DALLAS LOVE FIELD

2019 Day-Night Average Sound Level Contours

HMMH Report No. 307412

July 2020

Prepared for:

City of Dallas Aviation Department
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Dallas, TX 75209

Prepared by:

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1 Summary

This report presents analysis of the 2019 noise conditions at Love Field (DAL) in Dallas, Texas. Harris Miller Miller & Hanson Inc. (HMMH) prepared this report under contract to the City of Dallas.

The development of the 2019 Day-Night Average Sound Level (DNL, or Ldn) contours used the current version (Version 3b) of the Federal Aviation Administration (FAA) Aviation Environmental Design Tool (AEDT) and a data pre-processor called RC for AEDT.[1] RC for AEDT converts every useable 2019 radar track into inputs for the AEDT noise model, ensuring that the modeling reflects runway closures, deviations from flight patterns, changes in flight schedules, and deviations from average runway use. This process resulted in the modeling of approximately 231,879 operations to develop the 2019 DNL contours.

In 2019, the estimated number of people exposed to DNL exceeding the federal guideline of DNL 65 dB is 11,792 people, a decrease of approximately 20 percent compared to 2018 (14,713 people DNL 65 dB or greater). The 2019-estimated number of people within the DNL 65 dB or greater contour is 30 percent smaller than the number of people within the DNL 65 or greater contour in 2006 (16,798 people in DNL 65 dB or greater). Analysis of the noise contours indicates the following:

- To the northwest and southeast of the airport, the contours decreased in several areas.
- These changes occurred in non-residential, multi-family residential, and single-family residential areas.
- The total area contained within the DNL 65 dB noise contours decreased from 4.30 square miles in 2018 to 3.95 square miles in 2019, which is 0.67 square miles smaller than the 2006 DNL contour area (4.62 square miles).

1.1 The Dallas Love Field Voluntary Noise Abatement Program

Love Field is in a noise-sensitive area of the city near residential neighborhoods, which are essential in providing economic, social, and cultural stability for the City. It is important that the airport operate in a manner that allows it to fulfill its vital role of attracting business to Dallas, while protecting and preserving the quality of life in the surrounding neighborhoods. To balance these needs, the City of Dallas has adopted policies that not only recognize Love Field's importance to the Dallas community but also establish a noise reduction goal to reduce the impact of the airport's operations on the neighborhoods

An integral part of the overall approach to noise control at Dallas Love Field is communication between the various parties involved in developing, monitoring, and improving the program. The Department of Aviation achieves this goal in several ways such as providing this report on an annual basis, providing access to the NoiseLab[2] system, and continued participation in the Love Field Environmental Advisory Committee (LFEAC).

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[1] HMMH developed RC for AEDT, which formats and prepares the radar data for import into AEDT. RC for AEDT only prepares the data and does not generate any noise results. Additional discussion of this software is provided in Section 3.2.

[2] Provided by Casper – https://dal.noiselab.casper.aero/

The LFEAC was established to provide a forum for discussion among airport neighbors, airport operators, and Federal and City aviation representatives on issues related to aircraft noise and noise abatement at Love Field. Members of the committee meet quarterly to review airport operations, propose changes in operations, evaluate the effectiveness of the noise abatement program, and propose potential adjustments and improvements to the noise control program.

The Department of Aviation utilizes a permanent noise and operations monitoring system (NoiseLab) for Love Field. 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 and construction activities, and reports on airport operations by group and by runway.[3]

The Department of Aviation for the City of Dallas has developed a Voluntary Noise Control Program for Dallas Love Field. It consists of the following measures:

- Nighttime Preferential Runway (Runway 13R/31L) for all jet aircraft and any aircraft weighing over 12,500 pounds, between the hours of 9:00 p.m. and 6:00 a.m.
- Noise abatement departure procedure (Trinity Departure) for night operations on Runway 13R for all turbojet aircraft and aircraft weighing over 12,500 pounds.
- Prohibition on aircraft engine maintenance run-ups between the hours of midnight and 6:00 a.m. Expanded to a voluntary moratorium between 10:00 p.m. and midnight.
- Aircraft use optimal take-off profile.

Pilots are instructed to observe all ATC instructions. At no time is operational safety to be compromised.

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

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[3] https://www.dallas-lovefield.com/airport-info/environmental/voluntary-noise-abatement-program/presentations

2 Noise / Land Use Compatibility Guidelines

DNL estimates have two principal uses in a noise study:

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

Both functions require the application of objective criteria for evaluating noise exposure. 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, resulting in 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. Quantification of the land areas and populations involved can provide a numerical measure of exposure that allows a comparison of at least the gross effects of existing or forecast operations.

14 CFR Part 150 guidelines indicate that all land uses are normally compatible with aircraft noise at exposure levels below DNL 65 dB. Standards adopted by the U.S. Department of Housing and Urban Development (HUD) formally support this limit by determining if 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 Aviation Environmental Design Tool (AEDT), Version 3b.

AEDT 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

RC for AEDT, HMMH's proprietary pre-processing software for AEDT, prepared the operational and spatial noise model inputs for AEDT. This proprietary pre-processing program enables modeling of all radar track data for a given period. Further details on this software are provided in Section 3.2.

The FAA's AEDT version 3b was released for general use on September 24, 2019. This version has been used for the 2019 DNL contour in this report as the primary analytical tool to assess the noise environment at Dallas Love Field. The AEDT aircraft database is continuously updated with new aircraft types as noise data becomes available. AEDT 3b includes updated data for the Boeing 737-800 and 737 MAX 8 aircraft and new data for the Gulfstream G650, Falcon 900EX, Airbus A350-900, and A320neo aircraft.

The AEDT 3b model includes data for most of the Boeing and Airbus fleet, as well as regional jet, corporate jet, and non-jet aircraft types. The model also includes modeling of helicopters, which were included in the development of the 2019 DNL contour for Love Field. Terrain data was included in the AEDT model to adjust the distance between the aircraft and the receiver. Following FAA guidelines, long-term average weather conditions are included in the modeling, which allows for adjustments in aircraft performance and the inclusion of atmospheric absorption effects.

3.2 Noise Modeling Process – RC for AEDT

HMMH prepared the 2019 noise exposure contours using the proprietary AEDT pre-processor RC for AEDT. RC for AEDT prepares each available aircraft flight track contained in the data sample for input into AEDT. The AEDT model is used for all noise calculations. RC for AEDT provides an organizational structure to model individual flight tracks in AEDT. RC for AEDT itself does not modify AEDT standard noise, performance, or aircraft substitution data, but rather selects the best standard data or FAA-approved non-standard data available to AEDT for each individual flight track.

RC for AEDT takes maximum possible advantage of the available data from the airport's NoiseLab system and AEDT's capabilities. It automates the process of preparing the AEDT inputs directly from recorded flight operations and models the full range of aircraft activity as precisely as possible. RC for AEDT improves the precision of modeling by using operations monitoring results in the following areas:

- Directly converts the flight track recorded by NoiseLab for every identified aircraft operation to an AEDT track, rather than assigning all operations to a limited number of prototypical tracks
- Models each ground track as it was flown in 2019, 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 at the time it occurred to accurately determine which operations incur the 10 dB penalty for nighttime operations when calculating DNL
- Selects the specific airframe and engine combination to model, on an operation-by-operation basis, by using the aircraft type designator and registration data associated with the flight plan and, if registration data is not available for commercial operations, the published composition of the individual operator's aircraft inventory
- Selects the stage length, a surrogate for aircraft weight, for each flight from the list of available stage lengths for each AEDT type based on the radar origin and destination data.
- 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 2019 used in the modeling were obtained from DAL's NoiseLab system and are all from the FAA's Nextgen radar data feed.

4 Noise Modeling Inputs

4.1 Airfield Layout and Runway Geometry

As shown in Figure 1, 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 a modeled helipad location. The 2019 radar data included helicopter flight tracks to and from the airport. The airport does not have a designated helipad, but for modeling purposes a helipad location (HS 1) was defined along taxiway A between taxiways A2 and A3.

Table 2. Runway Layout

Runway	Latitude	Longitude	Elevation	Displaced Arrival Threshold (ft)	Glide Slope	Width (ft.)	Length (ft.)
13L	32.857274	-96.856801	476.6	399	3	150	7,752
31R	32.842043	-96.839152	486.7	0	3		
13R	32.851317	-96.863452	476.1	489	3	150	8,800
31L	32.834029	-96.843415	476.2	0	3		
HS-1	32.849059	-96.845502	487	-	-	0.00	0.00
Source: FAA Airport Master Record 5010							

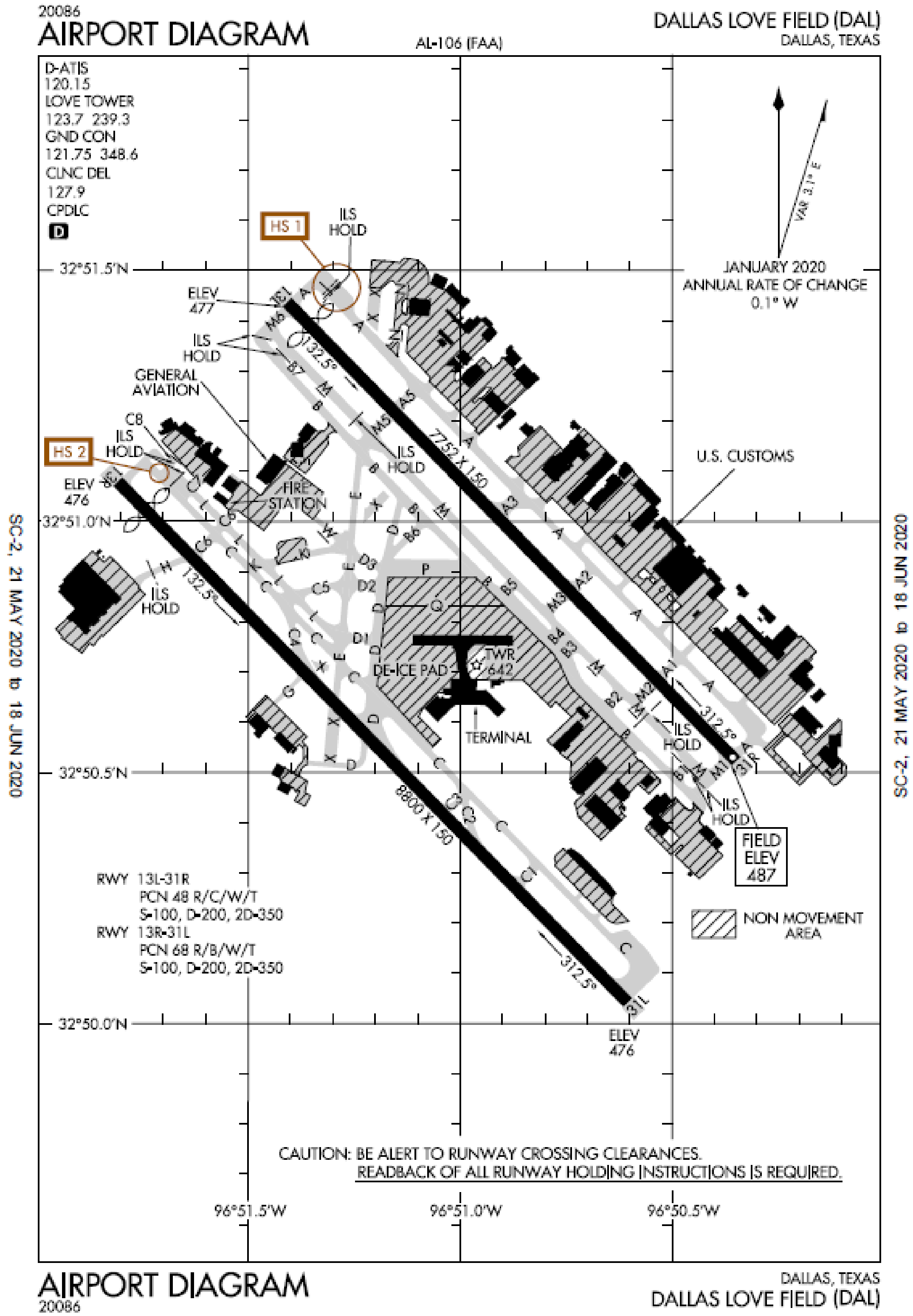

Figure 1. Dallas Love Field Airport Diagram

4.2 Aircraft Operations

The 2019 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 classifies operations in the following four categories:

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

As described in above Section 3.2, the Casper 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 Casper data with data from the FAA's Aircraft Registration Database where necessary to further identify aircraft types to enhance the modeling dataset. The RC for AEDT software assigns each flight to one of the FAA tower count categories to allow for the scaling of the data to match the FAA tower count totals.

In summary, 222,275 individual flight tracks recorded by NoiseLab were directly used for the preparation of the 2019 DNL contours. The operations were scaled within each FAA category (e.g., air carrier, air taxi, etc.) to the 231,879 operations recorded by OPSNET.[4] The number of modeled flight tracks and the FAA operations count totals differ for the following primary reasons:

1. RC for AEDT filters flight track data and only uses data suitable for modeling with AEDT (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. Most 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 972 annual operations from OPSNET were distributed over the air carrier and general aviation group totals with a 23 percent to 77 percent split, respectively. This distribution was determined by evaluating the military fleet aircraft types available for DAL in 2019 through the FAA Traffic Flow Management System Counts (TFMSC).[5]

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[4] FAA Operations Network Data (OPSNET) accessed March 18, 2020.

[5] FAA Traffic Flow Management System Count (TFMSC) data accessed March 18, 2020.

Table 3. 2019 Modeled Average Daily FAA Category Operations

Source: FAA OPSNET, HMMH 2020

FAA Operational Category	2019 Operations	
	2019 FAA OPSNET	2019 Average Annual Day Modeled Operations
Air Carrier	146,744	402.66
Air Taxi	30,656	83.99
General Aviation	53,507	148.64
Military	972	0
Total	**231,879**	**635.29**

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 2019 average annual day operations group by FAA aircraft category, engine type, and AEDT aircraft type for Daytime and Nighttime arrivals and departures. The fleet mix is dominated by the Boeing 737-700, with 44.5 percent of all operations. The share among all 737 variants is 57.9 percent.

