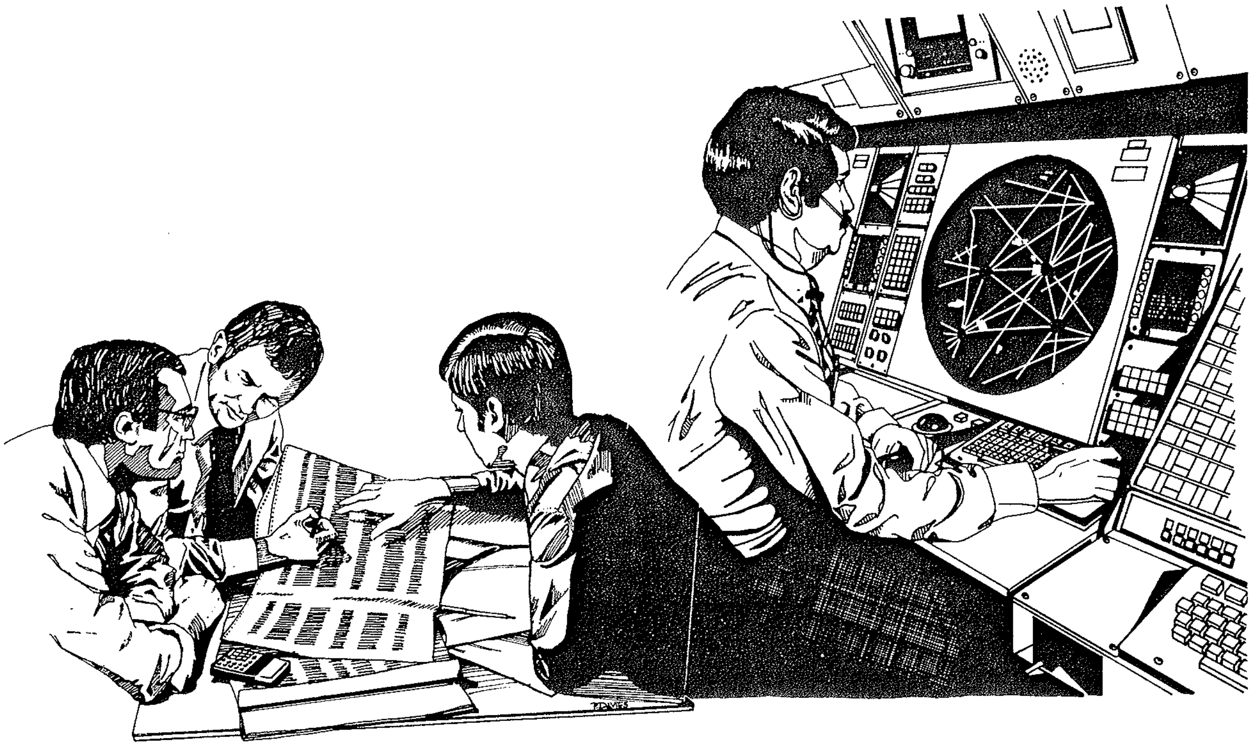
Chapter Two
AVIATION NOISE



Chapter Two
AVIATION NOISE

This chapter describes the work performed to develop maps of current and unabated future aircraft noise for Phoenix Sky Harbor International Airport. The unabated noise contours serve as a baseline against which the hypothetical noise exposure pattern of various alternative noise abatement measures will be compared in later chapters. Future aircraft noise contours are provided to indicate the probable changes in aircraft noise levels if no additional effort is made for noise abatement. Noise exposure impacts will be detailed in later chapters via an estimation of population and noise sensitive land uses within the affected area. These, in turn, will be compared with the impacts associated with various noise abatement alternatives to determine the relative effectiveness of each.

The basic methodology employed to define aircraft noise levels involves the extensive use of a mathematical model for aircraft noise prediction. The results of a field measurement and radar tracking program are used to calibrate the standard inputs to the model and validate its results. The following pages contain a discussion of the formulation of the noise exposure patterns of aircraft using the airport.

NOISE METHODOLOGY

Selection of a noise methodology is keyed to its intended use. In Part 150 studies, the calculations of aircraft noise levels are used for the following basic purposes:

- To describe the current adverse effects of aircraft noise. In so doing, it is necessary to specify how many people are affected, in what way, and at which locations. Thus, the methodology must describe the effects geographically (where), quantitatively (how many people), and qualitatively (how badly affected). Methodologies which provide noise contours best fit these requirements because the contours define the geographical dimensions and permit counting of residents within the appropriate contour bands. The qualitative effects are best described in terms of the predictable reaction of people to the given noise levels. Many studies have been performed nationally to identify typical human reaction to aircraft noise and to define the interference of noise levels on the activities customarily conducted in conjunction with different land uses.

- To permit comparison of alternative noise abatement actions. The primary aims of Part 150 studies are to reduce aircraft noise impacts and to prevent new adverse impact situations from developing. In order to compare noise abatement alternatives, the methodology must provide a simple measure of the effects of each alternative so that it is clear for all to see which alternatives result in the greatest noise relief.

In addition to its intended use, other factors play a role in the selection of a noise methodology. The measure (or metric) should be based on its ability to meet the following criteria:

- The measure should be capable of describing the accumulated effect of all noise perceived at a location over a specified period of time. A one-year period is directed for Part 150 studies, as it allows consideration of the fluctuations of the seasonal effects of climate and aviation activity levels.

- The measure should correlate with degrees of human response such as annoyance, speech interference and hearing loss.

- The single measure of aircraft noise at a given location should be predictable from knowledge of the actual aircraft events producing that noise.

- The measure should be closely related to measures used for noise produced by other sources.

- The measure should be recognized by appropriate governmental bodies.

The **Day-Night Average Sound Level (Ldn)** is used to assess aircraft noise exposure at Phoenix Sky Harbor International Airport. Ldn is consistent with existing measurement technologies and meets the above defined criteria for an appropriate metric. Ldn is the metric currently preferred by the Federal Aviation Administration (FAA), Environmental Protection Agency (EPA) and Department of Housing and Urban Development (HUD) as an appropriate measure of cumulative noise exposure. All federally-funded Part 150 noise compatibility studies use Ldn (or a derivative methodology) as the sole or primary measure of noise exposure.

LDN NOISE METRIC

Ldn is defined as the average A-weighted sound level during a 24-hour period with a 10 decibel penalty applied to noise events occurring at night (10:00 p.m. to 7:00 a.m.). A decibel is a measure for expressing the relative intensity of sound on a scale upward from nearly zero for the average least perceptible sound, with about 130 for the average pain level. Ldn addresses the relationship between daytime and nighttime **equivalent noise levels (Leq)**. Leq is the basic summation measurement used to calculate Ldn values and is formulated in terms of the equivalent steady noise level which, in a given time period, contains the same noise energy as would the sum of the individual noise events (as measured by their Sound Exposure Level) during the same time period. The Sound Exposure Level, commonly referred to as the SEL value, is a representation of the sound energy from a single noise event, compressed into a single second. Exhibit 2A indicates a standard method of converting individual aircraft noise events to the average (Ldn) level of exposure.

Summation methodologies such as Ldn and Leq were developed in response to a need to define noise in a way subject to objective analysis. Previous techniques such as **ASDS (Aircraft Sound Description System), Time Above** (above preset thresholds), and single event analysis did not prove to have a direct and predictable correlation to human response characteristics. Summation metrics were developed on the basis of extensive research to correlate highly with human response. In their research, acousticians have formulated the "equal energy" rule which holds that, over a given period of time, people respond most predictably to the total noise energy they receive rather than to the characteristics of any normal single noise event.

The summation metrics allow the development of objective comparative analysis among various alternatives, while the earlier measures required a subjective comparison of these alternatives and resulted in judgments of preference (i.e. are many events at low levels preferable to a few events at high levels, or vice versa) which vary from individual to individual. Ldn and Leq reduce the subjective characteristics of the evaluation and can describe noise exposure comprehensively over a large area. Ldn was developed under EPA auspices, and embodies extensive information regarding the physical description of noise as related to human acceptability in residential areas. Ldn is the basic parameter for level-weighted population (LWP) assessments which will be made in later chapters. The basic elements and concepts of Ldn are as follows:

- Frequency Weighting - Use of the standard A-weighted decibel characteristic reflects the greater human tolerance for low-pitched sound (or conversely, intolerance of high-pitched sound).

- Time-of-day Weighting - The 10 decibel nighttime penalty accounts for greater sensitivity to noise and/or lower background levels at night.

- Energy Averaging - The energy-mean is the best general single-number description of sound level which varies with time in terms of average community response.

There are factors other than noise exposure level known to affect response, such as the attitudes of different people and their relationships to the aviation industry. These vary among communities and individuals. They are not included in the noise assessment parameter and process because they cannot be physically measured and, thus, must be subjectively considered in later phases of this study.

The basic Ldn exposure parameter may be computed in several ways, depending on the type of noise being investigated and the kind of measurement instrumentation available. The basic mathematical expression is:

$$\mathbf{Ldn = 10 \log \frac{1}{86400}\left(\int_{day} 10^{LA/10}\,dt + \int_{night} 10^{(LA+10)/10}\,dt\right)}$$

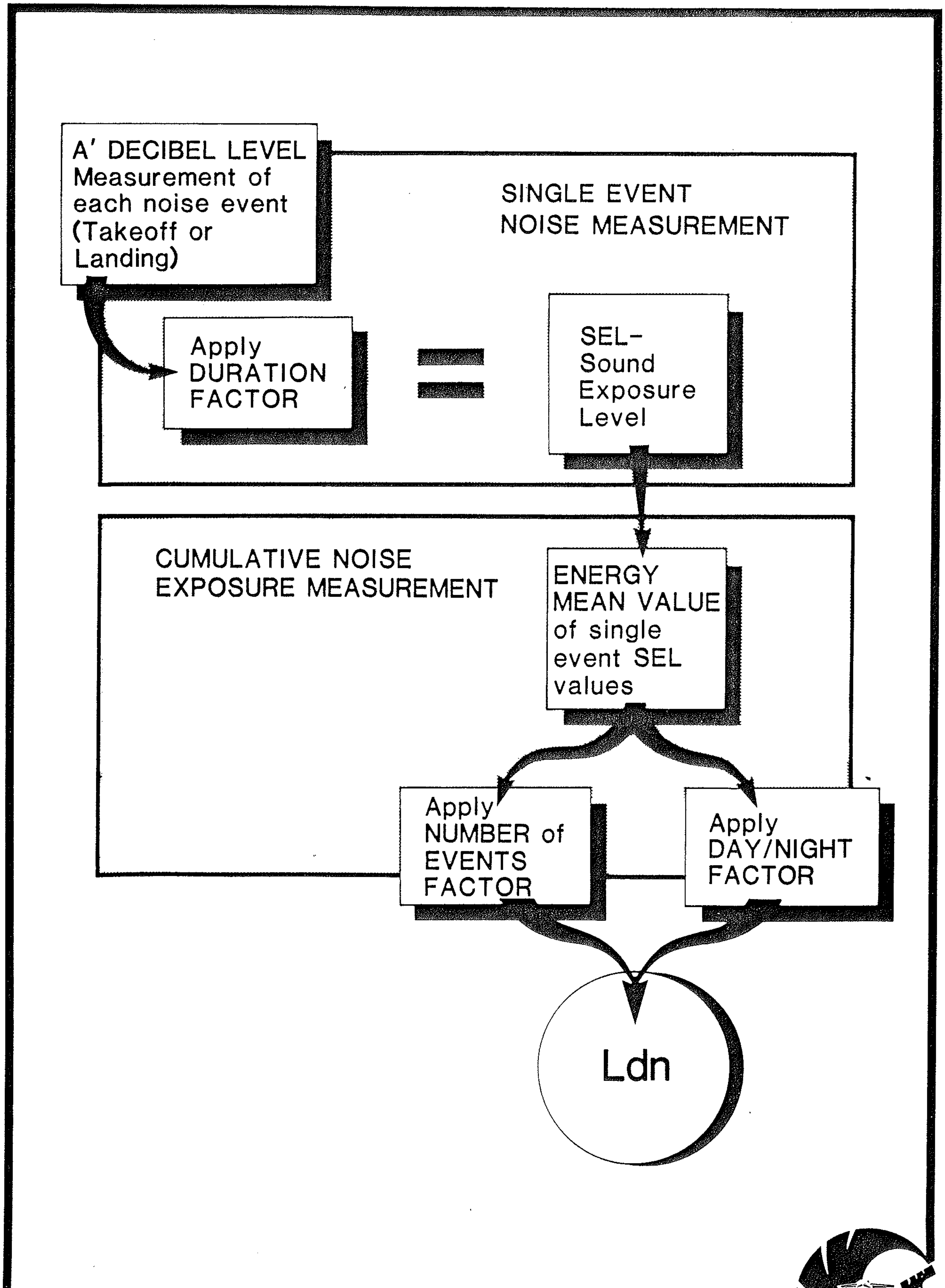


Exhibit 2A
DAY-NIGHT SOUND LEVEL
METHOD OF CALCULATION

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where LA is the time varying A-weighted sound level, measured with equipment meeting the requirements for sound level meters (as specified in a standard such as ANSI S1.4- 1971) and dt is the duration time in seconds. The averaging constant 86,400 is the number of seconds in a day. The integrals are taken over the daytime (0700-2200) and nighttime (2200-0700) periods respectively. If the sound level is sampled at a rate of once per second rather than measured continuously, the equations still apply if the level samples replace LA and the integrals are changed to summations.

Where the basic element of sound measurement is the hourly equivalent sound level (Leq), Ldn is calculated from:

$$Ldn = 10 \text{ Log } \frac{1}{24}\left(\sum_{d=1}^{15} 10^{[Leq(d)]/10} + \sum_{n=1}^{9} 10^{[Leq(n)+10]/10} \right)$$

where Leq (d) and Leq (n) are the daytime and nighttime hourly Leq values. This expression is convenient where Leq values for only one hour or a few hours are available and the values for the remainder of the 24-hour day can be predicted from a knowledge of day/night variation in levels. This methodology is applied in this study to the prediction of ambient noise, while the previous formula was used in the noise monitoring equipment to calculate aircraft noise exposure levels.

NOISE CONTOURS

Ldn noise levels are indicated by a series of contour lines connecting points of equal Ldn values and superimposed on a map of the airport and its environs. These levels are calculated for designated points on the ground from the weighted summation of the effects of all aircraft operations. Some operations are far enough away from the location that their effect is minimal, while other operations may dominate noise exposure at that location.

This summation of noise levels is made on an energy basis. One might think of this accumulation of noise energy from passing aircraft in the same way as a series of passing rain showers. Each shower would produce an amount of rain in direct proportion to the degree of acoustical energy produced by the passing aircraft. At the end of a 24-hour period, a measurement would indicate the total rainfall received during that period although the rain fell only during brief periods. Therefore, a graph of aircraft noise energy accumulation would show a peak burst of energy with the passing of each aircraft and a period of no aircraft noise energy between these events. These bursts are then superimposed upon a graph of ambient noise levels to yield a graph of the total noise pattern. Exhibit 2B illustrates this concept.

The Ldn level represents the average noise energy, expressed in decibels, during an average second, received at a given location during the total time considered. Each peak represents the passing of an aircraft while the baseline represents the background or ambient noise present at the location. When aircraft noise contours are calculated, however, the noise levels are solely due to aircraft and do not include background noise.

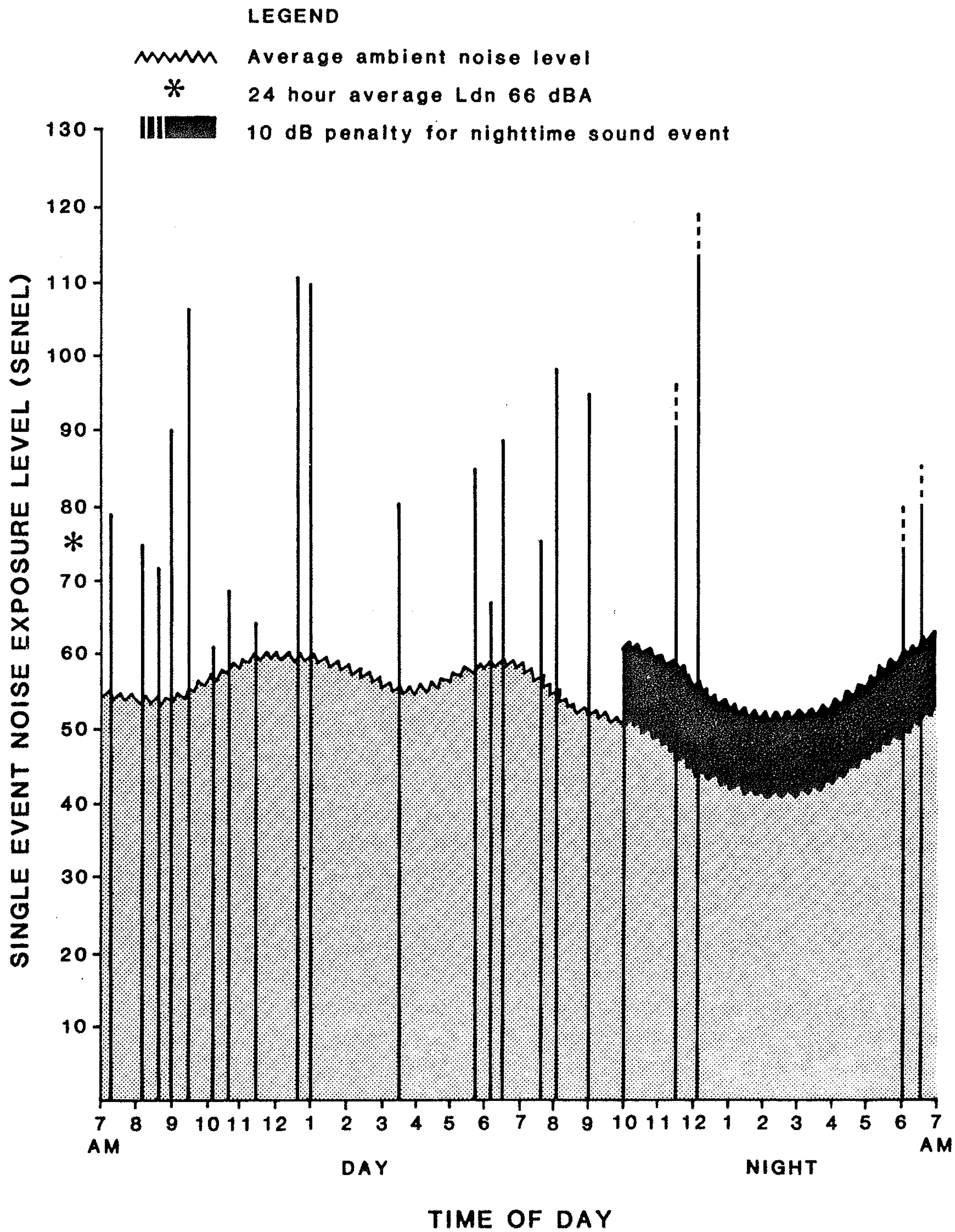


Exhibit 2B
TYPICAL NOISE-PATTERN
OF LDN SUMMATION METHODOLOGY

Sky Harbor International Airport

Ldn contour mapping will be used, during the course of this study, as a tool to assist in the preparation of recommendations for land use planning around the airport. The mapping is best used for comparative purposes, rather than for providing absolute values. That is, Ldn calculations provide valid comparisons between different conditions, so long as consistent assumptions and basic data are used for all calculations. Thus, sets of Ldn calculations can show which of a series of simulated situations is better--and generally how much better--from a noise impact viewpoint. However, a fine ink line drawn on a map does not imply that a particular noise condition exists on one side of the line and not on the other. Ldn contour maps are a means of comparing average noise impacts, not precisely defining impacts at specific locations at specific times.

