Review and Evaluation of Aircraft Noise Spectra used to Estimate Noise Level Reduction for Airport Sound Insulation Programs based on the Loudspeaker Test Method

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February 2016

Prepared for:

Federal Aviation Administration – Office of Environment & Energy (AEE-100)

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Executive Summary

Airport sound insulation programs (SIPs), as implemented in accordance with the Federal Aviation Administration's (FAA's) Airport Improvement Program (AIP), require acoustical testing of habitable structures: (i.) to determine eligibility based on interior noise levels and (ii.) to ensure the acoustical goals for noise level reduction (NLR) are obtained by the installation of sound insulation treatments. In both cases, the NLR is determined through acoustical testing by calculating the difference between noise levels measured outside and inside the room under test. NLR calculations are dependent on both the frequency content of the exterior noise source and the transmission loss (TL) characteristics of the structure. Program sponsors are currently using one of two testing methods to determine NLR:

1. Actual aircraft noise level measurements, or
2. Artificial sound source (loudspeaker) measurements.

For the artificial sound source method, the aircraft noise spectrum (frequency content of the sound source) used in the data analysis process plays an important role in the estimate of NLR. Program sponsors are currently using a variety of methods to determine aircraft sound sources and associated frequency spectra to represent the exterior noise source. This report documents an evaluation of aircraft noise spectra determination methods used to estimate NLR in loudspeaker tests. The objectives of this study are to:

- Compile the various aircraft sound source spectra and methods used in a sampling of airport sound insulation programs across the country
- Evaluate the sensitivity in the calculation of NLR using various methods and the resultant aircraft noise spectra
- Recommend a preferred method(s) for the selection and use of exterior noise spectra for airport sound insulation programs being completed in accordance with the FAA AIP

To achieve the first objective of the study, a data request form was sent to each of seven acoustical consulting firms that are actively working on sound insulation programs that make use of the loudspeaker test method. The data request form was distributed not only for the purpose of collecting the aircraft sound source spectra, but also for the purpose of documenting the methods and processes used to develop these spectra. A total of 35 airport SIPs were represented in the responses from the consultants.

The data collection effort revealed that some consultants, representing a majority of the SIPs in the survey, make use of measurement data to determine the source spectrum, while others make use of the FAA Integrated Noise Model (INM) Spectral Class (SC) database. In the former case, a composite spectrum is used in the calculation of NLR, while in the latter case a spectrum for a single aircraft is typically used. Depending upon the SIP, the aircraft noise spectrum is provided in either full octave bands or in one-third octave bands.

Based on the results of the data collection effort and our experience, HMMH developed eight generalized evaluation methods to test the sensitivity of NLR to the selection of an aircraft noise spectrum. The authors evaluated a range of methods from those that are relatively straight-forward to implement, but likely to be less accurate, to those that require a higher level of effort and/or more resources to implement, with an expected increase in accuracy. Our overall approach was to identify a method that directly utilizes measured Outdoor/Indoor Level Reduction (OILR) data to provide the best estimate of the overall NLR for a structure, then evaluate the NLRs calculated using other methods to match, as closely as possible, the NLR calculated for the reference scenario. The methods that were evaluated in this study include:

1. Loudest aircraft
2. Most frequently operating aircraft
3. Largest single aircraft contributor to the exterior Day-Night Average Sound Level (DNL)
4. Generalized spectrum for aircraft groupings
5. Standardized spectrum
6. Average exterior aircraft noise spectrum
7. Calculated NLR based on noise spectra for all aircraft operations at an airport (**the reference method**)
8. Simulated aircraft noise measurements

Using each of the eight methods identified above, an overall NLR (based on the average of individual room NLRs) was calculated for a total of 40 residential structures, covering two study airports, which remain anonymous for the purposes of this report. The accuracy of each method was evaluated by comparing the calculated NLR values to the NLRs determined using the reference method (refer to item #7 above).

The authors found that the average exterior aircraft noise spectrum method (item #6 above) has high overall accuracy. This method determines a composite spectrum based on all of the aircraft operations that underlie the calculation of an airport's Noise Exposure Map (NEM).[1] The authors also found that other methods (items #2 and #3, above), which each utilize a single aircraft spectrum, also produced reasonably accurate results, since operations at both of the study airports are largely dominated by a single INM aircraft type (e.g., Boeing737-700).

Our recommendations are based on a tiered approach for identifying an aircraft noise spectrum to use in airport SIPs. Initially, we recommend an Interim Approach at the request of FAA that uses the most frequently operating aircraft at an airport by runway end (a variation of item #2 above). This Interim Approach is relatively straight-forward and requires a low level of effort to implement. The Interim Approach yields reasonably accurate results for airports dominated by frequent commercial jet operations and may be used immediately. The Long-term Approach is based on a calculation of the average exterior aircraft noise spectrum (item #6 above). The Long-term Approach requires a medium-high to high level of effort to implement and yields more accurate results. While this approach could also be implemented for immediate use, we believe the development of a stand-alone spreadsheet tool and/or future revisions to AEDT, as directed by FAA, would provide consistent and repeatable results.

[1] An airport's NEM depicts the aircraft noise exposure in the vicinity of an airport in terms of the Day-Night Average Sound Level (DNL) for the annual-average day.

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1 Introduction

Airport sound insulation programs, as implemented in accordance with the Federal Aviation Administration's (FAA) Airport Improvement Program (AIP), require acoustical testing to determine eligibility based on interior noise levels and to ensure the acoustical goals for noise level reduction are obtained by the installation of recommended sound insulation treatments.[i] To determine the interior noise levels within a non-compatible land use, program sponsors must first determine the noise level reduction (NLR) of all habitable rooms within the structure, and then subtract the NLR from the exterior noise level associated with the land parcel of interest. The exterior aircraft noise level is typically provided in an FAA-accepted Noise Exposure Map (NEM) for the airport. The exterior aircraft noise exposure is described in terms of the Day-Night Average Sound Level (DNL), or in California, in terms of the Community Noise Equivalent Level (CNEL).