Table 4. 2019 Modeled Average Daily Aircraft Operations

Aircraft Category	Engine Type	AEDT Aircraft Type	Arrivals		Departures		Total
			Day	Night	Day	Night	
Air Carrier	**Jet**	717200	2.76	0.05	2.80	<0.01	5.61
		727EM2	0.05	<0.01	0.05	<0.01	0.12
		737300	0.02	<0.01	0.02	<0.01	0.05
		7373B2	0.02	<0.01	0.03	<0.01	0.06
		737400	0.11	0.05	0.10	0.06	0.32
		737700	123.30	18.14	121.92	19.51	282.87
		737800	35.14	5.55	35.12	5.57	81.39
		737MAX8	1.36	0.22	1.38	0.21	3.17
		737N17	0.02	0.02	0.03	<0.01	0.07
		757PW	0.15	0.08	0.11	0.12	0.48
		767300	0.02	<0.01	0.01	<0.01	0.04
		767CF6	0.04	0.05	0.07	0.03	0.19
		A319-131	0.09	0.02	0.07	0.03	0.22
		A320-211	0.93	0.92	1.84	0.02	3.71
		A321-232	<0.01	<0.01	<0.01	<0.01	0.02
		CRJ9-ER	0.02	<0.01	0.02	<0.01	0.04
		DC93LW	<0.01	<0.01	<0.01	<0.01	<0.01
		EMB175	9.59	2.53	11.65	0.47	24.24

Aircraft Category	Engine Type	AEDT Aircraft Type	Arrivals		Departures		Total
			Day	Night	Day	Night	
		EMB190	<0.01	<0.01	<0.01	<0.01	<0.01
		737500	0.01	<0.01	0.01	<0.01	0.02
		757RR	<0.01	<0.01	<0.01	<0.01	0.01
		A320-232	<0.01	<0.01	<0.01	<0.01	0.02
		MD83	<0.01	<0.01	<0.01	<0.01	0.02
Air Carrier Subtotal			173.64	27.63	175.24	26.03	402.66
Air Taxi	**Jet**	BD-700-1A10	0.34	0.03	0.34	0.03	0.73
		BD-700-1A11	0.21	0.04	0.23	0.02	0.50
		CIT3	0.07	0.02	0.07	0.01	0.17
		CL600	5.40	0.34	5.35	0.39	11.48
		CL601	0.50	0.05	0.49	0.07	1.11
		CNA500	0.08	0.01	0.08	0.01	0.19
		CNA510	2.09	1.68	2.41	1.36	7.54
		CNA525C	0.35	0.06	0.37	0.04	0.81
		CNA55B	4.92	0.25	4.82	0.34	10.33
		CNA560U	2.72	0.35	2.81	0.26	6.14
		CNA560XL	1.91	0.38	1.97	0.33	4.59
		CNA680	3.73	0.20	3.73	0.20	7.86
		CNA750	2.31	0.12	2.34	0.09	4.86
		EMB145	0.11	<0.01	0.10	0.01	0.23
		EMB14L	0.01	<0.01	0.01	<0.01	0.03
		FAL20	<0.01	0.02	<0.01	0.01	0.03
		FAL900EX	0.27	0.02	0.27	0.02	0.59
		G650ER	0.12	0.01	0.13	<0.01	0.27
		GIV	0.80	0.09	0.84	0.05	1.78
		GV	0.15	<0.01	0.14	<0.01	0.30
		IA1125	0.67	0.02	0.68	<0.01	1.38
		LEAR35	3.87	0.60	3.92	0.55	8.93
		MU3001	0.67	0.07	0.68	0.05	1.47
		ECLIPSE500	0.05	<0.01	0.05	<0.01	0.09
	Turbine propeller	CNA208	0.47	0.21	0.55	0.12	1.35
		CNA441	0.14	0.10	0.14	0.10	0.48
		DHC6	3.10	1.13	3.18	1.05	8.46
		PA42	0.02	0.03	0.02	0.03	0.09

Aircraft Category	Engine Type	AEDT Aircraft Type	Arrivals		Departures		Total
			Day	Night	Day	Night	
		EMB120	0.03	<0.01	0.03	<0.01	0.06
	Piston propeller	BEC58P	0.02	0.72	0.66	0.07	1.47
		CNA172	0.05	<0.01	0.05	<0.01	0.11
		GASEPV	0.03	<0.01	0.03	<0.01	0.07
		PA30	0.06	0.02	0.06	0.02	0.15
		PA31	<0.01	<0.01	<0.01	<0.01	0.01
	Helicopter	B206L	<0.01	<0.01	<0.01	<0.01	0.01
		B407	0.02	<0.01	<0.01	0.02	0.06
		B429	0.02	0.02	0.03	0.01	0.09
		EC130	0.04	0.02	0.02	0.04	0.11
		S76	0.02	0.02	0.03	0.01	0.07
Air Taxi Subtotal			35.35	6.62	36.63	5.31	83.99
General Aviation	**Jet**	727EM1	<0.01	<0.01	<0.01	<0.01	<0.01
		737700	0.02	<0.01	0.03	<0.01	0.06
		757PW	0.03	0.07	0.09	<0.01	0.20
		BD-700-1A10	0.71	0.06	0.71	0.06	1.54
		BD-700-1A11	0.21	0.03	0.23	0.02	0.49
		CIT3	1.83	0.15	1.88	0.09	3.95
		CL600	5.28	0.48	5.33	0.44	11.53
		CL601	2.21	0.14	2.26	0.09	4.70
		CNA500	0.27	0.01	0.27	0.01	0.57
		CNA510	1.00	0.02	1.00	0.02	2.05
		CNA525C	4.92	0.23	4.91	0.24	10.29
		CNA55B	2.62	0.14	2.65	0.11	5.52
		CNA560E	0.08	<0.01	0.08	<0.01	0.16
		CNA560U	2.10	0.10	2.12	0.08	4.39
		CNA560XL	2.77	0.11	2.79	0.10	5.77
		CNA680	2.32	0.06	2.31	0.07	4.76
		CNA750	3.55	0.24	3.60	0.19	7.59
		ECLIPSE500	0.44	0.02	0.44	0.02	0.91
		EMB145	0.42	0.05	0.45	0.02	0.93
		EMB14L	<0.01	<0.01	<0.01	<0.01	0.02
		EMB190	<0.01	<0.01	<0.01	<0.01	0.02
		FAL20	0.05	<0.01	0.05	<0.01	0.10

Aircraft Category	Engine Type	AEDT Aircraft Type	Arrivals		Departures		Total
			Day	Night	Day	Night	
		FAL900EX	3.86	0.27	3.90	0.23	8.27
		G650ER	0.67	0.10	0.74	0.04	1.55
		GIIB	0.10	<0.01	0.10	<0.01	0.20
		GIV	2.62	0.30	2.75	0.16	5.82
		GV	2.74	0.21	2.77	0.18	5.90
		IA1125	3.46	0.24	3.59	0.11	7.40
		LEAR35	6.39	0.44	6.46	0.37	13.66
		MD81	<0.01	<0.01	<0.01	<0.01	<0.01
		MU3001	1.10	0.06	1.06	0.11	2.33
		737N17	<0.01	<0.01	<0.01	<0.01	<0.01
		LEAR25	<0.01	<0.01	<0.01	<0.01	0.01
		MD83	<0.01	<0.01	<0.01	<0.01	<0.01
		T-38A	<0.01	<0.01	<0.01	<0.01	0.01
	Turbine propeller	CNA208	3.69	0.16	3.56	0.28	7.69
		CNA441	0.49	<0.01	0.49	<0.01	0.99
		DHC6	7.04	0.36	6.70	0.69	14.79
		HS748A	0.29	<0.01	0.29	<0.01	0.58
		1900D	<0.01	<0.01	<0.01	<0.01	0.01
		PA42	0.02	<0.01	0.02	<0.01	0.04
		SF340	<0.01	<0.01	<0.01	<0.01	<0.01
	Piston propeller	BEC58P	1.48	0.03	1.44	0.08	3.03
		CNA172	0.21	0.07	0.21	0.08	0.57
		CNA182	0.25	0.02	0.24	0.03	0.53
		CNA206	0.13	0.02	0.14	<0.01	0.29
		COMSEP	1.29	0.04	1.28	0.05	2.65
		GASEPF	0.43	0.02	0.42	0.02	0.88
		GASEPV	1.80	0.19	1.76	0.23	3.98
		PA28	0.09	0.03	0.09	0.03	0.23
		PA30	0.02	0.01	0.02	<0.01	0.06
		PA31	0.19	<0.01	0.20	<0.01	0.40
		CNA20T	0.02	<0.01	0.02	<0.01	0.04
		DC3	<0.01	<0.01	<0.01	<0.01	0.01
		DC6	<0.01	<0.01	<0.01	<0.01	0.01
	Helicopter	B206L	0.02	<0.01	<0.01	<0.01	0.03

Aircraft Category	Engine Type	AEDT Aircraft Type	Arrivals		Departures		Total
			Day	Night	Day	Night	
		B407	0.05	0.02	0.06	<0.01	0.14
		B429	0.08	0.03	0.05	0.05	0.21
		EC130	0.06	0.15	0.08	0.13	0.42
		H500D	0.01	<0.01	<0.01	<0.01	0.02
		S76	0.11	0.02	0.09	0.03	0.24
		A109	<0.01	<0.01	<0.01	<0.01	0.02
		SA350D	<0.01	<0.01	<0.01	<0.01	0.01
		SA365N	<0.01	<0.01	<0.01	<0.01	<0.01
General Aviation Subtotal			69.51	4.70	69.71	4.45	148.64
Grand Total			278.50	38.95	281.58	35.78	635.28

Note: Military Ops are Scaled into AC, AT, and GA depending on weight class

4.2.1 Aircraft Sound Exposure Levels

Sound Exposure Level (SEL) represents noise exposure due to a single noise event such as an aircraft overflight while accounting for both the sound level and duration of the event. A noise "footprint" for a given type of aircraft can be generated by simulating an event that combines a single arrival with a single departure and calculating the SEL over the affected area. This results in SEL contours that can be compared for different aircraft types to show their relative influence in the overall noise level at an airport. Appendix A Section 5.4A.1.4 provides a more detailed explanation of SEL.

Figure 2 through Figure 4 display SEL contours for the most common aircraft types in use in 2019 at DAL. Larger aircraft generally affect a larger area, as would be expected. However, the introduction of newer engine technology has resulted in lower SELs. For example, the departure portion of the SEL contour for the larger Embraer 145 affects a much smaller area than the CRJ 200.

These figures also include the percent of operations represented by each aircraft type. The overall influence of an aircraft type combines its SEL footprint with its share of operations.

