

## Appendix C

### AIRCRAFT NOISE EXPOSURE

The following is a discussion of the general characteristics of aircraft noise and the methodologies used to analyze aircraft noise for Byron Airport.

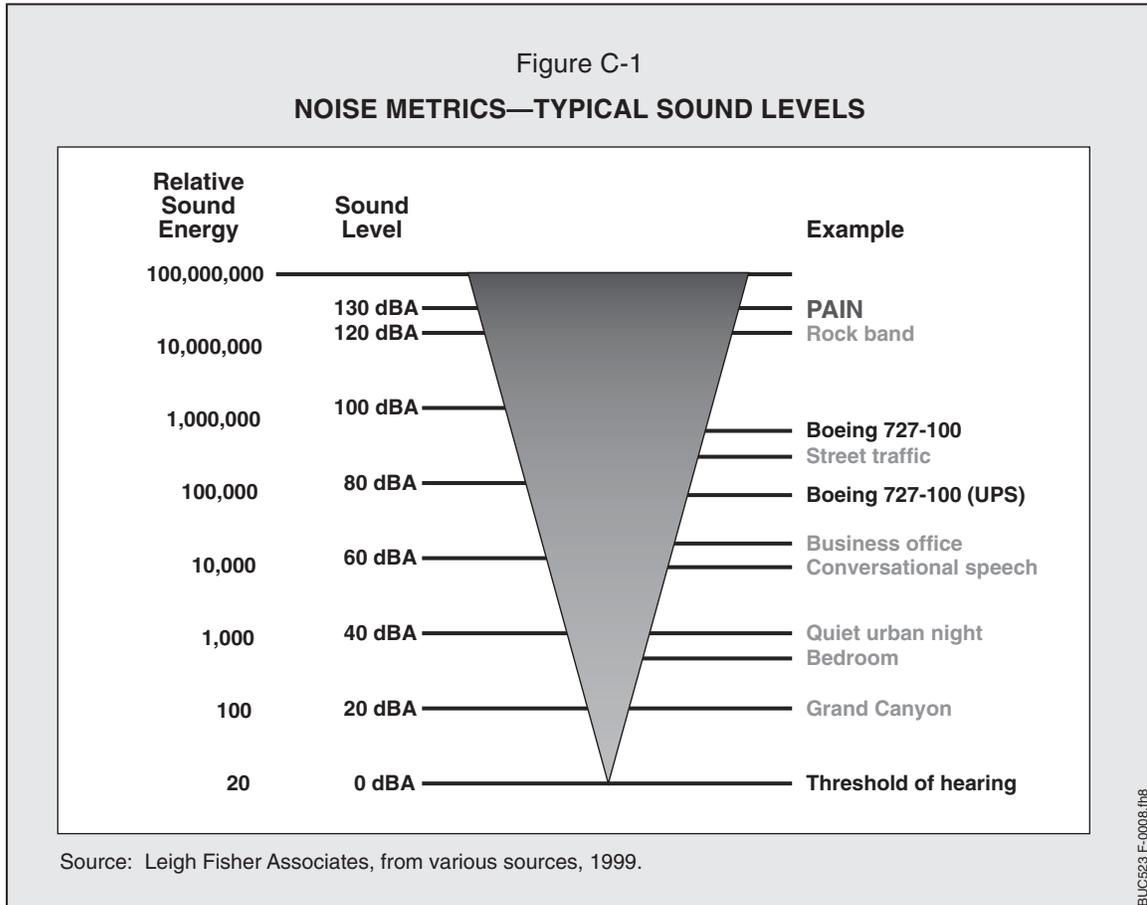
#### NOISE MEASUREMENT

Noise is defined as unwanted sound. In other words, noise is sound that disturbs routine activities or quiet, and/or causes feelings of annoyance. Whether sound is interpreted as pleasant (e.g., music) or unpleasant (e.g., jackhammer) depends largely upon the listener's current activity, past experience, and attitude toward the source.

