DALLAS LOVE FIELD

2014 Day-Night Average Sound Level Contours

HMMH Report No. 307410

September 2015

Prepared for:

City of Dallas Aviation Department
Dallas Love Field Airport
8008 Cedar Springs Rd, LB 16
Dallas, TX 75235

Prepared by:

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1 Summary

This report presents analysis of the 2014 noise conditions at Love Field in Dallas, TX. It was prepared by Harris Miller Miller & Hanson Inc. d/b/a HMMH under contract to the City of Dallas.

The 2014 Day-Night Average Sound Level (DNL, or L_{dn}) contours were developed using the latest version of the Federal Aviation Administration (FAA) Integrated Noise Model (INM) and a data pre-processor called RealContours™. RealContours™ converts every useable 2014 radar track into inputs for the noise model ensuring that the modeling includes runway closures, deviations from flight patterns, changes in flight schedules and deviations from average runway use. This process resulted in the modeling of over 170,000 flight tracks to develop the 2014 DNL contours.

In 2014, the estimated number of people exposed to Day-Night Average Sound Levels (DNL) exceeding the federal guidelines of 65 dB is 4,083 people; an increase of approximately 32 percent compared to 2013 (3,091 people DNL 65 dB or greater). Analysis of the noise contours indicates the following:

- Noise levels in 2014 increased along the extended runway centerline of Runway 13L/31R, and decreased slightly along the extended runway centerline of Runway 13R/31L when compared to noise levels in 2013.
- However, noise levels in 2014 compared to 2006 have decreased in all areas except a small area in the DNL 60 dB along the extended runway centerline to the northwest of Runway 13L.
- The total area contained within the DNL 65 dB noise contours has increased from 2.17 square miles in 2013 to 2.28 square miles in 2014, but is still well below 2006 area (4.19 square miles).

The Department of Aviation utilizes a permanent noise and operations monitoring system. This system provides a variety of important capabilities, including: (1) investigation of noise complaints, (2) monitoring of compliance with the noise control program, and (3) preparation of various reports. The Department of Aviation provides weekly updates on Runway Closures, Construction Activities, and a report on airport operations by group and a report on operations by runway.

The rest of this report describes noise terminology and aircraft noise effects (Section 2), the noise modeling process (Section 3), the noise modeling inputs (Section 4) and resulting contours and population assessment (Section 5).

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2 Introduction to Noise Terminology and Evaluation

Noise is a complex physical quantity. The properties, measurement, and presentation of noise involve specialized terminology that can be difficult to understand. Throughout this study, we will use graphics and everyday comparisons to communicate noise-related quantities and effects in reasonably simple terms.

To provide a basic reference on these technical issues, this chapter introduces fundamentals of noise terminology (Section 2.1), the effects of noise on human activity (Section 2.2), weather and distance effects (Section 2.3), and Federal Aviation Administration Part 150 noise-land use compatibility guidelines (Section 2.4).

2.1 Introduction to Noise Terminology

The noise contours rely largely on a measure of cumulative noise exposure over an entire calendar year, in terms of a metric called the Day-Night Average Sound Level (DNL). However, DNL does not provide an adequate description of noise for many purposes. A variety of other measures is available to address essentially any issue of concern, including:

- Sound Pressure Level, SPL, and the Decibel, dB
- A-Weighted Decibel, dBA
- Maximum A-Weighted Sound Level, L_{max}
- Sound Exposure Level, SEL
- Equivalent A-Weighted Sound Level, L_{eq}
- Day-Night Average Sound Level, DNL

2.1.1 Sound Pressure Level, SPL, and the Decibel, dB

All sounds come from a sound source – a musical instrument, a voice speaking, an airplane passing overhead. It takes energy to produce sound. The sound energy produced by any sound source travels through the air in sound waves – tiny, quick oscillations of pressure just above and just below atmospheric pressure. The ear senses these pressure variations and – with much processing in our brain – translates them into "sound."

Our ears are sensitive to a wide range of sound pressures. The loudest sounds that we can hear without pain contain about one million times more energy than the quietest sounds we can detect. To allow us to perceive sound over this very wide range, our ear/brain "auditory system" compresses our response in a complex manner, represented by a term called sound pressure level (SPL), which we express in units called decibels (dB).

Mathematically, SPL is a logarithmic quantity based on the ratio of two sound pressures, the numerator being the pressure of the sound source of interest (P_{source}), and the denominator being a reference pressure ($P_{reference}$)[1]

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[1] The reference pressure is approximately the quietest sound that a healthy young adult can hear.

$$Sound\ Pressure\ Level\ (SPL) = 20 * Log\left(\frac{P_{source}}{P_{reference}}\right) dB$$

The logarithmic conversion of sound pressure to SPL means that the quietest sound that we can hear (the reference pressure) has a sound pressure level of about 0 dB, while the loudest sounds that we hear without pain have sound pressure levels of about 120 dB. Most sounds in our day-to-day environment have sound pressure levels from about 40 to 100 dB.[2]

Because decibels are logarithmic quantities, we cannot use common arithmetic to combine them. For example, if two sound sources each produce 100 dB operating individually, when they operate simultaneously they produce 103 dB -- not the 200 dB we might expect. Increasing to four equal sources operating simultaneously will add another three decibels of noise, resulting in a total SPL of 106 dB. *For every doubling of the number of equal sources, the SPL goes up another three decibels.*

If one noise source is much louder than another is, the louder source "masks" the quieter one and the two sources together produce virtually the same SPL as the louder source alone. For example, a 100 dB and 80 dB sources produce approximately 100 dB of noise when operating together.

Two useful “rules of thumb” related to SPL are worth noting: (1) humans generally perceive a six to 10 dB increase in SPL to be about a doubling of loudness,[3] and (2) changes in SPL of less than about three decibels are not readily detectable outside of a laboratory environment.

2.1.2 A-Weighted Decibel

An important characteristic of sound is its frequency, or "pitch." This is the per-second oscillation rate of the sound pressure variation at our ear, expressed in units known as Hertz (Hz).

When analyzing the total noise of any source, acousticians often break the noise into frequency components (or bands) to consider the “low,” “medium,” and “high” frequency components. This breakdown is important for two reasons:

- Our ear is better equipped to hear mid and high frequencies and is least sensitive to lower frequencies. Thus, we find mid- and high-frequency noise more annoying.
- Engineering solutions to noise problems differ with frequency content. Low-frequency noise is generally harder to control.

The normal frequency range of hearing for most people extends from a low of about 20 Hz to a high of about 10,000 to 15,000 Hz. Most people respond to sound most readily when the predominant frequency is in the range of normal conversation – typically around 1,000 to 2,000 Hz. The acoustical community has defined several “filters,” which approximate this sensitivity of our ear and thus, help us to judge the relative loudness of various sounds made up of many different frequencies.

The so-called "A" filter (“A weighting”) generally does the best job of matching human response to most environmental noise sources, including natural sounds and sound from common transportation sources.

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[2] The logarithmic ratio used in its calculation means that SPL changes relatively quickly at low sound pressures and more slowly at high pressures. This relationship matches human detection of changes in pressure. We are much more sensitive to changes in level when the SPL is low (for example, hearing a baby crying in a distant bedroom), than we are to changes in level when the SPL is high (for example, when listening to highly amplified music).
[3] A “10 dB per doubling” rule of thumb is the most often used approximation.

"A-weighted decibels" are abbreviated "dBA." Because of the correlation with our hearing, the U. S. Environmental Protection Agency (EPA) and nearly every other federal and state agency have adopted A-weighted decibels as the metric for use in describing environmental and transportation noise. Figure 1 depicts A-weighting adjustments to sound from approximately 20 Hz to 10,000 Hz.

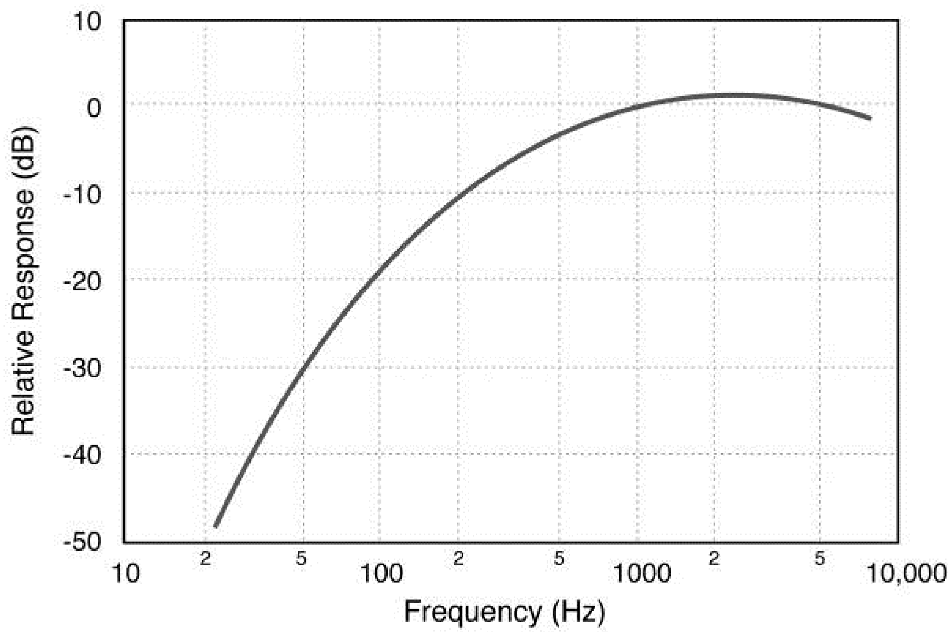

Figure 1 A-Weighting Frequency-Response

Source: Extract from Harris, Cyril M., Editor; "Handbook of Acoustical Measurements and Noise Control," McGraw-Hill, Inc., 1991, pg. 5.13, HMMH

As the figure shows, A-weighting significantly de-emphasizes noise content at lower and higher frequencies where we do not hear as well, and has little effect, or is nearly "flat," in mid-range frequencies between 1,000 and 5,000 Hz.

All sound pressure levels presented in this document are A-weighted unless otherwise specified.

Figure 2 depicts representative A-weighted sound levels for a variety of common sounds.

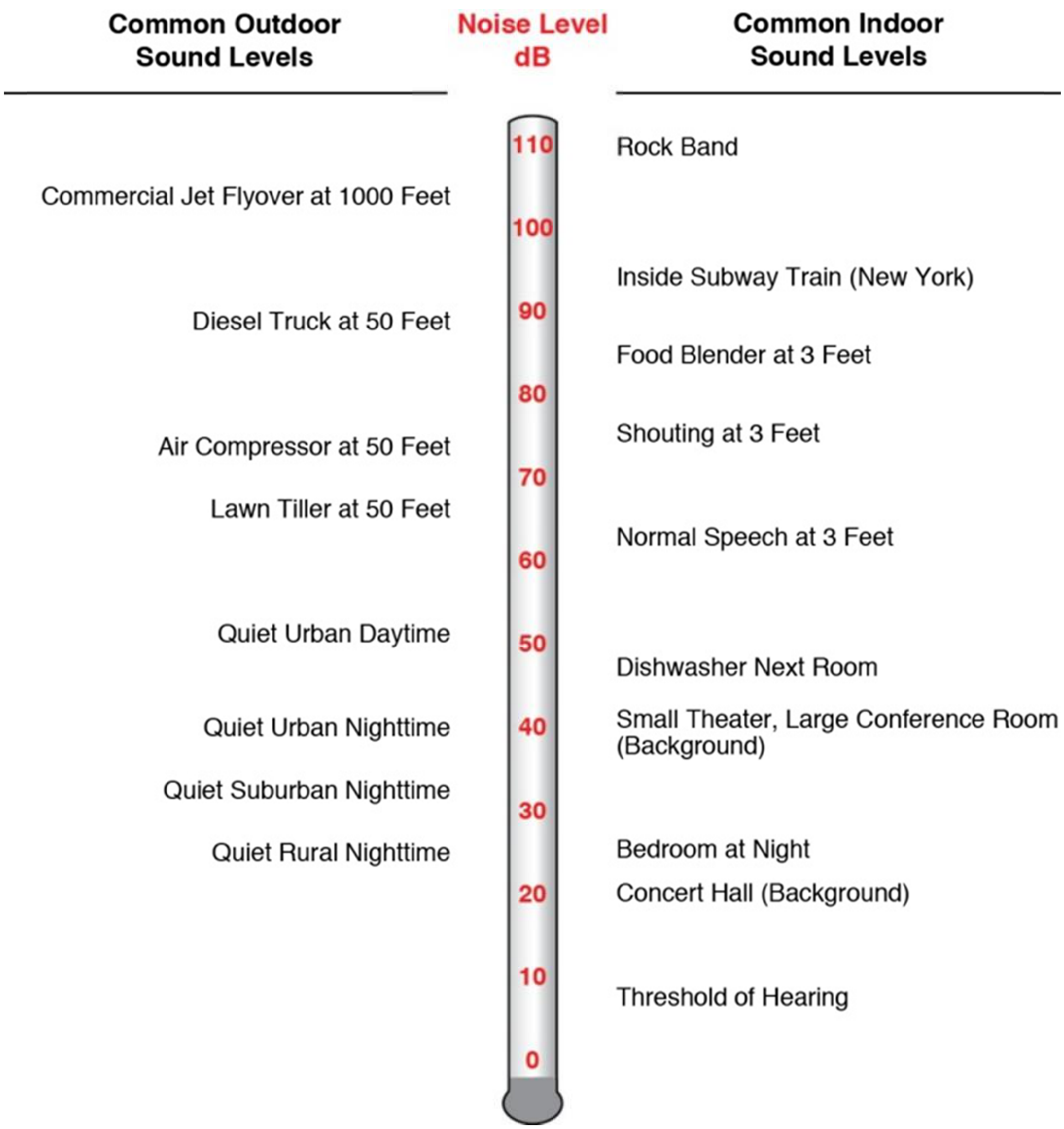

Figure 2 A-Weighted Sound Levels for Common Sounds

Source: HMMH

2.1.3 Maximum A-Weighted Sound Level, L_{max}

An additional dimension to environmental noise is that A-weighted levels vary with time. For example, the sound level increases as a car or aircraft approaches, then falls and blends into the background as the aircraft recedes into the distance. The background or "ambient" level continues to vary in the absence of a distinctive source, for example due to birds chirping, insects buzzing, leaves rustling, etc. It is often convenient to describe a particular noise "event" (such as a vehicle passing by, a dog barking, etc.) by its maximum sound level, abbreviated as L_{max}.

Figure 3 depicts this general concept, for a hypothetical noise event with an L_{max} of approximately 102 dB.