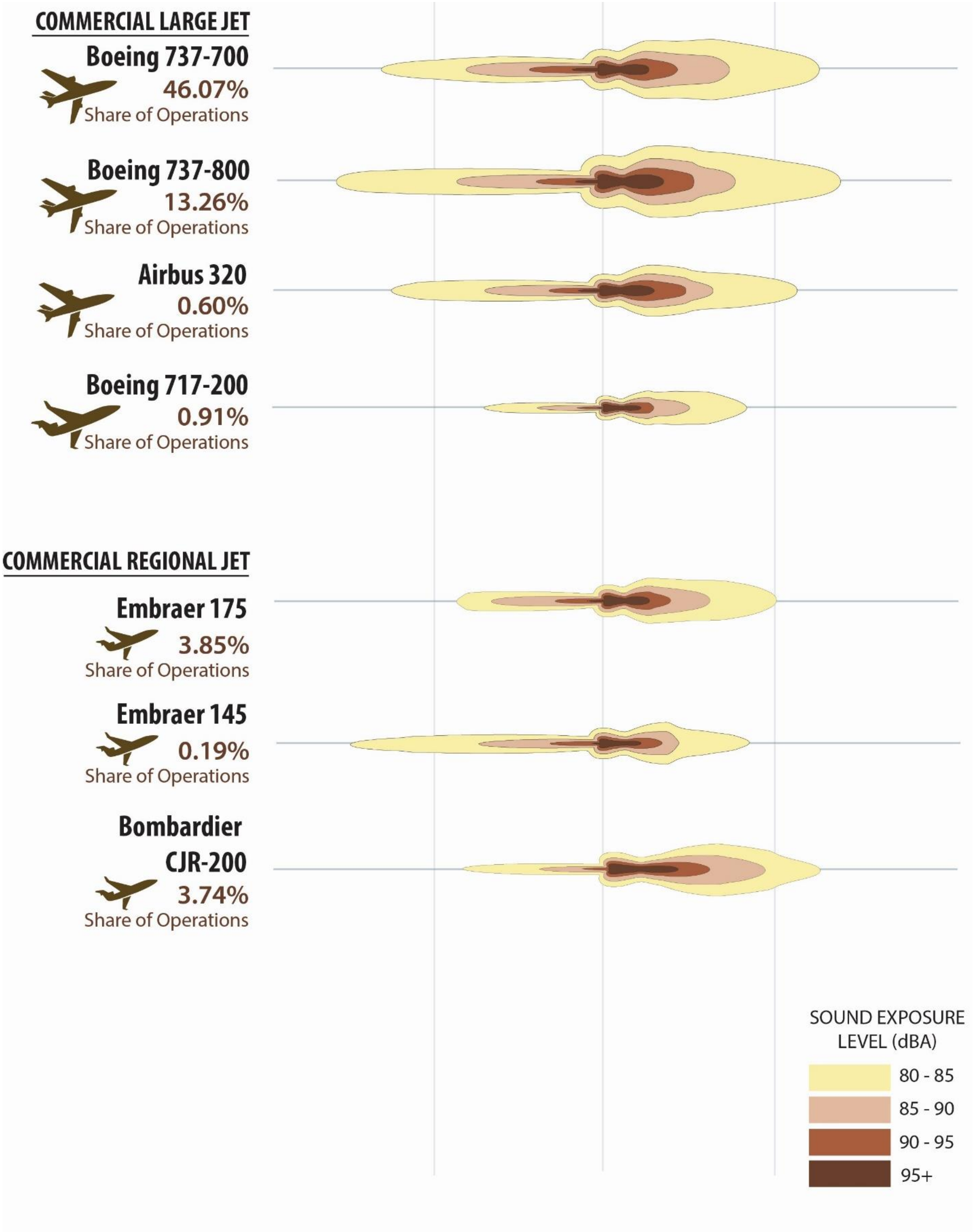

Figure 2. SEL Contours - Commercial Aircraft

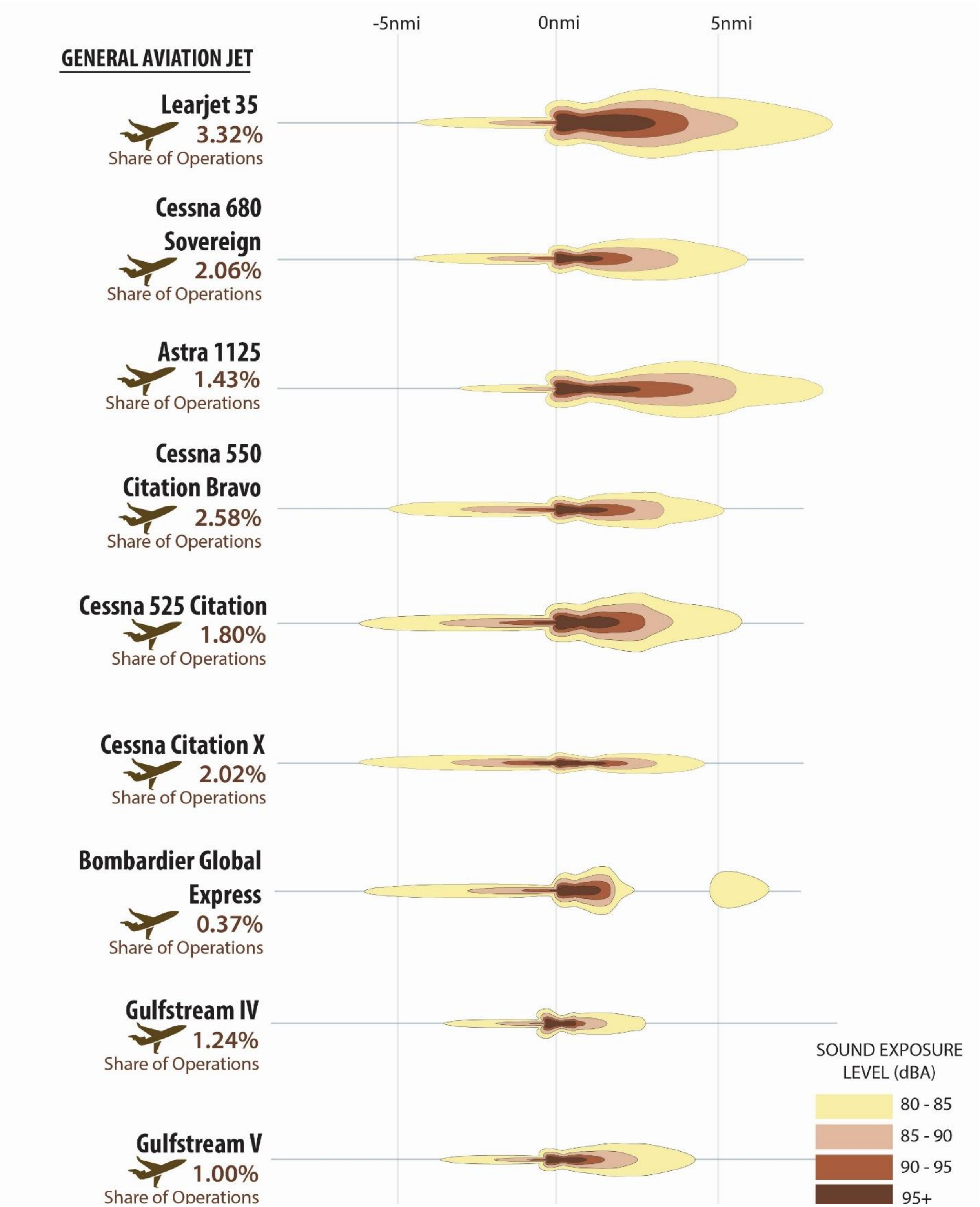

Figure 3. SEL Contours - General Aviation Jets

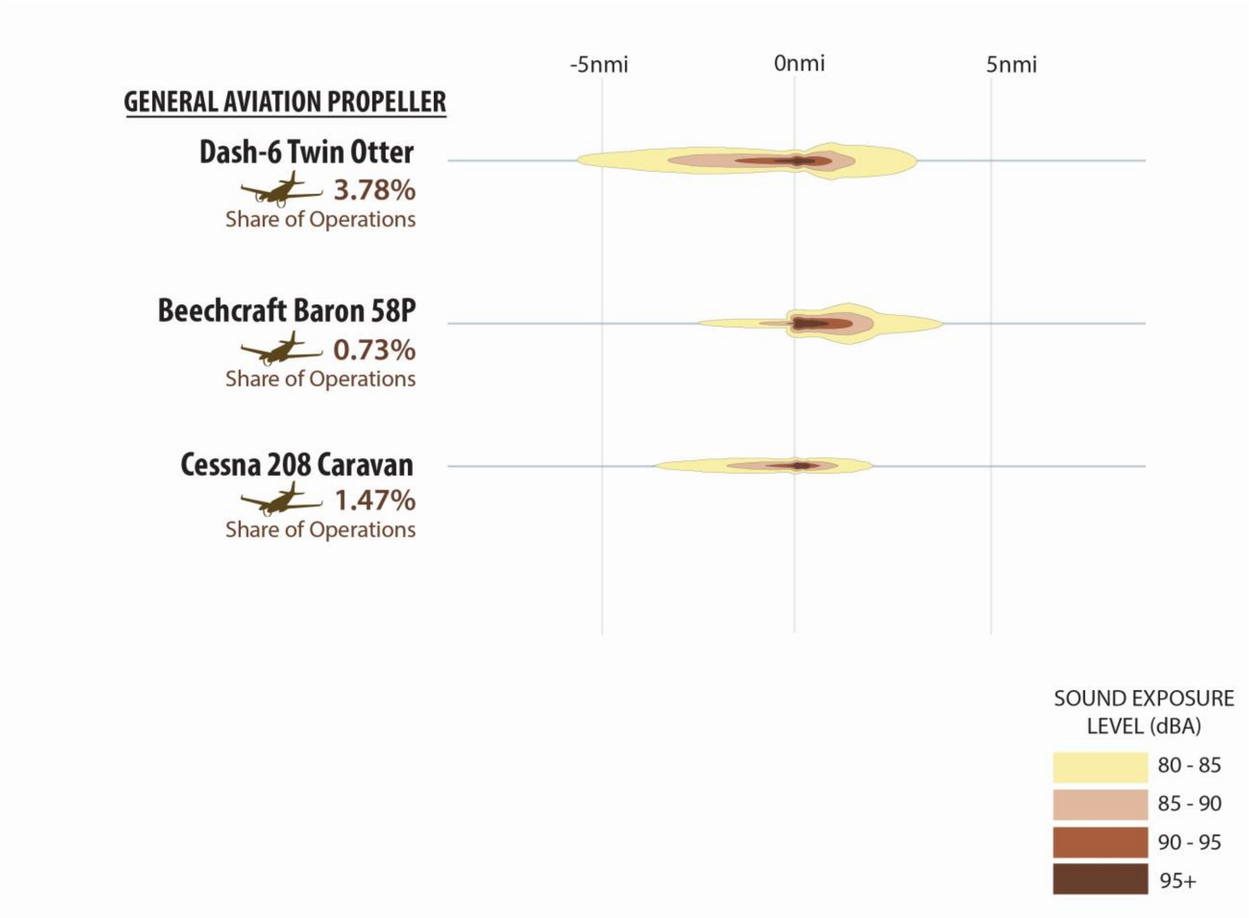

Figure 4. SEL Contours - General Aviation Propellers

4.3 Runway Utilization

Runway 13R/31L in the Nighttime Preferential Runway for all jet aircraft and any aircraft weighing over 12,500 pounds, between the hours of 9:00 p.m. and 6:00 a.m. at Love Field. Table 5 provides percentages by runway of Jet arrivals and Jet departures that occurred between 9 p.m. and 6 a.m. for 2019. These counts show that the operations during this time overwhelmingly use the preferred runways, with 76.9 percent of Jet operations using these runways. 53.4 percent of arrivals and 59.7 percent of departures use Runway 13R, while 23.1 percent of arrivals and 17.8 percent of departures use Runway 31L. 15.9 percent of arrivals and 10.2 percent of departures use Runway 13L, and 7.7 percent of arrivals and 12.2 percent of departures use Runway 31R.

Table 5. Jet Operations by Runway Between 9 p.m. and 6 a.m.

Source: Casper data, HMMH 2019 analysis

Runway	Arrivals	Departures	Total
13L	9.9%	3.8%	13.7%
31R	4.8%	4.6%	9.4%
13R	33.3%	22.5%	55.8%
31L	14.4%	6.7%	21.1%
Total	62.4%	37.6%	100.0%

Table 6 summarizes the runway utilization for the average annual day conditions modeled for 2019. Separate utilization percentages for each aircraft category and for all aircraft are given, and in general show 70 percent of operations in south flow (use of Runways 13L/13R) and 30 percent in north flow (use of Runways 31R/31L) in 2019. The share of south flow operations is up from 68 percent in 2018. The share of north flow operations is down from 32 percent in 2018.

Use of the voluntary noise abatement runway at night resulted in a 67 percent share of the nighttime air carrier operations on Runway 13R/31L. In south flow operations during 2019, air carrier operations favored Runway 13R, with a 69 percent share for arrivals and an 84 percent share for departures. In north flow, air carrier operations favored Runway 31R, with a 73 percent share for arrivals and a 58 percent share for departures. The south flow arrival and north flow departure percentages are similar to 2018. However, the south flow departure percentage changed more significantly increasing from 74 percent in 2018 to 84 percent in 2019 and the north flow arrivals increased from 73 percent in 2018 to 78 percent in 2019.

Air taxi operations mainly occurred on Runway 13L/31R during the day and Runway 13R/31L during the night. General aviation favored Runway 13L/31R for both daytime and nighttime operations.

There were no extended runway closures in either 2018 or 2019 to affect comparisons between the two years.

Table 6. 2019 Modeled Runway Use

Source: Casper data, HMMH 2019 analysis

Aircraft Category	Runway	Arrivals		Departures	
		Day	Night	Day	Night
Air Carrier	13L	23.42%	14.50%	11.52%	8.07%
	13R	47.24%	55.06%	59.01%	62.31%
	31R	8.22%	6.19%	12.62%	11.53%
	31L	21.12%	24.25%	16.84%	18.08%
	HS 1	0.00%	0.00%	0.00%	0.00%
	Total	100.00%	100.00%	100.00%	100.00%
Air Taxi	13L	39.43%	25.35%	38.15%	29.12%
	13R	29.82%	44.73%	31.79%	39.38%

Aircraft Category	Runway	Arrivals		Departures	
		Day	Night	Day	Night
	31R	19.99%	13.31%	19.86%	15.23%
	31L	10.45%	15.69%	9.98%	14.56%
	HS 1	0.31%	0.93%	0.22%	1.70%
	Total	100.00%	100.00%	100.00%	100.00%
General Aviation	13L	38.04%	30.66%	37.84%	33.93%
	13R	31.47%	37.85%	32.05%	32.78%
	31R	19.07%	15.91%	18.80%	17.24%
	31L	10.93%	11.10%	10.87%	10.71%
	HS 1	0.48%	4.48%	0.44%	5.33%
	Total	100.00%	100.00%	100.00%	100.00%
All Aircraft	13L	29.10%	18.30%	21.50%	14.45%
	13R	41.10%	51.22%	48.80%	55.19%
	31R	12.42%	8.58%	15.09%	12.80%
	31L	17.23%	21.20%	14.47%	16.63%
	HS 1	0.16%	0.70%	0.14%	0.92%
	Total	100.00%	100.00%	100.00%	100.00%

Figure 5 through Figure 8 display the data in Table 5 graphically by aircraft category. This helps to visualize the usage of each category on the runways.