The NLR is determined through acoustical testing by calculating the difference between noise levels measured outside and inside the room being tested. NLR calculations are dependent on both the frequency content of the exterior noise source and the transmission loss (TL) characteristics of the structure. Program sponsors are currently using one of two methods to determine NLR:

1. Actual aircraft noise level measurements
2. Artificial sound source (loudspeaker) measurements

For the artificial sound source method, the aircraft noise spectrum (frequency content of the sound source) used in the data analysis process plays an important role in the estimate of NLR. Program sponsors are currently using a variety of aircraft sound sources and associated frequency spectra to represent the exterior noise source, as the selection of an aircraft noise spectrum is not standardized for the artificial sound source testing method.

1.1 Study Purpose

This report provides the results of a study to evaluate the selection of the aircraft noise spectrum used to calculate NLR. The objectives of this study are to:

1. Compile the various methods for selecting the aircraft sound source spectra used in a sampling of airport sound insulation programs across the country;
2. Evaluate the sensitivity in the calculation of NLR using the various methods for determining aircraft noise spectra that were compiled; and
3. Recommend a preferred method(s) for the selection and use of exterior noise spectra for airport sound insulation programs being completed in accordance with the FAA AIP.

HMMH conducted the study as a task-order (Technical Directive Memorandum 0043) under our PEARS (DTFAWA-11-D-00019) contract with ATAC Corporation. The FAA work assignment managers for this TDM were Dr. Hua He (AEE-100) and Mr. James Byers (APP-400).

1.2 Background

This section provides background information related to acoustical testing procedures when using a loudspeaker, the calculation of NLR, the determination of the exterior DNL, and the determination of interior DNL.

1.2.1 Acoustical Testing Procedures using a Loudspeaker

An SIP's acoustical test plan will identify the methods and procedures for acoustical testing. Many SIPs require the use of an artificial noise source (a tripod-mounted loudspeaker) to expose the exterior façade of a building located within a non-compatible land use area. The testing procedure typically utilizes a broadband electronic signal generated through an amplified loudspeaker. This signal contains equal energy levels in each octave band (known as "pink noise").

The loudspeaker is positioned outside the dwelling so that uniform distribution of the amplified sound is achieved over the exterior building facade under evaluation. Outdoor and indoor octave-band noise levels are then measured with a Type 1 sound level meter/spectrum analyzer; ambient noise levels are also collected to ensure the accuracy of the results. The indoor noise levels are measured using both time-averaging and three dimensional spatial-averaging of sound levels throughout each room tested. Outdoor noise levels are also collected using time/spatial-averaging of sound levels across each exterior room façade.

1.2.2 Determination of Noise Level Reduction (NLR)

Based on the measurement data, the Outdoor/Indoor Level Reduction (OILR) is calculated for each tested room by subtracting the interior noise levels measured in each octave band or 1/3-octave band from the corresponding exterior noise level measurements. The indoor sound level data collected with the artificial noise source turned on are adjusted to account for the measured ambient sound level with the artificial noise source turned off. The outdoor sound level data are also adjusted to account for the acoustic energy reflected from the room façade under evaluation.

The NLR is then calculated for each room by applying the computed OILR to an A-weighted aircraft noise spectrum.

1.2.3 Determination of Exterior Day-Night Average Sound Level (DNL)

The exterior annual-average day DNL value for each property is determined from the FAA-approved Noise Exposure Map (NEM) for the airport's SIP.

1.2.4 Determination of Interior Day-Night Average Sound Level (DNL)

The interior DNL is calculated for each tested room by subtracting the computed room NLR from the assigned exterior DNL noise level, as follows:

Interior DNL = Exterior DNL minus Room NLR

An average interior DNL value is then calculated for each residence from the interior noise levels that were determined for each habitable room in each home.

1.3 Outdoor-Indoor Level Reduction (OILR) Data for this Evaluation

For this study, HMMH obtained both pre-construction and post-construction acoustical data for a total of 40 residential structures located within the noise mitigation boundaries for the two study airports. The acoustical data were given in terms of the OILR, in octave bands, for each habitable room that was tested within each of the structures. Figure 1 plots the measured OILR data for the two study airports that were selected for this evaluation and which will remain anonymous for the purposes of this report. The airports are simply designated as Study Airports A and B. Table 14 in Appendix D provides the measured OILR for 10 homes with a total of 60 measured rooms in the vicinity of Study Airport A, while Table 15 in the same appendix provides the measured OILR for 30residences with a total of 60 measured rooms near Study Airport B.