It should be reiterated that, in Part 150 studies, Ldn contours are presented for annual average conditions. Consequently, the contours will tend to understate noise exposure levels associated with peak periods and overstate levels during slow activity periods. These variations, however, are not as significant as might be expected. The logarithmic nature of noise results in several rules of thumb which are useful to remember throughout the evaluation process:

- To increase (or decrease) actual noise levels by ten decibels (Ldn, Leq, SEL, etc.) the energy level must be changed by a factor of ten. Restated, for the average noise created by ten operations to increase by ten decibels, 100 operations of the same type must occur.

- An increase of 10 decibels will be perceived (heard) as a relative doubling of the noise level.

- One nighttime operation is considered equal in impact to ten daytime operations by the same aircraft. A 10 dB penalty is assessed for late night noise events in the Ldn methodology to account for this effect.

- A doubling of operations will result in an average three decibel noise increase if by the same aircraft.

- Arrivals are generally quieter than departures because they require less engine thrust.

In summary, Ldn contours can be used to (1) highlight an existing or potential aircraft noise problem that requires mitigation; (2) assess relative exposure levels of various noise abatement alternatives; (3) assist in the preparation of airport environs land use plans; and (4) provide guidance in the development of land use control devices, such as zoning ordinances, subdivision regulations, and building codes. They are not, however absolute definitions which reflect every conceivable operating condition. They represent typical conditions for planning purposes.

AIRCRAFT NOISE CALIBRATION MEASUREMENT PROGRAM

A calibration noise measurement program was conducted around the Phoenix Sky Harbor International Airport during a two-week period of late February and early March 1987. This field measurement program was designed to gather information related to specific noise levels associated with individual aircraft overflights. The collection of these single event levels assisted the calibration of the computer model to accurately represent local conditions.

For aircraft noise, the measurement program is designed to obtain aircraft noise measurements throughout the area of anticipated impact. This information includes the acoustical output, as measured at known locations, and the flight trajectory (ground track and altitude profile). These data are analyzed to estimate sound exposure level (SEL) values for distances from the measurement site to the noise source to compare with standardized data that are included in the model.

The basic goals of the aircraft noise measurement program are to assure, as thoroughly as possible, the accuracy of the computer-generated predictions of the noise environment created by aircraft using the airport. At Sky Harbor, aircraft noise measurements were collected both east and west of the airport under the primary routes of flight.

Since field measurements made over a short period are applicable only to that one period of time and may not--in fact in many cases, do not--reflect the average conditions present at the site, a series of validation measurements were collected during late March and early April of 1987. These validation measurements will be presented later in this chapter and compared to noise exposure contours for existing conditions. The relationship between field measurements and computer-generated noise exposure forecasts is analogous to the relationship between weather and climate. While an area may be characterized as having a moderate climate, many individual days of temperature extremes may occur. In other words, the modeling process simulates overall average annual conditions (climate), while field measurements reflect daily fluctuations (weather). The ten-day validation measurements should provide a more accurate assessment of average conditions, while calibration measurements are conducted to collect data on the noise levels generated by individual aircraft events.

In addition to aircraft noise measurements, sample measurements of other transportation and ambient noise sources were also collected. These background measurements are detailed in Chapter Four.

AIRCRAFT NOISE MEASUREMENT SITES

The selection of general locations for aircraft noise measurement was made early during the study and was presented to the study's Planning Advisory Committee and to the general public during a public information workshop. General sites were selected on the basis of background information, historical noise complaint locations, the locations of previous noise contours and local observation during the field effort. Exhibit 2C indicates the distribution of noise complaints (by zip code of complainant) for the year 1986. The complaint distribution indicates a high frequency of complaint in the Tempe area and suggests the placement of several sites in the area of greatest complaint. Specific sites were suggested by volunteers from among the Advisory Committee membership and members of the public. Specific selection criteria include the following:

- Emphasis on areas of numerous aircraft noise events according to earlier evaluations; less emphasis on areas further from the airport since these have greater variation in aircraft operation and exposure.
- Representative sampling of all major types of operations and aircraft using Phoenix Sky Harbor International Airport.

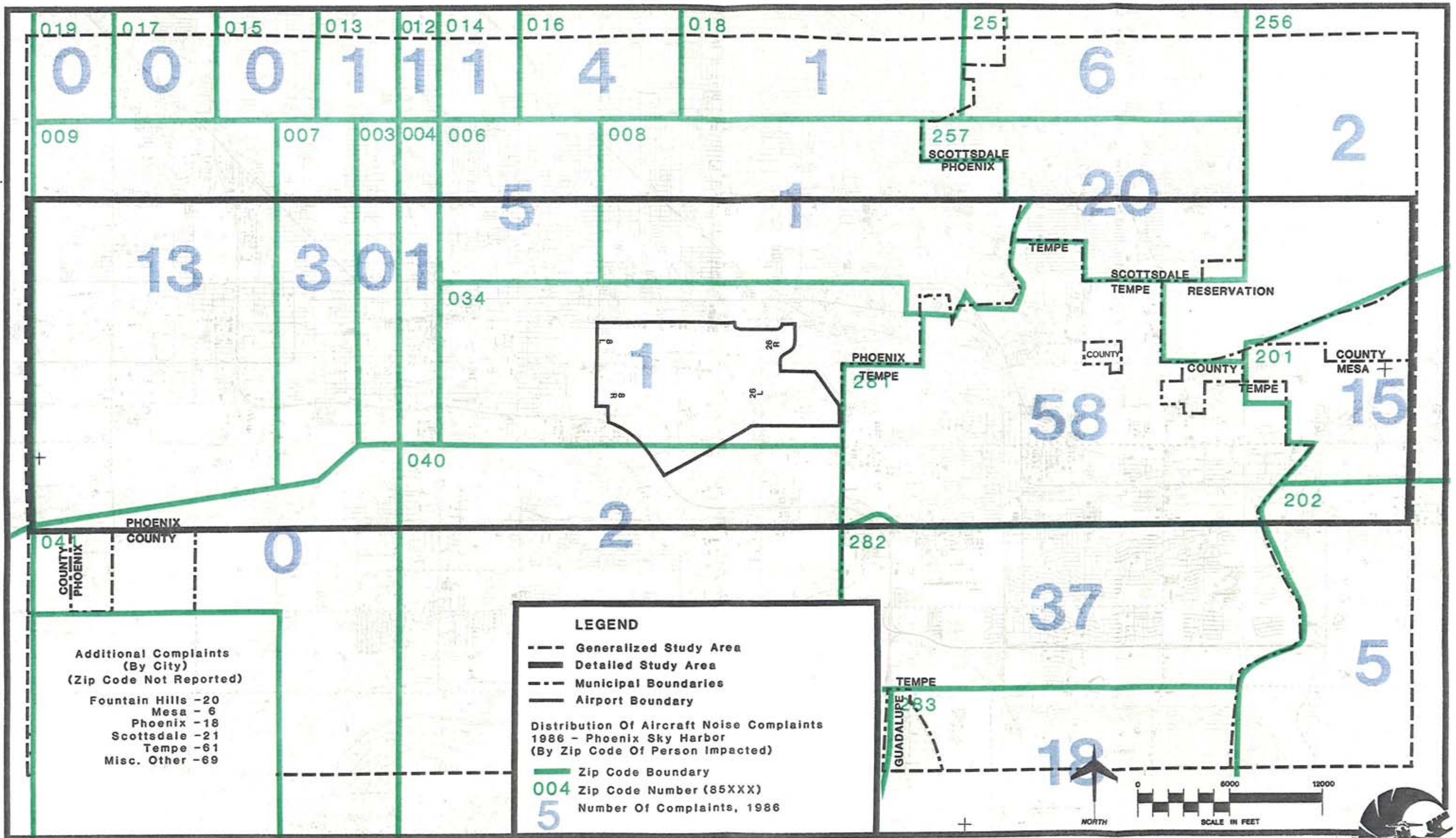


Exhibit 2C
DISTRIBUTION OF AIRCRAFT
NOISE COMPLAINTS

Sky Harbor
INTERNATIONAL AIRPORT

- Screening of each site for local noise sources or unusual terrain characteristics which could affect measurements.

- Location in or near areas from which complaints about aircraft noise were received, or where there are concentrations of people exposed to numerous aircraft overflights.

While there is no end to the number of locations available for monitoring, the selected sites, as shown on Exhibit 2D and individually discussed in the following paragraphs, fulfill the above criteria and provide a representative sampling of the noise levels associated with the principal types of aircraft using the airport.

Site A-1 is located at the Salt River VOR facility, approximately six miles east of the airport on the extended centerline of Runway 8R. The site is adjacent to the Salt River and the terrain around the site is generally clear of obstructions. The location was exposed to both approach and departure traffic during the measurement period. The location was set up at noon on February 23, 1987.

Site A-2 was located in southern Scottsdale at 8604 E. Diamond. The site is 5 3/4 miles east of Runway 8L, approximately 1 1/2 miles north of the runway's extended centerline. The site is situated on a cul-de-sac in a medium density residential area (five to eight homes per acre). Approach and departure traffic were observed south of the site. Vehicular traffic levels in the area were observed to be light. The location was set up at 12:30 p.m. on February 23, 1987.

Site A-3 was located near the Rio Salado NDB at the intersection of Scottsdale and Curry Roads. The site is 3 1/2 miles east of the airport near the extended centerline of Runway 8L. The location of the monitor was in a multi-family, high density housing area. The microphone was elevated above an auto shelter. During set up and monitoring, numerous aircraft were observed departing over the measurement location. The site was established at 1:00 p.m. on February 23, 1987. A second set of measurements were collected at the site on February 26-27, 1987 to supplement measurements which might have been (but did not prove to be) partially rain effected.

Site A-4 was established at the Pueblo Grande Museum at 1:30 p.m. on February 23, 1987. The museum is located near the intersection of Washington Avenue and the Hohokam Expressway, approximately 1/2 mile east of Runway 8L and 1/2 mile north of the runway centerline. The microphone was set up on the south side of the museum in an area outside the protecting walls of the building. Vacant land lies to the south, east and west of the site. The site received noise events from arrivals (both final descent and reverse thrust from the east) and departures (lift off to the east and initiation of take-off roll to the west).

Site A-5 was established at 1621 S. Cedar, Tempe, on the morning of February 24, 1987. Light rain was falling at the time of set up. The site is located 4 3/4 miles east of Runway 8R, approximately 1 1/4 miles south of the extended Runway centerline. The character of the area is single-family residential use, the location is on a dead-end street. Rail tracks are located south of the site.

Site A-6 was located in a high-density apartment complex at 602 North May Street in Mesa. The site was initially established on February 24, but the measurements were lost due to equipment mal-function, so the site was re-established on the following day. Aircraft were observed on approach directly north of the site during set up of the equipment.

Site A-7 was located at a residence in the 1400 block of West 6th Street in Tempe. The site is located 1 3/4 miles east and approximately 1/2 mile south of the extended centerline of Runway 8R. Aircraft were observed north of the site when departing to the east. The microphone was placed in the rear yard, away from influences by vehicular traffic. Moderate rain fell during the measurement period.

Site A-8 was located at the Porter Construction Company offices on West Lincoln in Phoenix. The site is approximately 4 1/2 miles west and 1/2 mile north of Runway 8L in an industrial-commercial area. The site was established on February 24, 1987. Although there appeared to be little yard activity, work crews loaded sheet metal onto a truck during the measurement period and heavy truck traffic in the alley made the resultant measurements impossible to decipher. Consequently, the equipment was relocated on the site and new measurements were taken on March 3-4, 1987 to obtain data useful to the evaluation process.

Site A-9 was located in the 3200 block of West Pima Street in Phoenix. The site is six miles west of Runway 8R, approximately 1/4 mile north of the centerline, in a low-density single family area. Light rain was falling when the site was established on February 24, 1987. The site is located under the primary approach to Runway 8R and under the departure path for all traffic using a Standard Instrument Departure from Runway 26R/L.

Site A-10 is situated at the Fort Knox Mini-Storage facility, 1964 E. University, in Tempe. It is located 5 1/4 miles east and 1/2 mile south of the centerline of Runway 8R. The equipment was located on the roof of the facility on the morning of February 25, 1987. Intermittent rainfall occurred on the first day of the measurement period.

Site A-11 is located in the 7500 block of McKinley Street in Scottsdale. The site is four miles east and approximately 1 1/4 miles north of the extended centerline of Runway 8L. It lies in a medium-density residential area. The initial measurements, collected February 24-25, were contaminated by rainfall, and replacement measurements were collected March 3-4, 1987.

Site A-12 was located 2 1/4 miles west and under the centerline of the approach to Runway 8R. The site is a home in a medium-density (four to five units per acre) residential area. Ground traffic in the area consisted of mixed private and commercial vehicles. Light rain fell on the first day of measurement (February 25) but had dispersed by the second day. Supplemental measurements were made at the location on March 3-4, 1987 to assure the validity of collected approach noise measurements.

Site A-13 was located at Mohave Avenue and 17th Street, Phoenix, in the WALA project. It is one mile west of the end of Runway 8R on centerline. The area was recognized as noise-impacted and has been purchased for redevelopment by the airport. Due to the unavailability of a secure location at the site, the equipment was personally monitored for approximately eight hours on February 25 and 26, with all aircraft overflying the site noted.

Site A-14 was located atop a building at 12th Street and Monroe in Phoenix. The site is 1 3/4 miles west and 3/4 miles north of the extended centerline of Runway 26R. The area is in mixed civic and residential land uses. The site was set up on February 26, 1987.

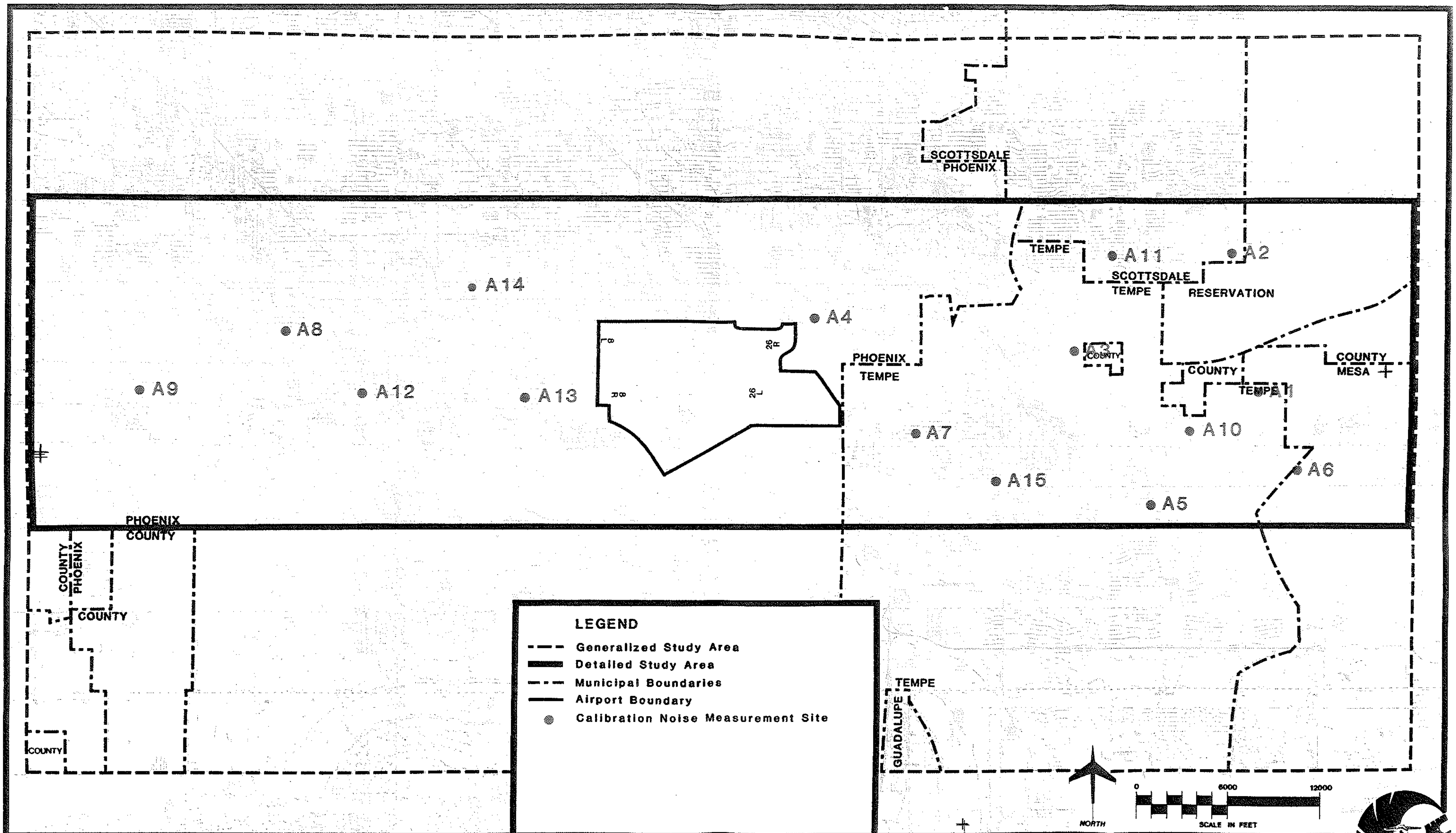


Exhibit 2D
CALIBRATION NOISE
MEASUREMENT SITES

Sky Harbor
INTERNATIONAL AIRPORT

Site A-15 was located in the 1200 block of South Farmer Street in Tempe. The site is three miles east of Runway 8R, and approximately one mile south of the runway's centerline. It lies in a medium density single family residential with intermixed multi-family units. The site was established during clear weather on February 26, 1987.

SOUND PROPAGATION EFFECTS

For noise produced by an aircraft, the surrounding terrain can affect the sound level received at a point on the ground in two ways. First, the altitude of the aircraft above the ground level is partly a function of topography, and the level of sound is affected by the distance sound travels from the aircraft to the ground position. Thus, an elevated site would receive a higher level of noise than would a similar site at the airport's elevation. Although minor variations in topography will have some small effect on noise levels at specific sites, the relatively flat topography around the airport allows the elimination of elevation as a major noise factor in these evaluations.

The second effect is the loss of energy as sound travels over, and more or less parallel to, the ground. This is called the ground effect and depends on the type of ground cover and the angle of sight between the aircraft and the measurement position. When this angle becomes appreciable (approximately 10 degrees or more) the ground effect is not significant, since the propagation path is well above and not parallel with the ground.