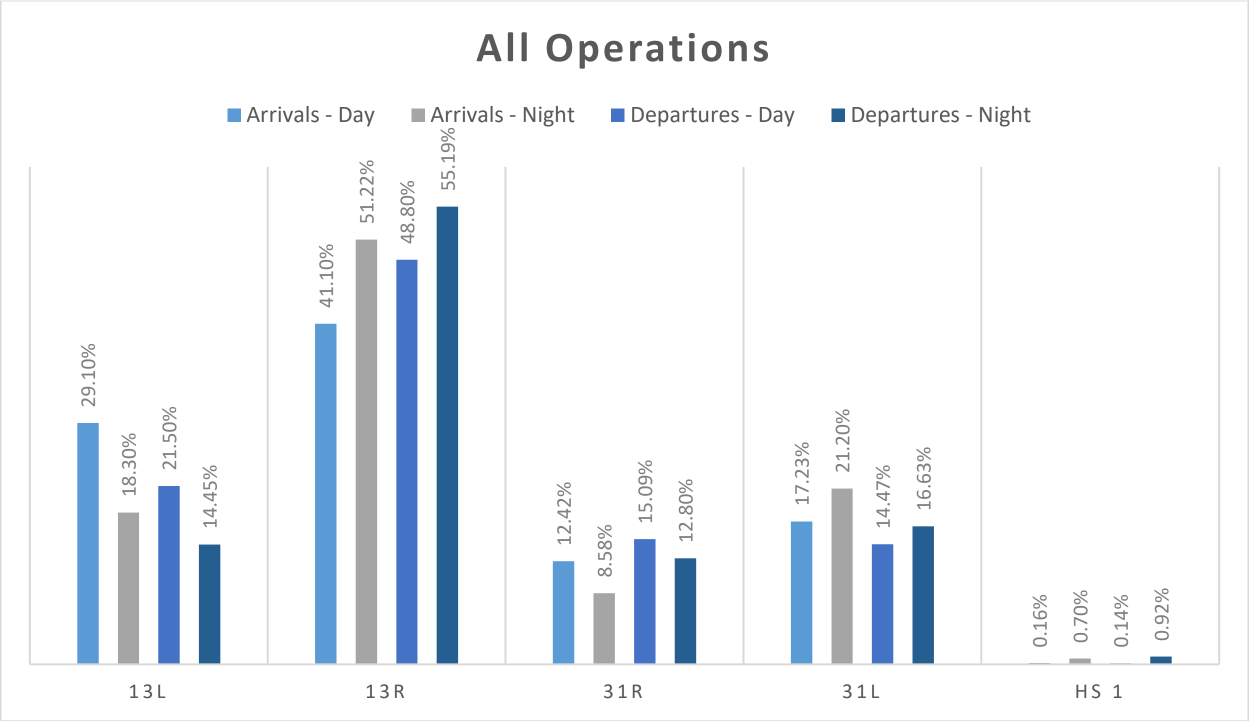

Figure 5. Runway Use for All Aircraft

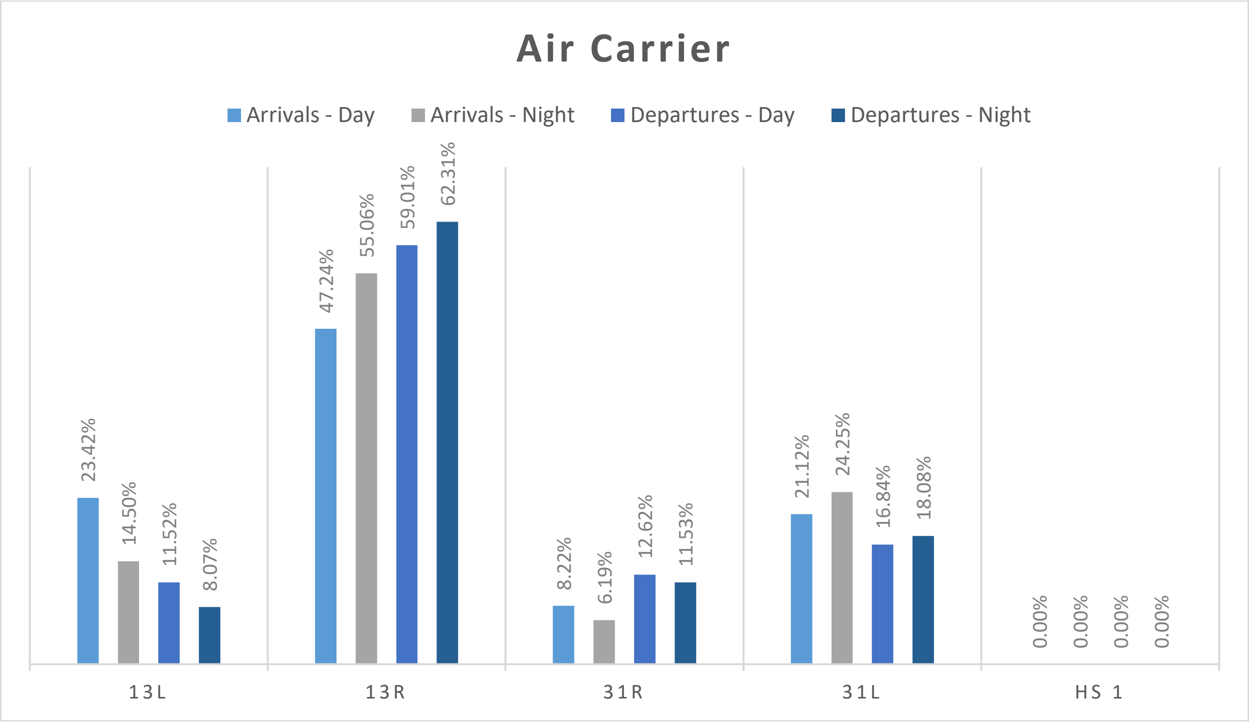

Figure 6. Runway Use for Air Carrier Aircraft

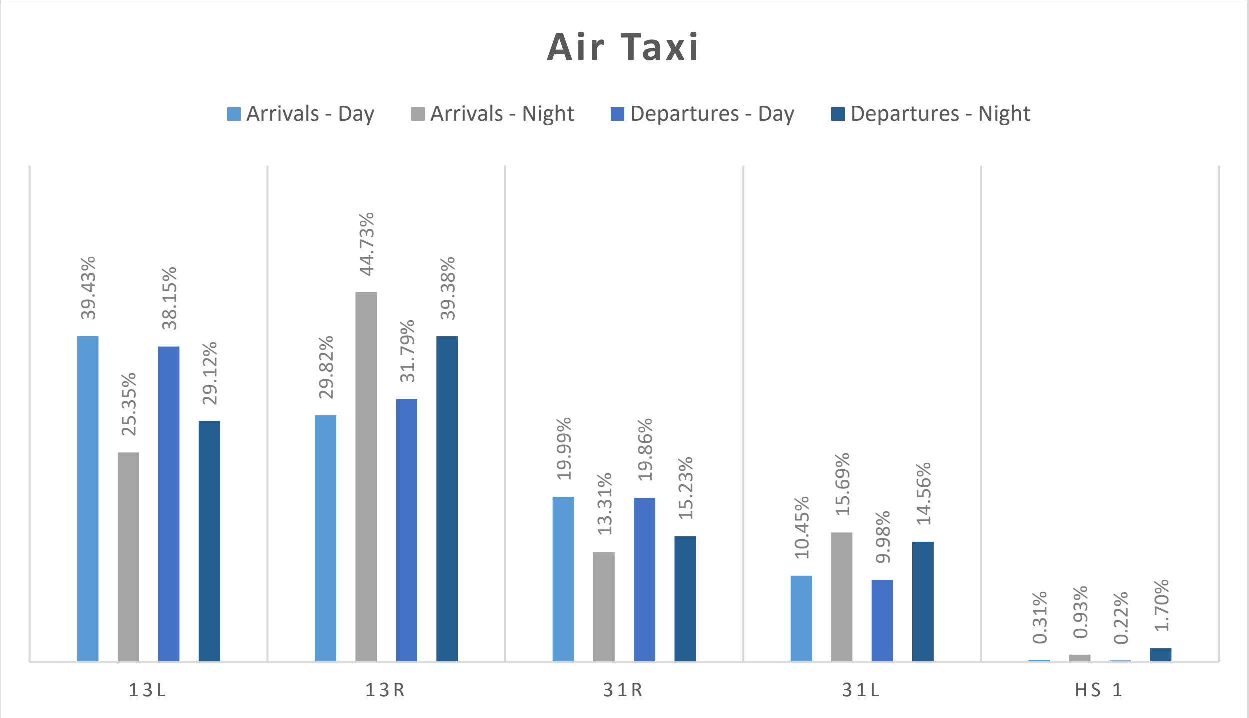

Figure 7. Runway Use for Air Taxi Aircraft

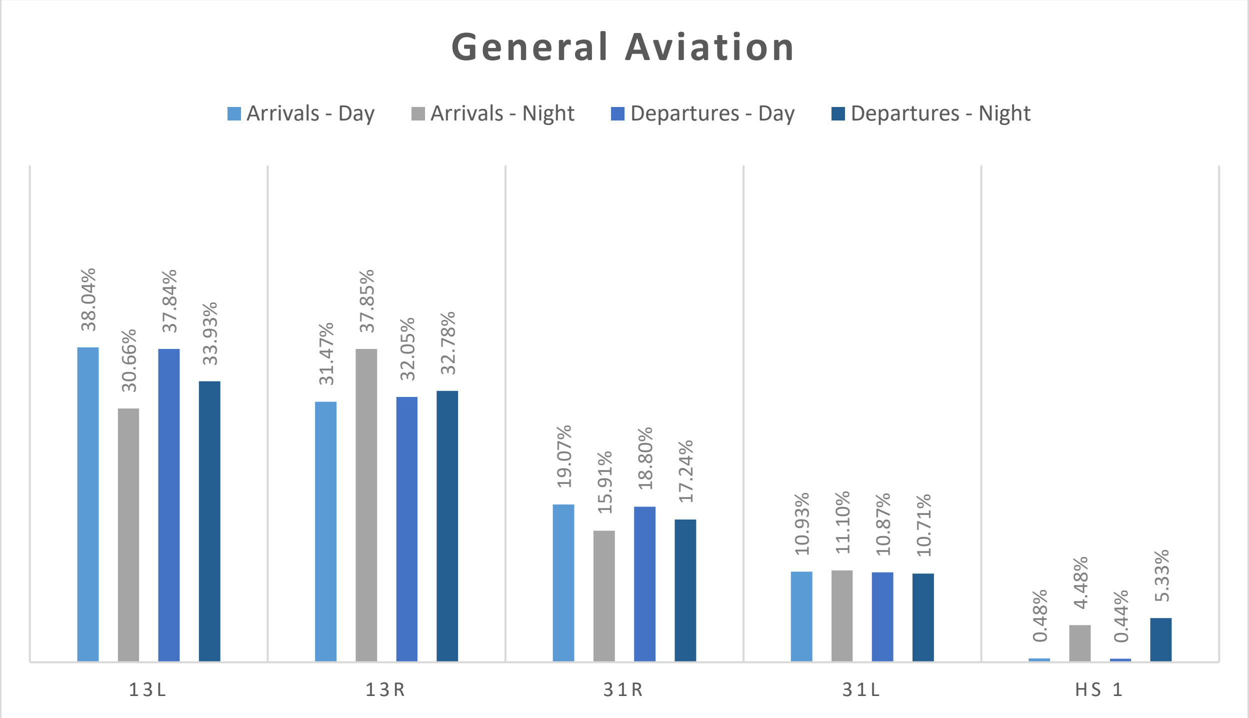

Figure 8. Runway Use for General Aviation Aircraft

Figure 9 through Figure 12 show geographic views of the runway use percentages for all aircraft operations. This helps to visualize the effect of specific operation types on surrounding areas.

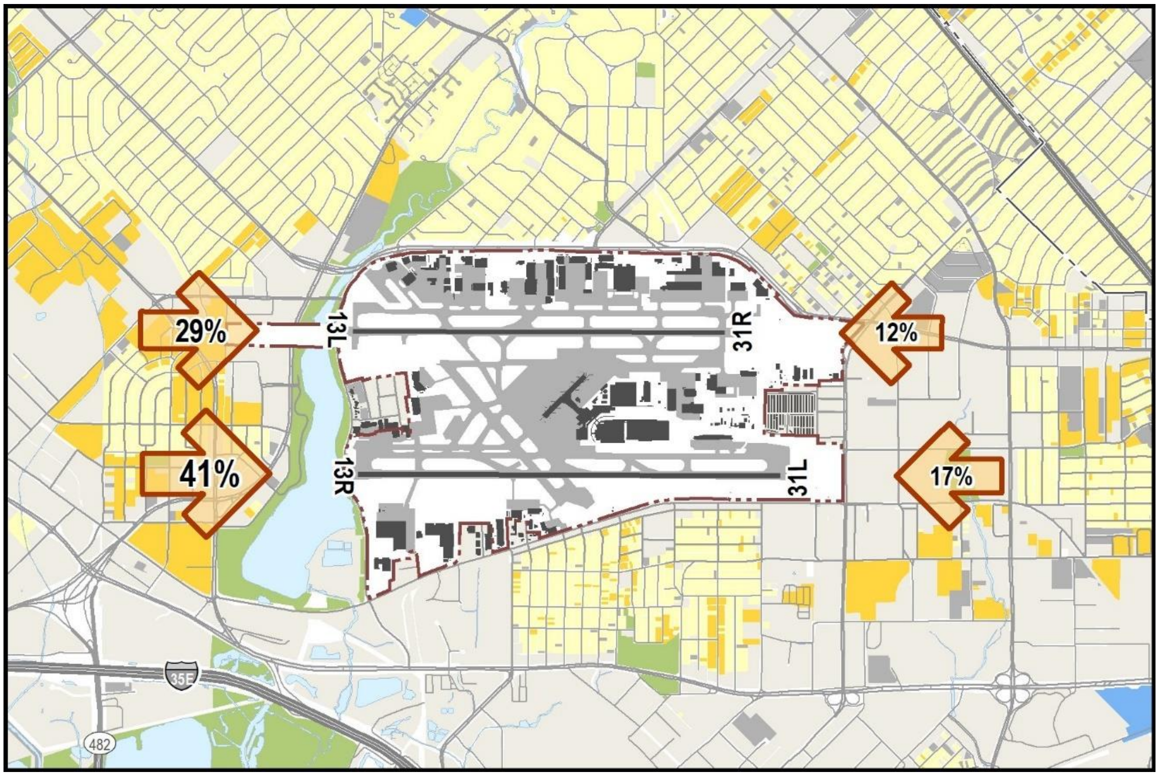

Figure 9. Runway Use: Daytime Arrivals

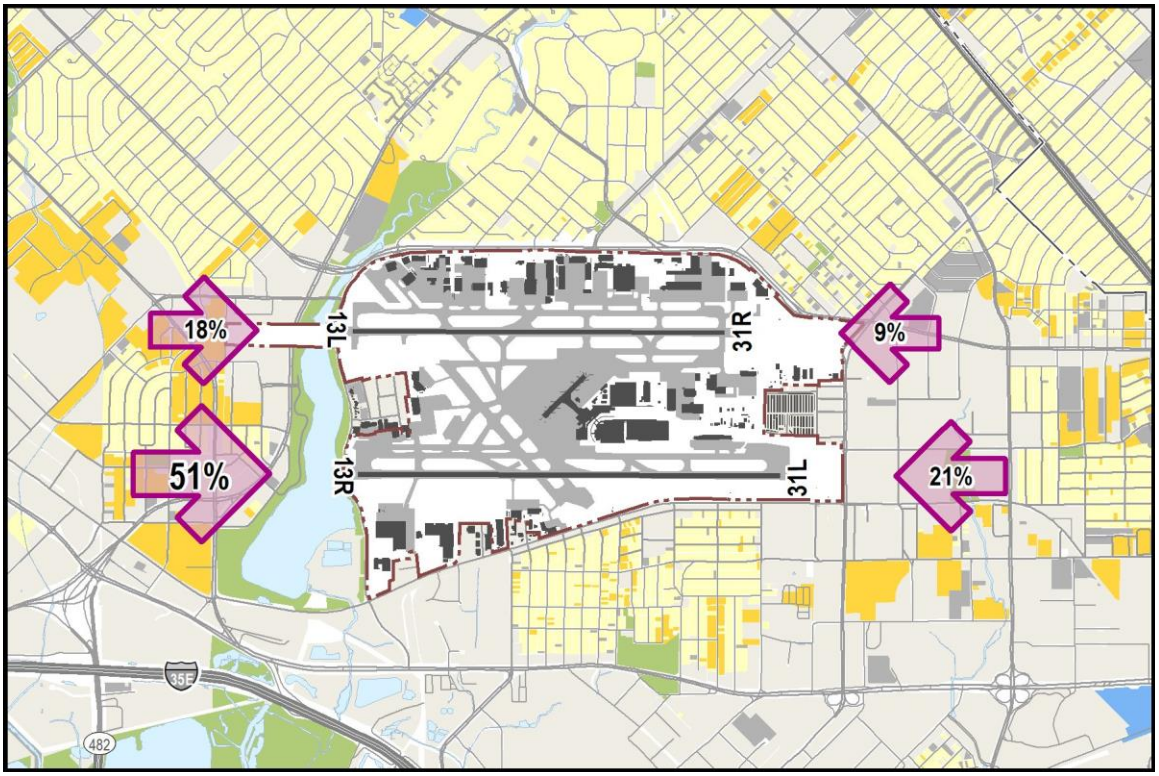

Figure 10. Runway Use: Nighttime Arrivals

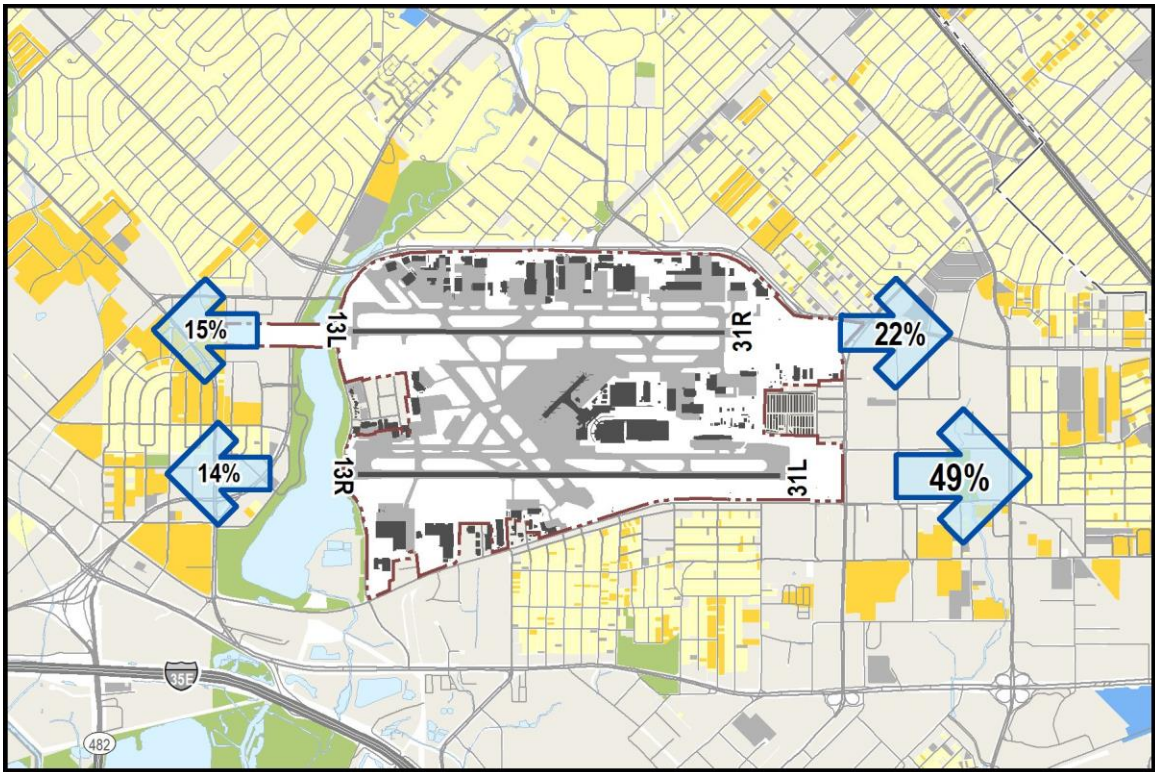

Figure 11. Runway Use: Daytime Departures

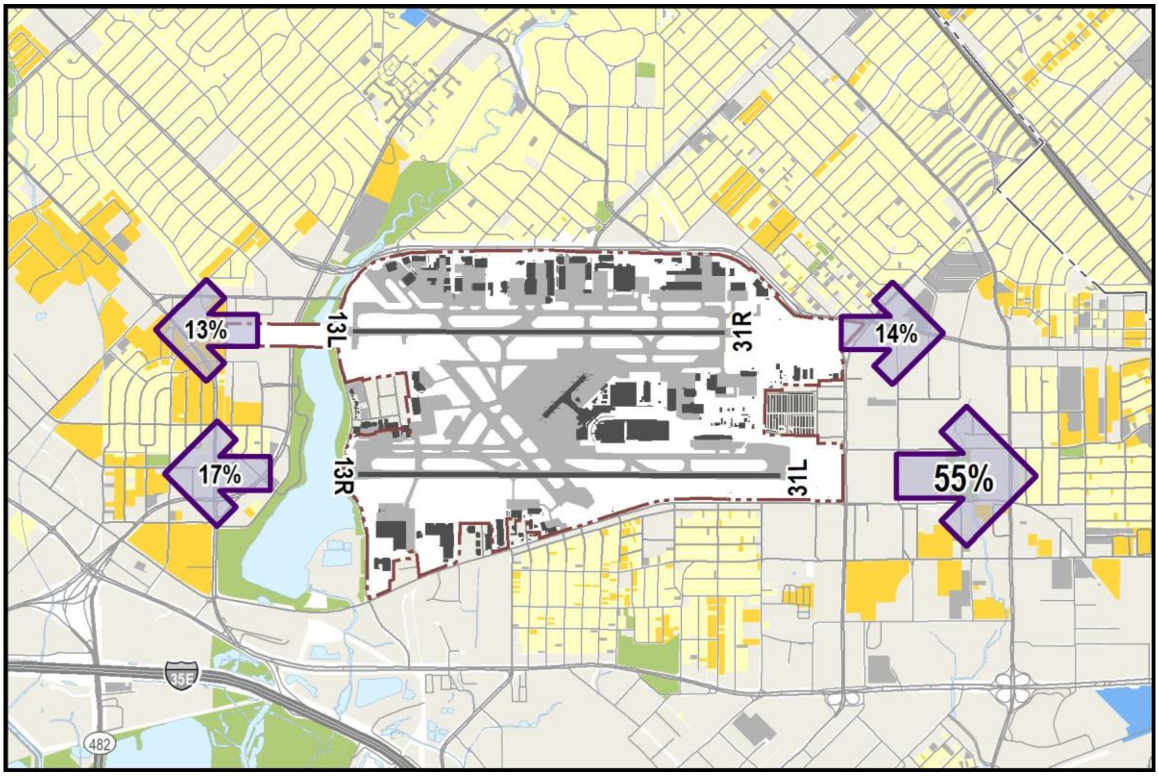

Figure 12. Runway Use: Nighttime Departures

4.4 Flight Track Geometry

As described in Section 3.2, RC for AEDT was used to develop AEDT tracks from radar flight data, thereby modeling every available radar flight record as an AEDT flight track.

