Noise Analysis

This report is presented in five major sections including this introduction. Section Two presents background information on sound, noise, and how noise affects people. Section Three describes the methodology used for this study. Section Four describes the existing noise setting in the environs of Centennial Airport. Section Five presents a description of the base-conditions future noise environment. The analyses presented in this working paper address existing aircraft noise and the predicted five-year future aircraft noise impacts.

Background/Introduction

The purpose of this section is to present background information on the characteristics of noise as it relates to Centennial Airport and summarize the methodologies that were used to study the noise environment. This section is intended to give the reader a greater understanding of the noise metrics and methodologies used to assess noise impacts. This section is divided into the following sub-sections:

- Characteristics of Sound
- Factors Influencing Human Response to Sound
- Health effects of Noise
- Sound rating scales
- Noise/Land Use Compatibility Standards and Guidelines

Characteristics of Sound

Sound Level and Frequency. Sound can be technically described in terms of the sound pressure (amplitude) and frequency (similar to pitch). Sound pressure is a direct measure of the 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 these pressures as sound pressure levels on a logarithmic scale. The standard unit of measurement of sound is the Decibel (dB). The sound pressure level in decibels describes the pressure of a sound relative to a reference pressure. The logarithmic scale compresses the wide range in sound pressures to a more usable range of numbers.

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 of this, various methods of frequency weighting have been developed. The most common weighting is the A-weighted noise curve (dBA). The A-weighted decibel scale (dBA) performs this compensation by discriminating against frequencies in a manner approximating the sensitivity of the human ear. In the A-weighted decibel, every day 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 C1.

Propagation of Noise. Outdoor sound levels decrease as a function of distance from the source, and as a result of wave divergence, atmospheric absorption, and ground attenuation. If sound is radiated from a source in a homogeneous and undisturbed manner, the sound travels as spherical waves. As the sound wave travels away from the source, the sound energy is distributed over a greater area dispersing the sound power of the wave. Spherical spreading of the sound wave reduces the noise level at a rate of 6 dB per doubling of the distance.

Atmospheric absorption also influences the levels that are received by the observer. The greater the distance traveled, the greater the influence of the atmosphere and the resultant fluctuations. Atmospheric absorption becomes important at distances of greater than 1,000 feet. The degree of absorption is a function of the frequency of the sound as well as the humidity and temperature of the air. For example, atmospheric absorption is lowest at high humidity and higher temperatures. Sample atmospheric attenuation graphs are presented in Figure C2. Turbulence and gradients of wind, temperature and humidity also play a significant role in determining the degree of attenuation. Certain conditions, such as inversions, can also result in higher noise levels than would result from spherical spreading as a result of channeling or focusing the sound waves.

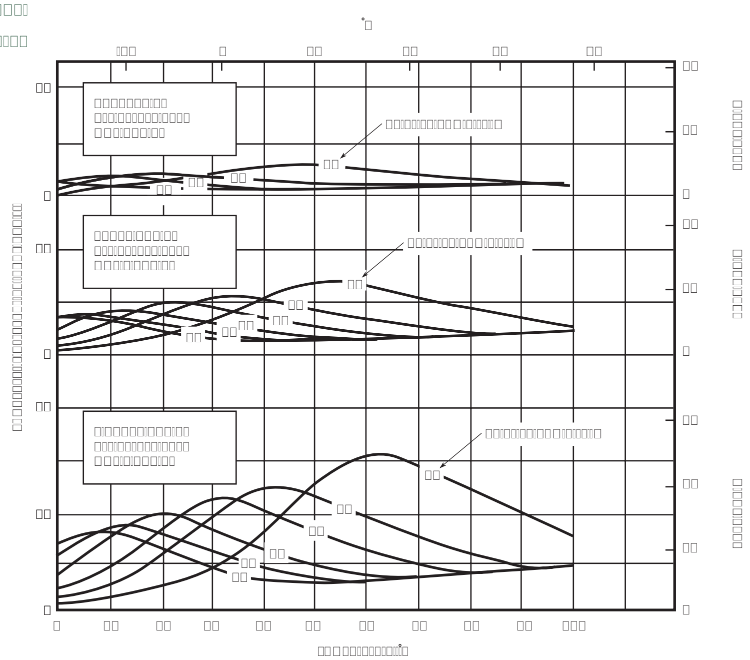
Absorption effects in the atmosphere vary with frequency. The higher frequencies are more readily absorbed than the lower frequencies. Over large distances, the lower frequencies become the dominant sound as the higher frequencies are attenuated.

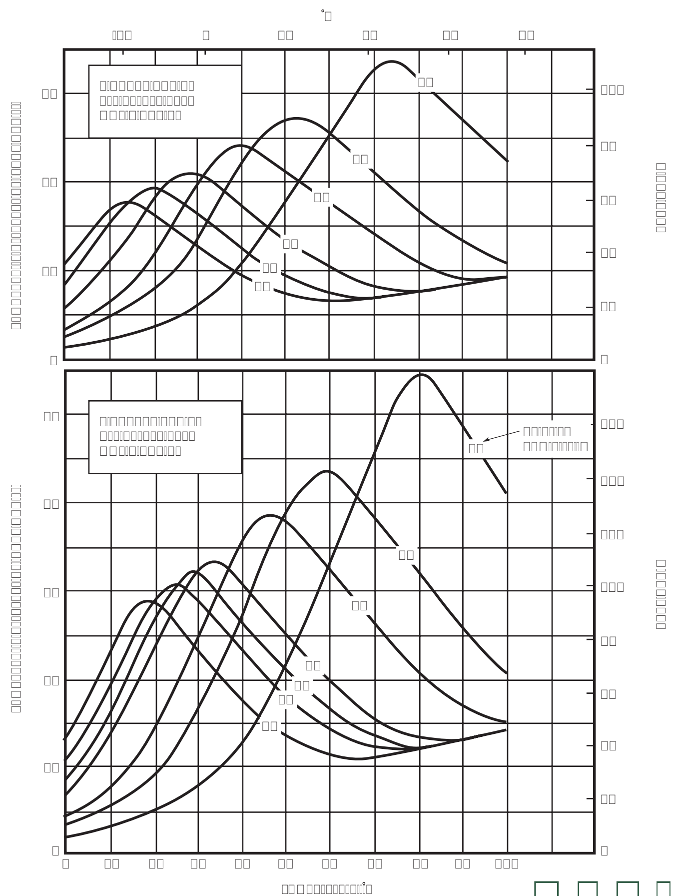
Duration of Sound. The annoyance from a noise event increases with increased duration of the noise event, i.e., and the longer the noise event lasts the more annoying it is. The "effective duration" of a sound is the time between when a

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]		[illegible]
[illegible]		[illegible]		[illegible]
	[illegible]	[illegible]		
[illegible]	[illegible]			

[illegible]

[illegible]





sound rises above the background sound level until it drops back below the background level. Psycho-acoustic studies have determined a relationship between duration and annoyance. These studies determined the amount a sound must be reduced to be judged equally annoying for increased duration. Duration is an important factor in describing sound in a community setting.

The relationship between duration and noise level is the basis of the equivalent energy principal of sound exposure. Reducing the acoustic energy of a sound by one-half results in a 3 dB reduction. Doubling the duration of the sound 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 [1]. CNEL, DNL, LEQ and SENEL are all based upon the equal energy principle and defined in subsequent sections of this study.

Change in Noise. The concept of change in ambient sound levels can be understood with an explanation of the hearing mechanism's reaction to sound. The human ear is a far better detector of relative differences in sound levels than absolute values of 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 10-decibel change is judged by most people as a doubling or a halving of the loudness of the sound.

Recruitment of Loudness. Recruitment describes the perception of loudness in situations where masking elevates the threshold of hearing of 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 background, would be judged as comfortable. In loud background settings, a sound that is approximately 20 dB above the masking threshold will be perceived as the same loudness as the sound would have been if no masking sound were present.

Masking Effect. A characteristic of sound is the ability of a sound to interfere with the ability of a listener 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 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 is dependent upon many factors, including the spectral (frequency) characteristics of the two sounds, the sound pressure levels and the relative start time of the sounds. The masking affect is greatest when the masking frequency is closest to the frequency of the signal. Low frequency sounds can mask higher frequency sounds, however, the reverse is not true

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, in the Handbook of Noise Control [2] describes human response to sound in terms of both acoustic and non-acoustic factors. These factors are summarized in Table C1.

Table C1
FACTORS THAT AFFECT INDIVIDUAL ANNOYANCE TO NOISE
Centennial Airport FAR Part 150 Study

Primary Acoustic Factors
- Sound Level
- Frequency
- Duration

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

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

Sound rating scales are developed to account for the factors that affect human response to sound. Nearly all of these factors are relevant in describing how sounds are perceived in the community. Many of the 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. Fields [4], in his analysis of the effects of personal and situation dependent variables on noise annoyance, has identified a clear association of reported annoyance and fear of an accident. In particular, Fields has stated that 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 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.

Health Effects of Noise

Noise, often described as unwanted sound, is known to have several adverse effects on people. 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. 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. 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 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, are not sufficiently loud to cause hearing loss.

