DALLAS LOVE FIELD

2020 Day-Night Average Sound Level Contours

HMMH Report No. 307412

July 2021

Prepared for:

City of Dallas Aviation Department
7555 Lemmon Ave
Dallas, TX 75209

Prepared by:

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QUALITY CONTROL PLAN

Project Name	DAL 2020 Annual Report	Project No.	307412.003	QC Plan Revision	☐Yes ☐No
Client Name	City of Dallas	Profit Center	AES	Document Author	Kate Larson
Owner	Department of Aviation	Quality Manager	Robert Mentzer	Technical Editor	Sarah Yenson
Project Manager	Sarah Yenson	AEDT QC Checker	Scott McIntosh	Subconsultant	
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QC CHECKLISTS TO UTILIZE / PROJECT MILESTONE			
☒	AEDT QAQC	Project milestone / schedule for checklist	Scott McIntosh iniitial review 3/10/2021 / final review 3/18/2021
☒	Develop Noise Model Inputs Memorandum	Project milestone / schedule for checklist	Sarah Yenson review 3/11/2021
☒	Internal Review of Noise Model Inputs Memorandum	Project milestone / schedule for checklist	Robert Mentzer review 3/12/2021
☒	Noise Model Inputs Memorandum to Client for review/comments	Project milestone / schedule for checklist	Isaac Ellison review 3/23/2021
☒	Develop Draft Report/Tables	Project milestone / schedule for checklist	Kate Larson review 3/22/2021
☒	1st Technical Review	Project milestone / schedule for checklist	Sarah Yenson review 4/7/2021
☒	2nd Round Review	Project milestone / schedule for checklist	Robert Mentzer review 4/13/2021
☒	Draft to Client	Project milestone / schedule for checklist	4/21/2021
☒	Respond to /Resolve comments	Project milestone / schedule for checklist	Comments received from Isaac Ellison 6/25/2021 Kate Larson edits 6/30/2021
☐	Review Final Report	Project milestone / schedule for checklist	Robert Mentzer 7/7/2021
☐	Final Report Delivery	Project milestone / schedule for checklist	

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1 Summary

This report, prepared by Harris Miller Miller & Hanson Inc (HMMH) under contract to the City of Dallas, presents analysis of the 2020 noise conditions at Love Field (DAL) in Dallas, Texas.

The development of the 2020 Day-Night Average Sound Level (DNL, or Ldn) contours used the current version (Version 3c) of the Federal Aviation Administration (FAA) Aviation Environmental Design Tool (AEDT). A data pre-processor converted every usable 2020 radar track into input for the AEDT noise model, ensuring that the modeling reflects any runway closures, deviations from flight patterns, changes in flight schedules, and deviations from average runway use. The 2020 year's total of 170,162 operations were modeled on 164,493 radar tacks to produce the 2020 DNL contours.

2020 was a highly unusual year, as worldwide commercial air travel responded to cancellations and restrictions imposed by the global COVID-19 pandemic. At DAL, annual operations for 2020 were 73.3 percent of the total count for the previous year. The percentage of operations occurring at night[1] was about 7.4 percent overall, down from almost 12 percent in 2019.

In 2020, the estimated number of people exposed to DNL exceeding the federal guideline of DNL 65 dB is 2,356 people, a decrease of approximately 80 percent compared to 2019 (11,639 people living within the DNL 65 dB contour). The estimated number of people within the 2020 DNL 65 dB contour is 86 percent smaller than the number of people within the DNL 65 reference contour prepared in 2006[2] (16,798 people in DNL 65 dB or greater). As air travel returns to normal, the size of the DNL contours and the corresponding estimates of people impacted by noise are expected to increase.

Analysis of the noise contours indicates the following:

- In general, due to the reduction in operations in 2020, the contours decreased in all areas around the airport.
- These changes occurred in non-residential, multi-family residential, and single-family residential areas.
- The total area contained within the DNL 65 dB contours decreased 44 percent, from 3.95 square miles in 2019 to 2.21 square miles in 2020. Compared to the reference 2006 DNL 65 dB contour area (4.62 square miles), the 2020 DNL 65 contour is 52 percent smaller.

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

[1] Night is defined as 10:00 p.m. to 7:00 a.m. in the calculation of DNL. The percentage of night operations is important since nighttime noise is weighted by a factor of 10 in the analysis.

[2] The reference contour was prepared in 2006 to represent forecasted 2020 conditions.

also establish a noise reduction strategy 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 Noise Lab[3] system, and continued participation in the Love Field Environmental Advisory Committee (LFEAC).

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 (Noise Lab) 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 monthly updates on runway closures and construction activities, and reports on airport operations by group and by runway.[4]

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:

- A 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.
- A noise abatement departure procedure (Trinity Departure) for night operations from Runway 13R for all turbojet aircraft and aircraft weighing over 12,500 pounds.
- Prohibition of 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 of optimal take-off profiles (departure profiles designed to reduce noise).

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).

[3] Provided by Casper Airport Solutions Inc. – https://dal.noiselab.casper.aero/

[4] 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. Title 14 of the Code of Federal Regulations (CFR) Part 150 Appendix A provides land use compatibility guidelines as a function of DNL values. Table 1 reproduces those guidelines, which 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.

Responses may also be affected by expectation and experience. People may get used to a level of noise exposure that guidelines indicate may be unacceptable, and changes in exposure may generate a 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 noncompatible land use. 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.

FAA land use compatibility guidelines, as set forth in 14 CFR Part 150, indicate that all land uses are normally compatible with aircraft noise at exposure levels below DNL 65 dB as shown in Table 1. Standards adopted by the U.S. Department of Housing and Urban Development (HUD)[5] formally support this limit by determining if residential 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.

[5] HUD’s noise standards may be found in 24 CFR Part 51, Subpart B

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

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

Land Use	Yearly Day-Night Average Sound Level, DNL, in Decibels (Key and notes on following page)					
	<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.

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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 3c.

AEDT requires inputs in the following categories:

- Physical description of the airport layout
- Number and mix of aircraft operations, including day-night split of operations (by aircraft type)
- Aircraft noise and performance characteristics
- Runway utilization rates
- Flight track geometry and utilization rates
- Meteorological conditions
- Terrain data

HMMH's proprietary pre-processing software for AEDT prepared the operational and spatial noise model inputs for AEDT from radar flight data. Use of this methodology 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 3c was released for general use in June 2020.[6] This version has been used as the primary analytical tool to assess the 2020 noise environment at Dallas Love Field. The AEDT aircraft database is continuously updated with new aircraft types as noise data becomes available. AEDT 3c includes updated data for the ATR-72, Gulfstream G650 and Boeing 767-300 aircraft.

The AEDT 3c 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 data for over 20 types of helicopters, several of which were included in the development of the 2020 DNL contour for Love Field. The AEDT terrain feature accessed topographical data 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 – AEDT Pre-processor

HMMH prepared the 2020 noise exposure contours using a proprietary AEDT pre-processor, which prepares each available aircraft flight track contained in the radar data set for input into AEDT. The AEDT model itself is used for all noise calculations. The pre-processor provides an organizational structure to model individual flight tracks in AEDT; it 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.

[6] AEDT version 3c was initially released in March 2020 but was re-released with error fixes three months later.

The AEDT pre-processor takes maximum possible advantage of the available data from the airport's Noise Lab system[7] and AEDT's capabilities. It automates the process of preparing the AEDT inputs and models the full range of aircraft activity as precisely as possible, improving the precision of modeling by doing the following:

- For every identified aircraft operation, it directly converts the flight track recorded by Noise Lab to an AEDT track (rather than assigning all operations to a limited number of prototypical tracks).
- It models each ground track as it was flown in 2020, including deviations from the typical flight patterns due to weather, safety, or other reasons.
- It models each operation on the specific runway that was actually used (rather than applying a generalized distribution of broad ranges of aircraft types to an average of runway use).
- It models each operation at the time it occurred to accurately determine which operations incur the 10 dB weighting for nighttime operations when calculating DNL.
- On an operation-by-operation basis, it selects the specific airframe and engine combination to model 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.
- Based on the radar origin and destination data, it selects the stage length for each flight (a surrogate factor for aircraft weight) from the list of available stage lengths for each AEDT type.
- It accurately incorporates the effects of runway closures due to construction (e.g., during a nighttime closure, the modeling will only include tracks on the active runway).

The flight track data for 2020 that were used in the modeling were obtained from DAL's Noise Lab system and are all from the FAA's Nextgen radar data feed.

[7] The Noise Lab system is provided by Casper Airport Solutions Inc.

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 and is referred to as the Lemmon runway. To its south, Runway 13R/31L is adjacent to Denton Drive and is referred to as the Denton runway. Table 2 provides further detail and runway coordinates for each runway end and a modeled helipad location. The 2020 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 (denoted HP) was defined along taxiway A between taxiways A2 and A3; all modeled helicopter flight operations begin or end at the helipad location.

Table 2. Runway Layout

Runway	Latitude	Longitude	Elevation (ft MSL)	Displaced Approach Threshold (ft)	Threshold Crossing Height (ft)	Glide Slope	Width (ft.)	Length (ft.)
13L	32.857274	-96.856801	476.6	399	57	3.0	150	7,752
31R	32.842043	-96.839152	486.7	0	55	3.0		
13R	32.851317	-96.863452	476.1	489	52	3.0	150	8,800
31L	32.834029	-96.843415	476.2	0	55	3.0		
HP	32.849059	-96.845502	487	-	-	-	-	-

Source: FAA Airport Master Record 5010 and IAPs on https://skyvector.com/files/tpp/2102/pdf/00106IL31L.PDF

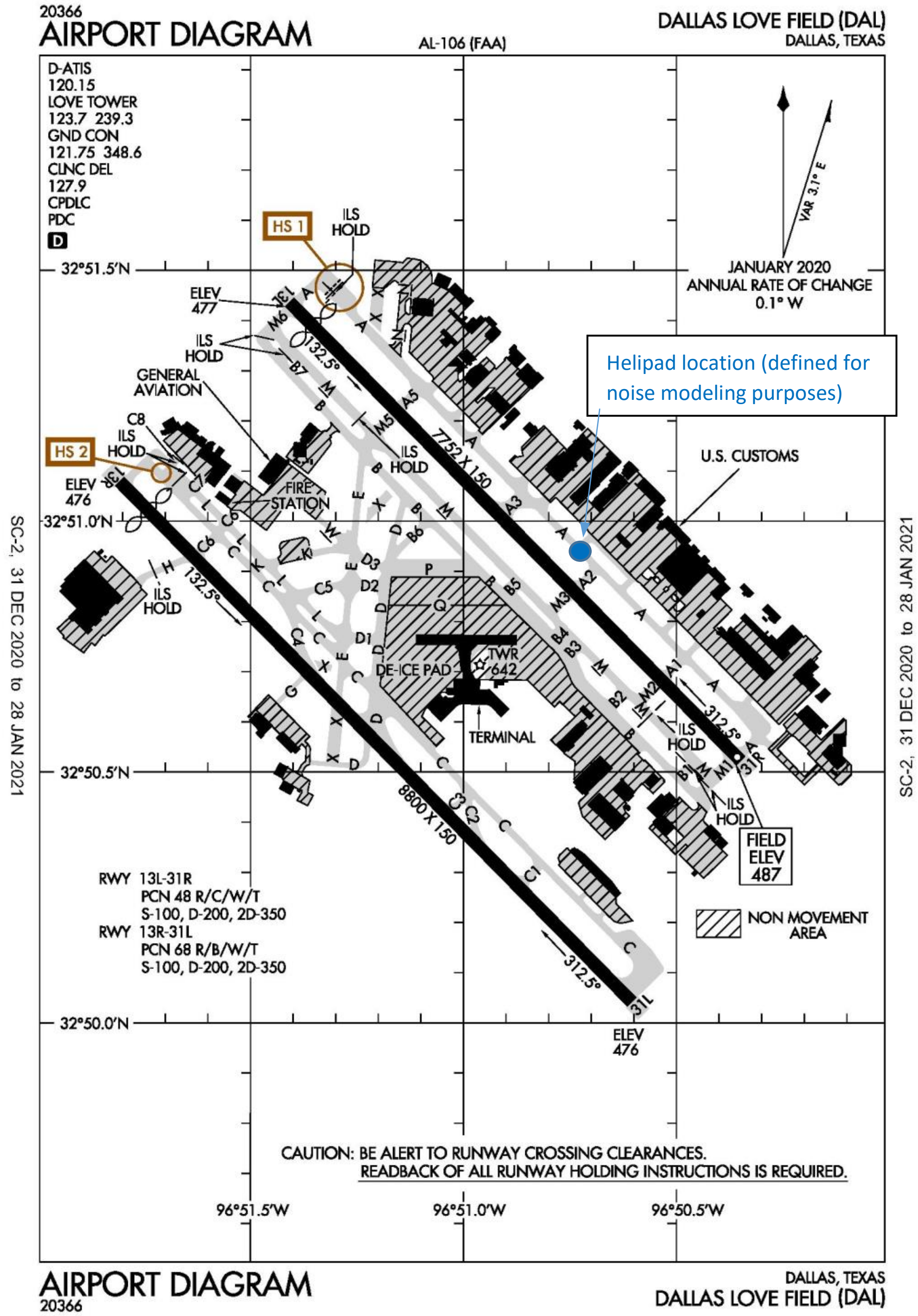

Figure 1. Dallas Love Field Airport Diagram

Source: FAA,[8] Effective 31 Dec 2020 to 28 Jan 2021

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[8] https://www.faa.gov/air_traffic/flight_info/aeronav/digital_products/dtpp/search/results/ 1/14/2021

4.2 Aircraft Operations

The 2020 DNL noise contours reflect all operations that occurred 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 Section 3.2, the Casper data source provided aircraft flight tracks from Noise Lab and identified individual operations as arrivals or departures by operator, aircraft type, and time of day. HMMH supplemented the Casper data with data from the FAA's Aircraft Registration Database where necessary to further identify aircraft types for noise modeling purposes. The pre-processor software assigned 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, 164,493 individual flight tracks recorded by Noise Lab were directly used for the preparation of the 2020 DNL contours. The operations were scaled within each FAA category (e.g., air carrier, air taxi, etc.) to the 170,162 operations recorded by OPSNET.[9] The number of modeled flight tracks and the FAA operations count totals differ for the following primary reasons:

1. The pre-processor filters the flight track data and only uses tracks meeting certain criteria, described below; and
2. Most military operations are not identified in the dataset.

In order to be modeled, each flight track/operation must have a runway assignment, have a valid aircraft type designation, and contain sufficient flight track points to define the aircraft's flight path and altitude profile. To address the military flights, the 802 annual operations from OPSNET were distributed over the air carrier and general aviation group totals with a 37 percent to 63 percent split, respectively. This distribution was determined by evaluating the military fleet aircraft types listed for DAL in 2020 through the FAA Traffic Flow Management System Counts (TFMSC).[10]

The 170,162 annual operations translate to 464.92 operations on the average annual day. Due to the pandemic, the overall operations in 2020 were reduced by almost 27 percent as compared to 2019. The air carrier operations category was reduced the most, by about 32.5 percent for the year. General aviation operations declined by about 29 percent. In contrast, operations in the air taxi category increased by about 4.5 percent from 2019 to 2020.