Figure 13 and Figure 14 provide samples of the radar-based AEDT model tracks. A total of 222,275 individual tracks were modeled.

Figure 13 presents a sample of 6,457 north flow model tracks and Figure 14 presents a sample of 15,492 south flow model tracks, representing approximately a ten percent sampling of all modeled flight tracks.

The flight tracks in these views are predominantly in line with the runways. As seen in Section 5, this is reflected in the shape of the noise contours, which vary in length due to operations volume on particular runways, but remain centered on the extended runway centerlines. In the top left corner of Figure 14, tracks are shown arriving from the north and turning onto runway heading. These arrivals cannot align with the runway farther from the airport due to airspace conflict with Dallas – Fort Worth Airport to the west. However, these tracks align with the runway far enough from the airport that this does not affect the shape of the noise contours.

The TRINITY EIGHT noise abatement departure procedure is designed to position aircraft departing Runway 13R at night over non-residential land, by directing a right turn to a heading of 163 degrees no later than 0.7 nautical miles from the end of the runway. However, minimal use of this procedure is evident in the flight track data for 2019, as shown in Figure 14.

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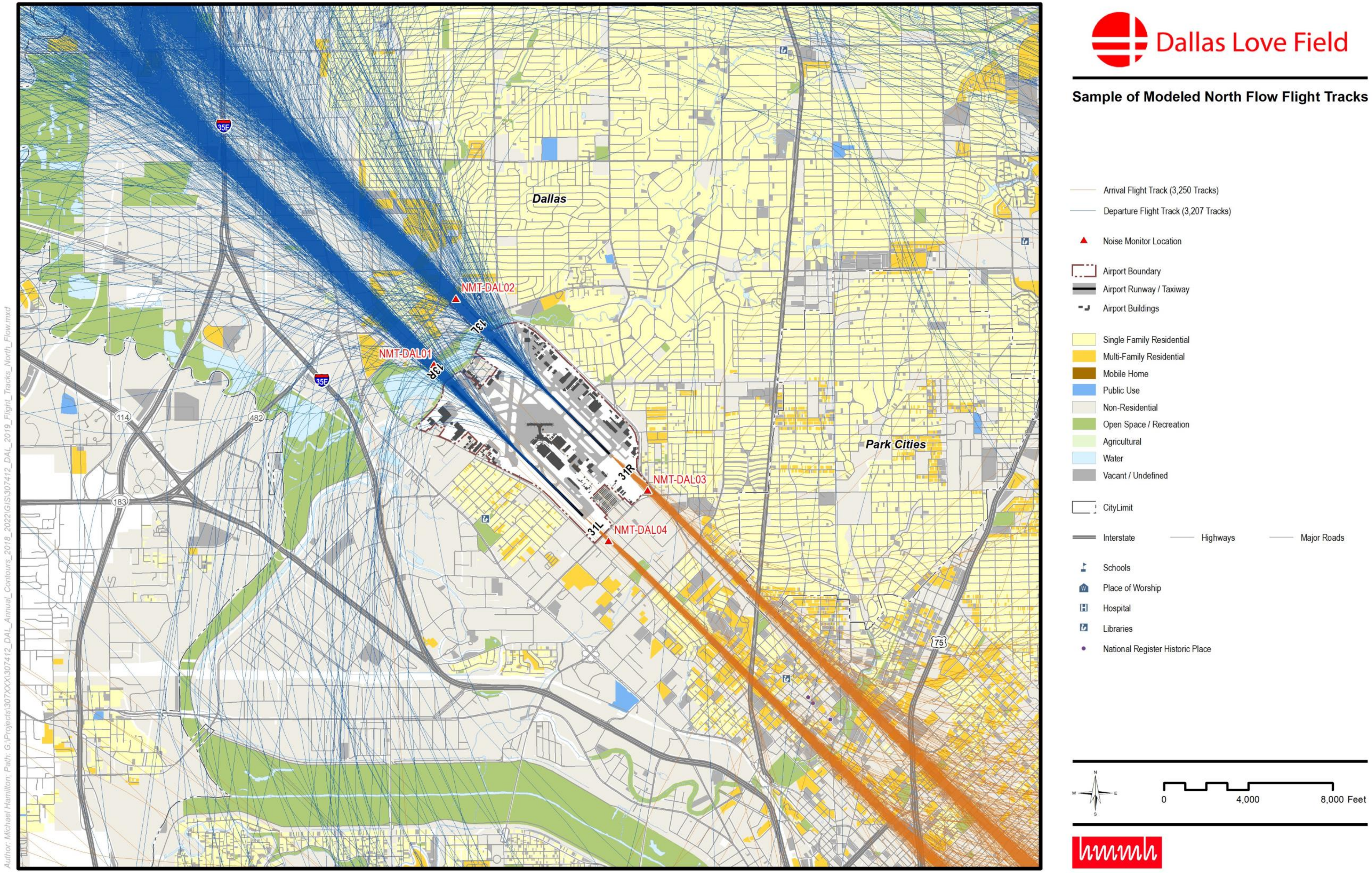

Figure 13. Sample of Modeled North Flow Tracks

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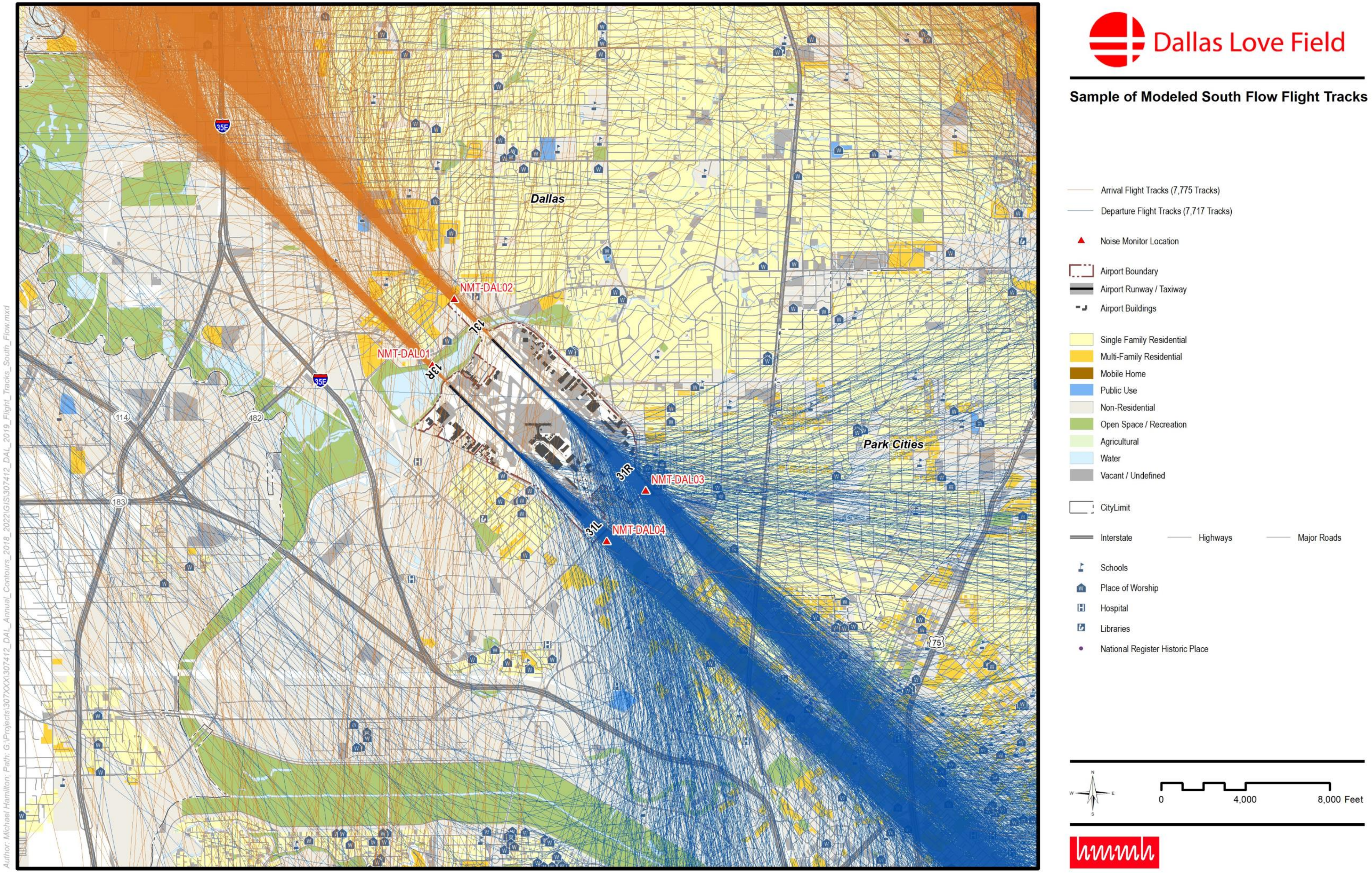

Figure 14. Sample of Modeled South Flow Tracks

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4.5 Departure Stage Length

AEDT uses an aircraft's weight to determine performance criteria during takeoff such as thrust and climb rate, which in turn affect the noise received from the aircraft on the ground. A substantial component of aircraft weight is fuel load. Fuel load varies according to several factors, primarily the distance to destination, which is referred to in AEDT as the stage length. In these analyses, stage length serves as a proxy for aircraft weight since weight data is not necessarily available. For each aircraft type, AEDT includes a database of departure profiles available for each stage length category that aircraft is likely to fly.

In preparing the AEDT study, RC for AEDT assigns stage lengths and departure profiles for each departure based on the destination airport on the flight plan. RC for AEDT calculates the great-circle distance between the two airports, finds the stage length category corresponding to this distance, and then determines the most appropriate departure profile available in the AEDT database. AEDT does not have profiles for all stage lengths available for all aircraft. In cases where the stage length is not available or exceeds the maximum stage-length profile available for that runway (i.e., the aircraft would overrun the runway on departure), the maximum stage length available without overrunning the runway is selected. If a particular AEDT aircraft has multiple available default profiles in AEDT for a given stage length, RC for AEDT compares the flight track's altitude profile to the available default AEDT profiles and assigns an AEDT profile based on the closest match.

Table 7 presents the twelve categories for departure stage length used in AEDT and the respective number of departures modeled for 2019. Sixty-three percent of departures from DAL were stage length D-1 operations in 2019. This includes destinations such as El Paso and Saint Louis. Stage length D-2 departures would include Las Vegas and Orlando, while stage length D-3 would reach most coastal cities including Seattle and Boston.

Table 7. Modeled 2019 Departure Stage Length Operations

Source: FAA AEDT 3b Technical Manual, HMMH

Stage Length Number	Trip Length (Nmi)	2019 Daily Departure Operations	
		Day	Night
D-1	0 - 500	171.20	44.47
D-2	500 - 1,000	65.18	9.91
D-3	1,000 - 1,500	44.01	5.50
D-4	1,500 - 2,500	0.17	0.17
D-5	2,500 - 3,500	0.05	0.00
D-6	3,500 - 4,500	0.08	0.01
D-7	4,500 - 5,500	0.03	0.01
D-8	5,500 - 6,500	0.00	0.00
D-9	6,500 - 7,500	0.00	0.00
D-10	7,500 - 8,500	0.00	0.00
D-11	Greater than 8,500	0.00	0.00
D-M	Max range at MTOW	0.00	0.00
Total		280.72	60.07

4.6 Meteorological Conditions

AEDT has several settings that affect aircraft performance profiles and sound propagation based on meteorological data at the airport. Meteorological conditions include temperature, barometric pressure, relative humidity, and wind speed. AEDT uses 30-year average values from the National Climatic Data Center (NCDC) weather station at Dallas Love Field (KDAL). The values used in the modeling were:

- Temperature: 66° Fahrenheit
- Dew point: 53.67° Fahrenheit
- Sea level pressure: 1016.28 millibars
- Pressure: 987.12 millibars
- Relative humidity: 63.37 percent.
- Average wind speed: 8.37 knots.

4.7 Terrain

Terrain data describe the elevation of the ground surrounding the airport and on airport property. AEDT 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 used are from the USGS 1/3-arcsecond National Elevation Dataset (NED), 2013 publication.