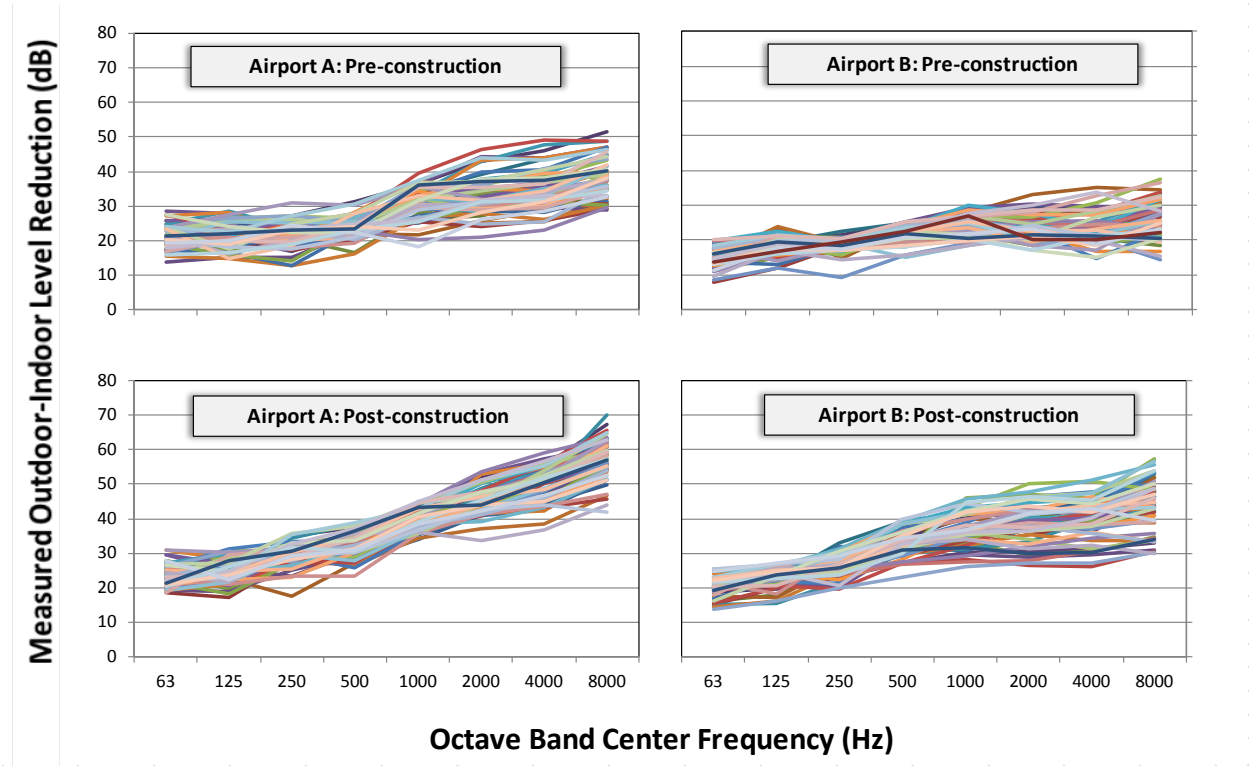

Figure 1. Measured Outdoor-Indoor Level Reductions at Study Airports A and B

1.4 Report Contents

Section 2 presents the results of a data collection effort to solicit information from acoustical consultants about their methods for selecting the aircraft noise spectra used in programs throughout the country. Section 3 provides an overview of the evaluation methods that were developed to evaluate the sensitivity of NLR to the selection of a noise source spectrum. Section 4 illustrates the outcome of the processes used to select an aircraft noise spectrum using each of the evaluation methods for a representative single-family home at Study Airport A. Section 4 also shows the results of the NLR calculations for each habitable room within the single-family home, for both pre-construction and post-construction conditions, as well as the average NLR for the entire unit. Section 5 presents the calculated NLRs for 10 single-family homes at Study Airport A and 30 residences at Study Airport B. Based upon the outcome of the analysis presented in Section 5, Section 6 provides the recommended method(s) used to identify the aircraft noise spectrum used by airport noise consultants to calculate NLR.

Appendix A provides a blank data request form used to compile the aircraft noise spectra and analysis methods used by the consulting community. Appendix B provides a consolidated summary of the consultants' responses to the data request effort. Appendix C includes figures that show the locations of each residential structure relative to the runway ends at each study airport. The figures in Appendix C also show representative arrival and departure aircraft flight tracks. Appendix D provides tables of measured pre-construction and post-construction OILR data for 60 rooms at Study Airport A and 60 rooms at Study Airport B. Appendix E provides generalized aircraft noise spectra that are based upon the aircraft groupings within the FAA Integrated Noise Model (INM) Spectral Class (SC) database. Appendix F includes tables and graphs of calculated average NLRs by evaluation method for each residential unit at both study airports.

2 An Overview of Current Practices

To achieve the first objective of the study, HMMH sent data request forms to seven acoustical consulting firms that are actively working on sound insulation programs that make use of the loudspeaker test method. A copy of the data request form that was distributed to each of the firms is included in Appendix A (see Figure 15 and Figure 16). The data request form was distributed not only for the purpose of collecting the acoustical data, but more importantly for the purpose of documenting the methods and processes that are used throughout the industry to develop an aircraft noise source spectrum to calculate the NLR of a structure.

HMMH received responses from six out of seven acoustical consulting firms. Five firms retuned completed data request forms and supplied aircraft sound source spectra in octave bands, with one of the five firms providing a supplemental spreadsheet containing aircraft sound level spectra in 1/3-octave bands. One consultant did not submit a form and simply indicated that the firm had no data to contribute to the study. HMMH supplemented the data collected from these five consulting firms with aircraft sound source spectra that we have used in our own projects. In total, HMMH compiled 35 unique aircraft noise spectra that are currently being used at 35 airport Sound Insulation Programs (SIPs) across the country.

The aircraft noise spectra obtained from the data request that were provided in octave bands are identified as Spectra 1 through 29 in Table 1. This table presents the aircraft sound source spectra as octave band sound pressure levels normalized to an overall A-weighted sound level of 65 dB. Table 1 also indicates whether each sound source spectrum was based on measurement data or the INM SC database. Figure 2 provides a graph of the octave band sound level data provided in Table 1.

The spectra in Table 2 were provided as 1/3 octave band sound level data and have been normalized to an overall A-weighted sound level of 65 dB. This table indicates whether the sound source spectra were based on measurement data or a standardized spectrum. As shown in Table 2, Spectrum 55 (which is in use at Survey Airport V) is based on a mix of Chapter 2 and 3 jet aircraft in the “Insulating Buildings Against Noise from Aircraft project,” sponsored by Transport Canada.[ii] Table 2 also includes the Reference Source Spectrum from ASTM Standard E 1332-90 (Reapproved 1998), “Standard Classification for Determination of Outdoor-Indoor Transmission Class,” as Spectrum 99. Based on the responses to the data request, the ASTM spectrum does not appear to be currently in use at any airport. However, HMMH included it in this evaluation because it is used in the calculation of the Outdoor-Indoor Transmission Class (OITC) rating. Figure 3 provides a graph of the 1/3 octave band sound level data provided in Table 2.

