Noise Analysis

This report is presented in five major sections including this introduction. Section 2 presents background information on sound, noise, and how noise affects people. Section 3 describes the methodology used for this study. Section 4 describes the existing noise setting in the environs of King County International Airport. Section 5 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 King County International 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.

For example, a sound level of 70 dB has 10 times as much acoustic energy as a level of 60 dB while a sound level of 80 has 100 times as much acoustic energy as 60 dB. In terms of human response to noise, the perception is very different. A sound 10 dB higher than another is usually judged to be twice as loud; and 20 dBA higher four times as loud; and so forth.

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

Loudness Level. This scale has been devised to approximate the human subjective assessment to the "loudness" of a sound. Loudness is the subjective judgment of an individual as to how loud or quiet a particular sound is perceived. The human ear is not equally sensitive to all frequencies with some frequencies judged to be louder for a given signal than others. This sensitivity difference also varies for different sound pressure levels.

This data is obtained through group laboratory studies of human response to noise. Generally a pure tone signal of 1000 hertz is played and then after an elapsed interval a second tone of a different frequency is played. The listener then adjusts the signal until the two tones are judged to be the same.

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

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 C2**.

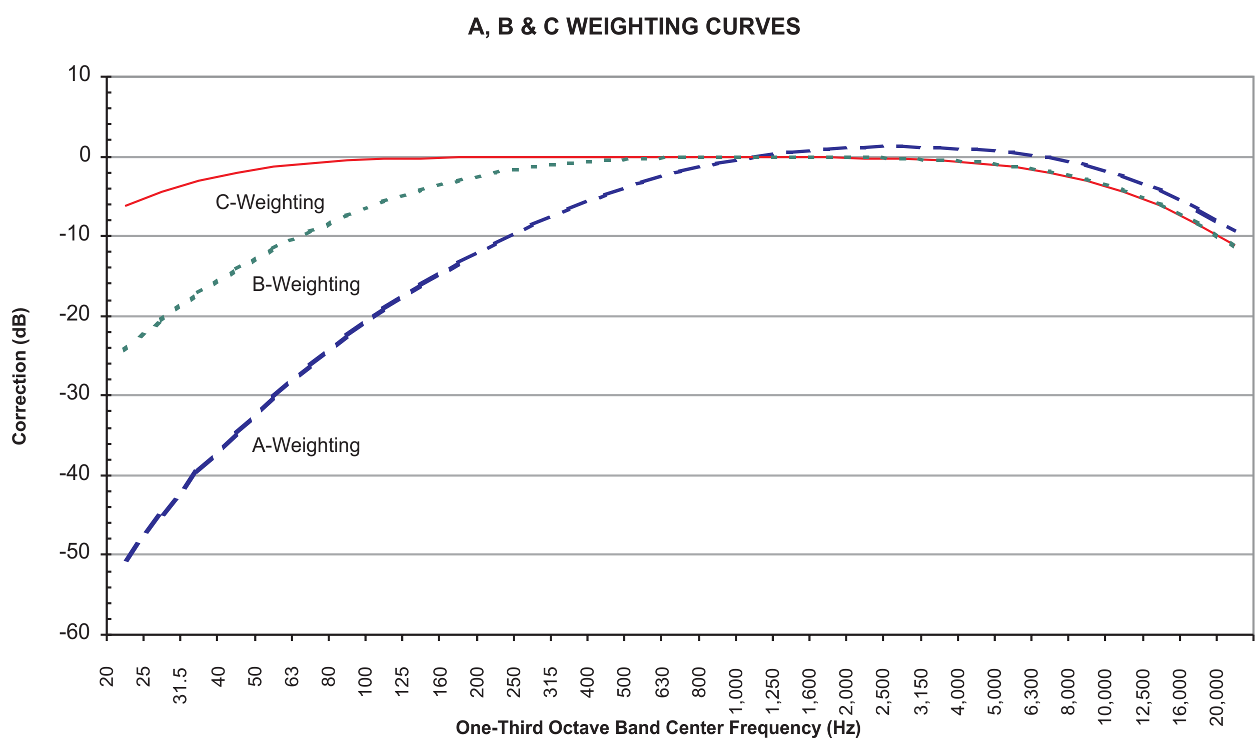


Figure C1 ***Frequency Weighted Contours***

dB(A)	OVER-ALL LEVEL Sound Pressure Level Approx. 0.0002 Microbar	COMMUNITY (Outdoor)	HOME or INDUSTRY	LOUDNESS Human Judgement of Different Sound Levels
130	UNCOMFORTABLY	Military Jet Aircraft Take-Off with Afterburner from Aircraft Carrier @ 50 ft. (130)	Oxygen Torch (121)	120 dB(A) 32 Times as Loud
120 110	LOUD	Turbo-Fan Aircraft @ Take-Off Power @ 200 ft. (90)	Riveting Machine (110) Rock and Roll Band (108-114)	110 dB(A) 16 Times as Loud
100	VERY	Boeing 707 @ 1000 ft. (103) DC-8 @ 6080 ft. (106) Bell J2A Helicopter @ 100 ft. (100)		100 dB(A) 8 Times as Loud
90	LOUD	Power Mower (96) Boeing 737. DC-9 @ 6080 ft. (97) Motorcycle @ 25 ft. (90)	Newspaper Press (97)	90 dB(A) 4 Times as Loud
80		Car Wash @ 20 ft. (89) Prop. Airplane Flyover @ 1000 ft. (88) Diesel Truck, 40 mph @ 50 ft. (84)	Food Blender (88) Milling Machine (85) Garbage Disposal (80)	80 dB(A) 2 Times as Loud
70	MODERATELY LOUD	High Urban Ambient Sound (80) Passenger Car, 65 mph @ 25 ft. (77) Freeway @ 50 ft., 10:00am (76)	Living Room Music (76) TV-Audio, Vacumn Cleaner	70 dB(A)
60		Air Conditioning Unit @ 100 ft. (60)	Cash Register @ 10 ft. (65-70) Electric Typewriter @ 10 ft. (64) Conversation (60)	60 dB(A) 1/2 Times as Loud
50	QUIET	Large Transformers @ 100 ft. (50)		50 dB(A) 1/4 Times as Loud
40		Bird Calls (44) Low Urban Ambient Sound (40)		40 dB(A) 1/8 Times as Loud
	JUST AUDIBLE	(dB(A) Scale Interrupted)		
10	THRESHOLD OF HEARING			

Figure C2 Examples of Various Sound Environments

SOURCE: Reproduced from Melville C. Branch and R. Dale Beland, "Outdoor Noise in the Metropolitan Environment". Published by the City of Los Angeles. 1970. p2.

Some interest has developed to utilize a different noise curve other than A-weighting for lower frequency noise sources. For example, the C-weighted curve is used for the analysis of the noise impacts from artillery noise, which is dominated by low frequency. Noise from departure ground roll is another source of noise that is a greater low frequency component.

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

As with loudness curves, noisiness curves have been developed from laboratory psychoacoustic surveys of individuals. However, in noisiness surveys, individuals are asked to judge in a laboratory setting when two sounds are equally noisy or disturbing if heard regularly in ones own environment. These surveys are more complex and therefore subject to greater variability. Aircraft certification data is based upon these types of noisiness scales.

Propagation of Noise. Outdoors 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 C3**. 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.

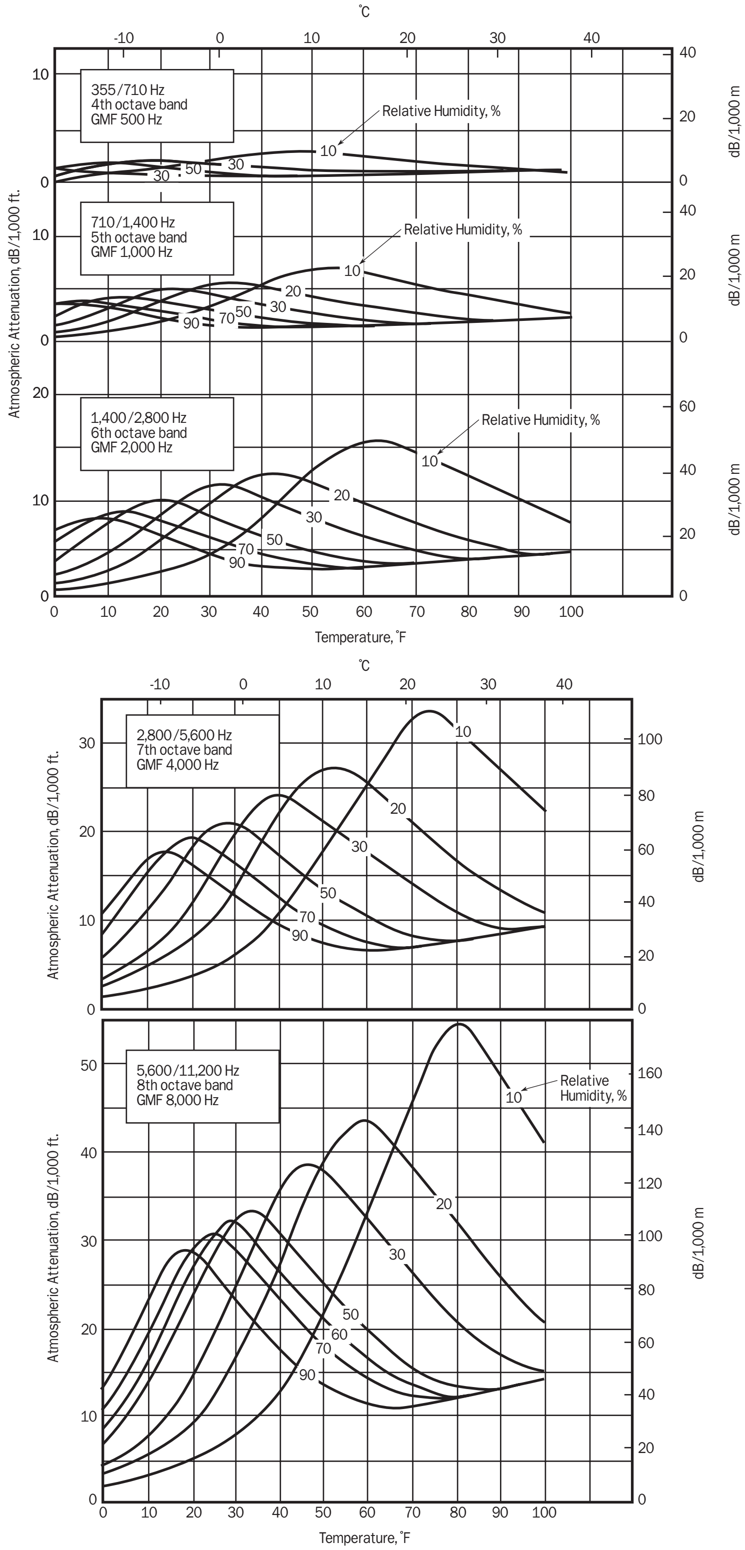


Figure C3 ***Atmospheric Attenuation Graphs***

SOURCE: Beranek, 1981

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 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
King County International 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 C4** 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 C5** as presented in the FICON curve from 1992.

  It is important to note that recent research from England [4] and the USAF [5] 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 studies 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. The results of that research is summarized in the 1997 FICAN curve of **Figure C5**. It is therefore likely that the data shown in the top of **Figure C5** overestimates the sleep disturbance at a given noise level and is more reflected by the field data presented in the bottom portion of the figure. The USAF study conculed that the preelance of awakening associated with noise events of an indoor SEL on the order of 70 dBA is 1.6%. An increase in prevelance of awakening of 1.6% is predicted for each 10 dB increase in the SEL.

- *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.

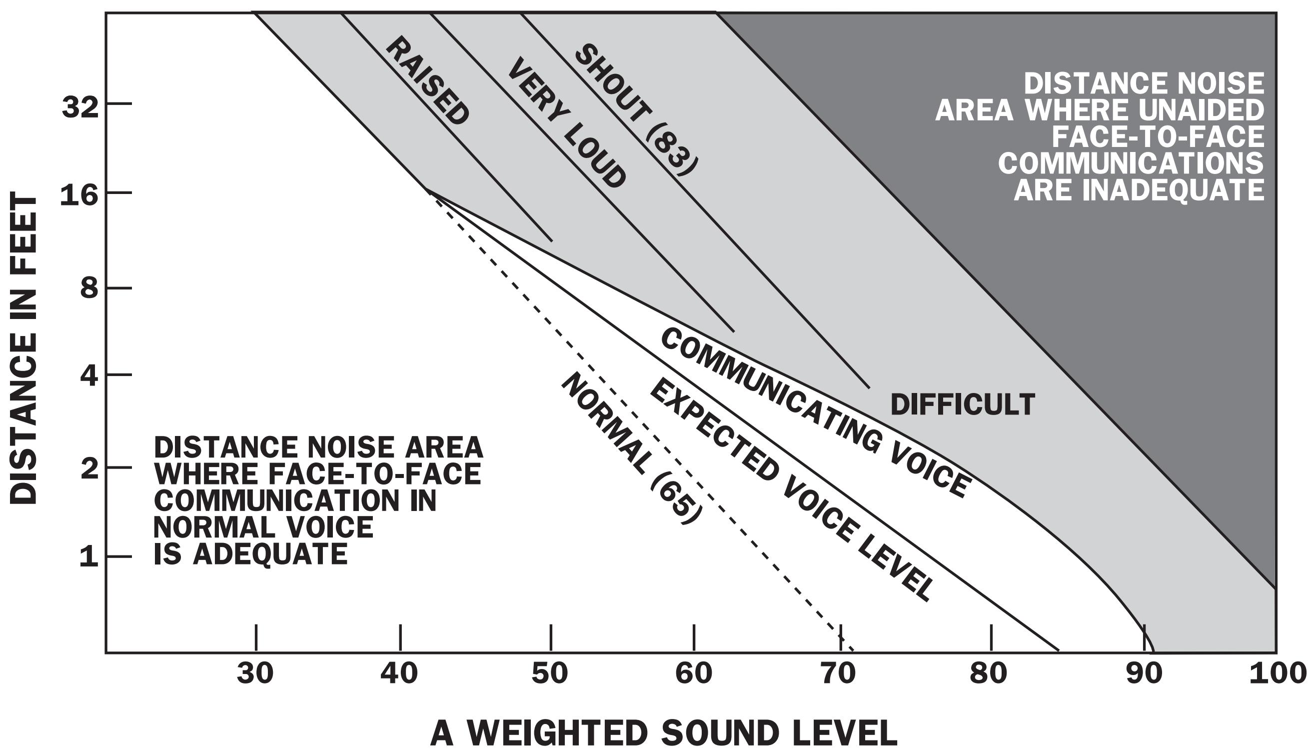


Figure C4 Quality of Speech Communication in Relation to Distance Between the Talker and the Listener

SOURCE: Noise Effects Handbook, EPA

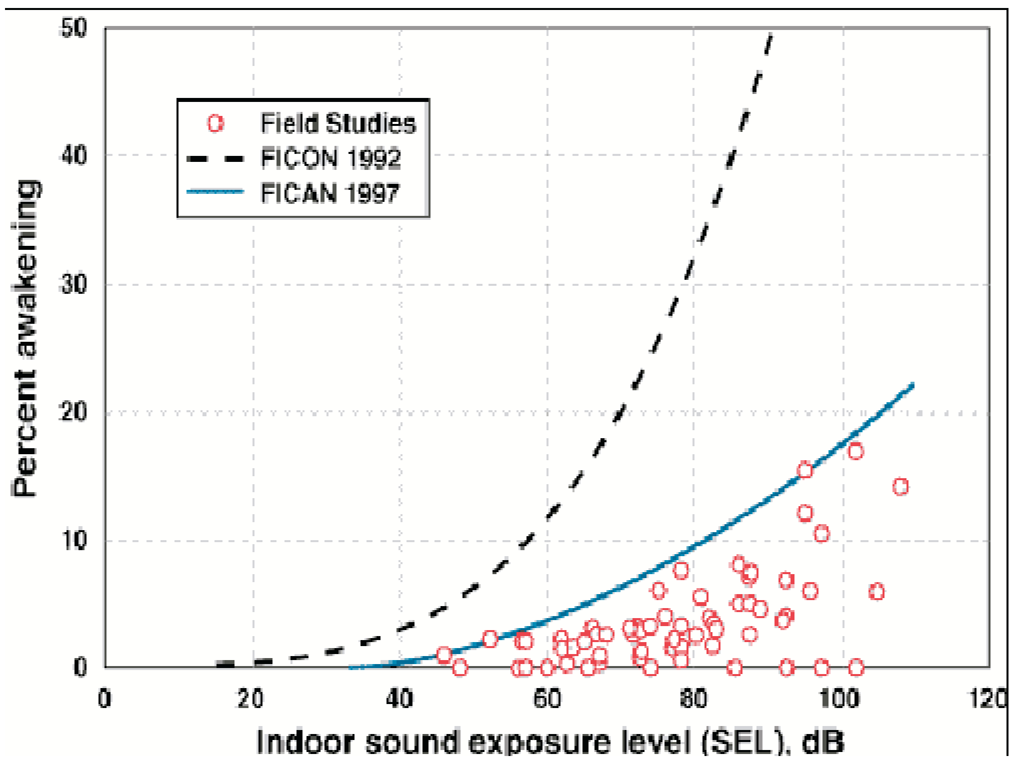


Figure C5 ***Probability of Awakening for Different Indoor Sound Exposure Levels***

- 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 C6**. 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 C6** 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.

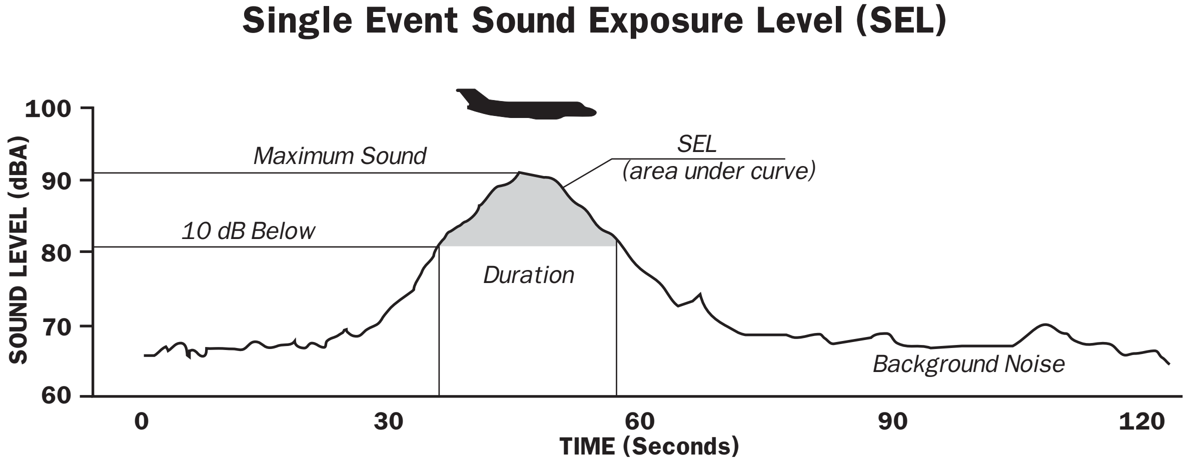
  This is graphically illustrated in the middle graph of **Figure C6**. LEQ can be measured for any time period, but is typically measured for 15 minutes, 1 hour or 24-hours. Leq for one hour is called Hourly Noise Level (HNL) and is used to develop the Day Night Noise Level (DNL) values for aircraft operations.