5 Noise Modeling Results and Land Use Exposure

5.1 Land Use

Figure 15 displays the land use in the area surrounding DAL. 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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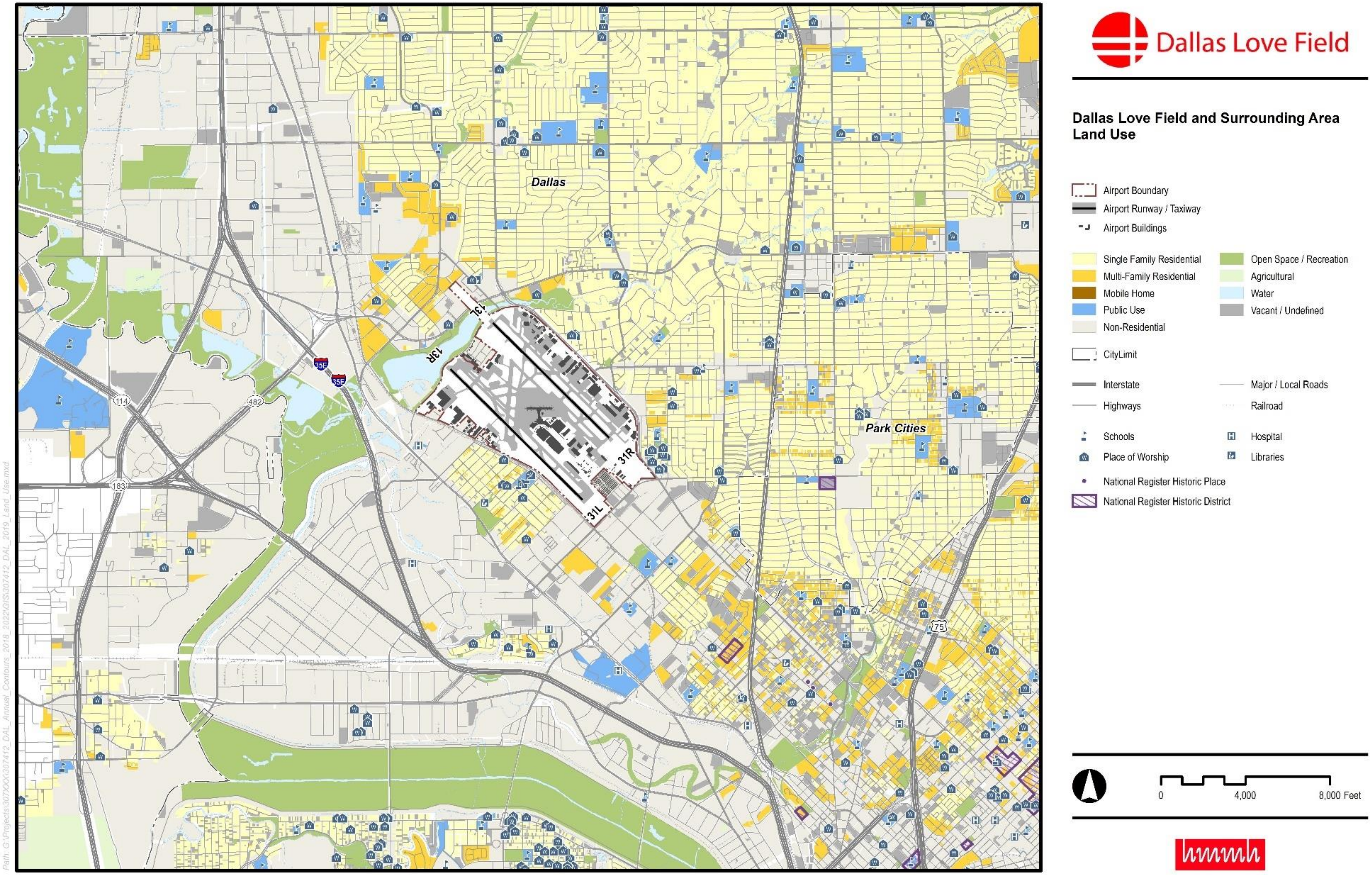

Figure 15. Dallas Love Field and Surrounding Area Land Use

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5.2 DNL Noise Contours

5.2.1 2019 Noise Contours

Figure 16 presents the 2019 DNL contours, 60 dB through 75 dB in five-dB intervals, overlaid on the land use base map provided in Section 5.1. The shape of the DNL contours is a function 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 due to both arrivals and departures, 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 northwest, the DNL 65 dB contour extends to the Calvary Hill Cemetery due to operations on Runway 13L/31R, and beyond Lombardy Lane to Brenner Drive due to operations on Runway 13R/31L.
- To the southeast, the DNL 65 dB contour extends slightly past Inwood Road due to operations on Runway 13L/31R, and past Hawthorne Avenue due to operations on Runway 13R/31L.
- To the southwest along the sideline of Runway 13R/31L, the DNL 65 dB contour remains primarily within airport property except towards the end of Runway 31L where sideline noise extends to Thurston Drive (Maple Avenue).
- To the northeast along the sideline of Runway 13L/31R, the DNL 65 dB 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 are also five schools and seven places of worship within the DNL 65 dB contour:

- Thomas J. Rusk Middle School,
- Obadiah Knight Elementary School,
- Maple Lawn Elementary School,
- Our Lady of Perpetual Help School,
- Letot Center Juvenile Detention Center
- Cristo Rey Presbyterian Church,
- Our Lady of Perpetual Help Catholic Church,
- Iglesia de Dios Love Field,
- Iglesia Pentecostal Roca De Poder
- New Jerusalem AME Church,
- North Temple Baptist Church, and
- Greater North Park Church of God In Christ

5.2.2 Comparison of the 2019 and 2018 Noise Contours

Figure 17 shows a comparison of the 2019 DNL contours to the 2018 DNL contours for the same DNL 60 dB through DNL 75 dB range. The contours have changed due to small changes in runway use, reductions in departures at night, and the increased use of quieter aircraft. While there was a small increase in traffic (231,879 total operations in 2019 vs. 231,016 in 2018), the 2019 contour is smaller compared to 2018. Use of Runway 13L/31R decreased compared to 2018 while use of Runway 13R/31L increased compared to 2019. The 2019 fleet continues to show a transition to new, quieter aircraft model types, especially in the small regional jet and general aviation categories, which also reduced the size of the contour.

To the northwest, the size of the contour has decreased in line with both Runway 13L/31R and Runway 13R/31L. In both cases, most of the change in the contour occurred in areas of non-residential land use. To the southeast, the size of the contour has decreased in line with both Runway 13L/31R and Runway 13R/31L. The decrease in line with Runway 13R/31L occurs mainly in areas of multi-family residential land use. The decrease in line with Runway 13L/31R mainly occurred in areas of non-residential land use.

These shifts in the contour reflect changes in the type of operations affecting these areas. Three louder aircraft types, the 767JT9, 747400 and F-18, while only having a few operations, were modeled in 2018 but not in 2019.

Modeled daily operations changed by more than an absolute value of two operations for 11 other aircraft types between 2018 and 2019. These aircraft are listed in Table 8, along with the modeled average daily operations for 2018 and 2019 and the difference between the two years. Overall, these changes contributed an overall decrease of 4.4 modeled daily operations at Love Field. When all increases and decreases are accounted for, regardless of magnitude, the modeled daily operations at DAL show a total decrease of 8.98 operations.

Table 8. Aircraft Types with Modeled Daily Operations Differences >±2 Between 2018 and 2019

Source: HMMH

Aircraft Type	Aircraft Category	2018 Modeled Operations	2019 Modeled Operations	Difference in Modeled Operations
Boeing 737-800	AC	66.6006	81.3904	14.7898
Boeing 737-700	AC, GA	270.9511	282.9327	11.9816
Cessna 560XL	AT, GA	5.9238	10.3697	4.4459
Embraer 175	AC	21.3294	24.2374	2.9080
Bombardier Challenger 601	AT, GA	3.6245	5.8042	2.1798
Cessna 560E	AT, GA	2.6860	0.1564	-2.5296
Cessna 560U	AT, GA	13.3537	10.5291	-2.8246
deHavilland DHC-6	AT, GA	26.2489	23.2439	-3.0050
Boeing 737 MAX 8	AC	8.3705	3.1693	-5.2012
Airbus A319-131	AC	6.2061	0.2157	-5.9904
Cessna 208	AT, GA	16.6268	9.0378	-7.5889
Total		467.9569	463.5279	-4.4290

Operations affecting the Runway 13L end (arrivals to Runway 13L and departures from Runway 31R) decreased by 2.2 percent, while operations affecting the Runway 13R end (arrivals to Runway 13R and departures from Runway 31L) increased by 7.7 percent.

Alongside the runways, the contour has shifted slightly away from the airport at the departure end of Runway 13R and remained almost unchanged along Runway 13L/31R and Runway 13R/31L. This reflects a corresponding shift in numbers of operations on Runway 13R; specifically, arrival and departure operations on Runway 13R increased by 17.8 percent from 2018.

5.2.3 Comparison of the 2019 and 2006 Noise Contours

Figure 18 shows a comparison of the 2019 DNL contours to the 2006 DNL contours for the same DNL 60 dB through DNL 75 dB range. In 2019, the overall aircraft fleet is quieter than the fleet in 2006. The 2006 DNL contours included some Stage 2 jets which are absent from the fleet in 2019. Also, the number of operations modeled for 2019 was smaller than for 2006 (231,879 vs. 248,010).

The extent of the 2019 DNL 65 dB contour in line with Runway 13L/31R is inside the 2006 contour, whereas the 2019 contour in line with Runway 13R/31L extends beyond the 2006 contour in both directions. The width of the 2019 contour is slightly smaller than the 2006 contour, particularly northeast of the airport.

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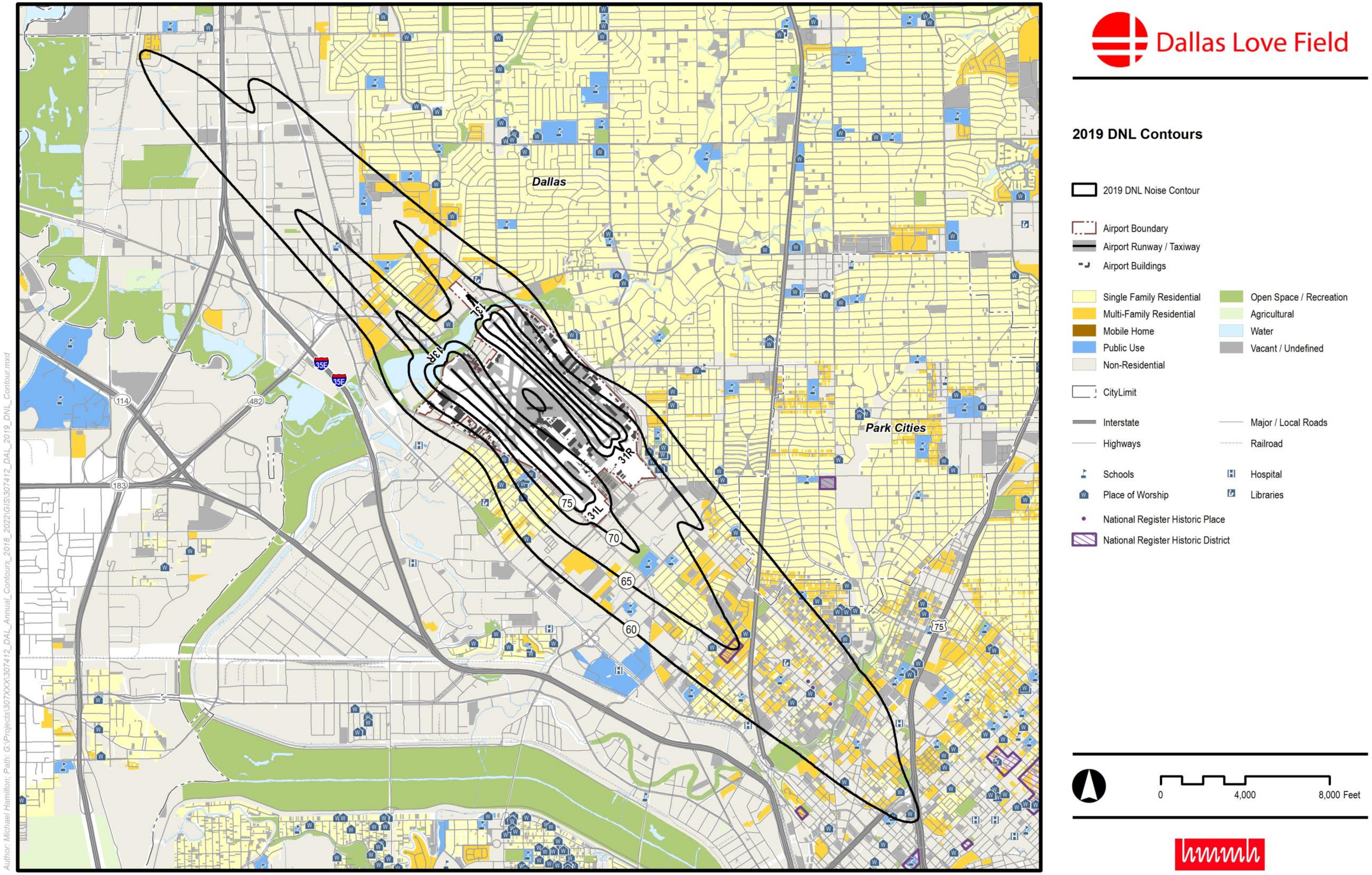

Figure 16. 2019 DNL Contours

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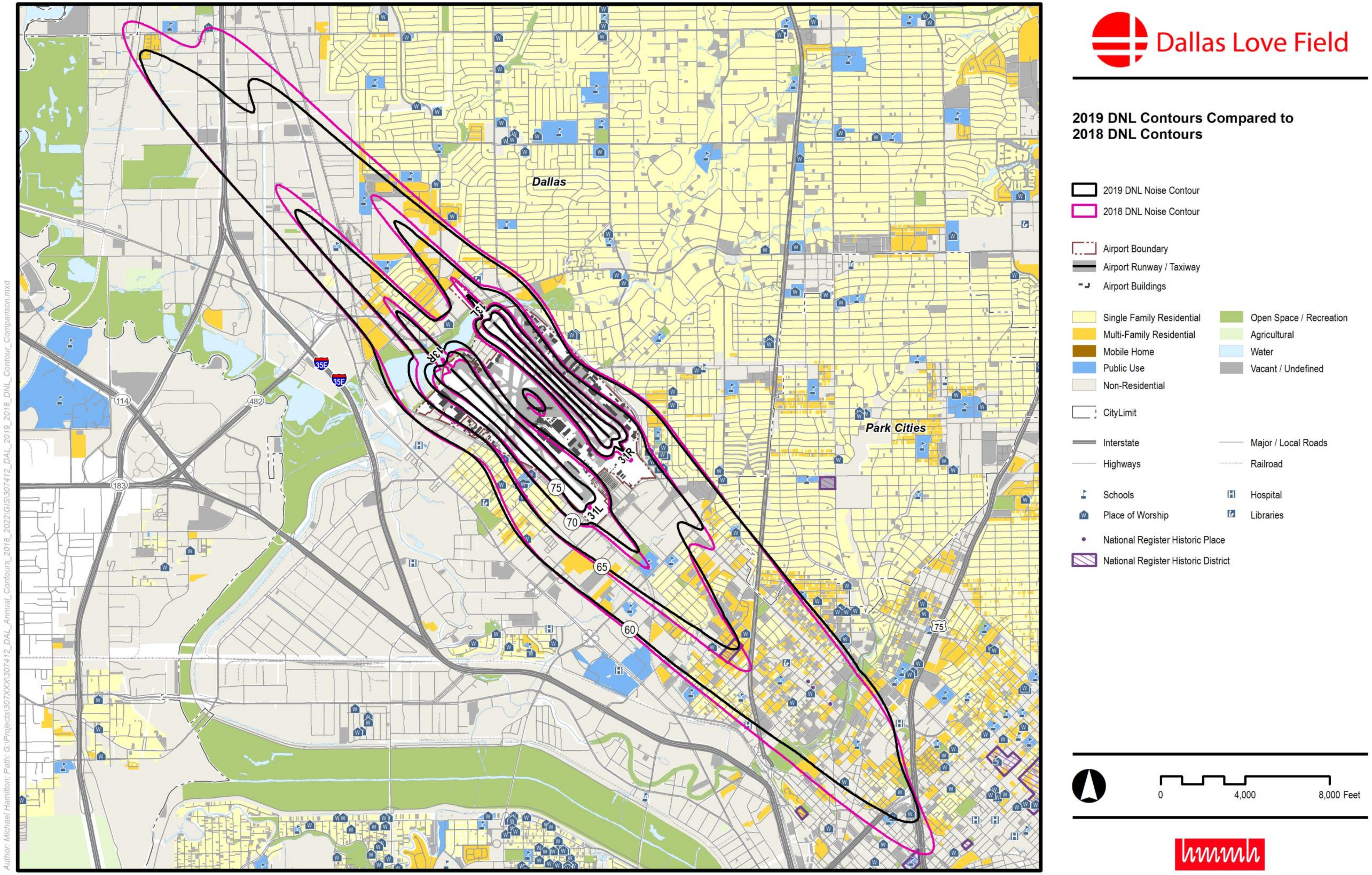