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[9] FAA Operations Network Data (OPSNET) accessed January 21, 2021

[10] FAA Traffic Flow Management System Count (TFMSC) data accessed February 24, 2021

Table 3. 2020 Modeled Average Daily FAA Category Operations

FAA Operational Category	2020 Operations	
	2020 FAA OPSNET	2020 Average Annual Day Modeled Operations
Air Carrier	99,245	271.98
Air Taxi	32,116	87.75
General Aviation	37,999	105.19
Military	802	0.00
Total	**170,162**	**464.92**

Source: FAA OPSNET, Casper data, HMMH 2021
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 2020 average annual day operations, grouped by FAA aircraft category, engine type, and AEDT aircraft type and listed separately for daytime and nighttime arrivals and departures. The fleet mix is dominated by the Boeing 737-700, with over 38 percent of all operations. The share among all 737 variants is 55 percent. Since every usable flight in 2020 that was recorded in the Casper data is included in the model inputs, several entries in Table 4 appear as "<0.01", meaning only one or two such flights occurred during the year.

The percentage of nighttime operations in 2020 was 7.4 percent overall (6.8 percent of air carrier operations, 11.8 percent of air taxi operations, and 5.3 percent of GA operations). This is a substantial decrease from the nighttime percentage in 2019 of 11.8 percent overall (13.3 percent of air carrier operations, 14.2 percent of air taxi operations, and 6.2 percent of GA operations).

Table 4. 2020 Modeled Average Daily Aircraft Operations

Aircraft Category	Engine Type	AEDT Aircraft Type	Arrivals		Departures		Total
			Day	Night	Day	Night	
Air Carrier	**Jet**	717200	0.05	<0.01	0.05	<0.01	0.12
		737300	0.12	0.03	0.13	0.02	0.29
		737400	83.53	5.15	82.93	5.75	177.37
		737700	35.41	3.63	36.82	2.22	78.08
		737800	0.03	-	0.03	-	0.07
		727EM2	0.06	0.04	0.03	0.07	0.19
		757PW	0.01	0.03	0.04	<0.01	0.08
		767CF6	0.07	<0.01	0.07	<0.01	0.15
		A319-131	0.65	0.20	0.84	<0.01	1.69
		A320-211	<0.01	-	<0.01	<0.01	0.02
		A320-232	0.01	-	<0.01	<0.01	0.03
		A321-232	0.11	-	0.11	-	0.22
		CRJ9-ER	-	<0.01	<0.01	-	<0.01

Aircraft Category	Engine Type	AEDT Aircraft Type	Arrivals		Departures		Total
			Day	Night	Day	Night	
		DC93LW	0.05	<0.01	0.05	<0.01	0.12
		EMB170	<0.01	-	<0.01	-	<0.01
		EMB175	3.56	0.83	4.20	0.19	8.77
		EMB190	<0.01	-	-	<0.01	<0.01
		MD82	-	<0.01	-	<0.01	<0.01
		MD83	<0.01	-	<0.01	-	0.01
Air Carrier Subtotal			**125.92**	**10.07**	**127.70**	**8.29**	**271.98**
Air Taxi	Jet	BD-700-1A10	0.39	<0.01	0.39	0.01	0.80
		BD-700-1A11	0.24	0.02	0.25	<0.01	0.51
		CIT3	0.07	<0.01	0.08	<0.01	0.17
		CL600	5.68	0.26	5.74	0.19	11.87
		CL601	0.38	0.04	0.40	0.02	0.84
		CNA500	0.09	<0.01	0.10	<0.01	0.20
		CNA510	1.82	0.77	1.74	0.85	5.18
		CNA525C	0.53	0.04	0.52	0.05	1.14
		CNA55B	9.66	0.20	9.56	0.30	19.72
		CNA560E	<0.01	-	<0.01	-	0.01
		CNA560U	1.86	0.14	1.90	0.10	4.00
		CNA560XL	1.74	0.34	1.72	0.36	4.16
		CNA680	3.83	0.16	3.81	0.18	7.97
		CNA750	2.11	0.06	2.09	0.09	4.35
		ECLIPSE500	0.05	-	0.05	<0.01	0.10
		EMB145	0.19	<0.01	0.18	0.01	0.39
		EMB14L	0.21	-	0.21	-	0.41
		FAL20	0.01	-	0.01	-	0.03
		FAL900EX	0.21	<0.01	0.21	0.01	0.44
		G650ER	0.15	<0.01	0.15	<0.01	0.32
		GIV	0.87	0.08	0.90	0.04	1.88
		GV	0.20	0.01	0.21	<0.01	0.43
		IA1125	0.78	0.02	0.78	0.02	1.60
		LEAR35	2.95	0.33	2.99	0.29	6.56
		MU3001	0.32	0.04	0.33	0.04	0.73
	Turbine propeller	CNA208	0.60	1.44	1.28	0.76	4.08
		CNA441	0.07	0.06	0.07	0.06	0.28
		DHC6	2.16	0.66	2.14	0.68	5.65
		EMB120	<0.01	-	<0.01	-	0.02
		PA42	0.02	<0.01	0.01	<0.01	0.04
		SD330	-	<0.01	-	<0.01	<0.01
	Piston propeller	BEC58P	0.02	0.71	0.72	<0.01	1.45
		CNA172	0.07	<0.01	0.07	<0.01	0.14
		COMSEP	<0.01	-	<0.01	-	0.01

Aircraft Category	Engine Type	AEDT Aircraft Type	Arrivals		Departures		Total
			Day	Night	Day	Night	
		GASEPV	0.02	-	0.02	-	0.04
		PA30	0.07	-	0.07	<0.01	0.14
	Helicopter	B206L	0.12	0.09	0.13	0.08	0.42
		B407	0.24	0.11	0.22	0.14	0.71
		B429	0.10	0.06	0.10	0.07	0.33
		EC130	0.12	0.11	0.13	0.11	0.47
		R44	<0.01	-	<0.01	-	<0.01
		S76	0.04	0.02	0.04	0.02	0.13
		SA350D	<0.01	-	<0.01	-	0.01
Air Taxi Subtotal			**38.05**	**5.83**	**39.33**	**4.54**	**87.75**
General Aviation	**Jet**	737500	<0.01	-	<0.01	-	<0.01
		737700	<0.01	-	<0.01	-	0.02
		727EM2	<0.01	-	<0.01	-	0.01
		757PW	0.01	0.03	0.04	<0.01	0.09
		BD-700-1A10	0.59	0.07	0.62	0.04	1.31
		BD-700-1A11	0.16	<0.01	0.15	0.01	0.32
		CIT3	1.55	0.08	1.53	0.09	3.25
		CL600	4.23	0.32	4.30	0.25	9.10
		CL601	1.47	0.09	1.51	0.04	3.10
		CNA500	0.17	<0.01	0.16	0.01	0.35
		CNA510	1.13	0.04	1.14	0.03	2.34
		CNA525C	3.45	0.14	3.48	0.12	7.18
		CNA55B	2.05	0.11	2.09	0.07	4.32
		CNA560E	0.08	<0.01	0.09	-	0.17
		CNA560U	1.57	0.07	1.59	0.05	3.28
		CNA560XL	1.92	0.08	1.95	0.05	4.00
		CNA680	1.70	0.06	1.73	0.03	3.52
		CNA750	2.14	0.09	2.17	0.05	4.44
		CRJ9-ER	0.01	-	0.01	-	0.02
		ECLIPSE500	0.36	<0.01	0.37	-	0.73
		EMB145	0.42	0.02	0.42	0.01	0.87
		EMB14L	0.01	-	<0.01	<0.01	0.02
		EMB190	0.03	<0.01	0.02	<0.01	0.06
		FAL20	0.02	<0.01	0.02	<0.01	0.05
		FAL900EX	1.92	0.09	1.87	0.14	4.02
		G650ER	0.64	0.04	0.64	0.03	1.36
		GIIB	0.03	<0.01	0.04	-	0.07
		GIV	1.76	0.15	1.81	0.10	3.83
		GV	2.05	0.12	2.00	0.18	4.35
		IA1125	2.26	0.08	2.27	0.08	4.70
		LEAR35	4.11	0.24	4.16	0.20	8.70

Aircraft Category	Engine Type	AEDT Aircraft Type	Arrivals		Departures		Total
			Day	Night	Day	Night	
		MD81	<0.01	-	-	<0.01	<0.01
		MU3001	0.86	0.02	0.85	0.03	1.75
	Turbine propeller	CNA208	2.18	0.09	2.07	0.20	4.54
		CNA441	0.59	0.02	0.59	0.01	1.21
		DHC6	4.69	0.17	4.50	0.37	9.72
		HS748A	0.16	<0.01	0.16	0.01	0.34
		PA42	0.01	-	0.01	-	0.02
	Piston propeller	BEC58P	0.90	0.02	0.90	0.02	1.84
		CNA172	0.31	0.04	0.29	0.06	0.70
		CNA182	0.21	0.01	0.21	0.02	0.46
		CNA206	0.13	-	0.12	<0.01	0.25
		COMSEP	1.12	0.02	1.11	0.04	2.28
		GASEPF	0.11	0.01	0.11	0.02	0.25
		GASEPV	1.38	0.07	1.38	0.08	2.91
		PA28	0.08	0.03	0.09	0.03	0.23
		PA30	0.05	0.01	0.05	0.01	0.13
		PA31	0.15	-	0.15	-	0.30
	Helicopter	A109	<0.01	-	<0.01	-	0.01
		B206L	0.04	0.01	0.04	0.01	0.09
		B407	0.47	0.05	0.44	0.08	1.03
		B429	0.11	0.04	0.11	0.04	0.30
		EC130	0.09	0.19	0.13	0.15	0.56
		H500D	0.03	-	0.03	<0.01	0.06
		R22	0.02	-	0.02	-	0.04
		R44	0.02	-	0.02	-	0.04
		S76	0.19	0.02	0.19	0.02	0.42
		SA341G	<0.01	-	<0.01	-	0.01
		SA350D	0.01	-	0.01	-	0.02
		SA365N	<0.01	-	<0.01	-	0.01
General Aviation Subtotal			**49.82**	**2.78**	**49.78**	**2.81**	**105.19**
Grand Total			**213.79**	**18.68**	**216.81**	**15.65**	**464.92**

Source: Casper data, HMMH analysis 2021

Notes: Military Ops are Scaled into AC, AT, and GA depending on weight class
Values in the table may not add exactly to the given totals due to rounding.

4.2.1 Aircraft Sound Exposure Levels

The noise exposure due to a single noise event (such as an aircraft overflight) can be quantified by its Sound Exposure Level (SEL), which accounts for both the sound level and duration of the event. Noise "footprint" graphics for many of the specific aircraft types operating at DAL have been generated by using AEDT to combine the SEL of a single arrival and a single departure. The resultant SEL contours can be compared to show their relative influence of the various aircraft types to the overall noise level around the airport. Section A.1.4 in Appendix A provides a more detailed explanation of the SEL metric.

Figure 2 through Figure 4 display SEL contours[11] for the most common aircraft types in use in 2020 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 several jet aircraft types. For example, comparing the departure portions of the SEL contours for two of the most common general aviation jets, we see that the newer Citation 550 Bravo affects a much smaller area than the older Lear 35.

The SEL figures indicate the percent of operations represented by each aircraft type in the DAL 2020 fleet mix. The overall influence of an aircraft type on the DNL contours is a combination of its relative loudness (as illustrated by its SEL footprint) and its share of operations.

[11] The SEL contours shown in the figures were generated by modeling arrival and departure operations in with AEDT version 3c. The SEL contour figures contained in the 2019/2018 reports included some mis-scaled noise footprints.