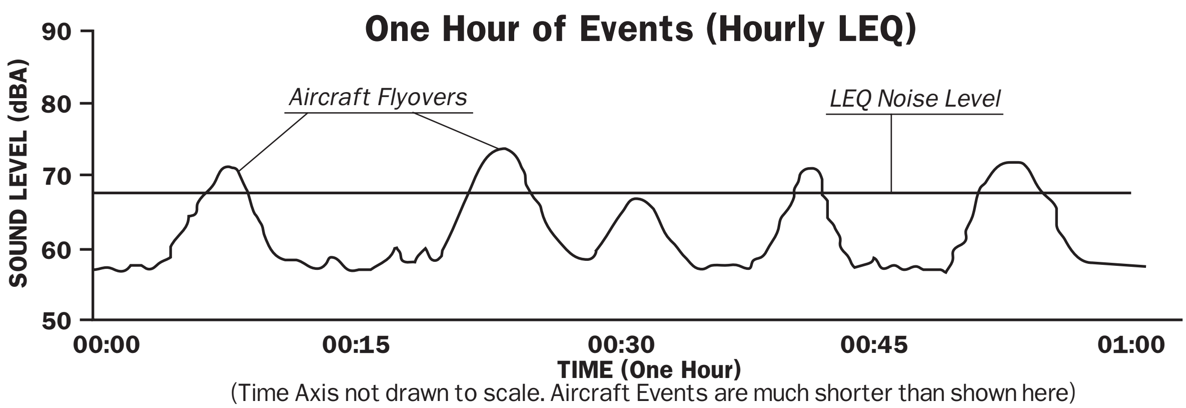
- Cumulative noise metrics have been developed to assess community response to noise. They are useful because these scales attempt to include the loudness of the noise, the duration of the noise, the total number of noise events and the time of day these events occur into one single number rating scale. 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 DNL, is graphically illustrated in the bottom of **Figure C6**. Examples of various noise environments in terms of DNL are presented in **Figure C7**.

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.





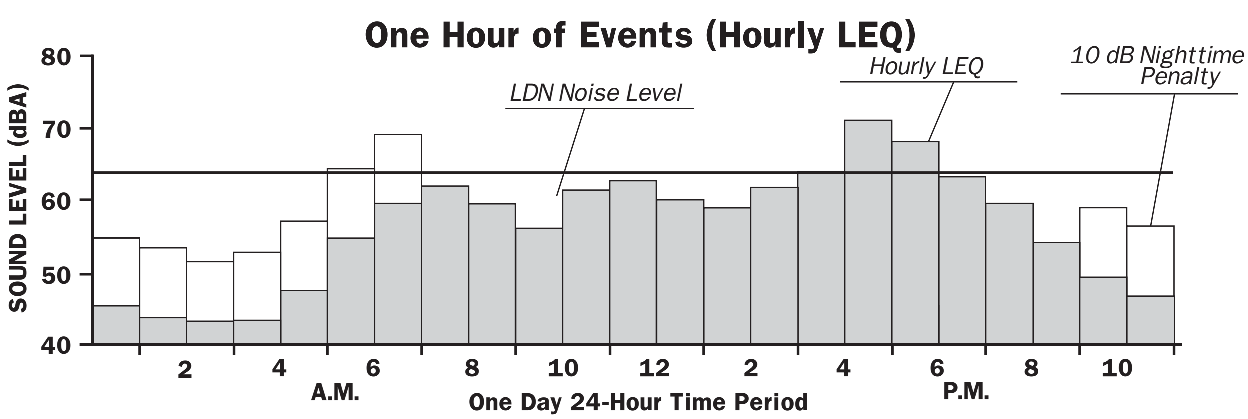


Figure C6 **SEL, LEQ, and DNL Illustrations**

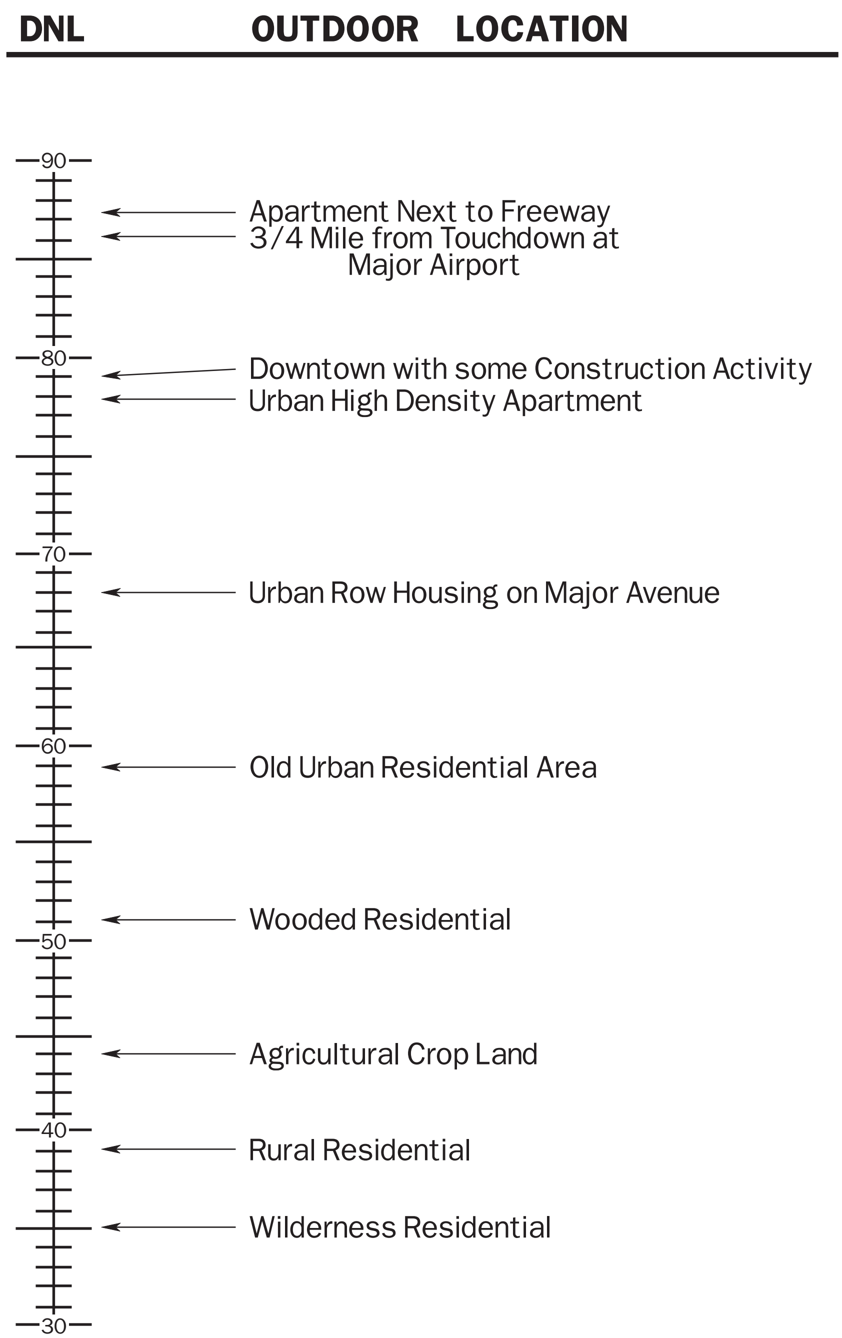


Figure C7 ***Typical Outdoor Noise Environments***

SOURCE: EPA Levels Document, 1974

- *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 C8** 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 (CNEL in California) 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

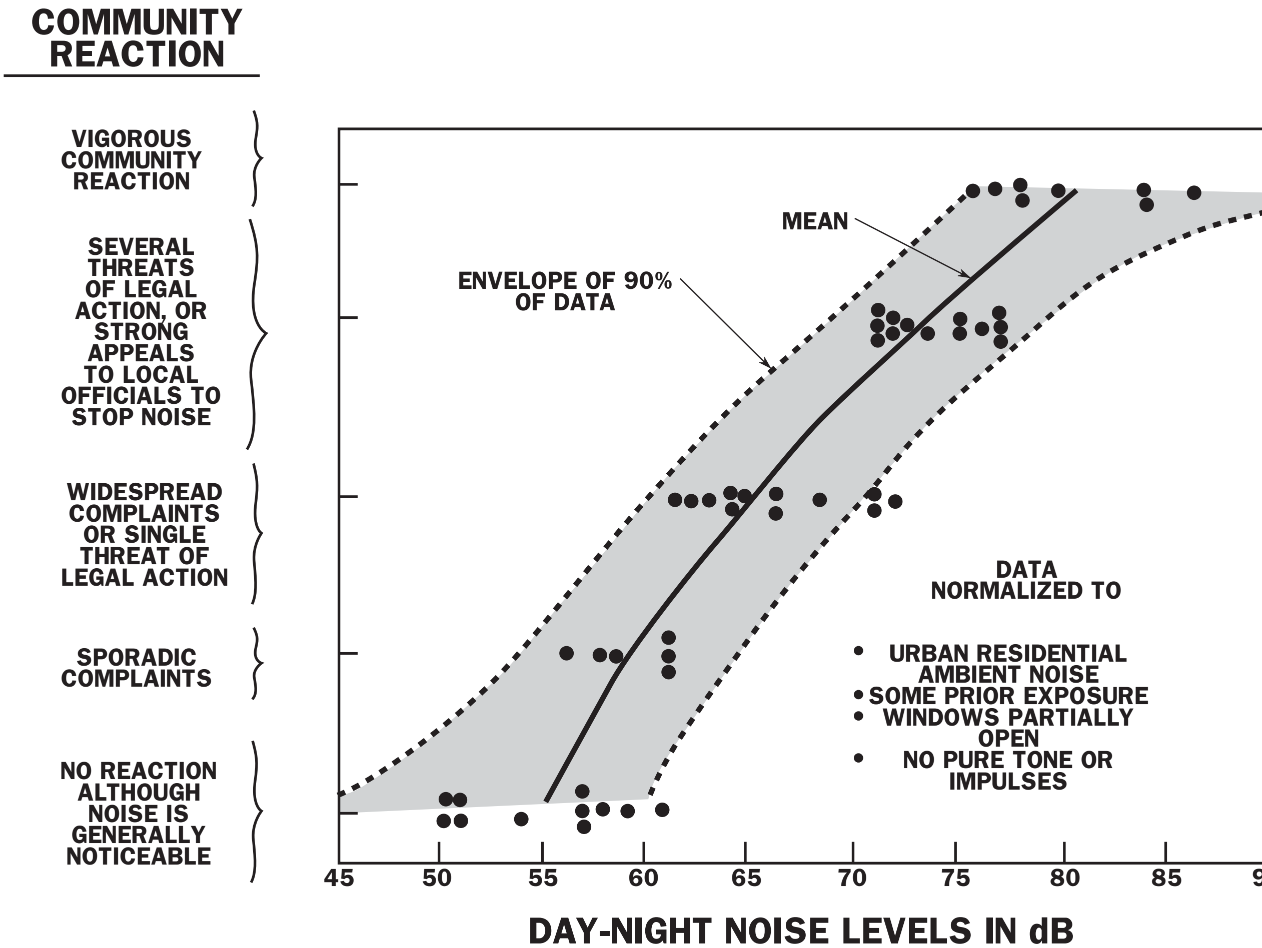


Figure C8 Community Reaction to Intrusive Noises

SOURCE: EPA Levels Document, 1974

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 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 C9**. 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 Orders 5050.A and Directive 1050.D for Environmental Analysis of Aircraft Noise Around Airports.

The FAA has developed guidelines (Order 5050.4A) 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. The FAA only considers noise impacts that occur at the 65 dB DNL or greater. No analysis is required beyond the 65 dB DNL.

Land Use	Yearly Day-Night Noise Level (DNL) in decibels					
	Below 65	65-70	70-75	75-80	80-85	Over 85
Residential						
Residential, other than mobile homes and transient lodgings	*Y*	*N(1)*	*N(1)*	*N*	*N*	*N*
Mobile home parks	*Y*	*N*	*N*	*N*	*N*	*N*
Transient lodgings	*Y*	*N(1)*	*N(1)*	*N(1)*	*N*	*N*
Public Use						
Schools	*Y*	*N(1)1*	*N(1)*	*N*	*N*	*N*
Hospitals and nursing homes	*Y*	*25*	*30*	*N*	*N*	*N*
Churches, auditoriums and concert halls	*Y*	*25*	*30*	*N*	*N*	*N*
Governmental services	Y	Y	25	30	N	N
Transportation	Y	Y	Y(2)	Y(3)	Y(4)	Y(4)
Parking	Y	Y	Y(2)	Y(3)	Y(4)	N
Commercial Use						
Offices, business and professional	Y	Y	25	30	N	N
Wholesale and retail-building materials, hardware and farm equipment	Y	Y	Y(2)	Y(3)	Y(4)	N
Retail trade-general	Y	Y	25	30	N	N
Utilities	Y	Y	Y(2)	Y(3)	Y(4)	N
Communication	Y	Y	25	30	N	N
Manufacturing and Production						
Manufacturing, general	Y	Y	Y(2)	Y(3)	Y(4)	N
Photographic and optical	Y	Y	25	30	N	N
Agriculture (except livestock) and forestry	Y	Y(6)	Y(7)	Y(8)	Y(8)	Y(8)
Livestock farming and breeding	Y	Y(6)	Y(7)	N	N	N
Mining and fishing resource production and extraction	Y	Y	Y	Y	Y	Y
Recreational						
Outdoor sports arenas and spectator sports	Y	Y(5)	Y(5)	N	N	N
Outdoor music shells, amphitheaters	Y	N	N	N	N	N
Nature exhibits and zoos	Y	Y	N	N	N	N
Amusements, parks, resorts and camps	Y	Y	Y	N	N	N
Golf courses, riding stables and water recreation	Y	Y	25	30	N	N

Numbers in parentheses refer to notes.

* The designations contained in this table do not constitute a Federal determination that any use of land covered by the program is acceptable or unacceptable under Federal, State or local law. The responsibility for determining the acceptable and permissible land uses and the relationship between specific properties and specific noise contours rests with the local authorities. FAA determinations under Part 150 are not intended to substitute federally determined land uses for those determined to be appropriate by local authorities in response to locally determined needs and values in achieving noise compatible land uses.

Key to Table 1

SLUCM — Standard Land Use Coding Manual.
Y(Yes) — Land Use and related structures compatible without restrictions.
N(No) — Land Use and related structures are not compatible and should be prohibited.
NLR — Noise Level Reduction (outdoor to indoor) to be achieved through incorporation of noise attenuation into the design and construction of the structure.
25, 30 or 35 — Land Use and related structures generally compatible; measures to achieve NLR of 25, 30 or 35 dB must be incorporated into design and construction of structure.

Notes

(1) Where the community determines that residential or school uses must be allowed, measures to achieve outdoor to indoor Noise Level Reduction (NLR) of at least 25 dB to 30 dB should be incorporated into building codes and be considered in individual approvals. Normal residential construction can be expected to provide a NLR of 20 dB, thus, the reduction requirements are often stated as 5, 10 or 15 dB over standard construction and normally assume mechanical ventilation and closed windows year round. However, the use of NLR criteria will not eliminate outdoor noise problems.

(2) Measures to achieve NLR of 25 dB must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

(3) Measures to achieve NLR of 30 dB must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

(4) Measures to achieve NLR of 35 dB must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

(5) Land use compatible provided that special sound reinforcement systems are installed.

(6) Residential buildings require an NLR of 25.

(7) Residential buildings require an NLR of 30.

(8) Residential buildings not permitted.

Figure C9 ***FAR Part 150 Land Use Compatibility Matrix***

SOURCE: FAR Part 150

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 do not require approval by the FAA.

Stage 3 restrictions are especially difficult to implement. A Stage 3 restriction involves considerable additional analysis, justification, evaluation and financial discussion. In addition, a Stage 3 restriction must result in a decrease in noise exposure of the 65 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 King County International 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 King County International 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 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 C10**. Each of the sites are also described in **Table C2**. The measurement sites are divided into two classes: semi-permanent sites, and temporary sites. The blue dots in **Figure C10** presents the semi-permanent locations that were used for continuous measurement of the aircraft noise. The red dots in **Figure C10** presents the temporary locations that were used for short-term spot measurement and ambient noise measurements.

Airport Noise Monitoring System. KCIA also has a permanent noise monitoring system. The system includes four permanent stations and portable noise monitors that have been located at various positions around the airport. These noise-monitoring locations from the airport's permanent system are presented in **Figure C11**. The airport noise monitor system also collects ARTS radar flight track information this data was obtained from the airport's system for the time period of the

Measurement Procedures. Noise measurements were conducted at various sites over several days for each site between November 16th, 1999 and December 1st, 1999. The equipment was checked and calibrated on a regular basis.

Aircraft identification was determined from on-site field observations by the acoustical engineer and ARTS flight track radar data. This data identified included the time of the operation, the type of aircraft, and the runway and flight track used.

