These laws and regulations provide the basis for local development of airport plans, analyses of airport noise impact, and the enactment of compatibility policies. Land use and development regulations often include compatibility guidelines for various levels of environmental noise.



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

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Figure C9 **Examples of Community Reaction to Noise**

The most common noise/land use compatibility guidelines or criteria used is 65 dB DNL for residential land use with outdoor activity areas. At 65 dB DNL the Schultz [9] curve as shown in Figure C9 predicts approximately 14% of the exposed population to be highly annoyed. At 60 dB DNL this decreases to approximately 8% of the population highly annoyed. However, recent updates to the Schultz curve, done by the U.S. Air Force, indicate that even a higher percentage of residents within these contours may experience annoyance.

A summary of pertinent regulations and guidelines is presented below:

- *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; it also limited 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 extended the required compliance dates. Aircraft may be certificated as Stage 1, Stage 2, or Stage 3 aircraft based on their noise level, weight, number of engines and in some cases, number of passengers. Stage 1 aircraft over 75,000 pounds are no longer permitted to operate in the U.S. Stage 2 aircraft over 75,000 pounds were phased out of the U.S. fleet as discussed below under Airport Noise and Capacity Act of 1990. 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.

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

  As a means of implementing the Aviation Safety and Noise Abatement Act (ASNA), the FAA adopted Federal Aviation Regulations Part 150 Airport Noise Compatibility Planning Programs including a noise and land use compatibility chart 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 C10. These guidelines offer recommendations to local authorities for determining acceptability and compatibility of land uses. The guidelines specify the maximum amount of noise exposure (in terms of the cumulative noise metric DNL) that would be considered acceptable or compatible to people in living and working areas.

LAND USE	BELOW 65	YEARLY DAY-NIGHT NOISE LEVEL (DNL) IN DECIBELS 65-70	70-75	75-80	80-85	OVER 85
RESIDENTIAL						
Residential, other than mobile homes 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
Governmental 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 parentheses 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.

TABLE KEY

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

(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 to 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 that 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.

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Figure C10 **FAR Part 150 Land Use Compatibility Matrix**

- *Federal Aviation Administration Order 5050.4 and Order 1050.1E for Environmental Analysis of Aircraft Noise Around Airports*

  The FAA issued Order 5050.4A containing guidelines for the environmental analysis of airports development. Federal requirements now dictate that increases in noise levels over 1.5 DNL at noise sensitive facilities located within the 65 DNL contour are considered significant (1050.1E, 6/8/2004) and require additional analysis. Per FAA guidance, airport environmental evaluations focus on the area affected by the FAA to be significant. FAA does not require additional analysis in areas exposed to sound less than 65 DNL. Noise abatement alternatives that result in shifting of noise may trigger an environmental process such as this before they can be implemented.

- *Airport Noise and Capacity Act of 1990*

  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 for the FAA: (1) establish a method to review aircraft noise, and airport use or access restriction, 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, MD-80/90).) To implement ANCA, FAA amended Part 91 to address the phase-out of large Stage 2 aircraft and the phase-in of Stage 3 aircraft. In addition, Part 91 states that all Stage 2 aircraft over 75,000 pounds were to be removed from the domestic fleet or modified to meet Stage 3 by December 31, 1999. There are a few exceptions but only Stage 3 aircraft greater than 75,000 pounds are now in the domestic fleet. The airlines have phased out Stage 2 aircraft, and the mainland domestic fleet is now all Stage 3 aircraft. Stage 2 aircraft less than 75,000 pounds include the F28 and various older corporate jet aircraft such as Lear 25s and Gulfstream IIs.

  Furthermore, FAR Part 161 was adopted to institute a highly stringent review and approval process for implementing use or access restrictions by airport proprietors. Part 161 sets out the requirements and procedures for implementing new airport use and access restrictions by airport proprietors. They 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.

  Part 161 identifies three types of use restrictions and treats each one differently: negotiated restrictions, Stage 2 aircraft restrictions and Stage 3 aircraft restrictions. Generally speaking, any use restriction that affects 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 also apply to smaller aircraft.

Negotiated restrictions are more favorable from the FAA's standpoint, but still require complex procedures for approval and implementation. Voluntary restrictions must be agreed upon by all airlines, and public notice must be given.

Stage 2 restrictions are more difficult, as one of the major reasons for ANCA was to discourage local restrictions more stringent that the ANCA's 1999 phase-out. To comply with the regulation and institute a new Stage 2 restriction, the proprietor 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 do not require approval by the FAA.

Stage 3 restrictions are especially 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 DNL to noise sensitive land uses (residences, schools, churches, parks). The regulation requires both public notice and FAA approval.

ANCA applies to all local noise restrictions that are proposed after October 1990, and to amendments to existing restrictions proposed after October 1990. The FAA has approved only one completed Part 161 Study to date (for restricting Stage 2 corporate jets), although they are still evaluating the possibility of the subject restriction violating airport grant assurances, which could result in loss of federal grant funds for the airport.

- *Federal Interagency Committee on Noise (FICON) Report of 1992 [8]*

The use of the DNL metric criteria has been criticized by various interest groups concerning its usefulness in assessing aircraft noise impacts. As a result, 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 on airport noise impacts and to recommend procedures for potential improvements. FICON included representatives from the Departments of Transportation, Defense, Justice, Veterans Affairs, Housing and Urban Development, the Environmental Protection Agency, and the Council on Environmental Quality.