Additionally, energy is lost through molecular processes as sound disperses in the air. The amount of loss is proportional to the distance traveled and is a function of temperature, relative humidity, and air density. Loss associated with the varying densities of air at various temperatures are automatically accounted for by the model used to calculate noise exposure levels. The model is incapable of adjusting for varied relative humidities. Air pressure changes associated with weather systems are ignored, but pressures associated with both airport elevation and average annual temperature are accounted for.

The propagation of sound is further affected by wind and temperature gradients, especially over long distances. Either of these can cause an increase or decrease in sound levels at a given point at certain times. This is due to the refraction of sound causing concentration and/or dispersion of energy at different locations. To assure that baseline comparative data were not unduly affected by abnormal conditions, field measurements were collected at several sites during both fair and inclement conditions. Abnormal conditions may, on occasion, cause unusually high noise levels in some parts of the community. However, the effects of such phenomena, like overall noise exposure levels, tend to average out in the course of a year.

ACOUSTICAL MEASUREMENTS

This section provides a technical description of the acoustical measurements which were performed for the Phoenix Sky Harbor Part 150 Noise Compatibility Study. Described here are the instrumentation which was employed, calibration procedures, general measurement procedures followed, and related data collection items and procedures.

Instrumentation

Five sets of acoustical instrumentation and analysis equipment were employed in order to obtain acoustical data to compare with standard and predicted data associated with aircraft noise. All noise measurement equipment used for this study complies with applicable requirements of the American National Standards Institute (ANSI) and the International Electrotechnical Commission (IEC) for Type I precision sound level meters. The major instrumentation which was utilized for these purposes is given in Table 2A.

The field measurement instrumentation basically consisted of a high quality microphone connected to a 24-hour environmental noise monitor unit. Each unit was calibrated before and after measurement to assure consistency between measurements at different locations. A GenRad Permissable Sound Level Calibrator, with an accuracy of within 0.7 decibels was used for all calibrations. At the completion of each field measurement, the accumulated output data were printed on a portable printer and the data memories were cleared before placement at a new site.

The equipment indicated in the table was supplemented by accessory cabling, windscreens, tripods, security devices, etc., as appropriate to each measurement site.

TABLE 2A
Acoustical Measurement Instrumentation

5 Metrosonics db-604 Portable Noise Monitors
5 GenRad Type 1962-9610 1/2" Electret-condenser Microphones
5 GenRad Type 1560-P42 Preamplifier Assemblies
1 GenRad GR1562 Permissable Sound Level Calibrator
1 Metrosonics dP-421 Portable Printer

Measurement Procedures

Noise from aircraft overflights was recorded using the equipment indicated in Table 2A at each of the fifteen sites shown on Exhibit 2D. During a large portion of the time measurements were made in the field, technicians were stationed in the FAA radar room. The technicians placed clear acetate over a radar screen and traced the track of each flight of interest, also recording on the acetate altitude information for each flight. A detailed log of these flights was maintained, including time, flight number, aircraft type, runway used and SID used. During a portion of the period, similar logs were maintained by measurement personnel in the field to obtain supplemental flight and noise information.

The noise monitor was programmed to provide an analysis of all significantly loud single events and to accumulate and analyze all noise received at the site. Two methods were used to minimize the potential for nonaircraft noise sources to unduly influence the results of the single-event measurements. First, a minimum noise threshold of 70 dB was selected. Second, a minimum event duration of three seconds of noise greater than 70 dB was programmed. The combination of these two thresholds limited the single events analyzed in detail to those which exceeded the preset threshold for longer than the preset duration. Field experience has indicated that this combination screens out most nonaircraft noise events and limits the data collected to aircraft overflights. The only identifiable events which exceeded both the loudness and duration thresholds, and were not aircraft events, were associated with heavy truck traffic, trains and a rainstorm.

Weather Information

The calibration measurement program was originally planned for a single week during late February of 1987. After completion of a portion of the program, rains moved into the Phoenix area and lasted for three days. Measurements continued during the week, but the program was expanded to provide remeasurement of those sites significantly effected by the rains, as well as comparative measurements at sites not effected by rain. The remeasurement was conducted late in the week or during the following week after the weather had cleared. Calibration noise measurements taken during this study were obtained during a period of cool weather conditions with temperatures below the average annual temperature for Phoenix. Where rain affected measurements, those measurements were deleted and the sites were retested. There were also many measurements taken with overcast sky conditions. The general weather pattern varied throughout the measurement period, with wind shifts providing operations to both the east and the west. Information pertaining to weather conditions during the calibration measurement period is included in Table 2B.

Summary of Site Measurements

General noise data collected during the measurement period are presented in Table 2C. The information includes, for the fifteen sites, measured SEL values for the B-737-100/200 and the B-727. These two aircraft accounted for more than 75 percent of the jet air carrier operations in 1986. The information includes the mean measured noise level for each aircraft at each location (where available) and the range of measured noise levels for each. For comparative purposes, ordinary conversation is normally heard at a sound level of 60 decibels and the noise of a busy street is approximately 80 decibels.

TABLE 2B
Measurement Program Weather Summary

Date	High/Low Temperature	Typical Sky Condition
2/23/87	67/45	Clear
2/24/87	53/40	Rain
2/25/87	47/40	Rain
2/26/87	59/44	Overcast
2/27/87	61/38	Clear
3/3/87	80/47	Clear
3/4/87	85/52	Overcast

Source: National Weather Service
Phoenix Sky Harbor International Airport

The information provided in Table 2C indicates only the summary ranges of noise levels associated with the two indicated aircraft at the various sites. It does not set noise curves for either aircraft type. The comparison of the collected noise levels to data in the noise model's computer data base is readdressed later in this chapter.

TABLE 2C
Aircraft/Site Noise Measurements
Phoenix Part 150 Study

		727-100/200				737-100/200			
Site*		N	Mean SEL	Low	High	N	Mean SEL	Low	High
A-1	D	13	94.5	76.1	97.8	22	89.2	76.4	92.6
A-2	D	9	93.6	77.9	100.9	15	88.2	79.4	92.3
A-3	D	17	100.5	92.9	106.5	37	94.5	80.0	103.9
	A	7	85.1	78.8	89.3	4	86.3	84.6	89.0
A-4	D	12	103.9	90.3	107.4	17	97.9	80.3	107.2
	A	5	84.9	80.9	88.3	7	85.0	78.6	88.4
A-5	D	4	85.6	77.6	87.0	3	87.2	83.2	90.0
A-6	D	5	93.3	79.3	97.6	14	91.3	78.2	96.2
A-7	D	8	85.9	80.4	90.5	15	86.1	79.4	90.1
A-8	D	7	96.9	86.6	101.4	--	ID	ID	ID
	A	3	88.0	87.3	88.7	6	88.0	79.8	91.5
A-9	A	-	ID	ID	ID	3	83.2	80.5	84.9
	D	3	90.9	88.7	92.4	--	ID	ID	ID
A-10	D	4	90.5	87.6	93.6	5	88.7	85.6	90.5
A-11	D	3	83.2	78.9	85.3	4	81.3	76.4	85.6
A-12	A	9	92.4	88.9	95.5	57	88.2	80.3	100.1
A-13	A	4	101.0	98.4	103.1	37	97.1	83.5	102.7
A-14	D	-	ID	ID	ID	9	85.8	79.4	89.0
A-15	D	7	82.0	75.6	86.1	6	81.7	78.0	84.1

N = number of samples
A = approach traffic D = departure traffic
ID = insufficient number of events identified to generate means
* sites previously described

ANALYSIS OF AIRCRAFT NOISE

Although a computer model was used to determine noise exposure related to aircraft operations at Phoenix Sky Harbor International Airport, its data base was checked and calibrated as a result of the noise measurement program. After contours of noise exposure were developed, field measurements were again conducted to verify the accuracy of the model in predicting noise for the local situation. The use of a computerized overflight noise prediction model is necessitated in Part 150 studies because noise impacts are generally more closely correlated with prevailing long-term noise conditions rather than occasional events and seasonal fluctuations. To attempt to measure prevailing noise levels directly would require months of measurements at numerous noise monitor sites in ever-changing conditions, an impractical, more-expensive, and potentially less accurate method of determination when attempting to deal with noise issues which are in need of immediate attention.

INTEGRATED NOISE MODEL

The Integrated Noise Model, Version 3.8, was used for Ldn contour calculations in this analysis. The Integrated Noise Model (INM) was developed by the Transportation Systems Center of the U.S. Department of Transportation at Cambridge, Massachusetts, and has been specified by the Federal Aviation Administration as one of two models acceptable for FAA-funded Part 150 noise studies. It is a computer model which, during an average 24-hour period at an airport, accounts for each aircraft flight along flight tracks defined as straight-line or curved segments. These flight tracks are coupled with separate tables in the data base relating to the noise, slant range distances, and engine thrust for each distinct aircraft type selected.

Briefly, this is how the model works: at irregular grid locations at ground level around the airport, the distance to each flight track is selected, and the associated noise exposure level is computed for each specific aircraft type and engine thrust level used along the flight track. Additional corrections are applied for excess air-to-ground acoustical attenuation, acoustical shielding of the aircraft engines by the aircraft itself, and speed variations. The individual noise exposure levels for each individual aircraft are then summed for each grid location. A nighttime penalty (equivalent to increasing night operations by a factor of ten) for increased annoyance is added to flights occurring between 10:00 p.m. and 7:00 a.m. The cumulative values of noise exposure at each grid location are then used to interpolate equal noise exposure contours for preselected Ldn values, (i.e. Ldn 65, Ldn 70, etc.).

INM PROGRAM INPUT

To use the Integrated Noise Model, a variety of user-supplied input data is required. These include a mathematical definition of the airport runways relative to a base reference point, the mathematical description of ground tracks above which aircraft fly, and the assignment of specific aircraft with specific engine types to individual flight tracks. Optionally, the user may adjust standard data base information to reflect locally applicable departure and approach altitude/distance profiles and noise curves. Additionally, aircraft not included in the model's data base may be defined for modeling. A discussion of the input data used to prepare the noise exposure contours for the airport is provided in the following sections.

Operational Forecasts

Part 150 of the Federal Aviation Regulations, which provides the guidance for the preparation of Noise Exposure Maps and Noise Compatibility Programs at our nation's airports, calls for the preparation of two separate maps showing aircraft noise exposure. These noise exposure contour exhibits are required to be representative of the airport's noise exposure during the year of submission (in this case, 1987) and for the fifth year following the year of submission (1992).

The Noise Compatibility Program to abate aircraft noise exposure impacts, prepared after the official Noise Exposure Maps, may affect noise-sensitive areas far beyond the five-year period. Consequently, projections of unabated noise contours for the years 1997 and 2007 also will be prepared. These longer-term evaluations will help assure that short-term solutions which reduce noise exposure will not, in the long run, increase that exposure. The present forecasts of aircraft operations (take-offs and landings) for Sky Harbor International Airport have been assessed with these needs in mind.

Prior to beginning the Part 150 study, it was agreed by the study sponsors and the consultant that the forecasts would be prepared as follows:

The Part 150 Study will utilize the air traffic activity (passenger, air carrier, and fleet mix) as shown in the Drover, Welch, and Lindlan Study (1985), amended by calendar 1986 actual data. The consultant will adjust the DWL projections for 1990, 1995, and 2000 by an amount equal to the difference in the 1986 actual data and the DWL 1986 forecast data. The forecast for 1992 and 1997 will be by direct extrapolation from the DWL estimates for 1990 and 1995, as amended pursuant to the preceding sentences. The estimate of air traffic activity for 2007 will be a direct extrapolation from the DWL amended estimate for the year 2000.

Develop forecasts for cargo operations as well as fleet mix associated with those activities for 1992, 1997, and 2007. In addition, utilizing the May 1986 Maricopa Association of Governments (MAG) Regional Airports Systems Plan (RASP), expand the general aviation forecasts of operations and fleet mix to include the years 1992, 1997, and 2007.

An evaluation of the aviation activity forecasts previously prepared for Sky Harbor International Airport has been conducted to evaluate their usability for the development of aircraft noise contours for the years 1987, 1992, 1997, and 2007. While the present forecasts are useful for a broader overview of the future operational levels which may be expected at the airport, they do not provide all of the data necessary to portray conditions within the vicinity of the airport. This section provides a validation or update of the present forecasts and a greater level of detail to meet the needs of the Part 150 Noise Compatibility study effort.

The critical parameters in noise contour development are numbers of operations and fleet mix, primarily within the user groups which operate turbine-powered aircraft, since these aircraft are the major source of aircraft noise at Sky Harbor International Airport. Measures of operational activity that are most critical to the Part 150 Study include:

- **Air Carrier** Operations
- **Commuter** Operations
- **Air Taxi** Operations
- **Cargo** Operations
- **Military** Operations
- **General Aviation** Operations

- ENPLANED PASSENGERS

The number of persons expected to use commercial aircraft operating from the airport is the principal determinant of both the number of operations and the type of aircraft used. The DWL forecasts for enplaned passengers on scheduled air carrier flights were, for the year 1986, approximately 538,200 persons high. For the purposes of this study, the DWL forecasts for future years were adjusted downward by that amount to represent estimates of future enplaned passenger levels. Beyond the end date (year 2000) of the DWL forecasts, growth in enplaned passengers was projected at 5.5 percent annually. The Part 150 and DWL enplaned passenger forecasts are presented in Table 2D.

TABLE 2D
Enplaned Passenger Forecasts
Scheduled Air Carrier Service
(in Thousands)

	Forecast Source	
	DWL	Part 150
1986	7,167.2	6,626.0 actual
1987	7,797.9	7,259.7
1992	11,498.2	10,960.0
1997	15,677.8	15,139.6
2007	26,780.0	26,241.8

- COMMERCIAL SERVICE FORECASTS

Commercial service activity at Sky Harbor International Airport includes certificated and commuter airlines. The 1985 DWL study outlined a set of operational forecasts for the air carriers and commuters at Sky Harbor International Airport. The listing of airlines shown in Table 2E represents the operators which served Sky Harbor during 1986.

TABLE 2E
Air Carriers and Commuters (1986)

Air Carriers	Commuters
Alaska Airlines	Air L.A.
America West	American Eagle
American Airlines	Golden Pacific
Braniff	Havasu Airlines
Continental	Mesa Air
Delta	Western Express
Eastern	
Frontier	
McLain Airlines	
Northwest	
PSA	
Republic	
Southwest	
States West	
TWA	
United	
US Air	
Western	

Table 2F shows the historical growth of airline activity from 1974 through 1986. For 1986, DWL had projected the air carriers operations to be 226,269 or 1,839 above the actual 224,430 operations. DWL had forecast commuter operations to be 26,655 in 1986. Actual commuter operations were 28,684, or 2,029 above the projected level. In total, the DWL air carrier/commuter operations forecast were 190 operations (or .07 percent) lower than the actual 1986 operations. As mentioned previously, for purposes of the Part 150 Study, the DWL forecasts have been adjusted by the difference in the 1986 actual data. The Part 150 forecasts are shown in Table 2G.

TABLE 2F
Historical Air Carrier and Commuter Operations

	Air Carrier	Commuters
1974	84,168	9,230
1975	87,530	9,090
1976	90,458	10,137
1977	95,698	15,308
1978	101,278	16,921
1979	113,528	15,086
1980	117,338	21,046
1981	108,868	22,668
1982	135,990	17,468
1983	150,916	17,597
1984	191,494	22,848
1985	202,890	25,868
1986	224,430	28,684

TABLE 2G
Part 150 Forecasts
Air Carrier and Commuter Operations

	Air Carrier	Commuter
1986 *actual*	224,430	28,684
1987	232,802	29,670
1992	278,460	35,048
1997	331,068	41,246
2007	467,759	57,348

- AIR TAXI OPERATIONS

The air taxi operations at Sky Harbor include the charter operations run by the Fixed Based Operators (FBO's) on the airport, as well as charter aircraft flown to the airport from other parts of the county. They also include other commercial operators such as the emergency medical transport aircraft used throughout the metropolitan area and the state of Arizona. The air taxi operations at Sky Harbor for 1986 totaled 24,522, and are comprised primarily of general aviation aircraft. (i.e., single engine, twin engine, helicopters, and small business jets). The forecasts used for the operations parallel the growth in the air carrier and commuter operations. While general aviation operations at the airport are declining as a whole, these commercial operations are expected to increase at a rate of 3.7 percent per year through 1990 and 3.5 percent annually between 1991 and 2007. The forecast of air taxi operations is shown in Table 2H.

TABLE 2H
Forecast Air Taxi Operations

1986 *actual*	24,522
1987	25,429
1992	30,482
1997	36,190
2007	51,050

- AIR CARGO OPERATIONS

Air Cargo operations currently account for approximately two percent of the total operations at Sky Harbor. These operations represent cargo operations such as Federal Express, Emery, and UPS. The cargo operators provide for freight and small package shipment, while mail is handled primarily by the scheduled air carriers. Table 2I represents the historical growth in enplaned freight at Sky Harbor.

TABLE 2I
Historical Freight/Express Enplaned Tons

1965	3,279
1970	7,477
1975	11,409
1980	14,435
1984	16,477

The FAA recently produced forecasts for the growth of air freight for Phoenix Sky Harbor. In the **FAA Aviation Forecasts - Phoenix, October 1986** it was projected that air freight will grow at the following rates: 6.0 percent until 1990; 5.0 percent from 1991 until 1995; 4.5 percent from 1996 until 2000. It has been estimated that it will then grow at a rate of 4.0 percent until 2007. In 1986 there were 18,480 tons of freight enplaned at Sky Harbor International Airport. Of the total, 10,349 tons (or 56 percent) were enplaned by cargo operators. The amount of freight enplaned by the cargo operators is expected to increase to 70 percent of the total by 2007. It is anticipated that the mail will still be hauled primarily by the air carriers. Forecasts of total enplaned freight and freight enplaned by the cargo operators is shown in Table 2J.

TABLE 2J
Sky Harbor International Airport Cargo Forecasts - Freight Only

	Total Freight Enplaned Tons	Cargo Operators Enplaned Tons	Percent of Total
1986 actual	18,480	10,349	56.0%
1987	19,600	11,113	56.7%
1992	25,800	15,480	60.0%
1997	32,700	20,699	63.3%
2007	49,100	33,840	70.0%

In 1986, the cargo operators averaged approximately 2.5 tons of enplaned freight per departure. The aircraft used range from small turboprop aircraft to the larger B-727 and DC9 jet aircraft. By the year 2007, it is expected that the average tons per departure will increase due primarily to the use of larger more efficient aircraft by the cargo operators. The forecast of total cargo operations is shown in Table 2K.

TABLE 2K
Sky Harbor Forecast Cargo Operations

	Enplaned Freight Tons	Average Tons Per Departure	Total Departures	Total Operations
1986 actual	10,349	2.5	4,158	8,316
1987	11,113	2.6	4,274	8,548
1992	15,480	2.9	5,338	10,676
1997	20,699	3.3	6,272	12,544
2007	33,840	4.0	8,460	16,920

- MILITARY OPERATIONS

Since 1978, military operations have remained relatively stable at Sky Harbor, averaging approximately 8,000 operations per year. The Arizona Air National Guard, which bases their KC-135's at Sky Harbor, accounted for 160 operations per month or approximately 2,000 of the total 7,597 military operations recorded in 1986. The remaining operations consists of a wide spectrum of military aircraft ranging from the Huey Cobre helicopters to the large C-130 transport aircraft. These aircraft are not based at Sky Harbor, but instead are transient aircraft passing through the area. Conversations with military representatives indicate that the forecasts for military operations are expected to remain the same for the foreseeable future. Table 2L illustrates the historical and forecast military operations at Sky Harbor.