#### Characteristics of Sound

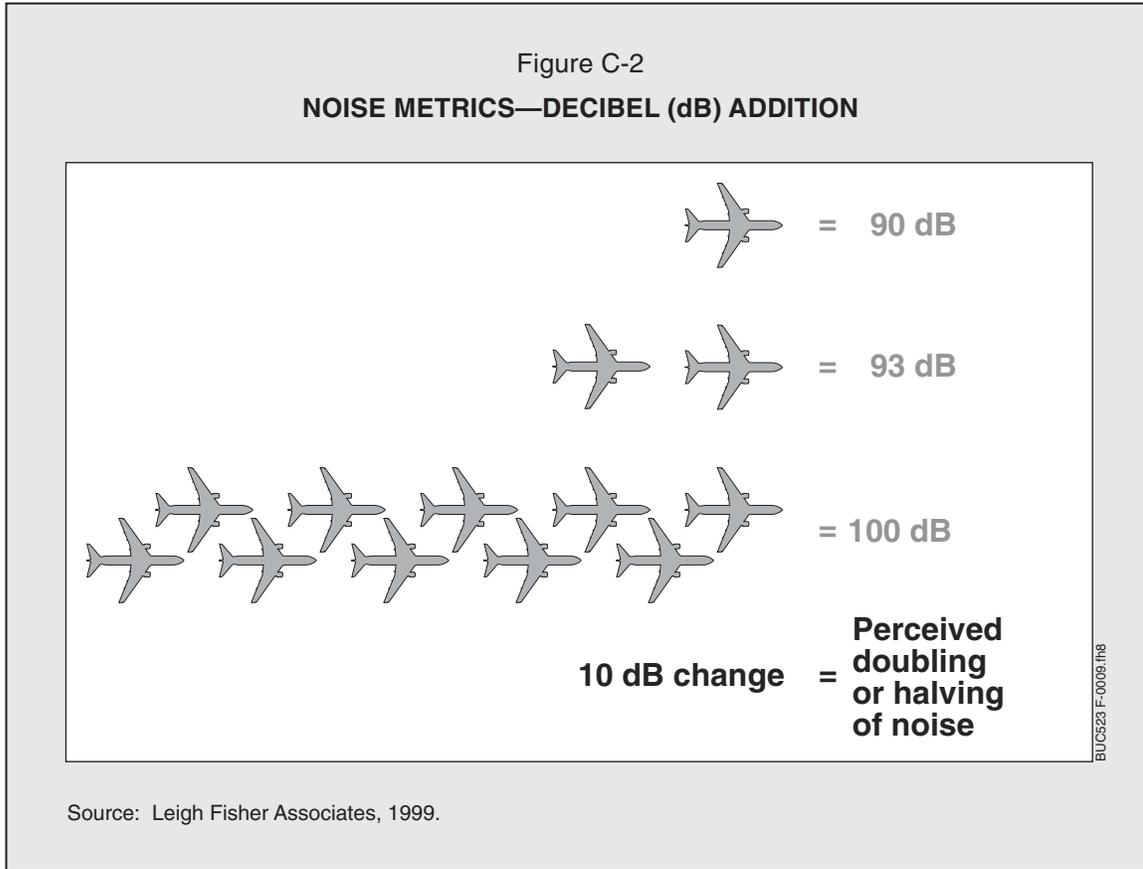
Sound is transmitted by alternating compression and decompression in air pressure. These relatively small changes in atmospheric pressure are called sound waves. The measurement and human perception of sound involve two physical characteristics—intensity and frequency. Intensity is a measure of the strength or magnitude of the sound vibrations, and is expressed in terms of the sound pressure level (SPL). The higher the SPL, the more intense the perception of that sound. The other characteristic is sound frequency, or “pitch”—the speed of vibration. Frequencies are expressed in terms of cycles per second or hertz (Hz). Examples of low frequency sounds might be characterized as a rumble or roar, while high frequency sounds are typified by sirens or screeches. Noise analysis accounts for both of these characteristics in the units used to measure sound.

**Decibel (dB).** The human ear is sensitive to an extremely wide range of sound intensity, which covers a relative scale of from 1 to 100,000,000. Representation of sound intensity using a *linear* index becomes difficult due to this wide range. As a result, the decibel, a logarithmic measure of the magnitude of sound, is typically used. Sound intensity is measured in terms of sound levels ranging from 0 dB, which is approximately the threshold of hearing, to 130 dB, which is the threshold of pain. Figure C-1 presents a comparison of the sound pressure levels of typical events.



Because of the logarithmic unit of measurement, decibels cannot be added or subtracted linearly (see Figure C-2); however, a number simple “rules” are useful.

- If two sounds of the same level are added, the sound level increases by approximately 3 dB. For example: 60 dB + 60 dB = 63 dB.
- The sum of two sounds of different levels is only slightly higher than the louder level. For example: 60 dB + 70 dB = 70.4 dB.
- Sound from a “point source,” such as an aircraft, decreases approximately 6 dB for each doubling of distance.
- Although the human ear can detect a sound as faint as 1 dB, the typical person does not perceive changes of less than approximately 3 dB.
- A 10 dB change in sound level is perceived by the average person as a doubling, or halving, of the sound’s loudness.