Table C2
NOISE MEASUREMENT LOCATIONS
King County International Airport FAR Part 150 Study

Sites	Address	Neighborhood
Semi-Permanent Sites		
1	1515 28th Ave. W	Magnolia
2	4117 SW Hill St.	West Seattle
3	37th Ave. W and W Smith St.	Magnolia
4	3303 S. 132	Tukwila
5	12646 60th Ave. S	Skyway
6	3903 S. Burns St.	Seattle
Temporary Sites		
7	S. Eddy and Flora	Georgetown
8	Campbell Hill Elementary School	Skyway
9	56th Ave S and S 133rd St.	Foster

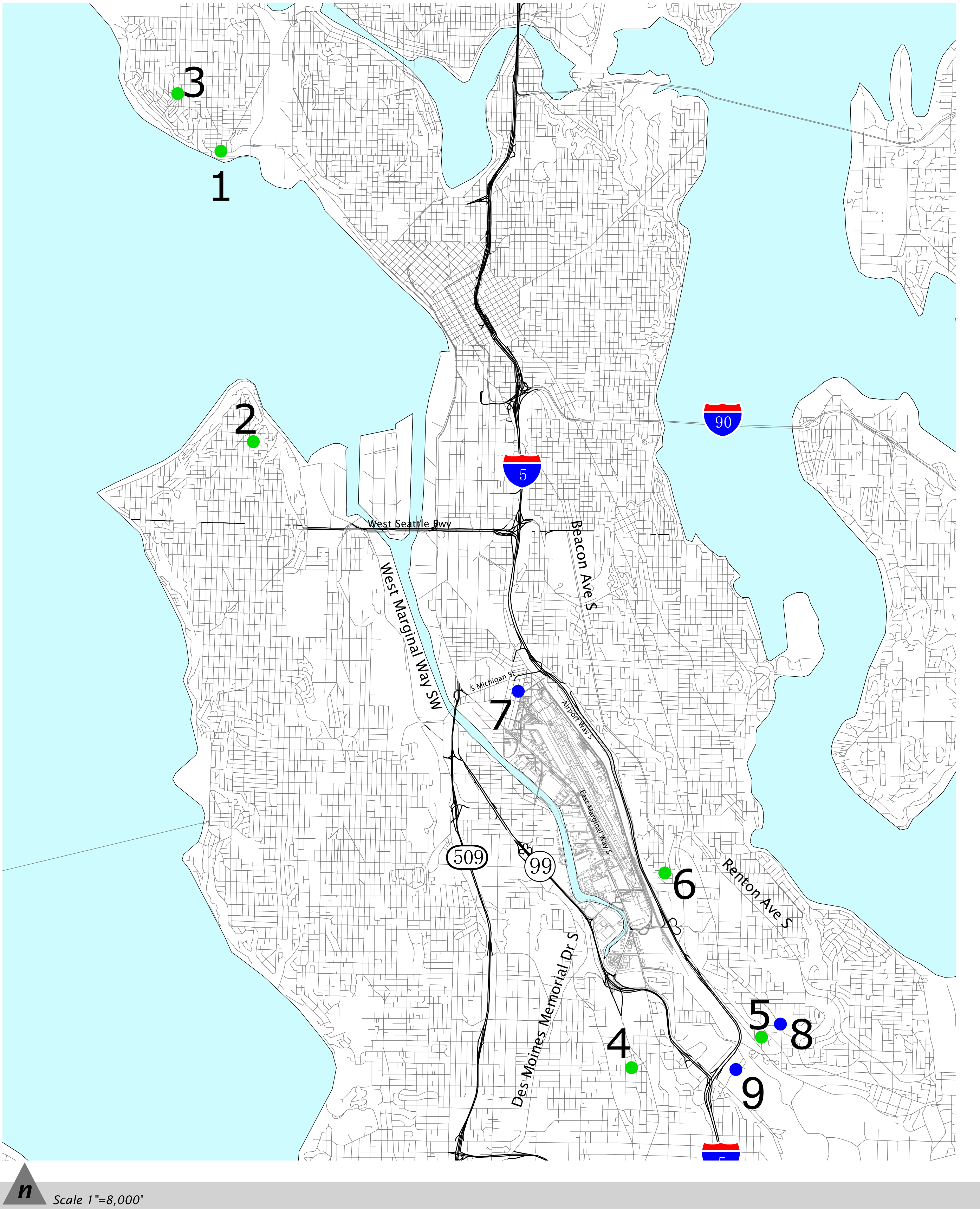
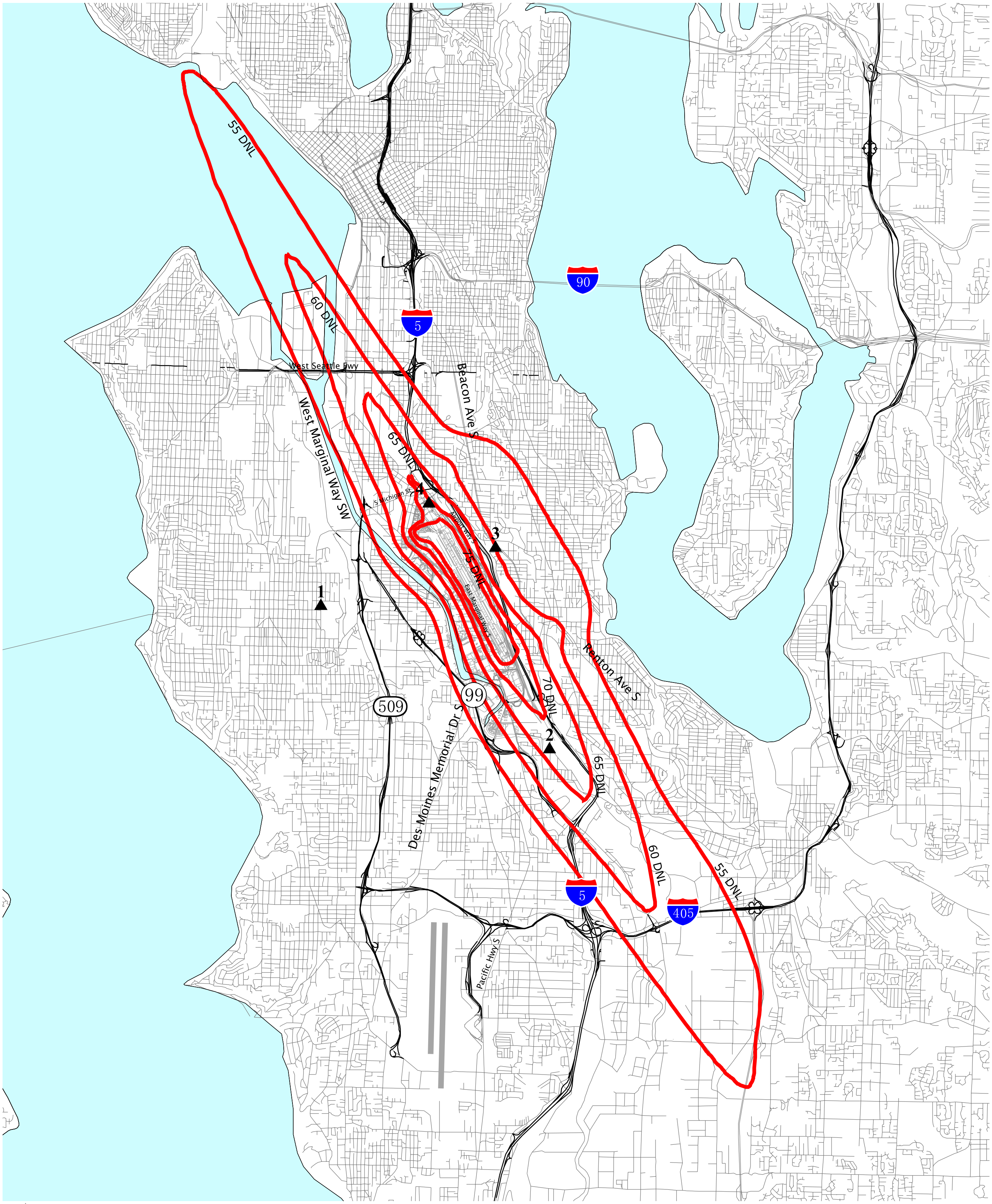


Figure C10 ***Noise Measurement Locations***

Semi-Permanent
Temporary



Scale 1"=10,000'

Figure C11 ***Noise Measurement Sites***

▲ Permanent

Existing Base Case Noise Contour

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INTERNATIONAL AIRPORT/Boeing Field
FAR Part 150 Study

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 and aircraft correlation at each of the sites will be presented in the subsequent version of 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 was used to model the flight operations contours at King County International 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. The original INM was released in 1977. The latest version, INM Version 6, was released for use in October 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 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

Existing Aircraft Operations

The existing noise environment for King County International Airport was analyzed based upon 1999 operational conditions. The data was derived from various sources. This includes aircraft tower counts, Aircraft Situational Display data, ARTS flight track data, Boeing commercial aircraft operations, commercial flight schedules, 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
- Seasonal Variation in Operations
- Time of Day
- Runway Use
- Flight Path Utilization
- Run-up Activity

Aircraft Activity Levels. The total aircraft operational levels were derived directly from the King County International Airport air traffic control tower count. The breakdown by aircraft category was determined by a review of all of the sources of flight information described above. The data showed that there were 325,788 operations during that time period, or an average of 893 operations per day (an operation is one takeoff or one landing). The 1999 aircraft operations for each category of operation are summarized in **Table C3**. These operations consist of commercial aircraft, air taxi, air cargo and general aviation aircraft.

Table C3
SUMMARY OF OPERATIONS, EXISTING 1999
King County International Airport FAR Part 150 Study

Operations by Category	Operations Annual	Operations Daily	Percent Nighttime
General Aviation	255,450	699.9	
Single Engine	*179,882*	*492.8*	*15%*
Multi-Engine	*59,080*	*161.9*	*15%*
Business Jet	*16,488*	*45.2*	*16%*
Air Cargo (< 60,000#)	8,164	22.4	41%
Air Cargo (> 60,000#)	6,478	11.2	41%
Aerospace	3,183	8.7	0%
Passenger	4,100	11.2	15%
Air Taxi	46,318	126.9	15%
Military	2,094	5.7	0%
Total Operations	**325,788**	**892.6**	

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 King County International Airport. The nighttime operational assumption data was summarized in Table C3.

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. Fleet mix data was determined from an extensive review of the data sources described earlier. The fleet mix assumptions 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 King County International Airport and these aircraft generate a wide range in noise. The analysis was based upon a compilation of the Aircraft Situational Display data for 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.

Table C4
OPERATIONS BY TYPE FOR CORPORATE JETS, EXISTING 1999
King County International Airport FAR Part 150 Study

Aircraft Type	**INM Type**	**Annual Operations**
Business Jets - Stage 2		
G-II	GIIB	643
LR-25	Lear25	646
Saberliner (Both 2/3)	SABR80	1,947
Business Jets - Stage 3		
Challenger	C600	2,343
Citations/Diamond	MU3001	4,326
Gulfstream	GIV	1,712
LR-35	Lear35	4,870
Air Cargo > 60,000		
B-727	727EM2	465
B-727	727Q15	408
B-747	74720B	458
B-757	757RR	2,173
Airbus/B-767	767300	688
DC-8	DC870	757
DC-8	DC8QN	1,470
DC-9	DC9Q9	151
Aerospace		
B-707 (AWACS)	707QN	151
B-737	737400	2,125
B-747	747400	10
B-757	757PW	661
B-767 (AWACS)	767300	35
B-777	777200	200

The airport has an average level 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. It is estimated that 11% of the total corporate jet fleet which operates out of King County International Airport are Stage II aircraft.

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 the dominate wind direction from the south. Therefore, Runways 13R and 13L are utilized about 69% of the time, while Runway 31L and 31R are used 31% of the time. The runway utilization assumptions used in the study are presented in **Table C5**. This table presents the percentage of operations by category utilizing each of the runways.

Table C5
RUNWAY UTILIZATION
King County International Airport FAR Part 150 Study

Aircraft Type	**Percentage Utilization**			
	13R	**31L**	**13L**	**31R**
General Aviation	34%	16%	35%	15%
Air Cargo	69%	31%	0%	0%
Aerospace	69%	31%	0%	0%
Passenger	69%	31%	0%	0%
Air Taxi	69%	31%	0%	0%
Military	69%	31%	0%	0%

Flight Path Utilization. The airport and tower have established paths for aircraft arriving and departing from King County International Airport. These paths are not precisely defined ground tracks, but represent a broad area over which the aircraft will generally fly. Example flight tracks from actual operations are presented in **Figures C12** and **C13**. These figures present north flow conditions and south flow conditions respectively.

The modeling analysis includes a total of 15 departure flight tracks and 8 arrival flight tracks to model the aircraft flight paths at King County International 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 flight track information. These flight tracks are presented in **Figures C14** and **C15** for both departure and arrival tracks respectively.

The noise monitoring system for King County International Airport provided several days of flight track data during November/December 1999. This flight track data was used to help define the location of the aircraft operations and in the correlation of the noise measurement data with the aircraft operational data. A daily plot of the flight tracks is presented in the Appendix.

Run-Up Operations. The run-up noise environment at King County International Airport was determined by incorporating the results of a survey of airport operators and the noise measurement survey with a computer modeling of the run-up operations. The primary source of noise analyzed in this report is nighttime run-up operations performed by Boeing as part of a maintenance program on their commercial jet aircraft.

Pertinent run-up information was obtained through a survey with airport operators. The majority of run-ups are at low power, but high power run-ups do occur and can last a number of minutes. Most run-ups take place near the ends of Runway 31L/13R. Run-ups do occur at other locations on the airport, but these are typically the smaller aircraft types. A synopsis of the most common aircraft types that conduct run-ups, the average number of run-ups per month, and the duration for the complete run-up process will be completed at the end of the calendar year.

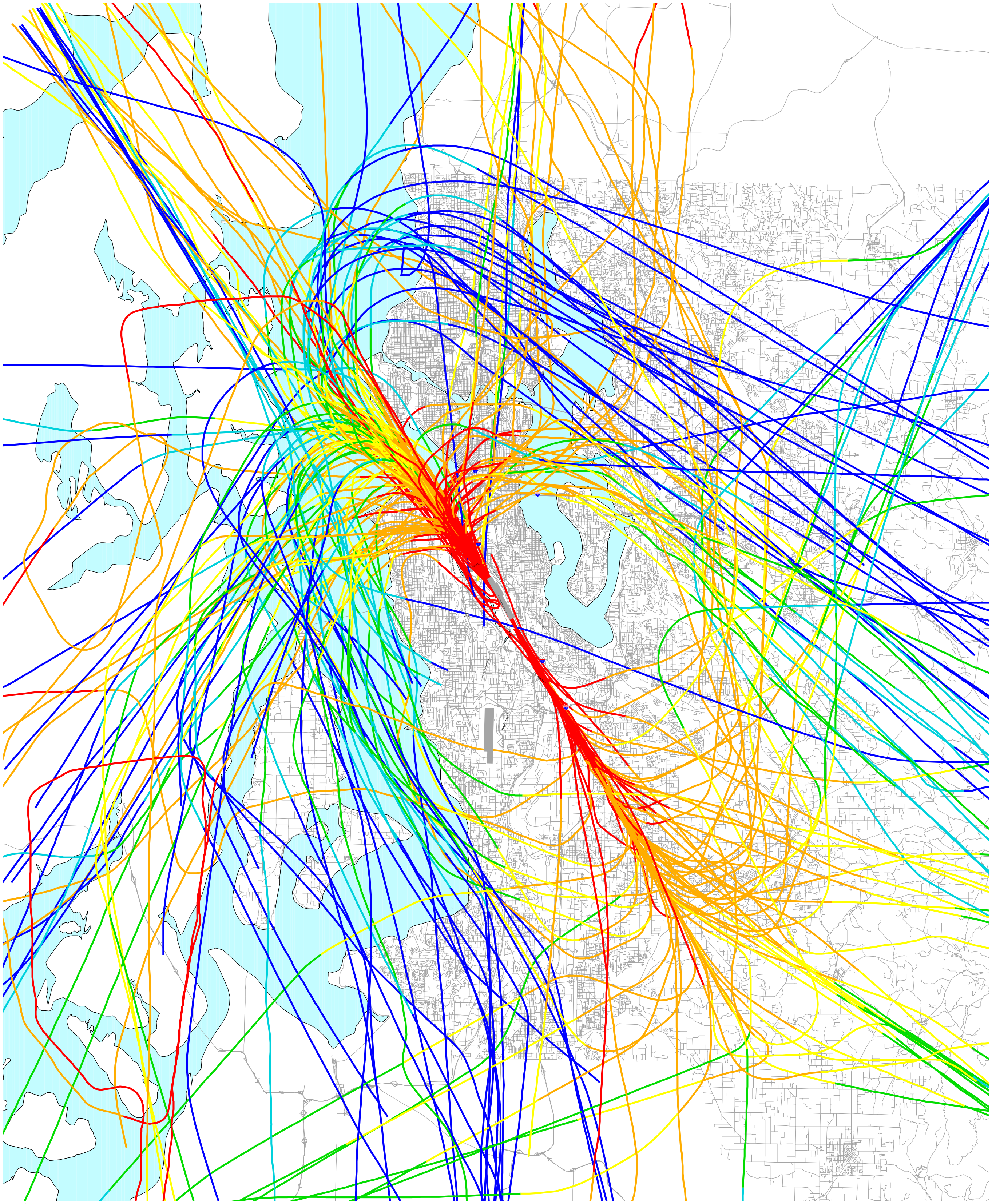

Figure C12 **North Flow Actual Tracks**

- 0-2000 AGL
- 2000 - 4000 AGL
- 4000 - 6000 AGL
- 6000 - 8000 AGL
- 8000 - 10000
- >10,000 AGL

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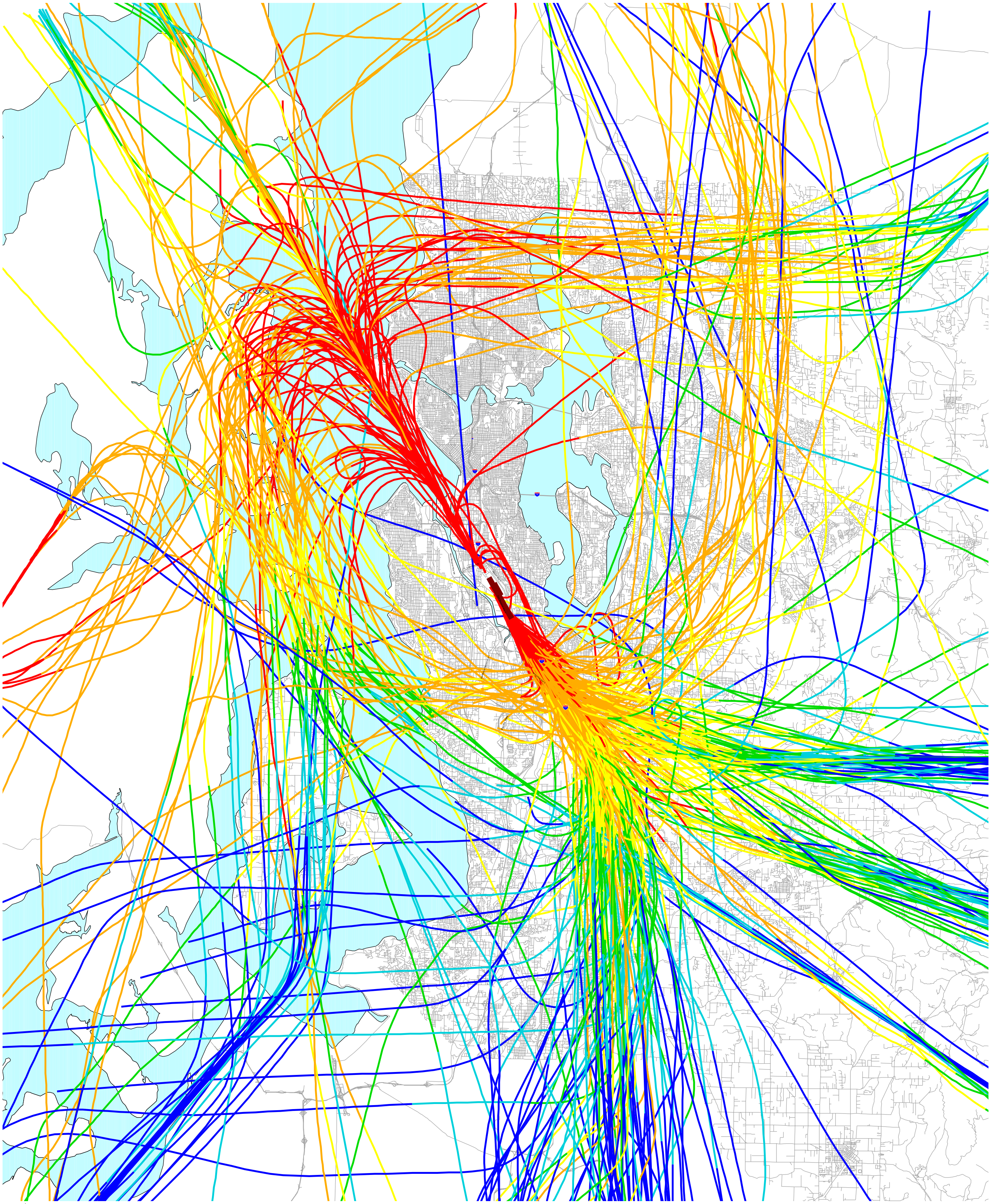