TABLE 2L
Historical and Forecast Military Operations - Sky Harbor

HISTORICAL		FORECAST	
Year	Total	Year	Total
1978	8,480	1987	8,000
1980	7,301	1992	8,000
1982	8,747	1997	8,000
1984	7,986	2007	8,000
1986	7,957		

- GENERAL AVIATION OPERATIONS

In 1986, a Regional Airport System Plan (RASP) was completed and approved by the Maricopa Association of Governments (MAG). As a part of the RASP, general aviation forecasts were developed for Sky Harbor International Airport and will be used for this study. As could be expected, general aviation activity at Sky Harbor has steadily decreased since 1975, primarily due to the economy but also as a result of the increase in air carrier activity at the airport. It is expected that this decrease will continue throughout the forecast period as the smaller, locally-based general aviation aircraft relocate to outlying airports and as transient general aviation aircraft utilize other airports to avoid delays at Sky Harbor. Table 2M shows the historical general aviation operations at Sky Harbor International Airport since 1973. Table 2N outlines the forecast general aviation operations for Sky Harbor.

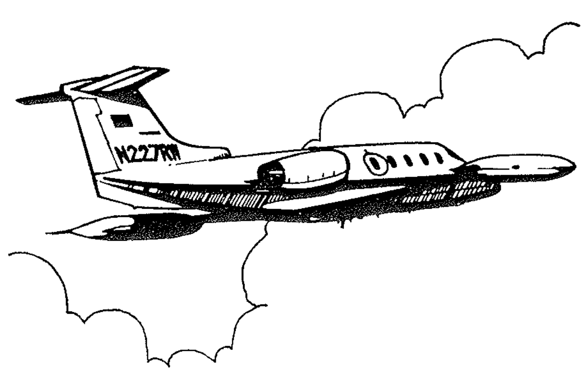


TABLE 2M
Historical General Aviation Operations
Sky Harbor

1973	259,566	1980	223,415
1974	314,648	1981	189,599
1975	322,433	1982	167,511
1976	310,812	1983	139,391
1977	306,672	1984	138,965
1978	264,192	1985	128,587
1979	260,239	1986	123,110

TABLE 2N
Forecast General Aviation Operations
Sky Harbor International Airport

1987	1992	1997	2007
121,631	114,236	106,842	92,052

- FORECAST SUMMARY

Table 2O provides a summary of forecast operations at Sky Harbor through 2007. Air carrier and air taxi operations are both expected to increase by 108 percent over twenty years while commuter operations will increase by nearly 100 percent. Air Cargo operations are expected to increase by 103 percent, while general aviation activity will decrease 25 percent and military activity will experience virtually no change. As a whole, operations at Sky Harbor will increase by 276,470, or 66 percent.

TABLE 2O
Sky Harbor International Airport
Part 150 Operations Forecast

	Actual 1986	1987	1992	1997	2007
Air Carrier	224,430	232,802	278,460	331,068	467,759
Commuter	28,684	29,670	35,048	41,246	57,348
Air Taxi	24,522	25,429	30,482	36,190	51,050
Cargo	8,316	8,548	10,676	12,544	16,920
General Aviation	123,110	121,631	114,236	106,842	92,052
Military	7,597	8,000	8,000	8,000	8,000
TOTAL	416,659	426,080	476,902	535,890	693,129

- FLEET MIX REFINEMENTS

Of even greater importance than the anticipated number of operations is the projected mixture of aircraft types. While the generalized forecasts of future operations are provided above, a more detailed fleet mix is necessary for Part 150 planning. The DWL Study presented forecasts of air carrier fleet mix for future years which appear to be relatively accurate for aircraft sizes, but its selection of more rapid growth among MD-80 aircraft and projection of slower growth by B-737 aircraft has resulted in the reassessment of fleet mix percentages for forecast years. The three years since the preparation of base data for the DWL fleet mix forecasts have seen the rapid expansion of America West and Southwest hub activities at Sky Harbor. The DWL forecasts for 1986 estimated 100,540 operations by B-737 aircraft, while the actual number of operations by that aircraft was 140,496 (40 percent higher than forecast). In contrast, operations by DC-9 and MD-80 aircraft during 1986 totaled 19,010 as compared to the 60,046 forecast for that year. As highlighted by Table 2P the variations between forecast and actual air carrier operations among other aircraft types are not significant. The DWL forecast fleet mix assignments must be adjusted to reflect changes in the composition of the actual air carrier fleet mix serving the airport that have occurred since the forecasts were prepared in 1984.

It should be recognized that the operational information provided in Table 2P refers solely to air carrier activity, while the composite fleet mix, shown later in Table 2Q, includes all operators. The composite fleet mix for 1986 air carrier, commuter and cargo operations is based on the operational mix in use at the airport, as derived from landing reports submitted by the various carriers. General aviation operations are based on operating statistical reports prepared by the control tower and applied to the based mix of general aviation aircraft. Non-scheduled or supplemental air taxi operations are based on the same tower reports of monthly operating statistics and include the difference between total "air taxi" operations and reported commuter operations. The based general aviation fleet mix was assumed to be representative of the air taxi mix. Military operations were divided between KC-135 tanker aircraft (approximately 25 percent of all military operations) and a wide variety of other military aircraft.

TABLE 2P
Actual and Forecast 1986 Air Carrier Fleet Mix/Operations
For Phoenix Sky Harbor International Airport

	Operations		Fleet Mix	
Aircraft Group	DWL 1986 Forecast	Actual 1986	DWL Forecast Percent	Actual Percent
B-747/DC-10/L-1011/A300	5,523	4,924	2.4	2.2
B-767/A310	5,540	1,876	2.5	0.8
B-757/A320	2,250	4,176	1.0	1.9
B-727-200	48,748	52,292	21.6	23.3
B-727-100	3,491	542	1.5	0.2
DC-9-10/30/50	39,588	6,314	17.5	2.8
MD-80	20,458	12,696	9.0	5.7
B-737-100/200	97,040	117,276	42.9	52.3
B-737-300/400	3,500	23,220	1.5	10.3
BAe-146	131	1,114	0.1	0.5

An assessment of the composition of the operating fleet mix for future years must also be made. The following paragraphs provide a review of current activities within the aviation industry which will affect the ultimate judgments of both operational levels and fleet mix and, later in this chapter, their associated noise exposure patterns and impact levels.

- AIR CARRIERS

Deregulation of the industry has forced airlines to become much more competitive. Market forces have decreased the airline fares on many routes, benefiting the consumer, but airlines faced with smaller revenues are being forced to revise their marketing strategies and address their basic operating costs. In recent years, both marketing and advertising have become more aggressive. Super-saver fares and travel clubs provide the discretionary traveller considerable savings. Aircraft size, configuration, frequency of use, and operating costs are constantly being reevaluated for each market.

The aviation industry is recognized as being among the most dynamic in the world. Technological advancements are continually being made to improve aircraft efficiency and safety. In conjunction with the regulatory and economic changes which occurred during the past few years, new technology has added to the unsettled aviation environment.

Only 40 years ago, the ultimate air transportation aircraft was the 21-passenger McDonnell Douglas DC-3, with no air conditioning, no pressurization, no radar and primitive support systems. This aircraft was soon followed by the much-improved DC-4s and DC-6s and the new Constellations and Stratocruisers. Low frequency radio ranges were available for enroute navigation and instrument approaches, necessitating very high takeoff and landing minimums. Most flights were conducted at low altitudes with long non-stops flying as high as 7,000 or 8,000 feet.

As demand for air travel increased, aircraft manufacturers responded with the development of the commercial jet airliner. The technological advancement of the jet engine has been nearly as dramatic as the development of the aircraft itself. Since the early 1960's, the jet engine has undergone continued refinement, making it more efficient and much quieter. As technology developed, low-noise design features were incorporated into the engine. This application of technology has led to a more balanced design in which several noise sources in the engine (fan noise, combustion noise, turbine noise, and jet noise) are approximately equal. Future efforts to mitigate noise at its source will be more complex because they will require the modification of several components which are different for each engine at each flight condition.

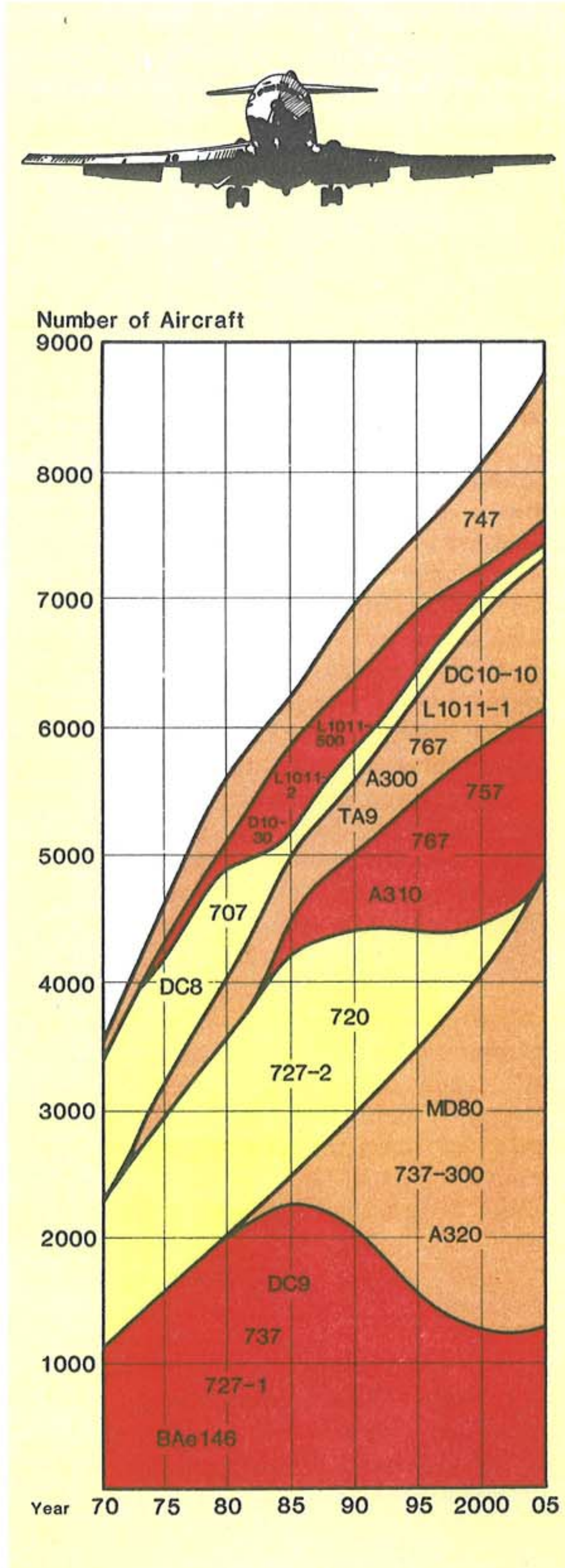
Past efforts by both industry and government to reduce engine noise have been largely successful. Application of advanced technology in engine design has reduced takeoff noise by engine bypass ratio changes, while approach noise has been quieted by acoustic treatment of the engine nacelles. A significant noise reduction was attained through the application of acoustical treatment to the early jet engines.

The additional gains which may be made by introduction of future technology to the new generation of airplane engines will be much less, due to limitations on what can be attained through engine noise control technology alone. Other components, such as airframe design, begin to contribute greater portions of the overall aircraft noise after the engine noise has been successfully reduced. It has been projected that application of future technology will yield only small further reductions in airplane approach noise since the landing configuration will continue to require a design that is not aerodynamically clean.

The accompanying illustration shows the forecast of the world airline jet fleet mix as prepared by the General Electric Corporation's Aircraft Engine Group, and presented in "Airline Fleets In The 1990's", by John Karraker, and published in Tenth Annual FAA Aviation Forecast Conference Proceedings, February, 1985. It projects the gradual elimination of those aircraft which have served as the foundation of the operating fleet for many years and their replacement with new technology aircraft. New technologies are in development which may extend the life of some of the older aircraft which are shown to drop out of the future mix. These include the re-engining or redesign of the B-727 to use quiet engines or even become a two engine aircraft. The useful life of the DC-8 has already been extended via its re-engining with extremely quiet CFM-56 engines and noise suppression kits have been developed for the B-707 and are in use on a few of these aircraft.

The replacement of other older aircraft, as witnessed by the swelling of new orders in the 1980s, has been accelerated by the availability of choices in new-technology aircraft the threat of reduced tax advantages for capital equipment investments. These sales extend to both domestic and regional carriers, each of which has recently seen remarkable progress in the design of new and derivative aircraft for application to their respective market areas.

Many of these new technology aircraft have recently begun to enter the operating fleet and fully comply with FAR Part 36, Stage III noise criteria for new airplanes. They are impressively quieter in flight than earlier jet aircraft.



WORLDWIDE AIRLINE
JET FLEET MIX FORECAST

American, Delta, and United Airlines have been operating B-767 aircraft, powered by the Pratt & Whitney JT9D-7R high-bypass-ratio turbofan engines, for several years, while Northwest and Eastern Airlines operate the more recent B-757 aircraft. Several local carriers use the MD-80 aircraft. Of greater significance to the Phoenix area, however are the equipment moves made by America West and Southwest Airlines. Both carriers have placed significant orders for and taken delivery of B-737-300 aircraft, while America West has begun to acquire B-757 aircraft. Each of these new generation aircraft have been designed to replace the B-727 and DC-9. While the B-737-200 is expected to remain the aircraft most frequently flown from the airport during the next twenty years, the new generation aircraft are expected to comprise increasingly larger portions of the airline operating fleet at Phoenix Sky Harbor International Airport.

Based on orders placed by the airlines now serving Phoenix, the B-737-300, MD-80 and B-757 are expected to capture a significant portion of the local market within the next ten years. These aircraft have high-bypass engines and lighter, more advanced airframes which yield decreased block-hour operating costs and seat-mile costs. In addition to their economical operation, they are among the quietest large jets in the air. Although Northwest Airlines has recently introduced B-747 service to Phoenix, demand for wide-body service is expected to be met primarily through the growth of current B-767 service, supplemented by additional L-1011/DC-10 service and the introduction of A-300 aircraft.

By the second half of the planning period (1997-2007), other new technology aircraft may be incorporating several recent design innovations. Newly designed prop-fan engines promise to provide the greatest restraint to spiraling operating costs. This new engine will have the fuel economy of a turbo-prop engine and the speed of a high-bypass turbo-fan jet. It is forecast to have fuel savings of up to 60 percent compared to current turbine engines. Composite materials will decrease aircraft weight, while at the same time maintaining structural integrity. As with today's aircraft, much of this technology will be marketed for the 100-180 seat aircraft. If these improvements can justify additional or accelerated replacement of fleet aircraft, the airlines will probably be purchasing these aircraft for delivery in the mid-to-late 1990's. However, since flight testing of the engine has only recently begun, and no orders for it have been placed, this engine type is not included in the fleet mix projections. Should it appear on the marketplace by the end of the century, its impact on the noise patterns of the airport should be evaluated at that time.

- COMMUTER/REGIONAL CARRIERS

Whereas new technology is having major impacts on aircraft in the air carrier fleet, it is also changing the image of the commuter airlines, which comprise approximately 12 percent of the total air carrier operations at Phoenix Sky Harbor International Airport. During 1986, local regional carriers depended on a variety of aircraft, ranging in size from small twin engine propeller aircraft to the more sophisticated 19-passenger twin turboprop Metroliner and 36-passenger Shorts 360. In the future, they will continue to use a wide range of aircraft, depending on their routes and frequency of travel. The acquisition of additional equipment is expected to have a sustained growth rate among the commuter operators as passenger travel demands increase, and as older, less efficient aircraft are replaced. The Saab-Fairchild 340 and Shorts 360, along with the de Havilland Dash 8 and BAe-

146 in the longer term, are expected to be a major beneficiaries of this change, as older smaller aircraft are removed from passenger service. For the foreseeable future, however, a large portion of the commuter fleet will remain in 17 to 21-passenger turboprop aircraft.

- AIR CARGO CARRIERS

Of less significance to the overall noise exposure for Phoenix Sky Harbor International Airport is its use by air cargo and freight carriers for shipments into and from the region. Several cargo operators currently serve the area with aircraft ranging in size from small business jets to an occasional B-747, with B-727s, DC-8s, and DC-9s being commonly used for long hauls to mid-western or west coast cargo hubs. Light business jet or turboprop aircraft are used to either feed to the larger carriers or in specialized overnight express service (such as check transfers). The ratio of cargo operations is forecast to remain approximately 2 percent of the total operations during the twenty year study period.

As has been found throughout the cargo industry, the transition to quieter, newer aircraft is expected to occur at a slower pace than that associated with passenger aircraft. Only recently have the first orders been placed for new Stage 3 compliant narrow-body freighter aircraft. The initiation of B-757 freighter use should be locally reflected in the long term, but is not expected to have an impact within the next five years.

The demand for all-cargo jet service at Phoenix will likely continue to be met primarily by B-727, DC-8 and DC-9 aircraft for the next ten years, although significant transitioning into wide-body and new generation freighters may be expected beyond the year 2000. Cargo service by small aircraft is expected to remain an important, although declining, proportion of the total market. The smaller market needs will likely continue to be served by aircraft similar to those now flown.

- GENERAL AVIATION

General aviation operations at Phoenix Sky Harbor International Airport are forecast to decline from slightly more than 123,000 in 1986 to approximately 92,000 by the year 2007. As the airport's operations approach its capacity, activity by smaller general aviation aircraft will transfer to the various reliever airports in the community. This will result in a shifting of the general aviation based aircraft fleet mix to reflect the use of greater numbers of sophisticated twin-engine and turbine-powered aircraft. Operational fleet mixes for use in preparing the Part 150 Noise Exposure Maps are assumed to reflect the changing base mixes. Similar changes in the composition of the air taxi fleet mix may be expected.

- MILITARY

Military operations at the airport are predominantly related to the Arizona Air National Guard unit stationed on the airfield. The nature of military commands is such that it is very difficult to anticipate changes in missions beyond the federal funding cycles. Therefore, for the purposes of this study, it is assumed that military operations will continue to be flown by the current aircraft types.

- FLEET MIX FORECASTS

Based upon the assumptions and guidance provided in the above paragraphs, the composite fleet mix and operations refinements for use in calculating noise exposure patterns at Phoenix Sky Harbor International Airport have been prepared and are presented in Table 2Q.