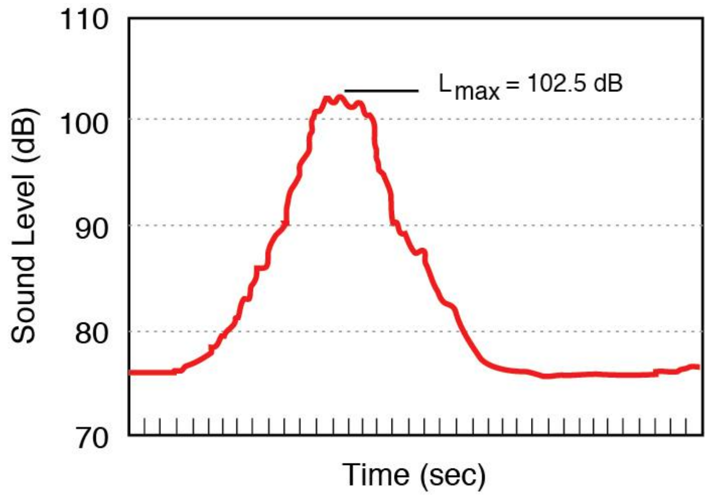

Figure 3 Variation in A-Weighted Sound Level over Time and Maximum Noise Level
Source: HMMH

While the maximum level is easy to understand, it suffers from a serious drawback when used to describe the relative "noisiness" of an event such as an aircraft flyover; i.e., it describes only one dimension of the event and provides no information on the event's overall, or cumulative, noise exposure. In fact, two events with identical maximum levels may produce very different total exposures. One may be of very short duration, while the other may continue for an extended period and be judged much more annoying. The next section introduces a measure that accounts for this concept of a noise "dose," or the cumulative exposure associated with an individual "noise event" such as an aircraft flyover.

2.1.4 Sound Exposure Level, SEL

The most commonly used measure of cumulative noise exposure for an individual noise event, such as an aircraft flyover, is the Sound Exposure Level, or SEL. SEL is a summation of the A-weighted sound energy over the entire duration of a noise event. SEL expresses the accumulated energy in terms of the one-second-long steady-state sound level that would contain the same amount of energy as the actual time-varying level.

SEL provides a basis for comparing noise events that generally match our impression of their overall "noisiness," including the effects of both duration and level. The higher the SEL, the more annoying a noise event is likely to be. In simple terms, SEL "compresses" the energy for the noise event into a single second. Figure 4 depicts this compression, for the same hypothetical event shown in Figure 3. Note that the SEL is higher than the L_{max}.

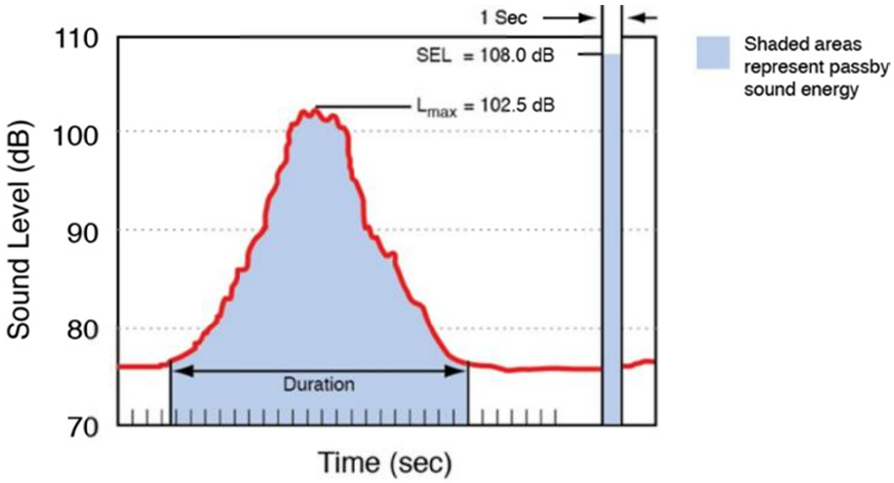

Figure 4 Graphical Depiction of Sound Exposure Level

Source: HMMH

The "compression " of energy into one second means that a given noise event's SEL will almost always will be a higher value than its L_{max}. For most aircraft flyovers, SEL is roughly five to 12 dB higher than L_{max}. Adjustment for duration means that relatively slow and quiet propeller aircraft can have the same or higher SEL than faster, louder jets, which produce shorter duration events.

2.1.5 Equivalent A-Weighted Sound Level, L_{eq}

The Equivalent Sound Level, abbreviated L_{eq}, is a measure of the exposure resulting from the accumulation of sound levels over a particular period of interest; e.g., one hour, an eight-hour school day, nighttime, or a full 24-hour day. L_{eq} plots for consecutive hours can help illustrate how the noise dose rises and falls over a day or how a few loud aircraft significantly affect some hours.

L_{eq} may be thought of as the constant sound level over the period of interest that would contain as much sound energy as the actual varying level. It is a way of assigning a single number to a time-varying sound level. Figure 5 illustrates this concept for a one-hour period. Note that the L_{eq} is lower than either the L_{max} or SEL.

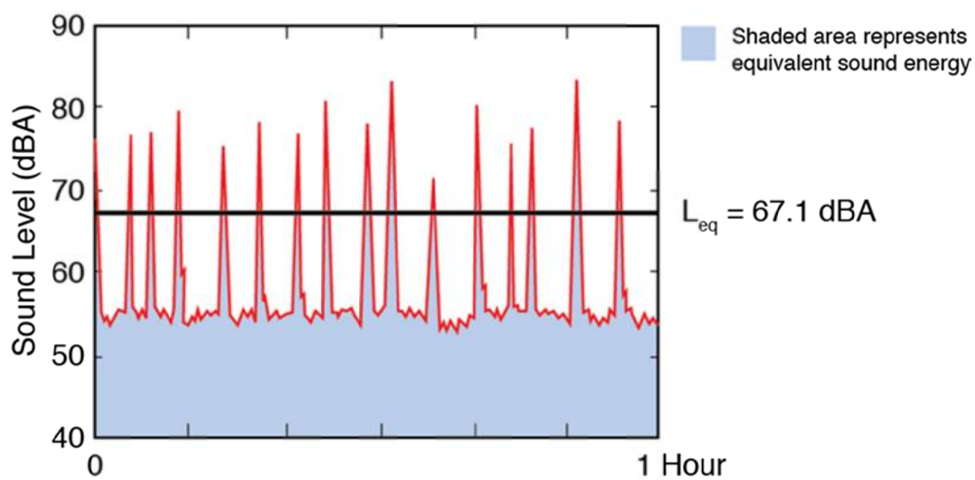

Figure 5 Example of a One Hour Equivalent Sound Level

Source: HMMH

2.1.6 Day-Night Average Sound Level, DNL or L_{dn}

The FAA requires that airports use a measure of noise exposure that is slightly more complicated than L_{eq} to describe cumulative noise exposure – the Day-Night Average Sound Level, DNL.

The U.S. Environmental Protection Agency identified DNL as the most appropriate means of evaluating airport noise based on the following considerations.[4]

- The measure should be applicable to the evaluation of pervasive long-term noise in various defined areas and under various conditions over long periods.
- The measure should correlate well with known effects of the noise environment and on individuals and the public.
- The measure should be simple, practical, and accurate. In principal, it should be useful for planning as well as for enforcement or monitoring purposes.
- The required measurement equipment, with standard characteristics, should be commercially available.
- The measure should be closely related to existing methods currently in use.
- The single measure of noise at a given location should be predictable, within an acceptable tolerance, from knowledge of the physical events producing the noise.
- The measure should lend itself to small, simple monitors, which can be left unattended in public areas for long periods.

Most federal agencies dealing with noise have formally adopted DNL. The Federal Interagency Committee on Noise (FICON) reaffirmed the appropriateness of DNL in 1992. The FICON summary report stated; "There are no new descriptors or metrics of sufficient scientific standing to substitute for the present DNL cumulative noise exposure metric."

In simple terms, DNL is the 24-hour L_{eq} with one adjustment; all noises occurring at night (defined as 10 p.m. through 7 a.m.) are increased by 10 dB, to reflect the added intrusiveness of nighttime noise events when background noise levels decrease. In calculating aircraft exposure, this 10 dB "penalty" is mathematically identical to counting each nighttime aircraft noise event ten times.

DNL can be measured or estimated. Measurements are practical only for obtaining DNL values for limited numbers of points, and, in the absence of a permanently installed monitoring system, only for relatively short periods. Most airport noise studies use computer-generated DNL estimates depicted as equal-exposure noise contours (much as topographic maps have contours of equal elevation). The FAA *requires* that airports use computer-generated contours, as discussed in Section 4.3.

The annual DNL is mathematically identical to the DNL for the average annual day; i.e., a day on which the number of operations is equal to the annual total divided by 365 (366 in a leap year).

Figure 6 graphically depicts the manner in which the nighttime adjustment applies in calculating DNL. Each bar in the figure is a one-hour L_{eq}. The 10 dB penalty is added for hours between 10 p.m. and 7 a.m. Figure 7 presents representative outdoor DNL values measured at various U.S. locations.

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[4] "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," U. S. EPA Report No. 550/9-74-004, March 1974.

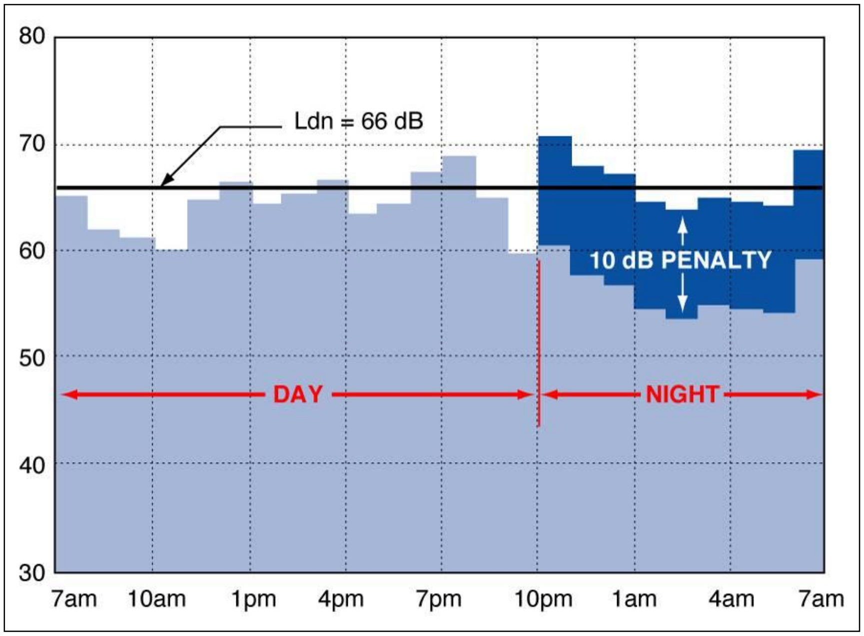

Figure 6 Example of a Day-Night Average Sound Level Calculation

Source: HMMH

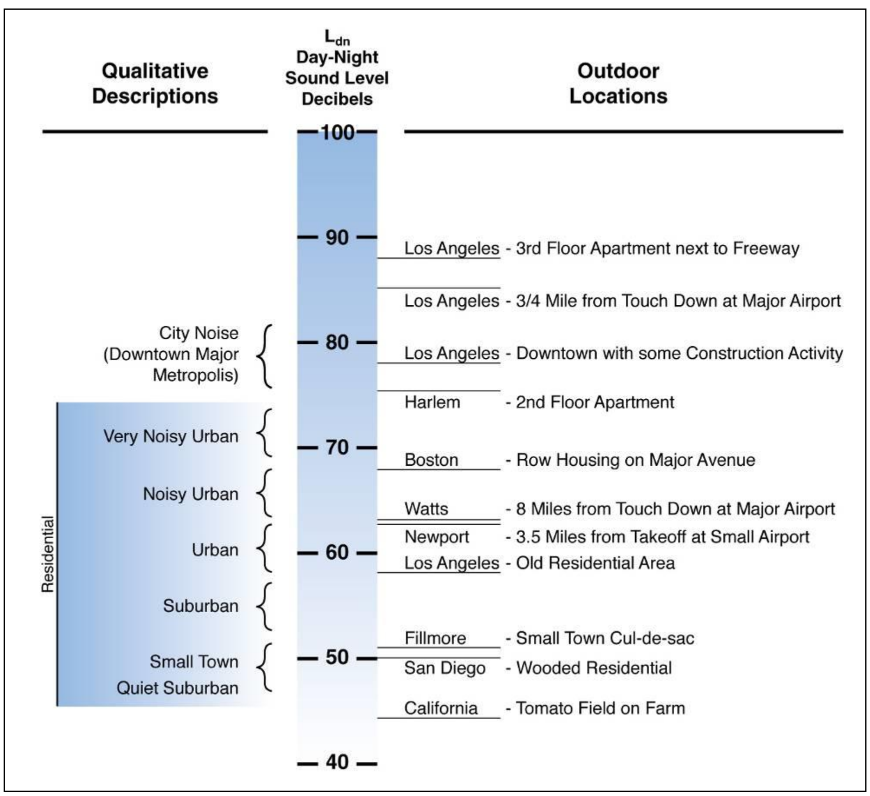

Figure 7 Examples of Measured Day-Night Average Sound Levels, DNL

Source: U.S. Environmental Protection Agency, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," March 1974, p. 14.

2.2 Aircraft Noise Effects on Human Activity

Aircraft noise can be an annoyance and a nuisance. It can interfere with conversation and listening to television, disrupt classroom activities in schools, and disrupt sleep. Relating these effects to specific noise metrics helps in the understanding of how and why people react to their environment.

2.2.1 Speech Interference

One potential effect of aircraft noise is its tendency to "mask" speech, making it difficult to carry on a normal conversation. The sound level of speech decreases as the distance between a talker and listener increases. As the background sound level increases, it becomes harder to hear speech.

Figure 8 presents typical distances between talker and listener for satisfactory outdoor conversations, in the presence of different steady A-weighted background noise levels for raised, normal, and relaxed voice effort. As the background level increases, the talker must raise his/her voice, or the individuals must get closer together to continue talking.