Figure C13 ***South Flow Actual Tracks***

0-2000 AGL
2000 - 4000 AGL
4000 - 6000 AGL
6000 - 8000 AGL
8000 - 10000
>10,000 AGL

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FAR Part 150 Study

Figure C14
Example Flight Tracks (South Flow)
King County International Airport Part 150 Study

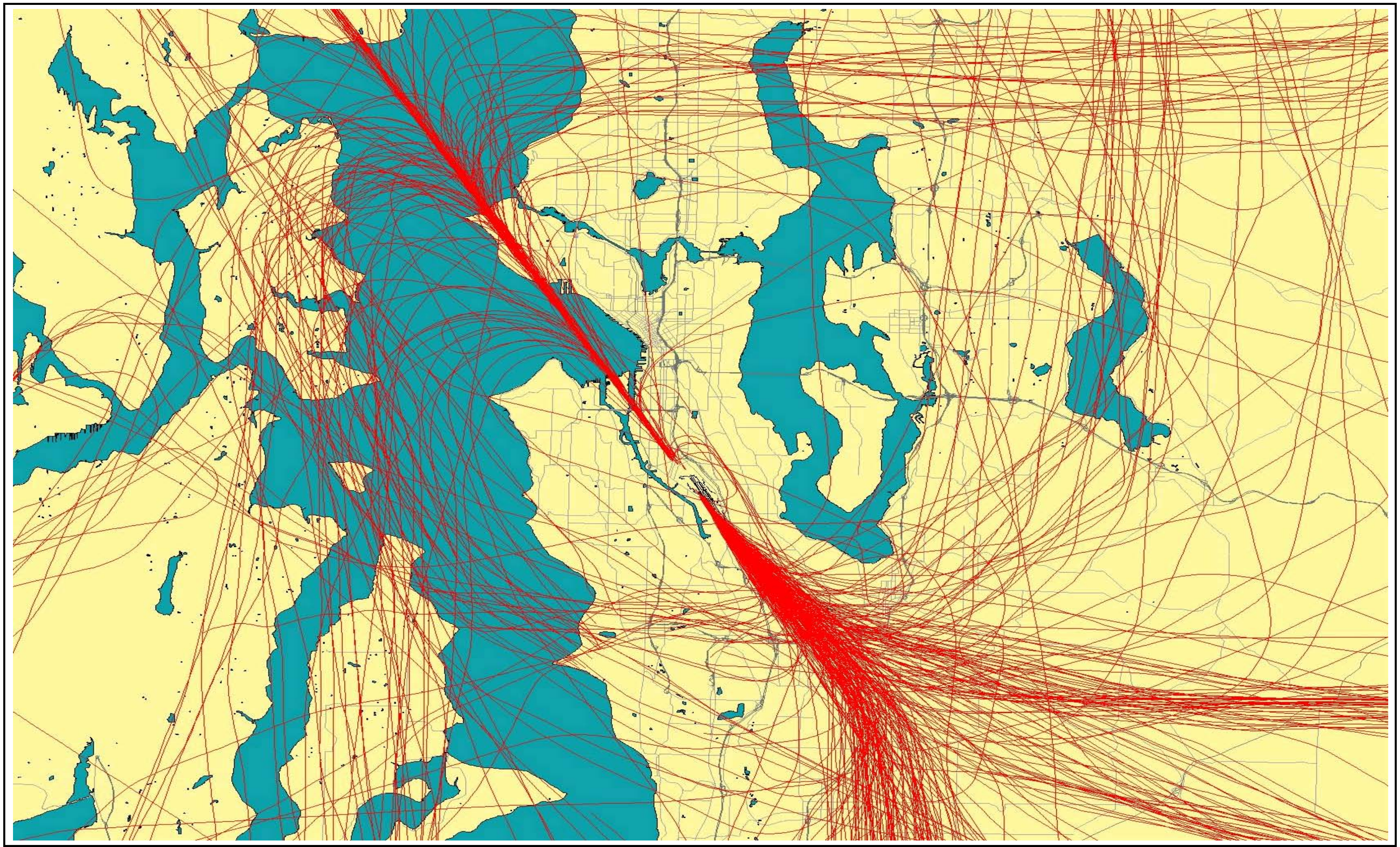
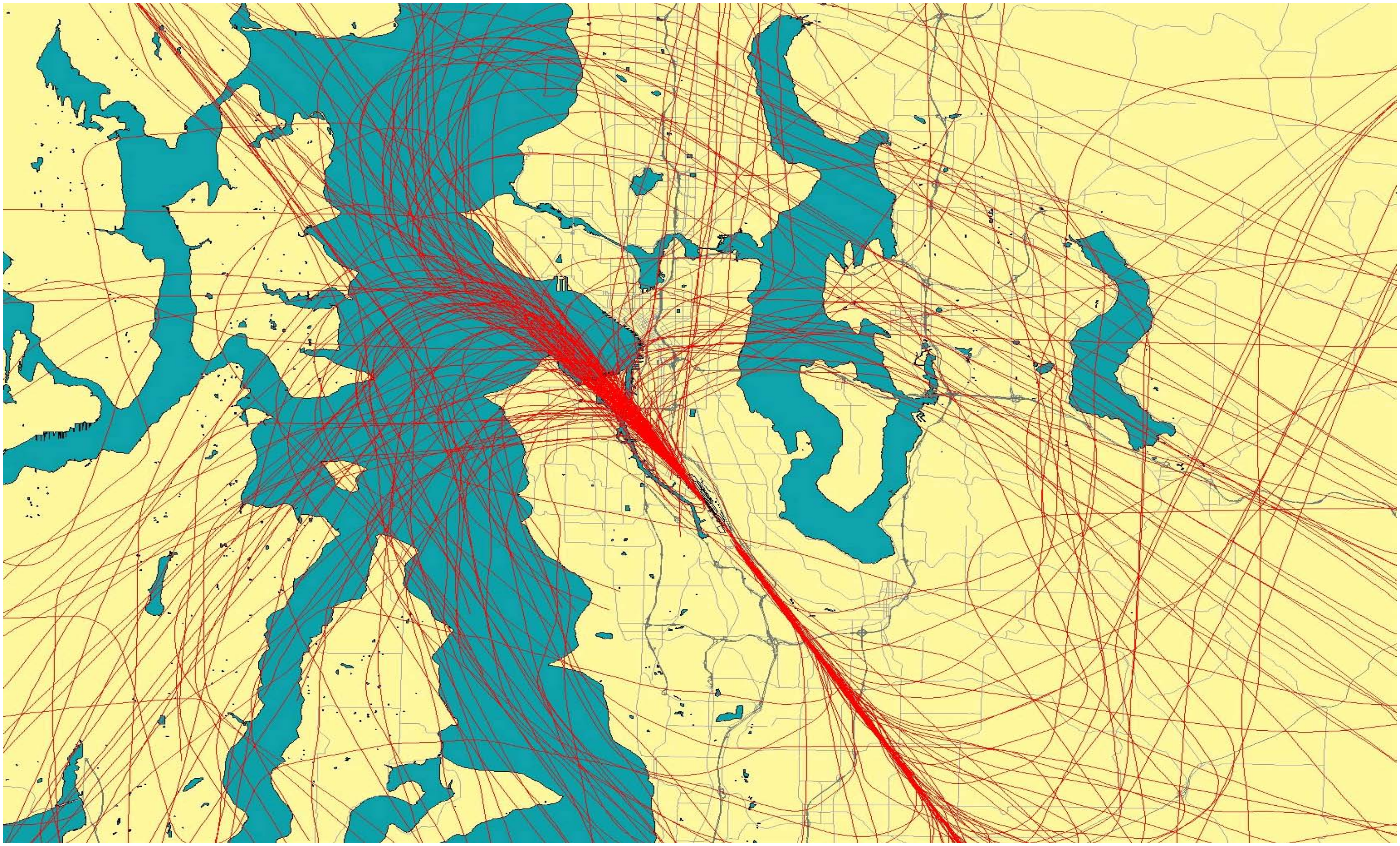


Figure C15
Example Flight Tracks (North Flow)
King County International Airport Part 150 Study



Future 2006 Aircraft Operations

The future noise environment for King County International Airport was analyzed based upon 2006 forecast operational conditions. The forecasts were presented in Chapter Two.

Aircraft Activity Levels. The forecasts estimate that there will be 425,647 operations during that time period, or an average of 1,166 operations per day (an operation is one takeoff or one landing). The 2006 aircraft operations for each category of operation are summarized in **Table C6**. These operations consist of air carriers and general aviation aircraft.

Table C6
SUMMARY OF OPERATIONS, FUTURE 2006
King County International Airport FAR Part 150 Study

Operations by Category	Operations Annual	Operations Daily	Percent Nighttime
General Aviation	343,058	938.1	
Single Engine	*235,735*	*645.8*	*15%*
Multi-Engine	*81,901*	*224.4*	*15%*
Business Jet	*25,422*	*69.7*	*16%*
Air Cargo (< 60,000#)	21,742	59.6	41%
Air Cargo (> 60,000#)	8,549	23.4	41%
Aerospace	4,040	11.1	0%
Passenger	7,560	20.7	15%
Air Taxi	37,660	103.2	15%
Military	3,090	8.5	0%
Total Operations	**425,647**	**1,166.2**	

All remaining assumptions are the same as with the existing conditions except for the mix of aircraft for the future year. The only assumption change is that the air cargo jets will either be hush kited to meet Stage III noise levels, or will be removed from the fleet and replaced by quieter aircraft, as mandated by federal law. The corporate jet fleet mix and night time percentages are assumed to remain the same.

Existing Noise Environment

The following section presents information concerning the existing noise environment at King County International 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 Appendix One.

Noise Measurement Results

Noise measurements were conducted between November 16th, 1999 and December 1st, 1999 at various locations around the airport. A total of nine (9) sites were monitored around King County International Airport using semi-permanent and temporary noise monitoring systems. 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 for about two weeks 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 utilized specialized equipment that allowed for the recording and display of the compete time history of noise events. The survey also included ambient or background noise measurements at the monitoring sites. Three of the sites were short-term measurement sites that also included some spot measurements of aircraft single event noise levels. The DNL noise level was not measured at these sites.

In addition to the temporary noise monitors used for this study, King County International Airport operates a series of their own noise monitors in the communities surrounding the airport. Some of these monitors are fixed in permanent locations while others are moved to different locations around the airport in response to residences' requests. The location of the noise monitors operated by King County International Airport were shown in **Figure C11**. Noise measurement data collected by some of these monitors was processed along with the data from the temporary monitors. Data from the airport monitors was taken for the same period the temporary monitors were in operation. The results of the measurement survey are presented in the following paragraphs.

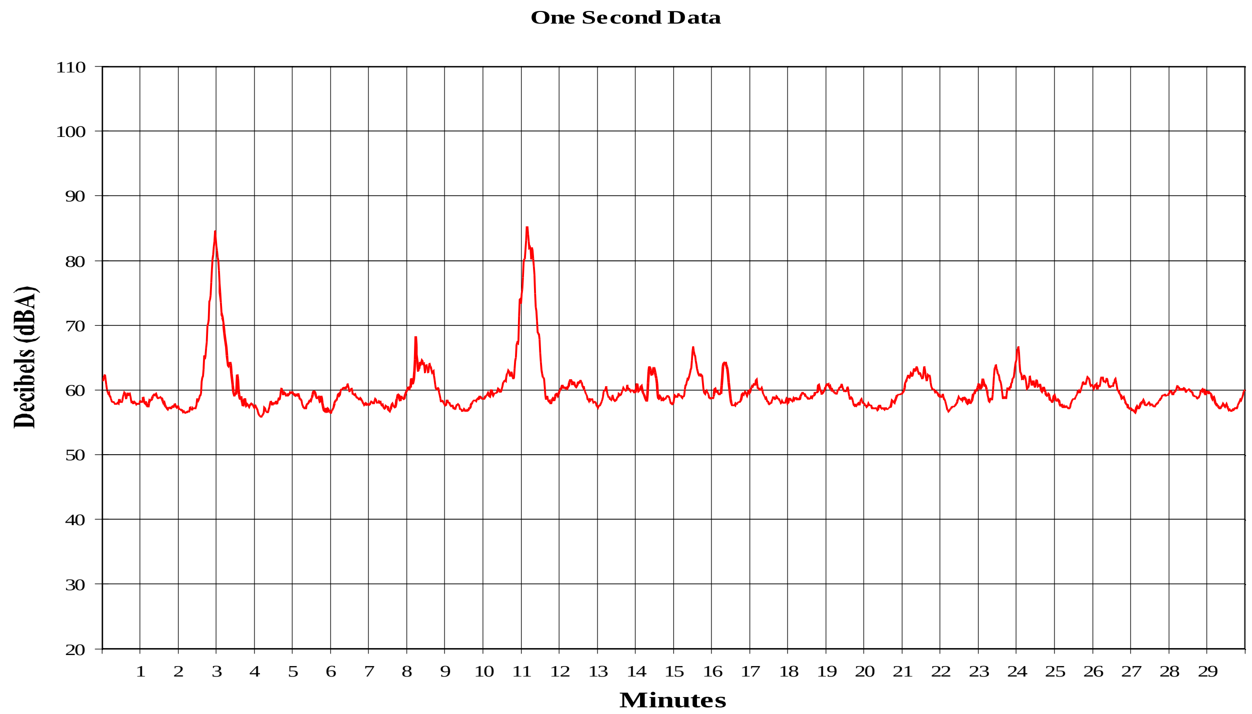
The noise level was continuously recorded at each of the temporary noise monitoring sites. In addition to recording the noise events from aircraft, the monitors also recorded the ambient noise level of the community surrounding the monitoring site. An example of this is presented in **Table C7** where 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 temporary noise monitoring sites is presented in Appendix A.

Single Event Noise Measurement Results. Aircraft single event noise levels were determined from this continuous noise data at each of the temporary measurement sites. The measurement data from the King County International Airport noise monitors consisted of single event levels. 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 C8**. 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 presents the hour of the day. The SEL values are plotted vertically for each event within each hour. This data is presented for additional days and additional sites in Appendix A.

The noise measurement data was used to determine the SEL noise levels for different types of aircraft operations. The ARTS data 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 C9** lists the departing aircraft correlated to noise levels measured at Site 3. The tables listing the correlated events measured at each of the monitoring sites and grouped by aircraft type are presented in Appendix A.

Period: Nov 24 1999 06:00:00 to Nov 24 1999 06:30:00



Period: Nov 24 1999 06:30:00 to Nov 24 1999 07:00:00

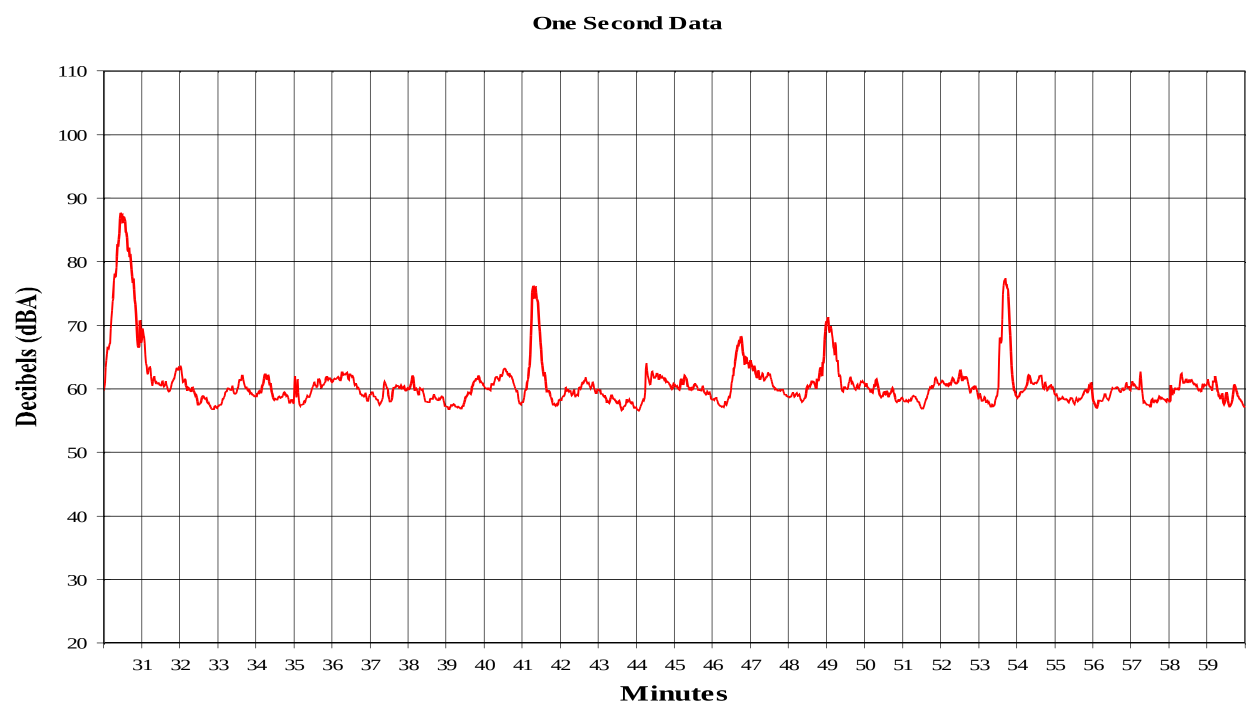


Table C8 - Daily Noise Events Histogram Report
King County International Airport Part 150 Study
Period: November 27, 1999
Site: BS1 - Tukwila - 3303 S. 132

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
23																								
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9																								
8								84.4																
7								84.9	83.5					82.6	82.6									
6								83.0	85.0					87.9	82.5									
5								78.2	79.6	85.3				87.4	81.8									
4							82.5	84.2	93.4	86.6				88.5	85.0					79.9				
3							80.5	81.8	85.4	82.6			85.6	89.1	81.2					81.2				
2							84.6	86.4	85.0	86.8	86.7		83.7	81.3	85.8					91.5	80.7	81.5		
1	81.7	81.9			76.3	81.2	84.7	83.2	90.6	79.4	88.5		79.7	86.2	82.6	79.8	82.5	86.3	85.6	81.3	83.5	82.9	83.0	90.0

Hour Of The Day

Table C9 - Single Event Noise Level by Aircraft Report

King County International Airport Part 150 Study

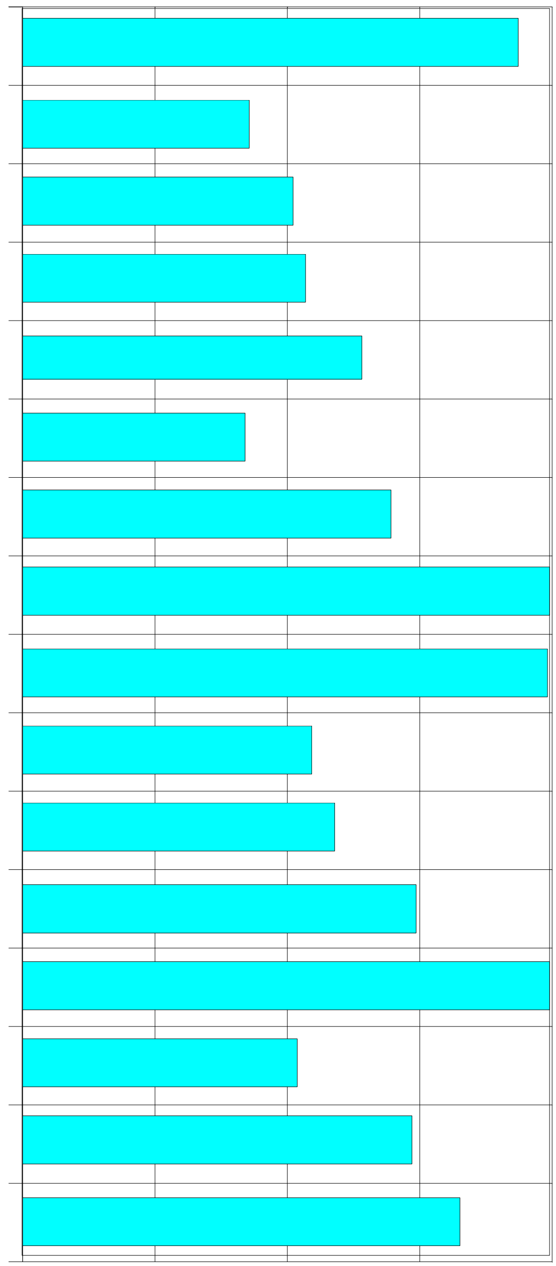
Period: November 1999 to December 1999

Site: BS3 - Seattle - 3903 S. Burns St.