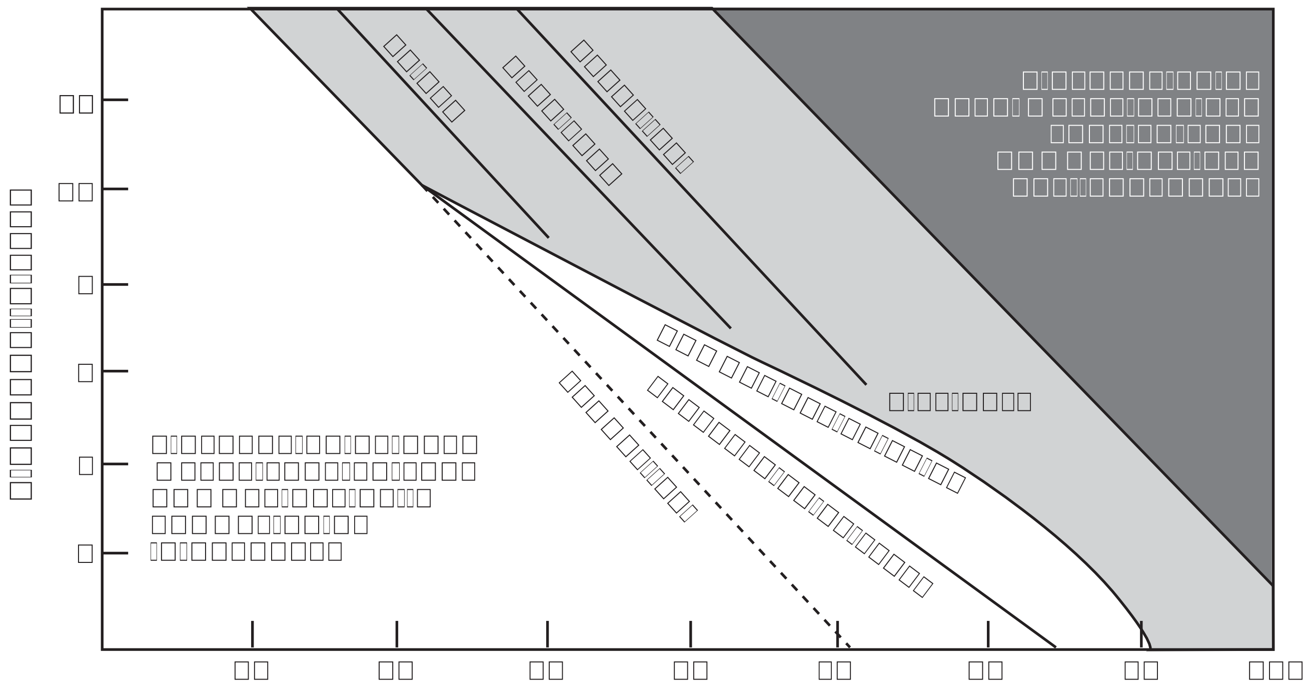
- *Communication Interference* is one of the primary concerns in environmental noise problems. Communication interference includes speech interference and interference with activities such as watching television. Normal conversational speech is in the range of 60 to 65 dBA and any noise in this range 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 C3 shows the relation of quality of speech communication with respect to various noise levels.

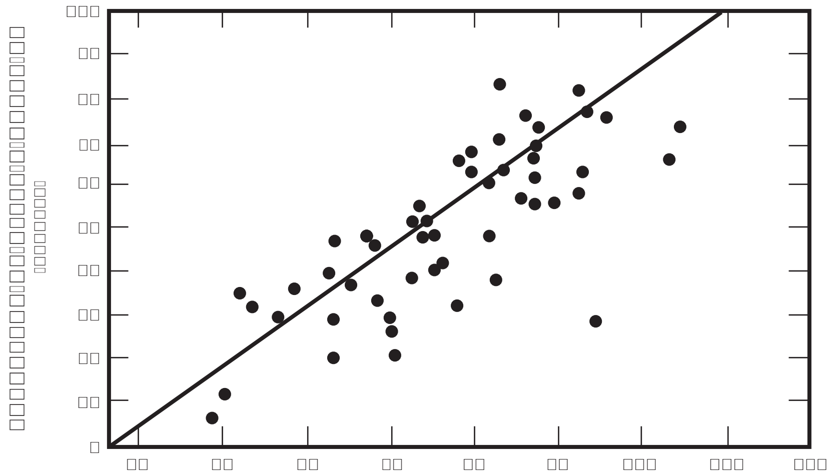
- *Sleep Interference* is a major noise concern in noise assessment and, of course, is most critical during nighttime hours. Sleep disturbance is one of the major causes of annoyance due to community noise. Noise can make it difficult to fall asleep, create momentary disturbances of natural sleep patterns 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.

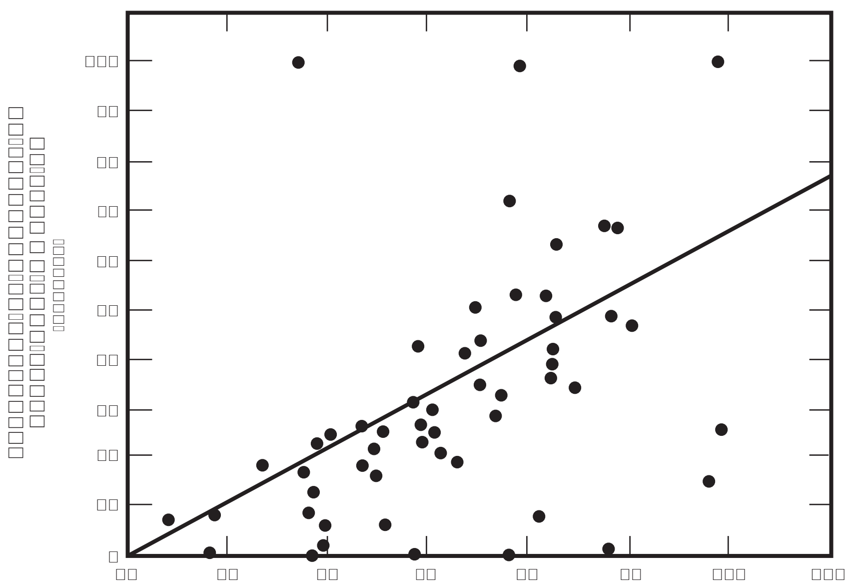
  Extensive research has been conducted on the effect of noise on sleep disturbance. Recommended values for desired sound levels in residential bedroom space range from 25 to 45 dBA, with 35 to 40 dBA being the norm. The National Association of Noise Control Officials [3] has published data on the probability of sleep disturbance with various single event noise levels. Based on experimental sleep data as related to noise exposure, a 75-dBA interior noise level event will cause noise induced awakening in 30 percent of the cases. A summary of these data is presented in Figure C4.

  It is important to note that recent research from England [4] has shown that the probability for sleep disturbance is less than what had been reported in earlier research. 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. It is therefore likely that the data shown in Figure C4 overestimates the sleep disturbance at a given noise level.

- *Physiological Responses* are those measurable effects of noise on people, which 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 overflight.







- Annoyance is the most difficult of all noise responses to describe. Annoyance is a very 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 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 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.

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 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 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. Noise metrics used in this study are summarized below:

<u>Single Event Metrics</u>

- *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. Its advantages are that it has shown good correlation with community response and is 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, 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 C5. 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) metric. It is computed from dBA sound levels. Referring again to the top of Figure C5 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 Noise Exposure Level data.

  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 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, CNEL and DNL can be computed from SEL data.

Cumulative Metrics

- *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 over 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 a noise to impact people is dependent on the total acoustical energy content of the noise. It is the energy sum of all the sound that occurs during that time period.

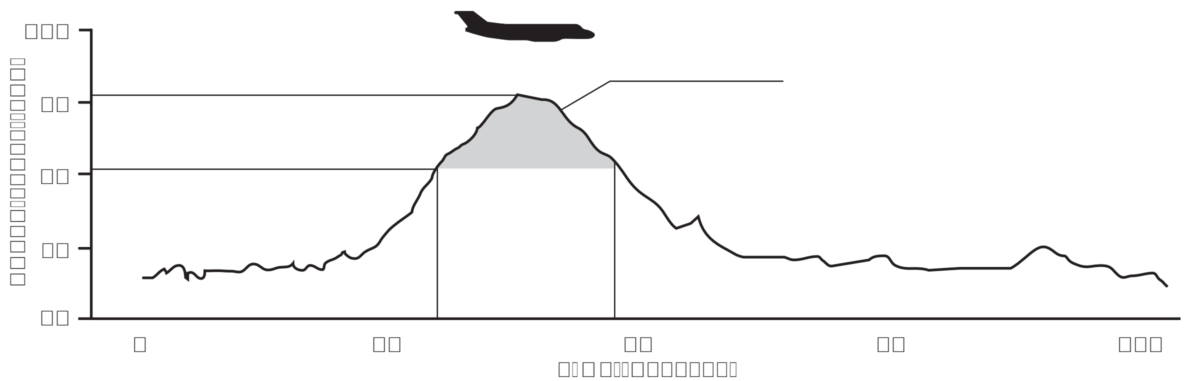
  This is graphically illustrated in the middle graph of Figure C5. LEQ can be measured for any time period, but is typically measured for 15 minutes, 1 hour or 24-hours. Leq for one hour is called Hourly Noise Level (HNL) in the California Airport Noise Regulations [6] and is used to develop the Day Night Noise Level (DNL) values for aircraft operations.