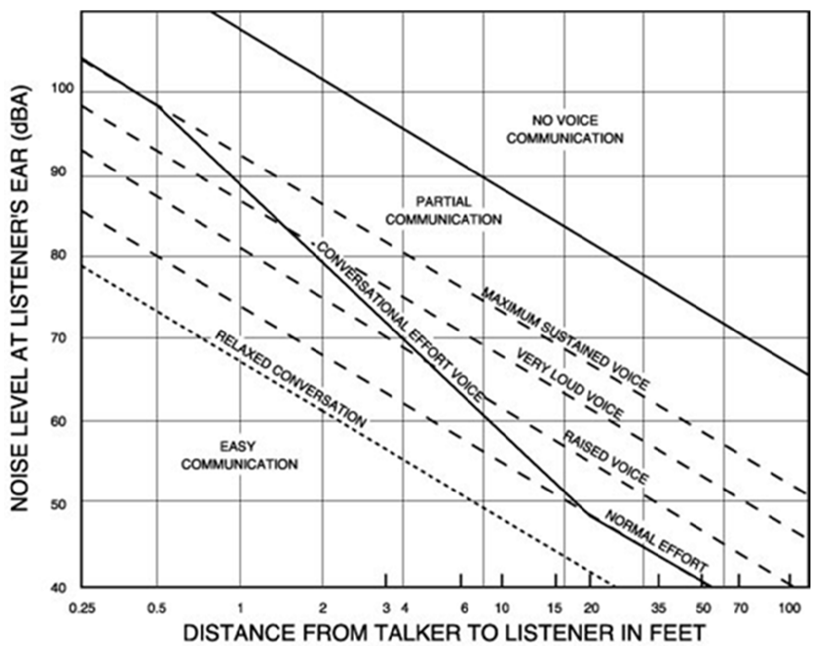

Figure 8 Outdoor Speech Intelligibility

Source: EPA 1973 "Public Health and Welfare Criteria for Noise, July, 1973. EPA Report 550/9-73-002. Washington, D.C.: US EPA page 6-5

Satisfactory conversation does not always require hearing every word; 95% intelligibility is acceptable for many conversations. In relaxed conversation, however, we have higher expectations of hearing speech and generally require closer to 100% intelligibility. Any combination of talker-listener distances and background noise that falls below the bottom line in the figure (which roughly represents the upper boundary of 100% intelligibility) represents an ideal environment for outdoor speech communication. Indoor communication is generally acceptable in this region as well.

One implication of the relationships in Figure 8 is that for typical communication distances of three or four feet, acceptable outdoor conversations can be carried on in a normal voice as long as the background noise outdoors is less than about 65 dB. If the noise exceeds this level, as might occur when an aircraft passes overhead, intelligibility would be lost unless vocal effort were increased or communication distance were decreased.

Indoors, typical distances, voice levels, and intelligibility expectations generally require a background level less than 45 dB. With windows partly open, housing generally provides about 10 to 15 dB of interior-to-exterior noise level reduction. Thus, if the outdoor sound level is 60 dB or less, there a reasonable chance that the resulting indoor sound level will afford acceptable interior conversation. With windows closed, 24 dB of attenuation is typical.

2.2.2 Sleep Interference

Research on sleep disruption from noise has led to widely varying observations. In part, this is because (1) sleep can be disturbed without awakening, (2) the deeper the sleep the more noise it takes to cause arousal, (3) the tendency to awaken increases with age, and other factors. Figure 9 shows a recent summary of findings on the topic.

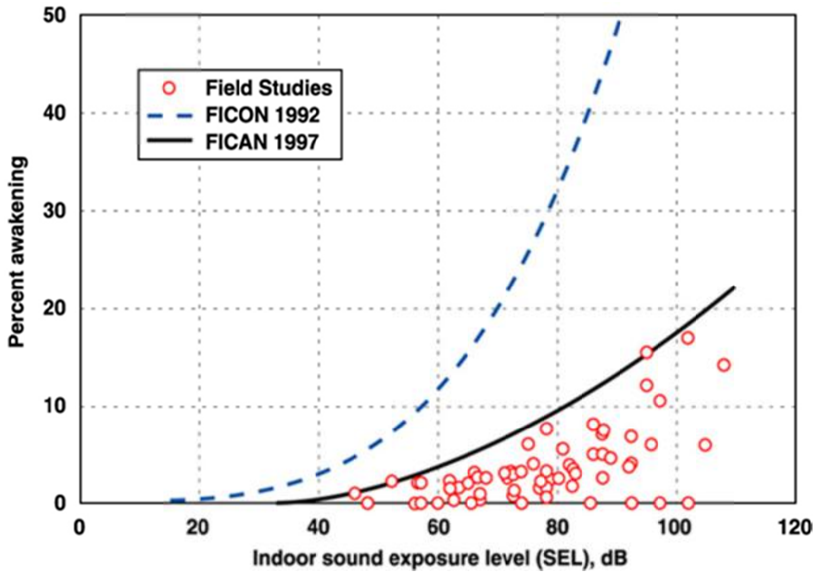

Figure 9 Sleep Interference

Source: Federal Interagency Committee on Aviation Noise (FICAN), "Effects of Aviation Noise on Awakenings from Sleep", June 1997, page 6.

Figure 9 uses indoor SEL as the measure of noise exposure; current research supports the use of this metric in assessing sleep disruption. An indoor SEL of 80 dBA results in a maximum of 10% awakening. Assuming the typical windows-open interior-to-exterior noise level reduction of approximately 12 dBA and a typical L_{max} value for an aircraft flyover 12 dBA lower than the SEL value, an interior SEL of 80 dBA roughly translates into an exterior L_{max} of the same value.[5]

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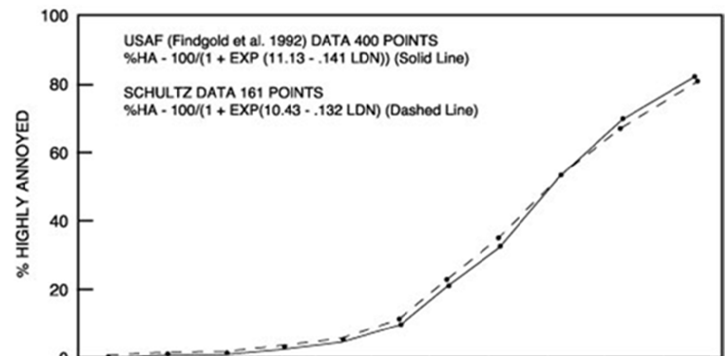
[5] The awakening data presented in Figure 2 9 apply only to individual noise events. The American National Standards Institute (ANSI) has published a standard that provides a method for estimating the number of people awakened at least once from a full night of noise events: ANSI/ASA S12.9-2008 / Part 6, "Quantities and Procedures for Description and Measurement of Environmental Sound – Part 6: Methods for Estimation of Awakenings Associated with Outdoor Noise Events Heard in Homes." This method can use the information on single events computed by a program such as the FAA's Integrated Noise Model, to compute awakenings.

2.2.3 Community Annoyance

Numerous psychoacoustic surveys provide substantial evidence that individual reactions to noise vary widely with noise exposure level. Since the early 1970s, researchers have determined (and subsequently confirmed) that aggregate community response is generally predictable and relates reasonably well to cumulative noise exposure such as DNL. Figure 10 depicts the widely recognized relationship between environmental noise and the percentage of people "highly annoyed," with annoyance being the key indicator of community response usually cited in this body of research.



Day - Night Average Sound Level in dB		40	45	50	55	60	65	70	75	80	85	100
Calculated %HA Points	USAF	0.41	0.831	1.66	3.31	6.48	12.29	22.1	36.47	53.74	70.16	82.64
	SCHULTZ	0.576	1.11	2.12	4.03	7.52	13.59	23.32	37.05	53.25	68.78	81

Figure 10 Percentage of People Highly Annoyed

Source: FICON. "Federal Agency Review of Selected Airport Noise Analysis Issues," September 1992.

Separate work by the EPA has shown that overall community reaction to a noise environment is also dependent on DNL. Figure 11 depicts this relationship.

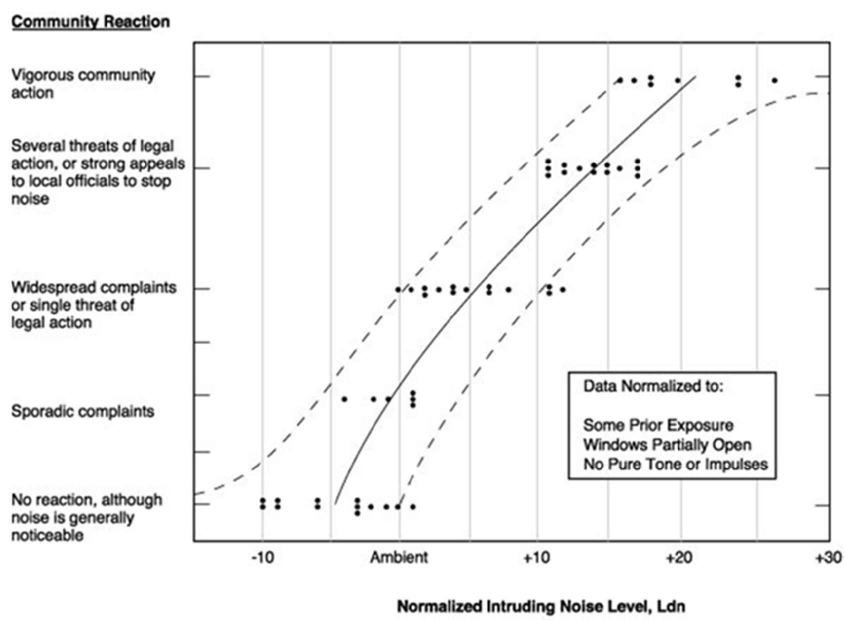


Figure 11 Community Reaction as a Function of Outdoor DNL

Source: Wyle Laboratories, "Community Noise," prepared for the U.S. Environmental Protection Agency, Office of Noise Abatement and Control, Washington, D.C., December 1971, page 63.

Data summarized in the figure suggest that little reaction would be expected for intrusive noise levels five decibels below the ambient, while widespread complaints can be expected as intruding noise exceeds background levels by about five decibels. Vigorous action is likely when levels exceed the background by 20 dB.

2.3 Effects of Weather and Distance

Participants in airport noise studies often express interest in two sound-propagation issues: (1) weather and (2) source-to-listener distance.

2.3.1 Weather-Related Effects

Weather (or atmospheric) conditions that can influence the propagation of sound include humidity, precipitation, temperature, wind, and turbulence (or gustiness). The effect of wind – turbulence in particular – is generally more important than the effects of other factors. Under calm-wind conditions, the importance of temperature (in particular vertical “gradients”) can increase, sometimes to very significant levels. Humidity generally has little significance relative to the other effects.

Influence of Humidity and Precipitation

Humidity and precipitation rarely effect sound propagation in a significant manner. Humidity can reduce propagation of high-frequency noise under calm-wind conditions. In very cold conditions, listeners often observe that aircraft sound “tinny,” because the dry air increases the propagation of high-frequency sound. Rain, snow, and fog also have little, if any noticeable effect on sound propagation. A substantial body of empirical data supports these conclusions.[6]

Influence of Temperature

The velocity of sound in the atmosphere is dependent on the air temperature.[7] As a result, if the temperature varies at different heights above the ground, sound will travel in curved paths rather than straight lines. During the day, temperature normally decreases with increasing height. Under such “temperature lapse" conditions, the atmosphere refracts ("bends") sound waves upwards and an acoustical shadow zone may exist at some distance from the noise source.

Under some weather conditions, an upper level of warmer air may trap a lower layer of cool air. Such a “temperature inversion” is most common in the evening, at night, and early in the morning when heat absorbed by the ground during the day radiates into the atmosphere.[8] The effect of an inversion is just the opposite of lapse conditions. It causes sound propagating through the atmosphere to refract downward.

The downward refraction caused by temperature inversions often allows sound rays with originally upward-sloping paths to bypass obstructions and ground effects, increasing noise levels at greater distances. This type of effect is most prevalent at night, when temperature inversions are most common

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[6] Ingard, Uno. “A Review of the Influence of Meteorological Conditions on Sound Propagation,” Journal of the Acoustical Society of America, Vol. 25, No. 3, May 1953, p. 407.
[7] In dry air, the approximate velocity of sound can be obtained from the relationship:
$c = 331 + 0.6T_c$ (c in meters per second, Tc in degrees Celsius). Pierce, Allan D., Acoustics: An Introduction to its Physical Principles and Applications. McGraw-Hill. 1981. p. 29.
[8] Embleton, T.F.W., G.J. Thiessen, and J.E. Piercy, “Propagation in an inversion and reflections at the ground,” Journal of the Acoustical Society of America, Vol. 59, No. 2, February 1976, p. 278.

and when wind levels often are very low, limiting any confounding factors.[9] Under extreme conditions, one study found that noise from ground-borne aircraft might be amplified 15 to 20 dB by a temperature inversion. In a similar study, noise caused by an aircraft on the ground registered a higher level at an observer location 1.8 miles away than at a second observer location only 0.2 miles from the aircraft.[10]

Influence of Wind

Wind has a strong directional component that can lead to significant variation in propagation. In general, receivers that are downwind of a source will experience higher sound levels, and those that are upwind will experience lower sound levels. Wind perpendicular to the source-to-receiver path has no significant effect.

The refraction caused by wind direction and temperature gradients is additive.[11] One study suggests that for frequencies greater than 500 Hz, the combined effects of these two factors tends towards two extreme values: approximately 0 dB in conditions of downward refraction (temperature inversion or downwind propagation) and -20 dB in upward refraction conditions (temperature lapse or upwind propagation). At lower frequencies, the effects of refraction due to wind and temperature gradients are less pronounced[12].

Wind turbulence (or "gustiness") can also affect sound propagation. Sound levels heard at remote receiver locations will fluctuate with gustiness. In addition, gustiness can cause considerable attenuation of sound due to effects of eddies traveling with the wind. Attenuation due to eddies is essentially the same in all directions, with or against the flow of the wind, and can mask the refractive effects discussed above.[13]

2.3.2 Distance-Related Effects

People often ask how distance from an aircraft to a listener affects sound levels. Changes in distance may be associated with varying terrain, offsets to the side of a flight path, or aircraft altitude. The answer is a bit complex, because distance affects the propagation of sound in several ways.

The principal effect results from the fact that any emitted sound expands in a spherical fashion – like a balloon – as the distance from the source increases, resulting in the sound energy being spread out over a larger volume. With each doubling of distance, spherical spreading reduces instantaneous or maximum level by approximately six decibels, and SEL by approximately three decibels.

"Atmospheric absorption" is a secondary effect. As an overall example, increasing the aircraft-to-listener distance from 2,000' to 3,000' could produce reductions of about four to five decibels for instantaneous or maximum levels, and of about two to four decibels for SEL, under average annual weather conditions. This absorption effect drops off relatively rapidly with distance. The Integrated Noise Model (INM) takes these reductions into account.

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[9] Ingard, p. 407.
[10] Dickinson, P.J., "Temperature Inversion Effects on Aircraft Noise Propagation," (Letters to the Editor) Journal of Sound and Vibration. Vol. 47, No. 3, 1976, p. 442.
[11] Piercy and Embleton, p. 1412. Note, in addition, that as a result of the scalar nature of temperature and the vector nature of wind, the following is true: under lapse conditions, the refractive effects of wind and temperature add in the upwind direction and cancel each other in the downwind direction. Under inversion conditions, the opposite is true.
[12] Piercy and Embleton, p. 1413.
[13] Ingard, pp. 409-410.