Operations: D   Runways: 13L;13R   Tracks: ALL

Aircraft	FAR 36 Stage	Event Count	Energy Average SEL
B722	2	10	**98.8**
B738	3	1	**88.6**
B73A	2	6	**90.3**
B752	3	8	**90.7**
B767	3	10	**92.9**
C560	3	3	**88.5**
DC8	2	4	**93.9**
DC8S	2	21	**101.9**
DC9	2	4	**99.9**
F900	3	2	**91.0**
FA50	3	6	**91.8**
GLF2	2	8	**94.9**
MD80	3	1	**99.9**
SBR1	2	1	**90.4**
T33		1	**94.8**
Other Aircraft		58	**96.6**

Graph of Energy Average SEL



Note: Energy Average is average of all events on a noise energy basis.
FAR36 Stage is for general categories and does not account for hushkitted aircraft.

The correlated events at each of the monitoring sites were sorted to determine which operations produced the loudest events. **Table C10** lists the date, time, aircraft type, aircraft noise stage, operation, runway, and measured noise levels for the ten loudest events measured at Site 3. The tables listing the loudest ten events and associated aircraft for all of the noise monitoring sites are presented in Appendix A. 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 C11** lists the measured parameters and shows the plot of the 1-second data for one of the loudest ten events measured at Site 3. The tables showing time history plots for one of the loudest events at each of the temporary noise monitoring sites are presented in Appendix A.

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 or hush kit aircraft is 10 to 15 dBA higher than for pure Stage III aircraft. 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.

Table C10 - Loudest Aircraft Noise Events Site Report
King County International Airport Part 150 Study
Period: November 16, 1999 to December 1, 1999
Site: BS3 - Seattle

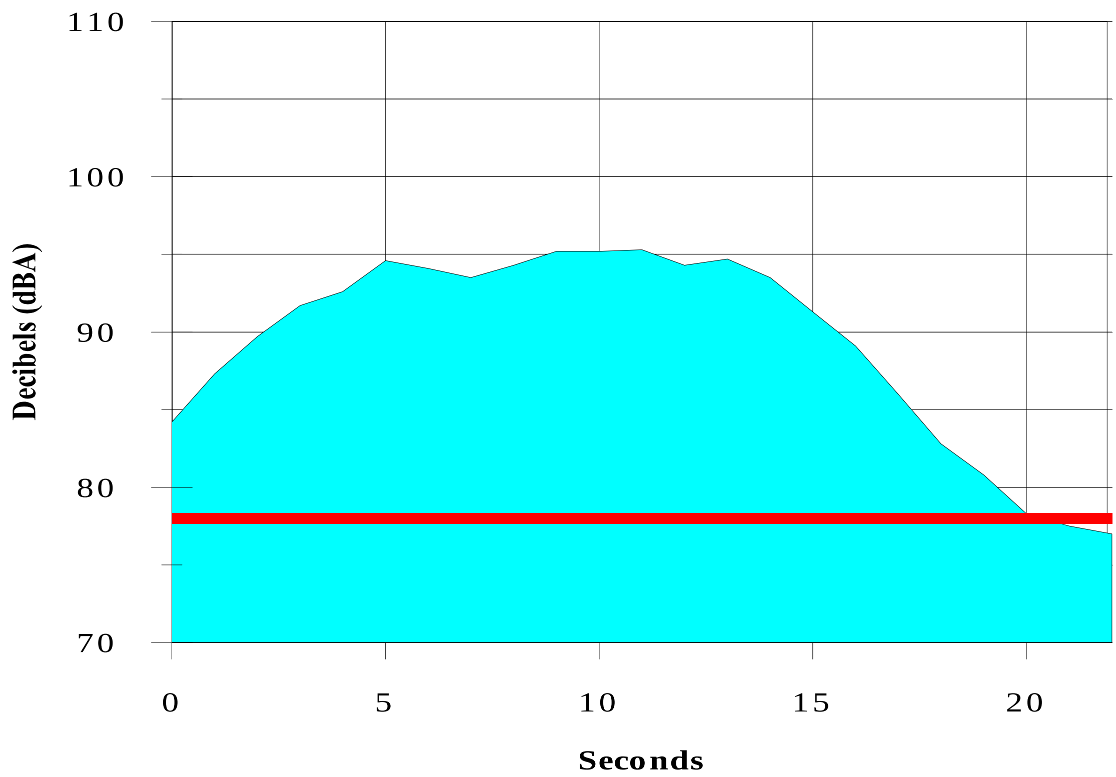
King County International Airport/Boeing Field

Aircraft	Airline	Event Time	Aircraft	Stage	Ops	Rwy	Lmax	SEL
	MIL	Nov 28, 17:15	C141	2	D	13R	95.3	105.6
	AIRBORNE EXPRESS	Nov 24, 19:33	DC8Q	3	D	13R	98.1	105.1
	AIRBORNE EXPRESS	Nov 29, 19:47	DC8Q	3	D	13R	95.2	104.7
	BURLINGTON	Nov 29, 19:00	DC8	2	D	13R	96.6	104.6
	AIRBORNE EXPRESS	Nov 24, 16:27	DC8Q	3	D	13R	94.9	104.2
	AIRBORNE EXPRESS	Nov 18, 19:42	DC8Q	3	D	13R	92.4	103.8
	NORTHWEST	Nov 20, 23:09	B72Q	3	D	13R	94.7	103.7
	AIRBORNE EXPRESS	Nov 29, 19:35	DC8Q	3	D	13R	95.1	103.3
	NORTHWEST	Nov 30, 22:47	B72Q	3	D	13R	93.3	102.8
	JUD	Nov 20, 13:05	B721	2	D	13R	93.9	102.5

Graph Of SEL

DateTime:	11/28/99 5:14:22 PM		
Aircraft Type:	C141	Lockheed Corp. C-141 Starlifter	
Airline Code:	RCH		
Operation:	Departure		
Runway:	13R		
Destination:	UNK		

SEL (dBA):	105.6	**Max (dBA):**	95.3
Duration (seconds):	21	**Start to peak (seconds):**	11
SEL threshold (dBA):	78		



DNL Noise Levels. **Table C12** lists the results of the DNL noise measurements at the 6 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 noise exposure at the six sites ranges from 49 DNL up to 65 DNL.

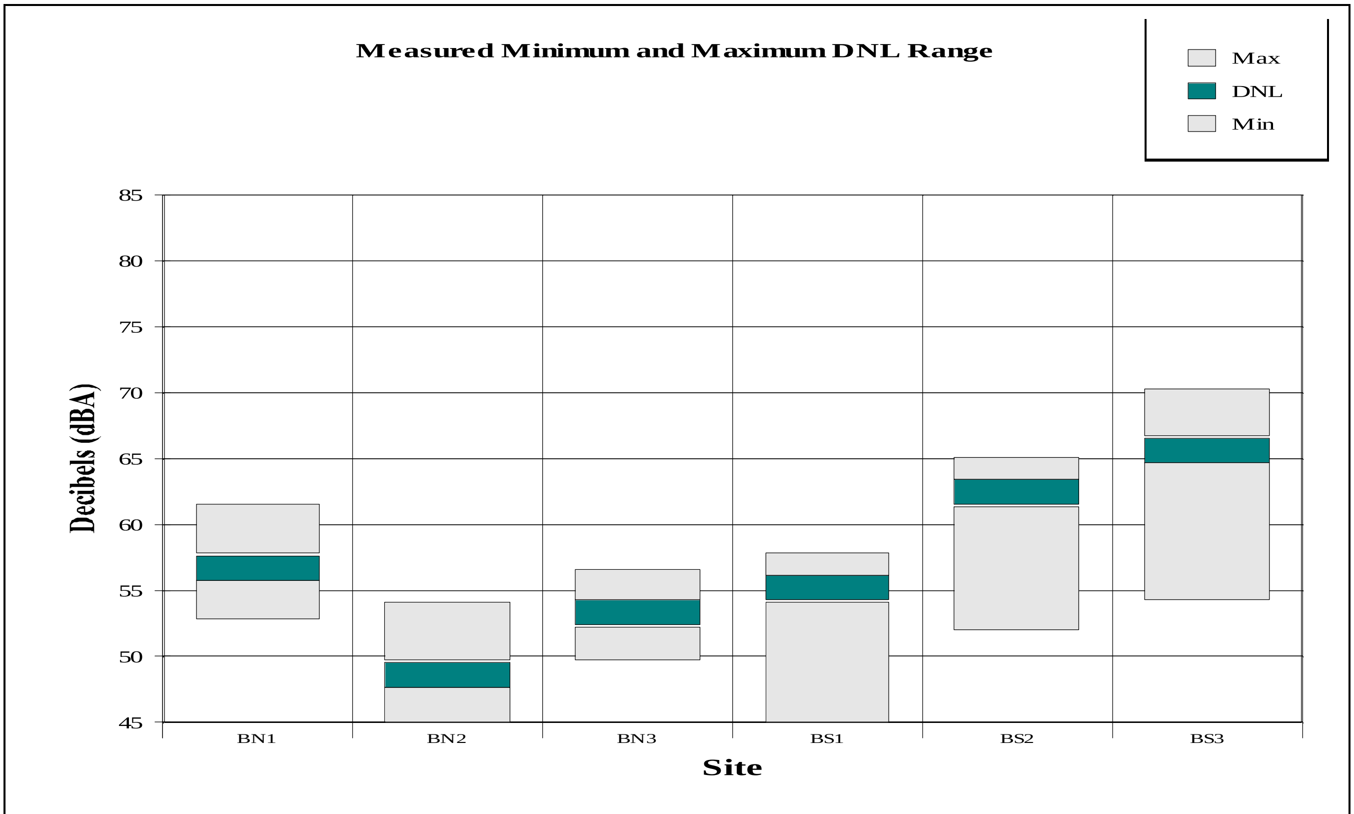
The major contributor to the DNL noise level at most of these sites is the corporate jet activity, especially the Stage 2 jets and those jets that occur during the nighttime hours. Sites 5 and 6 are exposed to more noise from traffic on the nearby freeway than from aircraft operations. **Table C13** shows the results of the DNL noise measurements at the 6 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 C14 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 1. 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 A.

Table C12
MEASURED DNL NOISE LEVELS
King County International Airport FAR Part 150 Study

Site	Description	Date of Measurements	Measured DNL Noise Level
1	28th Ave. W	Nov 17th – Dec 1st	57
2	SW Hill St	Nov 16th – Dec 1st	49
3	37th Ave. W and W Smith St.	Nov 16th – Dec 1st	53
4	S. 132	Nov 16th – Nov 30th	56
5	60th Ave. S	Nov 16th – Dec 1st	62
6	S. Burns St	Nov 16th – Dec 1st	65

Table C13 - Periodic Site Noise Report
King County International Airport Part 150 Study
Period: November 18, 1999 to November 30, 1999
Neighborhood: Part 150 Study Sites



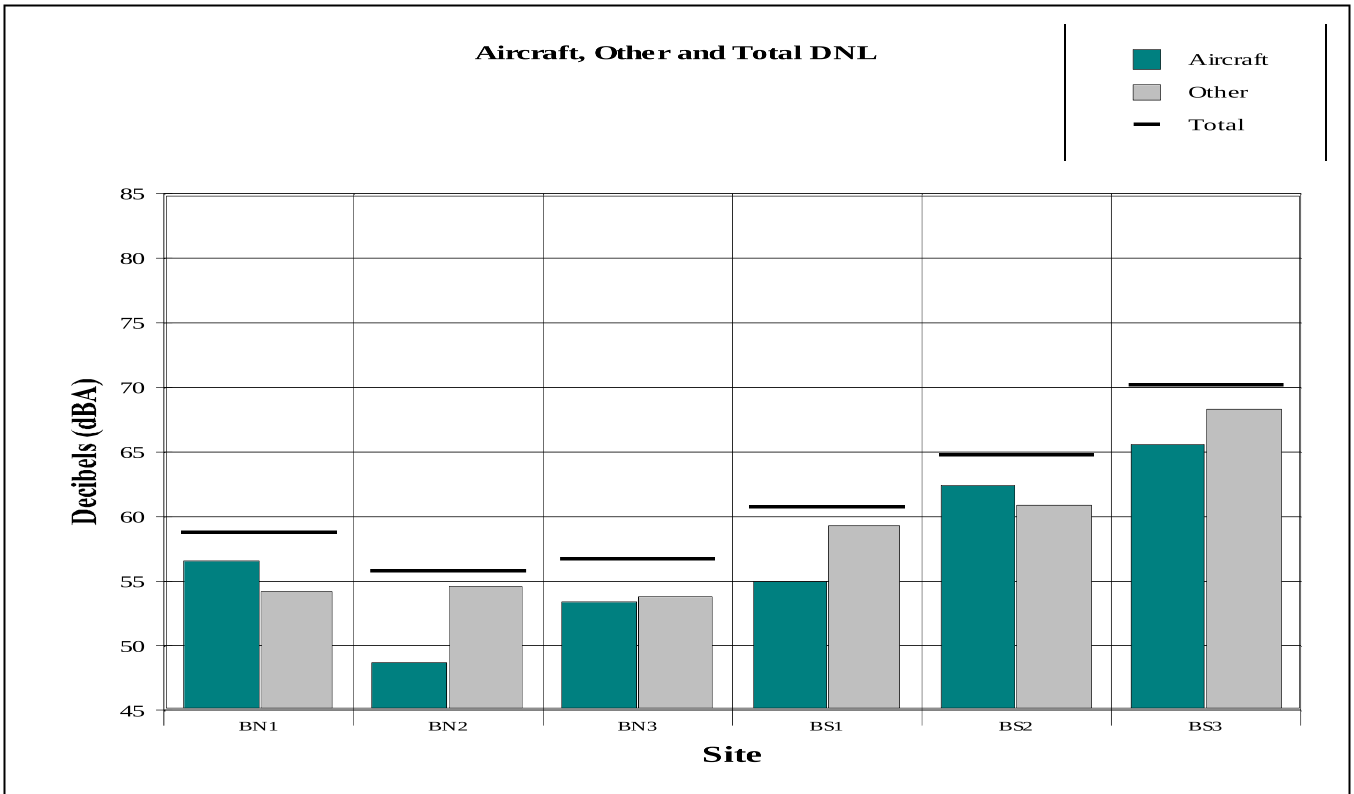
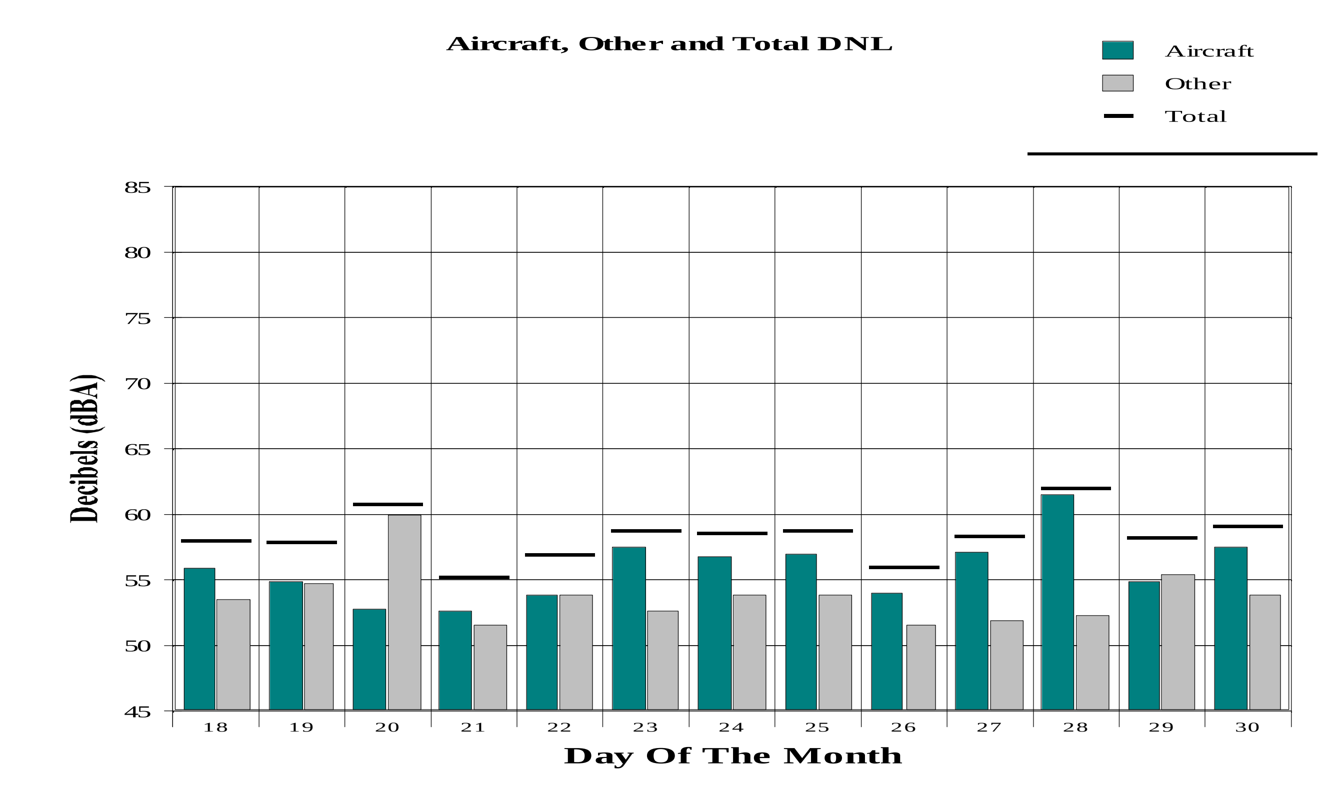
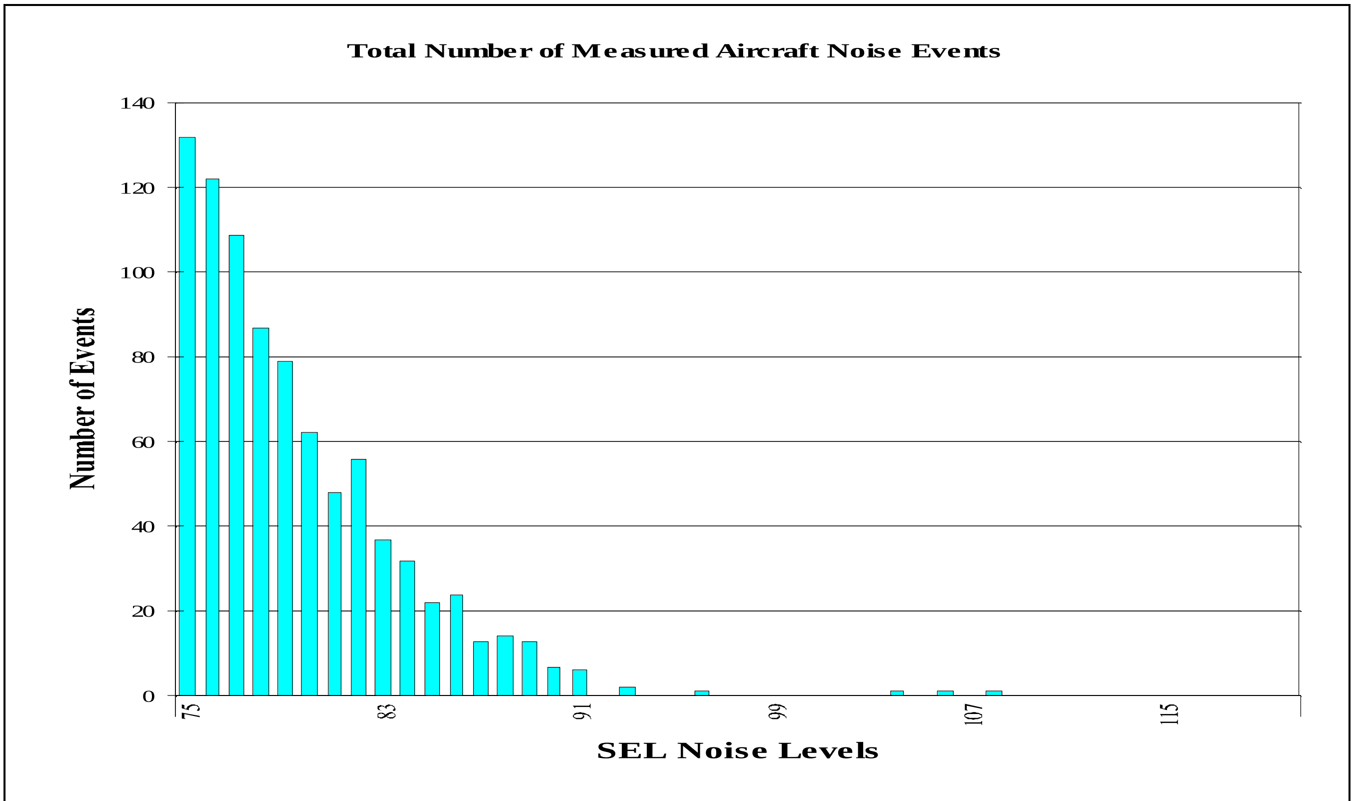