TABLE 2Q
Composite Annual Fleet Mix/Operations Forecast
For Phoenix Sky Harbor International Airport

	1986 (Actual)	1987	1992	1997	2007
B-747/DC-10/ L-1011/A300	5,030	6,628	15,170	19,687	35,667
B-767/A310	1,876	4,889	13,923	29,796	56,131
B-757/A320	4,176	6,984	25,140	45,751	102,233
B-727-200	52,292	48,422	31,352	25,715	18,678
B-727-100	3,630	3,174	4,056	5,018	4,230
DC-8-71/73	1,586	1,630	1,600	1,560	0
DC-9-10/30/50	6,864	7,084	5,698	753	0
MD-80	12,696	12,571	17,851	29,564	55,093
B-737-100/200	117,276	121,523	136,618	136,930	103,279
B-737-300/400	23,220	24,444	33,415	43,039	98,978
BAe-146	1,114	931	813	3,056	9,210
Medium Twin-engine Turboprop	22,146	22,901	30,420	37,993	57,910
Light Twin-engine Turboprop	6,739	6,650	9,025	11,000	13,800
Twin-engine Piston Prop	38,401	38,625	36,218	32,866	29,043
Single-engine Piston Prop	103,185	102,761	97,064	91,416	81,227
Business Jet	4,790	4,833	5,919	7,713	11,045
Helicopter	4,041	4,030	4,620	6,033	8,605
KC135	1,920	2,000	2,000	2,000	2,000
C-130/KC97/Huey/Etc.	5,677	6,000	6,000	6,000	6,000
Total Operations	416,659	426,080	476,902	535,890	693,129

Part 36/Part 91 Compliance

The final factor required in defining the operational levels and fleet mix is the consideration of current levels of certification under Federal Aviation Regulation, Part 36, by the various carriers serving Phoenix Sky Harbor International Airport. The regulation, commonly referred to as Part 36, sets standards for maximum permissible noise emissions by new aircraft at the time of their certification. FAR Part 91, Subpart E provides a phased schedule to meet Part 36, Stage 2 certification levels by all jet aircraft with certificated operating weights in excess of 75,000 pounds. The last of the aircraft covered by Part 91 must meet the decreased levels no later than January 1, 1988.

Air carriers have initiated a program of either retrofitting, re-engining, or replacing aircraft which do not meet the new lower noise standards. During 1984, the last of the non-compliant three-engine passenger jets was removed from domestic service. Two-engine jet aircraft which are intended to be used in providing regular service to small communities are not required to be brought into compliance until the end of

1987. A number of four-engine narrow body aircraft (DC-8s and B-707s) have been re-engined to obtain compliance with Part 91. According to the FAA's Office of the Environment, several airlines have not completed their conversions of their two-engine aircraft to full Stage 2 compliance. Among the aircraft which will be brought into compliance before January 1, 1988 are several B-737s operated by Delta/Western Airlines and DC-9s operated by Continental and Northwest Airlines. During 1986, these aircraft accounted for approximately two operations per day.

The Integrated Noise Model also allows the user to select a variety of engine types for common aircraft. For example, seven different combination of B-727 model/engine are available. Three separate B-737 combinations may be selected. Since each combination results in a slightly different noise footprint, the fleets of each carrier serving the airport were assessed and appropriate models were selected proportionate to the carrier's total level of operation. These carrier totals were then summed for the full fleet and used as basic input to the modeling of current noise conditions.

Time of Day

The time of day at which operations occur is important as input to the INM due to the penalty weighting of nighttime (10:00 p.m. to 7:00 a.m.) flights. There is no reason to believe that the percentage of flights in the two time periods will change significantly in future years, when taken on an annualized basis. Therefore, the percentages of nighttime use which are currently experienced are assumed to be representative of nighttime use distributions for future conditions. Information provided by the City of Tempe, from its compilation of flight strip data for the year 1986, indicated that between 10 and 11 percent of all departures occurred during the nighttime hours. An assessment of airline schedules for 1986 indicated that between 12 and 13 percent of all air carrier arrivals occurred during the hours between 10:00 p.m. and 6:59 a.m. In composite, between 11 and 12 percent of all operations occur at night. These percentages are, for the purposes of this study, assumed to be representative of general aviation and air taxi operations at the airport. All scheduled air carrier, commuter, and cargo operations, as well as military flights are assigned in accordance with their hours of operation. The time of day distribution of traffic is held constant for each forecast year.

Runway Use

Runway usage data are another essential input to the INM. As was indicated in Chapter One, detailed flight strip data has been compiled for 1986 which provides runway utilization. The distribution of operations between the two parallel runways are assummed to be representative of 1987 conditions, but the directional flows from each runway are forecast to be in accordance with the agreement between Tempe and Phoenix. This agreement calls for an equal amount of traffic during both the day and night hours to both the east and west of the airport. These data indicate the following percentages of use for 1987 conditions:

	Day	Night
Runway 8R	38.4%	34.9%
Runway 8L	11.6%	15.1%
Runway 26R	10.1%	12.2%
Runway 26L	39.9%	37.8%
Total	100.0%	100.0%

The completion of America West's new terminal facilities on the north side of the central core area is expected to result in the virtual equalization of runway use between the north and south parallel runways by 1992. The presence of new general aviation facilities on the south side of the airport will result in the movement of much general aviation activity to the south runway. Therefore, for the purposes of this study, the percentages of use between the two facilities and the directions of flow are assumed to become equal for future conditions. This adjustment results in the following 1992 and 1997 runway use percentage assumptions:

	Day	Night
Runway 8R	25%	25%
Runway 8L	25%	25%
Runway 26R	25%	25%
Runway 26L	25%	25%
Total	100%	100%

The development of a third parallel runway, south of the existing Runway 8R-26L, as well as additional south-side general aviation facilities, is proposed by the airport master plan prior to the end of the study period, but after 1997.

For the purposes of these evaluations, the complete separation of air carrier and general aviation category aircraft is assumed as an aid to the enhancement of airport capacity. This has been accomplished by assigning almost all year 2007 general aviation category aircraft operations to the new south runway in equalized east/west flows.

Flight Tracks

To determine projected noise levels on the ground, it is necessary to determine not only how many aircraft are present, but also where they fly. The radar tracking program was designed to provide this information. As a result of the program, ground tracks of several hundred individual flight operations were available for analysis.

In conjunction with origin/destination data derived from airline schedules and an evaluation of the operating characteristics of the local airspace, the collected flight tracks were analyzed to develop consolidated flight tracks. This analysis required the reduction of data to individual tracks used by various categories of aircraft. The resultant groupings of individual tracks were then further reduced to form consolidated flight tracks describing the average corridors which lead to or from the various initial or final fixes for departure or arrival routes. The effort is concentrated to the area within a few miles of the airport, because beyond that distance aircraft seldom fly low enough to generate contours of noise above 60-65 Ldn.

While the consolidated flight tracks shown on Exhibits 2E and 2F appear as distinct, specific paths, they, in fact, represent averages of the areas of concentrated tracks, with greater variability as the distance from the airport increases. This process of grouping and averaging tracks resulted in the delineation of 52 distinct arrival and departure tracks from existing runways. Of these, 36 are used by high performance aircraft, including all jets and large turboprop aircraft, while the remainder are used by lighter propeller-engine aircraft. Several of the existing tracks at Phoenix Sky Harbor Airport are used by both air carrier and commuter/general aviation groups.

For future years, the flight tracks from the relocated Runway 8R-26L are virtually the same as the tracks indicated for the current flights using the runway, although they will begin 400 feet south of the present runway. These relocated tracks are so little different than the current tracks that their adjustment is not indicated on the exhibits. On the other hand, the proposed construction of the new south general aviation runway will result in the addition of new arrival and departure tracks. The eight tracks anticipated to be associated with that facility are shown on the exhibits.

The typical departure tracks from the four existing runways which are flown by jet and large propeller aircraft proceed along one of six designated Standard Instrument Departure Routes. For Runway 8R/L departures, large aircraft overfly the Rio Salado NDB prior to turning onto one of five standard routes which follow radials from the Salt River VOR out of the immediate area of the airport. Large aircraft following the SID procedures to depart on Runway 26R/L generally maintain the runway centerline until reaching a position 13 nautical miles west of the VOR (or in the vicinity of the intersection of Buckeye Road and 43rd Avenue), at which time they turn to follow departure headings leading from the area. Smaller commuter and general aviation propeller aircraft weighing less than 12,500 pounds are assigned turns to the right or left from the runway heading to provide rapid separation from the heavier traffic. These turns are made at or near the overflight ends of the runways.

Arrival tracks for large aircraft observed during the measurement program indicated that the predominant approach pattern to Phoenix Sky Harbor International Airport is straight-in from the VOR from the east or from approximately five miles west of the airport (beyond the Black Canyon Freeway). These observed arrival courses are consistent with the airport's published instrument and visual approach procedures. Light aircraft were observed to fly approach courses which generally mirrored their departure courses with turns to final approaches occurring within two miles of the landing threshold.

The general aviation arrival and departure flight tracks indicated from the planned new south runway were defined similarly to those used by light general aviation traffic on the two existing runways. Tracks for light business jets using the new south runway were assummed to fly straight-out to the 13 mile DME fix before turning on course, while departures to the east on the new runway were assummed to turn left to overfly the NDB before joining the typical departure routes flown by air carrier traffic. Small business jet arrivals to the new runway were projected to be straight-in.

Flight Profiles

Altitude-distance profiles for departing and arriving aircraft were collected as a portion of the noise calibration measurement and radar tracking program. The standard arrival profile normally used in INM analysis is a 3-degree approach (slightly more than 300 feet per nautical mile). This appears to be an adequate representation of the typical descent slopes used by aircraft operating at Phoenix Sky Harbor International Airport, particularly within six miles of the airport.

The definition of departure profiles is also a standard portion of the INM data base. Average departure profiles for each of the various types of aircraft using the airport were prepared as a result of the radar tracking data collected. In the case of most aircraft types, the average departure profile was appropriately represented by the standards presented in the Integrated Noise Model.

More importantly, however are those aircraft which were not well-represented by the standard departure profiles maintained as a portion of the INM data base. Shown on exhibits 2G and 2H is departure profile information for the aircraft types which accounted for nearly 90 percent of all air carrier operations at the airport during 1986.

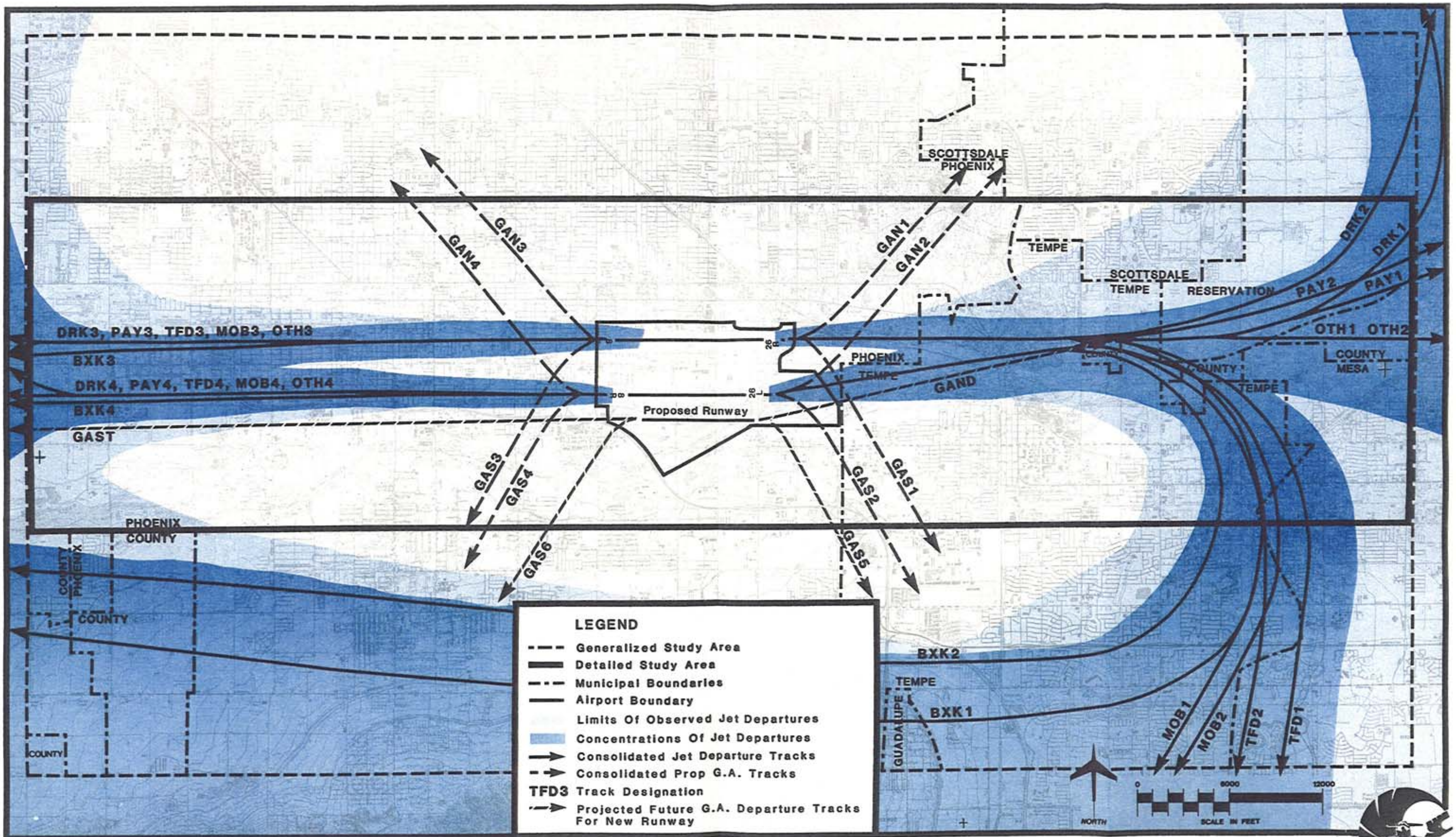


Exhibit 2E
DEPARTURE TRACKS

Sky Harbor
INTERNATIONAL AIRPORT

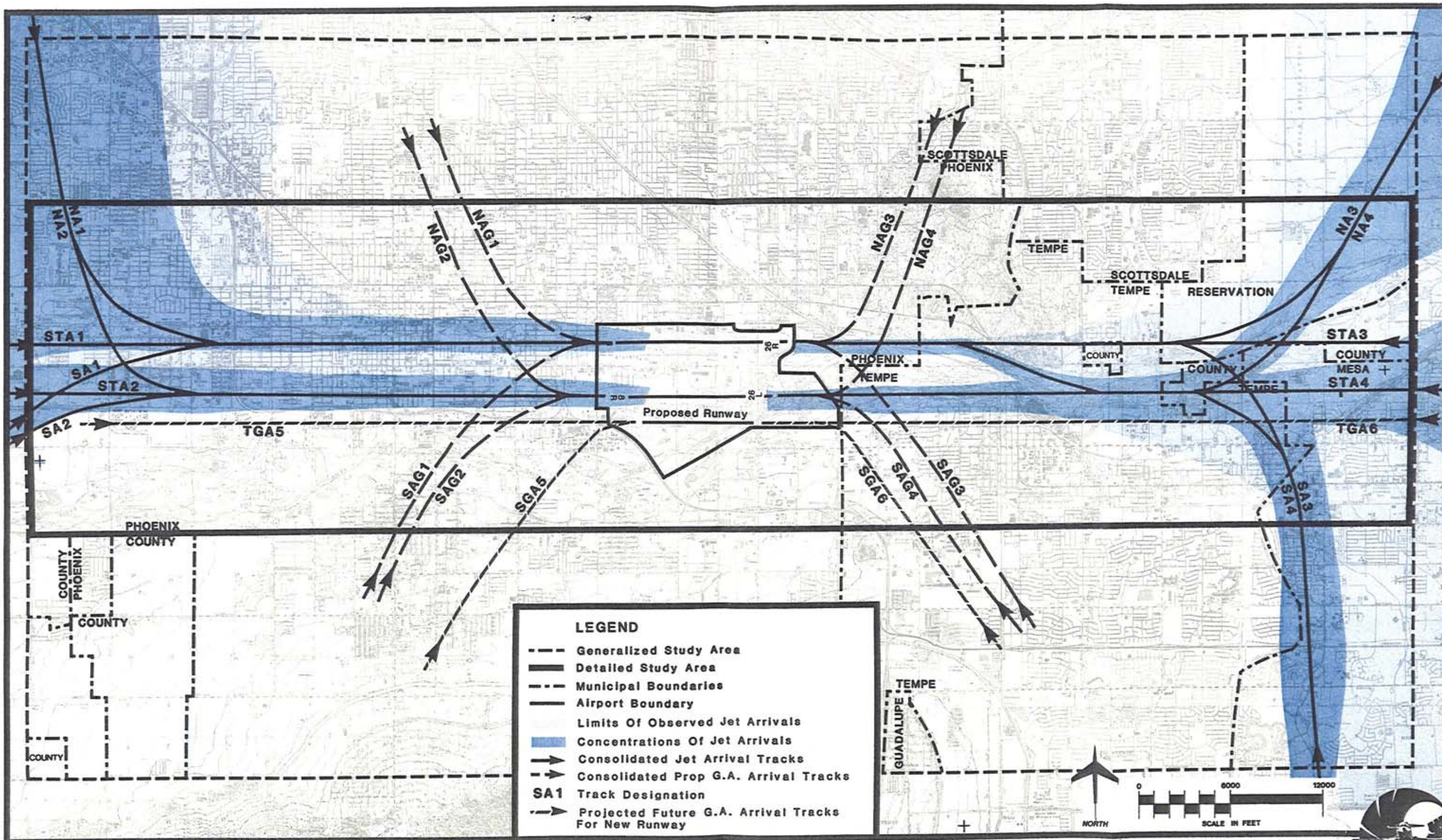
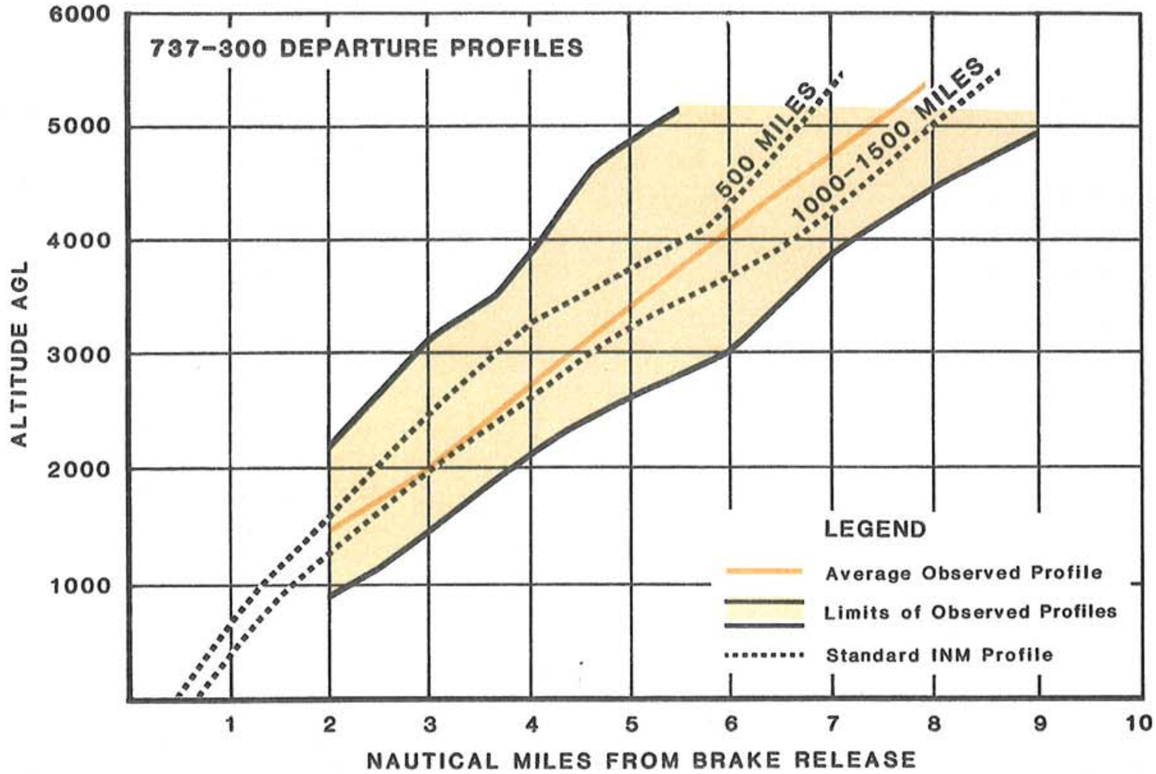