2.4 Noise / Land Use Compatibility Guidelines

DNL estimates have two principal uses in a noise study:

1. Provide a basis for comparing existing noise conditions to the effects of noise abatement procedures and/or forecast changes in airport activity.
2. Provide a quantitative basis for identifying potential noise impacts.

Both of these functions require the application of objective criteria for evaluating noise impacts. 14 CFR Part 150 Appendix A provides land use compatibility guidelines as a function of DNL values. Table 1 reproduces those guidelines.

These guidelines represent a compilation of the results of extensive scientific research into noise-related activity interference and attitudinal response. However, reviewers should recognize the highly subjective nature of response to noise, and that special circumstances can affect individuals' tolerance. For example, a high non-aircraft background noise level can reduce the significance of aircraft noise, such as in areas constantly exposed to relatively high levels of traffic noise. Alternatively, residents of areas with unusually low background levels may find relatively low levels of aircraft noise annoying.

Response may also be affected by expectation and experience. People may get used to a level of exposure that guidelines indicate may be unacceptable, and changes in exposure may generate response that is far greater than that which the guidelines might suggest.

The cumulative nature of DNL means that the same level of noise exposure can be achieved in an essentially infinite number of ways. For example, a reduction in a small number of relatively noisy operations may be counterbalanced by a much greater increase in relatively quiet flights, with no net change in DNL. Residents of the area may be highly annoyed by the increased frequency of operations, despite the seeming maintenance of the noise status quo.

With these cautions in mind, the Part 150 guidelines can be applied to the DNL contours to identify the potential types, degrees and locations of incompatibility. Measurement of the land areas involved can provide a quantitative measure of impact that allows a comparison of at least the gross effects of existing or forecast operations.

14 CFR Part 150 guidelines indicate that all uses are normally compatible with aircraft noise at exposure levels below DNL 65 dB. This limit is supported in a formal way by standards adopted by the U. S. Department of Housing and Urban Development (HUD). The HUD standards address whether sites are eligible for Federal funding support. These standards, set forth in Part 51 of the Code of Federal Regulations, define areas with DNL exposure not exceeding 65 dB as acceptable for funding. Areas exposed to noise levels between DNL 65 and 75 dB are "normally unacceptable," and require special abatement measures and review. Those at DNL 75 dB and above are "unacceptable" except under very limited circumstances.

Table 1 14 CFR Part 150 Noise / Land Use Compatibility Guidelines

Source: 14 CFR Part 150, Appendix A, Table 1

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

Key to Table 1

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

Notes for Table 1

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

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

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

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

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

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

(6) Residential buildings require an NLR of 25.

(7) Residential buildings require an NLR of 30

(8) Residential buildings not permitted.

3 Noise Prediction Methodology

3.1 Approach to Aircraft Noise Exposure Modeling

The Day-Night Average Sound Level (DNL) contours for this study were prepared using the most recent release of the FAA's Integrated Noise Model (INM), Version 7.0d.

The INM requires inputs in the following categories:

- Physical description of the airport layout
- Number and mix of aircraft operations
- Day-night split of operations (by aircraft type)
- Runway utilization rates
- Representative flight track descriptions and flight track utilization rates
- Meteorological conditions
- Terrain

The operational and spatial noise model inputs were developed using RealContours™, a proprietary program that enables modeling of all radar track data for a given period.

The FAA's INM Version 7.0d was released for general use on May 23, 2013 with a Software Service Update on September 24, 2013. The latest version has been used for the 2014 DNL contour in this report as the primary analytical tool to assess the noise environment at Dallas Love Field. This latest version of the model included data for the Boeing 787-8R, Boeing 747-800, Embraer E170, E175, E190, and E195. The model aircraft database has not changed since the 2013 DNL contour was developed.

The INM 7 versions of the model include updated data for most of the Boeing and Airbus fleet and an expanded set of corporate jet and non-jet aircraft types. The model also now includes modeling from helicopters and these were included in the development of the 2014 DNL contour for Love Field. Terrain data can also be utilized in the INM model to adjust the distance between the aircraft and the receiver. Annual average weather conditions are included in the modeling which allows for adjustments in aircraft performance and the inclusion of atmospheric absorption effects.

The FAA recently released the Aviation Environmental Design Tool (AEDT) which replaces the INM model. The INM was used for this project since the modeling effort began before the release of AEDT. This first release of AEDT contains the same aircraft database and aircraft performance models as INM.

3.2 Noise Modeling Process - RealContours™

HMMH prepared the 2014 noise exposure contours using the proprietary INM pre-processor RealContours™[14]. RealContours™ prepares each available aircraft flight track during the course of the year for input into INM. It should be noted that INM is used for all noise calculations. RealContours™ provides an organizational structure to model individual flight tracks in INM. RealContours™ itself does

[14] RealContours™ is proprietary software developed by Harris Miller Miller & Hanson Inc.

not modify INM "standard" noise, performance or aircraft substitution data, but rather selects the best standard data or FAA approved non-standard data, available to INM for each individual flight track.

RealContours™ takes maximum possible advantage of the available data from the Airports NOMS systems and the INM's capabilities. It automates the process of preparing the INM inputs directly from recorded flight operations and models the full range of aircraft activity as precisely as possible. RealContours improves the precision of modeling by using operations monitoring results in the following areas:

- Directly converts the flight track recorded by the NOMS for every identified aircraft operation to an INM track, rather than assigning all operations to a limited number of prototypical tracks
- Models each ground track as it was flown in 2014, including deviations (due to weather, safety or other reasons) from the typical flight patterns
- Models each operation on the specific runway that was actually used, rather than applying a generalized distribution to broad ranges of aircraft types to an average of runway use
- Models each operation in the time period (i.e. day = 0700 to 2159 and night = 2200 to 0659) in which that operation occurred
- Selects the specific airframe and engine combination to model, on an operation-by-operation basis, by using the aircraft type designator associated with the flight plan and, if available for commercial operations, the published composition of the individual operator's aircraft inventory
- Compares each flight profile to the standard INM aircraft profiles and selects the best match for each flight
- Accurately incorporates runway closures due to construction (e.g. during a nighttime closure the modeling will only include tracks on the active runway)

The flight tracks for 2014 used in the modeling were obtained from DAL's EnvironmentalVue[15] flight tracking system and are all from the FAA's Nextgen radar data feed.

[15] EnvironmentalVue is a product of Exelis

4 Noise Modeling Inputs

4.1 Airfield Layout and Runway Geometry

As shown in Figure 12, the airfield consists of two parallel 150-foot wide runways running along a northwest/southeast axis. The northern runway, Runway 13L/31R is adjacent to Lemmon Avenue. To its south, Runway 13R/31L is adjacent to Denton Drive. Table 2 provides further detail and runway coordinates for each runway end and the modeled helipad location. The 2014 radar data included helicopter flight tracks to and from the airport. The airport does not have a designated helipad, however the noise model needs a location defined to use in the modeling. A helipad location (H01) was defined along taxiway Alpha between taxiways Alpha2 and Alpha3.

An additional cross wind runway (18/36) is also shown in Figure 12; however it was closed for all of 2014 and was not used in modeling the 2014 conditions.

Table 2 Runway Layout

Source: FAA Airport Master Record 5010

Runway	Latitude	Longitude	Elevation (ft. MSL)	Displaced Arrival Threshold	Glide Slope	Width (ft.)	Length (ft.)
13L	32.857274	-96.856801	477	400	3.0	150	7,752
31R	32.842043	-96.839152	487	0	3.0		
13R	32.851317	-96.863452	476	490	3.0	150	8,800
31L	32.834029	-96.843415	476	0	3.0		
H01	32.849059	-96.845502	487	0	3.0	100	100

Note: Runway 18/36 was closed for all of 2014.

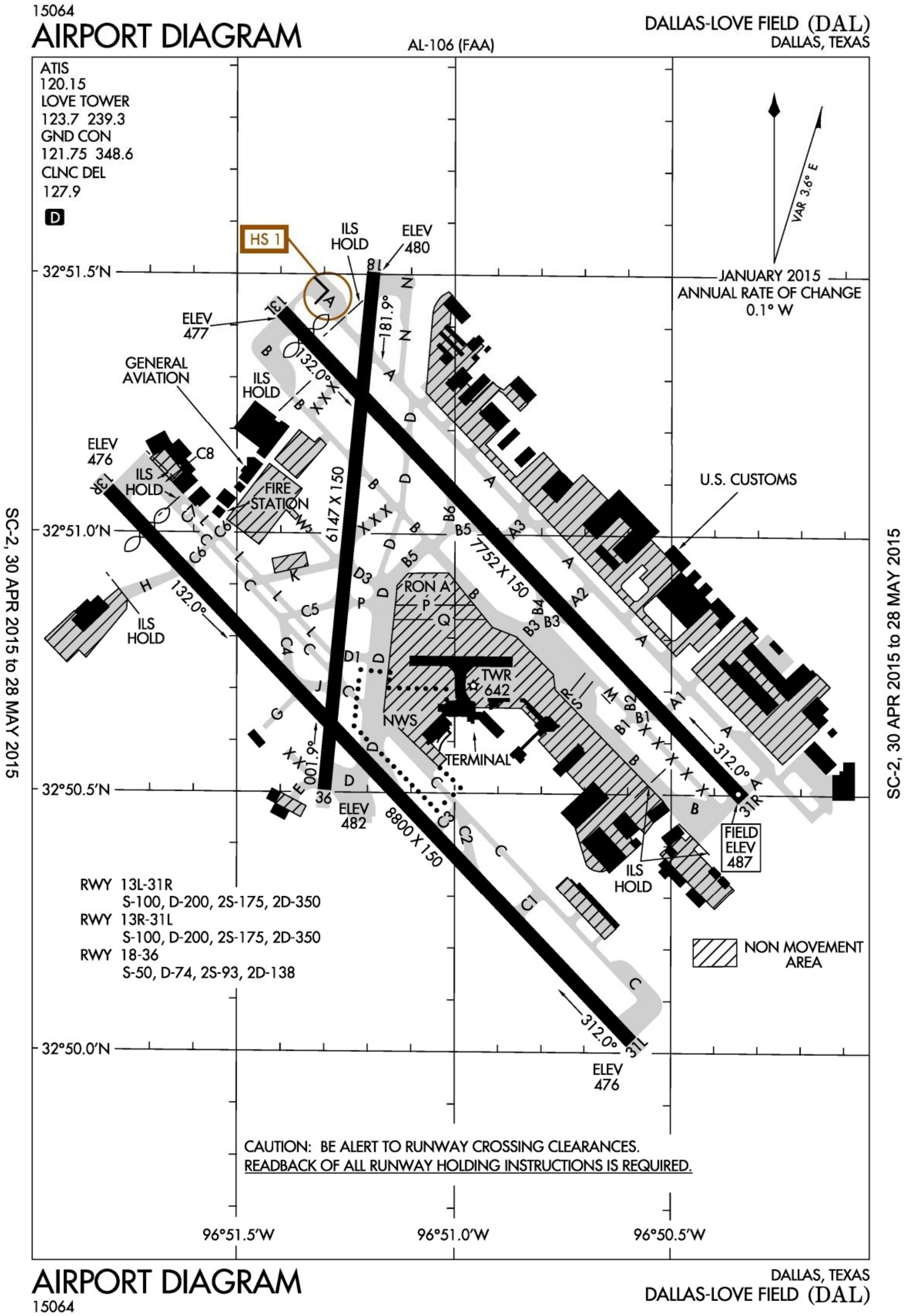


Figure 12 Dallas Love Field Airport Diagram

4.2 Aircraft Operations

The 2014 DNL noise contours reflect operations during the entire calendar year. Operations totals were obtained from the FAA, Operations Network (OPSNET) (otherwise known as the tower counts) and are shown in Table 3

The FAA groups aircraft traffic into one of four categories:

- Air Carrier – Operations by aircraft capable of holding 60 seats or more and are flying using a three letter company designator.
- Air Taxi - Operations by aircraft less than 60 seats and are flying using a three letter company designator or the prefix "Tango".
- General Aviation – Civil (non-military) aircraft operations flying without a three letter company destination or the prefix "Tango".
- Military – all classes of military operations.

As described in Section 3.2 the EnvironmentalVue data source provided aircraft flight tracks from DAL's flight tracking system and identified individual operations by operator, aircraft type and time of day (daytime or nighttime) for both departures and arrivals. HMMH supplemented the EnvironmentalVue data with data from the FAA's Aircraft Registration Database to further identify aircraft types to enhance the modeling dataset. The RCV2 system assigns each flight to one of the FAA tower count categories to allow for the scaling of the data to match the FAA tower counts totals.

In summary, 171,911 individual flight tracks recorded by EnvironmentalVue were directly used for the preparation of the 2014 DNL contours. The operations were scaled within each FAA category (e.g. air carrier, air taxi, etc.) to the 182,949 operations recorded by OPSNET. The difference between the number of flight tracks modeled and the FAA operations counts is expected and occurs for the following primary reasons:

1. RealContours™ filters flight track data and only uses data suitable for modeling with the INM (e.g. the track must be defined by a certain number of points, the aircraft type cannot be missing, tracks must be assigned to a runway end, etc.)
2. Military operations are not identified in the dataset.

Each flight track must meet several criteria, including having a runway assignment, providing a valid aircraft type designator and containing sufficient flight track points to define the aircraft's flight path and altitude profile. To address the military flights, the 774 annual operations from OPSNET[16] were distributed over the air carrier and general aviation group totals with a 45% to 55% split, respectively. This distribution was determined by evaluating the military fleet aircraft types available for DAL in 2014 through the FAA Traffic Flow Management System Counts (TFMSC)[17].

[16] FAA Operations Network Data (OPSNET) accessed June 1, 2015.
[17] FAA Traffic Flow Management System Count (TFMSC) data accessed 5/28/2015

Table 3 2014 Modeled Average Daily FAA Category Operations

Source: FAA OPSNET, HMMH 2015

FAA Operational Category	2014 Operations	
	2014 FAA OPSNET	2014 Average Annual Day Modeled Operations
Air Carrier	91,138	250.65
Air Taxi	33,019	90.46
General Aviation	58,018	160.12
Military	774	0.00
Total	**182,949**	**501.23**

Notes: Totals may not add due to rounding
Average Annual Day Air Carrier and General Aviation include the Military counts

Table 4 shows the modeled 2014 average annual day operations group by FAA aircraft category, engine type and INM aircraft type for daytime and nighttime arrivals and departures.