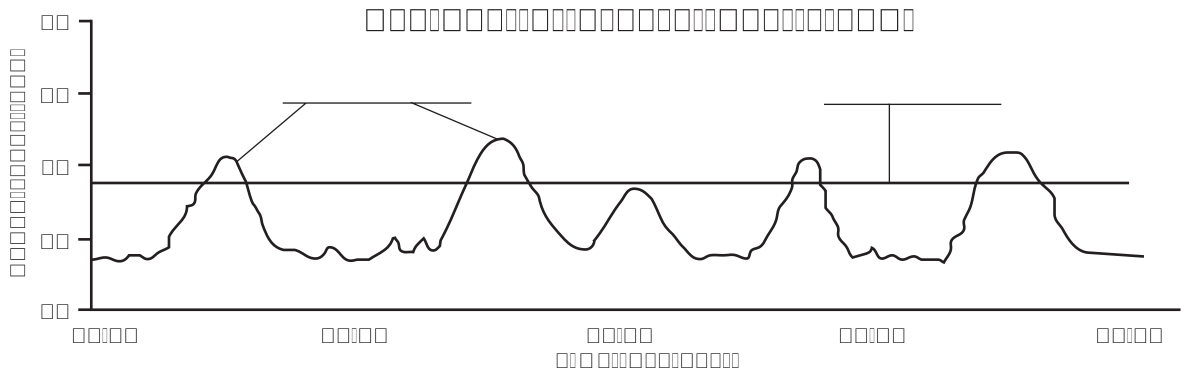
- Cumulative noise metrics have been developed to assess community response to noise. They are useful because these scales attempt to include the loudness of the noise, the duration of the noise, the total number of noise events and the time of day these events occur into one single number rating scale.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

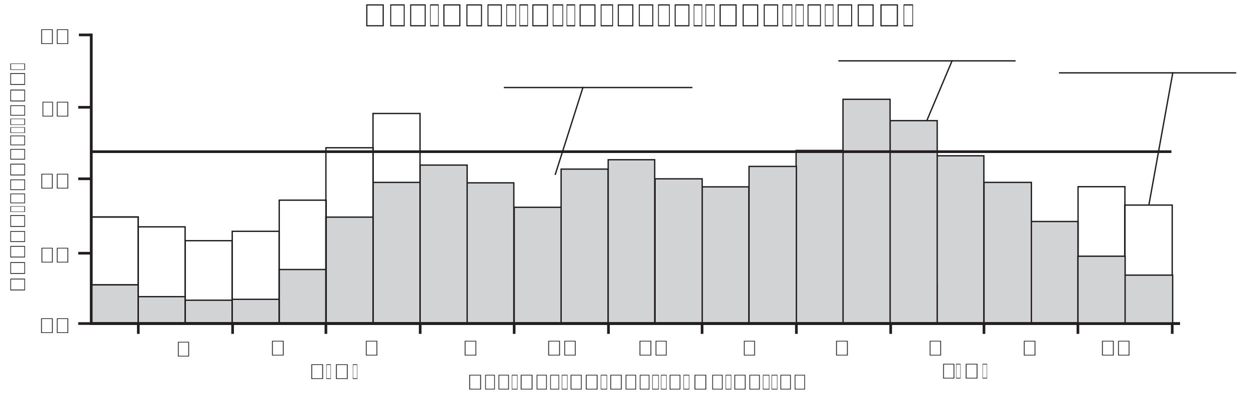
- Day Night Noise Level (DNL). The DNL index is a 24-hour, time-weighted energy average noise level based on the A-weighted decibel. It is a measure of the overall noise experienced during an entire day. The time-weighted refers to the fact that noise that occurs during certain sensitive time periods is penalized for occurring at these times. 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 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. The FAA for airport noise assessment specifies DNL, and the Environmental Protection Agency (EPA) specifies DNL for community noise and airport noise assessment. DNL, also referred to as LDN, is graphically illustrated in the bottom of Figure C5. Examples of various noise environments in terms of LDN are presented in Figure C6.

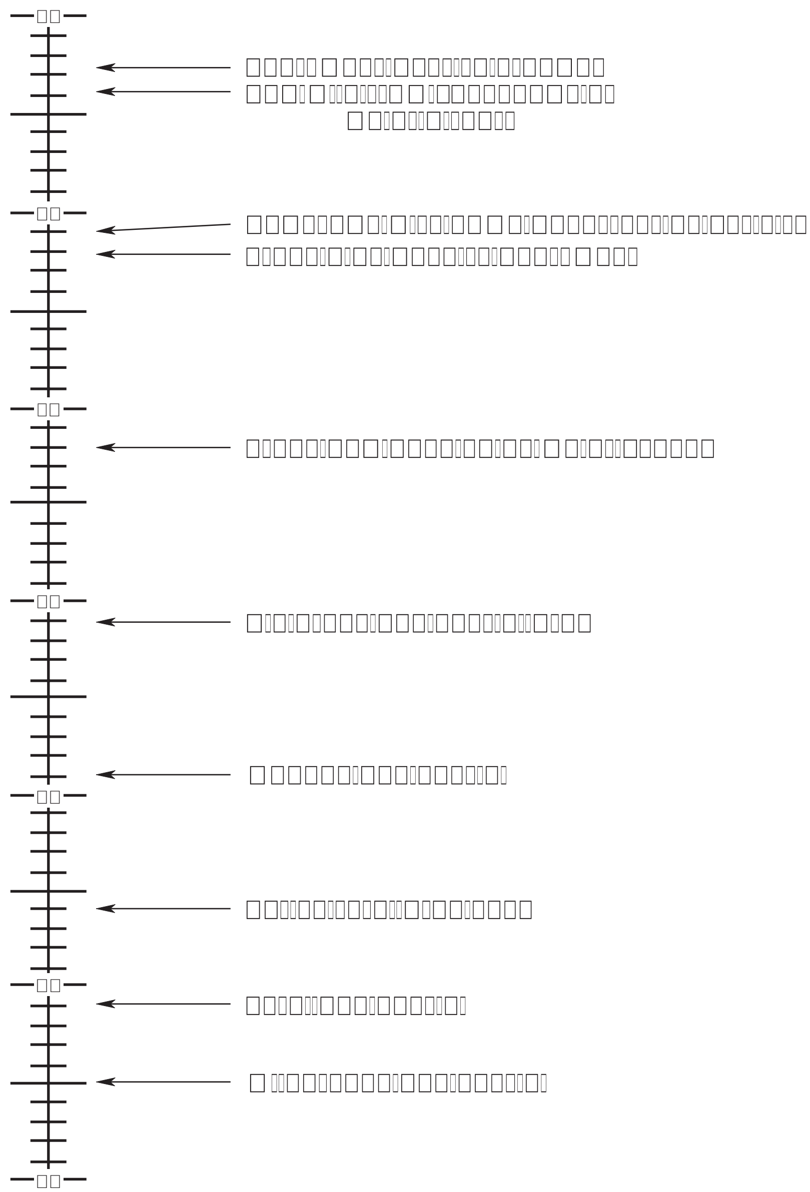
Supplemental Metrics

- *Time Above (TA).* The FAA has developed the Time Above metric as a second metric for assessing impacts of aircraft noise around airports. The Time Above index 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 75 and 85 dBA sound levels. While this index is not widely used, it may be used by the FAA in environmental assessments of airport projects that show a significant increase in noise levels. There are no noise/land use standards in terms of the Time Above index.