Figure 17. 2019 DNL Contours Compared to 2018 DNL Contours

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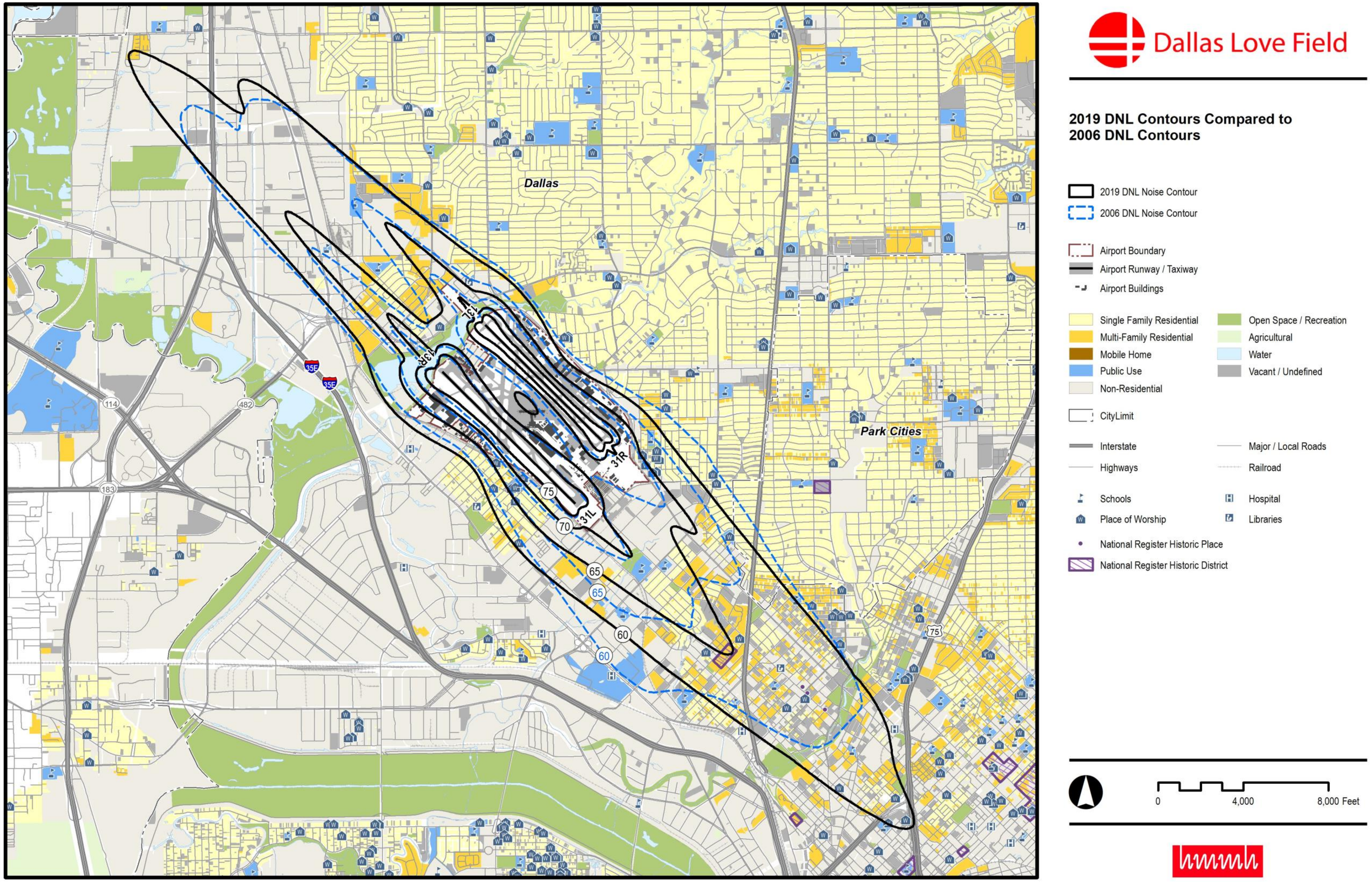

Author: Michael Hamilton; Path: G:\Projects\307XXX\307412_DAL_Annual_Contours_2018_2022\GIS\307412_DAL_2019_2006_DNL_Contour_Comparison.mxd

Figure 18. 2019 DNL Contours Compared to 2006 DNL Contours

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5.3 Noise Monitor Location Results

The prior Noise and Operations Monitoring System (NOMS) at Dallas Love Field had 13 permanent monitors that measured noise levels 24 hours a day. This system was decommissioned in March of 2018 as DAL prepared for the installation of new monitors. The new NoiseLab system installed three monitors in late 2018, with the fourth installed in May of 2020. At each of the new sites, DNL levels were computed and averaged over the associated operational period, resulting in an average measured DNL value. The NoiseLab system matches noise events to aircraft operations and supplied the aircraft-only noise event data. DNL values from aircraft operations were modeled at each of these sites using AEDT and are reported in Table 9. Two of the new sites (DAL02, DAL03) have modeled values between DNL 65 dB and 70 dB. One new site (DAL04) exceeded DNL 70 dB.

The measured values are provided for comparison. Measured and modeled values are generally within 1 to 2 dB with excellent agreement at DAL04. DAL01 was not installed until May 2020 and is not included in this report.

Table 9. Modeled DNL at Noise Monitor Locations

Source: HMMH, DAL Noise Office

Noise Monitor Location			Day-Night Average Sound Level (DNL) dBA	Day-Night Average Sound Level (DNL) dBA	Periods Offline
Site	**Latitude**	**Longitude**	**Modeled (AEDT)**	**Measured**	
DAL01	32.853960	-96.866067	--	--	--
DAL02	32.862532	-96.862499	69.1	67.9	5/7/2019, 5/13/2019, 7/16/2019, 7/19/2019-7/21/2019, 7/28/2019, 7/31/2019, 8/2/2019, 8/4/2019-8/5/2019, 8/8/2019-8/10/2019, 8/16/2019, 8/18/2019-8/20/2019, 8/25/2019, 8/31/2019-9/4/2019, 9/8/2019, 9/12/2019, 9/19/2019-9/20/2019
DAL03	32.837125	-96.833364	68.1	66.6	9/19/2019-9/20/2019
DAL04	32.830612	-96.839535	72.2	72.3	9/19/2019-9/20/2019

5.4 Exposed Population and Land Area

As described in Section 5.2.2, from 2018 to 2019, the extent of the DNL contours decreased in most areas, but the overall change in contour size was not substantial. Between 2018 and 2019, the area exposed to DNL 65 dB or greater decreased from 4.30 square miles in 2018 to 3.95 square miles. The estimated population, based on 2010 US Census Data, within each DNL 5 dB contour interval is summarized in Table 11; between 2018 and 2019, the population experiencing noise levels greater than 65 dB decreased by 20 percent from 14,713 to 11,792. This contrasts with increases of 51 percent in 2018 and 11 percent in 2017. The exposed population for 2019 is 30 percent smaller than the exposed population in 2006.

Table 10. Estimated Area within Noise Contours

Source: HMMH 2020

DNL Noise Level (dBA)	Estimated Land Area Exposed to Given Noise Exposure Level (square miles)		
	2006	2018	2019
60-65	5.71	7.30	6.75
>65	4.62[6]	4.30	3.95
65-70	2.68	2.92	2.65
70-75	1.08	0.83	0.76
>75	0.867[7]	0.55	0.54

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

Table 11. Estimated Population within Noise Exposure Area

Source: HMMH 2019, U.S. Census 2010

DNL Noise Level (dBA)	Estimated Number of People Exposed to Given Noise Exposure Level (2010 US Census Data)		
	2006	2018	2019
60-65	42,603	52,931	52,538
>65	16,798	14,713	11,792
65-70	15,858	14,352	11,489
70-75	936	361	303
>75	4	0	0

---

[6] The 2006 >65 contour band area has increased due to the error discovered in the 2006 >75 contour band. Within the 2013-2017 reports the 2006 >65 contour band area was listed as 4.19 sq. mi; the correct area is 4.62 square miles. The 2006 > 65 contour band area is now correct within the 2018 and 2019 Annual Reports.

[7] When HMMH was completing the 2018 Annual Report, an error was discovered in the >75 contour from 2006. Within the 2013-2017 reports the 2006 >75 contour band area was listed as .43 sq. mi; the correct area is .86 square miles. The 2006 > 75 contour band area is now correct within the 2018 and 2019 Annual Reports.

Appendix A Noise Terminology

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 A.1), the effects of noise on human activity (Section A.2), and weather and distance effects (Section A.3).

A.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

A.1.1 Sound Pressure Level (SPL) and the Decibel

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 ($P_{reference}$)[8].

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

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.[9]

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,[10] and (2) changes in SPL of less than about three decibels are not readily detectable outside of a laboratory environment.

A.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.

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

[9] 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).

[10] A "10 dB per doubling" rule of thumb is the most often used approximation.

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. “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 19 depicts A-weighting adjustments to sound from approximately 20 Hz to 10,000 Hz.

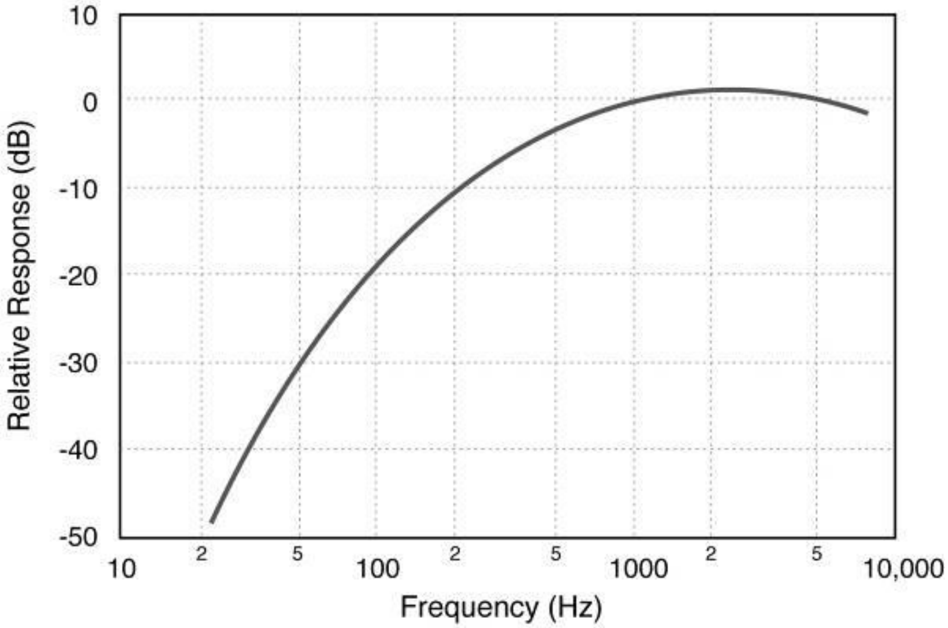

Figure 19. A-Weighting Frequency-Response

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 the curve 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 20 depicts representative A-weighted sound levels for a variety of common sounds.

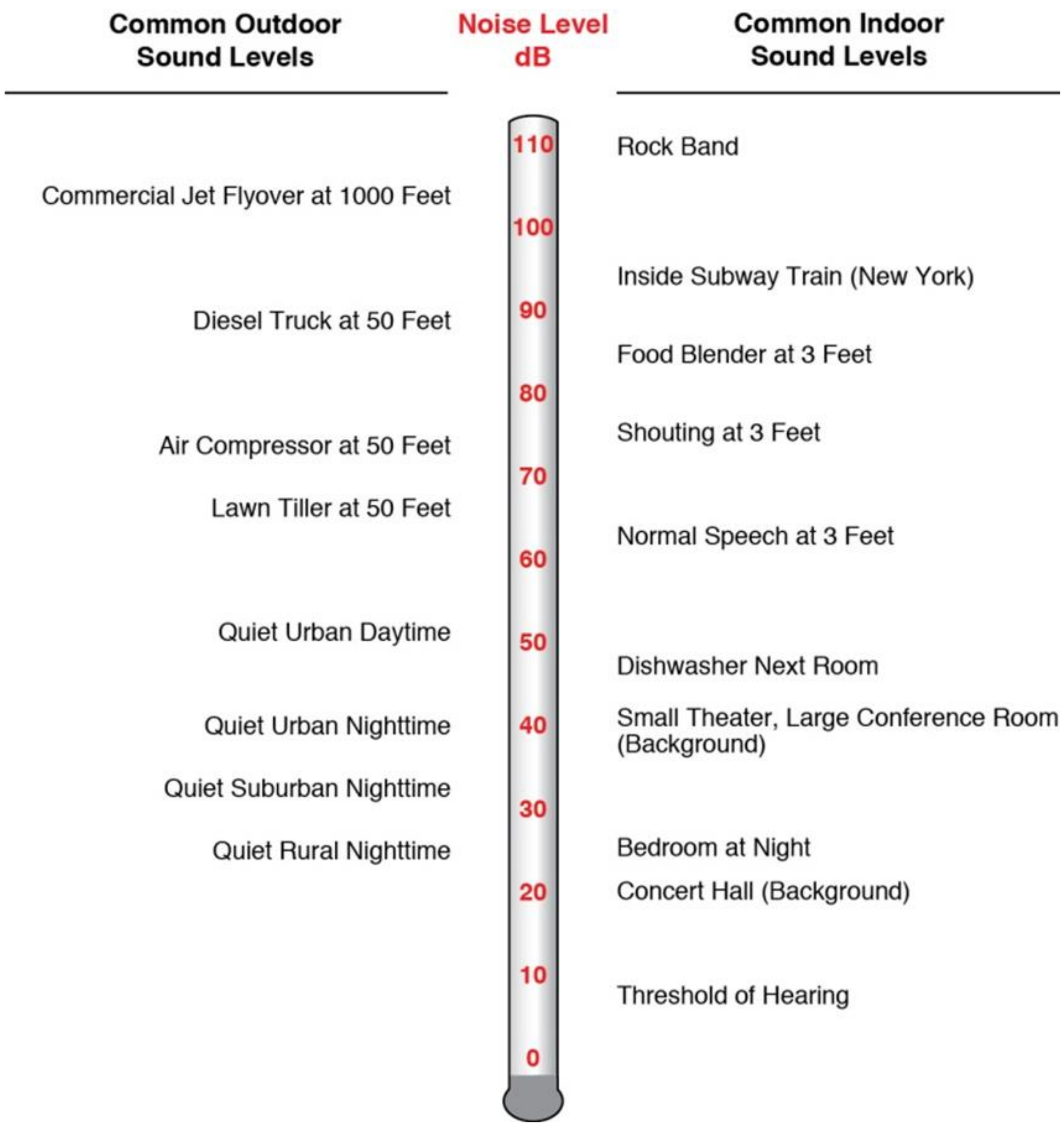

Figure 20. A-Weighted Sound Levels for Common Sounds

Source: HMMH

A.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 21 depicts this general concept for a hypothetical noise event with an L_{max} of approximately 102 dB.

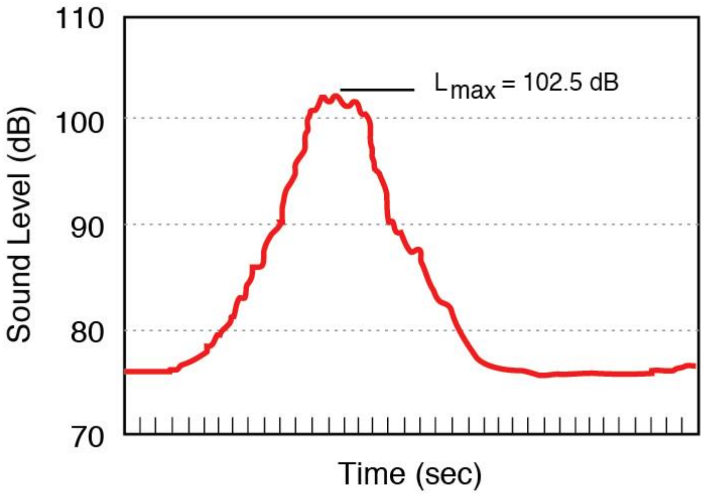

Figure 21. Variation in A-Weighted Sound Level over Time and Maximum Noise Level

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.