Table 4 2014 Modeled Average Daily Aircraft Operations

Source: HMMH 2015

Aircraft Category	Engine Type	INM Aircraft Type	Arrivals		Departures		Total
			Day	Night	Day	Night	
Air Carrier	Jet	717200	0.63	0.08	0.59	0.12	1.42
		727EM2	0.02	<0.01	0.02	0.01	0.05
		727Q15[1]	0.08	0.02	0.08	0.02	0.2
		727Q9[1]	0.02	0.02	0.02	0.01	0.07
		737300	30.92	2.76	31.09	2.59	67.35
		7373B2	1.49	0.10	1.49	0.09	3.17
		737400	0.08	0.03	0.06	0.05	0.22
		737500	19.26	1.19	19.14	1.31	40.89
		737700	56.09	6.83	56.88	6.03	125.83
		737800	1.49	0.47	1.70	0.26	3.91
		737N17	0.03	0.01	0.04	<0.01	0.08
		757PW	0.02	<0.01	0.01	<0.01	0.03
		757RR	0.02	0.01	0.02	0.01	0.06
		767CF6	0.05	0.06	0.09	0.02	0.20
		A319-131	1.74	0.30	1.85	0.19	4.08
		A320-211	0.73	0.06	0.77	0.01	1.57
		A320-232	0.01	<0.01	<0.01	0.01	0.02
		A321-232	<0.01	<0.01	<0.01	<0.01	0.01
		A330-301	<0.01	<0.01	<0.01	<0.01	0.01
		CRJ9-ER	0.11	<0.01	0.11	<0.01	0.22
		CRJ9-LR	0.13	<0.01	0.13	<0.01	0.25
		DC93LW	0.03	0.02	0.03	0.03	0.11
		F10062	0.39	0.02	0.39	0.02	0.83
		MD82	0.01	<0.01	0.01	<0.01	0.03
		MD83	0.02	<0.01	0.02	0.01	0.05
		MD9025	<0.01	<0.01	<0.01	<0.01	0.01
Air Carrier Subtotal			113.37	11.98	114.54	10.79	250.67
Air Taxi	Jet	CIT3	0.06	0.01	0.06	<0.01	0.13

Aircraft Category	Engine Type	INM Aircraft Type	Arrivals		Departures		Total
			Day	Night	Day	Night	
		CL600	2.48	0.21	2.55	0.14	5.38
		CL601	6.38	0.62	6.81	0.20	14.01
		CNA500	0.05	<0.01	0.05	<0.01	0.10
		CNA510	1.14	1.29	1.52	0.92	4.87
		CNA525C	0.38	0.03	0.38	0.03	0.81
		CNA55B	0.83	0.08	0.85	0.07	1.82
		CNA560E	2.91	0.18	2.82	0.27	6.18
		CNA560U	0.15	0.01	0.14	0.02	0.32
		CNA560XL	3.46	0.27	3.42	0.30	7.44
		CNA680	1.32	0.15	1.38	0.09	2.94
		CNA750	2.00	0.15	1.96	0.18	4.28
		ECLIPSE500	0.03	<0.01	0.03	<0.01	0.06
		EMB145	4.05	0.18	3.78	0.46	8.47
		EMB14L	2.22	0.19	2.10	0.31	4.82
		FAL20	0.02	0.01	0.03	0.01	0.06
		GIIB	0.03	0.01	0.03	<0.01	0.06
		GIV	0.41	0.06	0.44	0.03	0.93
		GV	0.54	0.07	0.55	0.06	1.23
		IA1125	0.09	0.01	0.10	<0.01	0.21
		LEAR35	3.95	0.22	3.92	0.25	8.35
		MU3001	1.78	0.15	1.84	0.09	3.86
	Turbo-Prop	1900D	<0.01	<0.01	<0.01	<0.01	0.01
		CNA208	1.74	0.40	2.13	0.01	4.28
		CNA441	0.54	0.25	0.51	0.28	1.58
		CVR580	<0.01	<0.01	0.01	<0.01	0.01
		DHC6	0.03	0.01	0.02	0.02	0.09
		DHC830	0.01	<0.01	0.01	<0.01	0.01
		DO228	0.58	0.03	0.56	0.05	1.22
		EMB120	0.01	<0.01	0.01	<0.01	0.03
		PA42	<0.01	<0.01	<0.01	<0.01	0.01
		SF340	<0.01	<0.01	<0.01	<0.01	0.01
	Prop	BEC58P	1.51	0.88	1.7	0.69	4.78
		CNA172	0.07	<0.01	0.06	0.01	0.15
		CNA182	0.02	<0.01	0.02	<0.01	0.04
		CNA206	0.04	0.01	0.04	0.01	0.09
		GASEPV	0.06	<0.01	0.05	0.01	0.12
		PA28	0.03	0.01	0.03	0.01	0.08
	Helicopter	B206B3	0.01	<0.01	0.01	<0.01	0.01
		EC130	0.01	<0.01	0.01	<0.01	0.01
		S76	0.54	0.24	0.53	0.25	1.56
		SA355F	0.01	<0.01	<0.01	0.01	0.02
Air Taxi Subtotal			39.49	5.73	40.46	4.78	90.44
General Aviation	Jet	727EM1	<0.01	<0.01	<0.01	<0.01	0.01
		727Q15[1]	<0.01	<0.01	<0.01	<0.01	0.01
		7373B2	0.01	<0.01	0.01	<0.01	0.01

Aircraft Category	Engine Type	INM Aircraft Type	Arrivals		Departures		Total
			Day	Night	Day	Night	
		737400	0.01	<0.01	0.01	<0.01	0.03
		737700	0.12	<0.01	0.12	0.01	0.26
		757PW	0.01	0.03	0.03	0.01	0.07
		757RR	0.05	0.09	0.12	0.02	0.27
		767300	<0.01	<0.01	<0.01	<0.01	0.01
		A310-304	<0.01	<0.01	<0.01	<0.01	0.01
		A319-131	<0.01	<0.01	0.01	<0.01	0.01
		CIT3	2.36	0.23	2.42	0.17	5.19
		CL600	3.35	0.20	3.44	0.11	7.10
		CL601	4.63	0.33	4.63	0.33	9.92
		CNA500	1.71	0.49	1.88	0.32	4.41
		CNA510	1.60	0.09	1.61	0.08	3.38
		CNA525C	4.78	0.39	4.72	0.46	10.36
		CNA55B	1.66	0.13	1.69	0.09	3.57
		CNA560E	1.04	0.04	1.06	0.02	2.16
		CNA560U	1.71	0.10	1.76	0.05	3.63
		CNA560XL	2.53	0.15	2.59	0.08	5.36
		CNA680	2.04	0.07	2.01	0.10	4.22
		CNA750	0.70	0.05	0.72	0.03	1.5
		DC93LW	<0.01	0.01	0.01	<0.01	0.02
		ECLIPSE500	0.34	0.05	0.34	0.04	0.78
		EMB145	0.17	<0.01	0.17	<0.01	0.35
		F10062	4.33	0.30	4.39	0.23	9.25
		FAL20	0.13	0.01	0.13	0.01	0.28
		GII	0.04	<0.01	0.04	<0.01	0.08
		GIIB	0.32	0.03	0.30	0.06	0.71
		GIV	2.57	0.17	2.58	0.16	5.48
		GV	2.65	0.32	2.74	0.23	5.94
		IA1125	1.59	0.18	1.63	0.14	3.54
		LEAR25	0.06	0.01	0.07	0.01	0.15
		LEAR35	8.10	0.57	8.11	0.55	17.33
		MD81	0.01	<0.01	<0.01	0.01	0.01
		MD83	0.01	<0.01	0.01	<0.01	0.03
		MU3001	1.07	0.18	1.11	0.14	2.50
	Turbo-Prop	1900D	0.01	<0.01	0.01	<0.01	0.02
		CNA208	3.33	0.13	3.34	0.13	6.93
		CNA441	7.37	0.78	7.28	0.87	16.3
		CVR580	0.01	<0.01	<0.01	<0.01	0.01
		DHC6	0.04	<0.01	0.04	0.01	0.09
		DO228	2.53	0.20	2.53	0.20	5.47
		HS748A	0.11	0.01	0.10	0.02	0.23
		PA42	0.03	<0.01	0.02	<0.01	0.05
		SD330	0.26	0.01	0.25	0.03	0.54
	Prop	BEC58P	3.01	0.13	2.93	0.2	6.27
		CNA172	0.58	0.06	0.56	0.08	1.28
		CNA182	0.39	0.01	0.39	0.01	0.80

Aircraft Category	Engine Type	INM Aircraft Type	Arrivals		Departures		Total
			Day	Night	Day	Night	
		CNA206	1.14	0.02	1.06	0.09	2.32
		CNA20T	0.28	0.03	0.29	0.01	0.61
		COMSEP	0.01	<0.01	0.01	<0.01	0.01
		DC3	0.02	<0.01	0.02	<0.01	0.04
		DC6	0.03	<0.01	0.03	<0.01	0.06
		GASEPF	0.24	0.05	0.26	0.02	0.57
		GASEPV	3.69	0.18	3.58	0.29	7.74
		PA28	0.15	0.01	0.14	0.01	0.31
		PA30	0.10	0.01	0.11	0.01	0.23
		PA31	0.17	0.04	0.17	0.04	0.43
	Helicopter	A109	0.03	0.01	0.04	<0.01	0.08
		B206B3	0.06	0.04	0.05	0.05	0.19
		B206L	0.01	<0.01	0.01	<0.01	0.03
		B212	0.01	<0.01	0.01	<0.01	0.01
		B407	0.23	0.03	0.21	0.05	0.52
		B427	0.01	<0.01	0.01	<0.01	0.01
		B429	0.07	0.04	0.07	0.04	0.22
		B430	<0.01	<0.01	<0.01	<0.01	0.01
		EC130	0.19	0.05	0.13	0.12	0.50
		R44	0.07	0.01	0.08	0.01	0.16
		S76	0.05	<0.01	0.05	0.01	0.11
		SA355F	0.02	0.01	0.02	<0.01	0.05
General Aviation Subtotal			73.95	6.08	74.26	5.76	160.14
Grand Total[2]			226.83	23.79	229.28	21.34	501.23

Note:
1 These are B727 aircraft using Raisbeck Stage 3 noise reduction kits
2 Grand Totals may not be equal to sum of subtotals due to rounding

4.3 Runway Utilization

Table 5 summarizes the runway utilization for the average annual day conditions modeled for 2014. Separate utilization percentages for each aircraft category as well as the total across all aircraft are shown and in general show approximately 66 percent of the operations in south flow (use of Runway 13L/13R) and 34 percent of the operations in north flow (use of Runway 31R/31L) in 2014.

Use of the voluntary noise abatement runway at night has decreased since 2013 (as noted below, construction projects in both years affected annual usage of the noise abatement runway), but is still dominant with 59 percent of the nighttime air carrier operations on Runway 13R/31L. In south flow operations during 2014, air carrier arrivals favored Runway 13L whereas departures utilized runways 13L/13R more evenly. In north flow, air carriers favored Runway 31R for all operations except nighttime arrivals. Air taxi and general aviation operations tended to prefer Runway 13L in south flow and Runway 31R in north flow, especially during the daytime.

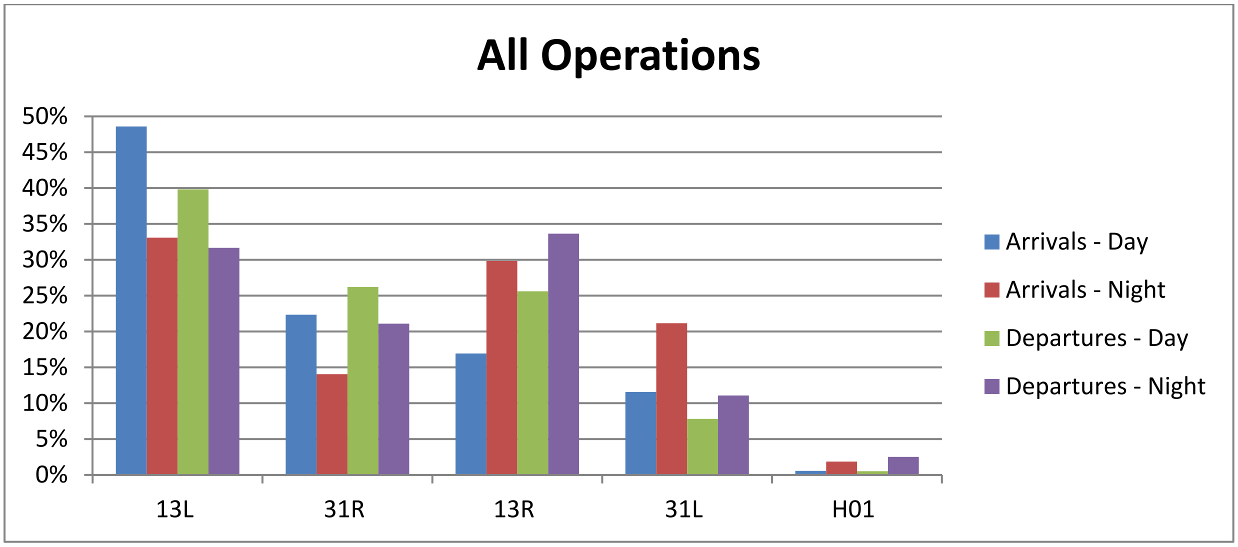
There were two temporary runway closures in 2014 and one in 2013 that affected runway use for both years. In 2013, modifications to Runway 13L/31R were made to have the appropriate amount of safety area (1,000 feet) at the north end of the runway. This resulted in the temporary closure of the runway for approximately 60 days in 2013 (February 18, 2013 – April 19, 2013) and was followed by a 120 day period of overnight closures as needed. Beginning at the end of May in 2014, Runway 13R/31L was temporarily closed for approximately 45 days to facilitate two airfield construction projects. Shortly after the completion of those projects in early July, Runway 13L/31R was closed for approximately three weeks for electrical upgrades to airfield signage.