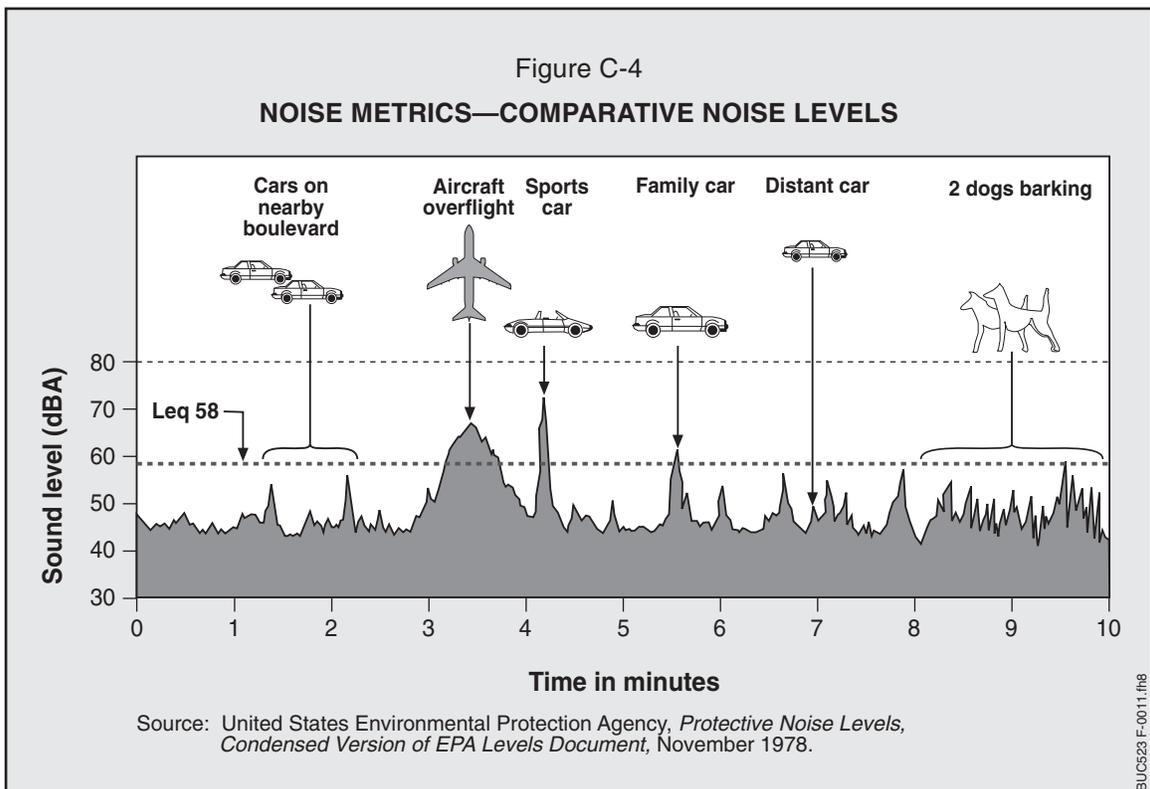
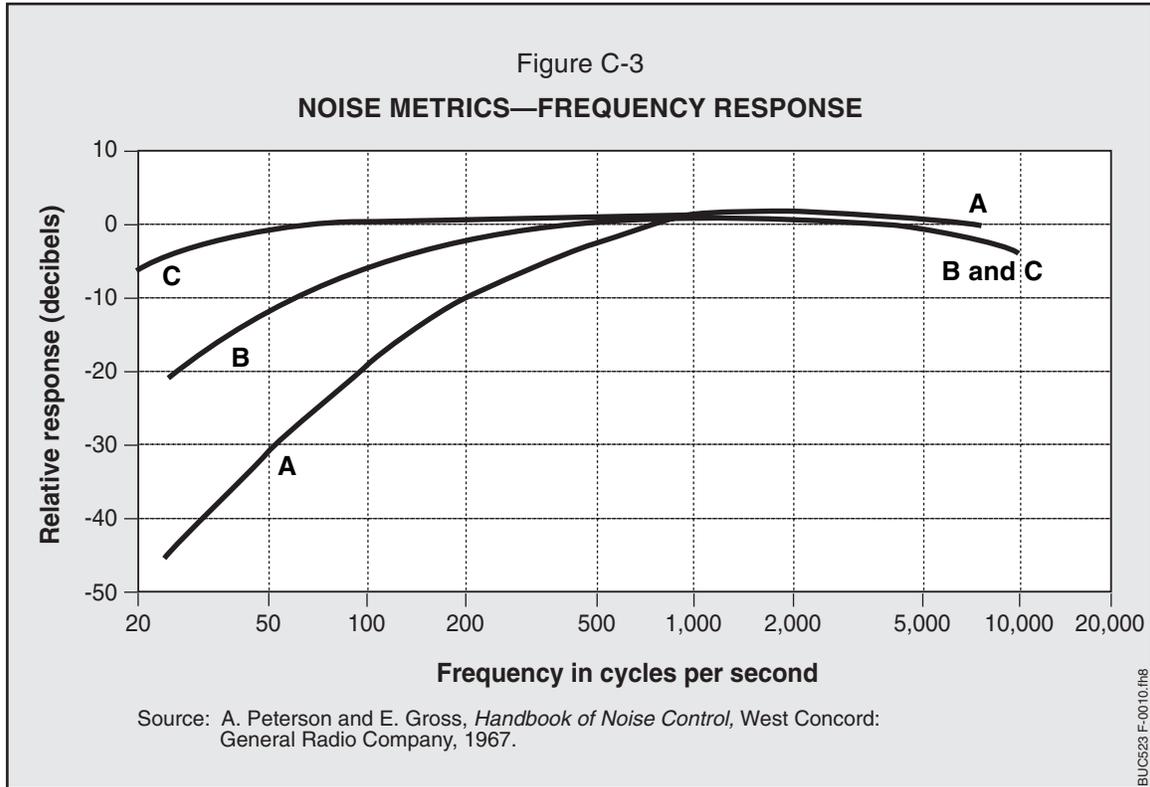
**A-Weighted Decibel.** Humans are most sensitive to frequencies near the normal range of speech communications. “A-weighting” reflects this sensitivity by emphasizing mid-range frequencies and de-emphasizing high and low frequencies (see Figure C-3). Since the A-weighted decibel (dBA) provides a better prediction of human reaction to environmental noise than the unweighted decibel, it is used as the basis for the metrics most frequently used in noise compatibility planning.\*

### Additional Noise Metrics

The measurement of sound is not a simple task. Consider typical sounds in a suburban neighborhood on a normal or “quiet” afternoon. If a short time in history of those sounds is plotted on a graph, it would look very much like Figure C-4

On Figure C-4, the background, or residential, sound level in the absence of any identifiable noise sources is approximately 45 dB. During roughly three-quarters of the time, the sound level is 50 dB or less. The highest sound level, caused by a nearby sports car is approximately 70 dB, while an aircraft generates a maximum

\*Chantlett, E. T., *Environmental Protection*, McGraw-Hill Book Co. New York, 1973.