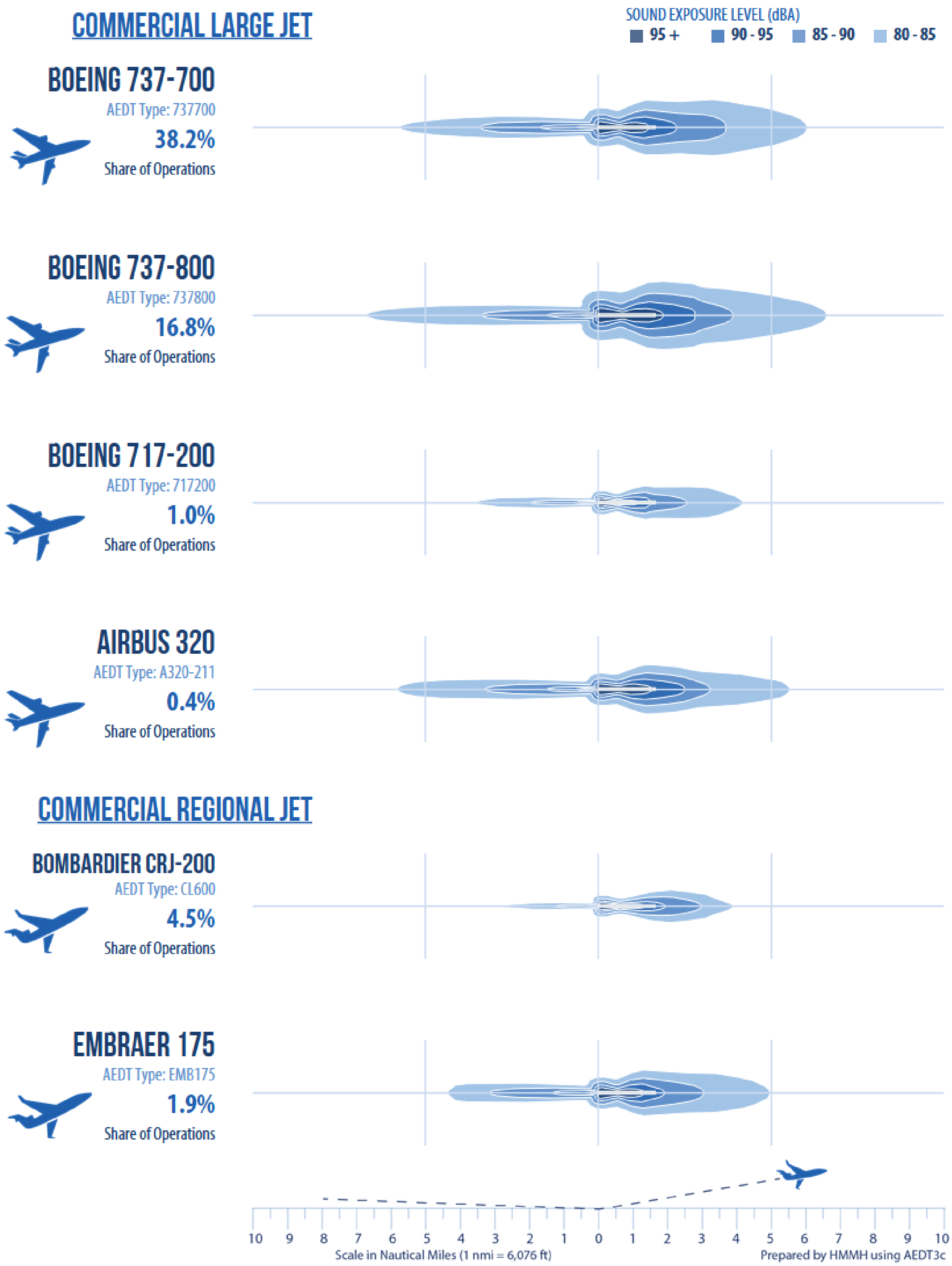

Figure 2. SEL Contours - Commercial Aircraft

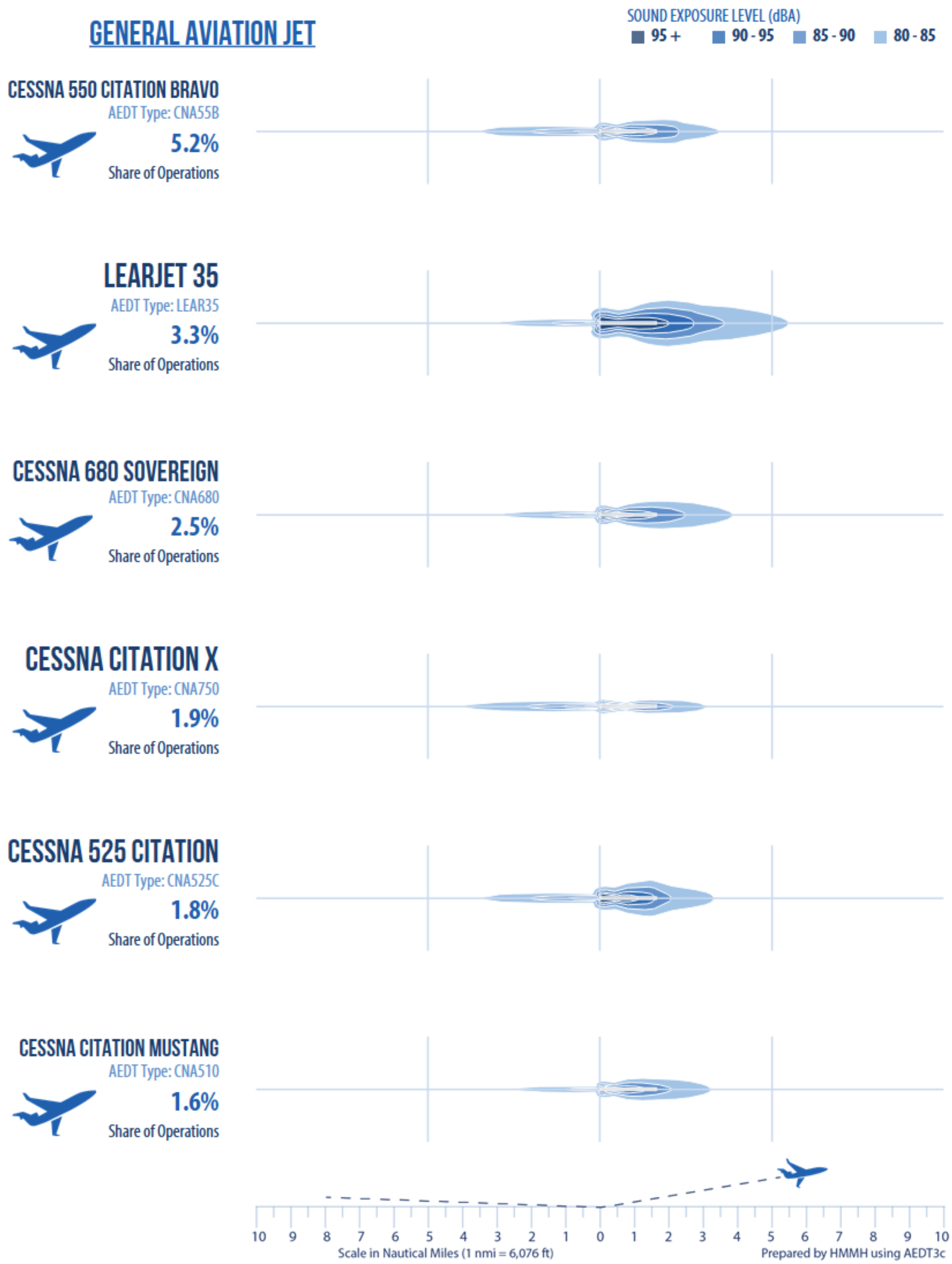

Figure 3. SEL Contours - General Aviation Jets

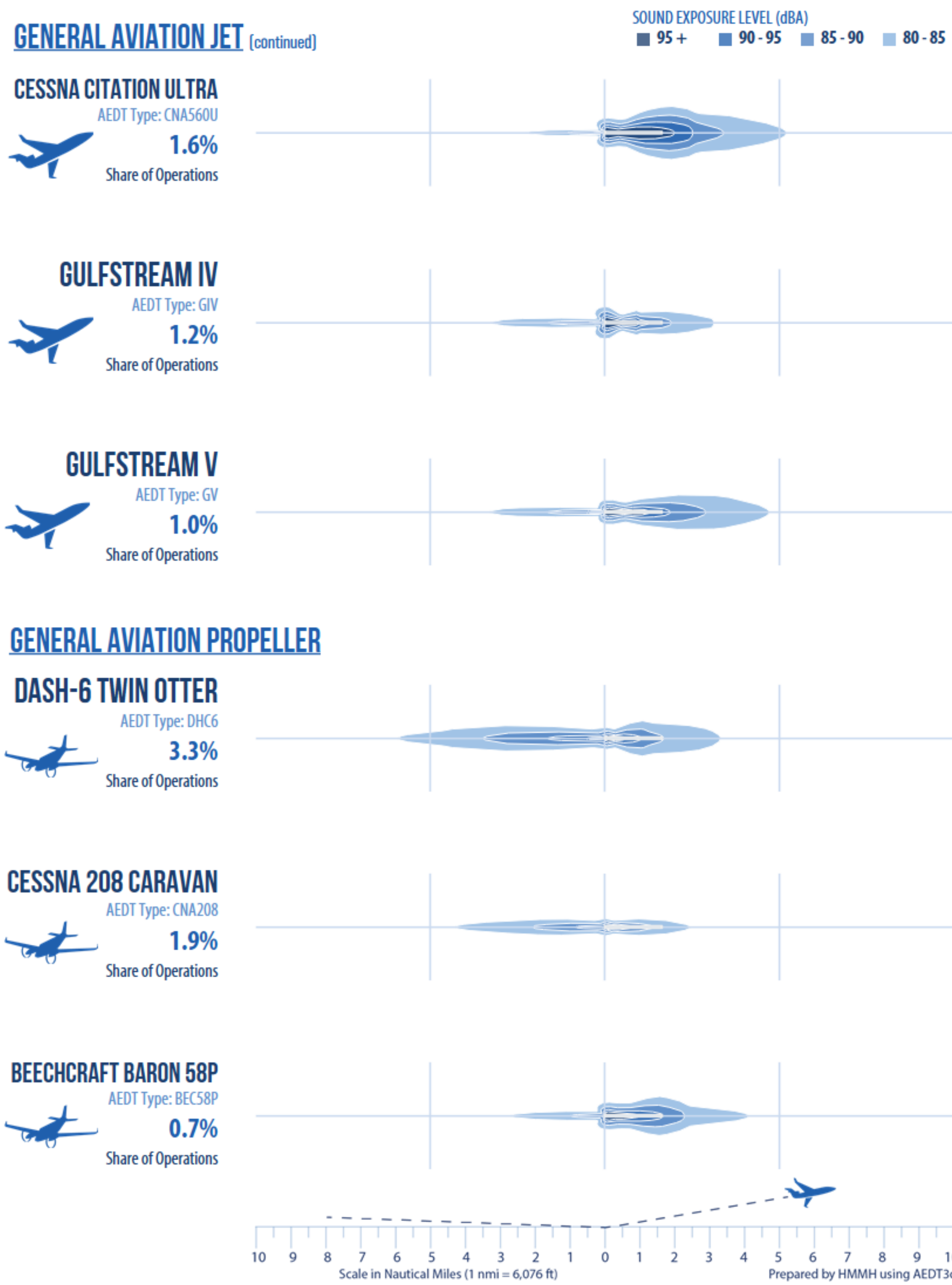

Figure 4. SEL Contours - General Aviation Jets (continued) and Propeller Aircraft

4.3 Runway Utilization

The primary factor affecting runway use at airports is weather, in particular the wind direction and wind speed. Additional factors that may affect runway use include the position of the facility or ramp relative to the runways or operational proficiency training for military units.

Runway 13R/31L is 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 2020. The data show that the operations during this time predominantly use the preferred runways, with about 67 percent of jet operations on either Runway 13R or 31L. Runway 13R handled 41 percent of the arrivals and 42 percent of the departures, while Runway 31L handled 26 percent of the arrivals and 23 percent of the departures.

Table 5. 2020 Jet Operations by Runway Between 9 p.m. and 6 a.m.

Runway	Arrivals	Departures	Total
13L	15.1%	5.7%	20.9%
31R	7.5%	4.9%	12.4%
13R	28.4%	13.2%	41.6%
31L	17.9%	7.2%	25.1%
Total	**69.0%**	**31.0%**	**100.0%**
Source: Casper data, HMMH 2021 analysis			

Table 6 summarizes the runway utilization for the average annual day conditions modeled for 2020. Separate utilization percentages for each aircraft category and for all aircraft are given and in general show about 65 percent of operations in south flow (use of Runways 13L and 13R) and 35 percent in north flow (use of Runways 31R and 31L) in 2020. The share of south flow operations is down from 70 percent in 2019 and 68 percent in 2018. The share of north flow operations is up from 30 percent in 2019 and 32 percent in 2018.

In south flow operations during 2020, air carrier operations favored Runway 13R over Runway 13L. In north flow, air carrier operations favored Runway 31L over Runway 31R. Use of the voluntary noise abatement runway at night (10pm to 7am) resulted in about three time as many nighttime air carrier operations on Runway 13R/31L than on Runway 13L/31R. In general, the 2020 split of air carrier operations between the two parallel runways during either flow direction was a less pronounced favoring of Runway 13R/31L than was seen 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 2020. However, Runway 13L/31R was closed from July 15 to September 24th, 2019, which affects the comparisons between the two years.

Table 6. 2020 Modeled Runway Use

Source: Casper data, HMMH 2020 analysis

Aircraft Category	Flow Direction	Runway	Arrivals		Departures	
			Day	Night	Day	Night
All Aircraft Operations	South flow	13L	34.88%	21.73%	31.04%	24.16%
		13R	29.87%	41.87%	33.56%	38.62%
	North flow	31R	17.10%	11.50%	18.75%	17.16%
		31L	18.15%	24.90%	16.65%	20.06%
	Total		**100.00%**	**100.00%**	**100.00%**	**100.00%**
Air Carrier	South flow	13L	26.59%	15.46%	20.69%	16.06%
		13R	38.45%	46.10%	44.23%	45.65%
	North flow	31R	11.77%	7.22%	14.28%	15.18%
		31L	23.19%	31.21%	20.80%	23.11%
	Total		**100.00%**	**100.00%**	**100.00%**	**100.00%**
Air Taxi	South flow	13L	49.48%	22.32%	47.59%	28.58%
		13R	15.39%	44.40%	16.65%	36.36%
	North flow	31R	25.25%	14.13%	25.72%	16.16%
		31L	9.88%	19.16%	10.03%	18.89%
	Total		**100.00%**	**100.00%**	**100.00%**	**100.00%**
General Aviation	South flow	13L	45.10%	46.06%	45.00%	43.62%
		13R	18.82%	18.98%	19.05%	19.12%
	North flow	31R	24.59%	23.23%	24.91%	25.34%
		31L	11.49%	11.74%	11.04%	11.92%
	Total		**100.00%**	**100.00%**	**100.00%**	**100.00%**

Figure 5 through Figure 8 display the data in Table 6 graphically by aircraft category. This helps to visualize the usage of each category on the runways.