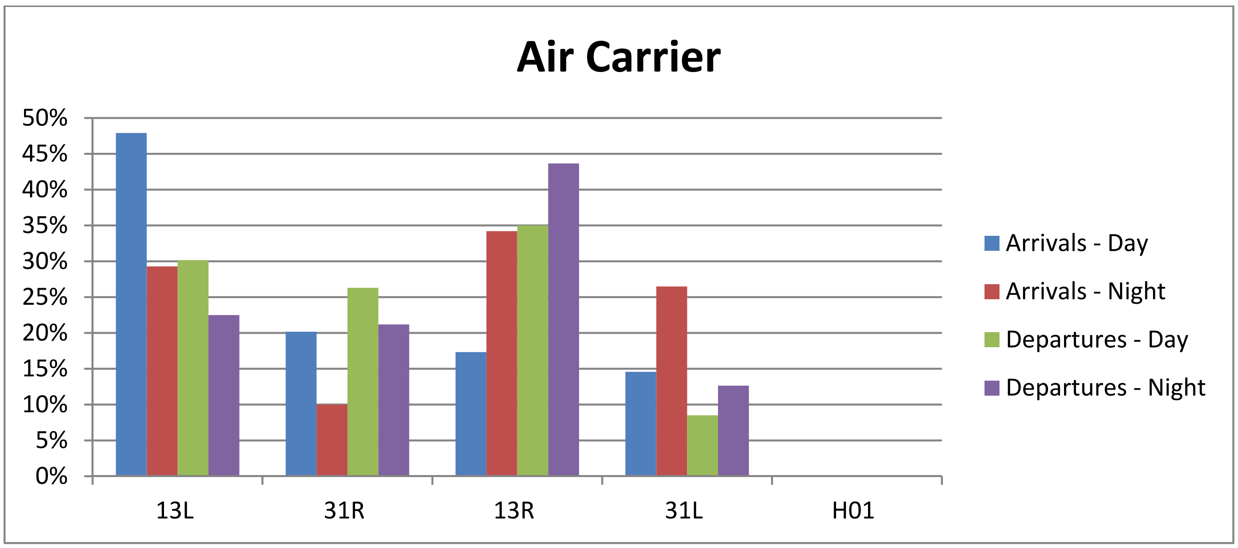
Table 5 2014 Modeled Runway Use

Source: EnvironmentalVue data, HMMH 2015 analysis

Aircraft Category	Runway	Arrivals		Departures	
		Day	Night	Day	Night
Air Carrier	13L	47.91%	29.29%	30.18%	22.50%
	31R	20.18%	10.00%	26.31%	21.19%
	13R	17.33%	34.22%	35.00%	43.66%
	31L	14.58%	26.49%	8.52%	12.65%
	H01	0.00%	0.00%	0.00%	0.00%
	Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**
Air Taxi	13L	52.63%	35.93%	50.90%	41.73%
	31R	25.62%	16.96%	26.29%	21.05%
	13R	13.44%	25.18%	15.09%	24.21%
	31L	6.90%	17.73%	6.38%	7.51%
	H01	1.42%	4.22%	1.33%	5.49%
	Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**
General Aviation	13L	47.47%	37.83%	48.67%	40.44%
	31R	23.92%	19.27%	26.04%	20.96%
	13R	18.18%	25.64%	16.86%	22.73%
	31L	9.43%	13.95%	7.54%	11.10%
	H01	1.00%	3.31%	0.90%	4.76%
	Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**
All Aircraft	13L	48.59%	33.08%	39.82%	31.67%
	31R	22.34%	14.06%	26.22%	21.10%
	13R	16.93%	29.84%	25.61%	33.64%
	31L	11.57%	21.16%	7.82%	11.08%
	H01	0.57%	1.86%	0.53%	2.52%
	Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Note: Totals may not match exactly due to rounding.


All Operations
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
13L
31R
13R
31L
H01
Arrivals - Day
Arrivals - Night
Departures - Day
Departures - Night


Air Carrier
50%
45%
40%
35%
30%
25%
20%
15%
10%
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0%
13L
31R
13R
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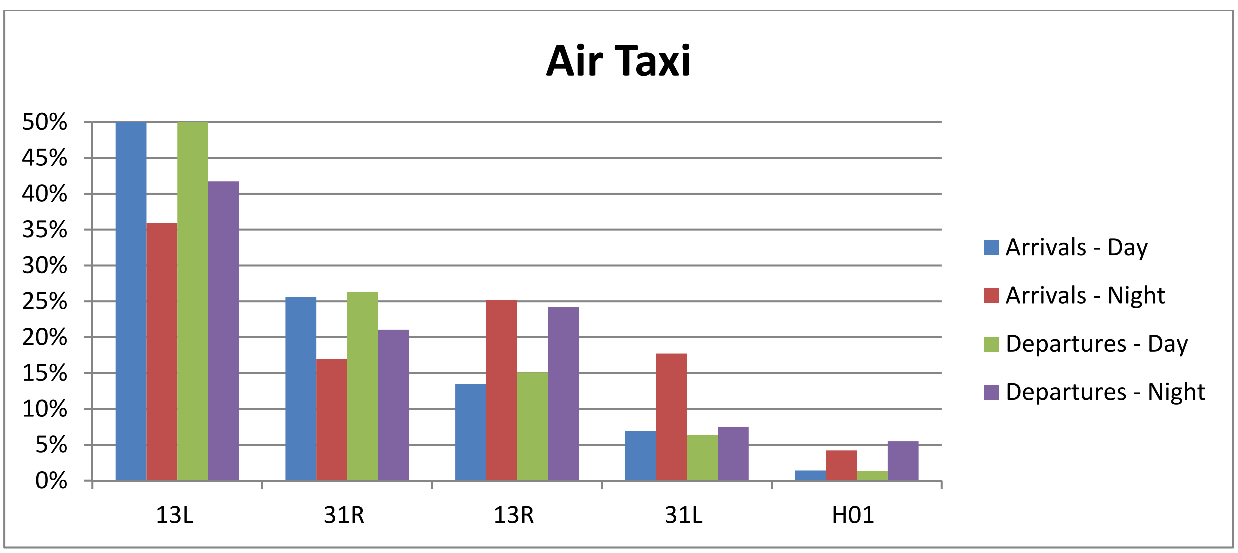
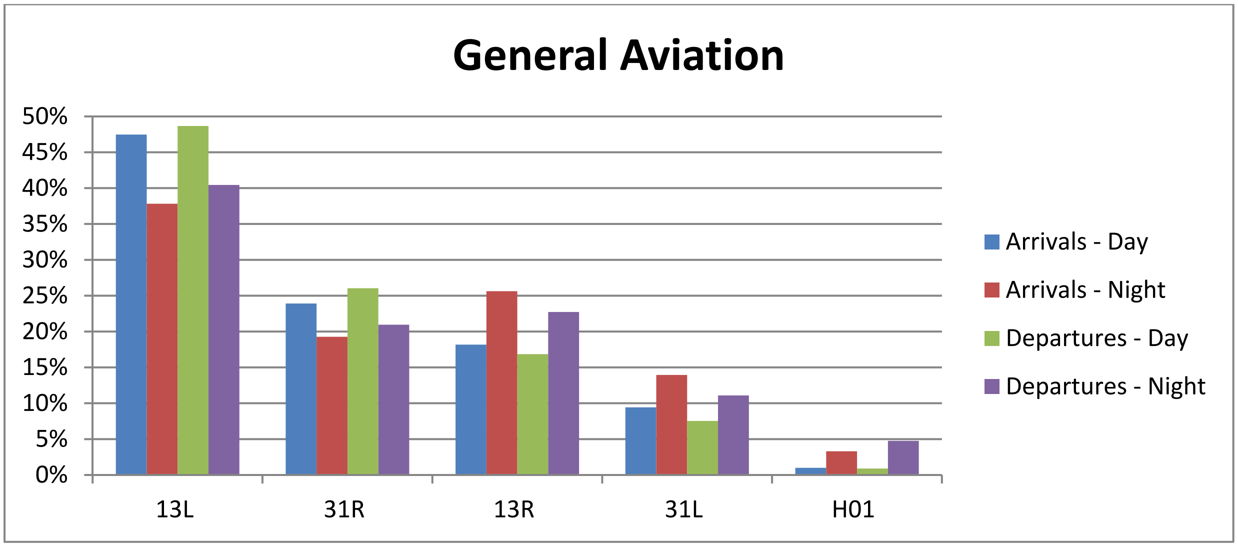
H01
Arrivals - Day
Arrivals - Night
Departures - Day
Departures - Night


Air Taxi
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
13L
31R
13R
31L
H01
Arrivals - Day
Arrivals - Night
Departures - Day
Departures - Night



4.4 Flight Track Geometry

As described in Section 3.2 RealContours™ was used to develop INM tracks from radar flight data, thereby modeling each and every available radar flight as an INM flight track. Figure 13 and Figure 14 provide samples of the radar developed INM model tracks. A total of 171,911 individual model tracks were modeled.

Figure 13 presents a sample of 5,750 north flow model tracks and Figure 14 presents a sample of 11,176 south flow model tracks, representing an approximately ten percent sampling of all modeled flight tracks.

The north flow tracks in Figure 13 show arrivals to Runways 31L and 31R with a higher concentration coming from the southwest side of the airport and then turning to line up for final approach to the runways. As for north flow departures, jet traffic makes up the concentration of tracks departing and remaining on or near runway heading. The departure tracks turning quickly to the northeast or to the southwest are non-jet aircraft flight tracks.

The south flow tracks in Figure 14 show arrivals to Runways 13L and 13R with a high concentration coming from the northeast side of the airport and then turning to line up for final approach to the runways. Arrivals tracks that are seen over the airport are passing over the airport at a higher altitude and then turning to line up with the runways. As for south flow departures, jet traffic makes up the concentration of tracks departing and remaining on or near runway heading.

The TRINITY SEVEN departure procedure (used at night for noise abatement) was included in the modeling and those tracks can be seen in Figure 14 departing from Runway 13R turning near Noise Monitor Site (NMS) 10 and passing just west of NMS 07. The procedure instructs aircraft to turn right heading 160 degrees as soon as possible but no later than 0.6 nautical miles from the end of the runway. The departure tracks turning quickly to the east or west (greater than 160 degrees) are non-jet aircraft flight tracks.

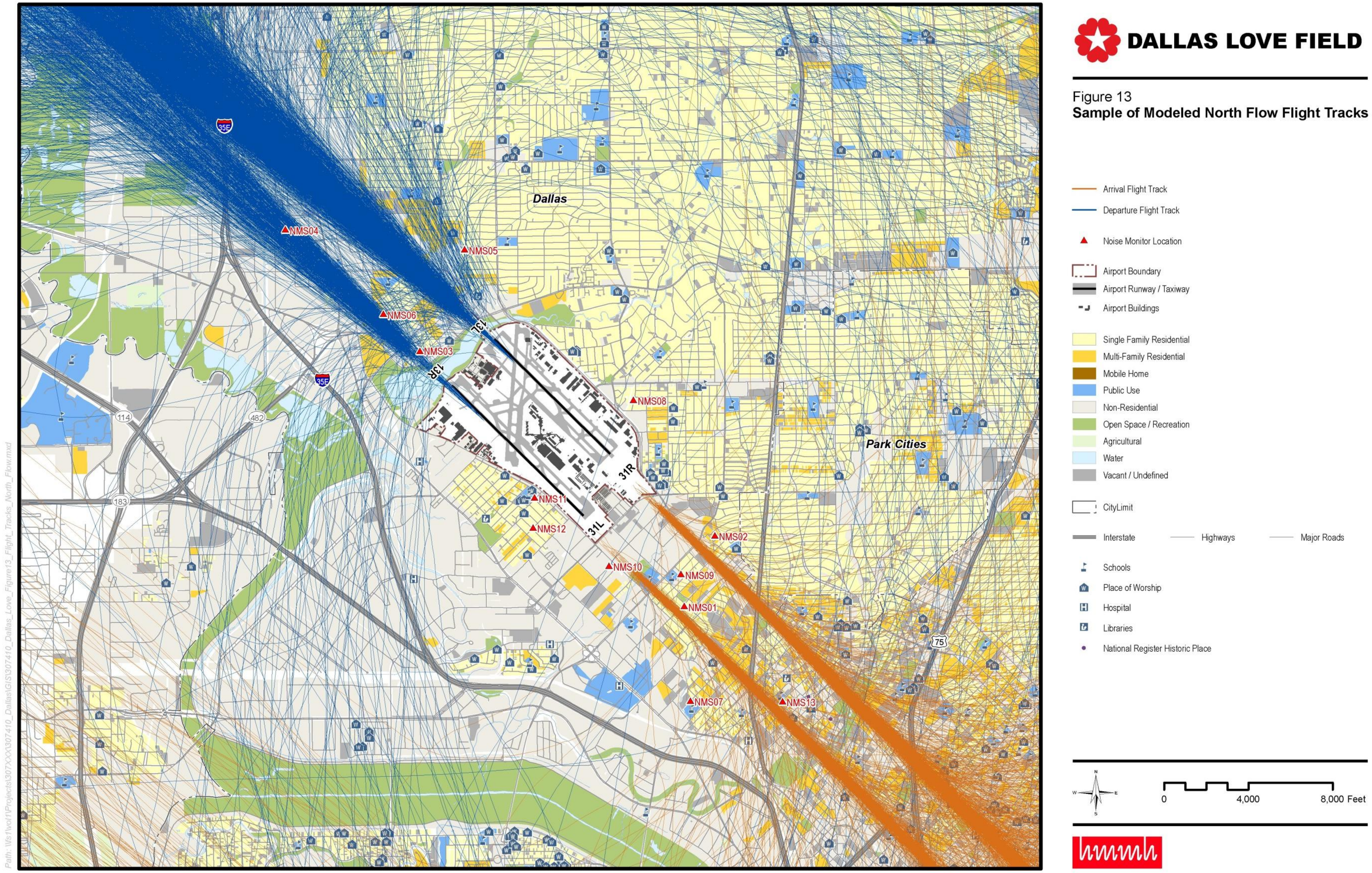


Figure 13 Sample of Modeled North Flow Flight Tracks

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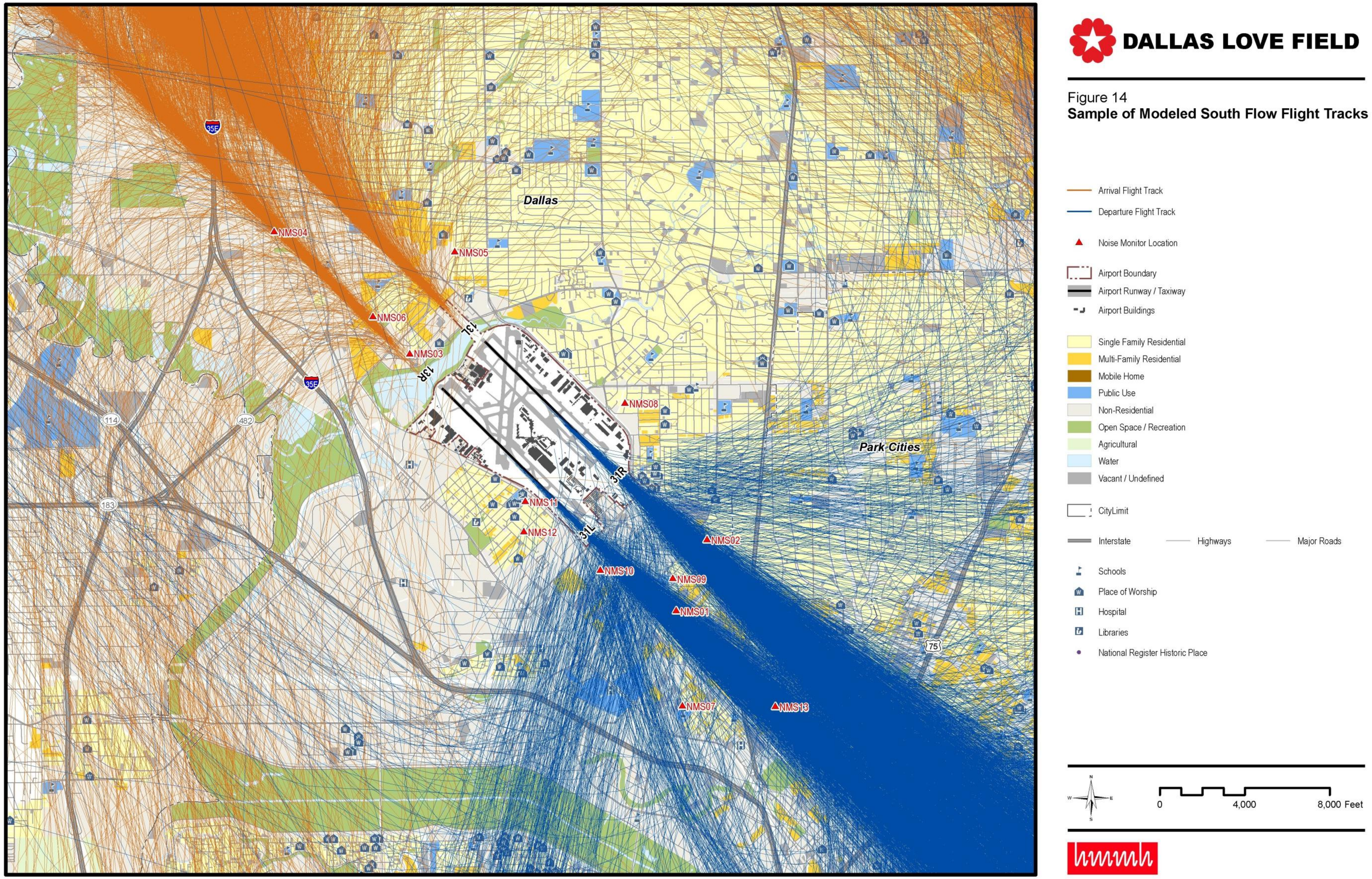