The FICON review focused primarily on the manner in which noise impacts are determined, including whether aircraft noise impacts are fundamentally different from other transportation noise impacts; how noise impacts are described; and whether impacts outside of Day-Night Average A-Weighted Sound Level (DNL)

65 decibels (dB) should be reviewed in a National Environmental Policy Act (NEPA) document.

The committee determined there are no new descriptors or metrics of sufficient scientific standing to substitute for the present DNL cumulative noise exposure metric. FICON determined that the DNL method contains appropriate dose-response relationships (expected community reaction for a given noise level) to determine the noise impact and is properly used to assess noise impacts at both civil and military airports. The report does support agency discretion in the use of supplemental noise analysis, recommends public understanding of the DNL and supplemental methodologies, as well as aircraft noise impacts. FICON did, however, recommend that if screening analysis shows a 1.5 dB increase within a 65 DNL or a 3.0 dB increase within a 60-65 DNL, then additional analysis should be conducted.

Introduction to Noise Assessment Methodology

Existing and future aircraft noise environments for airports are typically determined through a combination of computer modeling and on-site sound level measurements. Computer generated noise contours of existing aircraft noise are developed and then verified using the on-site measurements. The on-site measurements also help establish the ambient, (non-aircraft) noise environment and identify noise levels at specific areas of interest. Once reliable computer generated contours are developed for existing conditions, the computer input files are altered to reflect future conditions based on forecasts of future operations and/or proposed noise abatement aircraft operational measures. New computer generated data and contours are then developed to assess those future conditions. The following sections provide the details on this process. This section is divided into the following sub-sections:

- Noise Measurement Survey – Describes the noise monitoring sites and the methodology used in the noise measurement survey.
- Computer Modeling – Describes the computer noise model and modeling techniques used in the study.
- Measurement and Analysis Procedures – Describes the measurement and analysis procedures used to develop the various noise metrics of use in this study.

Noise Measurement Survey

Purpose of Measurement Survey

Measuring noise directly using calibrated and reliable monitoring devices augments computer modeling and offers several advantages over relying solely on computer modeling. While not specifically required by FAR Part 150, such programs are often very useful and productive. The noise measurement survey is an integral part of this Study; it serves to:

- Identify aircraft noise levels specific to the local Milwaukee environment and unique conditions.
- Validate the computer model using actual noise measurement data from aircraft operating at General Mitchell International Airport. Specific issues unique to the Airport include:
    - The hush-kit DC9 aircraft that operate at the airport
    - The MD80 aircraft that operate at the airport
- Identify the aircraft and ambient noise level at representative locations around the community using a variety of noise metrics. These same locations can later be used to illustrate the changes in noise that may occur with future alternatives under consideration.
- Give confidence to the community in the accuracy of the noise exposure contours.

The primary goal of the measurement program for the General Mitchell International Airport Part 150 Noise Compatibility Study is the identification of the single event noise levels that can then be correlated to a variety of different aircraft types flying the different paths and procedures that are present in the Milwaukee area. Based upon this single event data and the annual operational flight data, it is then possible to calculate various different noise metrics of interest. These data can also be compared to the predicted single event noise levels incorporated within the FAA Integrated Noise Model (INM). The modeling assumptions can then be adjusted to more accurately reflect real-world conditions. With the verified noise model, it is then possible to ensure that the contours reflect real measurements and to prepare supplemental noise metrics. When it is not possible to have the contour exactly match the measurements, that difference is known.

Types of Noise Measurements

The measurement program included the following types of measurement sites:

- General Mitchell International Airport Permanent Noise Monitoring System sites
- Portable Measurement sites

Permanent Noise Monitoring System Sites (PNMS). Noise data from the Milwaukee Airport permanent noise monitoring system was collected and used in the noise measurement program. There are a total of seven (7) noise monitoring locations as part of the system. All available DNL noise data (Aircraft DNL, Other DNL, and Total DNL) and single event noise data (SEL, Lmax) for 2002 and the noise monitoring period (June 3, 2003 through July 2, 2003) were collected from the PNMS. Note that a full year (2002) of noise data that reflects all seasonal conditions was collected and used in the analysis.

Portable Measurement Sites. Measurements were conducted at eleven (11) locations where the noise monitors were placed at a site for roughly a 30 day period. These measurements consisted of A-weighted measurements as defined earlier in this section. The noise monitors recorded the one-second average noise levels on a continuous basis and were later analyzed to compute noise metric levels. These noise metrics included DNL, hourly LEQ, Time Above noise levels (TA85, TA75 and TA65), single event (SEL, Lmax and duration), and ambient descriptors (L1, L10, L50, L90, L99).

Site Selection Criteria

Sites include locations within the communities, sites exposed to ground noise sources and additional sites located along the primary flight paths within the study area. Noise monitoring sites were selected based upon technical suitability as well as locations of public interest. These sites were also selected to supplement the location of the permanent system sites. Information used in the selection of the noise monitoring sites includes complaint history, land use pattern, flight tracks, distribution of the sites representatively around the Airport, and proximity to the 65 DNL noise contour. Examples of the site selection criterion are listed below:

General Criteria

- exposure to a variety of different aircraft activity sources
  - Departures and arrivals
  - Commercial jets, military jets, commuter and General Aviation
  - Ground noise and flight operations noise

- proximity to the 65 DNL noise contour
- representation of the potential exposure to surrounding residents
- representation of the noise environment in the local area
- locations that are not in close proximity to localized noise sources
- locations that are not exposed to excessive higher wind speeds
- locations that are not severely shielded from the aircraft activity
- locations different from those already being measured by the Airport's PNMS
- locations of public interest
- security and ease of access to the noise monitoring equipment

Specific Criteria

- Multiple locations at different distances sideline from the departure and arrival flight paths.
- Locations exposed to both jet aircraft and commuter aircraft flight paths
- Locations at different distances along the flight path to measure the departure noise and climb profiles of aircraft. This should include those sites both close to and more distant from the Airport.