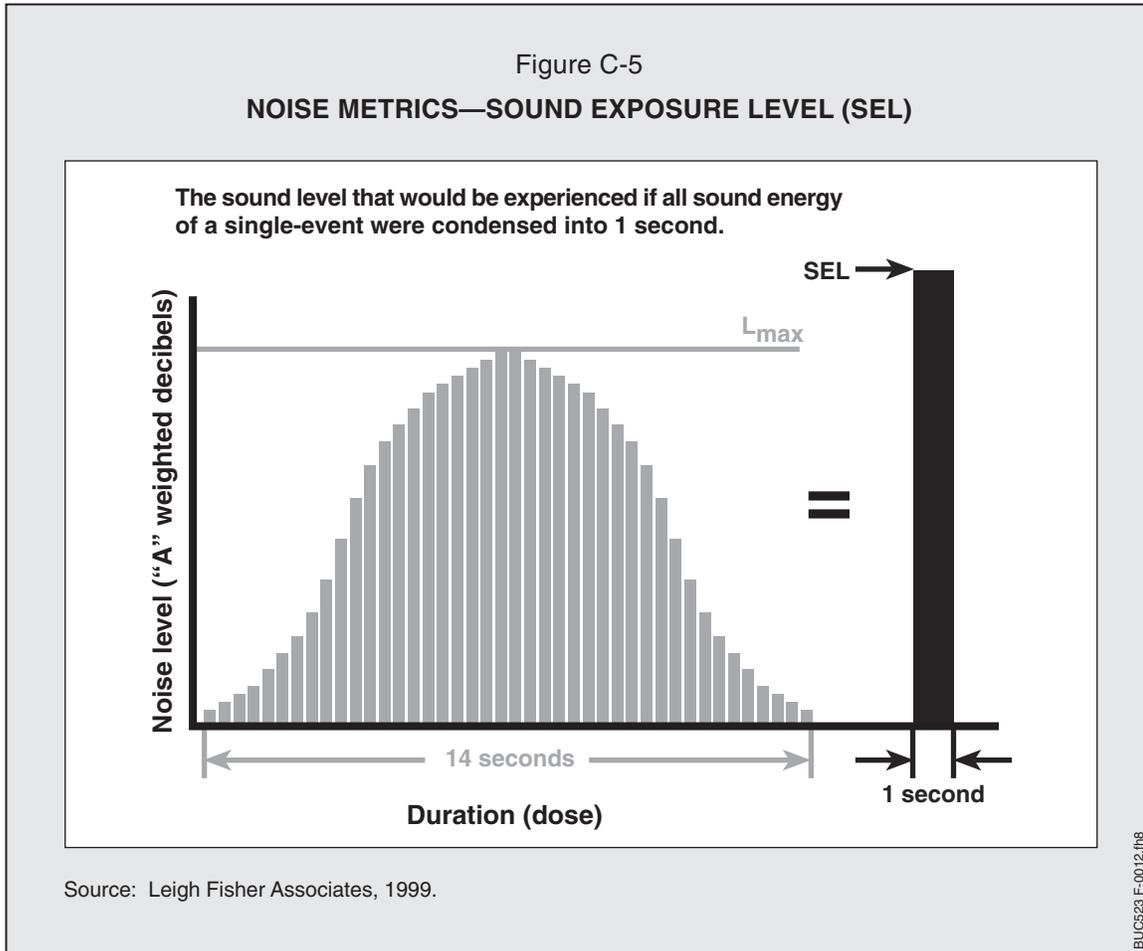
sound level of about 68 dB. The following subsections provide a discussion of how variable community noise is measured.

**Maximum Sound Level.** One way of describing noise is to measure the maximum sound level—typified by the sports car at 70 dB on Figure C-4. The maximum sound level measurement does not account for the duration of the sound. Studies have shown that human response to noise involves both the maximum level and its duration. For example, the aircraft in this case is not as loud as the sports car, but the aircraft sound lasts longer. For most people, the aircraft overflight would be more annoying than the sports car. Thus, the maximum sound level alone is not sufficient to predict reaction to environmental noise.