Figure 14 Sample of Modeled South Flow Flight Tracks

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4.5 Aircraft Stage Length

Within the INM database, aircraft takeoff or departure profiles are usually defined by a range of trip distances identified as "stage lengths." A longer trip distance or higher stage length is associated with a heavier aircraft due to the increase in fuel requirements for the flight. For this study, city pair distances were determined for each departure flight track and used in most cases to define the specific stage length using the INM standard definitions.

INM uses stage length as a means to estimate the aircraft weight on departure. Aircraft weight is required to determine the climb performance profile of the aircraft on departure. Stage length is the term used in INM to refer to the length or distance of the complete nonstop flight planned for each departure operation from origin to destination. The flight distance influences the take-off weight of the aircraft as more fuel is required to go greater distances. Aircraft weight is a factor in the aircraft's thrust and performance. The great-circle distance is used to calculate a stage length for each aircraft operation. Great-circle distance is the shortest distance between any two points on the surface of a sphere (Earth) measured along the path on the surface of the earth. Nine categories for departure stage length are used in INM.

The stage-length of each individual flight was calculated based on the destination airport on the flight plan. RealContours™ compares each flight's city-pair great-circle distance to the available stage-lengths available in the default INM database and makes an appropriate selection. INM does not have all stage lengths available for all aircraft. In cases where the stage length was not available or exceeded the maximum stage-length profile available for that runway (i.e., the aircraft would not over run the runway on departure), the maximum stage length available without overrunning the runway was selected. If a particular INM aircraft has multiple available default profiles in INM for a given stage-length, RealContours™ compares the flight track's altitude profile to the available default INM profiles, and assigns a default INM profile based on the closest match.

Table 6 presents the nine categories for departure stage length used in INM and the respective number of departures modeled for 2014.

Table 6 Modeled 2014 Departure Stage Length Operations

Source: FAA INM 7.0 Technical Manual, HMMH

Stage Length Number	Trip Length (Nmi)	2014 Departure Operations	
		Day	Night
D-1	0 - 500	202.78	19.40
D-2	500 - 1,000	17.74	1.57
D-3	1,000 - 1,500	8.16	0.33
D-4	1,500 - 2,500	0.12	0.01
D-5	2,500 - 3,500	0.47	0.03
D-6	3,500 - 4,500	0.01	0.00
D-7	4,500 - 5,500	0.00	0.00
D-8	5,500 - 6,500	0.00	0.00
D-9	Greater than 6,500	0.00	0.00
Total		229.28	21.34

4.6 Meteorological Conditions

The INM has several settings that affect aircraft performance profiles and sound propagation based on meteorological data at the airport. Meteorological settings include average temperature, barometric pressure, relative humidity, and headwind speed. A calendar year 2014 average from the National Climatic Data Center (NCDC) Integrated Surface Database (ISD) for DAL (WBAN number 13960) was collected and reviewed. Based on analysis of the NCDC data, the average conditions used in the INM for DAL noise modeling include:

- Temperature: 66.4° Fahrenheit
- Sea level pressure: 30.02 inches of Mercury (in-Hg)
- Relative humidity: 59.0 percent.
- Average headwind speed: INM default of 8.0 knots.

4.7 Terrain

Terrain data describe the elevation of the ground surrounding the airport and on airport property. The INM uses terrain data to adjust the ground level under the flight paths. The terrain data do not affect the aircraft's performance or emitted noise levels, but do affect the vertical distance between the aircraft and a "receiver" on the ground. This in turn affects the noise levels received at a particular point on the ground. The terrain data were obtained from the United States Geological Survey (USGS) National Map Viewer.

5 Noise Modeling Results and Land Use Impacts

5.1 Land Use

Land Use in the area surrounding DAL is shown on Figure 15. The land use is differentiated into three residential categories; Single Family Residential, Multi-Family Residential, and Mobile Home and six non-residential categories; Public Use, Non-Residential, Open Space /Recreation, Agricultural, Water, and Vacant / Undefined.

Residential areas are predominantly located to the north, east and southeast of the airport with smaller groups of homes immediately to the northwest of the airfield and immediately adjacent to the airport on the west side.

Figure 15 also identifies locations of noise sensitive sites such as schools, places of worship, hospitals and libraries within the surrounding area.

All land use data was obtained through the City of Dallas GIS Services Division.

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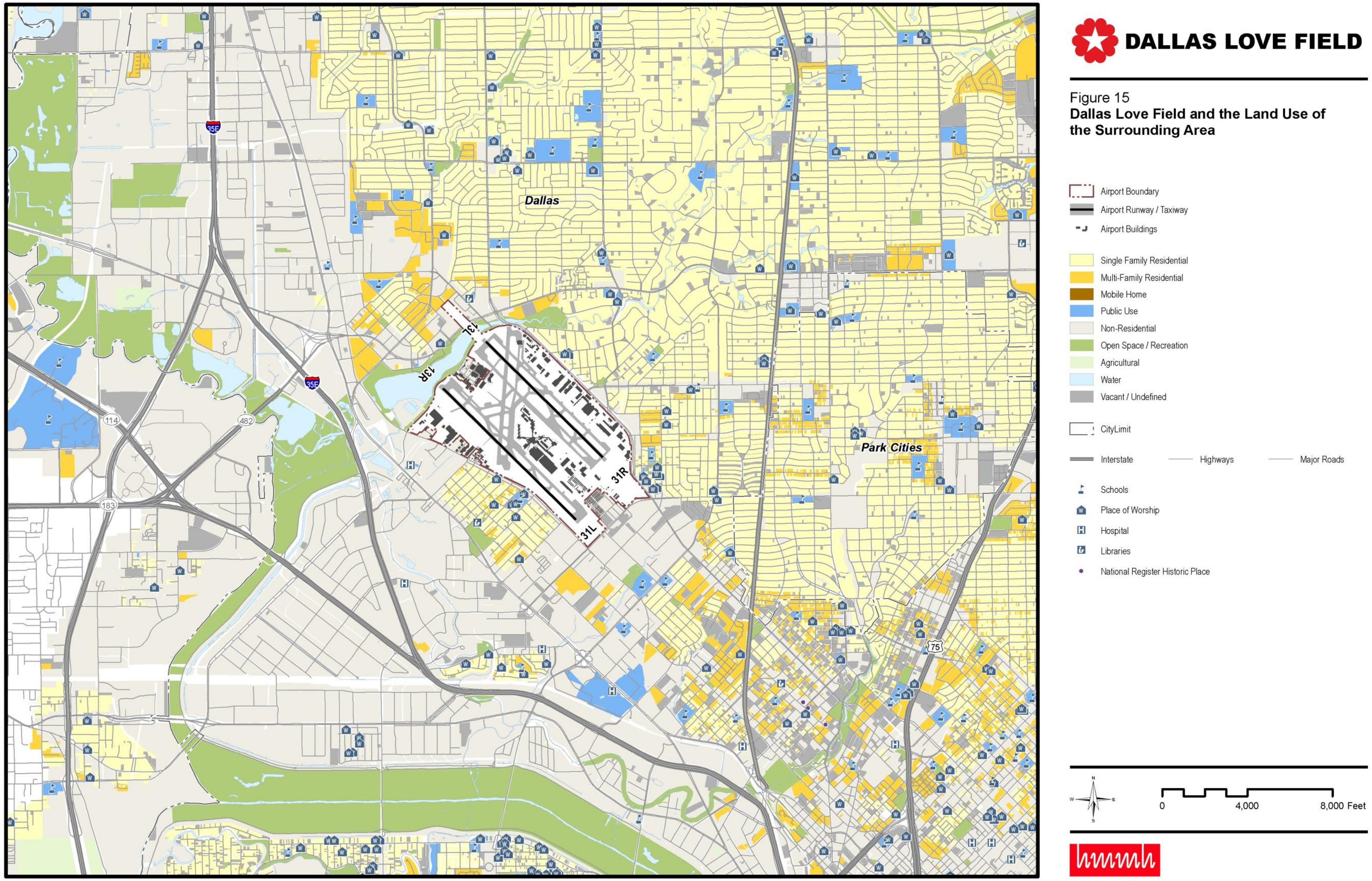

Figure 15 Dallas Love Field and Surrounding Area Land Use

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5.2 DNL Noise Contours

5.2.1 2014 Noise Contours

Figure 16 presents the 2014 DNL contours, 60dB through 75dB in 5dB intervals overlaid on the land use base map described in Section 5.1. The shape of the DNL contours is representative of the number of operations, the type of operation, the period during which the operations occurred, and, to some degree, the aircraft/engine combination. Arrival operations influence contour shapes in a different manner than departure operations do. The extended regions along the extended runway centerlines are primarily due to arrival operations whereas the wider bulges at the runway ends and sides are primarily the result of sideline noise associated with departures.

The DNL 65 dB contour extends from the airfield as follows:

- To the North; the DNL 65dB contour leaves airport property and extends almost to Brockbear Drive due to operations on Runway 13L and to Kendale Drive due to operations on Runway 13R.
- To the South; the DNL 65dB contour leaves airport property and extends to Inwood Road due to operations on Runway 31R and to Carlson Drive due to operations on Runway 31L.
- To the West; the DNL 65dB contour remains primarily within airport property except to the southwest where sideline noise extends just past Concord Avenue.
- To the East; the DNL 65dB contour remains almost entirely within airport property except a small area that crosses Lemmon Avenue near Thedford Avenue.

There are residential areas within the DNL 65 dB contour to the northwest of Runways 13L and 13R, to the west of Runway 13R/31L, southeast of Runway 31L, and east of Runway 31R.

There is also one school and one place of worship within the DNL 65 dB contour:

- Thomas J. Rusk Jr. High School
- North Temple Baptist Church

5.2.2 Comparison of 2014 and 2013 Noise Contours

Figure 17 shows a comparison of the 2014 DNL contours to the 2013 DNL contours for the same DNL 60 dB through DNL 75 dB range. The 2014 DNL contours reflect several changes at the airport;

- Due to construction in 2014, Runway 13L/31R was closed for three weeks and Runway 13R/31L was closed for over seven weeks.
- In September of 2014, the FAA implemented Performance Based Navigation (PBN) arrival and departure procedures and the 2014 DNL contour reflects three months of use of these procedures
- In October 2014, the Wright Amendment ended allowing airlines to expand their routes and destinations from Love Field

DNL levels have increased between one and two dB for areas directly off the end of Runways 13L and 31R due to departure operations and increases of between DNL one and three dB are seen in the extended runway centerline regions following runway centerlines primarily due to arrival operations. Noise increased slightly on the easterly sideline of Runway 13L/31R and decreased slightly on the westerly sideline of Runway 13R/31L. It also increased slightly along the extended runway centerline of the end of Runway 31L, and increased approximately DNL one dB along the extended runway centerline of the end of Runway 13R. The extended closure of Runway 13L/31R in 2013 resulted in a higher use of Runway 13R/31L. Runway closures in 2014 somewhat offset each other but preferred use of Runway 13L/31R returned in 2014 explaining the shifting of the contours.

5.2.3 Comparison of 2014 and 2006 Noise Contours

Figure 18 shows a comparison of the 2014 DNL contours to the 2006 DNL contours for the same DNL 60 dB through DNL 75 dB range. In 2014, the overall aircraft fleet is quieter than the fleet in 2006. The 2006 DNL contours included some Stage 2 corporate jets which are almost completely removed from the fleet in 2014. 2014 was also modeled with a lower level of operations than were modeled in 2006.

DNL levels have decreased notably in all areas between 2006 and 2014, except to the northwest of Runway 13L which remained the same. Noise decreases of between DNL two and three dB are seen for areas directly off all runways and between DNL four and five dB for areas along the sideline of all runways due to departure operations. Noise decreases of between DNL one and two dB are seen in the extended runway centerline regions following runway centerlines primarily due to arrival operations.