Noise Measurement Locations

Noise measurements were conducted at selected locations within the Airport environs. The Airport PNMS locations, along with the portable noise monitoring sites are presented in Figure C11. Table C2 reflects the addresses of those locations where noise equipment was placed for monitoring purposes. The portable sites located north and south of the Airport were designed to measure the departure and arrival noise associated with operations on Runways 1/19, as the sites located east and west of the Airport were designed to measure the departure noise associated with operations on Runways 7/25. The array of sites is designed to measure the difference in the sideline noise at different distances away from the flight path in conjunction with the data from the permanent noise monitoring system.

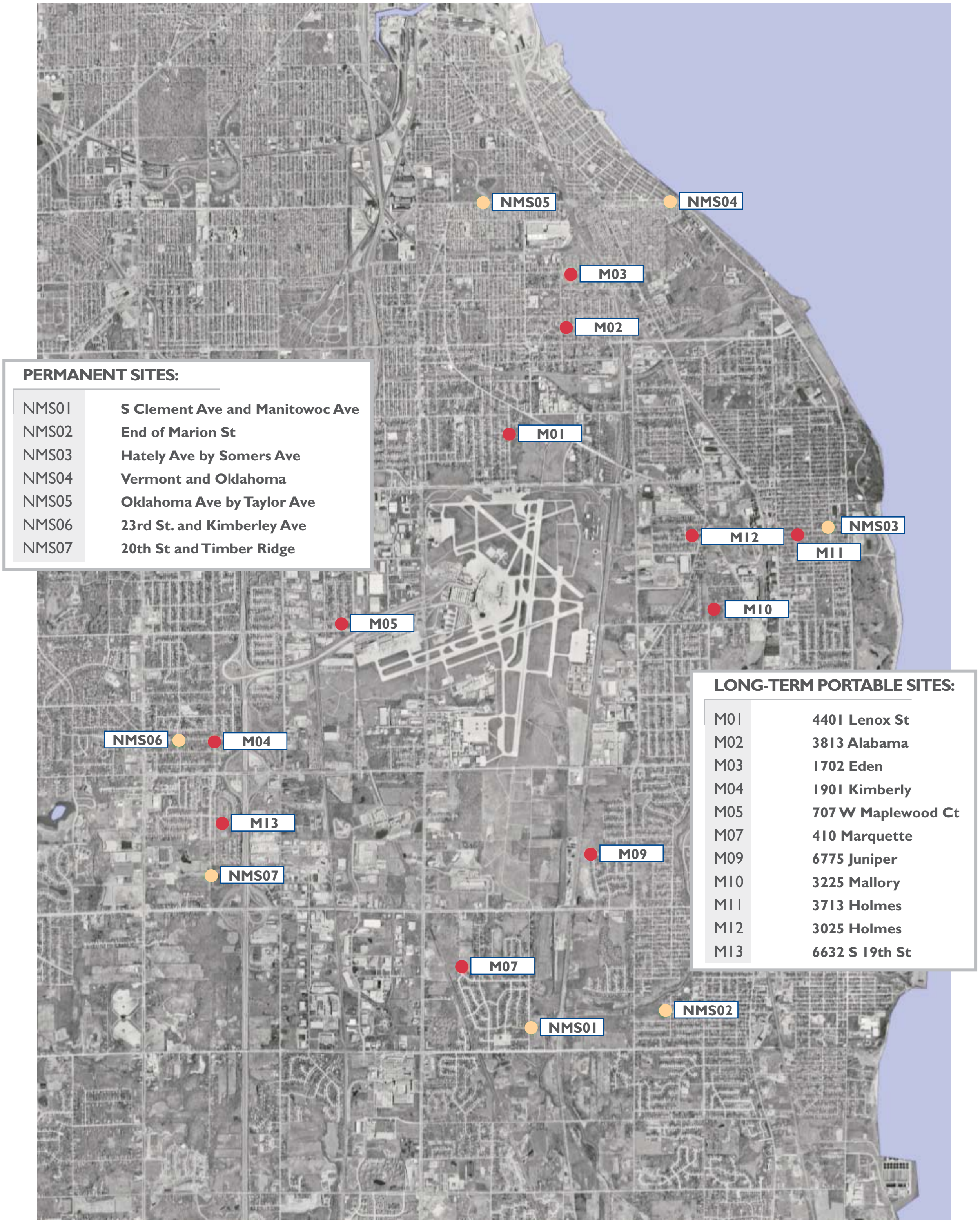

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Figure C11 **Noise Monitoring Sites**

Table C2
COMBINED NOISE MEASUREMENT SITES
General Mitchell International Airport FAR Part 150 Noise Compatibility Study