Note that the airport SIPs that were represented in the data collection effort are identified as Survey Airports in Table 1 and Table 2 to maintain their anonymity. The Survey Airports in these tables do not necessarily correspond to Study Airports A and B that were used for the evaluation of the sensitivity of NLR to the choice of aircraft noise spectrum.

Table 1. Aircraft Noise Spectra in Octave Bands used in Loudspeaker Tests to Determine NLR (Normalized to an A-weighted Sound Level of 65 dBA by Octave Band Center Frequency (Hz))

No.	Aircraft*	Survey Airport‡	Type**	63 dBA	125 dBA	250 dBA	500 dBA	1000 dBA	2000 dBA	4000 dBA	8000 dBA
1	B727-200	Multiple	INM	23.8	46.4	54.7	60.4	61.1	55.8	48.1	30.9
2	B737-700	A	INM	24.0	46.6	54.4	60.2	61.0	57.0	46.0	26.5
3	ERJ-170	B	INM	25.3	46.8	54.8	60.2	60.7	57.0	49.0	31.7
4	Composite	U & Z	INM	39.5	49.6	56.1	59.5	59.7	57.9	52.7	—
5	Composite	C	Meas.	37.6	49.3	56.3	59.9	59.8	58.1	50.0	32.2
6	Composite	D	Meas.	33.4	52.1	54.3	59.2	58.0	57.7	56.9	52.6
7	Composite	E	Meas.	38.9	49.8	56.1	59.8	59.7	58.1	50.7	33.9
8	Composite	F	Meas.	23.8	46.4	54.7	60.4	61.1	55.8	48.1	30.9
9	Composite	G	Meas.	39.7	47.3	55.6	61.8	60.1	53.3	39.4	29.4
10	Composite	E	Meas.	38.9	49.8	56.1	59.8	59.7	58.1	50.7	33.9
11	Composite	H	Meas.	38.6	50.1	56.6	60.4	60.2	56.2	45.7	33.1
12	Composite	I	Meas.	40.5	50.0	56.1	59.9	60.5	56.8	48.3	34.4
13	Composite	I	Meas.	48.6	51.1	54.8	59.9	60.4	57.3	47.1	23.6
14	Composite	I	Meas.	36.0	48.6	56.1	60.4	60.6	56.0	42.8	29.1
15	Composite	C	Meas.	37.6	49.3	56.3	59.9	59.8	58.1	50.0	32.2
16	Composite	F	Meas.	23.8	46.4	54.7	60.4	61.1	55.8	48.1	30.9
17	Composite	G	Meas.	39.7	47.3	55.6	61.8	60.1	53.3	39.4	29.4
18	Composite	J	Meas.	37.7	51.5	56.3	59.5	59.7	57.9	51.5	36.4
19	Composite	K	Meas.	41.1	49.5	56.7	62.2	59.3	48.6	38.4	29.4
20	Composite	D	Meas.	33.4	52.1	54.3	59.2	58.0	57.7	56.9	52.6
21	Composite	L	Meas.	41.9	53.4	59.5	61.7	57.1	45.5	25.3	18.5
22	Composite	M	Meas.	40.4	48.0	56.9	61.0	60.0	55.0	41.1	25.2
23	Composite	N	Meas.	31.5	47.2	55.7	58.9	60.2	58.5	53.0	39.8
24	Composite	O & P	Meas.	37.3	43.8	53.1	57.2	59.2	60.1	57.4	40.5
25	Composite	Q	Meas.	41.6	53.8	58.1	60.2	57.9	53.9	53.9	49.9
26	Composite	R	Meas.	40.3	53.2	56.1	60.7	59.8	55.0	49.5	35.0
27	Composite	S	Meas.	41.2	46.9	56.1	60.3	60.2	56.9	48.0	32.6
28	Composite	T	Meas.	41.8	51.0	58.8	60.1	59.7	54.5	37.8	18.4
29	Composite	X	Meas.	37.1	45.2	54.1	59.3	59.9	59.0	53.9	39.7

Notes:

* Composite spectra are based on aircraft noise measurement data, and then adjusted to represent an "Annual Average" aircraft.

** "Meas" = based on measurement data; "INM" = based on INM spectral class database.

‡ The identities of the Survey Airports are anonymous for this study. The Survey Airports in this table do not necessarily correspond to Study Airports A and B for the evaluation of the sensitivity of NLR to the choice of aircraft noise spectrum.

Sources:

Acentech; BridgeNet International; HMMH; and Landrum & Brown. Compiled by HMMH, 2015.

Table 2. Aircraft Noise Spectra in 1/3 Octave Bands used in Loudspeaker Tests to Determine NLR (Normalized to an A-weighted Sound Level of 65 dBA)