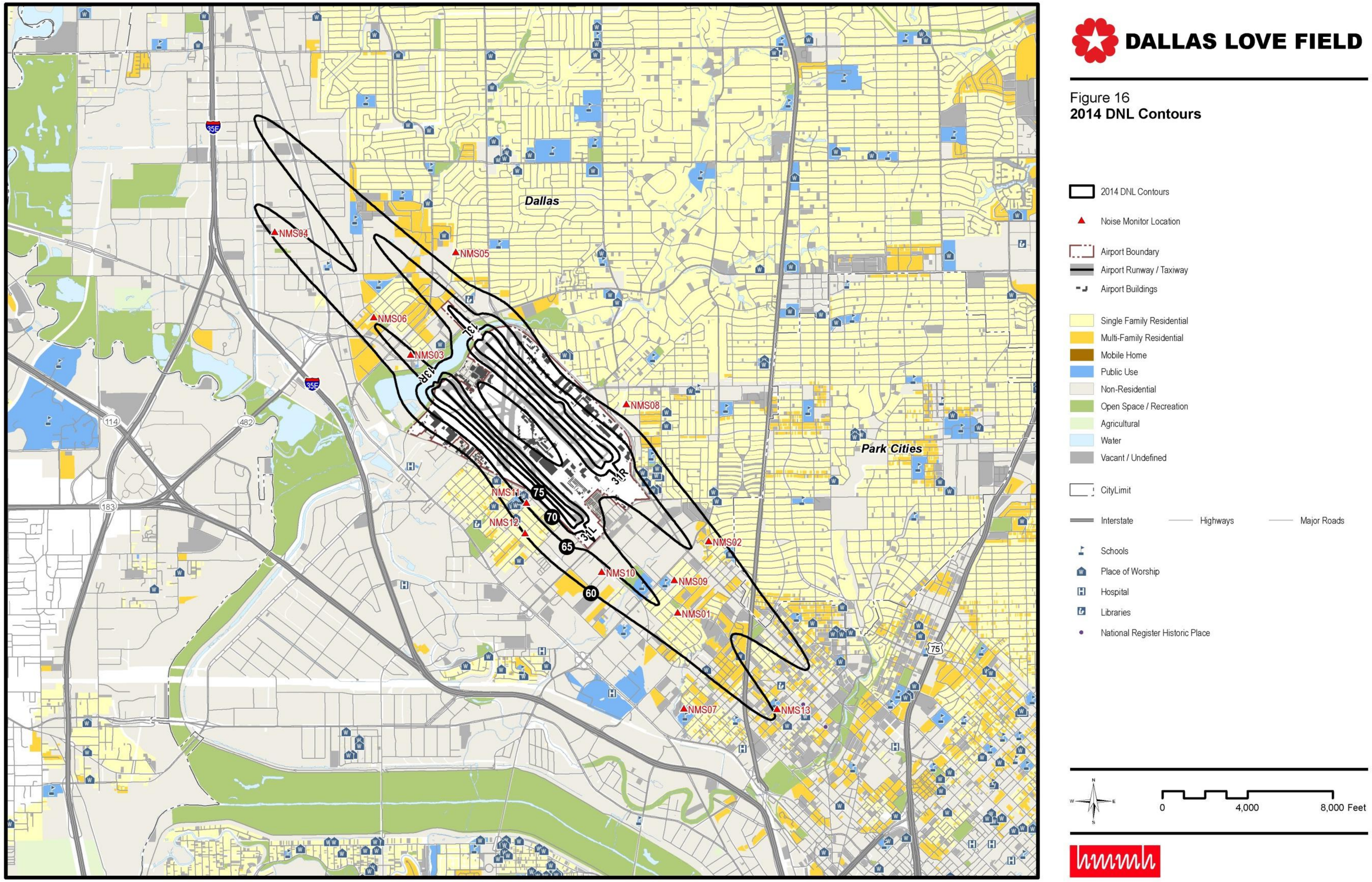

Figure 16 2014 DNL Contours

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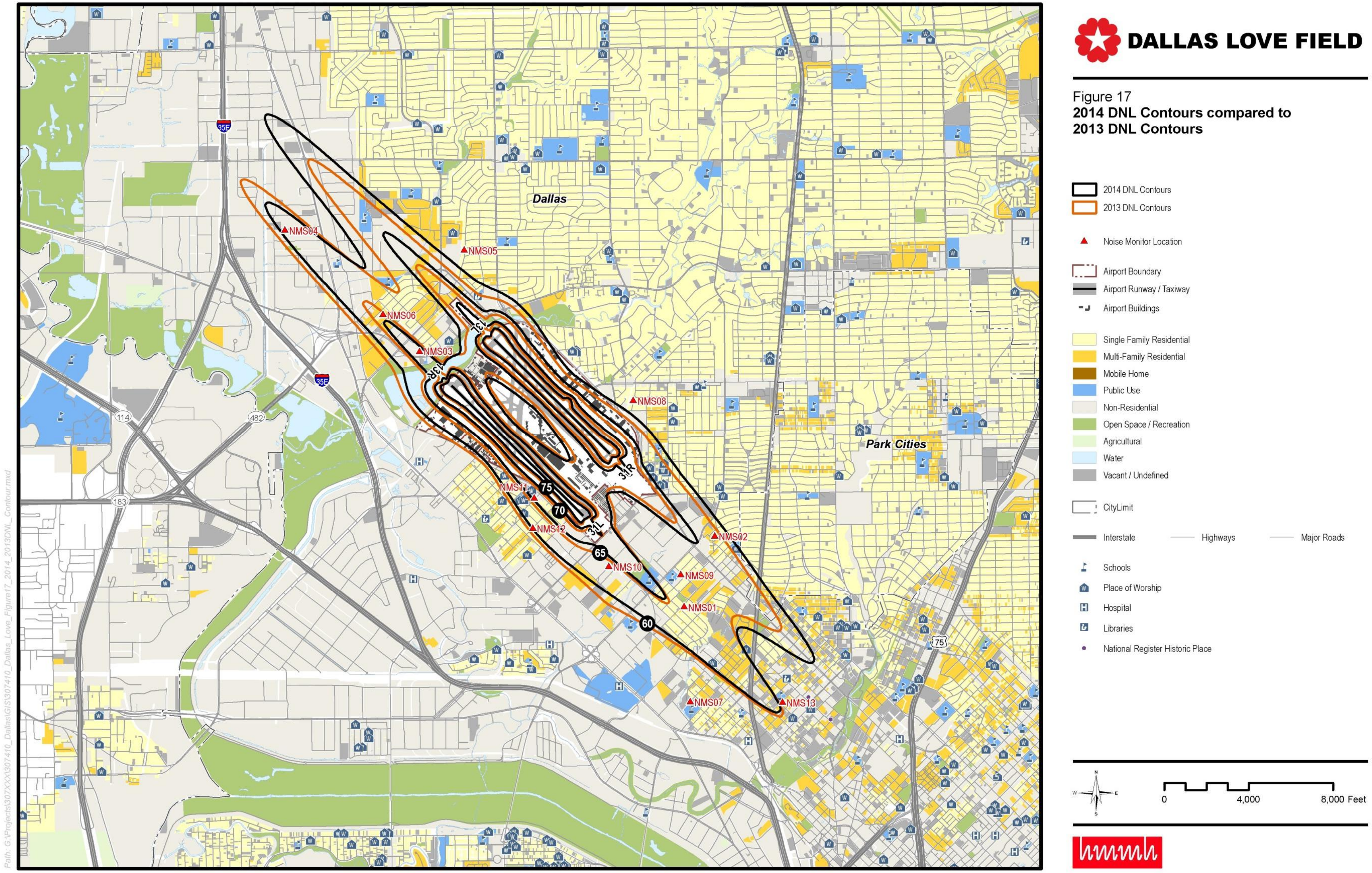

Figure 17 2014 DNL Contours compared to 2013 DNL Contours

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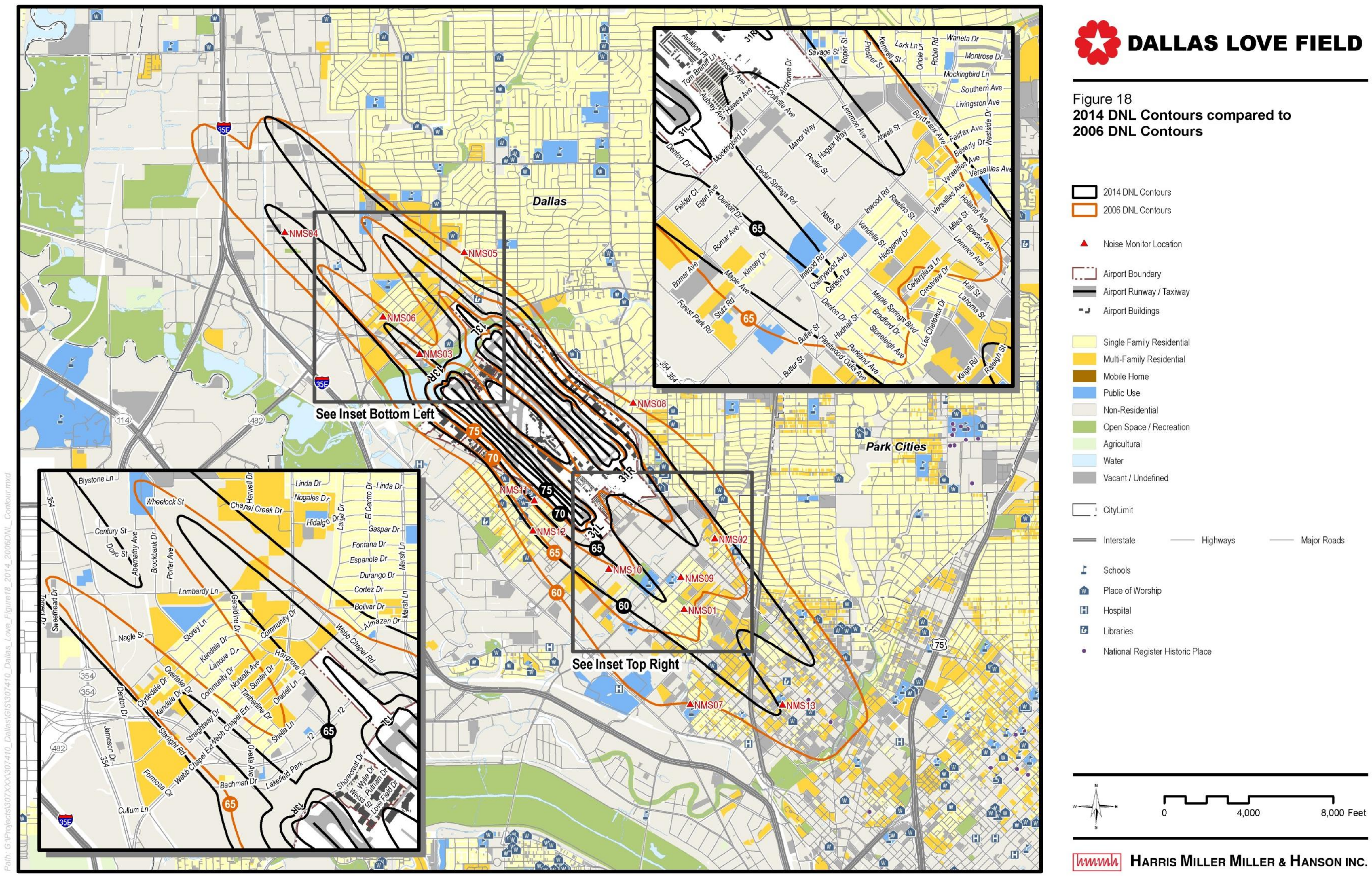

Figure 18 2014 DNL Contours compared to 2006 DNL Contours

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5.3 Noise Monitor Location Results

The NOMS at Dallas Love Field has 13 permanent monitors which measure noise 24 hours a day. DNL levels are computed at each site and averaged over the year resulting in an average annual measured DNL value. However, the measured value represents all sources of noise (aircraft plus cars, trucks busses etc.). The DNL values from aircraft only were modeled at each of these sites and are reported in Table 7. Two sites (NMS03 and NMS11) have a modeled value greater than DNL 65 dB and none are above DNL 70 dB.

Table 7 Modeled DNL at Noise Monitor Locations

Source: HMMH, DAL Noise Office

Noise Monitor Location				Day-Night Average Sound Level (DNL) dBA
Site	Address	Latitude	Longitude	Modeled (INMv7.0d)
NMS01	5125 Maple Springs	32.821920	-96.828070	63.3
NMS02	5620 LaFoy Blvd	32.831097	-96.823170	61.8
NMS03	9449 Ovella Ave.	32.855780	-96.868300	67.2
NMS04	2618 Andjon Dr.	32.871914	-96.888780	60.6
NMS05	9618 Larga Dr.	32.868954	-96.861130	56.8
NMS06	9959 Overlake Dr.	32.860687	-96.873860	64.5
NMS07	2227 Hawthorne Ave.	32.809563	-96.827350	55.5
NMS08	7608 Taos Rd.	32.848976	-96.835410	57.2
NMS09	5637 Vandelia St.	32.826140	-96.828500	61.6
NMS10	2721 Manor Way	32.827370	-96.839580	63.3
NMS11	2717 Anson Rd.	32.836403	-96.850920	65.5
NMS12	2451 Lovedale Ave.	32.832510	-96.851234	60.1
NMS13	2823 Throckmorton St.	32.809296	-96.813110	59.7

5.4 Exposed Population and Land Area

As described in Section 5.2.1 the overall extent of DNL contours has increased between 2013 and 2014 and has resulted in an accompanying increase to the land area and population exposed to noise. The estimated land area within each 5dB contour interval is summarized in

Table 8. Between 2013 and 2014 the contour area greater than DNL 65 dB has increased by five percent from 2.17 sq. mi. to 2.28 sq. mi. The estimated population (based on 2010 US Census Data) within each DNL 5 dB contour interval is summarized in Table 9; between 2013 and 2014 the population experiencing noise levels greater than 65dB has decreased by 32 percent from 3,091 to 4,083. The proportionally larger increase to the exposed population is due to an increase in operations (the 2013 DNL contour represents 486 Average Annual Day (AAD) operations and the 2014 represents 501 AAD operations).

Despite the increase in the overall extent of the DNL contours in 2014 as compared to 2013, the 2014 DNL contours are well within the extent of the 2006 DNL contours. Furthermore, the accompanying land area and population exposed to noise in 2014 has decreased greatly compared to 2006 levels. The estimated land area within each 5 dB contour interval is summarized in

Table 8. Between 2006 and 2014 the contour area greater than DNL 65 dB has decreased by 46 percent from 4.19 sq. mi. to 2.28 sq. mi. The estimated population (based on 2010 US Census Data) within each DNL 5 dB contour interval is summarized in Table 9; between 2006 and 2014 the population experiencing noise levels greater than DNL 65 dB has decreased by 76 percent from 16,798 to 4,083. The large decrease in land area and population exposed to noise from 2006 to 2014 are expected and consistent with a change in the aircraft fleet to quieter aircraft, the near complete removal of Stage 2 aircraft, and overall lower modeled aircraft operation levels.

Table 8 Estimated Area Within Noise Contours

Source: HMMH 2015

DNL Noise Level dBA	Estimated Land Area Exposed to Given Noise Exposure Level		
	2006	2013	2014
60-65	5.71	3.84	4.13
>65	**4.19**	**2.17**	**2.28**
65-70	2.68	1.37	1.46
70-75	1.08	0.42	0.44
>75	0.43	0.38	0.38

Note: Airport property is included in total (1.93 sq. mi.)

Table 9 Estimated Population Within Noise Exposure Area

Source: HMMH 2015, U.S. Census 2010

DNL Noise Level dBA	Estimated Number of People Exposed to Given Noise Exposure Level (2010 US Census Data)		
	2006	2013	2014
60-65	42,603	26,958	28,653
>65	**16,798**	**3,091**	**4,083**
65-70	15,858	3,088	4,083
70-75	936	3	0
>75	4	0	0