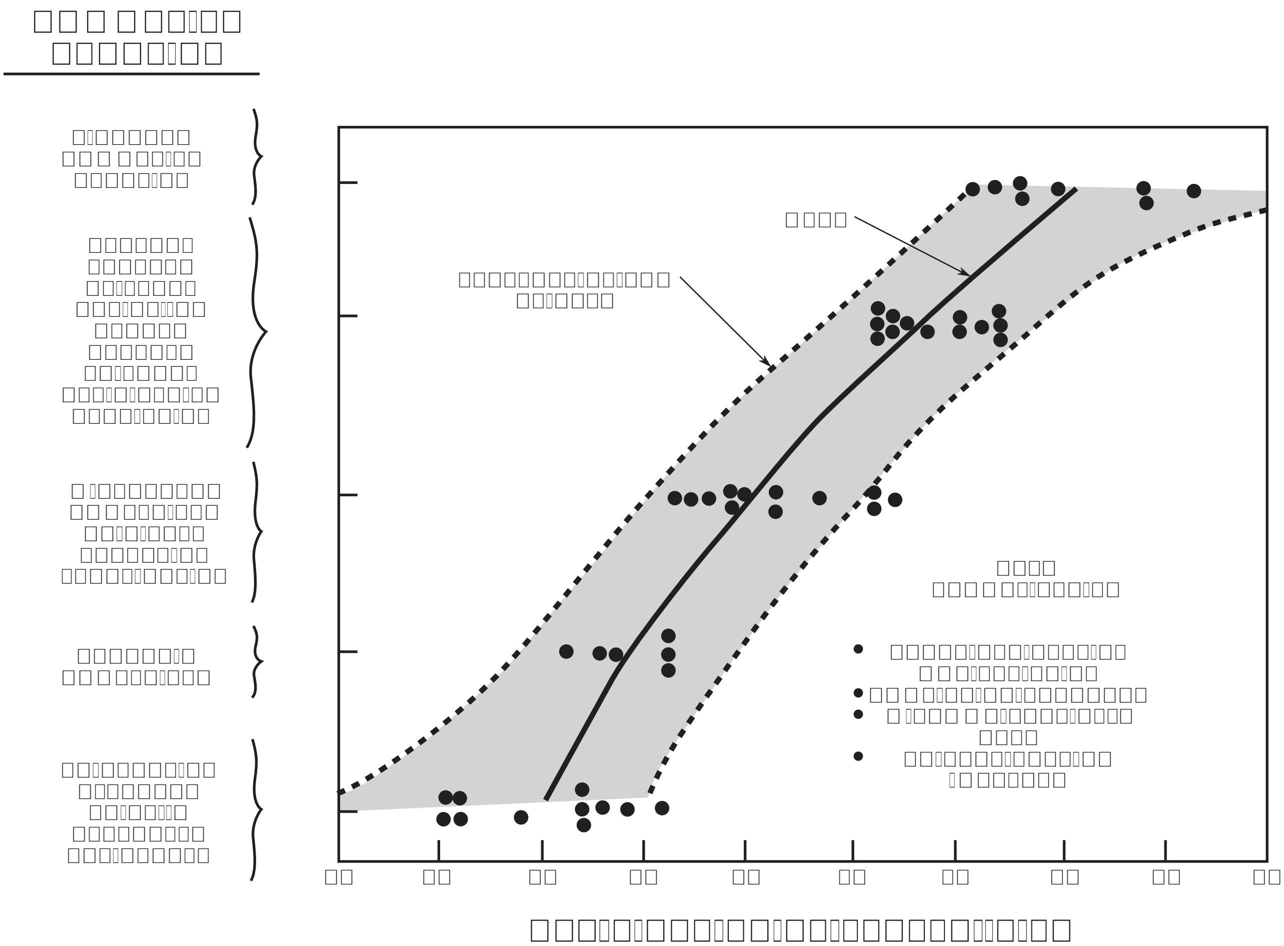


- *Percent Noise Level (Ln).* To account for intermittent or fluctuating noise, another method to characterize noise is the Percent Noise Level (Ln). The Percent Noise Level is the level exceeded n% of the time during the measurement period. It is usually measured in the A-weighted decibel, but can be an expression of any noise rating scale. Percent Noise Levels are another method of characterizing ambient noise where, for example, L90 is the noise level exceeded 90 percent of the time, L50 is the level exceeded 50 percent, 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 which regulate noise from mechanical equipment, entertainment noise sources, and the like. It is not normally used for transportation noise regulation (although the FHWA Leq criterion for roadways was originally stated as an L10 criterion).

Noise/Land Use Compatibility Standards and Guidelines

The use of noise metrics is an attempt to quantify 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 C7 relates DNL noise levels to community response from one of these surveys. Community noise standards are derived from tradeoffs between community response surveys, such as this, and economic considerations for achieving these levels. These standards generally are 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 standards for assessing the compatibility of various land uses with the noise environment.

The purpose of this section is to present information regarding noise and land use criteria that may be useful in the evaluation of noise impacts. With respect to airports, the Federal Aviation Administration 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 impacts, and the enactment of compatibility policies. Other agencies, including the EPA and the Department of Defense, have developed noise/land use criteria. The most common noise/land use compatibility standard or criteria used is 65 dB DNL for residential land use with outdoor activity areas. At 65 dB DNL the Schultz curve 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. It should be further pointed out that the data upon which the Schultz curve and the more recent updates are based include a very wide range of scatter among the data with communities near some airports



reporting a much higher percentage of the population highly annoyed at these noise exposure levels. 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 certified 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 are no longer permitted to operate in the U.S. Stage 2 aircraft over 75,000 pounds are being phased out of the U.S. fleet as discussed in a later paragraph on the 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.

U.S. Department of Transportation 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 thrust 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 in the allocation of ADAP (now AIP) funds 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.

Aviation Safety and Noise Abatement Act of 1979.

Further weight was given to the FAA's supporting role in noise compatibility planning by congressional adoption of this legislation. Among the stated purposes of this act is "To provide assistance to airport operators to prepare and carry out noise compatibility programs". The law establishes funding for noise compatibility planning and sets the requirements by which airport operators can apply for funding. The law does not require any airport to develop a noise compatibility program.

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 C8. These guidelines represent recommendations to local authorities for determining acceptability and permissibility of land uses. The guidelines specify a maximum amount of noise exposure (in terms of the cumulative noise metric DNL) that will 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 dB DNL. Recreational areas are also considered acceptable for noise levels above 65 dB DNL (with certain exceptions for amphitheaters that are recommended not to exceed 65 dB DNL). Several important notes appear for the FAA guidelines including one which indicates that ultimately "the responsibility for determining the acceptability and permissible land uses remains with the local authorities."

Federal Aviation Order 5050.4 and Directive 1050.1 for Environmental Analysis of Aircraft Noise Around Airports.

The FAA has developed guidelines (Order 5050.4D) for the environmental analysis of airports. Federal requirements now dictate that increases in noise levels in noise sensitive land uses of over 1.5 dB DNL within the 65 dB DNL contour are considered significant (1050.1A, 12.21.83). The FAA only considers noise impacts that occur at the 65 dB DNL or greater. No analysis is required beyond the 65 dB DNL. However, the FAA is now being revised and comments have been solicited, through the Federal Register, on proposed changes to the Order.

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 to the FAA; (1) establish a method to review aircraft noise, and airport use or access restrictions, imposed by airport proprietors, and (2) institute a program of 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 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, will be out of the domestic fleet by December 31, 1999. There are a few exceptions, but for the most part, only Stage 3 aircraft greater than 75,000 pounds will be in the domestic fleet after that date. The airlines have options on how and when to phase-out Stage 2 aircraft, but it is anticipated that the domestic fleet in the mainland will be all Stage 3 by the year 2000.

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 that the Part 150 land use guideline table, including 65 dB DNL as the threshold contour, be used 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: negotiated restrictions, Stage 2 aircraft restrictions and Stage 3 aircraft restrictions. Generally speaking, any use restriction which 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 applies as well to the smaller aircraft.

Negotiated restrictions are more favorable from the FAA's standpoint, but still require unwieldy procedures for approval and implementation. They 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 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 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 dB 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. It also applies to amendments to existing restrictions proposed after October, 1990. There have not been any Part 161 evaluations approved by the FAA to date.

Environmental Protection Agency Noise Assessment Guidelines

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 the EPA published a very important document [1] entitled "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare With an Adequate Margin of Safety" (EPA 550/9-74-004). In this document, 55 dB DNL is described as the requisite level with an adequate margin of safety for areas with outdoor uses, this includes 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 economic cost for achieving these levels.

Federal Interagency Committee on Noise

Federal Interagency Committee on Noise (FICON) Report of 1992 [13]

The use of the DNL metric and the 65 dB CNEL criteria has been subject to criticism from 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 of airport noise impacts and to make recommendations regarding potential improvements. FICON is composed of 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 that are used in the assessment of airport noise impacts. 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; the manner in which noise impacts are described; and the extent of impacts outside of Day-Night Average A-Weighted Sound Level (DNL) 65 decibels (dB) that should be reviewed in a National Environmental Policy Act (NEPA) document.

The committee determined that there are no new descriptors or metrics of sufficient scientific standing to substitute for the present DNL cumulative noise exposure metric. The methodology employing DNL as the noise exposure metric and appropriate dose-response relationships to determine noise impact is considered the proper one for civil and military aviation scenarios in the general vicinity of airports. The report does support agency discretion in the use of supplemental noise analysis. The report does recommend improvement in public understanding of the DNL, supplemental methodologies and aircraft noise impacts.

The report states that if the screening analysis shows that noise-sensitive areas that are exposed to noise levels at or above DNL 65 dB and have an increase of DNL 1.5 dB or more, then further analysis should be conducted. For noise sensitive areas between DNL 60-65 dB and an increase of DNL 3 dB or more due to the proposed airport noise exposure then further analysis should also be conducted.

Methodology

The existing noise environment at Centennial Airport was determined through a comprehensive noise measurement survey and modeling assessment. The foundation of a Part 150 Noise Study is the accurate prediction of airport noise levels. The noise environment at Centennial Airport has been depicted through the employment of noise measurement surveys of aircraft events and ambient noise levels, collection of aircraft operational data, and the incorporation of this information into an airport noise computer model.

The methods used here for forecasting the future noise environment rely heavily on computer noise modeling. These noise contours are supplemented here with specific noise data for selected points on the ground. The noise environment is commonly depicted in terms of lines of equal noise levels, or noise contours. Generating accurate noise contours is largely dependent upon the use of a reliable, validated, and updated noise model. Testing the validity of the computer model results using on-site noise measurements is one of the most effective methods of ensuring accurate noise contours. The following section details the methodology that was used in the measurement survey and the computer modeling of these results into noise contours. The operational data used in the analysis is also presented.