Sites	City	Address
Permanent Sites		
NMS01	Oak Creek	S Clement Ave and Manitowoc Ave
NMS02	South Milwaukee	End of Marion St.
NMS03	Cudahy	Hately Av by Somers Ave
NMS04	Milwaukee	Vermont and Oklahoma
NMS05	Milwaukee	Oklahoma Av by Taylor Ave
NMS06	Milwaukee	23rd St and Kimberley Ave
NMS07	Milwaukee	20th St and Timber Ridge
Portable Sites		
M01	Milwaukee	4401 Lenox St.
M02	Milwaukee	3813 Alabama
M03	St. Francis	1702 Eden
M04	Milwaukee	1901 Kimberly
M05	Milwaukee	707 W. Maplewood Ct.
M07	Oak Creek	410 Marquette
M09	Oak Creek	6775 Juniper
M10	Cudahy	3225 Mallory
M11	Cudahy	3713 Holmes
M12	Cudahy	3025 Holmes
M13	Milwaukee	6632 S. 19th St.

Measurement Procedures

Noise measurements were conducted starting in June 2003. Portable noise monitoring sites were set up to simultaneously collect continuous 1-second noise levels during the entire time the noise monitor was at a given location. The equipment was checked and calibrated on a regular basis throughout the measurement survey. Measurements were conducted at each site for roughly 30 days in duration.

Acoustic Data

The noise measurement survey utilized specialized monitoring instrumentation that allowed for the measurement of aircraft single event data and ambient noise levels. The data determined at each portable noise measurement site is listed below:

- continuous one-second noise levels
- single event data (SEL, Lmax and Duration) for individual aircraft
- hourly noise data (LEQ, Level Percent, Time Above)
- daily noise level (DNL)
- correlation of noise data with aircraft identification
- non-aircraft ambient sound level (Level Percent)

The survey utilized software that provides continuous measurement and storage of the 1-second LEQ noise level. From this data, the above noise descriptors could be calculated. In addition, this data can be used to plot the time histories for noise events of interest.

Instrumentation

The monitoring program was consistent with state-of-the-art noise measurement procedures and equipment. The measurements consisted of monitoring A-weighted decibels in accordance with procedures and equipment that comply with specific International Standards (IEC), and measurement standards established by the American National Standards Institute (ANSI) for Type 1 instrumentation.

These sites utilized either the Brüel & Kjaer 2236 or the Larson Davis 824 Sound Level Meters. The analyzers automatically calculate the various single event data. Both the Brüel & Kjaer and the Larson Davis systems include software that provides data storage for later retrieval and analysis.

During the survey the noise monitoring instrumentation was calibrated at the start and end of each measurement cycle. This calibration was based on standards set by the National Institute of Standards and Technology, formerly the National Bureau of Standards. An accurate record of the meteorological conditions during measurement times was also maintained.

Measurement Duration

The noise monitoring survey was completed between June 3, 2003 and July 2, 2003. The duration of the measurements ensured that data were obtained for both arrivals and departures at each measurement site.

Computer Modeling

Computer modeling generates maps or tabular data of an airport's noise environment expressed in the various metrics described above such as SEL, DNL, or TA. Computer models are most useful in developing contours that depict, like elevation contours on a topography map, areas of equal noise exposure. Accurate noise contours are largely dependent on the use of a reliable, validated, and updated noise model, and collection of accurate aircraft operational data.

The FAA's Integrated Noise Model (INM) models civilian and military aviation operations. The original INM was released in 1977. The latest version, INM Version 6.1, was released for use in May 2003 and is the state-of-the-art in airport noise modeling. The program includes standard aircraft noise and performance data for over 100 aircraft types that can be tailored to the characteristics of specific individual airports. Version 6.1 includes an updated database that includes some newer aircraft, the ability to include run-ups (maintenance test when the aircraft is on the ground) and topography in the computations, and a provision to vary aircraft profiles in an automated fashion. It also includes more comprehensive and flexible contour plotting routines than earlier versions of the model.

Operational data for input to the INM are gathered in a meticulous manner to assure its accuracy, and the data are arranged for input to the model. The INM program requires the input of the physical and operational characteristics of an airport. Physical characteristics include runway coordinates, airport elevation, and temperature and optionally, topographical data. Operational characteristics include aircraft types, flight tracks, departure procedures, arrival procedures and stage lengths (flight distance) that are specific to the operations at the Airport. Aircraft data needed to generate noise contours include:

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

Measurement and Analysis Procedures

The following section outlines the methodology used to measure and quantify noise levels from aircraft operations and from ambient noise level conditions. Measurement methodology and analysis techniques used in the study are also described.

Continuous Measurement of the Noise

The methodology employed in this study used a data collection program that was designed to continuously measure and record the noise at each measurement location. An example of the time history of the continuous noise measured by each portable noise monitor is presented in Figure C12. This graph shows the continuous noise at one site for a 15-minute period. It is possible to see the duration of noise events and the time period of ambient noise in between the events. Since all of the noise data are collected during the measurements, it is possible to process the data and calculate different metrics of interest that may arise, including the aircraft single event noise event level, cumulative daily noise levels, time above levels, and the ambient levels. The process of calculating noise events from this data includes the use of floating threshold methodology. This allows for the measurement of lower noise level events. The parameters are adjustable and can be modified so that it is possible to recalculate noise events from raw data any time in the future.