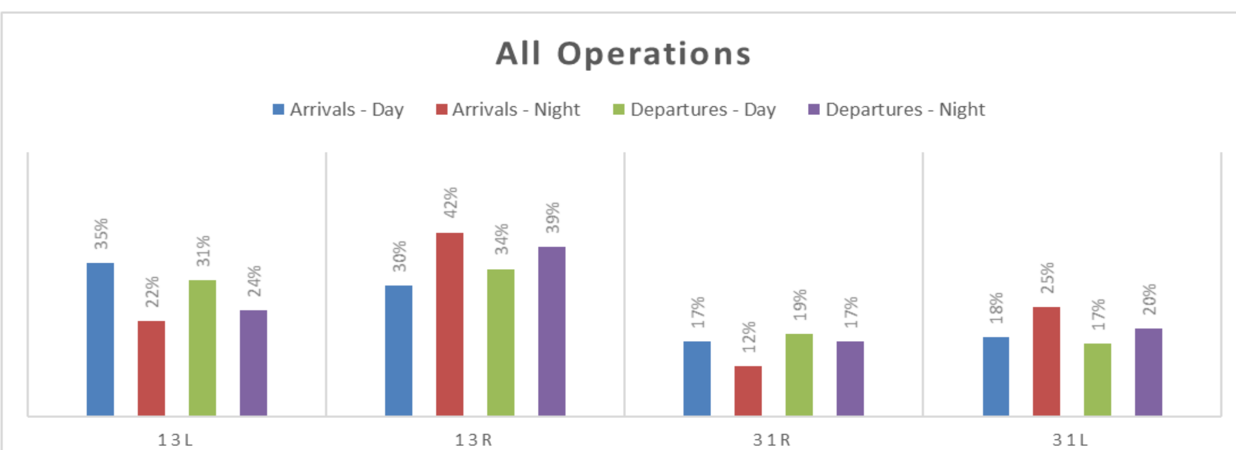

Figure 5. Runway Use for All Aircraft

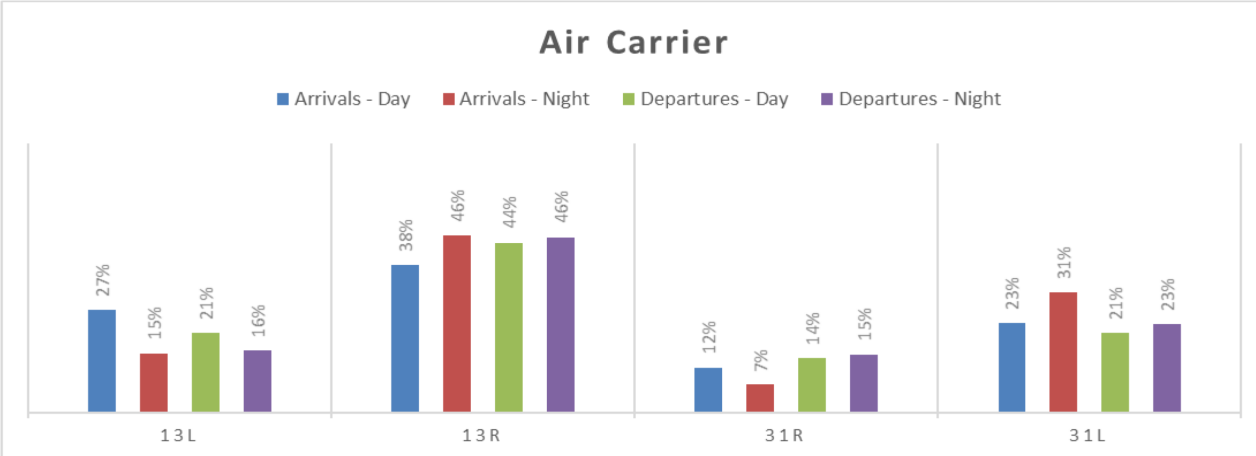

Figure 6. Runway Use for Air Carrier Aircraft

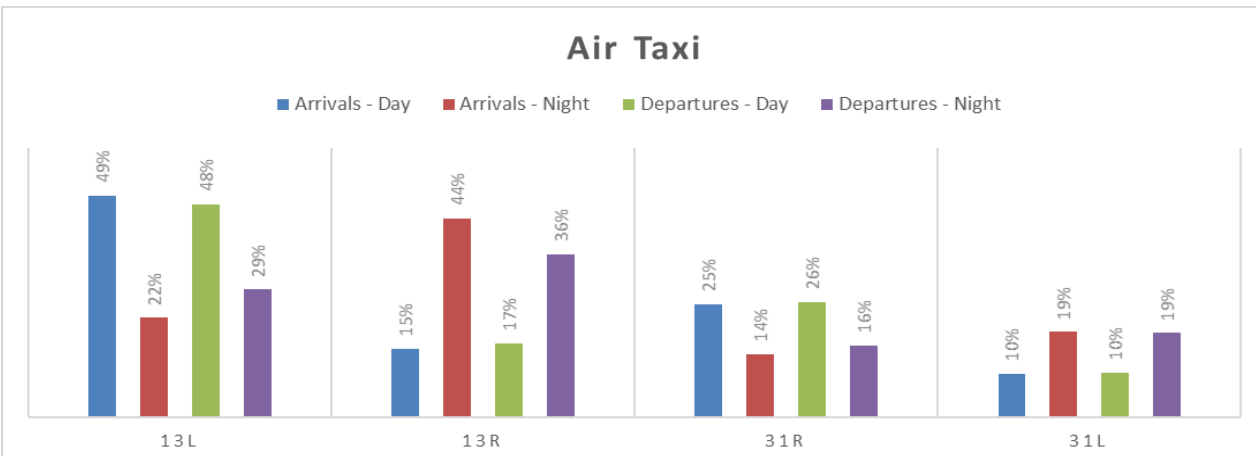

Figure 7. Runway Use for Air Taxi Aircraft

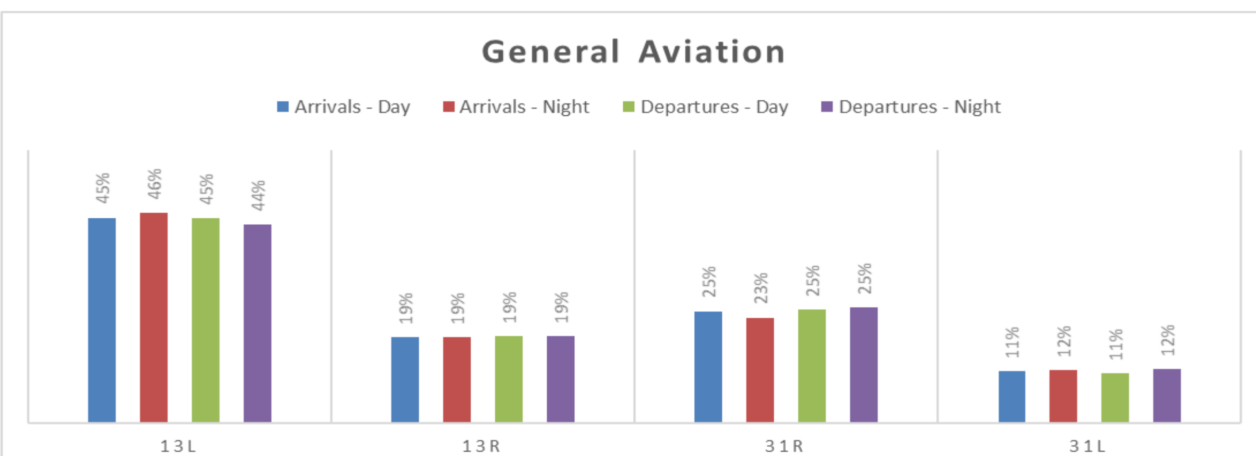

Figure 8. Runway Use for General Aviation Aircraft

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.

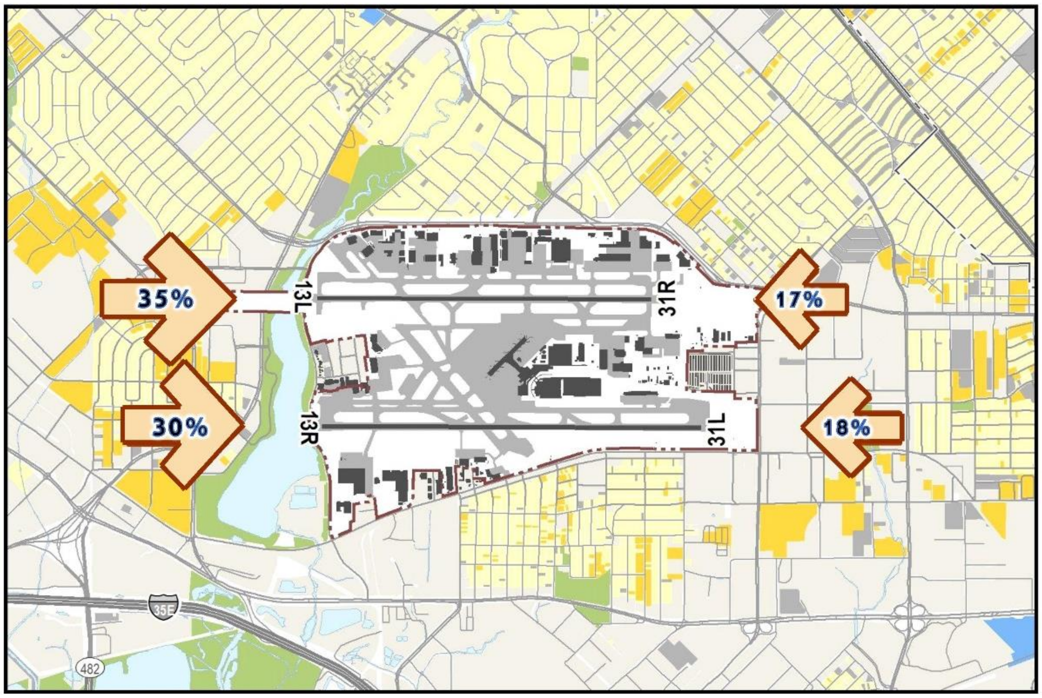

Figure 9. Runway Use: Daytime Arrivals

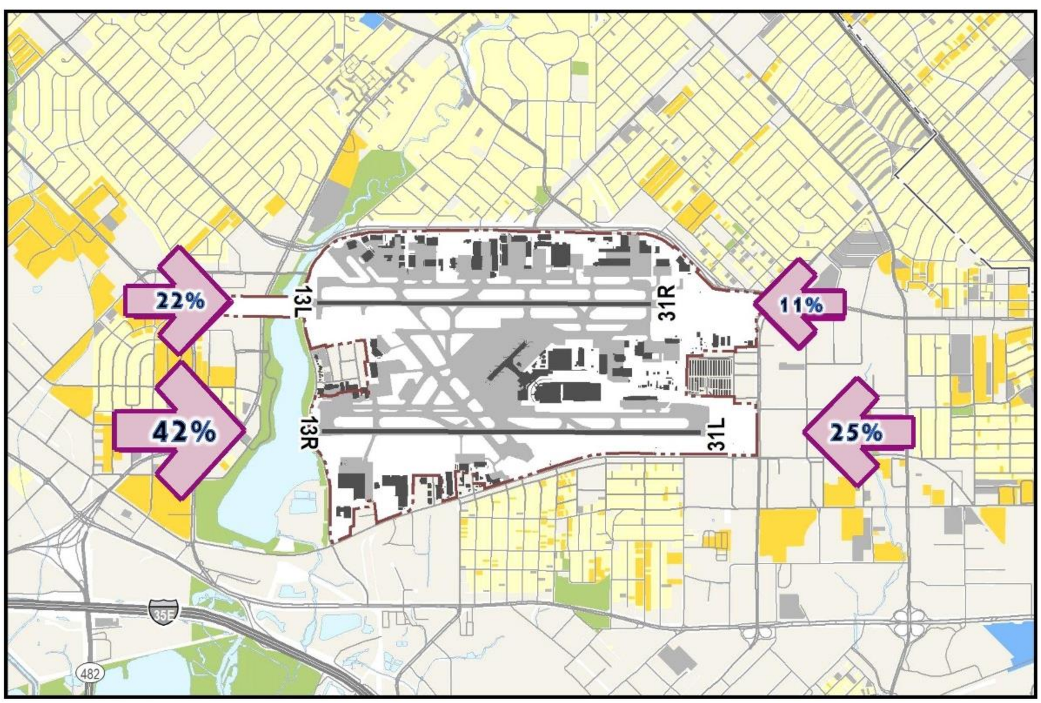

Figure 10. Runway Use: Nighttime Arrivals

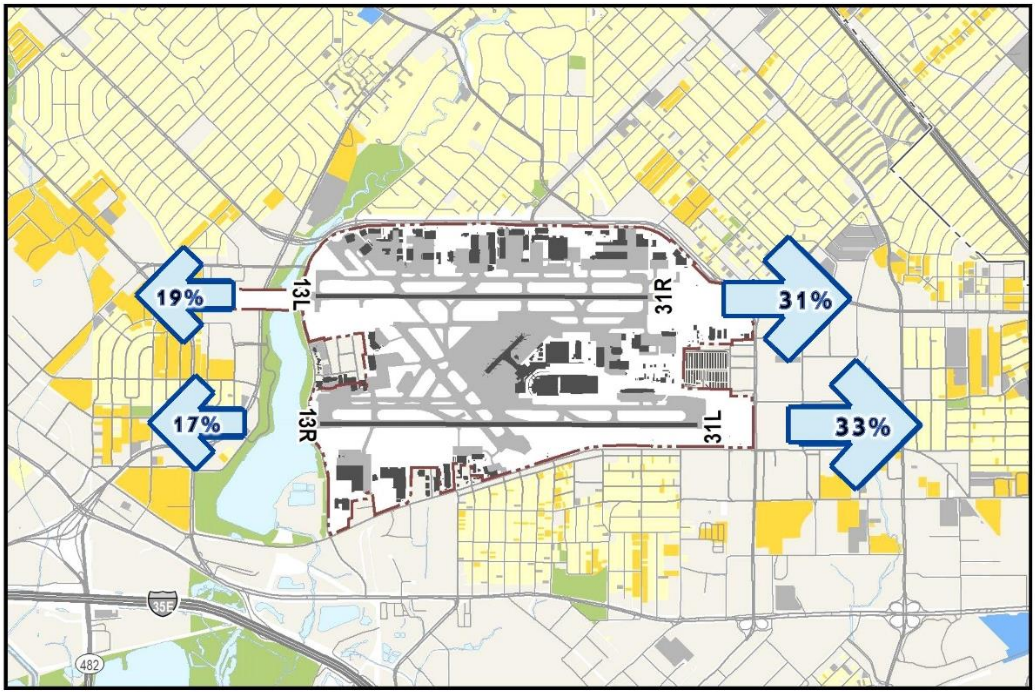

Figure 11. Runway Use: Daytime Departures

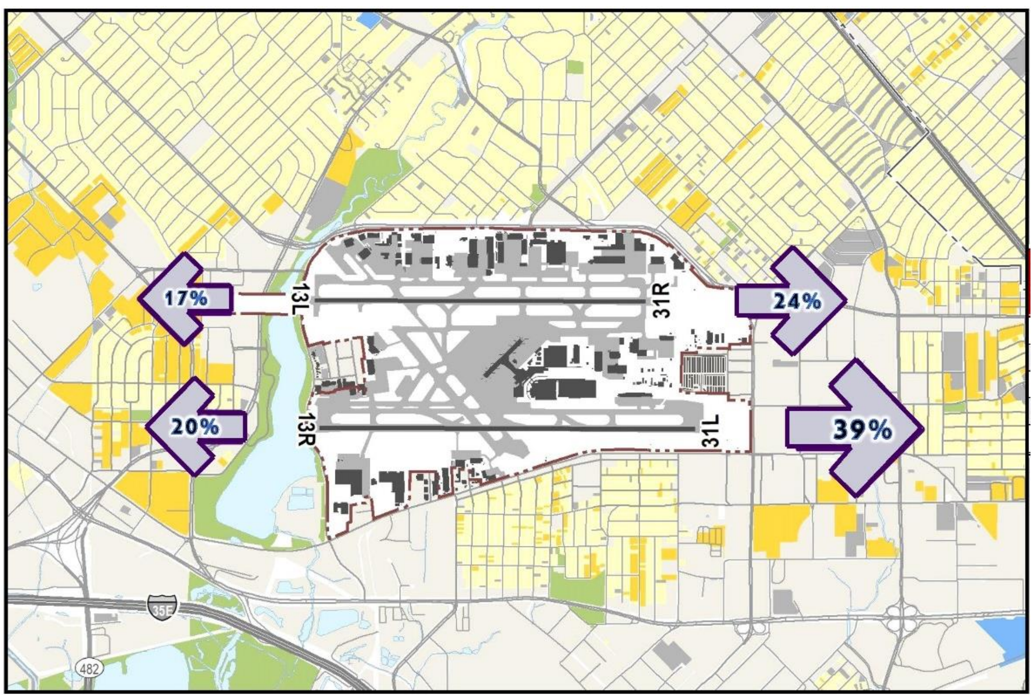

Figure 12. Runway Use: Nighttime Departures

4.4 Flight Track Geometry

As described in Section 3.2, HMMH used a pre-processor to develop AEDT tracks from radar flight data, thereby modeling every available radar flight record as an AEDT flight track.

A total of 164,493 individual flight tracks were modeled for 2020. Figure 13 and Figure 14 provide samples of the radar-based AEDT model tracks. Figure 13 presents a sample of 5,784 north flow model tracks and Figure 14 presents a sample of 10,525 south flow model tracks, representing approximately a ten percent sampling of all modeled flight tracks.

The flight tracks in these figures are predominantly in line with the runways. As documented 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 essentially centered on the extended runway centerlines. A comparison of the arrivals (orange flight tracks) in Figure 13 and Figure 14 shows that the arrivals to Runways 31L and 31R (north flow) tend to align with the runway centerline further from the airport than do the arrivals to Runways 13L and 13R (south flow). South flow arrivals cannot align with the runway farther from the airport due to airspace conflict with Dallas – Fort Worth Airport to the west; generally, by the time they are about 1.5 nautical miles from the runway end, all aircraft are on the extended centerline.