Noise Measurement Survey

Purpose of Measurement Survey. A noise measurement survey is an integral part of the Part 150 Noise Study. The purpose of the noise survey includes:

- Determine aircraft noise levels specific to the local environment
- Validate the computer model using the measurement results
- Determine the noise level at example locations around the Airport
- Give confidence to the community in the accuracy of the results of the study

Noise Measurement Locations. Noise measurements were recently conducted at selected locations around the airport. The measurement locations were selected on the basis of: (1) proximity to aircraft flight tracks, (2) the proximity to noise sensitive land use areas, and (3) ambient noise levels.

The measurement locations are presented in Figures C9 and C10. Each of the sites are also described in Table C2. The measurement sites are divided into two classes. Figure C9 presents the semi-permanent locations that were used for continuous measurement of the aircraft noise. Figure C10 presents the temporary locations that were used for short-term spot measurement and ambient noise measurements.

Measurement Procedures. Noise measurements were conducted at various sites over several days for each site between July 26th, 1999 and August 21st, 1999. The equipment was checked and calibrated on a regular basis. The noise measurement survey was in compliance with FAR Part 150 guidelines

Aircraft identification was determined from on-site field observations by the acoustical engineer, flight strip information, night aircraft logs, Aircraft Situational Display (ASD) data, and aircraft radar tracking system (ARTS) flight track data. The ARTS collected during the survey identified included the time of the operation, the type of aircraft, and the runway and flight track used.

Table C2
NOISE MEASUREMENT LOCATIONS
Centennial Airport FAR Part 150 Study

Sites	Address	Neighborhood
Semi-Permanent Sites		
1	9766 Edgewater Place	Lone Tree
2	12270 Orchard Avenue	Cherry Creek State Park
3	9880 E. Chenango Avenue	Village on the Lake
4	9672 S. Meridian Blvd.	Meridian Golf Club
5	16701 E. Costilla Avenue	Foxfield
6	12577 N. 2nd Street	Grand View Estates
7	15603 E. Chenango Avenue	Aurora
8	S. Yosemite & Crooked Stick Tr.	Heritage Estates
9	6090 Nome Street	Cherry Creek Vista
10	10026 E. Berry Drive	Sundance Hills
Temporary Sites		
11	Cottonwood Creek Elem. School	Cherry Creek Vista
12	9819 Ida Circle	Sundance Hills
13	8851 Xanthia Street	Hunter's Hill
14	West Shade Shelters	Cherry Creek State Park
15	East Shade Shelters	Cherry Creek State Park

Figure C10

Temporary Monitoring Locations (Sites 11 – 15)

Acoustic Data. The noise measurement survey utilized specialized noise monitoring instrumentation that allowed for the measurement of aircraft single event data and ambient noise levels. The noise data that was determined from each of the semi-permanent noise measurement sites is listed below:

- Daily DNL Noise Level
- Hourly Noise Data (LEQ, Level Percent, Time Above)
- Single Event Data (SEL, Lmax and Duration) for Individual Aircraft
- Correlation of Noise Data with Aircraft Identification
- Non-aircraft Ambient Sound Level (Level Percent)

For portions of the noise measurement the survey utilized instrumentation that included software that provide 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 could be used to plot the time histories of any of the noise events of interests. Examples of the time histories of various noise events are presented throughout the report.

The temporary sites were used to measure aircraft single event noise levels (SEL) and ambient noise level descriptors.

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

These sites utilized Brüel and Kjaer 2236 Sound Level Meters. The analyzers automatically calculate the various single event data. The Brüel and Kjaer system includes software that provides storage of the data 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 traceable to the National Institute of Standards and Technology, formerly the National Bureau of Standards. An accurate record of the meteorological conditions that existed during the time of the measurements was kept.

Computer Modeling

Contour modeling is a very key element of this noise study. Generating accurate noise contours is largely dependent on the use of a reliable, validated, and updated noise model. It is imperative that these contours be accurate for the meaningful analysis of airport and roadway noise impacts. The computer model can then be used to predict the changes to the noise environment as a result of any of the development alternatives under consideration.

The FAA's Integrated Noise Model (INM) Version 6.0 was used to model the flight operations contours at Centennial Airport. The INM has an extensive database of civilian aircraft noise characteristics and this most recent version of INM incorporates the advanced plotting features that are part of the Air Forces Noisemap computer model.

Airport noise contours were generated in this study using the INM Version 6.0. The original INM was released in 1977. The latest version, INM Version 6.0, was released for use in late 1999 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 200 aircraft types that can be tailored to the characteristics of the airport in question. Version 6.0 includes an updated data base that includes some newer aircraft, the ability to include run-ups in the computations, the ability to include topography in the computations, and the provision to vary aircraft profiles in an automated fashion.

One of the most important factors in generating accurate noise contours is the collection of accurate operational data. The INM programs require the input of the physical and operational characteristics of the 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 that are specific to the operations at the airport. Aircraft data needed to generate noise contours include:

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

INM Modeling Assumptions

The Integrated Noise Model Version 6.0 was used to develop DNL contours for the existing conditions and each of the alternatives. Operations data in existing conditions section describe the runway use percentages, aircraft types, and time of day of operations used in the INM to develop the DNL contours. Topographic effects were not included in the DNL computations, however average wind effects were included. These are described in the following paragraphs:

Topographic Effects - The effect of topography on noise levels near an airport may be important where there are significant elevation differences between the airport and surrounding environs. The INM Version 6.0 has the optional capability to include topographic effects on sound propagation from aircraft. The INM modeling completed for these analyses did not include using the topographic feature of the INM, since the changes in the elevation surrounding the airport is relatively insignificant.

Average Wind Effects - The Integrated Noise Model includes standard takeoff and approach profiles. The takeoff and approach profiles include a description of the aircraft altitude and airspeed along the flight path. These profiles are based on an assumed 8-knot headwind for all operations. INM Version 6.0 allows the use of other headwind assumptions that result in changes in aircraft profiles. The Centennial Airport site has no unique runway, topographic, and winds characteristics that will result in aircraft operating into headwinds significantly different than 8 knots. Therefore, for all approach and departure profiles, it was assumed that the average headwind for all operations on all runways was 8 knots.

Existing Aircraft Operations

The existing noise environment for Centennial Airport was analyzed based upon 1999 operational conditions. The data was derived from various sources. This includes aircraft tower counts, night traffic counts, review of aircraft flight strips, ASD data, ARTS flight track data, field observations and a review of the results of the noise measurement survey. A variety of operational data is necessary in order to determine the noise environment around the airport. This data includes the following summary information and is discussed in detail in the following paragraphs:

- Aircraft Activity Levels
- Fleet Mix
- Time of Day
- Runway Use
- Flight Path Utilization

Aircraft Activity Levels. The total aircraft operational levels were derived directly from the Centennial Airport air traffic control tower counts. The tower count data showed that for the year 1999 there were a total of 436,081 operations, or an average of 1,195 operations per day (an operation is one takeoff or one landing). The breakdown by aircraft category was determined from a variety of sources this includes:

- Review of the aircraft based at Centennial
- Percentages presented in the 1996 Noise and Land Use Study
- Radar flight data from July 26th, 1999 through August 21st, 1999
- Aircraft Situational Display (ASD) Radar data for 1999

The 1999 aircraft operations for each category of operation are summarized in Table C3. These operations are categorized as business jets, turboprop, and general aviation aircraft. The total number of annual corporate jet aircraft was determined from the ASD data source. The ASD provides information on aircraft that file an instrument flight plan. It accounts for nearly all larger aircraft including corporate jets. Larger twin engine propeller aircraft are also counted in ASD. But smaller visual flight aircraft are not included.

Table C3
SUMMARY OF OPERATIONS, EXISTING 1999
Centennial Airport FAR Part 150 Study

Category Type	Annual Operations	Daily Operations	Percent Nighttime
Business Jets			
Stage 3	27,406	75.1	25%
Business Jets			
Stage 2	5,594	15.3	19%
General Aviation			
Single Engine Piston	330,081	904.6	5%
Multi-Engine Piston	37,000	101.4	5%
Turboprop	24,000	65.7	5%
Helicopter	12,000	32.9	5%
Total Operations	**436,081**	**1,195**	

Fleet Mix. The fleet mix of aircraft that operate at the airport is one of the most important factors in terms of the aircraft noise environment. The corporate jet fleet mix data was determined from an extensive review of the ASD database. The fleet mix assumptions for the corporate jets are presented in Table C4.

The mix of corporate jet aircraft is an important consideration. There are a wide variety of corporate jets that operate at Centennial Airport and these aircraft generate a wide range in noise. The analysis was based upon a compilation of over 25,000 corporate jet aircraft operations at the airport. Table C4 presents the percentage of operations by type for corporate jets. The operations were grouped into multiple categories of corporate jets.

The airport has a number of Stage II corporate jet aircraft. Stage II refers to the FAA's Federal Aircraft Regulations 36 that categorizes jet aircraft based upon noise levels. Stage II refers to the older louder aircraft. Stage III refers to the newer generation quieter aircraft. For corporate jet aircraft the fleet was calculated to be 17 percent Stage II.