Network of Multiple Noise Monitors

A network of 11 portable noise monitors was set up (along with the 7 permanent monitors) to simultaneously and continuously measure noise at multiple monitoring sites. The network of continuously operating noise monitors is useful to compare noise levels at different locations for the same aircraft. For example, networks of noise monitors are established to illustrate the sideline noise levels at varying distances from the flight path centerline. An example of data from three sites is presented in Figure C13. This figure shows the continuous noise levels for the three sites north of the airport. It is possible to see the different noise levels and different time sequences of the noise as the aircraft passes over the set of sites. In addition, the network of noise monitors is also used to help separate aircraft noise from other noise sources. Knowing the time sequence of noise events provides a pattern that is one of the components of the noise and flight data correlation process.

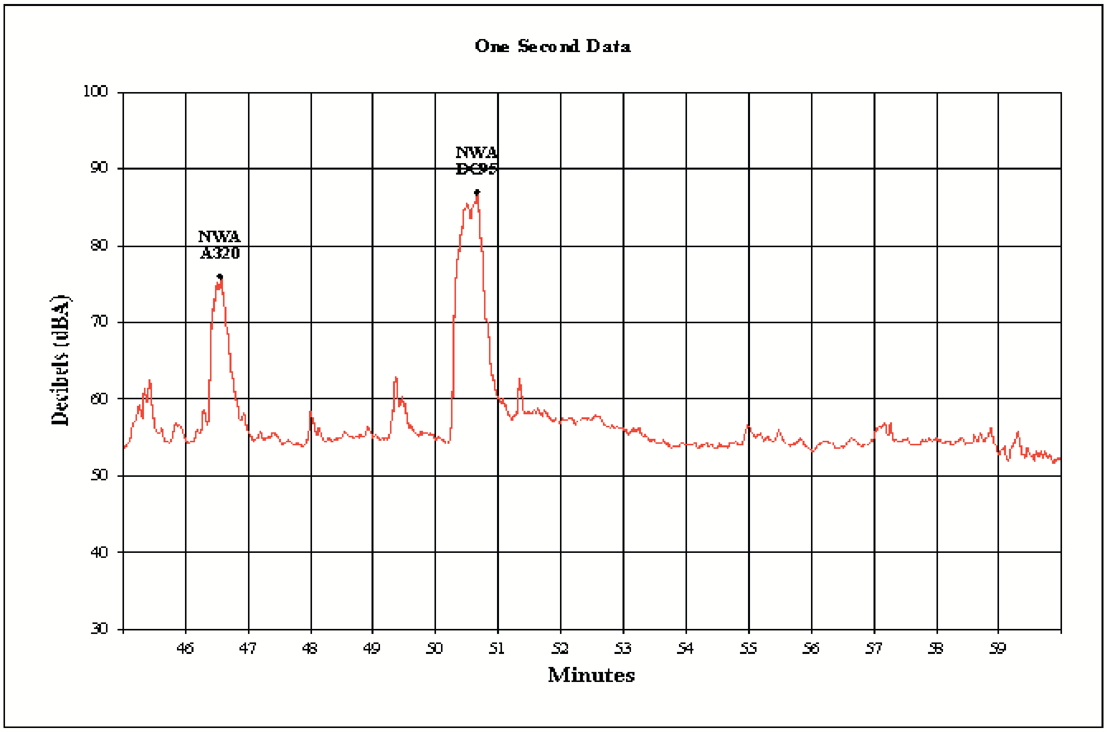
Operational Data and Field Observations

The General Mitchell International Airport Noise Management Office utilizes a noise and flight track data collection and analysis program to collect and process noise data from a permanent noise monitoring network and from Airport radar data. This radar data are collected by the FAA's Aircraft Radar Tracking System – more commonly referred to as ARTS data. Once collected, the software program performs a number of processes, including determining if the track is associated with a departure or arrival operation, and assigning a runway to the track. One full year of data were collected during the study period of 2002. In addition, radar data were also collected during the time period of the noise measurement survey. Flight data, radar tracks and noise monitoring data were collected and integrated in a database for analysis and reporting of the radar data.

The radar data includes flight information about the aircraft that is operating on each track as well as position information as to the location of the flight. The flight information includes data such as the ARTS aircraft type, ARTS airline code, flight number, type of operation, and runway. The position information includes the X and Y coordinates that position each aircraft for the flight track every four seconds of the flight, as well as the altitude of the aircraft at each point.

Example flight information data are listed below. An example of the data are also presented in Table C3. These input data were registered into a database that included all of the information associated with each flight.

- date and time of flight
- base or airport of operation
- operator
- aircraft type
- airline and flight number
- type of operation (departure or arrival)
- flight path
- runway
- comments