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 2020, as shown in Figure 14.

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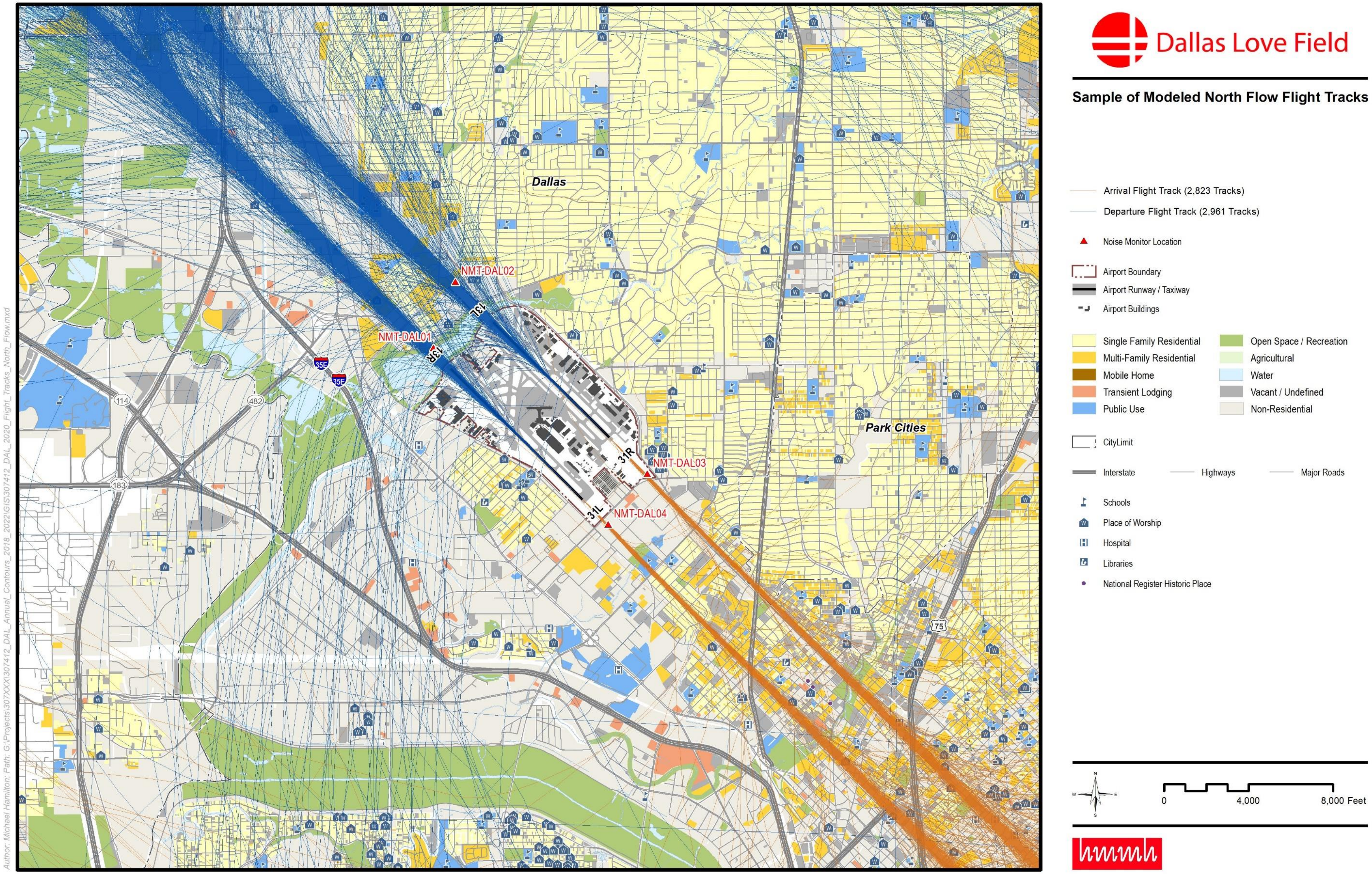

Figure 13. Sample of Modeled North Flow Tracks

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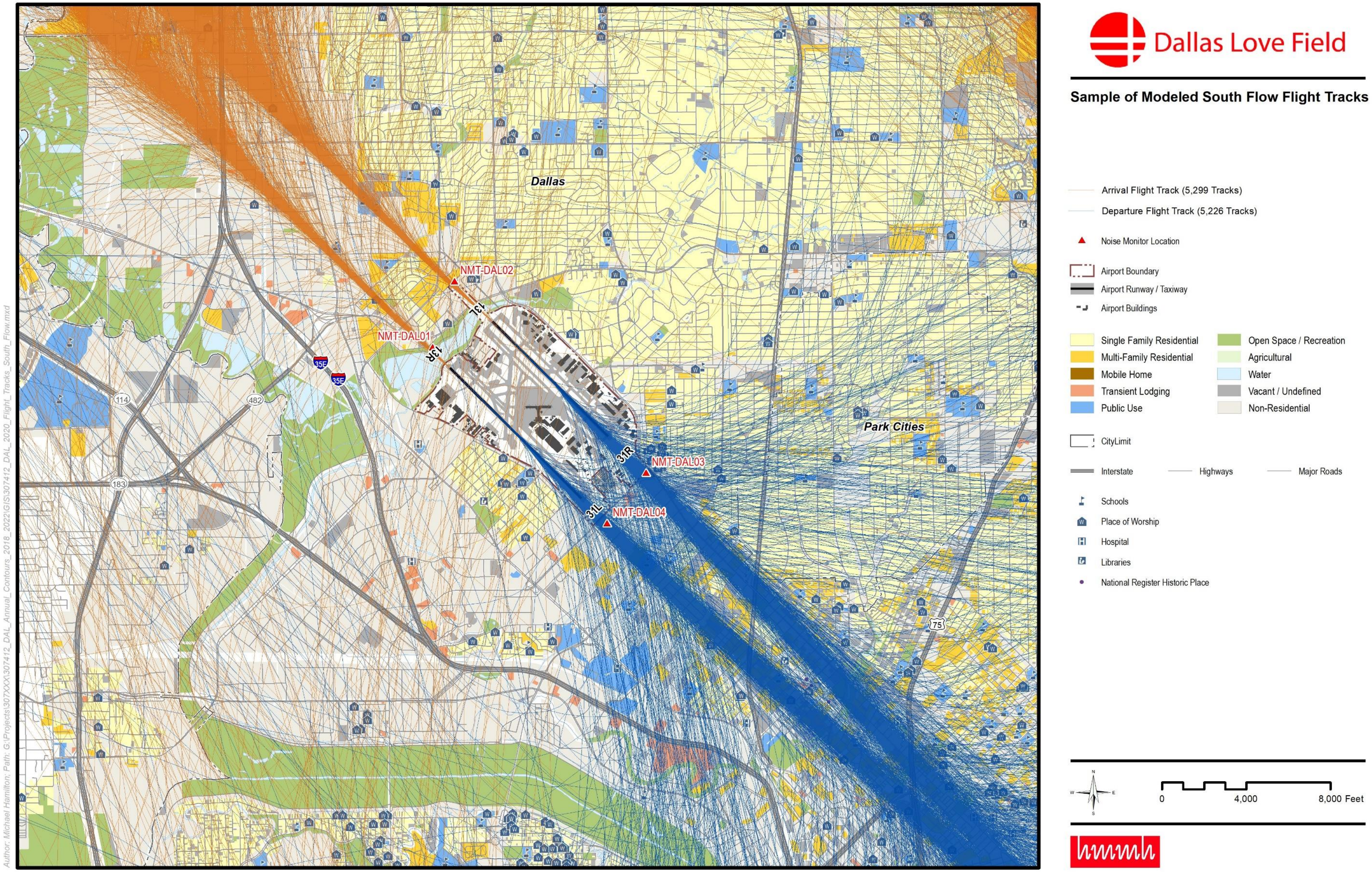

Figure 14. Sample of Modeled South Flow Tracks

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4.5 Departure Stage Length

AEDT uses an aircraft's weight to determine takeoff performance criteria such as thrust and climb rate, which in turn affect the sound exposure level at locations on the ground. A substantial component of aircraft weight is fuel load. Fuel load of a departing aircraft varies primarily with the distance to its destination, which is referred to in AEDT as the stage length; in noise analyses, stage length serves as a proxy for aircraft weight. The AEDT noise and performance database includes a set of departure profiles for each aircraft type, covering each stage length category that the aircraft is likely to fly.

In preparing the AEDT study, the preprocessor assigns a stage length to each departing flight based on the destination airport on the flight plan. The program calculates the great-circle distance between the two airports and finds the stage length category corresponding to this distance, which 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 (as determined by the distance calculation) is not available, the maximum stage length profile for that aircraft is selected. The preprocessor also checks the length of the takeoff roll in the given profile against the length of the runway being used; if the profile's takeoff roll is longer, then the maximum stage length available without overrunning the runway is selected.

Table 7 presents the ten categories for departure stage length used in AEDT and the respective number of departures modeled for 2020. 62 percent of departures from DAL were stage length 1 operations in 2020. This includes destinations such as El Paso and Saint Louis. Stage length 2 departures would include Las Vegas and Orlando, while stage length 3 would reach most coastal cities including Seattle and Boston. Fewer than 1 percent of departures were stage length 4 or higher.

Table 7. Modeled 2020 Departure Stage Length Operations

Source: FAA AEDT 3b Technical Manual, HMMH

Stage Length Number	Trip Length (Nmi)	2020 Daily Departure Operations		Percentage of Operations
		Day	Night	
1	0 - 500	134.74	10.15	62.33%
2	500 - 1,000	58.44	3.24	26.53%
3	1,000 - 1,500	23.19	2.00	10.84%
4	1,500 - 2,500	0.32	0.25	0.25%
5	2,500 - 3,500	0.04	0.00	0.02%
6	3,500 - 4,500	0.06	0.00	0.03%
7	4,500 - 5,500	0.02	0.00	0.01%
8	5,500 - 6,500	0.00	0.00	0.00%
9	6,500 – 11,000	0.00	0.00	0.00%
M	Max range at MTOW	0.00	0.00	0.00%
Total		**216.81**	**15.65**	100.00%

Note: MTOW = Maximum takeoff weight
The data contained in this table in the 2019/2018 reports inadvertently included some arrival operations.

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. The AEDT 3c database, containing updated meteorological averages for the most recently available 10-year period (2009 through 2018), holds the following values for DAL:

- Temperature: 68.2° Fahrenheit
- Dew point: 51.98° Fahrenheit
- Sea level pressure: 1015.95 millibars
- Pressure: 998.65 millibars
- Relative humidity: 56.11 percent.
- Average wind speed: 8.25 knots.

FAA guidance requires that these weather data be used in noise modeling; specific FAA approval are required if the parameters are adjusted.

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. Terrain data obtained from the United States Geological Survey (USGS) National Map Viewer[12] are used with the terrain feature of the AEDT in generating annual noise contours for DAL.

[12] GridFloat USGS data in 1/3 arc second (about 33 feet) increments

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 in 2019. The airfield layout, taxiways and buildings on the figure were updated for 2020.

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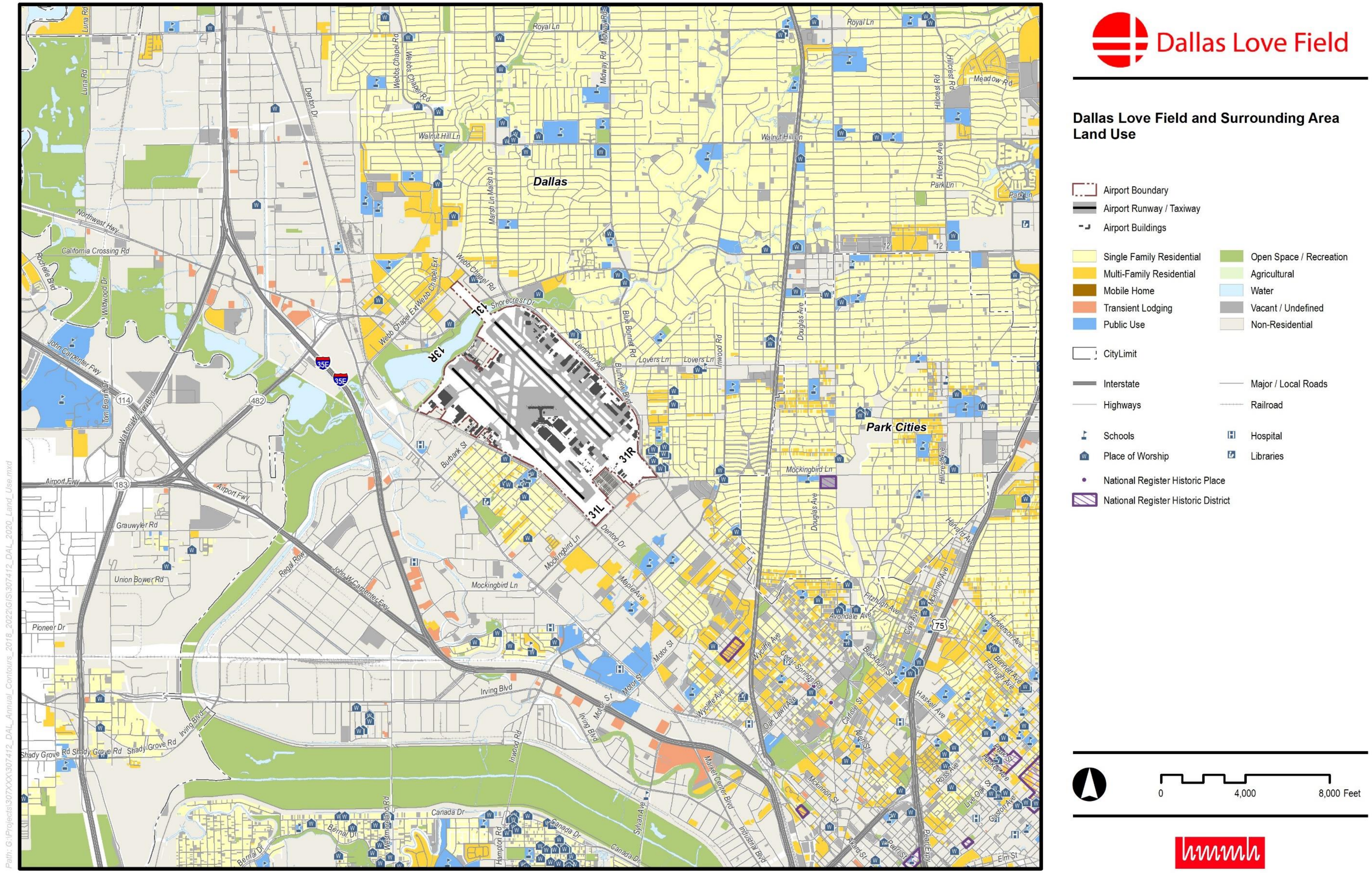

Figure 15. Dallas Love Field and Surrounding Area Land Use

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5.2 DNL Noise Contours

5.2.1 2020 Noise Contours

Figure 16 presents the 2020 DNL contours, in five-decibel intervals from 60 dB to 75 dB, overlaid on the land use base map provided in Section 5.1. The size and shape of the DNL contours are functions of the number of operations, the runway usage, the percentage of nighttime operations, and, to some degree, the aircraft frame/engine combinations in the fleet. Arrival operations influence DNL contour shapes in a different manner than departure operations do. The contour lobes 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, which FAA uses as a criterion for assessing residential land use compatibility with noise, extends from the airfield as follows:

- To the northwest, the DNL 65 dB contour lobe that aligns with Runway 13L/31R extends past Webb Chapel Road but does not quite reach Lombardy Lane. The lobe that aligns with Runway 13R/31L reaches as far as Storey Lane, near its intersection with Overlake Drive, inside of the Lombardy Lane/Denton Drive intersection.
- To the southeast, the DNL 65 dB contour lobe that aligns with Runway 13L/31R extends along Lemmon Avenue to just past Manor Way, about 500 yards before Inwood Road. The lobe that aligns with Runway 13R/31L reaches about 300 yards past Inwood Road, to Hedgerow Drive.
- On the southwest side of the airport, along the sideline of Runway 13R/31L, the DNL 65 dB contour encompasses a few blocks of a residential neighborhood towards the southern end of the runway. The sideline noise contour crosses Denton Drive between Gilford Street and W Mockingbird Lane.
- On the northeast side of the airport, along the sideline of Runway 13L/31R, the DNL 65 dB contour remains within airport property.