Table C4
PERCENTAGE OF OPERATIONS BY TYPE FOR CORPORATE JETS
EXISTING 1999
Centennial Airport FAR Part 150 Study

Aircraft Type	Stage	INM Type	Annual Operations *Arrivals Day*	*Arrivals Night*	*Departures Day*	*Departures Night*	Total	Percent Night
Astra Jet	3	IA1125	445	46	473	18	983	7%
Beech Jet	3	LEAR35	299	28	313	14	654	6%
Cessna 500/501	3	CNA500	424	33	442	15	914	5%
Cessna 525	3	CNA500	367	22	355	34	779	7%
Cessna 550/551	3	MU3001	415	233	589	60	1298	23%
Cessna 560	3	MU3001	807	51	759	98	1715	9%
Cessna 650	3	CIT3	469	34	462	41	1005	7%
Cessna 750	3	CL601	245	19	235	29	528	9%
Challenger	3	CL601	779	79	805	53	1715	8%
Diamond	3	MU3001	68	18	82	4	172	12%
Falcon 10	3	LEAR35	150	22	161	11	344	10%
Falcon 20	2/3	FAL20	134	12	135	11	292	8%
Falcon 20/200	3	FAL20	118	15	125	7	265	8%
Falcon 200	3	LEAR35	452	57	440	69	1017	12%
Falcon 2000	3	CL601	155	15	163	6	339	6%
Falcon 50	3	GIV	351	29	356	25	762	7%
Falcon 900	3	GIV	226	16	219	23	484	8%
Gulfstream II/III	2	GIIB	550	49	573	26	1199	6%
Gulfstream IV/V	3	GIV	340	22	337	26	725	7%
Hawker A	3/2	SABR80	285	14	259	39	597	9%
Hawker A/B/C	3/2	SABR80	106	10	107	9	231	8%
Hawker B	3/2	SABR80	731	54	738	47	1570	6%
Hawker C	3	SABR80	192	7	183	16	398	6%
Jet Commander	2	LEAR25	25	1	24	1	52	5%
Jet Star	2	LEAR25	29	-	28	1	59	2%
Lear 23/24/25/28	2	LEAR25	1,113	453	1,084	483	3133	30%
Lear 31/35/36	3	LEAR35	2,433	2,705	2,445	2,693	10277	53%
Lear 45/55/60	3	GIV	587	36	572	51	1246	7%
Saberlinear	2/3	SABR80	122	-	113	8	243	3%
Total			**12,419**	**4,081**	**12,578**	**3,922**	**33,000**	**24%**

Time of Day. In the DNL metric, any operations that occur after 10 p.m. and before 7 a.m. are considered more intrusive and are weighted by 10 dBA. Therefore, the number of nighttime operations is very critical in determining the DNL noise environment and is also very important to the residences around Centennial Airport. The nighttime operations assumptions was estimated from a variety of sources. This included a review of the ASD data, radar data and the noise measurement survey data. The nighttime operational assumption data was summarized in Table C3 and C4. Table C4 presents the actual nighttime operations by each type of corporate jet for the entire year of 1999. This is based upon the ASD data information. Operations per each hour of the data is presented in Appendix A.

Runway Use. An additional important consideration in developing the noise contours is the percentage of time each runway is utilized. The speed and direction of the wind dictate the runway direction that is utilized by an aircraft. From a safety and stability standpoint, it is desirable, and usually necessary, to arrive and depart an aircraft into the wind. When the wind direction changes, the operations are shifted to the runway that favors the new wind direction.

The wind is generally calm with predominate wind direction from the south. Therefore, Runways 17L and 17R are utilize more than the reverse runway direction (Runways 35R and 35L). In addition, Centennial Airport has one crosswind runway that is also used to a lessor degree by small aircraft. The airport also has a preferential runway use program to use south flow departures during the nighttime hours (10 pm to 6 am). The runway utilization assumptions used in the study are presented in Tables C5 and C6. These tables present the percentage of operations by category utilizing each of the runways, for daytime and nighttime hours, respectively. A graphical presentation of this data is presented in the Appendix.

Table C5
DAYTIME RUNWAY UTILIZATION
Centennial Airport FAR Part 150 Study
(7 am to 10 pm)

Aircraft Type	Percentage Utilization					
	35R	**17L**	**35L**	**17R**	**10**	**28**
Arrivals						
Single Engine Local	4%	6%	33%	51%	1%	5%
Single Engine Itinerant	33%	51%	4%	6%	1%	5%
Multi Engine Prop	34%	53%	4%	6%	1%	2%
Corporate Jets	38%	60%	0%	0%	1%	1%
Departures						
Single Engine Local	4%	6%	33%	51%	5%	1%
Single Engine Itinerant	33%	51%	4%	6%	5%	1%
Multi Engine Prop	34%	53%	4%	6%	2%	1%
Corporate Jets	38%	60%	0%	0%	1%	1%

Table C6
NIGHTTIME RUNWAY UTILIZATION
Centennial Airport FAR Part 150 Study
(10 pm to 7 am)

Aircraft Type	Percentage Utilization					
	35R	**17L**	**35L**	**17R**	**10**	**28**
Arrivals						
Single Engine Local	3%	7%	26%	61%	1%	2%
Single Engine Itinerant	26%	61%	3%	7%	1%	2%
Multi Engine Prop	26%	61%	3%	7%	1%	2%
Corporate Jets	30%	68%	0%	0%	1%	1%
Departures						
Single Engine Local	3%	7%	21%	66%	2%	1%
Single Engine Itinerant	21%	66%	3%	7%	2%	1%
Multi Engine Prop	21%	66%	3%	7%	2%	1%
Corporate Jets	24%	74%	0%	0%	1%	1%

Flight Path Utilization. The airport and tower have established paths for aircraft arriving and departing from Centennial Airport. These paths are not precisely defined ground tracks, but represent a broad area over which the aircraft will generally fly. The modeling analysis includes a total of 19 departure flight tracks and 16 arrival flight tracks to model the aircraft flight paths at Centennial Airport. Aircraft flight tracks were obtained by observations during the measurement survey, discussions with airport staff and air traffic control personnel, review of aeronautical charts, and actual radar data plots of the aircraft departures and arrivals. The flight tracks presented in Figures C11 show the departure and arrival jet tracks for a typical south flow day, and flight tracks presented in Figure C12 show the departure and arrival jet tracks for a typical north flow day. The departure and arrival flight tracks for each day during the noise monitoring survey are show in the Appendix A.

The flight track data was used to help define the location of the aircraft flight paths and in the correlation of the noise measurement data with the aircraft operational data.

The flight paths developed for use in the INM model are presented in Figures C13 and Figure C14. Figure C13 presents departure flight paths. Figure C14 presents arrival flight paths.

Figure C11
Typical South Flow Jet Flight Tracks

Figure C12
Typical North Flow Jet Flight Tracks

Figure C13
INM Departure Flight Tracks

Figure C14
INM Arrival Flight Tracks

Future 2005 Aircraft Operations

The future noise environment for Centennial Airport was analyzed based upon 2005 forecast operational conditions. The forecasts were presented in Chapter Two.

Aircraft Activity Levels. The forecasts estimates that there will be 472,000 operations during that time period, or an average of 1,293 operations per day (an operation is one takeoff or one landing). The 2005 aircraft operations for each category of operation are summarized in Table C7.

Table C7
SUMMARY OF PRELIMINARY OPERATIONS, FUTURE 2005
Centennial Airport FAR Part 150 Study

Category Type	Annual Operations	Daily Operations	Percent Nighttime
Business Jets			
Stage 3	34,860	95.5	25%
Business Jets			
Stage 2	7,140	19.6	19%
General Aviation			
Single Engine Piston	340,000	931.5	5%
Multi-Engine Piston	43,000	117.8	5%
Turboprop	35,000	95.9	5%
Helicopter	12,000	32.9	5%
Total Operations	**472,000**	**1,293**	

All remaining assumptions are the same as with the existing conditions except for the mix of aircraft for the future year. The corporate jet fleet mix and night time percentages are assumed to remain the same.

These are Preliminary Forecasts, which will be refined based upon input from the committee. The total numbers are based on the Terminal Area Forecasts and the fleet mix existing fleet mix which also were used to identify the Stage 2/Stage 3 business jet fleet mix. Alternative forecasts with different fleet mix assumptions are presented in the future noise contour analysis section of this report.

Existing Noise Environment

The following section presents information concerning the existing noise environment at Centennial Airport. The existing noise environment was determined through a noise measurement and modeling assessment. Operational data used to describe the existing conditions was summarized in the previous subsection. The results of the noise measurement survey and contour modeling are presented in the following paragraphs. The analysis presents noise data in terms of the DNL metric and supplemental Single Event noise data. More detailed information is presented in the Appendices.

Noise Measurement Results

Noise measurements were conducted between July 26, 1999 and August 21, 1999 at various locations around the airport. A total of ten (10) sites were monitored around Centennial Airport using semi-permanent noise monitors. These sites were presented in Figure C9 and included noise monitors that measured around the clock for as long as the monitors were present. These sites were measured from 10 to 27 days during the time period of the survey.

The measurements consisted of: (1) single event noise levels from individual aircraft flyovers, (2) cumulative 24-hour continuous measurements, and (3) ambient non-aircraft noise sources. The survey also utilized specialized equipment that allowed for the recording and display of the compete time history of the noise.

The survey also included temporary event noise measurements at five (5) additional monitoring sites. These sites were short-term measurements that also included some spot measurements of aircraft single event noise levels, and were presented in Figure C10. The DNL noise level was not measured at these sites. The results of the measurement survey are presented in the following paragraphs.