Exhibit 2F
ARRIVAL TRACKS

Sky Harbor
INTERNATIONAL AIRPORT



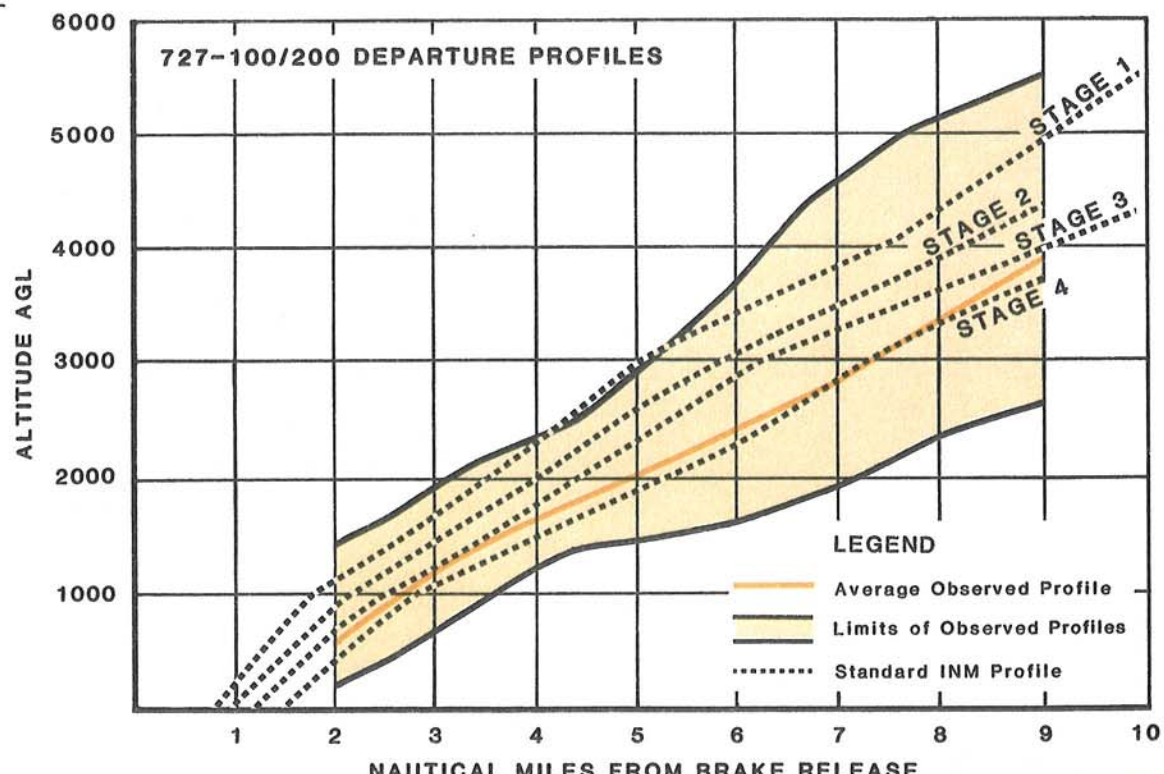


Exhibit 2G
737-300 AND 727-1/200
DEPARTURE PROFILES

Sky Harbor
INTERNATIONAL AIRPORT

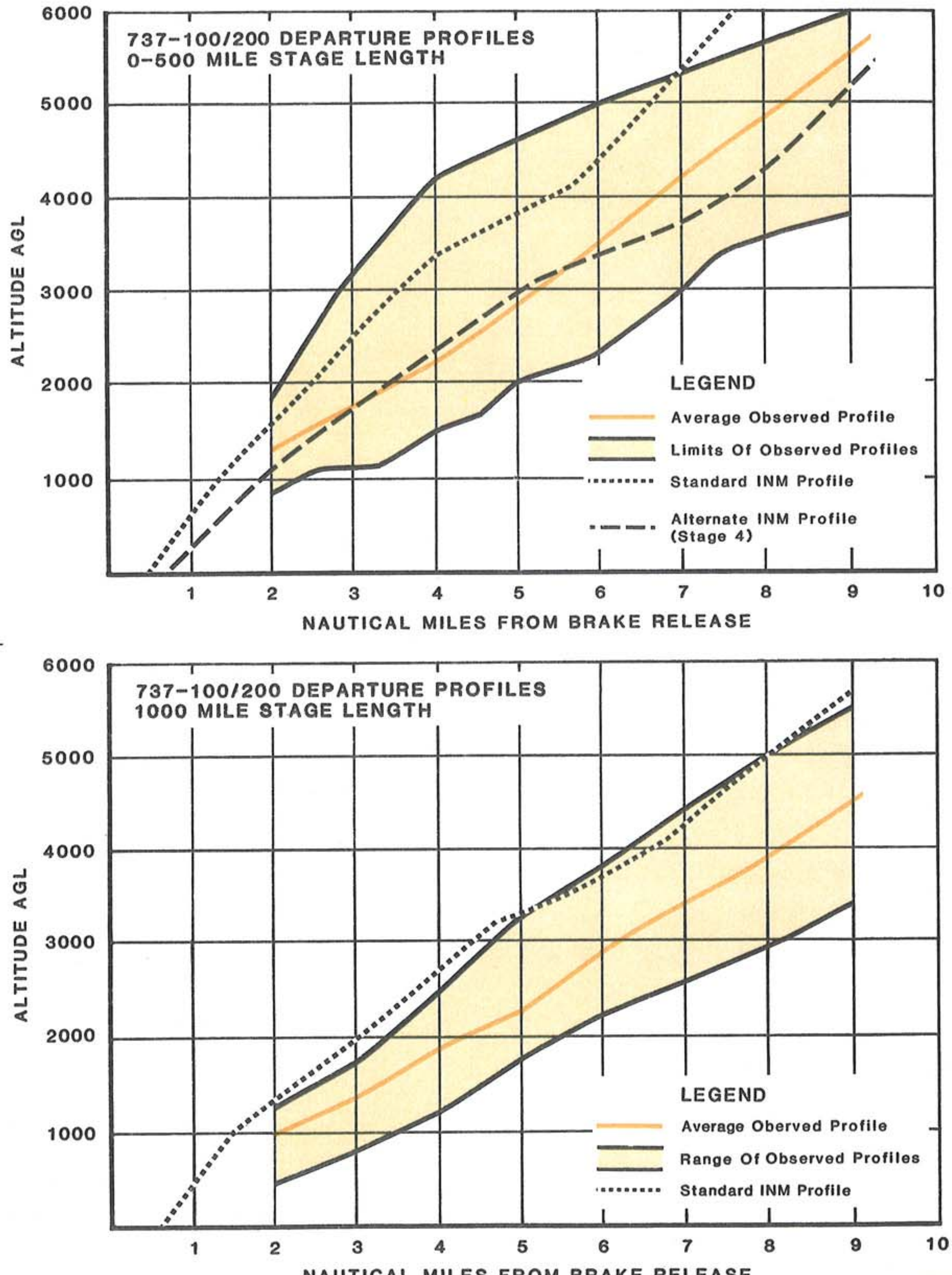


Exhibit 2H
737-1/200
DEPARTURE PROFILES

Sky Harbor
INTERNATIONAL AIRPORT

The exhibits show the upper and lower limits of observed climb profiles, the average observed departure profile, and the standard profile defined in the INM data base. There appears to be a deviation between the standard profiles and the observed profiles which is greater than would be expected for normal varying conditions, particularly for B-737-100/200 and B-727-200 aircraft. The rate of climb-out is usually related to stage length and aircraft weight, as well as temperature, but an assessment of the components of the profile data from Phoenix Sky Harbor International Airport indicated that there was no mathematical correlation between the stage length and profile flown by B-727s (i.e., the departure climb profile for a flight to the west coast would sometimes be flatter than that for a flight to the east coast).

The average observed profile for B-727 departures was well defined by the profile for B-727 stage lengths greater than 1500 miles. This is not an unreasonable conclusion since a large portion of the B-727 flights are to midwestern destinations more than 1,000 miles away. Consequently, the Stage 4 departure profile for the B-727 was used to model all departures by such aircraft.

As indicated on the top half of Exhibit 2G, there was little variation between the standard B-737-200 profiles and the typical observed climbs by B-737-300 aircraft, although that airplane is noted for its more rapid rate of climb. Based on the observed data, the flatter B-737-200 climbs were used to define B-737-300 climbouts.

The average observed B-737-100/200 aircraft profiles indicated on Exhibit 2H are not as steep as the INM standard profiles and were redefined for computer modeling to more accurately reflect local conditions. In the case of the B-737s bound for destinations less than 500 miles from Phoenix, the profile for 1500-2500 mile stage lengths closely represented the observed climbout to an altitude of 3,000 feet AGL, but exceeded the standard profile above that height. Consequently, a new profile, partially based on the Stage 4 standard profile was developed to represent the average observed departure profile for B-737-200 flights of less than 500 miles.

In the case of B-737-200 aircraft having initial flight distances of greater than 500 miles, the average observed departure profile fell well below the standard incorporated in the INM data base. Consequently, the average observed altitude/distance were used to define a locally applicable climbout profile for this aircraft flight length combination.

The INM standard profiles are based on the performance characteristics of the aircraft on a standard day having a temperature of 59 degrees Fahrenheit. The typical temperatures for Phoenix during the recording period ranged from the forties to lower eighties, slightly below the area's annual average of 71 degrees. There did not appear to be an appreciable difference between the climb rates at different temperatures. The performance characteristics of the B-727 and B-737 aircraft (per Reports FAA-EQ-73-7,3 and 4, **Aircraft Noise Definition Individual Aircraft Technical Data**) were evaluated for summer maximum and annual average temperature levels to determine the typical climbout profiles. It was found that although the high temperatures would result in altitude/distance profiles generally below the average observed profile, the profile for the average annual (as well as average monthly maximum) temperatures fell above the observed profile. Consequently, since a higher profile will result in lower observed surface noise levels (unless the lower profile is the result of a noise abatement cutback), the more noise impactive average observed profiles were used for definition of annual average conditions.

Rates of climb are normally less while an aircraft is turning than when it is flying straight, but the profiles defined for Runway 8 departures turning to the south were not different than those flown by aircraft flying straight out. The generally flatter climb gradients may reflect the use of a corporate fuel saving or noise abatement cutback procedure, but measurements of individual noise levels by specific aircraft did not reflect significant reductions in noise levels associated with cutback procedures. The presence of inclement weather during a portion of the assessment period did not result in profiles which were significantly different than those collected during clear weather conditions, so the flatness of the profile does not appear to be related to low ceiling conditions.

In addition to assessments of the departure profiles of the two most common air carrier aircraft groups, evaluations were made of a more limited number of observations for wide-body DC-10, L-1011, and 767 aircraft, as well as MD-80s. While not indicated on the exhibits, the average observed departure profiles for these aircraft approximated the standard data base profiles. Therefore, the INM departure profiles for these newer, quieter aircraft are considered acceptable for their modeling of annual average conditions at the airport. Consequently, the profiles used in the preparation of the noise exposure mapping more accurately reflect real world conditions at Phoenix, Arizona than would the unadjusted use of the profiles in the model's standard data base.

Noise Versus Distance

To ensure accuracy in the development of noise contours for the airport, a comparative analysis was conducted between the INM data base and measured noise vs. distance curves. The purpose of this analysis is to ensure that a reasonable relationship exists between the noise data found in the INM data base and the actual field measurements taken at various measuring sites around the airport. The three-decibel tolerance level used by the FAA during INM validation testing (FAA Integrated Noise Model Validation, R.G. Grados and J. M. Aldred, the MITRE Corporation, December, 1979) is used to assess the reasonableness of the relationship between average measured and standard noise levels. While some variation is expected, it is important to verify that the model is not grossly overstating or understating the noise generated by individual aircraft types.

The process utilized in the assessment of the INM data base involved both the noise measurement of aircraft overflights and the recording of the location, altitude, and expected thrust levels at the monitoring location. The operational nature of the airport allowed the collection of noise samples in both directions from the airport along a variety of separate flight tracks. A comparison of the measurement data to the INM noise vs. distance curves was made and the variations noted.

Individual flight operations were recorded at the ATCT radar facility located on the airport. Technicians observing the radar screen traced arrivals and departures noting the time of day, the flight number, type of aircraft, and altitude. At the same time, noise measurement equipment which recorded the noise generated by the individual aircraft overflights was placed at the noise measurement sites. The measurement equipment's internal clock recorded the time of overflights by aircraft which had noise characteristics exceeding preset thresholds. By direct field observation and by comparison of the departure and arrival times recorded at the radar facility with the recorded time of the individual noise events, measurement data could be related to a specific flight and aircraft type. This information was recorded, analyzed, and compared to the noise vs. distance curves in the INM data base.

Two aircraft types which represent the major portion of the total noise exposure at the airport - the B-727, and the B-737-100/200 were evaluated in detail, while measurements of other aircraft types were checked against their standard curves.

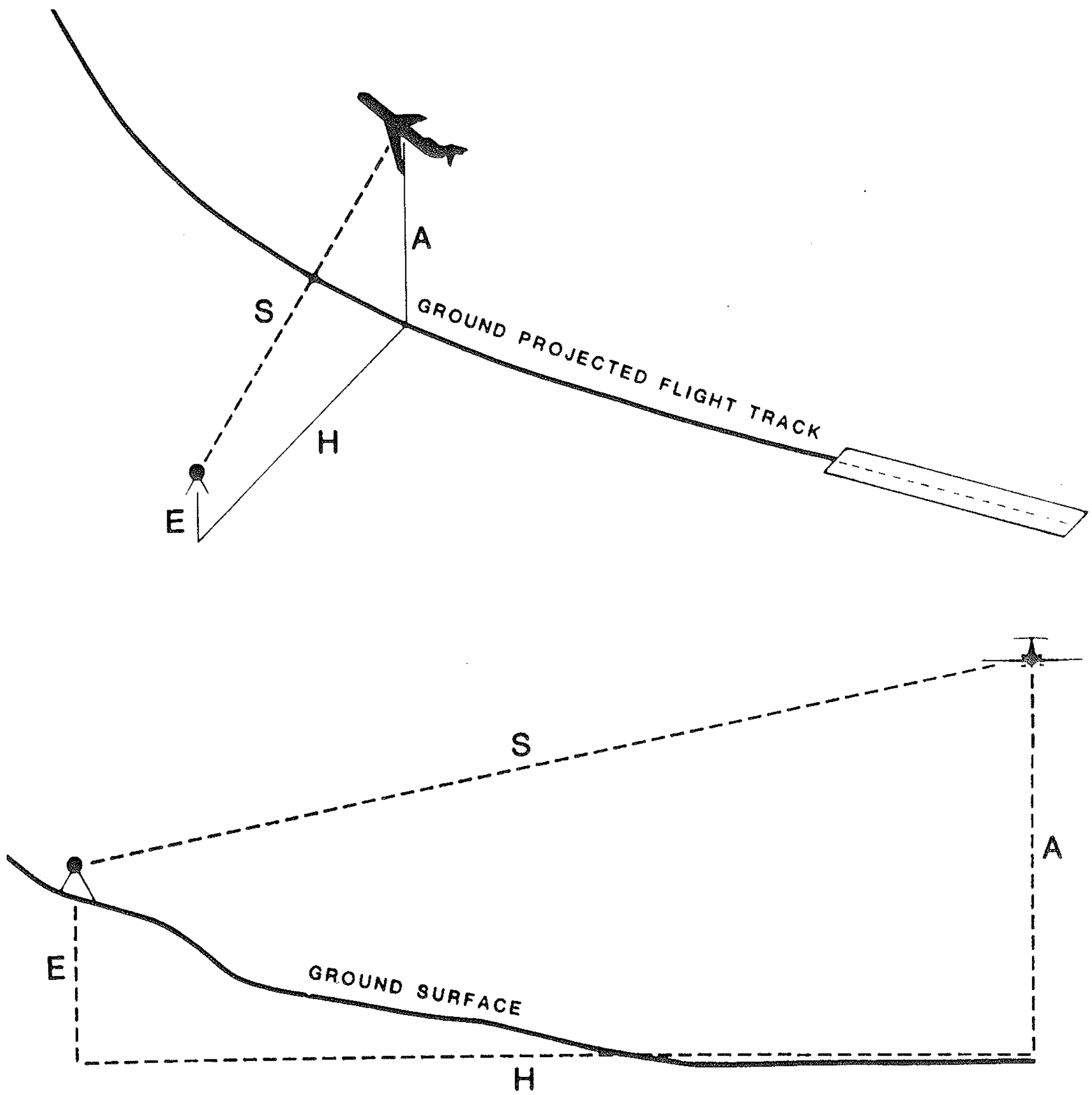
In order to compare the noise measurements with the INM data base, an assessment of the distance between the aircraft and each monitoring site was necessary. This **slant-range distance** was determined by obtaining the altitude of the aircraft from the radar tracking, measuring the distance along the ground from the flight track to the measurement site, and calculating the distance between the aircraft and the site. When applicable, the elevation difference between the airport and the monitoring site is subtracted from the altitude of the aircraft prior to calculating the slant range distance. This methodology is illustrated in Exhibit 2I. It should be noted that the SEL measurements in the data base noise curves are based on a straight fly-by the given aircraft. Noise levels recorded in the field may be greater than data base measurements if collected inside the curve of a flight track. This was true of the location of several of the measurement sites on the southeast side of the airport which fell within the curve of west turning flights. The greater SEL values of this condition are accommodated in the noise model's calculation process.

The results of the assessment indicate that, in the case of arriving traffic, the measured noise values were closely clustered around the noise curve and did not warrant further investigation. Comparison of the INM departure noise curves with measured SEL values for B-737-100/200 aircraft showed a clustering of individual measurements around the appropriate noise curves for departure and climb-out thrust levels. The measured SEL values do not indicate the significant use of deep thrust cutback procedures (although they may occasionally be used).

Similar results were found in the measurement of B-727 aircraft. The measured departure noise levels were also clustered around the takeoff and climbout noise curves provided by the model for distances from 1,000 to 10,000 feet between the aircraft and the receiver. There is some evidence that the average measured noise level for distances in excess of one mile falls slightly below the standard curve, but not by more than three decibels. Variations in pilot techniques, thrust management, rate of climb, aircraft weight, weather conditions, as well as numerous factors affecting local noise attenuation can all potentially contribute to these variations.