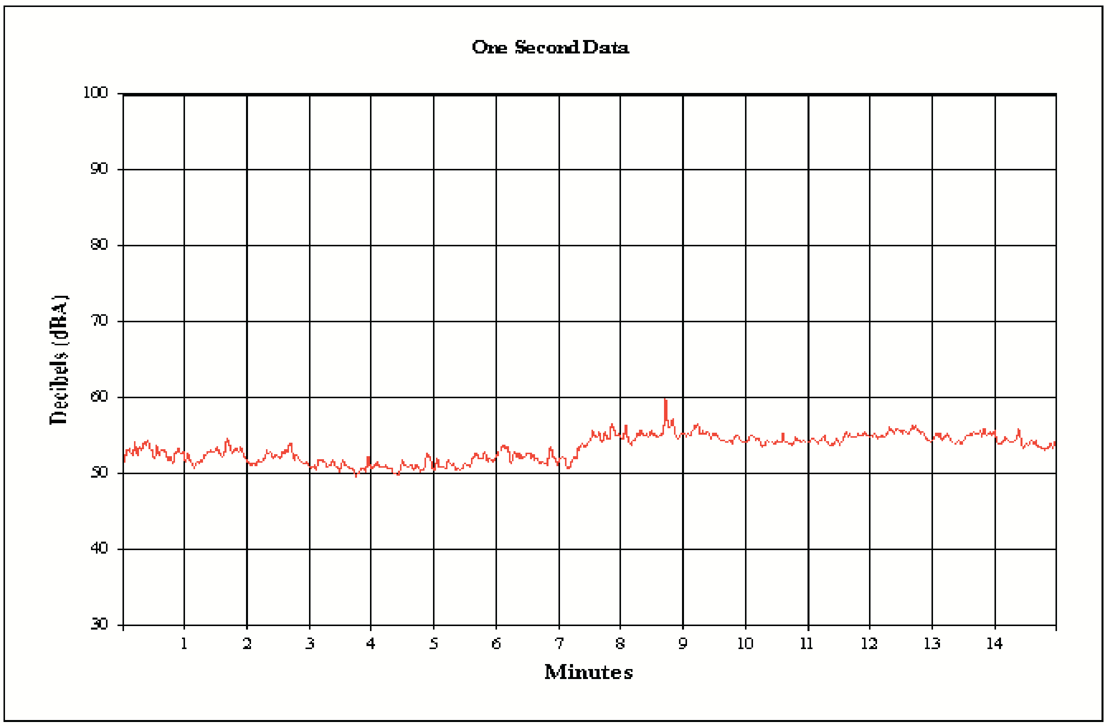
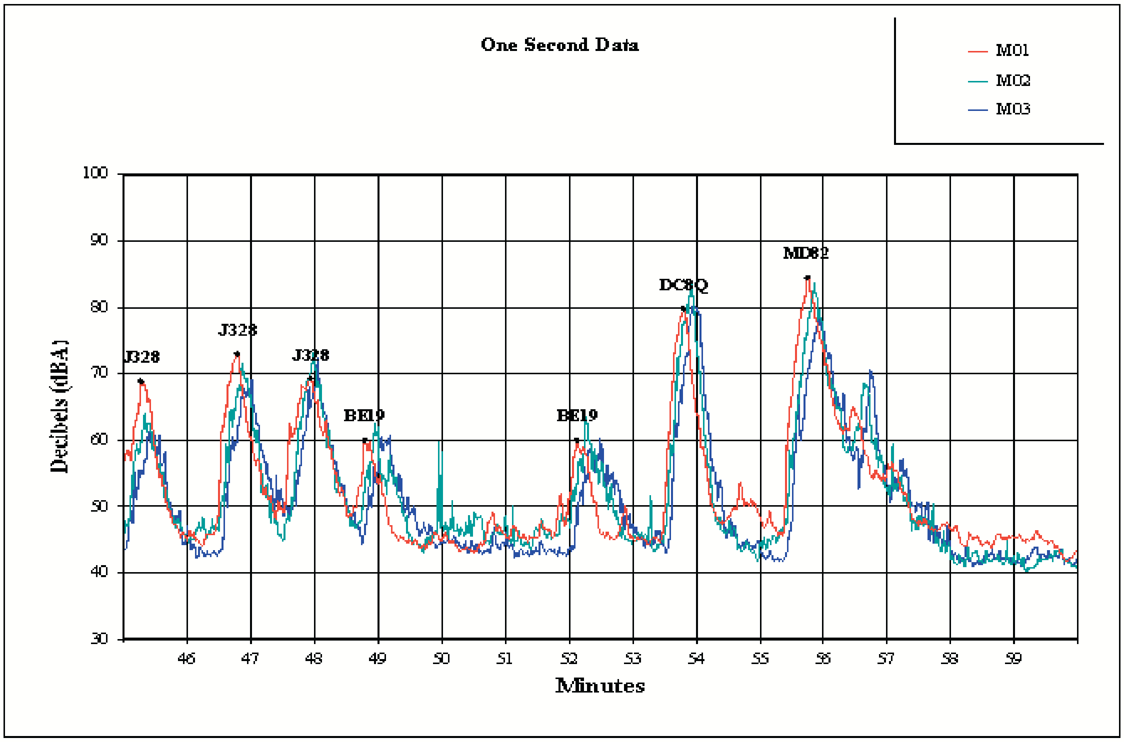