The noise level was continuously recorded at each of the ten noise monitoring sites. In addition to recording the noise events from aircraft, the monitors also recorded the ambient noise level of the community surrounding the monitoring site. An example of this is presented in Table C8 where one hour of continuous noise data is shown for one site. The difference between an aircraft event and the ambient noise can be easily distinguished in this plot. Sample one-hour noise plots for each of the noise monitoring sites is presented in Appendix B.

Table C8
Example Time History Plot of One Hour of Aircraft and Ambient Noise

Single Event Noise Measurement Results. Aircraft single event noise levels were determined from this continuous noise data at each of the measurement sites. The acoustic data included the maximum noise level (Lmax), Sound Exposure Level (SEL), and the time duration of the aircraft events. The noise data was correlated to the aircraft that caused the event using the flight track data that was simultaneously collected. The aircraft data included the aircraft type, type of operation and runway. The single event noise level data measured in the field was reduced and coded into a microcomputer-based data management program. This program includes a list of all of the aircraft events that can be analyzed in order to present various types of aircraft noise event information.

The daily number of noise events measured at each site is presented graphically in Table C9. This table presents one day of events for one measurement site. The table presents the SEL noise value plotted as a histogram. The vertical axis presents the number of events in each hour. The horizontal axis is the hour of the day. The SEL values are plotted vertically for each event in each hour. This data is presented for additional days and additional sites in Appendix B.

The noise measurement data was used to determine the SEL noise levels for different types of aircraft operations. The ARTS data and the ASD were then used to correlate the measured noise levels to the specific aircraft operation that generated them. The noise events from each monitoring sites that were correlated to specific aircraft departures or arrivals were grouped by aircraft type. Table C10 lists the departing corporate jets correlated to noise levels measured at Site 9. In this table the aircraft type "C560" represents the group of all Citation jets correlated to noise events measured at this site, where in this case there were 72. The aircraft type "LJ25" represents all of the Stage 2 Lear jets measured at the site, while the type "LJ35" represent all of the Stage 3 Lear jets measured at the site. The tables listing the correlated events measured at each of the monitoring sites and grouped by aircraft type are presented in Appendix B.

The correlated events at each of the monitoring sites were sorted to determine which operations produced the loudest events. Table C11 lists the date, time, aircraft type, aircraft noise stage, operation, runway, and measured noise levels for the ten loudest events measured at Site 9. The tables listing the loudest ten events and associated aircraft for all of the noise monitoring sites are presented in Appendix B. The measured 1-second data from one of the loudest events at each of the monitoring sites was plotted to show the characteristic profile of an aircraft event at that location. Table C12 lists the measured parameters and shows the plot of the 1-second data for one of the loudest ten events measured at Site 1. The tables showing time history plots for one of the loudest events at all of the monitoring sites are presented in Appendix B.

Table C9
Single Event Noise Levels by Aircraft Type Report

Table C10
Loudest 10 Aircraft Noise Events

Table C11
Aircraft Noise Event Data Plot

Table C12
One-Second Noise Data Plot

The results of the departure noise analysis show that that many of the operations generate single event noise levels in excess of 95 SEL, up to a level of 110 SEL. These results show the wide range in aircraft events that occur at each site as well as some very high noise events. The noise levels generated by the corporate jet aircraft varies significantly for each type of aircraft. The older low-bypass-ratio engines (Stage II) generate significantly higher noise levels than the newer generation high-bypass-ratio engines (Stage III).

An analysis of the data showed that the average SEL for Stage II aircraft is 10 to 15 dBA higher than for Stage III aircraft. All of the very loud noise events were the Stage II corporate jets. The results show that the arrival noise for Stage III aircraft is quieter than for Stage II aircraft. This difference is less than with the departures. The difference between the energy average Stage II and Stage III aircraft SEL noise for arrival operations is approximately 5 dBA.

DNL Noise Levels. Once the aircraft noise and ambient noise were calculated at each monitoring site, the total noise level was determined. Table C13 lists the noise level due to the aircraft events, the noise due to the everything other than aircraft, and the total DNL for each day the noise level was monitored at Site 9. This table also includes a histogram of the noise levels of all of the events measured at the site. This helps illustrate the range in the single event noise levels measured at the site and the relative number of events. Additional tables presenting this information for the other sites is presented in Appendix B.

Table C14 lists the results of the DNL noise measurements at the 10 semi-permanent noise monitoring locations. This table lists the DNL due to aircraft events for the period the noise level was monitored at each site. The measurement results show that nearly all of these locations are exposed to noise levels ranging from 49 to 64 DNL. The major contributor to the DNL noise level at most of these sites is the corporate jet activity, especially the Stage 2 jets and those jets that occur during the nighttime hours. Sites 5 and 7 are exposed to more noise from traffic on local roadways than from aircraft operations. Table C15 shows the results of the DNL noise measurements at the 10 semi-permanent noise monitoring locations in a graphical format. The top portion of the table shows the range of daily DNL values along with the overall DNL for the entire measurement period. The bottom portion of the table shows the total DNL level as well as the amount of aircraft noise and ambient noise that contributed to the overall level.

Table C13
Measured DNL Noise Levels and Noise Event Histogram

Table C14
MEASURED DNL NOISE LEVELS
Centennial Airport FAR Part 150 Study

Site	Description	Date of Measurements	Measured DNL Noise Level
1	Lone Tree	July 26th – Aug 21st	52
2	Cherry Creek State Park	July 28 – Aug 6th	55
3	Village on the Lake	Aug 5th – Aug 21st	55
4	Meridian Golf Club	July 26th – Aug 21st	64
5	Foxfield	July 27th – Aug 6th	52
6	Grand View Estates	July 26th – Aug 5th	53
7	Aurora	July 27th – Aug 5th	51
8	Heritage Estates	Aug 5th – Aug 21st	49
9	Cherry Creek Vista	July 26th – Aug 21st	60
10	Sundance Hills	July 27th – Aug 21st	53

Table C15
Range of DNL Noise Levels

Ambient Noise Measurement Results. The ambient noise environment was also determined from the measurement survey. The ambient noise levels were determined at each of the measurement sites. The ambient noise levels were determined for all sources of noise affecting the sites. The quantities measured were the Hourly LEQ noise level and the Percent Noise Levels (Ln). These metrics were described in the background section. The data was used to help establish the ambient noise environment for all other sources other than airport operations in order to serve as an aid in assessing how intrusive the aircraft noise is on the ambient environment. This includes all other sources of noise including roadway, commercial sources and the residual background noise.

The results of the ambient noise measurement survey at the semi-permanent sites are presented graphically in Table C16. An example of data from one of the sites for each day of the measurements is presented in Table C17. These results for the other sites are presented in Appendix B. This exhibit presents a summary of the noise levels for each of the sites. This exhibit presents the statistical noise data (*the L(minimum), L90, L50, L10 and L(maximum)*) and graphically illustrating the range in noise. This illustrates the range in noise levels that exist at the sites. The L(*maximum*) is presented for the peak dBA measurement. Aircraft noise is included in this data. These metrics were defined on page C.16.

Table C16
Ambient Noise Levels for All Sites

Table C17
Ambient Noise Levels for All Sites

Noise Contour Modeling Results

The noise contour were generated using the INM Noise Model version 6.0. A description of the noise model and the operational data used to develop these contours was presented in previous sections. The existing noise contours are based upon 1999 operational conditions.

Noise contours were developed for both cumulative noise levels and single event noise levels. The cumulative noise levels were determined in terms of DNL. The single event analysis is in terms of SEL. The computer model was used to determine the SEL, DNL.

The primary noise criteria that will be used in the Part 150 Noise Study to describe the existing noise environment is DNL. DNL is the metric that is required by the FAA to be used in the Part 150. The SEL data will be used to supplement the DNL analysis.

The noise contours presented in this report where based upon the use of the FAA INM noise model, with modeling assumptions validated through use of the noise measurements. During the time period of the survey, the jet operations where lower than the annual average levels. Therefore, these modeled levels are higher than the noise levels measured during the survey. Data on measured versus predicted noise levels are presented in Appendix B.

DNL Noise Contours. While single event noise levels can be useful to help anticipate a community's response to noise, community noise standards are expressed in terms of cumulative noise exposure metrics such as the DNL. Therefore, the aircraft single event noise level data are combined with aircraft operational data to develop cumulative noise exposure levels over the full 24-hours. This combination of data generates the DNL noise level value. The existing annual 1999 DNL noise contours for Centennial Airport are presented in Figure C15. This exhibit presents the 55, 60, 65, 70 and 75 DNL noise contours.

As a means of implementing the Aviation Safety and Noise Abatement Act, the FAA adopted Regulations on Airport Noise Compatibility Planning Programs. The guidelines specify a maximum amount of noise exposure (in terms of the cumulative noise metric DNL) that will be considered acceptable to or compatible with people in living and working areas. Residential land use is deemed acceptable for noise exposures up to 65 DNL. However, at levels below 65 DNL there can still be adverse community reaction to aircraft noise.