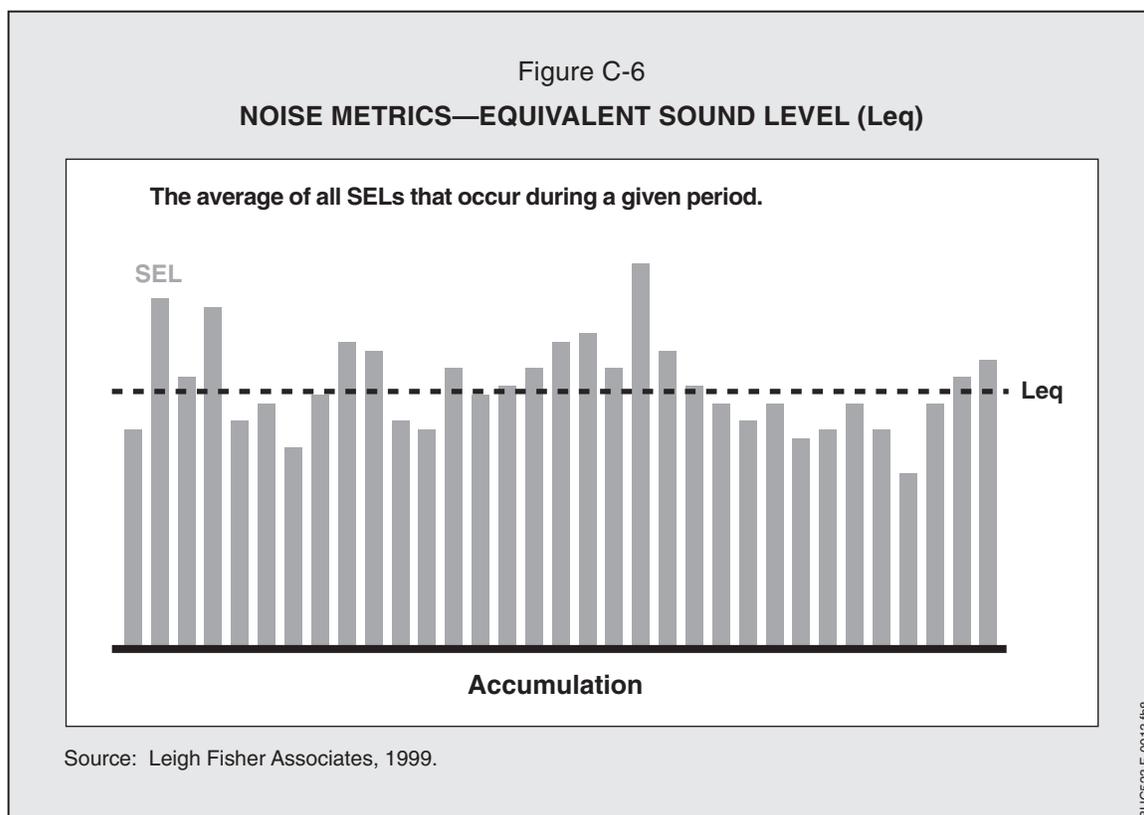
**Sound Exposure Level.** Clearly, the longer a noise lasts the more it disrupts activity and the more annoying it is likely to be. Laboratory tests indicate that the acceptability of noise decreases at a rate of roughly 3 dB per doubling of duration.\* In other words, two sounds would be judged equally acceptable if one had an intensity of 3 dB more than the other, but half the duration of the other. Accordingly, a second way to describe noise is to measure the sound exposure level (SEL), which is the total sound energy of a single sound event. By accounting for both intensity and duration, SEL allows us to compare the “annoyance” of different events. One way to understand SEL is to think of it as the sound level you would experience if all of the sound energy of a sound event occurred in one second (see Figure C-5). This normalization to a duration of one second allows the direct comparison of sounds of different duration. In the sample time history on Figure C-4, the sports car generates an SEL of about 77 dB, while the aircraft generates an SEL of about 81 dB.

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\*Galloway, William J., “Predicting Community Response to Noise from Laboratory Data,” in *Transportation Noises: A Symposium on Acceptability Criteria*, Ann Arbor Science Publishers, Ann Arbor Michigan, 1970.



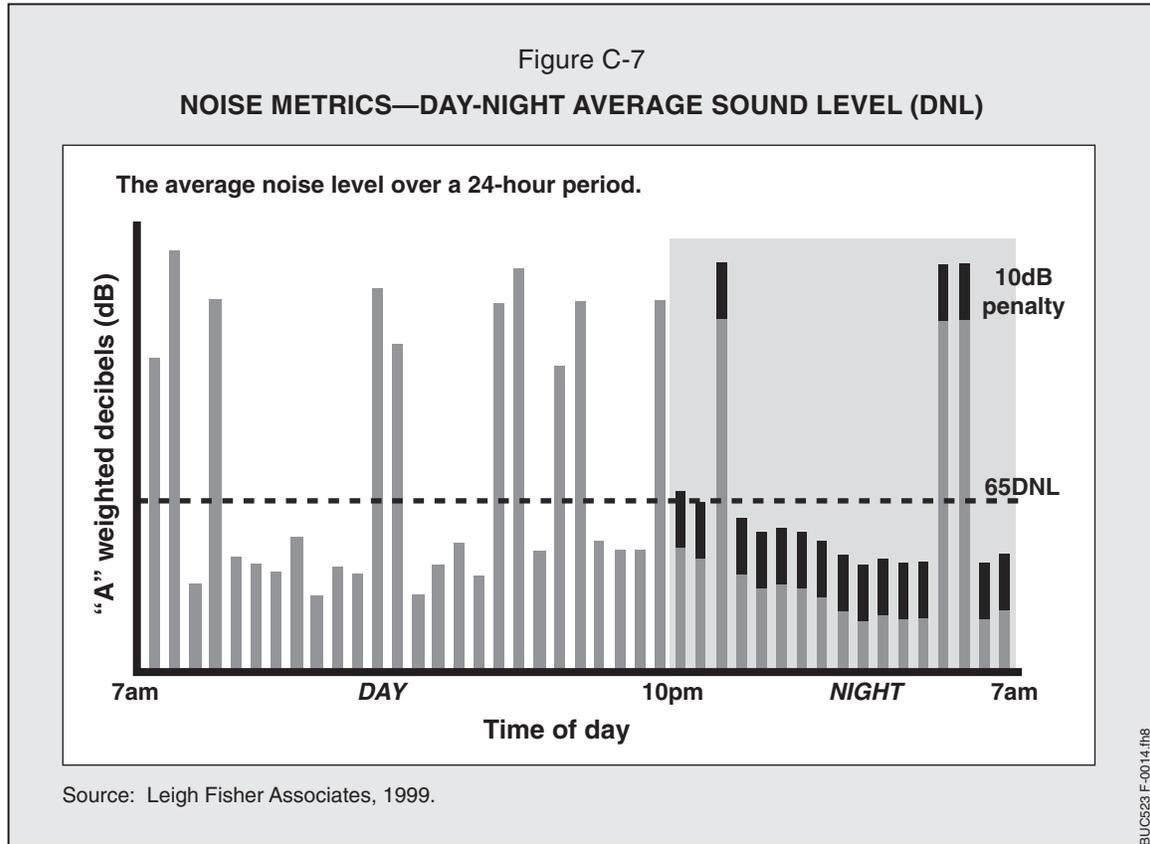
**Equivalent Sound Level.** The maximum sound level and sound exposure level measure individual events. The number of events can also be an important consideration in estimating the effect of noise. One way to describe this factor might be to count the number of events exceeding SEL 80 dBA, plus the number that exceed SEL 75 dBA, plus the number that exceed SEL 70 dBA, etc. A more efficient way to describe both the number of such events and the sound exposure level of each is the time-average of the total sound energy over a specified period (see Figure C-6), referred to as the equivalent sound level ( $L_{eq}$ ). Research indicates that community reaction to noise corresponds to the total acoustic energy that is represented by the  $L_{eq}$ . In the example shown on Figure c-6, the  $L_{eq}$  is roughly 56 dBA. This accounts for all of the sound energy during the sample period and provides a single-number descriptor.