There are residential areas within the DNL 65 dB contour at the northern end Runway 13L/31R, at both ends of Runway 13R/31L, and along the sideline of Runway 13R/31L.

There are two schools and two places of worship within the DNL 65 dB contour:

- Thomas J. Rusk Middle School,
- Obadiah Knight Elementary School,
- Iglesia Pentecostal Roca De Poder, and
- North Temple Baptist Church.

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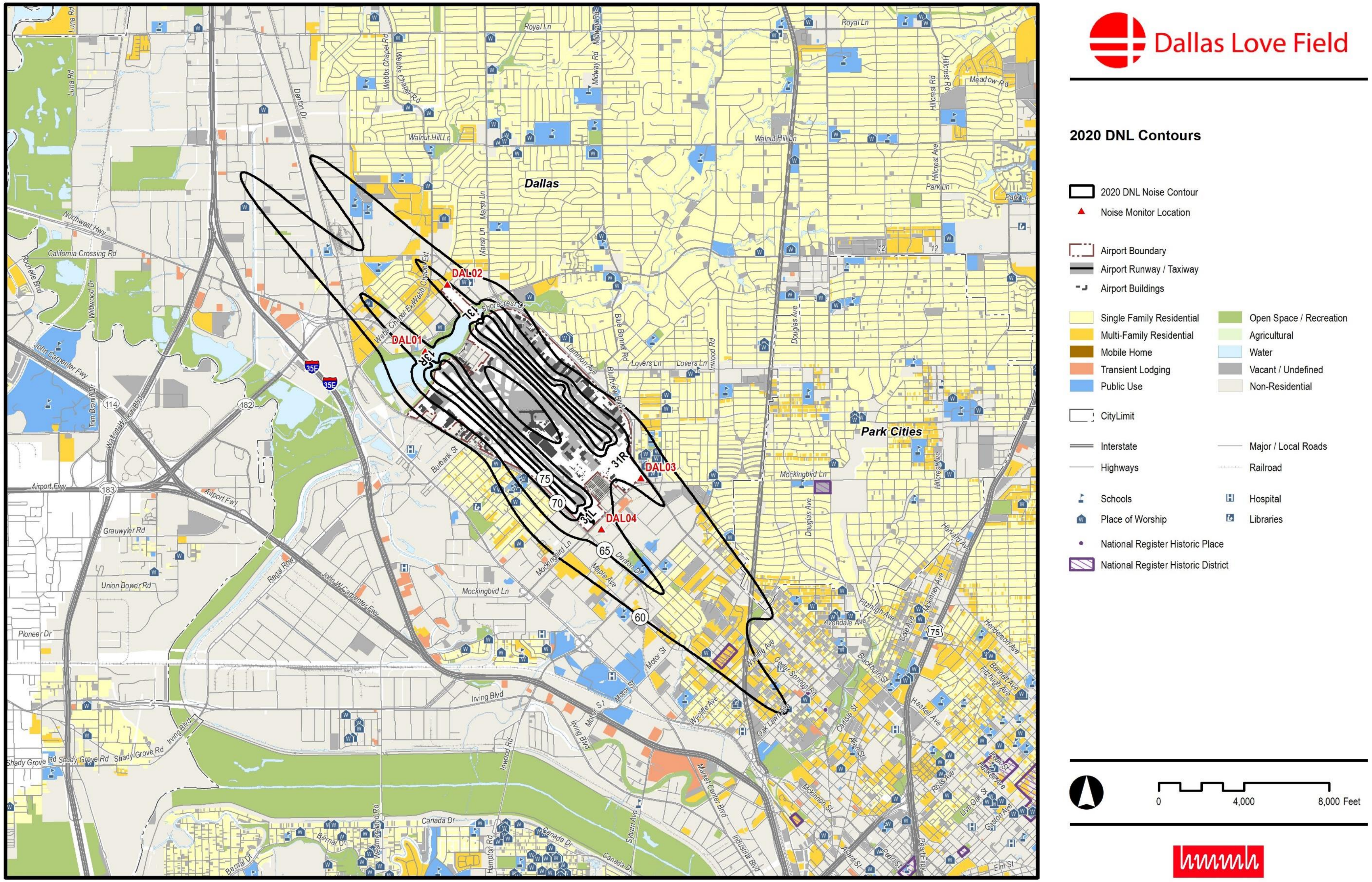

Figure 16. 2020 DNL Contours

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5.2.2 Comparison of the 2020 and 2019 Noise Contours

Figure 17 shows a comparison of the 2020 DNL contours to the 2019 DNL contours for the DNL 60 dB through DNL 75 dB range. The contours have changed dramatically from 2019 to 2020 due to the effects of the global pandemic on air travel.

The main factors affecting contour size are changes in the number and type of aircraft operations, particularly in nighttime operations. As noted in section 4.2, total airport operations were reduced by almost 27 percent from 2019 to 2020. Additionally, the percentage of nighttime operations in 2020 was 7.4 percent overall (6.8 percent of air carrier operations, 11.8 percent of air taxi operations, and 5.3 percent of GA operations). This is a substantial decrease from the nighttime percentage in 2019 of 11.8 percent overall (13.3 percent of air carrier operations, 14.2 percent of air taxi operations, and 6.2 percent of GA operations).

Looking more closely at changes in modeled daily operations by specific aircraft types, although the number of operations decreased for almost every type, a few types showed significant changes in their proportion of operations. These aircraft are listed in Table 8, along with the modeled average daily operations for 2019 and 2020, the percentage of total airport operations, and the difference in percentage between the two years. In general, from 2019 to 2020, the proportion of operations by Boeing 737-700, Embraer 175, and Boeing 737-800 Max aircraft decreased, while the proportion by Bombardier CRJ-200, Cessna 550 Citation Bravo, and Boeing 737-800 increased.

Table 8. Aircraft Types with Significant Changes in Proportion of Operations Between 2019 and 2020

Source: HMMH

Aircraft Type	AEDT Aircraft Type	Aircraft Category	2019 Modeled Daily Operations	2019 Percent of Total	2020 Modeled Daily Operations	2020 Percent of Total	Difference in Percent of Total
Boeing 737-700	737700	AC, GA	282.9	44.5%	177.4	38.2%	-6.4%
Embraer 175	EMB175	AC	24.2	3.8%	8.8	1.9%	-1.9%
Boeing 737-800 Max	737MAX8	AC	3.2	0.5%	--	--	-0.5%
Bombardier CRJ-200	CL600	AT, GA	23.0	3.6%	21.0	4.5%	0.9%
Cessna 550 Citation Bravo	CNA55B	AT, GA	15.9	2.5%	24.0	5.2%	2.7%
Boeing 737-800	737800	AC	81.4	12.8%	78.1	16.8%	4.0%
Note: There were no operations by Boeing 737-800 Max aircraft at DAL in 2020							

The main factors affecting contour shape are changes in the runway utilization, particularly at night. For the unusual year 2020, the effects of runway usage shifts are overshadowed by the reductions in operations. However, the DNL contours show a greater reduction in size along the extended centerline of Runway 13R/31L than they do along Runway 13L/31R; this is a result of the runway use changes from 2019 to 2020, described in section 4.3.

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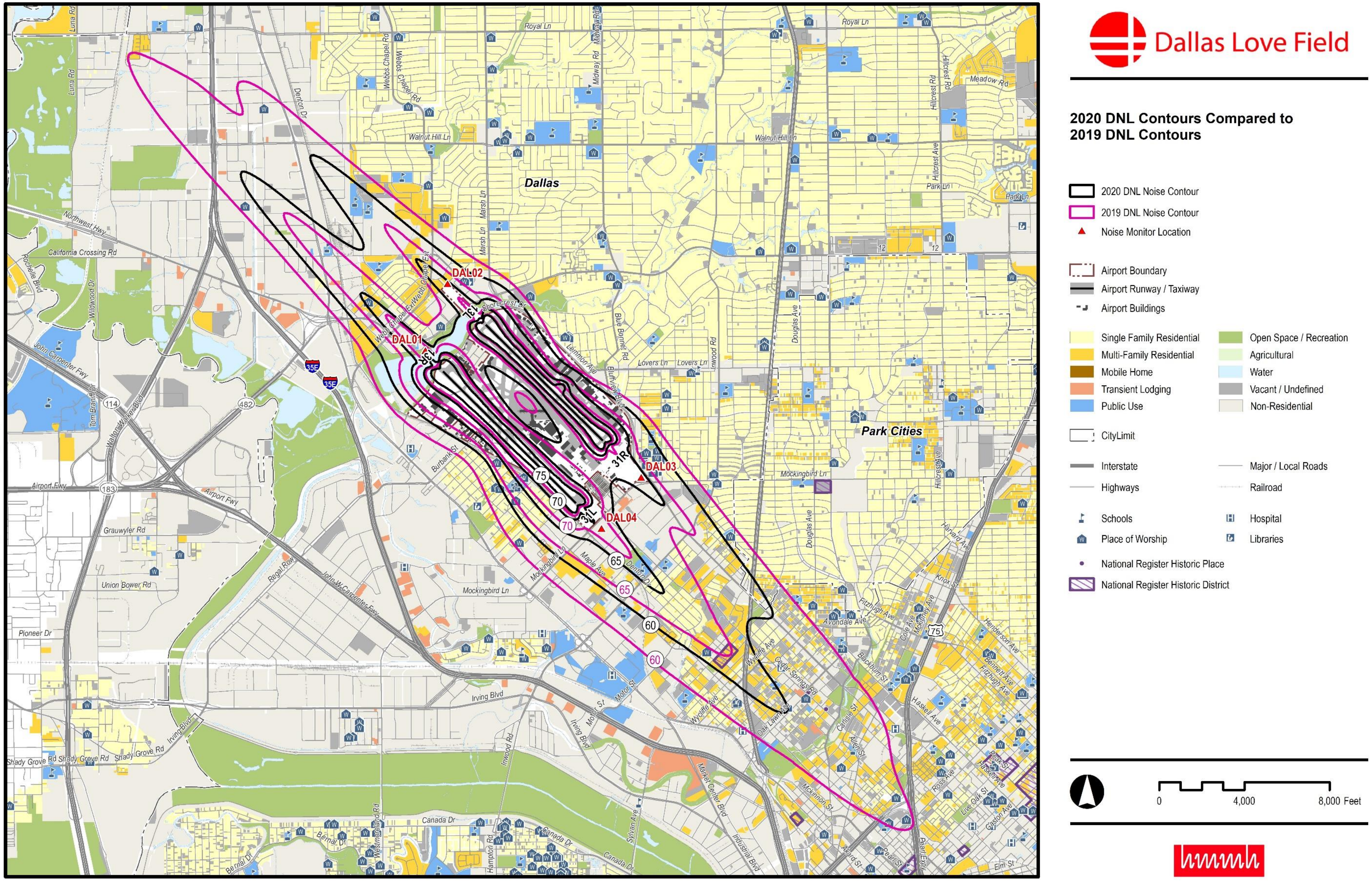

Figure 17. 2020 DNL Contours Compared to 2019 DNL Contours

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5.2.3 Comparison of the 2020 and 2006 Noise Contours

Figure 18 shows a comparison of the 2020 DNL contours to the reference 2006[13] DNL contours for the same decibel range. In 2020, the overall aircraft fleet is quieter than the fleet in the 2006 prediction. The 2006 DNL contours included some Stage 2 jets which are absent from the fleet in 2020 due to modernization. Also, the number of operations modeled for 2020 was much smaller than for 2006, due to the pandemic (170,162 vs. 248,010). The extents of the 2020 DNL 65 contour are completely contained within the 2006 DNL 65 contour.

5.3 Noise Monitor Location Results

In 2018, DAL began installation of a new Noise and Operations Monitoring System (NOMS) at the airport. The new Noise Lab system includes four permanent noise monitors, three of which were installed in late 2018, with the fourth installed in March of 2020. The locations of the monitors are shown on Figure 16 through Figure 18.

The Noise Lab system matches noise events to aircraft operations and supplies the aircraft-only noise event data. For each of the noise monitor sites, DNL levels were computed for each day of the year. Table 9 reports the measured DNL averaged over the full year[14] for each site, compared to the AEDT-computed value. For 2020, all four of the sites Table 9. have modeled values between DNL 65 dB and 70 dB. The measured and modeled values show good agreement, with the modeled results slightly higher than the average daily measured DNL. The site with the largest difference was not operational for two months of the year.

Table 9. Comparison of Measured vs. Modeled DNL at Noise Monitor Locations

Source: HMMH, DAL Noise Office

Noise Monitor Location			Day-Night Average Sound Level (DNL) dBA			Periods Offline
Site	Latitude	Longitude	Modeled (AEDT)	Measured	difference	
DAL01	32.853960	-96.866067	68.7	65.4	3.3	1/1 – 3/10/2020
DAL02	32.862532	-96.862499	66.3	65.7	0.6	--
DAL03	32.837125	-96.833364	66.6	64.8	1.8	5/17 – 6/10/2020, 7/29 – 8/5/2020
DAL04	32.830612	-96.839535	69.3	68.3	1.0	10/1 – 10/3/2020

[13] The reference contour was prepared in 2006 to represent forecasted 2020 conditions.

[14] For site DAL01, which became operational on March 10, 2020, the annual average for measured DNL consists of 296 days. Site DAL02 has data for all 366 days of the year, site DAL03 has 333 days, and site DAL04 has 363 days.