Assignment of Aircraft to Tracks

After defining flight tracks and profiles, assessing noise-versus-distance information, determining runway utilization, and Part 91 compliance, and evaluating operational totals by various aircraft models, the final step in developing input data for the INM is the assignment of aircraft to specific flight tracks. For this study, it was assumed that an aircraft would utilize the consolidated flight track which led most directly to its origin or destination. For example, an aircraft departing to the east coast would be vectored to the east rather than in another direction.



$$S = \sqrt{(A-E)^2 + H^2}$$

LEGEND

E MONITOR ELEVATION (from USGS quadangle maps)

A ALTITUDE ABOVE GROUND PROJECTED TRACK

H SHORTEST DISTANCE FROM GROUND PROJECTED TRACK TO MONITOR (measured)

S SLANT RANGE DISTANCE (calculated)

MONITOR LOCATION

Exhibit 2I
TYPICAL SLANT RANGE
DISTANCE CALCULATION

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Airline departure assignments were made to specific flight tracks based on 1986 destination data drawn from the Official Airline Guide and Standard Instrument Departure utilization recorded on flight strips and summarized for the full year. These SID utilizations for 1986 are presented in Table 2R. Large general aviation and military aircraft, including small jets, were assumed to use SIDs proportionally similar to the air carrier and commuter fleet. Aircraft under 12,500 pounds were assigned departure vectors in accordance with standard tower instrument operating procedures (as was indicated on Exhibit 2E). Approach traffic was assumed to use the approach paths most closely associated with the Standard Terminal Arrival Route from their point of entry to the local airspace.

To determine the specific number of aircraft assigned to any one flight track, a long series of mathematical calculations was performed. In general, the number of aircraft of each specific type was factored by the percentage utilization of the runway and the time of day. These permutations resulted in hundreds of individual entries describing the annual average operating conditions for 1987 and the three future year conditions. These listings of aircraft-to-track assignments run approximately forty pages for each year and consequently have been included with in Appendix C.

TABLE 2R
Percentage Use of Standard Instrument Departure Routes - 1986

SID (Direction)	Day	Night
Drake (N/NW)	16.3	13.4
Payso (E/NE)	31.6	28.7
Stanfield (SE)	13.9	10.8
Mobie (SW)	6.2	6.8
Buckeye (W)	21.7	25.3
Other (Various)	10.4	15.1
Total	100.0	100.0

INM OUTPUT

Output data selected for calculation by the Integrated Noise Model were annual average noise contours of 60, 65, 70, and 75 Ldn. Part 150 guidelines indicate that contours of 65, 70, and 75 Ldn should be mapped on the official Noise Exposure Maps, but the inclusion of other contours with these required contours allows and guides additional noise abatement alternative analyses to be presented in later chapters. This section presents the noise exposure contours resulting from the modeling of the previously described information and assumptions.

Current Condition Contours

Exhibit 2J presents the INM contours for 1987 conditions which were developed using the previously discussed input data. The resulting contours are essentially restricted to those areas along the extended centerlines of the runways, although at their furthest reaches, they begin to exhibit indications of the effect of turns from initial departure courses.

East of the airport, the 75 Ldn contour remains confined to the channel of the Salt River or to non-residential area south and west of, or within, Papago Park. To the west, the contour extends along the extended centerline of the parallel runways over both developed and cleared areas. The greater length and breadth of the contour associated with the south parallel runway reflects its more extensive use for westerly departures and instrument approaches. West of the north parallel runway, the 75 Ldn contour remains east of 16th Street, while west of Runway 8R-26L, the contour extends nearly to 6th Avenue just north of I-10. The noise exposure associated with traffic on each parallel runway is obvious west of the airport, while east of the facility, the departure procedure calling for overflight of the NDB by Runway 8R/L departures forces the joining of the noise from each runway. Islands within the 75 Ldn contour are present in the terminal area and immediately east of the airport, but lie solely over compatible land. The shape and location of the 70 Ldn contour also is associated directly with initial departure or final arrival courses. West of the airport, noise associated with separate operations on the two parallel runways melds together to form a broader area within the contour. This area is 1.3 miles wide at Central Avenue and then gradually tapers to its western end about 4.4 miles west of the airport just west of I-10. East of the airport, the contour reaches to the intersection of Hayden and Curry Roads. As will be discussed in a later chapter on noise impacts, the 70 Ldn contour includes several areas of incompatible development both east and west of the airport.

The 65 Ldn contour west of the airport remains directly under initial departure and final approach paths. The departure procedures from Runway 26R/L generally call for straight-out flight to a point thirteen miles west of the Salt River VOR. Therefore, the Ldn 65 noise pattern over Phoenix retains its lineal character and tapers to an end near 35th Avenue as aircraft climb to higher altitudes. To the east, the 65 Ldn pattern remains over the general alignment of the Salt River and northern Tempe, ending just west of Price Road. The pattern terminates in a rounded bulge, rather than a more pointed taper, reflecting the beginnings of aircraft turns onto various departure courses.

The effect on the noise exposure pattern of departure turns from Runway 8R/L becomes noticeable on the 60 Ldn contour. This is the largest contour presented on the map. West of the airport, the pattern retains the straight-out characteristic noted among contours of higher noise levels. To the east, however, northeasterly turns by aircraft flying the Drake or Payso SIDs and southerly turns by aircraft flying the Buckeye, Mobie and Stanfield SIDs are more obvious. The extension to the northeast reaches nearly to Alma School Road at McKellips Road. The southerly extension reaches to the Southern Pacific Railroad tracks between Price Road and Dobson Road.

The land use and population impacts associated with the Part 150 current and future noise exposure patterns will be discussed in Chapter Four (Noise Impact). The surface area falling within each contour indicated on the 1987 map is provided in Table 2S.

TABLE 2S
1987 Noise Exposure

Ldn Level	Total Square Miles	Acres	Square Miles Within 5 Ldn Range
60 Ldn	39.08	25,011	17.05 Ldn 60-65
65 Ldn	22.03	14,099	8.68 Ldn 65-70
70 Ldn	13.35	8,544	7.45 Ldn 70-75
75 Ldn	5.90	3,776	5.90 Ldn 75+

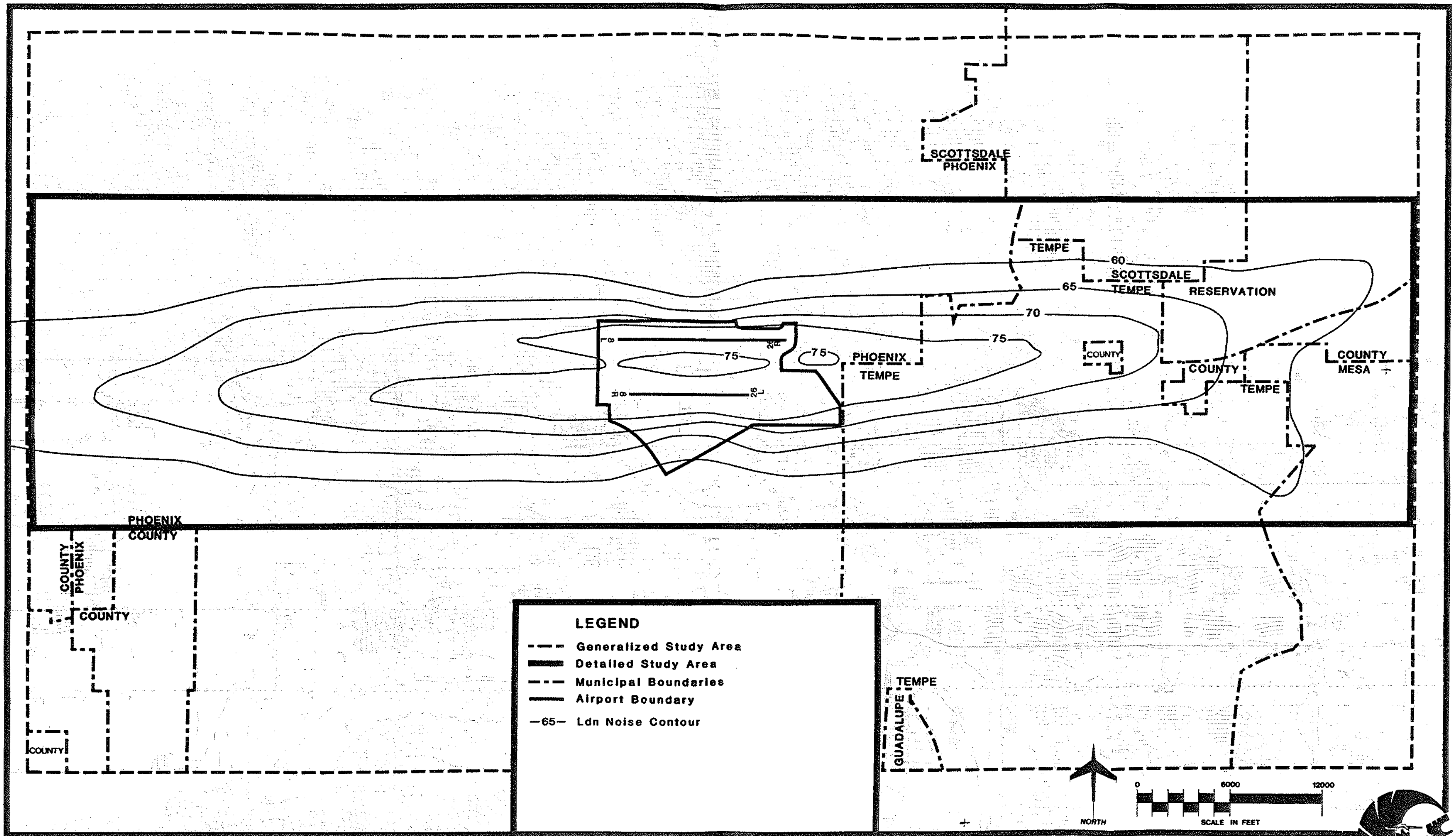

Exhibit 2J
1987 NOISE
EXPOSURE CONTOURS

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In addition to the aircraft flight noise predicted by the Integrated Noise Model, the area surrounding an airport is subject to varying levels of ground and taxi noise. Normally the cumulative noise energy from these activities is masked by noise from departure or arrival traffic. This appears to be true of current conditions at Phoenix Sky Harbor International Airport. Noise from engine maintenance runups are controlled during the late night hours by airport regulation. The Arizona Air National Guard has recently installed a hush house to deaden noise from its engine runup activity. America West is constructing a maintenance facility at the east end of the terminal core which is expected to be the site of future engine maintenance runups. Although there is no noise from such activity now, and projections of the degree of such activity in the future are not available, the potential for noise impact may occur. At other airports within the consultant's experience, such as Indianapolis, Indiana and Portland, Oregon, the presence of nighttime runup activity has had little, if any, effect on the location of the noise contours. For a large commercial airport such as Sky Harbor, the impacts of ground maintenance and runup noise tend to be related more noticably as single events than as cummulative noise levels. Additional assessments after the facility is opened may prove to be beneficial in addressing noise abatement associated with runup noise. The aircraft noise abatement alternatives to be evaluated in Chapter Five (Aviation Alternatives) could include a variety of options to abate this noise if it should prove to be of significant concern. These alternatives may include noise barriers, berms, and hush houses, as well as optimized positioning and orientation of aircraft on the ramp.

Future Aircraft Noise Exposure

Projected aircraft noise contours were prepared for three future years, 1992, 1997 and 2007, to provide a basis for judging the potential decrease or increase of aircraft noise levels with no additional noise abatement actions. As with the current contours, future noise levels were computed with the Integrated Noise Model. The year 1992 was selected to conform with requirements of Part 150 for a five-year exposure map from the time of its submission for FAA approval. The years 1997 and 2007 were selected to provide a view to the longer term to assure that the ultimate development of the airport is considered and, as alternatives are evaluated in later analyses, short-term reductions in noise do not become long-term increases in the noise exposure.

Changes to the model's input to reflect anticipated conditions were based on the forecasts of operations and fleet mix, as presented earlier in this chapter, as well as the equalization of runway use based in the completion of Terminal 4. The contours assume the unconstrained growth of operations at the airport in accordance with the forecasts. Even with constraints, it is assummed that those operations which would be forced from the facility would be general aviation flights which have virtually no effect on the noise exposure pattern. To accommodate the unconstrained growth, the ultimate development of the airport, including extended runways, a relocated Runway 8R/26L and the construction of a third parallel runway for general aviation use on the south side of the airport is assummed for the year 2007 scenario. Flight tracks from existing runways were not changed from 1987. As described earlier, flight tracks associated with the planned new general aviation runway were assummed for year 2007 conditions. Average day operations on each flight track were modified for each scenario year in proportion to the forecast growth or decline of total annual operations by each aircraft type and that aircraft's anticipated use of the track.

The resulting future aircraft noise contours for 1992, 1997 and 2007 are shown on Exhibits 2K, 2L, and 2M, respectively. The surface area falling within the indicated contours is shown below in comparison with that of the 1987 baseline contours:

Ldn Level	Total Acres Within Contour 1987	1992	1997	2007
60 Ldn	25,011	24,774	24,710	23,872
65 Ldn	14,099	13,997	13,939	13,427
70 Ldn	8,544	8,313	8,166	7,667
75 Ldn	3,776	3,667	3,558	2,784

The 1992 forecast noise contours, as indicated on Exhibit 2K, project a slight decrease in the overall size of the exposure pattern. From 1987 to 1992, the area within the computed 75 Ldn decreases by 3 percent, and its shape remains generally the same. Its length is reduced east of the airport by 1/4 to 1/2 of a mile and its width is slightly decreased on the south and increased on the north. West of the airport, the contour extends approximately 3/4 mile beyond 16th Street along the extended centerlines of both runways. A portion of the decrease in the size of this contour may be attributed to the reduction of the contour area along the extended centerline of Runway 8R-26L west of the airport. The 70 and 65 Ldn contours east of the airport are likewise slightly reduced in width through their full length and terminate near their 1987 end positions. Their breadth is shifted to the north by as much as 1/4 mile. West of the airport, the 65 and 70 contours do not extend as far to the west as the 1987 contours, but are more rounded at their ends, reflecting an increase in use of Runway 26R for departures. The 60 Ldn contour is reduced by 1 percent from its 1987 acreage. Again, there is a slight reduction in the contour's width and length, balanced by a slight increase in the contour size over the Salt River Indian Reservation under the Payso and Drake SIDs. Together, these two departure routes are used by nearly half of all easterly departures, and a disproportionately large number of 727 departures are along these tracks. The area also falls under the standard approach routes from the east and north.

The forecast contours for the year 1997, as shown on Exhibit 2L, are virtually identical to those for the year 1992, although the number of air carrier jet operations increases by 18.9 percent. This reflects the balancing of the total noise exposure resulting from decreased individual aircraft exposure and increased numbers of operations.

By the year 2007, there should be a significant reduction in the proportion of the fleet which is not compliant with Part 36, Stage 3 noise limitations. In fact, proposals are being considered to require compliance with them in the mid- to late-1990's, but none have been adopted. The projected noise contours presented in Exhibit 2M indicate a significant change in the shape of the 75 Ldn contour. The contour is projected to separate into two islands, one surrounding Runway 8L-26R and the other surrounding the relocated south air carrier and the proposed new general aviation runway. Each other contour is slightly reduced from earlier years, but there appear to be no aberations in the patterns associated with specific aircraft types.