Spectrum No.	51	52	53	54	55	56	99
Aircraft*	Composite	Composite	Composite	Composite	Composite	Composite	Standard
Survey Airport‡	W	X	X	X	V	Y	—
Type**	Meas.	Meas.	Meas.	Meas.	IBANA	INM	ASTM†
1/3 OBCF (Hz)	Sound Pressure Levels (dBA) by 1/3 OBCF	Sound Pressure Levels (dBA) by 1/3 OBCF	Sound Pressure Levels (dBA) by 1/3 OBCF	Sound Pressure Levels (dBA) by 1/3 OBCF	Sound Pressure Levels (dBA) by 1/3 OBCF	Sound Pressure Levels (dBA) by 1/3 OBCF	Sound Pressure Levels (dBA) by 1/3 OBCF
50	26.1	28.6	27.2	27.7	27.6	—	—
63	32.1	33.4	31.5	30.8	32.9	—	—
80	38.2	39.9	35.9	34.4	38.1	31.3	45.4
100	41.8	40.3	38.5	38.5	42.8	36.9	47.8
125	43.2	43.0	41.8	41.9	46.2	45.6	49.8
160	46.3	45.0	45.6	44.8	48.6	45.1	49.5
200	47.8	46.5	47.4	46.7	50.7	47.7	51.0
250	50.5	49.4	48.8	48.6	51.9	51.3	51.3
315	52.2	51.8	50.8	51.1	52.9	52.5	52.3
400	53.7	53.6	53.5	52.9	54.0	52.7	53.1
500	55.0	54.5	55.0	53.9	55.0	54.0	54.7
630	54.9	55.1	55.2	54.5	55.8	56.1	54.0
800	55.1	56.0	55.8	55.3	55.9	56.6	54.1
1,000	55.1	56.5	56.3	55.5	55.5	55.2	53.9
1,250	55.2	56.0	56.0	55.3	54.7	54.4	54.5
1,600	54.8	54.3	55.2	55.0	53.6	54.8	53.9
2,000	54.1	52.6	53.7	54.4	51.7	53.8	54.1
2,500	52.7	51.3	51.4	53.6	49.9	51.1	53.2
3,150	50.2	50.4	47.2	52.3	47.6	48.5	51.1
4,000	46.6	44.9	41.5	48.9	44.2	48.0	49.9
5,000	40.0	38.6	35.7	45.1	37.9	—	—
6,300	—	—	—	—	—	—	—

Notes:
* Composite spectra are based on measurement data, and then adjusted to represent an "Annual Average" aircraft.
** "Meas" = based on measurement data; "INM" = based on INM spectral class database; "IBANA" = based on a mix of Chapter 2 and 3 jet aircraft in the Insulating Buildings Against Noise from Aircraft project, sponsored by Transport Canada (See http://tc.gc.ca/eng/civilaviation/standards/aerodromeairnav-standards-noise-ibana-922.htm#)
‡ The identities of the Survey Airports are anonymous for this study. The Survey Airports in this table do not necessarily correspond to Study Airports A and B for the evaluation of the sensitivity of NLR to the choice of aircraft noise spectrum.
† Based on the Reference Source Spectrum in Table 1 of ASTM Standard E 1332-90 (Reapproved 1998), "Standard Classification for Determination of Outdoor-Indoor Transmission Class."
Sources: Andrew S. Harris, Inc. and CSDA Design Group. Compiled by HMMH, 2015.

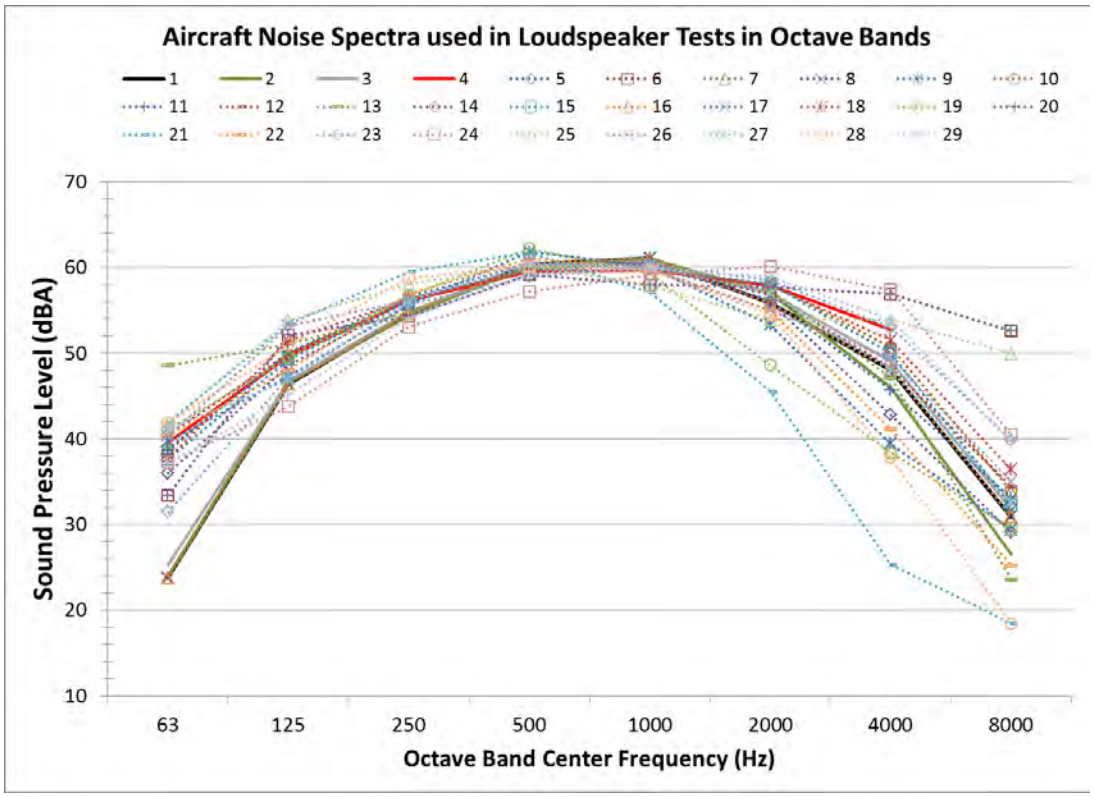

Figure 2. Aircraft Noise Spectra in Octave Bands used in Loudspeaker Tests to Determine NLR (Normalized to 65 dBA)