Figure C12 **Example of Continuous Measurement of Noise**



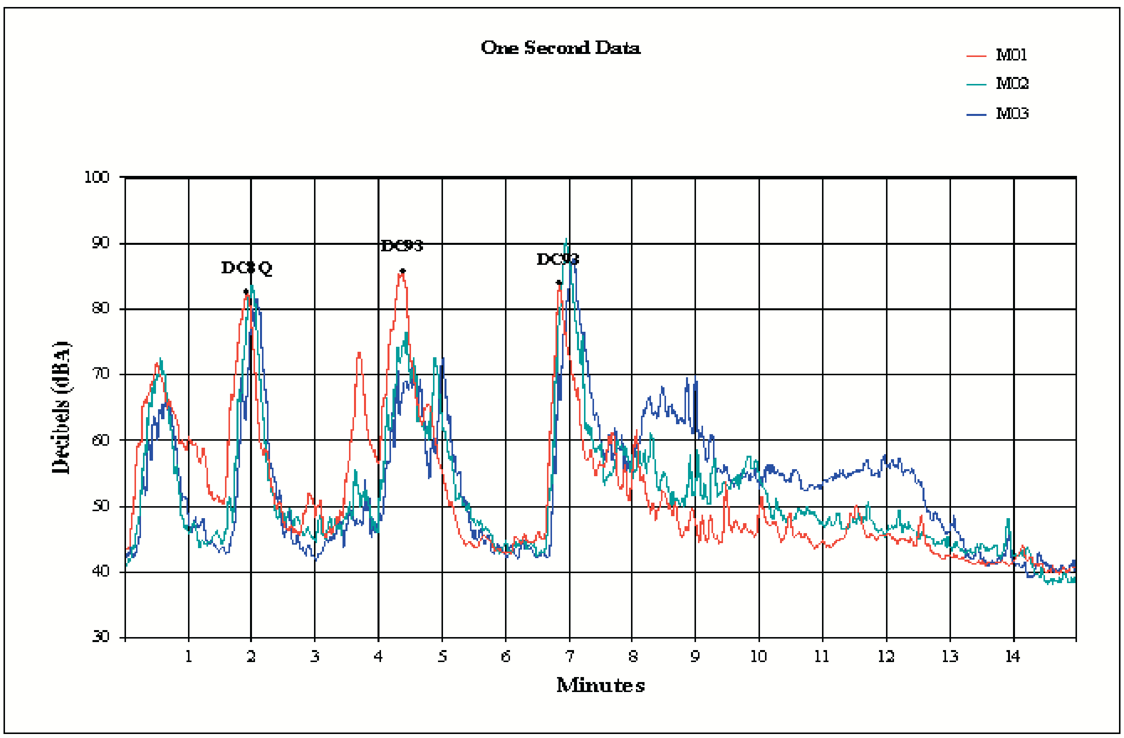


Figure C13 **Continous Noise Measurement at Multiple Sites**

In addition to the radar data, other sources of flight data used in the study included:

- field observations by engineers conducting the measurements
- aircraft situational display data (data from FAA national airspace system)
- airport tower counts

Correlation of Noise and Flight Data

From the radar data it is possible to reconstruct the flight path for each operation. An example of flight paths for aircraft operations is presented in Figure C14. This figure illustrates the flight path of an aircraft at one point in time. The noise levels from each monitor at that same point in time is also shown. Computer software was used to correlate noise events with aircraft operating in the sky near the noise monitor at that same point in time. Figure C15 represents a sample noise event time history taken from a site that is correlated with its source of operation.

Calculation of Aircraft Noise Metrics

Once the collection and correlation of the noise and flight data are complete, the various noise metrics can then be calculated. A computer program is used to calculate the single event, time above, and cumulative noise metrics of interest. These results are presented in the next section.

Date And Time	Airline Code	Aircraft ID	Aircraft Type	Runway	Operation
Jun-04 00:01:38	RYN	RYN209	U	19R	D
Jun-04 00:12:06	U	U	U	1L	A
Jun-04 00:14:38	U	NTC202	U	19R	D
Jun-04 00:22:05	USC	USC431	U	19R	D
Jun-04 01:15:08	U	U	U	1L	A
Jun-04 01:43:27	USC	USC431	C208	19R	A
Jun-04 01:46:40	USC	USC603	BE58	19R	A
Jun-04 01:55:40	U	U	U	19R	D
Jun-04 01:56:26	USC	USC361	C208	19R	D
Jun-04 01:58:45	U	N3640G	C310	19R	D
Jun-04 02:44:30	USC	USC603	BE58	19R	D
Jun-04 04:05:28	UPS	UPS544	DC8Q	1L	A
Jun-04 04:29:24	FDX	FDX1436	A306	1L	A
Jun-04 04:43:42	UPS	UPS542	DC8Q	1L	A
Jun-04 05:10:01	IRO	IRO70	C208	1R	D
Jun-04 05:10:43	WDY	WDY3482	SF34	19R	D
Jun-04 05:36:52	IRO	IRO78	C208	7R	D
Jun-04 05:37:47	RYN	RYN210	B722	1L	A
Jun-04 05:43:11	ABX	ABX148	DC9Q	1L	A
Jun-04 05:48:34	FRG	FRG1510	BE99	1R	D
Jun-04 05:56:38	SYX	SYX1053	BE19	7R	D
Jun-04 05:57:34	SNC	SNC44	SH33	7R	D
Jun-04 06:00:10	TRS	TRS601	B712	7R	D
Jun-04 06:00:52	SYX	SYX1004	BE19	7R	D
Jun-04 06:01:47	MEP	MEP278	B712	7R	D
Jun-04 06:02:15	FRG	FRG1532	C402	7R	D
Jun-04 06:03:06	EGF	EGF734	E145	7R	D
Jun-04 06:05:24	NWA	NWA1722	DC93	7R	D
Jun-04 06:05:47	AMF	AMF615	E120	7L	A
Jun-04 06:07:34	ASH	ASH4343	CRJ2	7R	D
Jun-04 06:09:15	DAL	DAL2053	B73Q	7R	D
Jun-04 06:09:43	IRO	IRO94	C208	7R	D
Jun-04 06:10:45	U	N75RL	BE40	7R	A
Jun-04 06:12:34	RYN	RYN210	B722	1L	D
Jun-04 06:13:01	SYX	SYX2320	J328	7R	D
Jun-04 06:14:06	IRO	IRO71	C208	7R	D
Jun-04 06:15:43	FDX	FDX3810	A306	7R	D
Jun-04 06:18:11	FRG	FRG1550	BE99	31	D
Jun-04 06:18:29	IRO	IRO58	C208	7R	D
Jun-04 06:19:29	FRG	FRG1540	C402	7R	D