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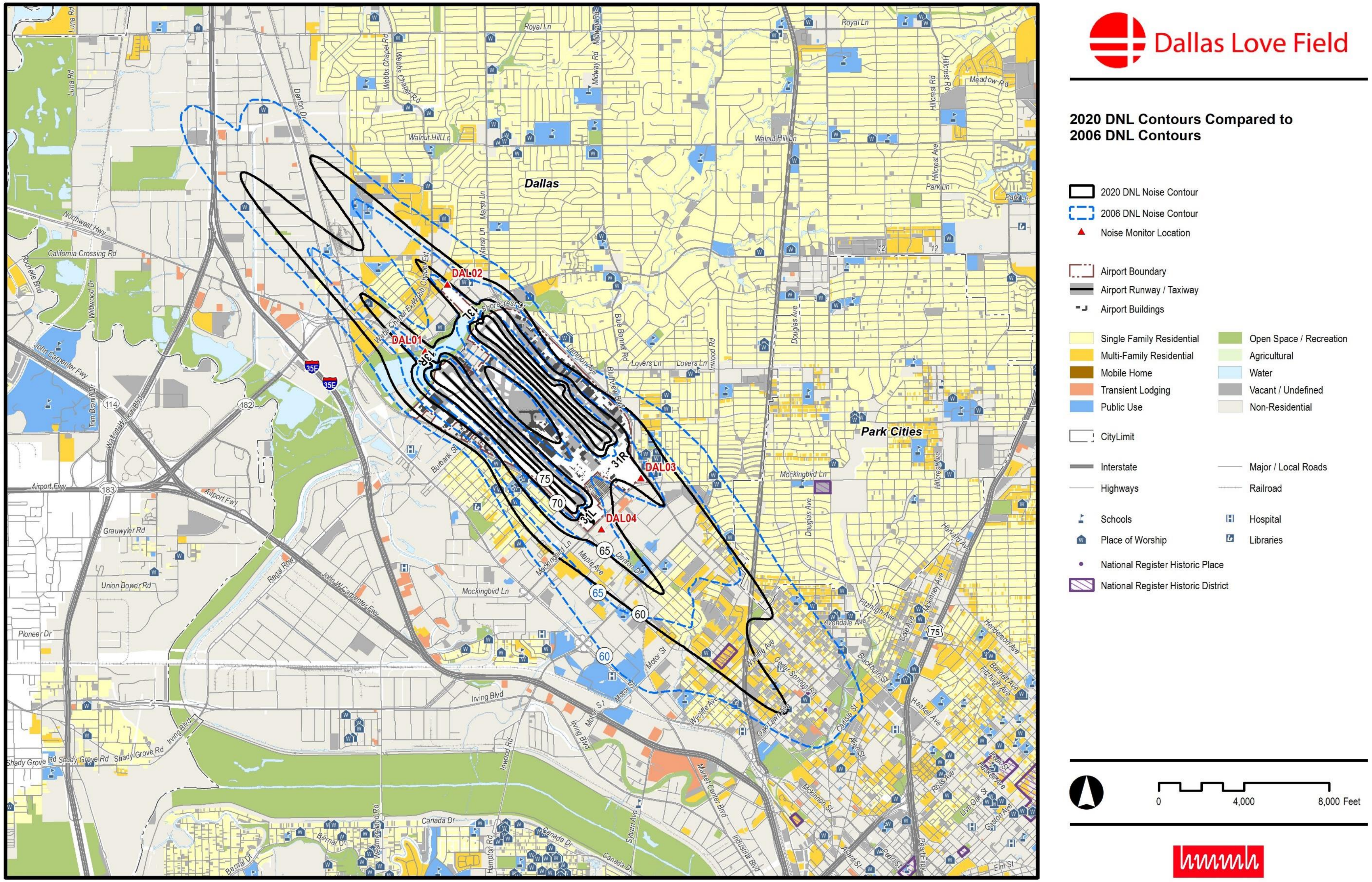

Figure 18. 2020 DNL Contours Compared to 2006 DNL Contours

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5.4 Exposed Population and Land Area

As described in Section 5.2.2, from 2019 to 2020, the overall change in contour size was substantial due to the effect of the global pandemic on passenger air traffic. The area exposed to DNL 65 dB or greater decreased 44 percent, from 3.95 square miles in 2019 to 2.21 square miles in 2020.

The estimated population, based on 2010 US Census Data, within each DNL 5 dB contour interval is summarized in Table 11. Between 2019 and 2020, the population experiencing noise levels greater than 65 dB decreased by almost 80 percent from 11,639 to 2,356. The reduction is attributable to the dramatic decline in aircraft operations resulting from the global pandemic.

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	2019	2020
60-65	5.71	6.75	4.00
>65	**4.62**	**3.95**	**2.21**
65-70	2.68	2.65	1.41
70-75	1.08	0.76	0.43
>75	0.86	0.54	0.37
Notes: Airport property is included in total (1.93 sq. mi.) In the 2013 – 2017 Annual Reports, the 2006 area within the DNL 75 contour was erroneously listed as 0.43 sq. mi. (instead of 0.86 sq. mi.) and the total area within DNL 65 was erroneously listed as 4.19 sq. mi. (instead of 4.62 sq. mi.)			

Table 11. Estimated Population within Noise Exposure Area

Source: HMMH 2020, U.S. Census 2010

DNL Noise Level (dBA)	Estimated Number of People Exposed to Given Noise Exposure Level (2010 US Census Data)		
	2006	2019	2020
60-65	42,603	51,904	30,818
>65	**16,798**	**11,639**	**2,356**
65-70	15,858	11,332	2,350
70-75	936	307	6
>75	4	0	0

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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. To aid in explaining, we 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 appendix 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}

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 ($P_{reference}$)[15].

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

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

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.[16]

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 ten dB increase in SPL to be about a doubling of loudness,[17] 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.

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

[16] 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).

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

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.

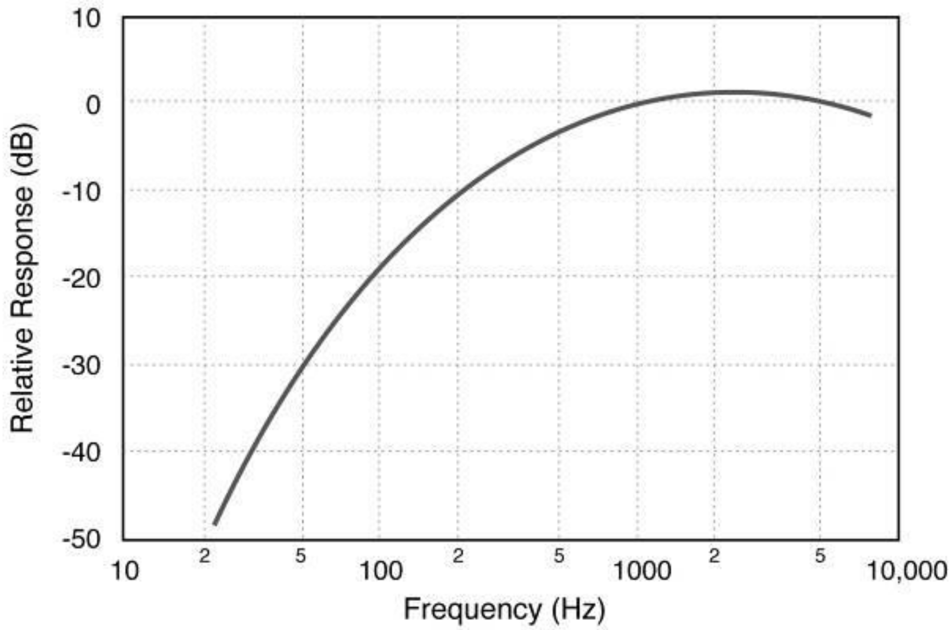

Figure 19. A-Weighting Frequency-Response

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.

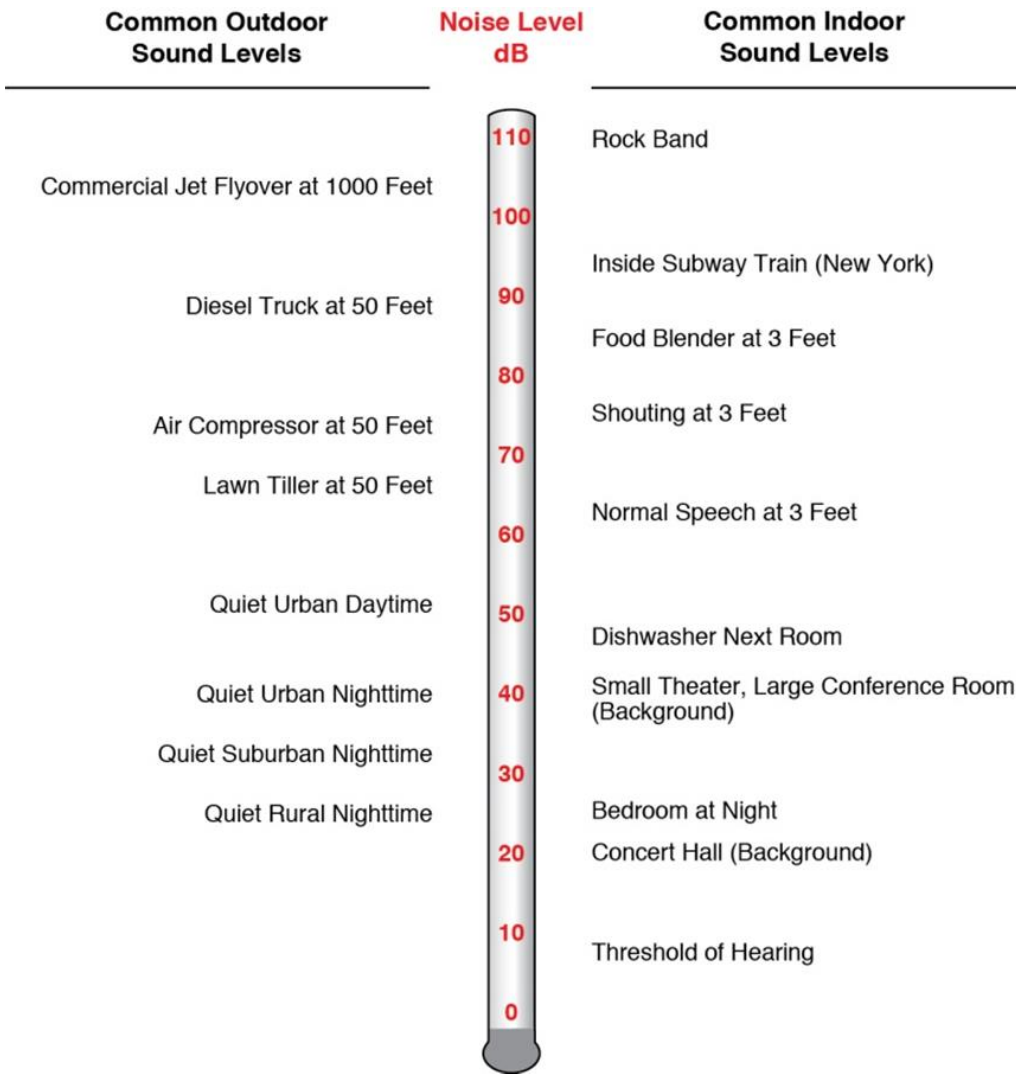

Figure 20. A-Weighted Sound Levels for Common Sounds

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.

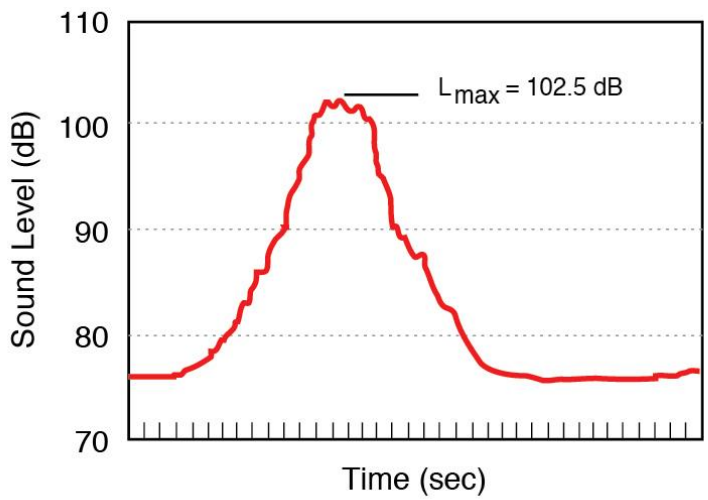

Figure 21. Variation in A-Weighted Sound Level over Time and Maximum Noise Level

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, abbreviated 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 matches 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}.

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.

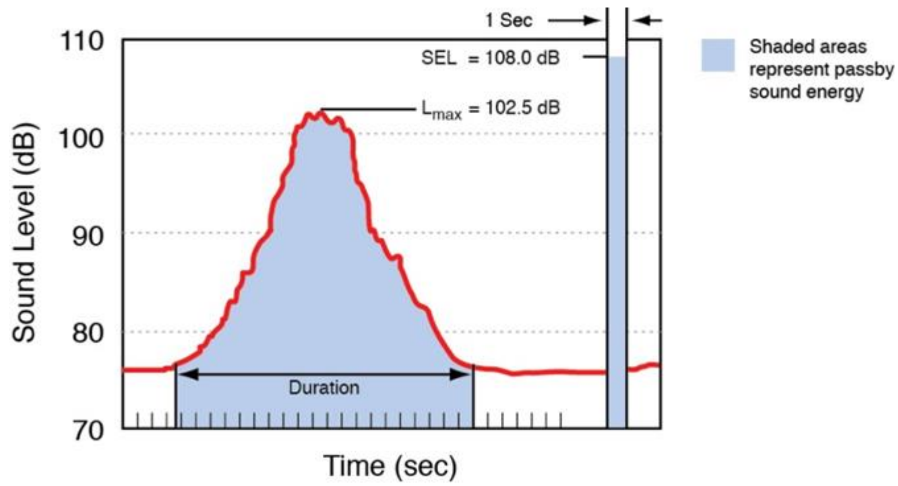

Figure 22. Graphical Depiction of Sound Exposure Level

Source: HMMH

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.

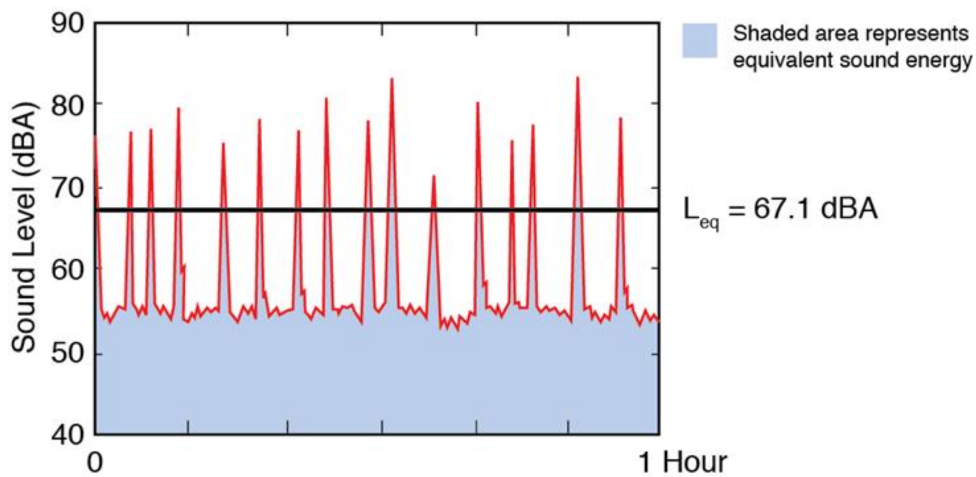

Figure 23. Example of a One Hour Equivalent Sound Level

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.[18]

- 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 report stated: "There are no new descriptors or metrics of sufficient scientific standing to substitute for the present DNL cumulative noise exposure metric."