Table C14 - Periodic Site Noise Report
King County International Airport Part 150 Study
Period: November 18, 1999 to November 30, 1999
Site: BN1 - Magnolia - 37th Ave W and W Smith St

KingCounty International Airport/Boeing Field





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 Maximum (LMAX) noise level, the Minimum (LMIN) 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 aircraft, roadway, commercial sources and the residual background noise.

The results of the ambient noise measurement survey at one of the semi-permanent sites is presented graphically in **Table C15**. An example of data from one of the sites for each day of the measurements is presented in **Table C16**. 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.18. The ambient measurement data for the other temporary sites is included in Appendix A.

Table C15 - Ambient Noise Measurement Results (All Sites)
King County International Airport Part 150 Study
Period: November 16, 1999 to December 1, 1999
Neighborhood: Part 150 Study Sites

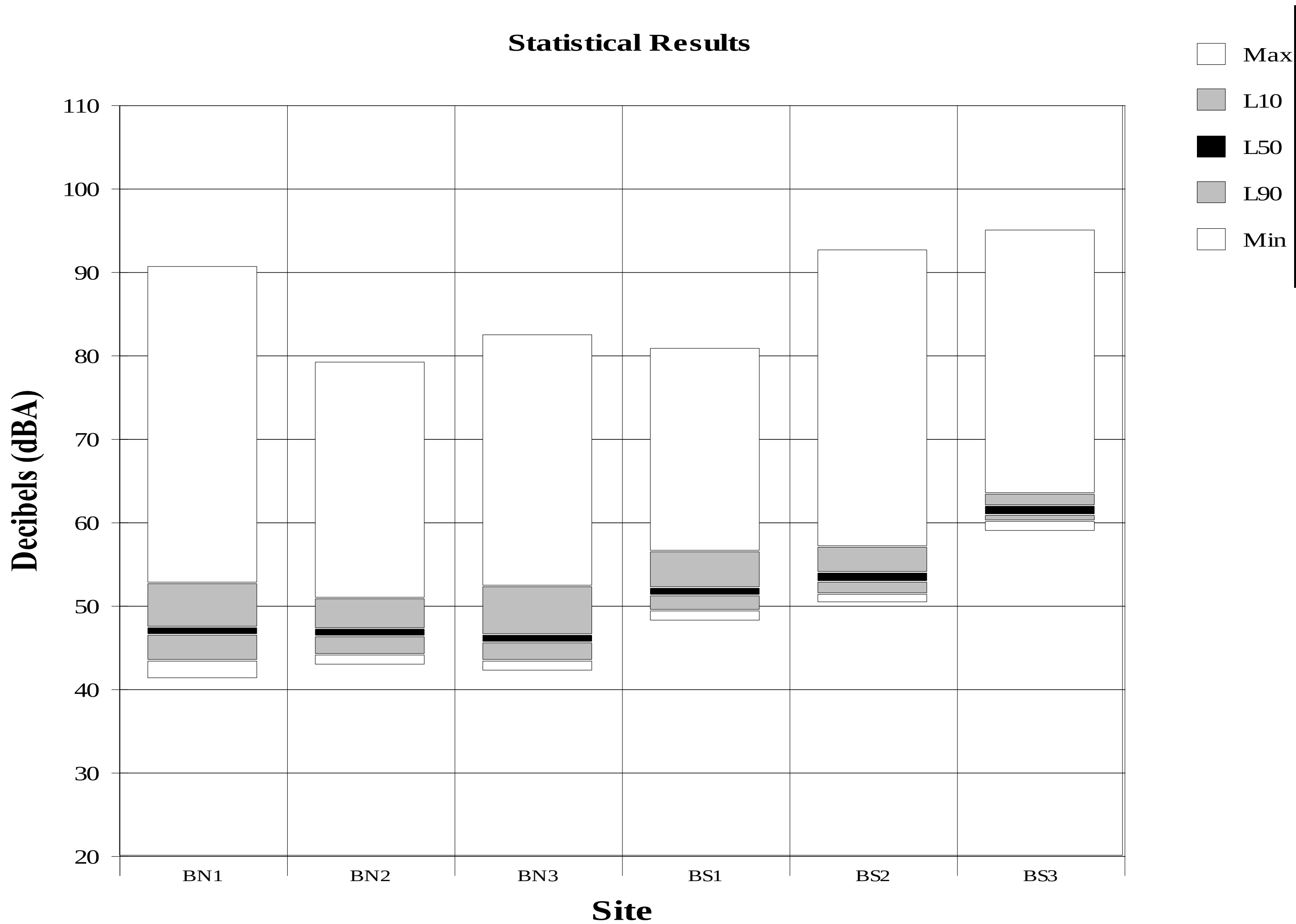
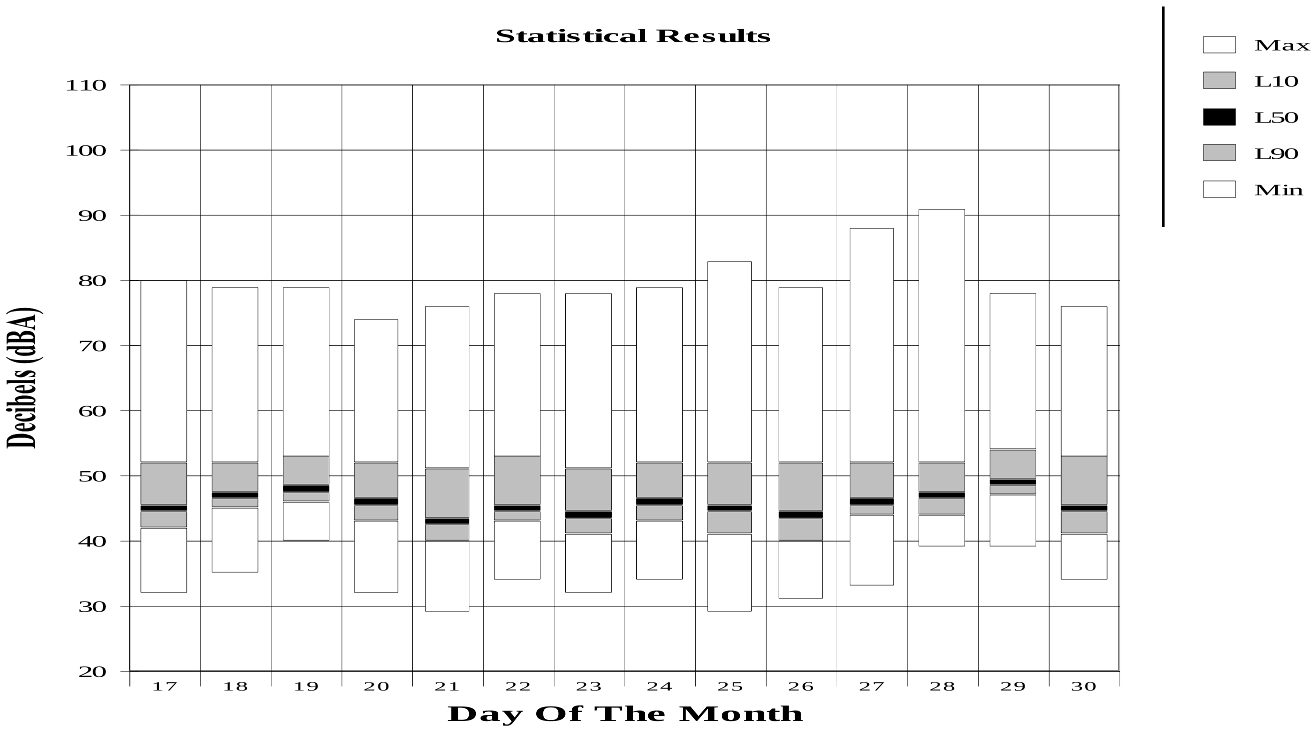


Table C16 - Ambient Noise Measurement Results
King County International Airport Part 150 Study
Period: November 17, 1999 to November 30, 1999
Site: BN3 - Magnolia



Noise Contour Modeling Results

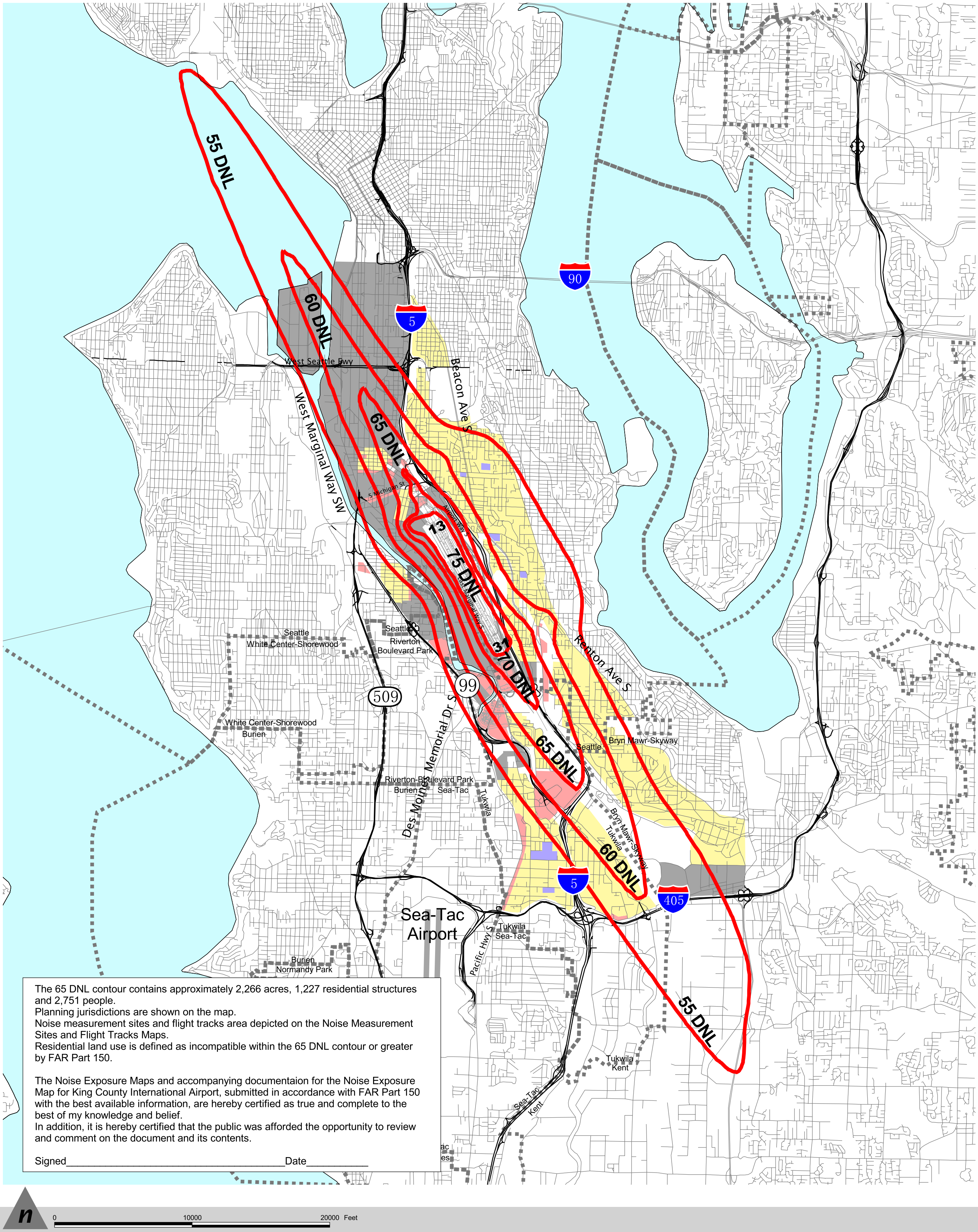
The results from the noise measurement survey were used to facilitate the development of airport noise contours that have been validated through the noise measurement survey. The noise contour were generated using the INM Noise Model version 6. A description of the noise model and the operational data 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.

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 King County International Airport are presented in **Figure C16**. This exhibit presents the 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.



The 65 DNL contour contains approximately 2,266 acres, 1,227 residential structures and 2,751 people.
Planning jurisdictions are shown on the map.
Noise measurement sites and flight tracks area depicted on the Noise Measurement Sites and Flight Tracks Maps.
Residential land use is defined as incompatible within the 65 DNL contour or greater by FAR Part 150.

The Noise Exposure Maps and accompanying documentaion for the Noise Exposure Map for King County International Airport, submitted in accordance with FAR Part 150 with the best available information, are hereby certified as true and complete to the best of my knowledge and belief.
In addition, it is hereby certified that the public was afforded the opportunity to review and comment on the document and its contents.

Signed_______________________________________Date___________

Figure C16 ***Existing Noise Exposure Map (1999)***

Existing Land Use
- Government
- Industrial
- Residential
- Retail-Commercial

Noise Contour

KingCounty
INTERNATIONAL AIRPORT/Boeing Field
FAR Part 150 Study

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 King County International 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 and freighters can generate a wide range in noise levels. To illustrate the range in single event noise levels, two corporate jets and two freighter aircraft were selected for modeling purposes. These aircraft are listed below:

- DC-8 Freighter
- B-757 Freighter
- Gulfstream II
- Gulfstream IV

The Gulfstream II aircraft represents the old generation Stage II corporate jets that generate the highest noise levels. The Gulfstream IV is representative of typical 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 different jet aircraft are presented in **Figures C17** through **C24**. These exhibits present the SEL noise contour for the DC-8 freighter, the B-757 freighter, the Gulfstream II and the Gulfstream IV respectively for both north and south flight operations. Each aircraft is departing and arriving on a typical track for operations on each runway. These exhibits present the departure and arrival SEL noise contours for 100, 95, 90 and 85 dBA. The results illustrate the wide range in noise generated by corporate jet and freighter 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 Stage II aircraft than the other stage 3 jets.

There are no standards in terms of single event criteria. An SEL level of 95 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 85 SEL 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.