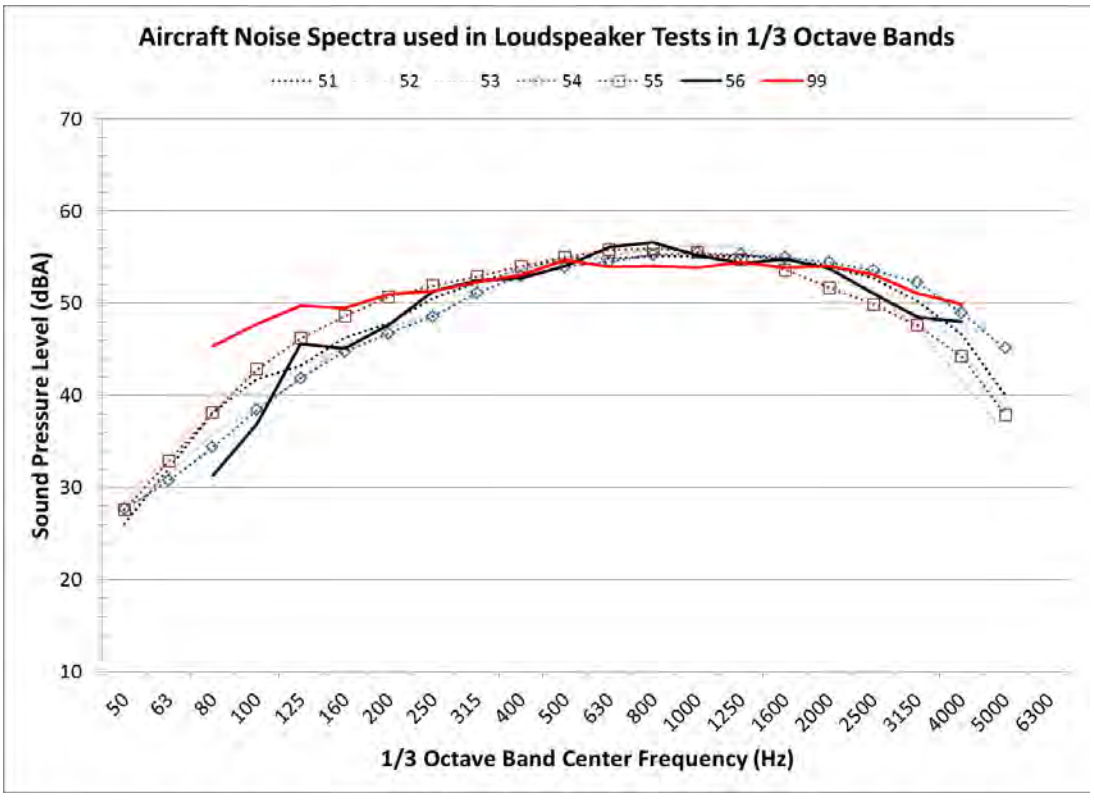

Figure 3. Aircraft Noise Spectra in 1/3 Octave Bands used in Loudspeaker Tests to Determine NLR (Normalized to 65 dBA)

In addition to the collection of aircraft sound source spectra, the primary purpose of the data request form was to document the processes and methods used to develop the source spectra, as summarized below:

- Two acoustical consulting firms, representing a majority of the SIPs that underlie the data request, make use of measured aircraft noise spectra.
    - In one case, the source spectrum is an average of the measured sound level spectra for an unidentified number of aircraft arrivals.
    - In another case, the source spectrum is an average of the measured sound level spectra for an unidentified number of aircraft arrivals and departures. Measurements were made at multiple locations in the neighborhoods being sound insulated and then averaged.
    - In the majority of cases, a location in a neighborhood eligible for sound insulation was selected for measurements. Then, the Sound Exposure Level (SEL) was measured for about 20 to 30 departures and 20 to 30 arrivals (approximately 50 operations in total), and on different days, if necessary. Using the measured SELs, the equivalent sound level (L_{eq}) is determined for both departures and arrivals, and then each L_{eq} value is weighted based on the ratios that they occur at a given airport to determine an overall L_{eq}. In some cases, the resultant source spectrum may be normalized to an overall A-weighted sound level to agree with a DNL/CNEL or maximum A-weighted sound level (L_{max}) from a Part 150 study.
- In one case, noise measurements were not possible in a particular neighborhood, due to the presence of elevated ambient sound levels produced by freeway traffic. The aircraft sound source spectrum that was used for this SIP was based on a mix of Chapter 2 and Chapter 3 jet aircraft in Transport Canada's research and development project entitled "Insulating Buildings against Noise from Aircraft" (IBANA).
- The balance of the SIPs in the survey use a spectrum from the INM SC database. In these cases, the methods used to develop the noise source spectra are as follows:
    - In one case, the INM SC data for the loudest frequently-operated departure aircraft (Airbus A321) and the two most common arrival aircraft were averaged to produce a composite spectrum. Specifically, Departure SC 103, Arrival SC 202, and Arrival SC 205 were A-weighted and normalized to the same overall A-weighted sound level. The arrival spectra were averaged and the result was then averaged with the departure spectrum, yielding a single "composite" aircraft noise spectrum.
    - In another case, the aircraft sound source spectrum was based on INM SC data for Stage 3 aircraft. Based on the consultant's response to Question 6, we infer that the resulting spectrum is a composite representing Stage 3 aircraft for both arrivals and departures.
    - In several cases, the sound source spectrum was based on a specific aircraft, such as:
        - The loudest aircraft operating at the airport (e.g. Boeing 727-200),
        - The most frequently operating aircraft (e.g. Boeing 737-700), or
        - The loudest, frequently operating commercial aircraft, which is also likely a large contributor to DNL as a result of nighttime operations (e.g. Embraer ERJ-170).
- Four acoustical consulting firms (three firms who responded to the data request plus HMMH) provided aircraft sound source spectra that are in octave bands, while two firms provided source spectra that are in 1/3-octave bands.

Figure 15 and Figure 16 in Appendix B provides a compiled list of the respondents' answers to questions 1 through 9 of the data request form. Based on the results of the data collection effort, as well as our own

experience, HMMH developed several methods to evaluate the sensitivity of a structure's NLR to the selection of an aircraft noise spectrum, as described in the next section.