In 2015, the FAA began a multi-year effort to update the scientific evidence on the relationship between aircraft noise exposure and its effects on communities around airports.[19] This was the most comprehensive study using a single noise survey ever undertaken in the United States, polling communities surrounding 20 airports nationwide. The FAA Reauthorization Act of 2018 under Section 188 and 173, required FAA to complete the evaluation of alternative metrics to the DNL standard within one year. The Section 188 and 173 Report to Congress was delivered on April 14, 2020[20] and concluded that while no single noise metric can cover all situations, DNL provides the most comprehensive way to consider the range of factors influencing exposure to aircraft noise. In addition, use of supplemental metrics is both encouraged and supported to further disclose and aid in the public understanding of community noise impacts. The full study supporting these reports was released in January 2021. If changes are warranted in the use of DNL, which DNL level to assess or the use of supplemental metrics, FAA will propose revised policy and related guidance and regulations, subject to interagency coordination, as well as public review and comment.

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[18] "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.

[19] Federal Aviation Administration. Press Release – FAA To Re-Evaluate Method for Measuring Effects of Aircraft Noise. https://www.faa.gov/news/press_releases/news_story.cfm?newsId=18774

[20] Federal Aviation Administration. Report to Congress on an evaluation of alternative noise metrics. https://www.faa.gov/about/plans_reports/congress/media/Day-Night_Average_Sound_Levels_COMPLETED_report_w_letters.pdf

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 weighting 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 weighting 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.

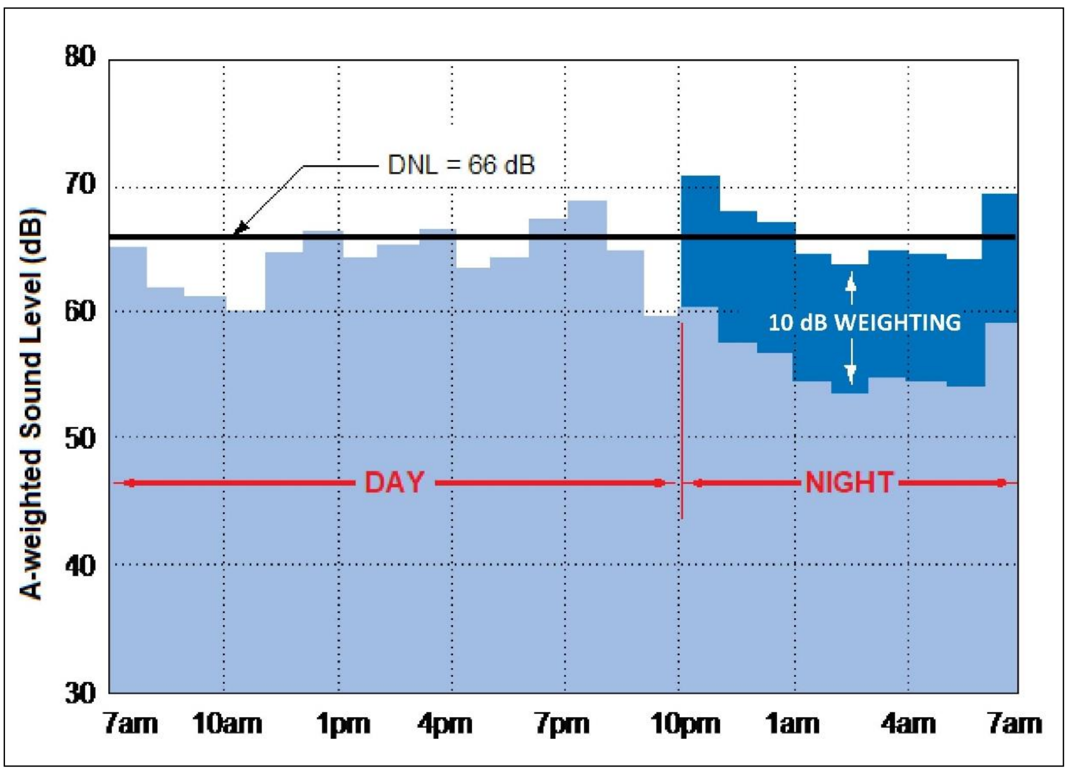


Figure 24. Example of a Day-Night Average Sound Level Calculation
Source: HMMH

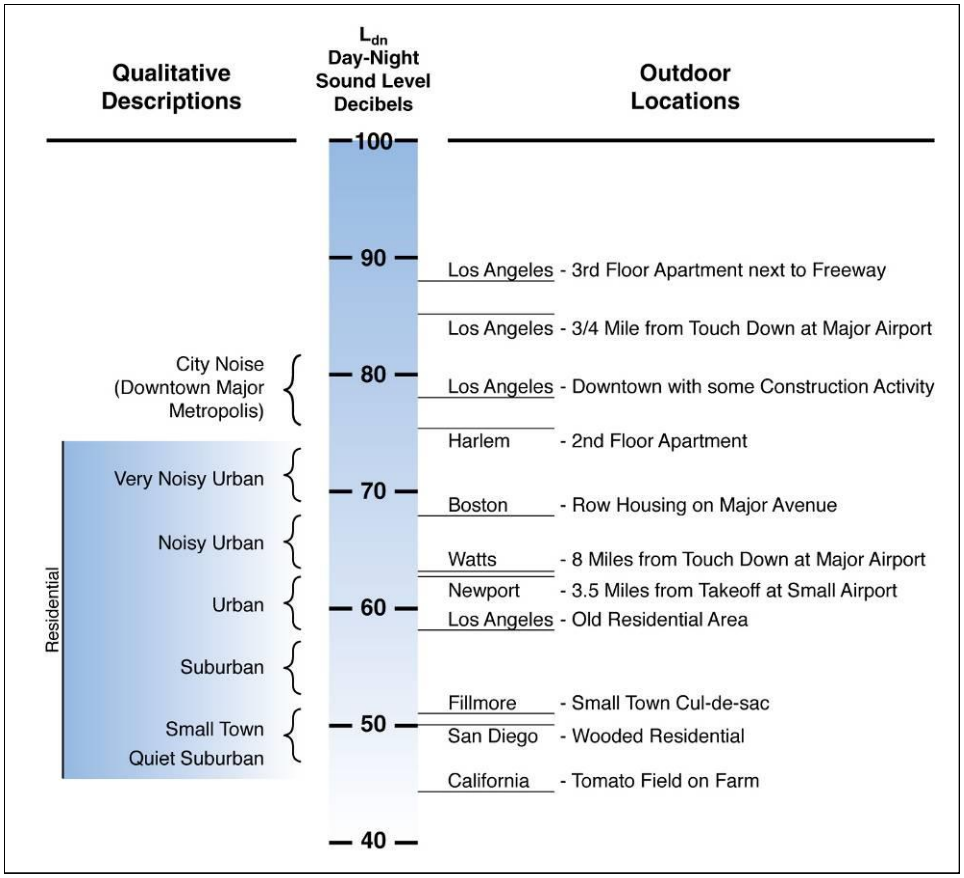


Figure 25. Examples of Measured Day-Night Average Sound Levels, DNL

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.

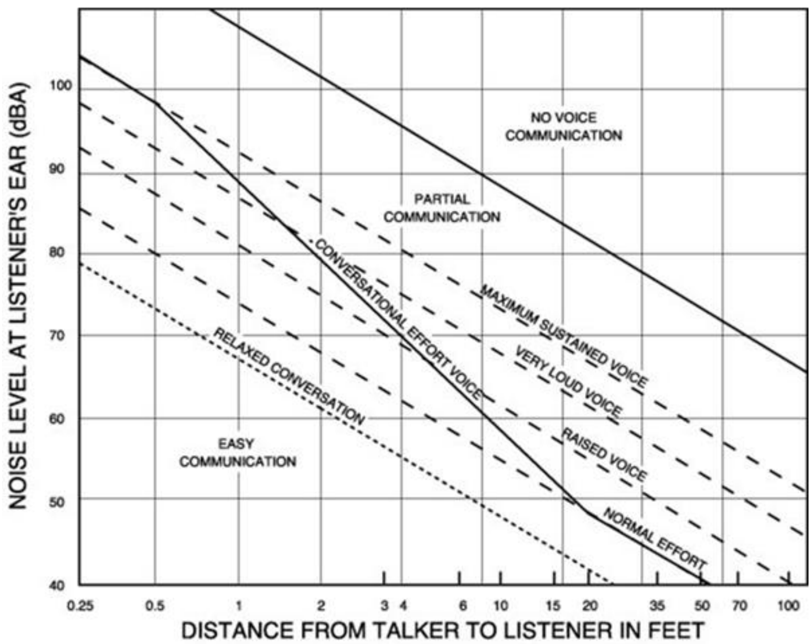


Figure 26. Outdoor Speech Intelligibility

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.

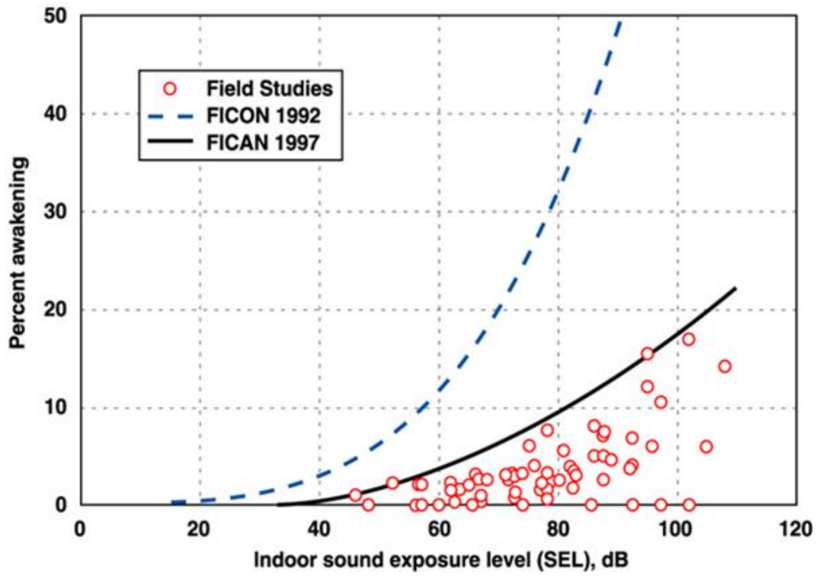


Figure 27. Sleep Interference

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

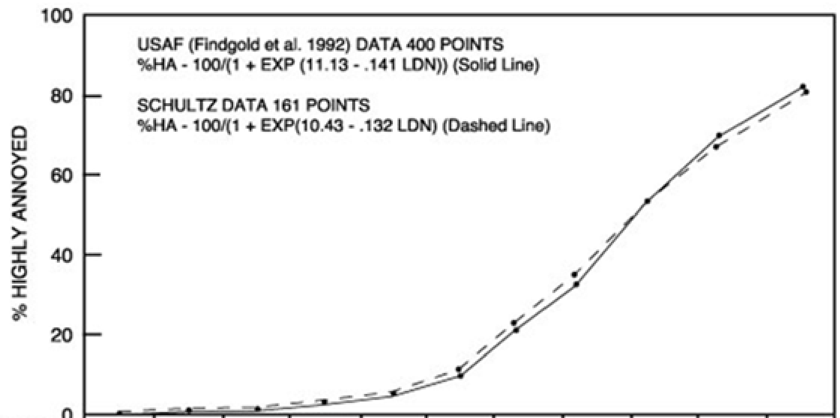
Figure 27 uses indoor SEL as the measure of noise exposure; current research supports the use of this metric in assessing sleep disruption. An indoor SEL of 80 dBA results in a maximum of 10 percent awakening. Assuming the typical windows-open interior-to-exterior noise level reduction of approximately 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.[21]

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.

As noted above in the discussion of DNL, the full report on the FAA's recent research, polling communities surrounding 20 airports nationwide, was released in January 2021. At the time of this reporting, that research is in the public review and comment period.

[21] The awakening data presented in Figure 27 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. 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.

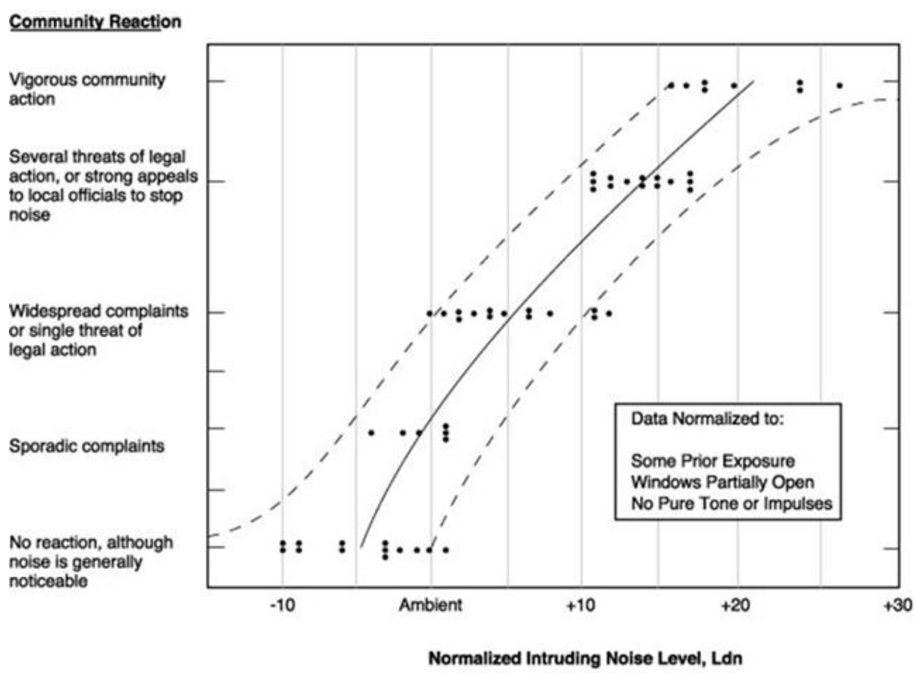


Figure 29. Community Reaction as a Function of Outdoor DNL

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.

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.[22]

A.3.1.2 Influence of Temperature

The velocity of sound in the atmosphere depends on the air temperature.[23] 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.[24] The effect of an inversion is 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.[25] Under extreme conditions, one study found that noise from aircraft on the ground might be amplified 15 to 20 dB by a temperature

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[22] 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.

[23] In dry air, the approximate velocity of sound can be obtained from this relationship: c = 331 + 0.6Tc (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.

[24] 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.

[25] Ingard, p. 407.

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.[26]

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.[27] 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.[28]

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.[29]

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

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[26] 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.

[27] 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.

[28] Piercy and Embleton, p. 1413.

[29] Ingard, pp. 409-410.