Figure C15
Existing DNL Noise Contour

The noise modeling results can also be expressed in terms of the DNL noise level at the noise monitoring locations. The INM version 6.0 was used to determine the noise levels at each of these locations. Table C8 presented the measured DNL noise levels at each of the ten noise monitoring locations. A table comparing the modeled annual average DNL noise level for 1999 at each of the measurement sites with the measured values will be presented in a future version of this report.

The number of operations picked up during the noise measurements were much fewer than those modeled for two reasons. First, the noise monitoring survey covered a few weeks of time while the noise modeling covers an entire years worth of the operations, and during he monitoring on the east side of the airport many of the departure operations were away from the microphone locations. Second, the existing operations tend to lean toward the conservative side during the modeling process.

Single Event Noise Contours. Single event noise levels are often a predictor of when annoyance from aircraft noise is likely to occur or other factors such as sleep interference. Single event noise contours are also useful in illustrating the various differences in the noise generated by different aircraft types. Single event noise contours were developed for Centennial Airport. These were developed using specific aircraft types and their associated flight procedures.

The single event analysis presents the single event noise levels along a typical flight track for a number of sample commercial aircraft. The INM noise model was used to generate the single event noise contours. Corporate Jets generate a wide range in noise levels. To illustrate the range in single event noise from corporate jets three aircraft were selected for modeling purposes. These aircraft are listed below:

- Lear 25
- Lear 35
- Citation III

The Lear 25 aircraft represents the old generation Stage II corporate jets that generate the highest noise levels. The Lear 35 is representative of typical Stage III corporate jets, while the Citation III is representative of the quietest Stage III corporate jets. Note that there are many different variations of the flight tracks. Different flight tracks will result in a different noise exposure to different areas of the community. These contours are intended to reflect the single event noise levels from one typical departure and arrival track.

Single event contours for these three different corporate jet aircraft are presented in Figures C16 through C21. These exhibits present the Lmax noise contour for the Lear 25, Lear 35 and Citation III respectively for both north and south flight operations. Each aircraft is departing and arriving on a typical track for operations on either Runway 17L or Runway 35R. These exhibits present the Lmax noise contours for 100, 95, 90 and 85 dBA. The results illustrate the wide range in noise generated by corporate jet aircraft. The older Stage II aircraft generate significantly higher noise levels than the newer generation jet aircraft. This is most pronounced on departure. Note also that the sideline noise is significantly higher on the older Stage II aircraft than any of the other corporate jets.

There are no standards in terms of single event criteria. An Lmax level of 85 is approximately equal to an SEL level of 95 which represents the level at which sleep disturbance starts to occur in the general population with the probability of awaking increasing with the noise level. An Lmax level of 75 is approximately equal to an SEL level of 85 which represents the level at which speech interference starts to takes place. For windows closed situations, SEL levels above 95 will typically result in conversation interruption within a home.

Figure C14
Single Event Contours

Figure C15
Single Event Contours

Figure C16
Single Event Contours

Figure C17
Single Event Contours

Figure C18
Single Event Contours

Figure C19
Single Event Contours

Future Base Case (2005) DNL Contours

Various scenarios where modeled to predict the future base conditions noise levels at the airport. These are all based upon 472,000 annual operations. The different scenarios involves changes to the fleet mix and time of day assumptions. Each of these Scenarios are described below.

The 2005 DNL contours for Centennial Airport were prepared using Integrated Noise Model (INM) version 6.0. These base case conditions will be used to develop future noise abatement alternatives at the airport. No noise abatement alternatives are included in these contours.

Scenario 1 – Existing Fleet Mix for Jet Aircraft

Scenario 1 assumes that the annual corporate jet aircraft increases from 33,000 to 42,000 operations. The mix of Stage 2 and Stage 3 aircraft remains the same as with existing conditions. The percentage of operations in the nighttime hours is also assumed to remain the same as with existing conditions. Scenario 1 assumptions are presented in Table C18.

Table C18
SUMMARY OF PRELIMINARY OPERATIONS, FUTURE 2005
Centennial Airport FAR Part 150 Study

Category Type	Annual Operations	Daily Operations	Percent Nighttime
Business Jets			
Stage 3	34,860	95.5	25%
Business Jets			
Stage 2	7,140	19.6	19%
General Aviation			
Single Engine Piston	340,000	931.5	5%
Multi-Engine Piston	43,000	117.8	5%
Turboprop	35,000	95.9	5%
Helicopter	12,000	32.9	5%
Total Operations	**472,000**	**1,293**	

Scenario 1 Noise contours for calendar year 2005 that depict the noise exposure in terms of DNL are shown in Figure C22. The contours shown are the 55, 60, 65, 70 and 75 dBA DNL. The results of the analysis show that these future contours are slightly larger than the existing conditions contours. These contours are approximately 1.4 dBA louder than the existing conditions contour.

Figure C22
Future DNL noise contours (Scenario 1)

Scenario 2 – Increases in Jet Aircraft with Stage 3 Only

Scenario 2 assumes that the annual corporate jet aircraft increases from 33,000 to 42,000 operations. The mix of Stage 2 and Stage 3 aircraft is assumed to change, with the increase in Corporate Jet aircraft all from Stage 3 aircraft. The number of Stage 2 aircraft would remain the same as with existing conditions. The percentage of operations in the nighttime hours is also assumed to remain the same as with existing conditions. Scenario 2 assumptions are presented in Table C19.

Table C19
SUMMARY OF PRELIMINARY OPERATIONS, FUTURE 2005
Centennial Airport FAR Part 150 Study

Category Type	**Annual Operations**	**Daily Operations**	**Percent Nighttime**
Business Jets			
Stage 3	36,406	99.8	25%
Business Jets			
Stage 2	5,594	15.3	19%
General Aviation			
Single Engine Piston	340,000	931.5	5%
Multi-Engine Piston	43,000	117.8	5%
Turboprop	35,000	95.9	5%
Helicopter	12,000	32.9	5%
Total Operations	**472,000**	**1,293**	

Scenario 2 Noise contours for calendar year 2005 that depict the noise exposure in terms of DNL are shown in Figure C23. The contours shown are the 55, 60, 65, 70 and 75 dBA DNL. The results of the analysis show that these future contours are about the same as the existing conditions contour

Figure C23
Future DNL noise contours (Scenario 2)

Scenario 3 - Increases in Jet Aircraft with Stage 3 and Hushkit Stage 2

Scenario 3 assumes that the annual corporate jet aircraft increases from 33,000 to 42,000 operations. The mix of Stage 2 and Stage 3 aircraft is assumed to change, with the increase in Corporate Jet aircraft all from Stage 3 aircraft. The number of Stage 2 aircraft would remain the same as with existing conditions, except that these aircraft have been hush-kitted to meet Stage 3 limits. The percentage of operations in the nighttime hours is also assumed to remain the same as with existing conditions. Scenario 3 assumptions are presented in Table C20.

Table C20
SUMMARY OF PRELIMINARY OPERATIONS, FUTURE 2005
Centennial Airport FAR Part 150 Study

Category Type	Annual Operations	Daily Operations	Percent Nighttime
Business Jets			
Stage 3	36,423	99.8	25%
Business Jets			
Huskitted Stage 2	5,570	15.3	19%
General Aviation			
Single Engine Piston	340,000	931.5	5%
Multi-Engine Piston	43,000	117.8	5%
Turboprop	35,000	95.9	5%
Helicopter	12,000	32.9	5%
Total Operations	**472,000**	**1,293**	

Scenario 3 noise contours for calendar year 2005 that depict the noise exposure in terms of DNL are shown in Figure C24. The contours shown are the 55, 60, 65, 70 and 75 dBA DNL. The results of the analysis show that these future contours are smaller than the existing conditions contour.

Figure C24
Future DNL noise contours (Scenario 3)

Scenario 4 – Existing Fleet Mix for Jet Aircraft and additional Night Stage 2

Scenario 4 assumes that the annual corporate jet aircraft increases from 33,000 to 42,000 operations. The mix of Stage 2 and Stage 3 aircraft remains the same as with existing conditions. The percentage of operations in the nighttime hours is assumed to increase. For this Scenario, 4 additional Stage 2 Lear 25 operations (2 departures and 2 arrivals) are assumed to occur in the nighttime hours. Scenario 4 assumptions are presented in Table C21.

Table C21
SUMMARY OF PRELIMINARY OPERATIONS, FUTURE 2005
Centennial Airport FAR Part 150 Study

Category Type	Annual Operations	Daily Operations	Percent Nighttime
Business Jets			
Stage 3	34,860	95.5	25%
Business Jets			
Stage 2	7,140	19.6	39%
General Aviation			
Single Engine Piston	340,000	931.5	5%
Multi-Engine Piston	43,000	117.8	5%
Turboprop	35,000	95.9	5%
Helicopter	12,000	32.9	5%
Total Operations	**472,000**	**1,293**	

Scenario 4 Noise contours for calendar year 2005 that depict the noise exposure in terms of DNL are shown in Figure C25. The contours shown are the 55, 60, 65, 70 and 75 dBA DNL. The results of the analysis show that these future contours are the largest of all the scenarios. These contours are larger than the existing conditions contours.

Selected Forecast/Fleet Mix Scenario

The Selected Scenario to be used for generating future noise contours has been determined to be most reasonable is Scenario 1. This forecast fleet mix will be used throughout the remainder of the document.

Figure C25
Future DNL noise contours (Scenario 4)