A.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 22 depicts this compression, for the same hypothetical event shown in Figure 21. Note that the SEL is higher than the L_{max}.

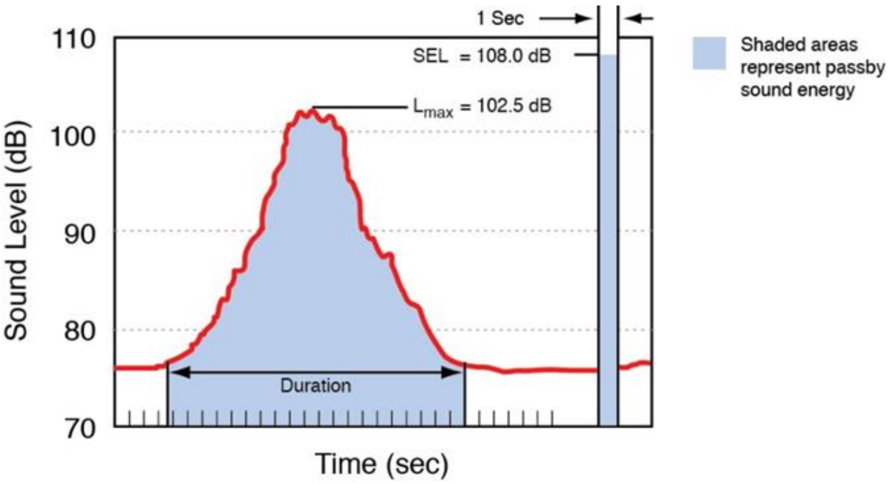

Figure 22. Graphical Depiction of Sound Exposure Level

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.

A.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 23 illustrates this concept for a one-hour period. Note that the L_{eq} is lower than either the L_{max} or SEL.

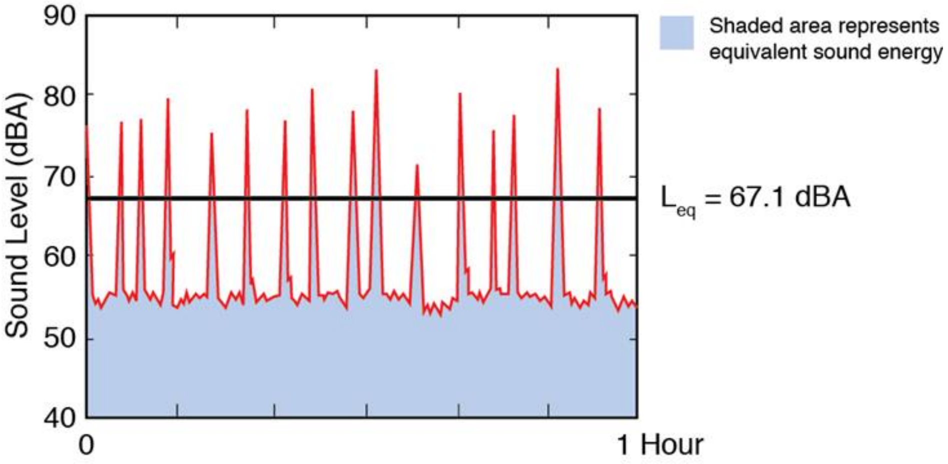

Figure 23. Example of a One Hour Equivalent Sound Level

Source: HMMH

A.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.[11]

- 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 principle, 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

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[11] "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.

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 the number of days in that year.

Figure 24 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 25 presents representative outdoor DNL values measured at various U.S. locations.

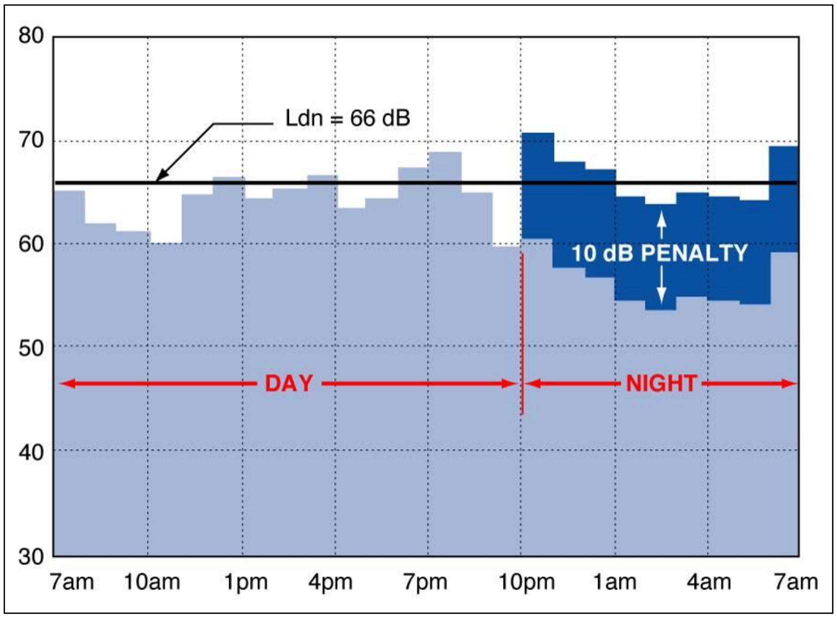

Figure 24. Example of a Day-Night Average Sound Level Calculation

Source: HMMH

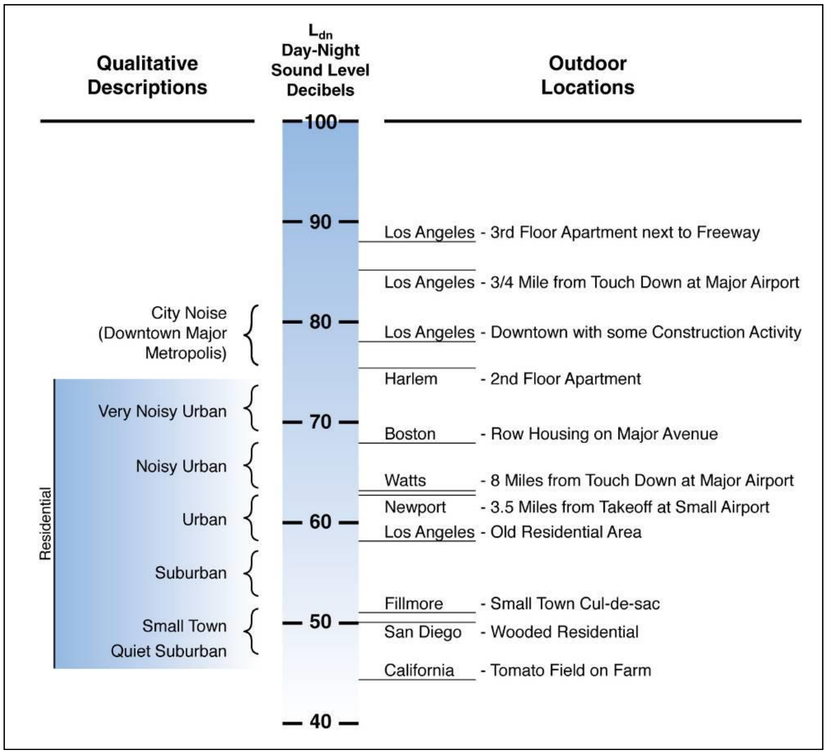

Figure 25. Examples of Measured Day-Night Average Sound Levels, DNL

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.

A.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.

A.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 26 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 or her voice or the individuals must get closer together to continue talking.

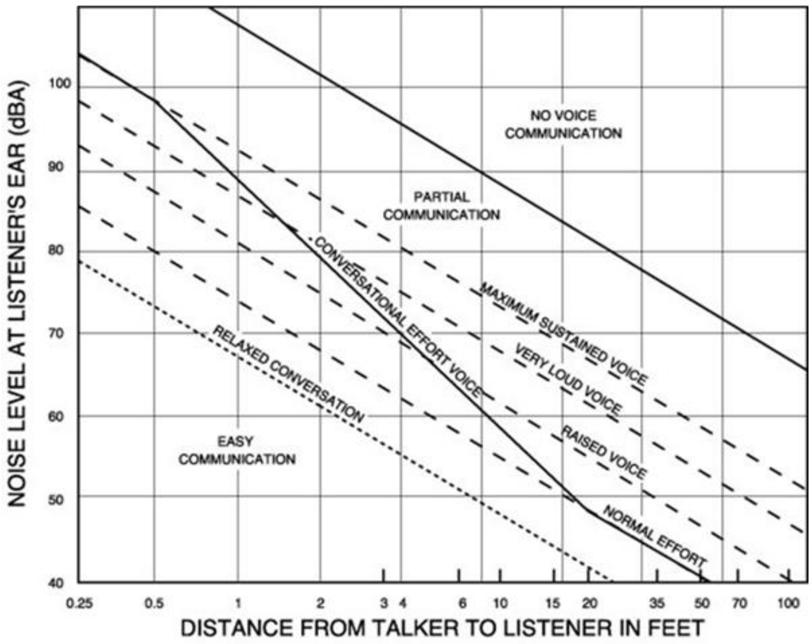

Figure 26. Outdoor Speech Intelligibility

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 percent intelligibility is acceptable for many conversations. In relaxed conversation, however, we have higher expectations of hearing speech and generally require closer to 100 percent 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 percent 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 26 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 was increased or communication distance 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.

A.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 27 shows a recent summary of findings on the topic.

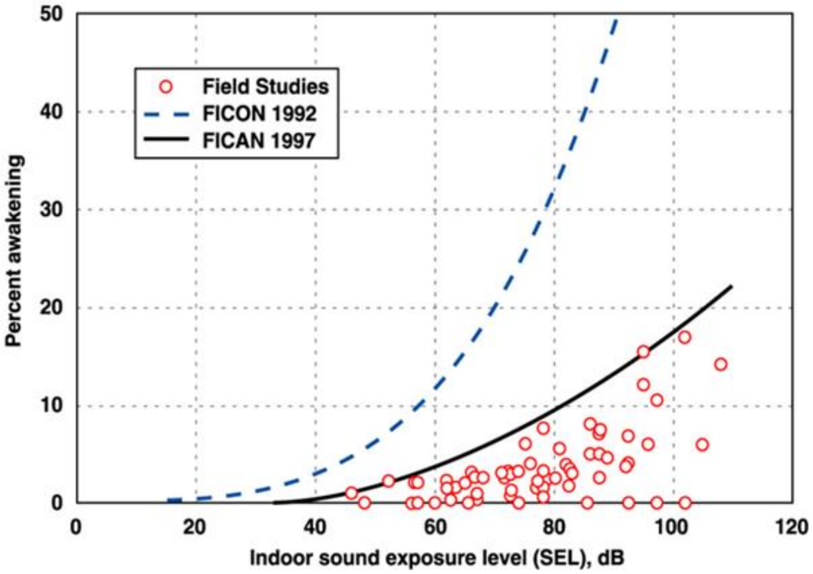

Figure 27. Sleep Interference

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

Figure 27 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 percent 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.[12]

A.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 28 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.

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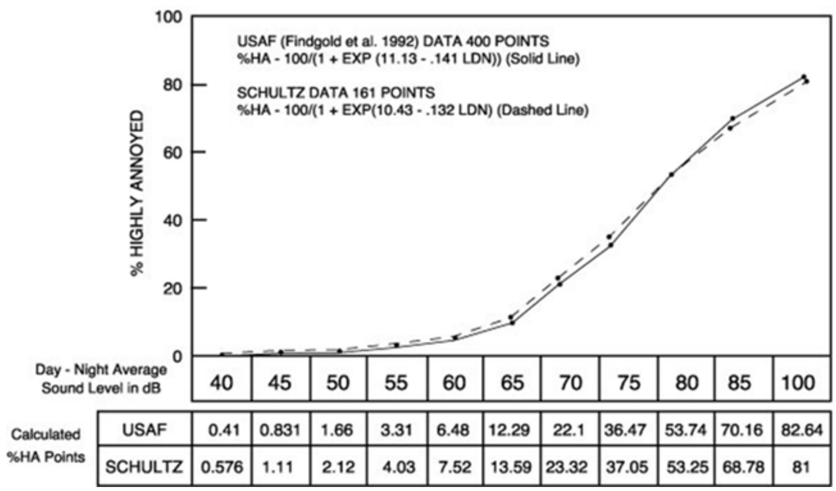
[12] The awakening data presented in Figure 2 9 apply only to individual noise events. The American National Standards Institute (ANSI) has published a standard that provides a method for estimating the number of people awakened at least once from a full night of noise events: ANSI/ASA S12.9-2008 / Part 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 or AEDT, to compute awakenings.



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 28. 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 29 depicts this relationship.

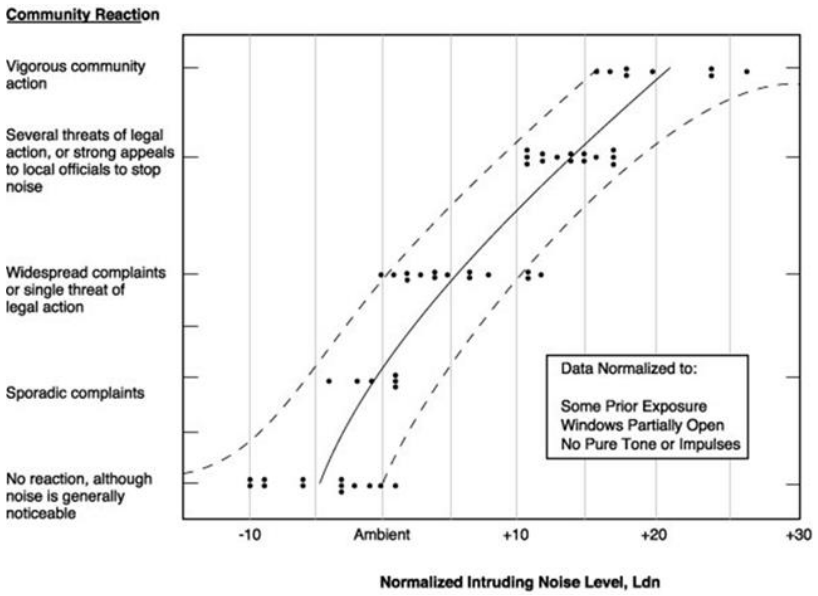


Figure 29. Community Reaction as a Function of Outdoor DNL

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.

A.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.

A.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.

A.3.1.1 Influence of Humidity and Precipitation

Humidity and precipitation rarely affect 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 have little, if any, noticeable effect on sound propagation. A substantial body of empirical data supports these conclusions.[13]

A.3.1.2 Influence of Temperature

The velocity of sound in the atmosphere depends on the air temperature.[14] 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, or 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.[15] 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 and when wind levels often are very low, limiting any confounding factors.[16] Under extreme

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[13] 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.

[14] 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.

[15] 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.

[16] Ingard, p. 407.

conditions, one study found that noise from aircraft on the ground 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.[17]

A.3.1.3 Influence of Wind

Wind has a strong directional component that can lead to significant variation in sound 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.[18] 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.[19]

Wind turbulence can also affect sound propagation. Sound levels heard at remote receiver locations will fluctuate with this 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.[20]

A.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 feet 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

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[17] 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.

[18] 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.

[19] Piercy and Embleton, p. 1413.

[20] Ingard, pp. 409-410.

weather conditions. This absorption effect drops off relatively rapidly with distance. The AEDT considers these reductions.