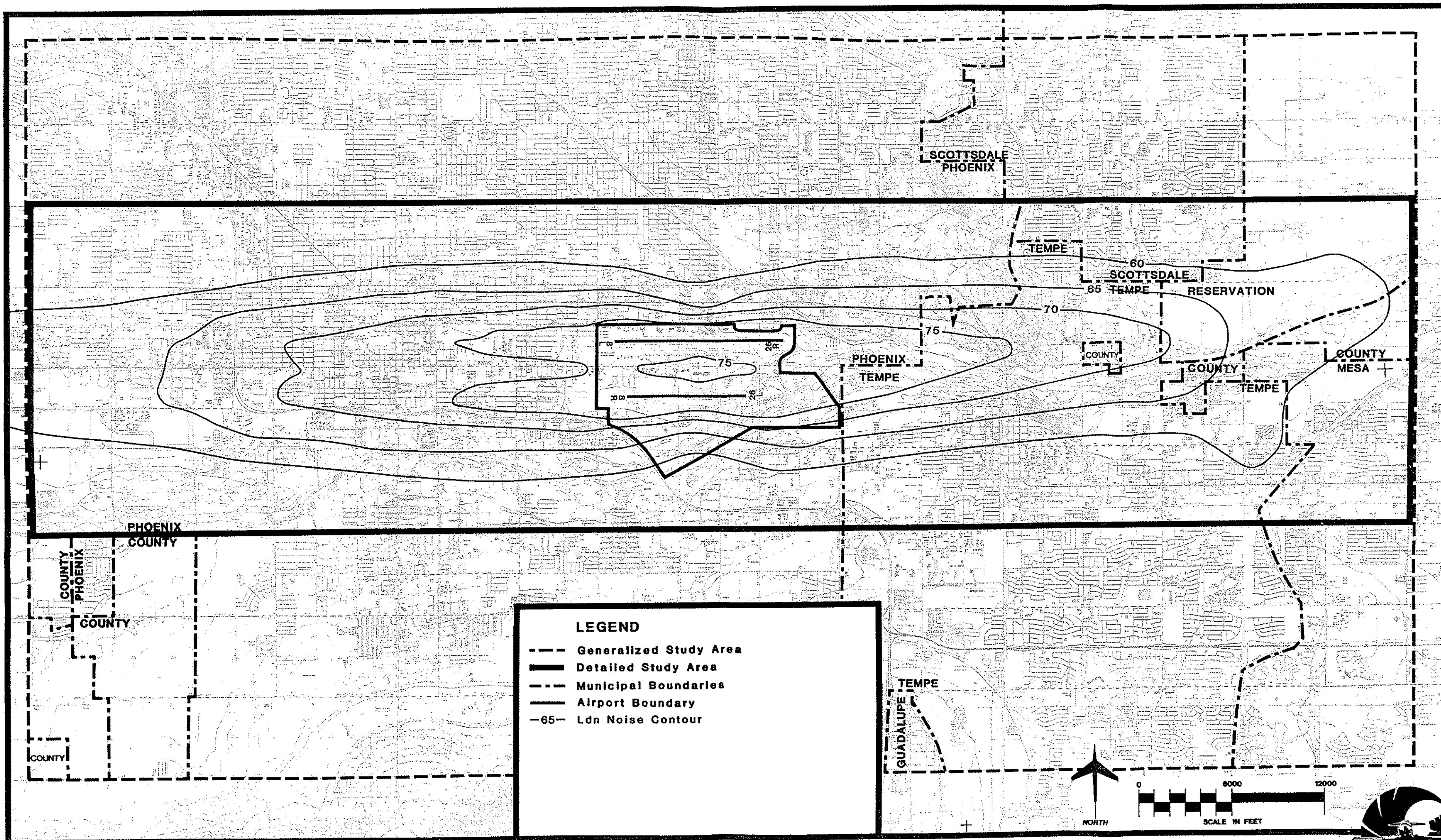

Exhibit 2K
1992 NOISE
EXPOSURE CONTOURS

Sky Harbor
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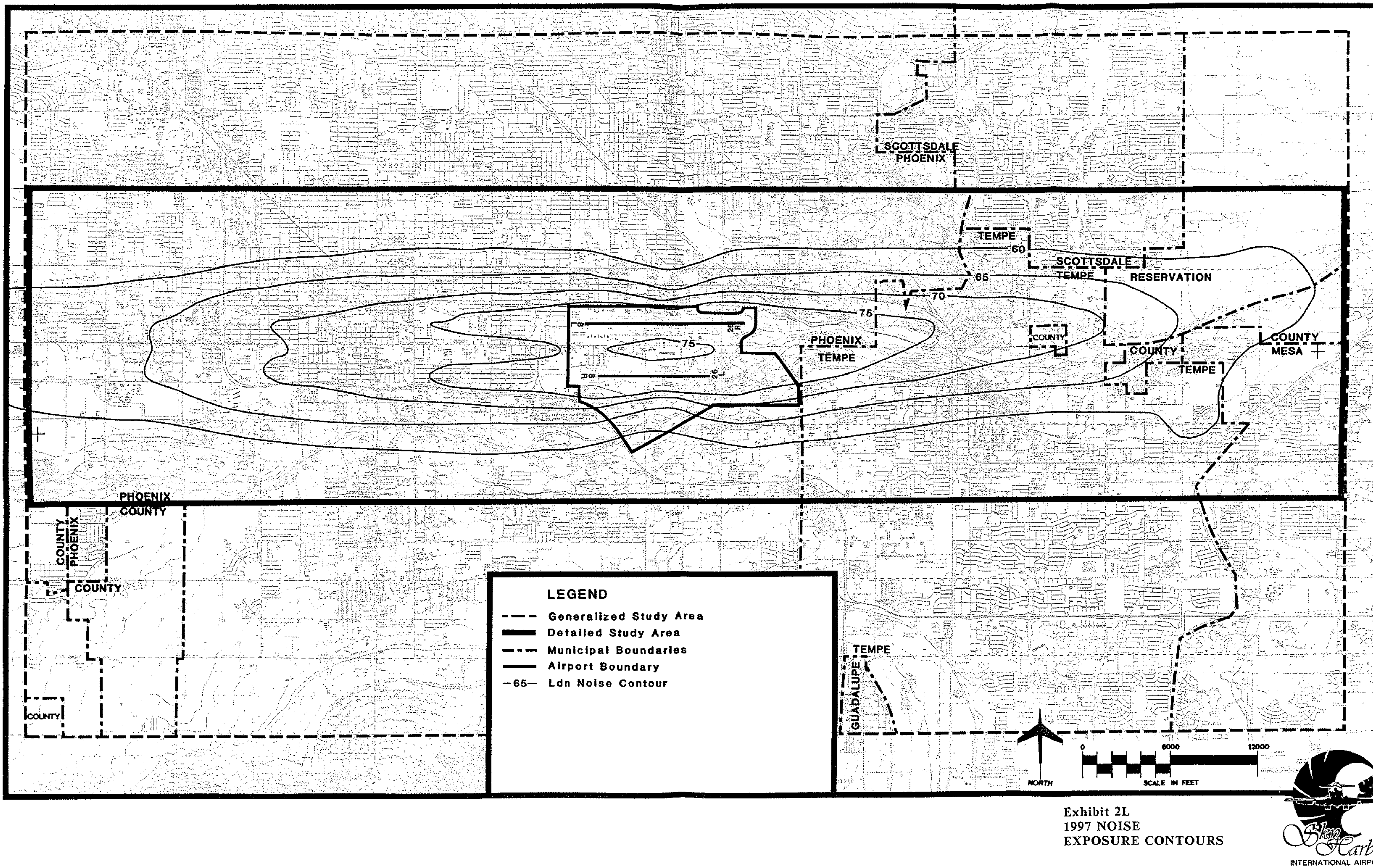

Exhibit 2L
1997 NOISE
EXPOSURE CONTOURS

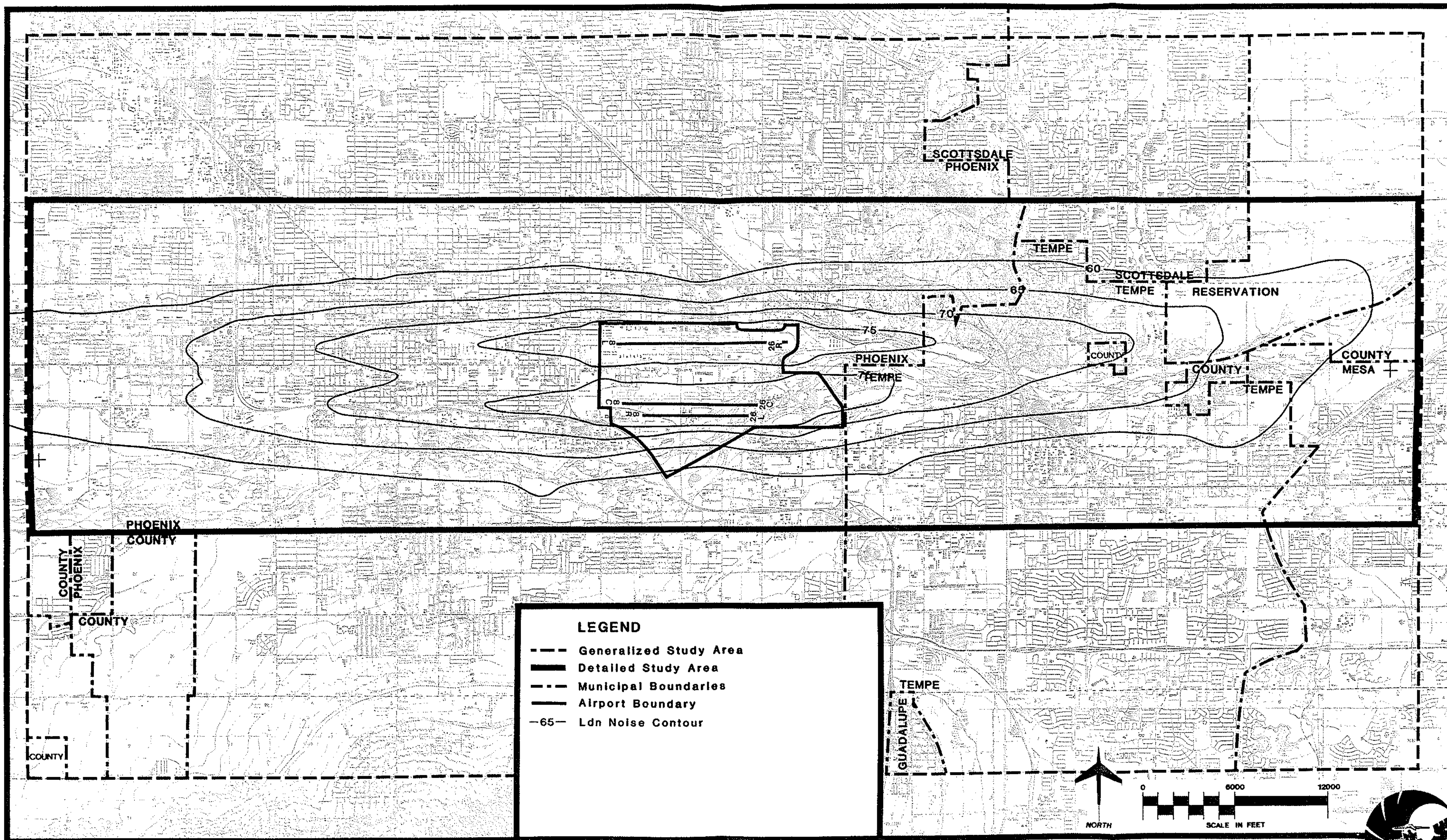

Exhibit 2M
2007 NOISE
EXPOSURE CONTOURS

Noise Contour Validation Measurements

To further assess the validity of the computer modeled noise contours for 1987 conditions, a supplemental noise measurement program was conducted between March 28 and April 20, 1987. A similar program was conducted by airport noise abatement staff during during two earlier occasions and has been reported in earlier reports.

Ten separate sites were selected for continuous noise monitoring for a period of eight to ten days each. The equipment used for calibration measurements, as described in an earlier section, was used for validation measurements. Each monitor was calibrated both before and after measurement to assure data continuity. Of these ten sites, nine were used in the collection of calibration measurements, while the tenth replaced a calibration site not considered secure for long term monitoring. Site identifications are consistent. Site A-16 is located at 1110 Mill Avenue in Tempe. The area is developed in mixed public and commercial use.

The following information is included on Exhibit 2N:

- locations of the sites
- INM-calculated Ldn levels
- measured average Ldn levels for aircraft
- 1987 noise exposure contours

Equipment at each monitoring site was identically programmed to accummulate overall noise levels as well as noise associated solely with the exceedances of a selected threshold of 70dB. All monitors were programmed to provide hour-by-hour reports of average Ldn noise levels for both overall (Ldn) and threshold-exceeding [Ldn(t)] conditions, as well as the maximum noise level recorded during each hour. The Ldn(t) values are assummed to be representative of aircraft noise and are not normally influenced by ambient noise to a significant degree. Ambient noise [Ldn(b)] must be calculated manually by subtracting aircraft noise from the overall noise.

Weather conditions throughout the measurement period were excellent. On only two days did traces of precipitation occur. Average daily temperatures for the period were slightly above annual average, while the average daily maximum temperature was also slightly above the annual average. Winds were predominently from the west during the later portion of the measurement period, but no wind predominence was present during the first half of the measurement period. Consequently, noise was recorded from both approach and departure traffic during large, but separate, portions of the time at each measurement site.

Table 2T provides the results of the validation monitoring program measurements and compares these results to the predicted aircraft Ldn values as calculated by the Integrated Noise Model.

TABLE 2T
Validation Noise Measurement Summary
Phoenix Sky Harbor International Airport

Site	Dates	Total Ldn Mean (Range)	Ambient Ldn(b) Mean (Range)	Aircraft Ldn(t) Mean (Range)	INM* Level	Variance
A-1	3/28-4/9	69.2 (65.6-70.9)	62.0 (58.7-64.7)	67.9 (64.6-70.4)	63.0	-4.9
A-3	3/28-4/6	70.8 (67.8-73.8)	59.4 (57.4-60.7)	70.4 (65.3-73.6)	74.0	+3.6
A-5	4/8-4/19	62.3 (59.8-64.9)	58.2 (56.3-60.9)	60.0 (57.2-62.7)	58.0	-2.0
A-7	4/11-4/19	63.3 (61.1-67.1)	58.4 (56.6-59.1)	61.6 (57.9-66.4)	65.0	+3.4
A-9	3/28-4/6	65.6 (63.8-69.3)	58.7 (57.3-59.2)	64.7 (62.1-68.9)	66.0	+1.3
A-10	4/8-4/19	63.6 (61.6-66.3)	59.2 (57.1-60.6)	61.7 (61.6-66.3)	63.0	+1.3
A-11	3/28-4/6	61.3 (57.4-64.6)	55.7 (52.3-57.2)	59.9 (53.2-63.9)	60.0	+0.1
A-12	3/28-4/6	70.7 (67.8-74.8)	59.0 (55.3-60.5)	70.4 (67.4-74.7)	74.0	+3.6
A-14	4/8-4/19	66.0 (63.4-67.2)	62.1 (60.5-63.0)	63.7 (60.2-65.1)	62.0	-1.7
A-16	4/8-4/19	60.5 (58.4-62.2)	58.8 (57.1-59.6)	55.4 (51.6-59.2)	55.0	-0.4

* Estimated from 1987 contour map.

A review of the data included in Table 2T indicates that, in general, the aircraft Ldn levels collected during the contour validation noise measurement program are not significantly different than those projected by the INM.

Data peresented in the table indicates that at Sites A-5, A-9, A-10, A-11, A-14, and A-16 the predicted noise levels are within 2.0 Ldn of the measured levels. This indicates an excellent relationship between the contours and the measurements at these locations. At sites A-3, A-7 and A-12, the predicted noise levels were approximately 3.5 Ldn greater than the measured levels. This relationship indicates that the noise

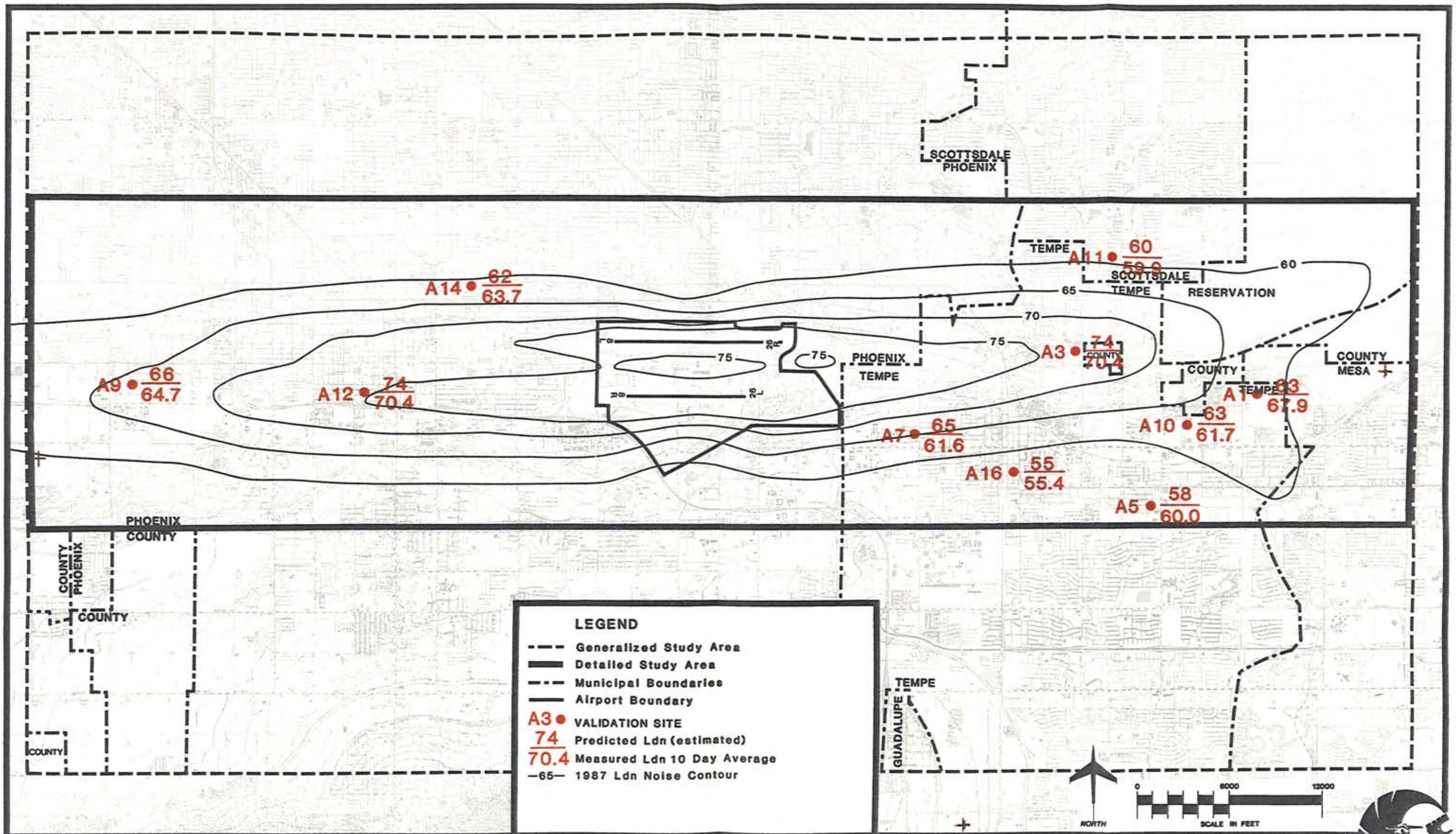

Exhibit 2N
CONTOUR VALIDATION
MEASUREMENT SITES

Sky Harbor
INTERNATIONAL AIRPORT

model overpredicted the noise for these locations during the period measured. At site A-1, the measured noise level exceeded the predicted noise level by 4.9 Ldn, indicating an underprediction of the noise at this site.

The variance between measured and predicted noise levels may lie in the relationship between the data modeled and the actual characteristics of operation during the measurement period. One must remember that the contours indicate predicted noise for a 1987 annual average traffic condition, while the measurements represent a twenty-four day period during March and April, 1987. Various factors may account for the variances.

For example, at site A-7, based on tower records of runway use, the site was subject to approximately 14 percent more approach traffic noise than is assummed by the computer for an average day of the year. Not only is this noise generally quieter that departure noise, it is, due to the aircraft's lower angle relative to the horizon, subject to greater ground propagation. Consequently, the noise at the site would be expected to be less than predicted.

At sites A-3 and A-12, the locations are subject to a relatively equal amount of departure and approach noise, yet are each measured 3.6 Ldn less than predicted. This would tend to indicate the use of a noise abatement power cutback on departure, but this solution to the question of variance is not borne out by single event measurements at the sites or by site/noise relationships of locations further from the airport under the same flight tracks. For example, sites A-9 and A-14 were measured nearly as predicted, and had a significant cutback been in place, the variance should have been greater.

Site A-1, the VOR, is the only site at which measured noise averaged more than three Ldn greater than that predicted by the model. Directional flow records maintained by the tower did not indicate a significant variation between the measurement period and the average utilization, nor did individual maximum levels during the measurement period indicate abnormal occurrences of very loud traffic. The site lies east of the flight tracks which turn south over Tempe and generally south of the Payso and Drake tracks to the east and north. Ambient noise at the site is high from quarrying and construction activity west of the site and may have had some influence on the elevated levels. Similarly, measurements at nearby sites A-10, A-3, and A-5 do not indicate a significant underprediction of noise by the model.

Given the relative accuracy of the field measurements in validating the predicted measurements at six sites, and the slight overprediction of the model for three additional sites, the model is believed to conservatively overpredict noise levels in the study area. The results of this noise validation program are consistent with the results of a similar program conducted in 1986 to investigate the 1985 predicted contours. Since the model appears to overpredict measured levels to a small degree, a retention of current program assumptions will result in a conservative approach to the projection of future noise levels and noise abatement alternatives.

SUMMARY

The information presented on the preceding pages defines the unabated noise patterns of current and anticipated future aviation activity of Phoenix Sky Harbor International Airport. However, no attempt has been made to evaluate or otherwise include that activity over which the airport has no control--such as aircraft passing through the area and not stopping at the airport, or local helicopter activity not using the airport. The contours are based on average day activity and will be used in subsequent analyses for comparison with alternative operational characteristics. As a whole, the measurement sites were found to have noise levels very close to those predicted by the computer model.

Again, it is stressed that Ldn contour lines drawn on a map do not represent absolute boundaries of acceptability or unacceptability in personal response to noise, nor do they represent the actual noise conditions present on any specific day, but rather the conditions of an average day derived from long-term information.