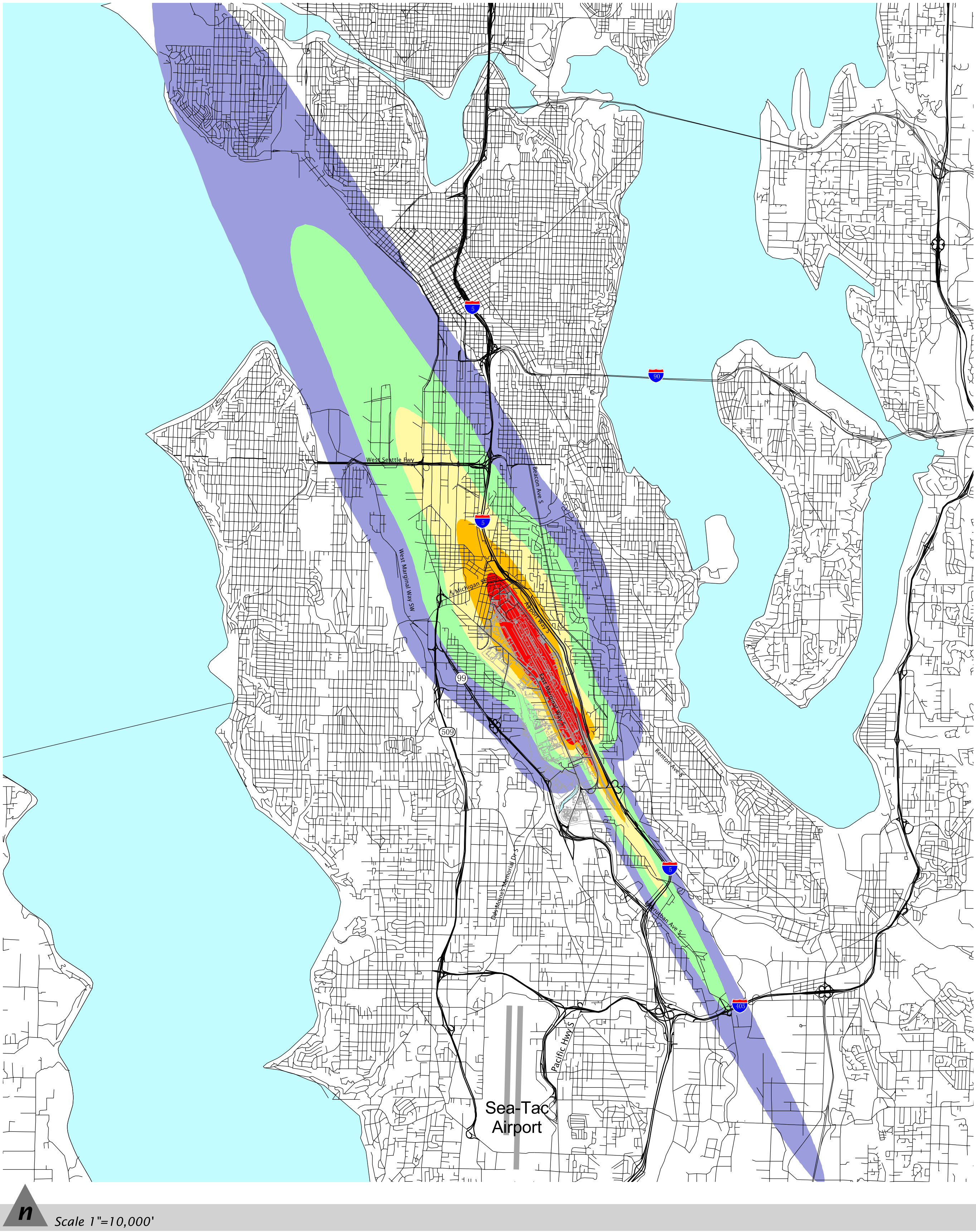


Figure C17 ***DC-8 SEL Contour North Departure***

- SEL 105
- SEL 100
- SEL 95
- SEL 90
- SEL 85

KingCounty INTERNATIONAL AIRPORT/Boeing Field FAR Part 150 Study

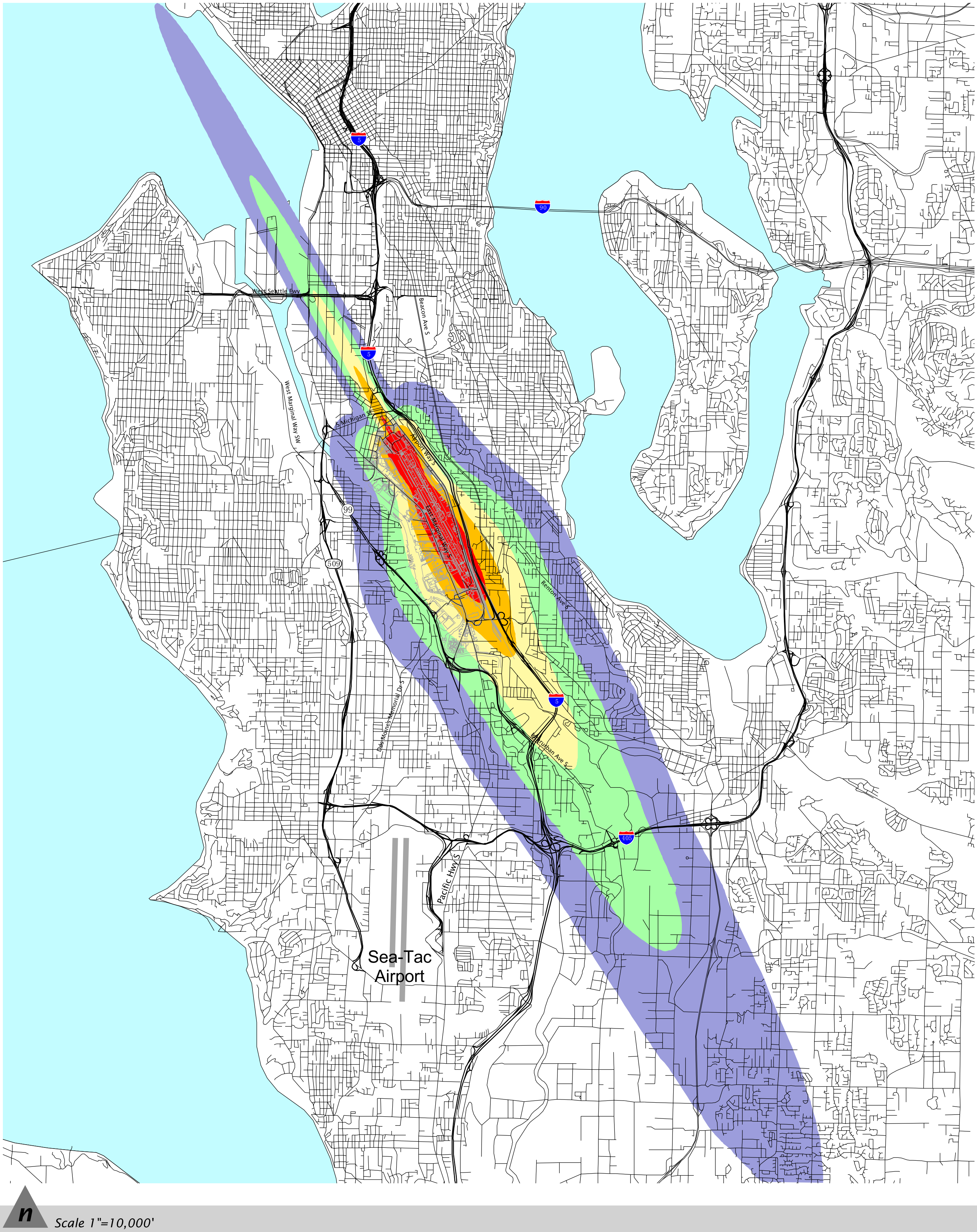


Figure C18 **DC-8 SEL Contour South Departure**

- SEL 105
- SEL 100
- SEL 95
- SEL 90
- SEL 85

KingCounty
INTERNATIONAL AIRPORT/Boeing Field
FAR Part 150 Study

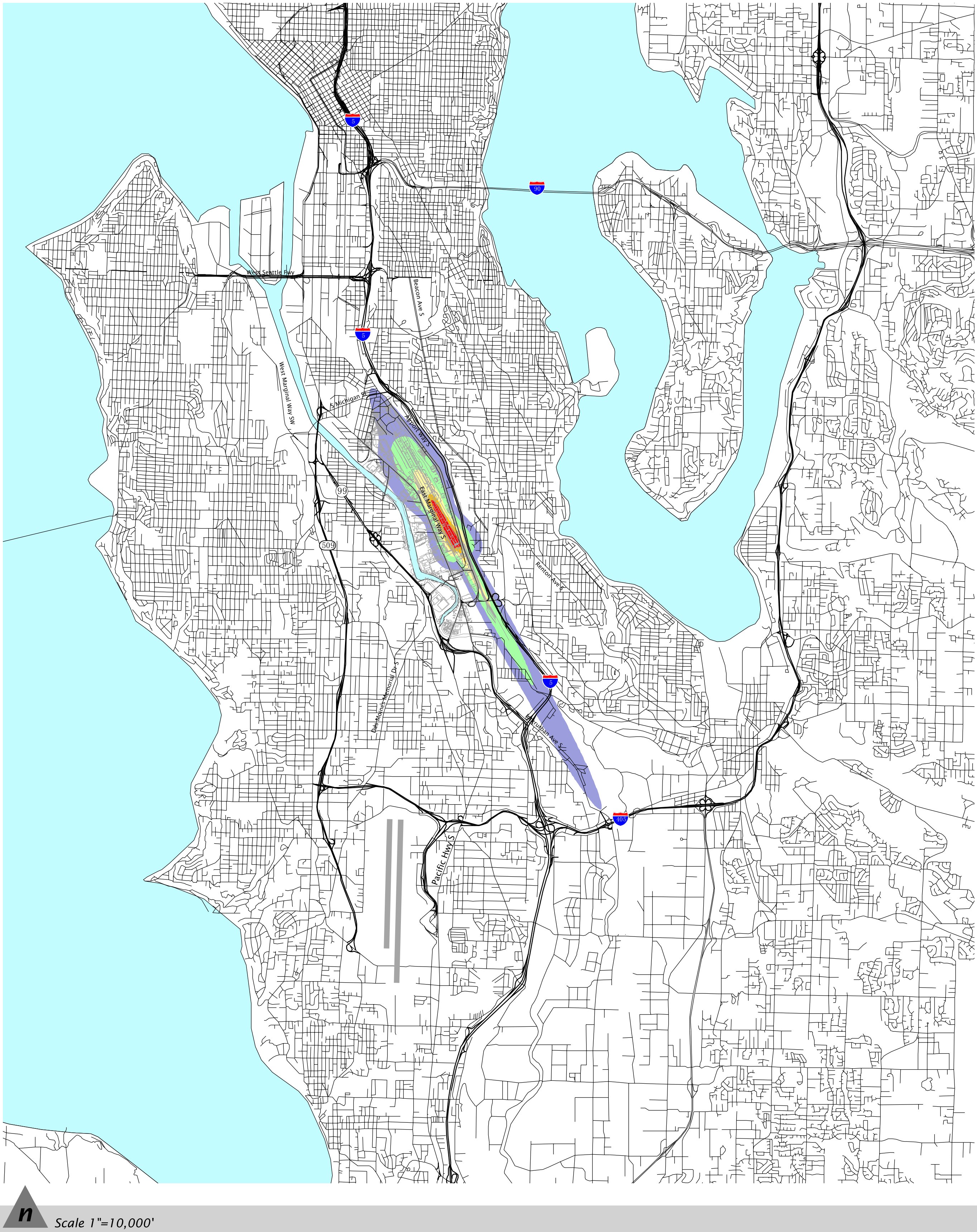
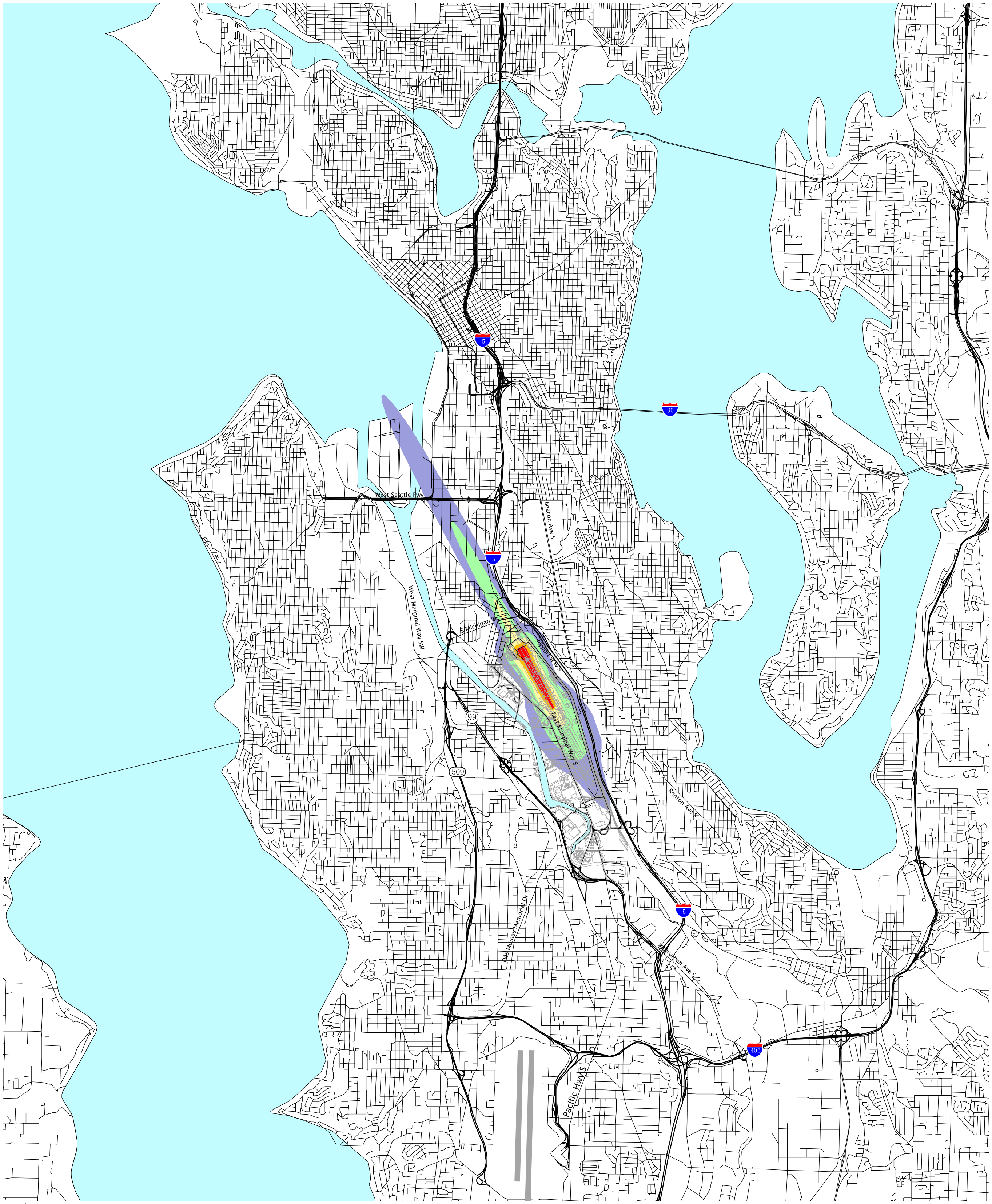


Figure C19 ***Boeing 757 Contour North Departure***

- SEL 105
- SEL 100
- SEL 95
- SEL 90
- SEL 85



n Scale 1"=10,000'

Figure C20 ***Boeing 757 Contour South Departure***

SEL 105
SEL 100
SEL 95
SEL 90
SEL 85

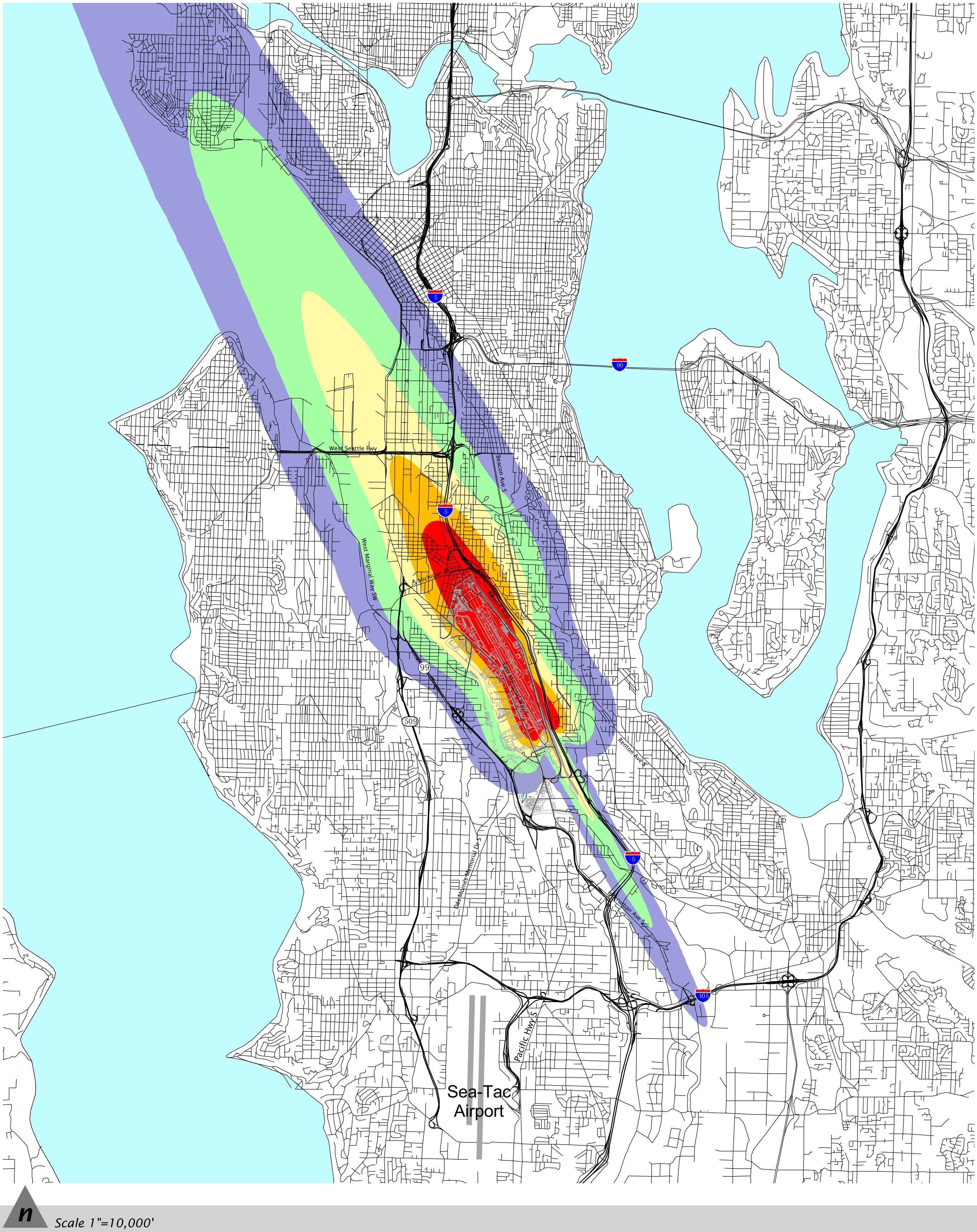
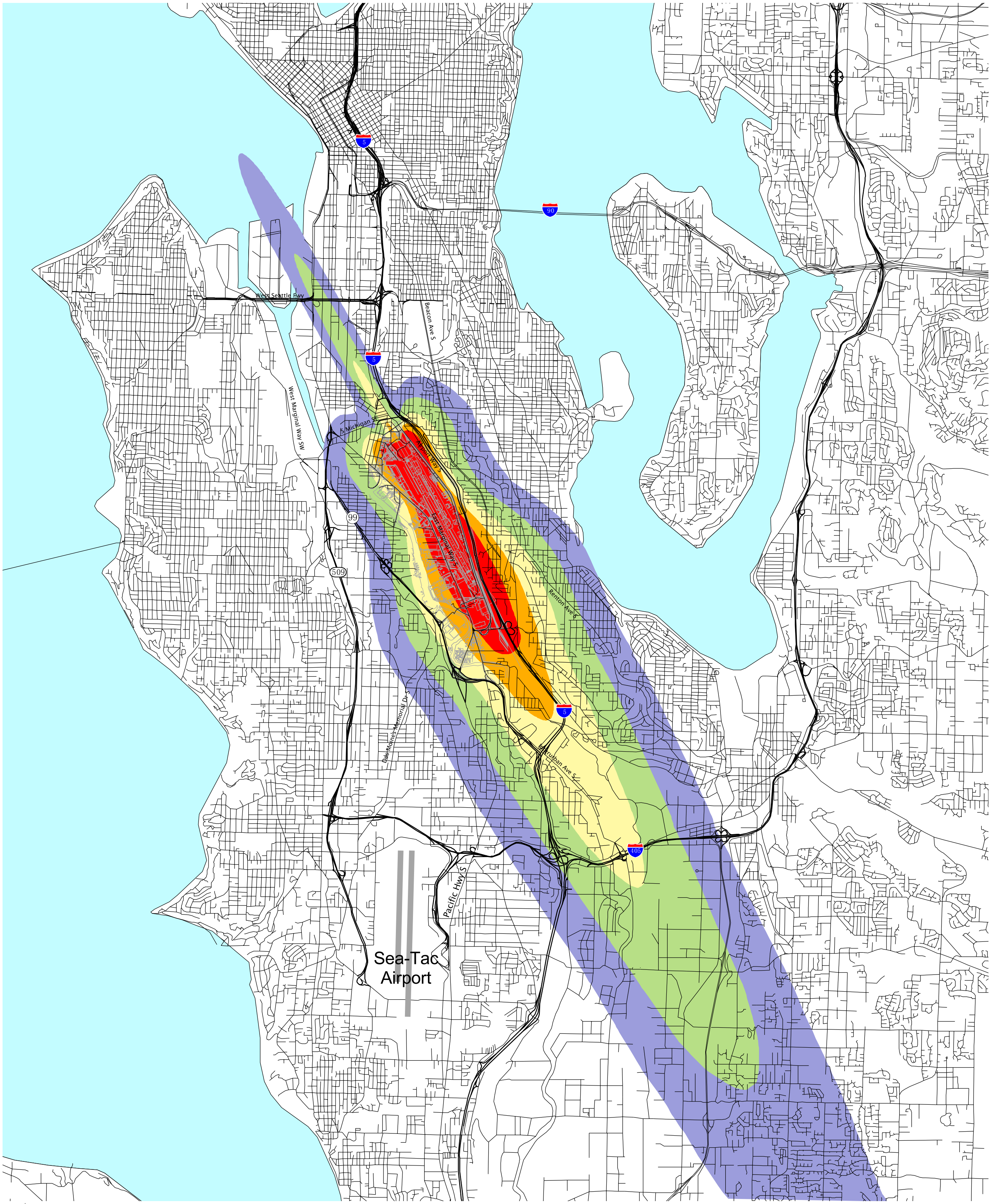