**Day-Night Average Sound Level.** One additional factor is also important in measuring sound—the occurrence of sound events during nighttime hours. People are normally more sensitive to intrusive sound events at night, and the background sound levels are normally lower at night because of decreased human activity. Therefore, noise events during the nighttime hours are likely to be more annoying than noise events at other times. To account for these factors, the day-night average sound level (DNL) adds a 10 dB penalty to sound levels occurring during the nighttime period (10:00 p.m. and 6:59 a.m.) (see Figure C-7). In essence, DNL is the 24-hour equivalent sound level (or  $L_{eq, 24}$ ), including the 10 dB penalty. This 10 dB penalty means that one nighttime sound event is equivalent to 10 daytime events of the same level. DNL has been identified by the U.S. Environmental Protection Agency (U.S. EPA) as the principal metric for airport noise analysis.\*

DNL is expressed as an average noise level on the basis of annual aircraft operations for a calendar year. To calculate the DNL at a specific location, SELs for that particular location are determined for each aircraft operation (landing or takeoff). The SEL for each operation is then adjusted to reflect the duration of the operation

\*U.S. Environmental Protection Agency, *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety*, U.S. EPA Report No. 550/9-74-004, 1974.



and arrive at a “partial” DNL for the operation. The partial DNLs are then added logarithmically—with the appropriate penalty for those operations occurring during the nighttime hours—to determine total noise exposure levels for the average day of the year.

The logarithmic addition process described earlier also applies to DNL. For example, a DNL increase or decrease of 3 dB would require either a doubling or halving of aircraft operations (assuming the same types of aircraft and the same proportion of nighttime activity). This same change of 3 dB could also be achieved by an average change of 3 dB per aircraft operation.

DNL is used to describe the existing and predicted cumulative noise exposure for communities in airport environs in most of the United States, and to estimate the effects of airport operations on land use compatibility. DNL has been widely accepted as the best available method to describe aircraft noise exposure and is the noise descriptor required by the FAA for use in aircraft noise exposure analyses and noise compatibility planning.\*

\*Federal Aviation Administration, Federal Aviation Regulations Part 150, *Airport Noise Compatibility Planning*, Appendix A, 1984.

**Community Noise Equivalent Level.** A variant of the DNL used in California and Europe is the community noise equivalent level (CNEL). Although FAR Part 150 requires that an airport operator use DNL, the FAA permits use of the CNEL metric for those civil airports in the State of California. A given CNEL value essentially averages the sound levels at a location over a 24-hour average sound level, weighted as follows: (1) aircraft noise occurring during the evening period (7:00 p.m. to 9:59 p.m.) has a 5-dB penalty, and (2) aircraft noise occurring during the nighttime period (10:00 p.m. to 6:59 a.m.) has a 10-dB penalty.\*\* The 5- and 10-dB penalties represent the added intrusiveness of sounds that occur during sleeping hours, both because of the increased sensitivity to noise during sleep, and because ambient sound levels during evening and nighttime hours are typically about 5 and 10 dB lower than during daytime hours.

## **INTEGRATED NOISE MODEL**

The FAA's Integrated Noise Model (INM) is a computer model used to develop aircraft noise exposure maps and is the primary means for calculating the level of aircraft noise at and around airports. The INM uses a database of aircraft noise characteristics to predict CNEL or DNL based on user input on the types and number of aircraft operations, annual average airport operating conditions, average aircraft performance, and aircraft flight patterns. Consistent with the CNEL metric, the primary use of the INM is to produce estimates of annual average noise conditions in an airport environs.