Table C3 **Example of Flight Data Information**

Figure C14 **VCR Flight Track Playback**

Start Time.	07:44:18	**Lmax Time.**	07:44:36
SEL (dBA).	100.0	**Max (dBA).**	92.7
Duration (seconds).	46	**Start to Peak (seconds).**	18
SEL Threshold (dBA).	52		
Flight Number.	MEP302		
Aircraft Type.	DC93		
Airline Code.	MEP		
Operation.	Departure		
Runway.	1L		

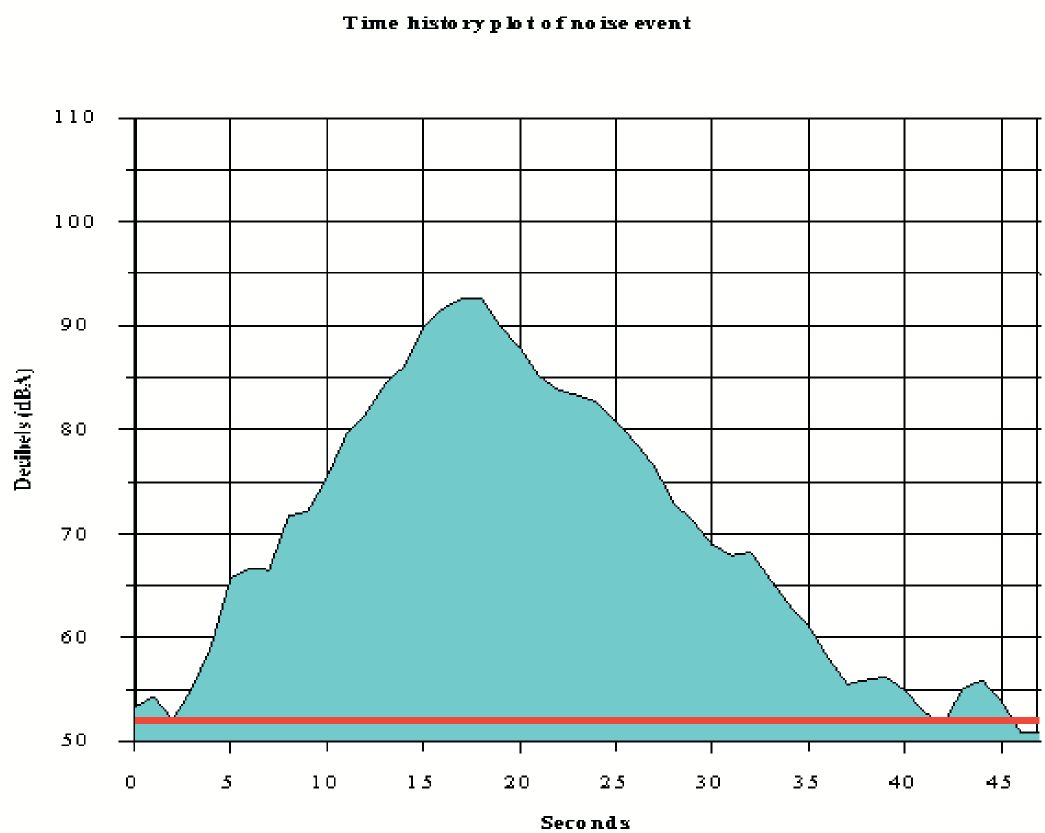


Figure C15 **Example of Correlated Noise and Flight Track Information**

REFERENCES:

1. Environmental Protection Agency, "Information on Levels on Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," U.S. Environmental Protection Agency, Office of Noise Abatement and Control, March 1974.

2. Harris, Cyril M., "Handbook of Noise Control," Second Edition, McGraw-Hill Book Co., 1979.

3. James M. Fields, Federal Aviation Administration and NASA Langley Research Center, 'Effect of Personal and Situational Variables on Noise Annoyance: With Special Reference to Implications for En Route Noise,' DOT/FAA/EE-92/03, August 1992.

4. Department of Transport, "Report of a Field Study of Aircraft Noise and Sleep Disturbance," Department of Safety, Environment and Engineering Civil Aviation Authority, December 1992.

5. 1992 British and Horne JA, Pankhurst FL, Reyner LA, Hume K, Diamond ID, "A Field Study Of Sleep Disturbance: Effects Of Aircraft Noise And Other Factors On 5,742 Nights Of Actimetrically Monitored Sleep In A Large Subject Sample. Sleep 1994 Mar;17(2):146-59

6. National Association of Noise Control Officials, "Noise Effects Handbook," New York, 1981.

7. Federal Interagency Committee on Noise, August 21, 1992.

8. Federal Interagency Committee on Noise (FICON). (1992). Final Report: Airport Noise Assessment Methodologies and Metrics. Washington, D.C.

9. Schultz, T.J. (1978). "Synthesis of Social Surveys on Noise Annoyance" Journal of the Acoustical Society of America, 64, 377-405.