Figure C21 **Gulfstream G II SEL Contour North Departure**

- SEL 105
- SEL 100
- SEL 95
- SEL 90
- SEL 85

King County INTERNATIONAL AIRPORT/Boeing Field FAR Part 150 Study

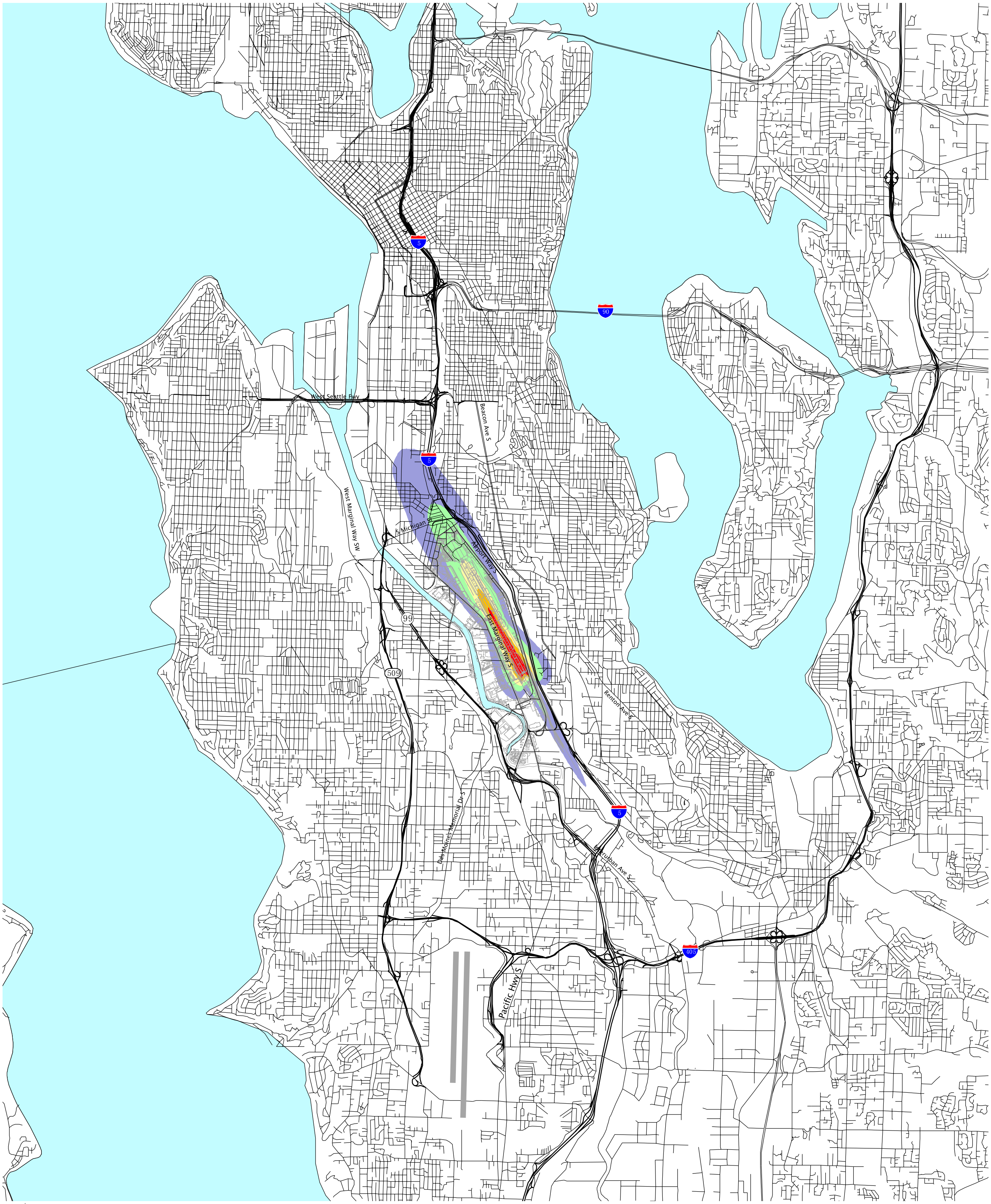


n

Scale 1"=10,000'

Figure C22 **Gulfstream G II SEL Contour South Departure**

- SEL 105
- SEL 100
- SEL 95
- SEL 90
- SEL 85



n Scale 1"=10,000'

Figure C23 **Gulfstream G IV SEL Contour North Departure**

- SEL 105
- SEL 100
- SEL 95
- SEL 90
- SEL 85

KingCounty
INTERNATIONAL AIRPORT/Boeing Field
FAR Part 150 Study

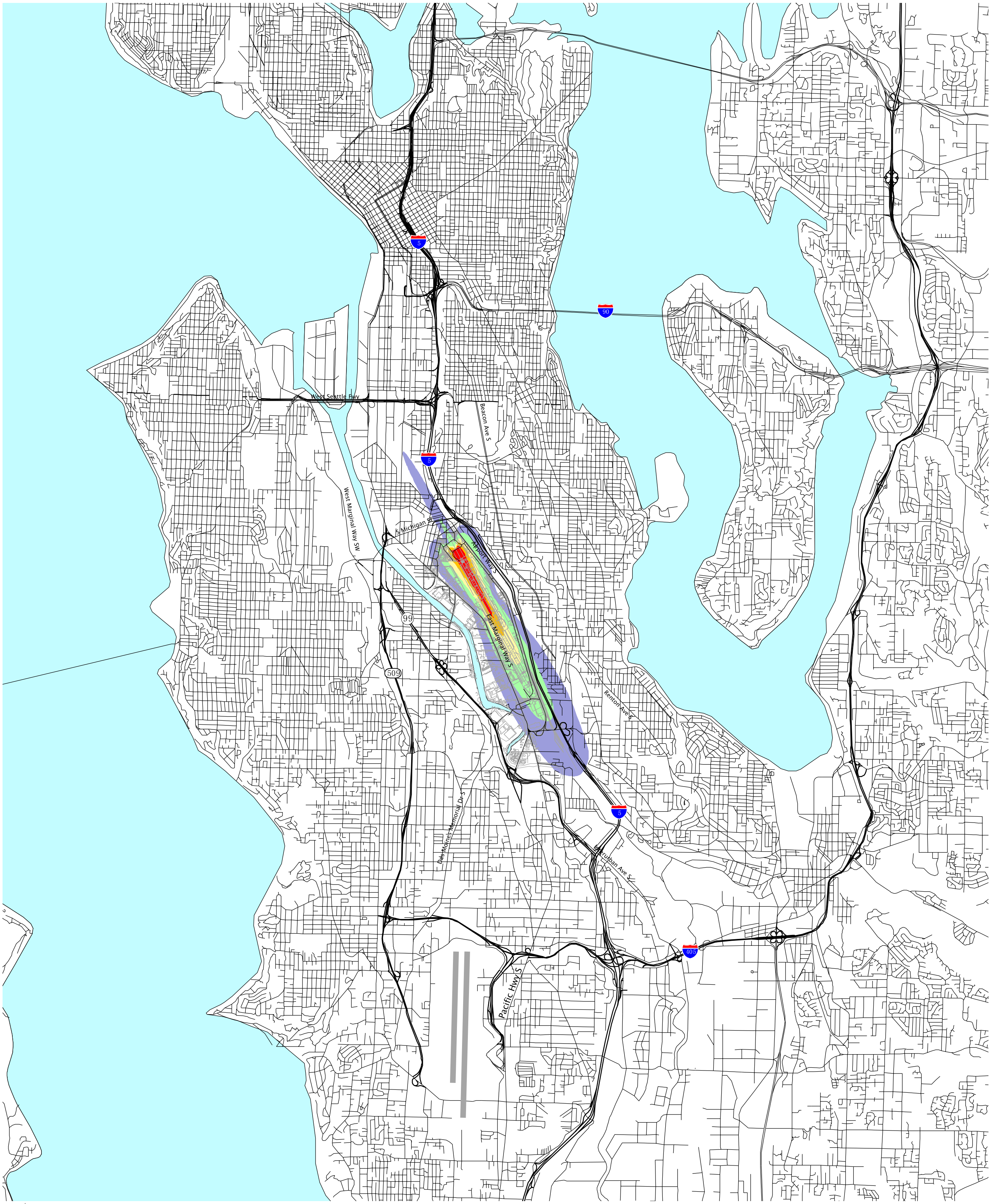


Figure C24 **Gulfstream G IV SEL Contour South Departure**

- SEL 105
- SEL 100
- SEL 95
- SEL 90
- SEL 85

King County
INTERNATIONAL AIRPORT/Boeing Field
FAR Part 150 Study

Existing Case (1999) Combined DNL Contours

King County International Airport is located a few miles east of SeaTac International Airport and as a result the neighboring communities are affected by noise from aircraft flights from both airports. A set of DNL noise contours was calculated which combines the existing (1999) cases for both airports. These contours are shown in **Figure C25**. The figure shows that some of the communities located to the north and northwest of King County International Airport are equally impacted by noise from flights at both airports. The existing combined contours are larger than the future combined contours since the SeaTac future contours are considerably smaller, which results in a smaller combined contour.

Future Base Case (2006) DNL Contours

The 2006 DNL contours for King County International Airport were prepared using Integrated Noise Model (INM) version 6. Noise contours for calendar year 2006 that depict the noise exposure in terms of DNL are shown in **Figure C26**. The contours shown are the 65, 70 and 75 dBA DNL. The operational assumptions used to generate these contours were presented in a previous section. The results of the analysis show that these future contours are slightly larger than the existing conditions contours. This is a result of the increase in operations that are forecasted to occur. These contours are approximately 0.5 dBA louder than the existing conditions contour.

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.

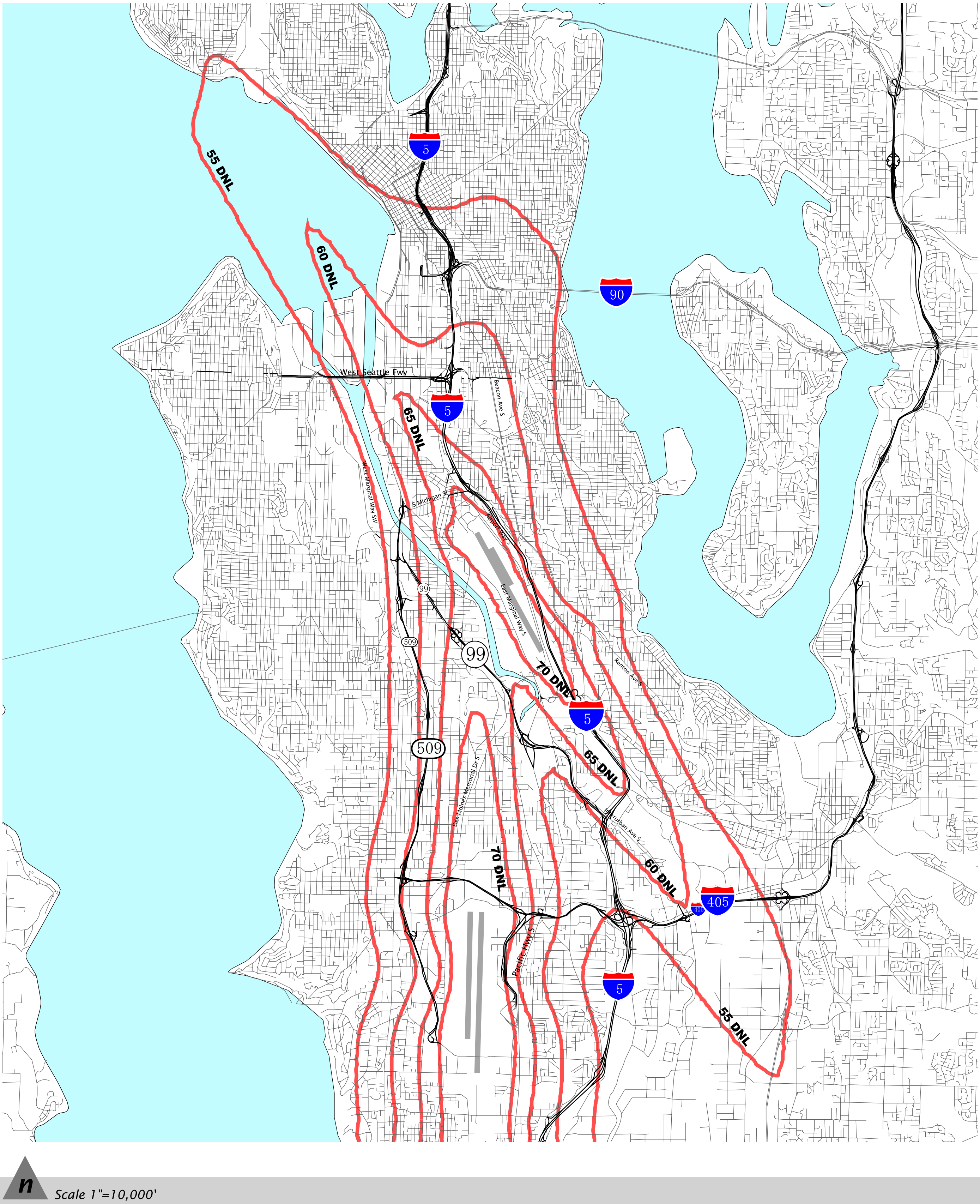


Figure C25 ***BFI & SEA Combined DNL Contours (1999)***

Noise Contour

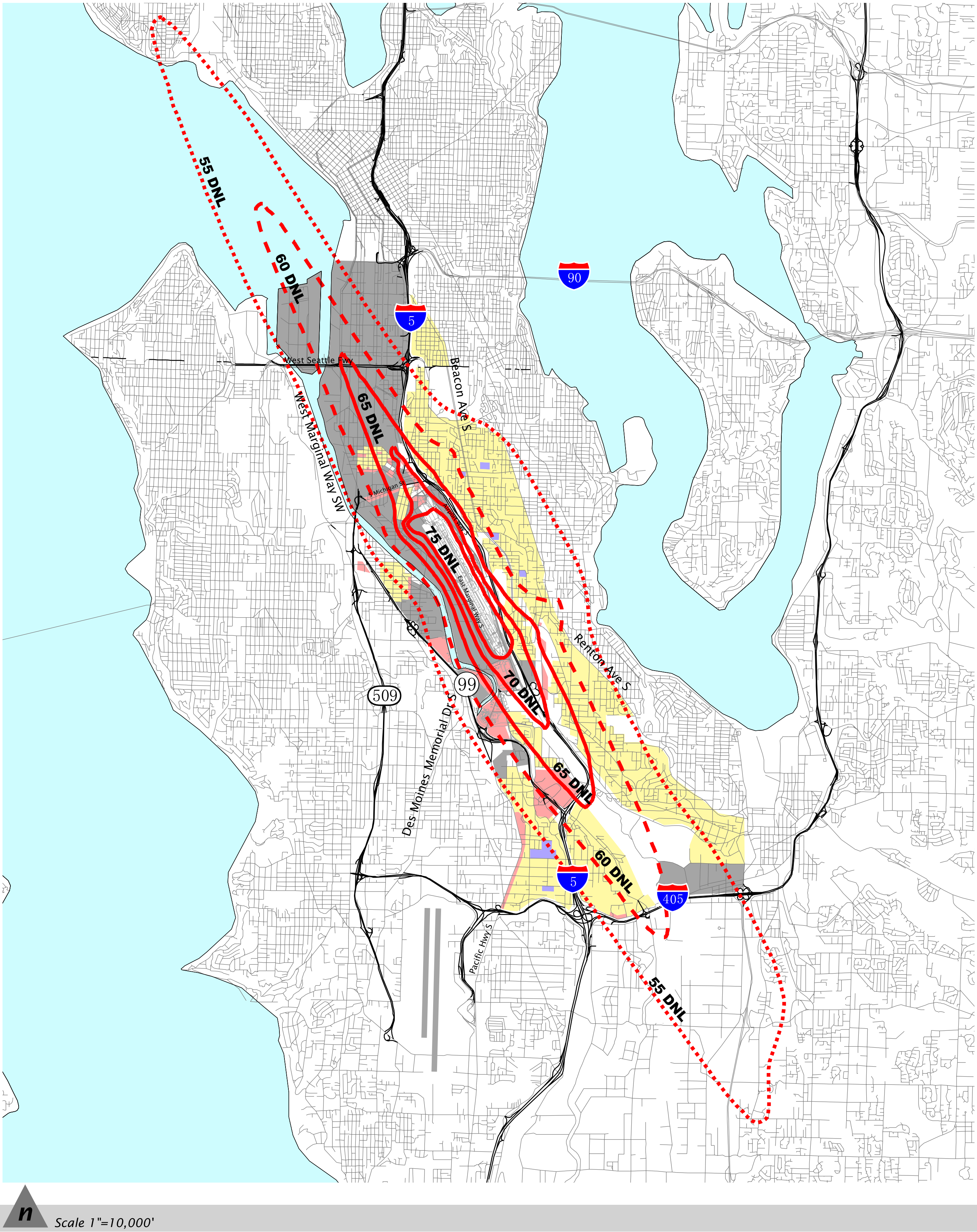


Figure C26 **Future Basecase (2006) DNL Noise Contours**

Existing Land Use
- Government
- Industrial
- Residential
- Retail-Commercial

Noise Contour

KingCounty
INTERNATIONAL AIRPORT/Boeing Field
FAR Part 150 Study