3 Overview of Evaluation Methods

Based on the results of the data collection effort and our own experience, HMMH developed eight generalized evaluation methods to test the sensitivity of NLR to the selection of an aircraft noise spectrum. In developing the methods, we identified a range of approaches, from those that are relatively straight-forward to implement, but likely to be less accurate, to those that require a higher level of effort and/or more resources to implement, with increased accuracy. Our overall approach was to identify a method that directly utilized measured OILR data to provide the best estimate of the overall NLR for a structure, then evaluate the NLRs calculated using other methods to match, as closely as possible, the NLR calculated for the reference scenario.

Many of the methods include subtle variations in the approach used to identify an aircraft noise spectrum. Some methods develop a "composite" noise spectrum with appropriate weightings that account for the airport's annual aircraft operations, the acoustic emissions of the aircraft, as well as distance and atmospheric effects. It should be noted that the majority of the evaluation methods make use of spectra the INM SC database. We expect that FAA would provide aircraft noise spectra to airport sponsors upon written request. The generalized evaluation methods are summarized in the following sub-sections.

3.1 Method 1: Loudest Aircraft

Method 1 uses the spectrum for the loudest aircraft**.** Variations on this method include Method 1A, which is based on the loudest aircraft in operation at the airport, and Method 1B, which is the loudest aircraft from the runway end with operations that affect the non-compatible land use of interest. Both variations of this method are not dependent upon the number of annual operations. The selection of the spectrum is based on the aircraft with the greatest reference Sound Exposure Level (SEL) in the INM database. A major advantage of this method is that it is straight-forward and requires a low level of effort. Disadvantages are that this method does not scale for operations, or include adjustments for distance or atmospheric effects. Since Method 1 is based on a single aircraft, it may not be representative of the aircraft noise exposure for the entire fleet.

3.2 Method 2: Most Frequently Operating Aircraft

Method 2 uses the spectrum for the most frequently operating aircraft. Variations on this method include Method 2A, which is based on aircraft operations for the airport as a whole, and Method 2B, which is based on operations from the runway end that affects the parcel of concern. The advantage of this method is that it is straight-forward and requires a low level of effort. Disadvantages are that this method does not include adjustments for distance or atmospheric effects, nor does it account for the aircraft's contribution to noise exposure. Like Method 1, this method is based on a single aircraft, so it may not be representative of the aircraft noise exposure for the entire fleet.

3.3 Method 3: Largest Contributor to Exterior DNL

Method 3A is based on the aircraft that is the largest contributor to exterior DNL on an airport-wide basis. It is based on the reference SELs for each aircraft, weighted by the number of annual operations. Method 3B is similar to Method 3A, but is based on the calculated SELs from the INM detailed grid analysis for each parcel of interest, and thus includes adjustments for distance and atmospheric effects, i.e. Method 3B is site-specific. One distinct advantage to Method 3 is that it is associated with the exterior DNL for the site of interest. However, like Methods 1 and 2, Method 3 is based on a single aircraft, therefore it may not be representative of the aircraft noise exposure for the entire fleet.

3.4 Method 4A: Generalized Aircraft Noise Spectrum

Method 4A was developed by HMMH to be analogous to Method 5 (described in the next section), which uses a standard spectrum for a generalized transportation noise source. In Method 4A, generalized aircraft noise spectra were developed from different aircraft groupings within the INM SC database.[iii] Table 3 shows the aircraft groupings used in the analysis. To develop a generalized aircraft spectrum for a grouping, the spectra in the INM SC database were normalized to an A-weighted sound level of 65 dBA. Then, the energy-average sound level was determined for each 1/3-octave band within each aircraft grouping. The only real advantage to this method is that it requires a low level of effort. The analyst simply chooses a spectrum for the aircraft grouping of interest. Disadvantages are that this method is not a standard approach, it is not easily scalable to operations, and it does not incorporate adjustments for distance or atmospheric effects.

Table 16 and Table 17 in Appendix E provide tables of the aircraft noise spectra derived for the different aircraft groupings that were identified for this method.

Table 3. Aircraft Groupings for Method 4A based on INM 7.0d SC Database

Aircraft Grouping	Operation	INM 7.0d Spectral Class
Turbofan (TF)	Arrival	201, 202, 203, 204, 205, 206, 207, 208, 209
Turbofan (TF)	Departure	101, 102, 103, 104, 105, 106, 107, 108
Turbojet/business jet (TJ)	Arrival	216
Turbojet/business jet (TJ)	Departure	113
Turboprop (TP)	Arrival	210, 211, 212, 214
Turboprop (TP)	Departure	111, 112
Turboprop/piston (TPP)	Arrival	213, 215
Turboprop/piston (TPP)	Departure	109, 110
Helicopter (HEL)	Arrival	217, 218, 219, 220, 221, 222
Helicopter (HEL)	Departure	114, 115, 116, 117, 118, 119, 120
Military (MIL)	Arrival	223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 301, 302, 303, 304, 305, 306, 307, 801, 802, 803, 804, 805, 806
Military (MIL)	Departure	121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131

Source: Based on Table 2 in FAA, "Spectral Classes for FAA's Integrated Noise Model Version 6.0," DTS-34-FA065-LR1, December 7, 1999. Compiled by HMMH, 2015.

3.5 Method 5: ASTM Standard Source Spectrum

Method 5 uses the noise source spectrum in ASTM Standard E1332 "Standard Classification for Rating Outdoor-Indoor Sound Attenuation."[iv] Note that Method 5 yields a single noise spectrum, i.e. there is no differentiation between arrivals and departures for Method 5. The advantages to this method are that it is very easy to implement and it is readily available. Disadvantages to Method 5 are that it is based on a generalized transportation noise source and that it is not easily scalable to operations.