### **INM Database**

The INM aircraft database includes information for commercial, general aviation, and military aircraft powered by turbojet, turbofan, or propeller-driven engines. For each aircraft in the database, the following information is provided: (1) a set of departure profiles for each applicable trip length, (2) a set of approach parameters, and (3) SEL versus distance curves for several thrust settings. As described above, SEL is essentially an A-weighted sound level corrected for time-duration effects. Thus, SEL represents the total noise exposure for each individual aircraft event.

### **Noise Contours**

The noise exposure maps derived from the INM consist of noise contours, or lines of equal noise exposure, expressed in terms of CNEL or DNL. These noise contours are analogous to topographic contour maps in that a set of concentric contours representing successively lower levels of CNEL that extend outward from the airport's runways. According to FAA Order 5050.4A, CNEL 75+ is considered to

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\*\*California Airport Noise Standards, California Code of Regulations, Title 21, § 5000 *et seq.* 1990.

represent “severe” noise exposure, while CNEL 65 represents the threshold of “significant” noise exposure.

### **Limitations of Noise Modeling**

The validity and accuracy of noise modeling depend on the basic information used in the calculations. For future airport activities, the reliability of calculations is affected by a number of uncertainties:

- Aviation activity levels—i.e., the forecast number of aircraft operations, the types of aircraft serving the airport, the times of operation (daytime, evening, and nighttime), and aircraft flight tracks—are estimates. The achievement of the estimated levels of activity cannot be assured.
- Aircraft acoustical and performance characteristics are also estimates. When new aircraft designs are involved, aircraft noise data and flight characteristics must be estimated.
- The CNEL and related metrics represent typical human response to aircraft noise. Because people vary in their responses to noise, the CNEL scale can show only an average response to aircraft noise that might be expected from a community, but cannot predict an individual’s reaction.
- Single flight tracks are used, as required, in computer modeling to represent a wider band of actual flight tracks.

The above considerations result in more reliable noise contours for existing conditions than those projected for future conditions. Also, noise contours are more reliable closer to the airport. As the distance from the airport increases, the potential for aircraft to deviate significantly from the assumed profiles and flight tracks also increases. Accordingly, noise exposure mapping is best used for comparative purposes rather than for providing absolute values. That is, calculations provide valid comparisons between different projected conditions so long as consistent assumptions are used for all calculations. Thus, sets of CNEL calculations can show (1) which of a series of potential situations would be better, and generally how much better, from the standpoint of noise exposure, or (2) anticipated changes in aircraft noise exposure over time.

### **ASSUMPTIONS USED FOR THIS MASTER PLAN**

This section presents an overview of the assumptions and basic data used in the noise analysis conducted for the Byron Airport Master Plan. An aircraft noise analysis depends largely on aircraft operations data, which include annual aircraft activity levels, fleet mix, stage length data, and operations by time of day. A noise analysis is also dependent on airport operational assumptions, which include

information on annual average runway use and flight tracks. Each of these factors is ultimately used as input to the INM to generate noise exposure maps, as discussed in the following paragraphs.

Accurate aircraft operations data are critical to the development of noise contours. Average daily aircraft operations are derived by dividing total annual aircraft operations by 365. Annual and average daily aircraft operations at Byron Airport are provided in Table C-1. As shown, annual aircraft operations are anticipated to increase from 40,000 in 2003 to 64,200 in 2023.

Table C-1  
**PROJECTED ANNUAL AND AVERAGE DAY AIRCRAFT OPERATIONS**  
Byron Airport

	Annual		Average annual day	
	2003	2023*	2003	2023
Single engine-fixed	19,200	29,700	52.6	81.4
Single engine-variable	8,800	13,500	24.1	37.0
Multi engine piston	1,200	2,100	3.3	5.8
Turboprop	4,400	10,100	12.1	27.7
Business jet	400	2,800	1.1	7.6
Historic/military jet	400	400	1.1	1.1
Glider tow plane	5,600	5,600	15.3	15.3
Helicopter	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
Total operations	40,000	64,200	109.6	175.9

\*High Case forecast

Source: Leigh Fisher Associates, 2004.

**Stage length** refers to the average distance an aircraft travels nonstop. Aircraft noise characteristics can vary depending on the takeoff weight of the aircraft. Thus, departure operations in the INM are divided into seven stage length categories that correspond to approximate nonstop flight distances. Each stage length associates the aircraft operation with a takeoff weight that represents a typical fuel requirement. In developing the noise contours for the Byron Airport it was assumed that all aircraft were flying stage lengths of up to but not exceeding 500 miles.

Because 5 and 10 dBA penalties are added for evening and night operations, CNEL contours can vary depending on the **time of day** an operation occurs. Day, evening, and night split assumptions were based on information provided by Byron Airport personnel and the general aviation community and assumed to remain constant in the future for all aircraft categories. It was assumed that the aircraft operations split homogeneously between daytime, evening and nighttime according as follows:

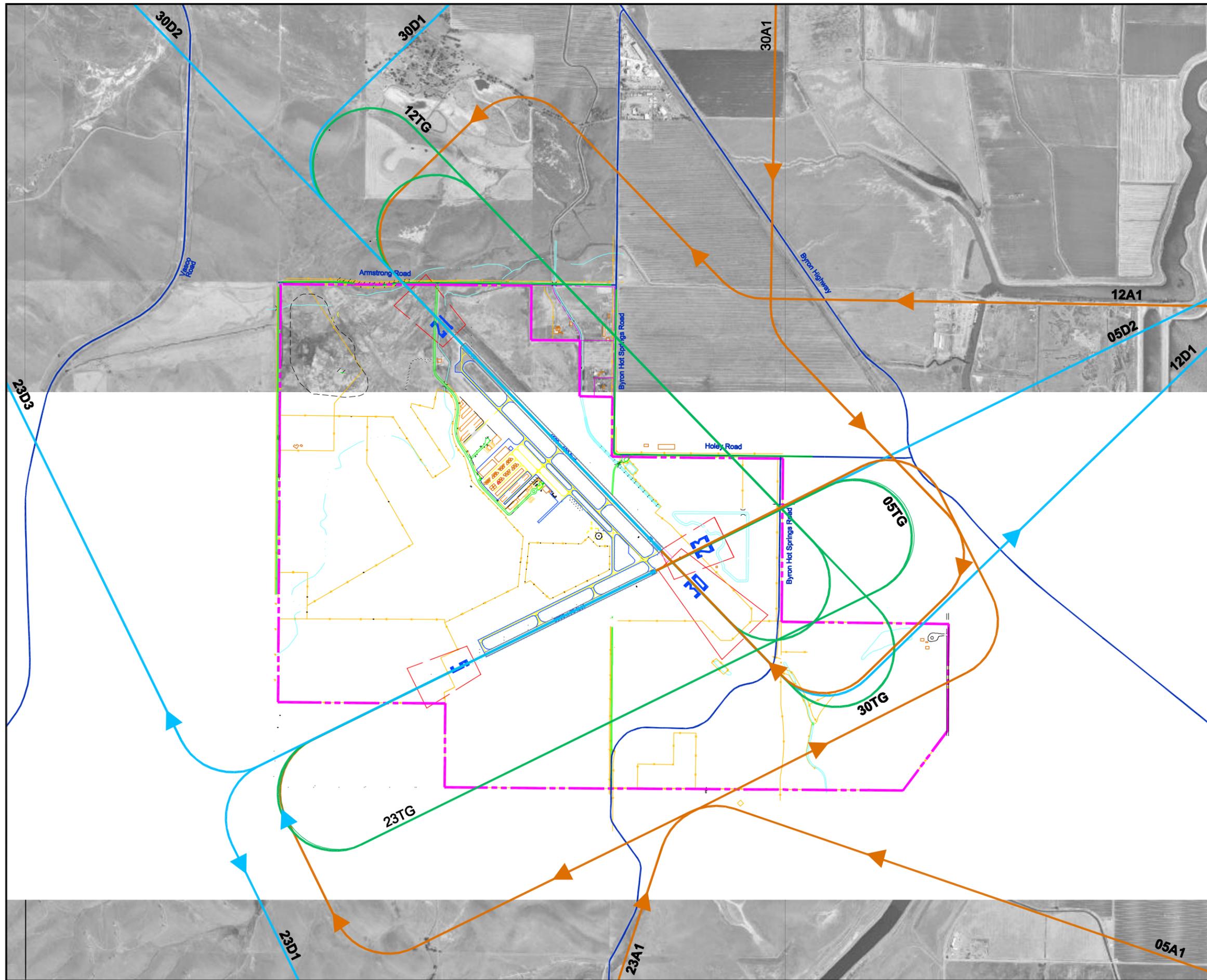
daytime—94%, evening—5%, and nighttime—1%, except for the historic military aircraft. It was assumed that these aircraft are unlikely to fly at night; accordingly a 95% daytime—5% evening split was assumed for historic military jets.

The existing and assumed future use of Byron’s runways is important in determining where aircraft are flying and what flight tracks pilots are following. The **runway uses** assumed for both 2003 and 2023 are shown in Table C-2.

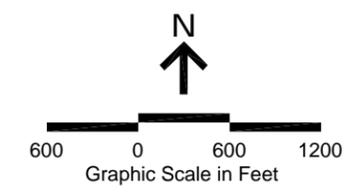
	Takeoffs	Landings
Piston (single-engine)		
Runway 5	0.0%	3.0%
Runway 23	27.0	50.0
Runway 12	8.0	5.0
Runway 30	65.0	42.0
Piston (twin-engine), turboprops		
Runway 5	0.5%	7.0%
Runway 23	21.0	25.0
Runway 12	9.0	2.5
Runway 30	69.5	65.5
Business jets, historic military jets		
Runway 5	0.5%	1.0%
Runway 23	15.0	20.0
Runway 12	9.5	10.0
Runway 30	75.0	69.0

Source: Leigh Fisher Associates, 2004.

A flight track is a projection on the ground of an aircraft’s path in the sky. Because of meteorological conditions, aircraft types, destinations, and pilot judgment, no two flight tracks are the same. To obtain a clear indication of where aircraft are flying, **generalized flight tracks** were developed based on actual observations and information provided by Airport personnel and the general aviation community. Figure C-8 depicts typical generalized departure, arrival, and touch-and-go flight tracks developed to model noise at Byron.



- LEGEND**
- - - Airport boundary
  - Off-airport road
  - On-airport road
- FLIGHT TRACKS**
- Departure tracks
  - Arrival tracks
  - Touch and go tracks



**Figure C-8**  
**FLIGHT TRACKS**  
 Byron Airport  
 November 2004

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