3.6 Method 6: Average Exterior Aircraft Noise Spectrum

Methods 6A to 6D calculate an average (composite) exterior aircraft noise spectrum based on annual operations in slightly different ways, each with an incrementally greater level of accuracy.

- Method 6A calculates a single average exterior spectrum, weighted by the aircraft operations over a one year period for the entire airport.

- Method 6B calculates a single average exterior spectrum, using reference SELs, weighted by the aircraft operations over a one year period.
- Method 6C calculates an average exterior spectrum for runway ends of interest, using reference SELs and runway use, weighted by the aircraft operations over a one year period.
- Method 6D calculates an average exterior spectrum at each parcel of interest based on detailed calculated exterior noise level contributions for all aircraft operations over a one year period. In effect, this method is mathematically equivalent to Method 7, described below.

3.7 Method 7: Composite Aircraft NLR based on Annual Airport Operations

Method 7 is the **baseline reference method** and represents the best estimate of the overall NLR for a habitable structure. This method is computationally intensive since it requires the calculation of detailed grid point(s) for the building(s) of interest. For this study, we used HMMH-proprietary software and INM preprocessor RealContours™ (RC) to run a complete year of aircraft operations using actual flight tracks as derived from radar data. RC converts each aircraft flight track into INM input data and uses the INM to calculate an exterior SEL at a specific point due to that operation and taking into account distance effects and adjustments for atmospheric absorption. Note that this same level of analysis is possible with more typical modeling methods, which include the creation of representative modeled flight tracks instead of directly modeling each individual flight track.

This method then applies the appropriate INM SC type to the A-weighted sound level, yielding one exterior sound level spectrum for each aircraft operation. Next, the measured OILR is applied to each computed exterior sound level spectrum, yielding one interior aircraft sound level spectrum for each aircraft operation. Finally, the exterior and interior DNL values are computed from the individual outdoor and indoor aircraft spectra, and then a composite NLR is calculated for the entire combination of aircraft operations by subtracting the interior DNL from the exterior DNL.

This method yields a composite NLR that includes contributions from all aircraft operations at an airport, including arrivals and departures. The objective of this study is to recommend a relatively straightforward method to develop an aircraft source spectrum that yields an NLR value that matches, as closely as possible, the composite NLR calculated using Method 7. Note that it is not the intent of this study to identify Method 7 as a recommended approach since this method directly utilizes measured OILR data within the computational process.

While an exterior aircraft noise spectrum is not explicitly calculated using Method 7, one can be derived from the process. The aircraft noise spectrum derived from Method 7 is essentially equivalent to the spectrum that is calculated using Method 6D.

3.8 Method 8: Simulated Aircraft Sound Level Measurements

Some consultants calculate a composite exterior aircraft spectrum that is based on noise measurement data collected in the communities surrounding an airport. Typically, the analyst will measure at least 20 departures and 20 arrivals at a representative location. The noise measurement data are then combined in a ratio representing the relative numbers of arrival and departure operations at that location to compute an overall exterior aircraft noise spectrum.

Since measurements were not included as part of the study scope, Method 8 was based on a simulated approach. Using a year's worth of aircraft operations and flight track data at each study airport, HMMH identified two days that were separated in time by about six months and that contained a mix of arrivals and departures. For each of the days, the simulated approach to Method 8 used the first 20 occurrences of an arrival operation and the first 20 occurrences of a departure operation, for periods with the appropriate flow configuration for each non-compatible site of interest. At each site, the 20 arrival and 20 departure aircraft noise spectra were used to calculate one composite arrival spectrum and one composite departure

spectrum, which were ultimately combined and weighted by the appropriate annual runway end operations to compute an overall exterior aircraft noise spectrum for both days of simulated noise measurements.

3.9 Summary of Evaluation Methods

The eight generalized evaluation methods developed for this study are summarized in Table 4. This table also includes a description of each method, the resultant number of aircraft noise spectra for each method (i.e. based on 1, 2, or more aircraft), the basis of the aircraft noise spectra (i.e. the INM SC database, measurements, or other), our estimate of the anticipated level of effort to implement each method, the advantages and disadvantages of each method, as well as some brief comments on each method.

Method 7 has been identified as the **baseline reference method** because it represents the best estimate of the overall NLR for a habitable structure. Method 7 yields a composite NLR for a structure that includes the contributions from all aircraft operations over the course of a year, including both arrivals and departures. Note that it is not the intent of this study to identify Method 7 as a recommended approach since this method directly utilizes measured OILR data within the computational process.

Table 4. Summary of Evaluation Methods

Method	Description	No. of Spectra	INM SC[1] or Other	Operations	Level of Effort	Advantages	Disadvantages	Comments
1A	Loudest aircraft using reference SELs	1 to 2	INM SC	All operations; whole airport	Low	Low level of effort	No scaling of operations; no adjustments (distance, atmospheric)	Based on A-weighted level (reference SEL)
1B	Loudest aircraft using detailed calculated SELs	1 to 2	INM SC	Runway ends; site-specific	Medium	Medium level of effort; includes adjustments (distance, atmospherics)	No scaling of operations	Based on A-weighted level (calculated SEL)
2A	Most frequently operating re: total Airport operations	1 to 2	INM SC	All operations; whole airport	Low	Low level of effort; no scaling of operations; no adjustments (distance, atmospherics)	No scaling, spectra based on single aircraft, so not representative of entire fleet; no adjustments (distance/ atmospherics); not site specific	Based on all operations at airport (no nighttime weighting); may not represent a specific site
2B	Most frequently operating re: total operations by runway end	1 to 2	INM SC	Runway ends; site-specific	Low	Low level of effort; no scaling of operations; no adjustments (distance, atmospherics)	No scaling, so limited number of spectra and not representative of entire fleet; no adjustments (distance/ atmospherics)	Based on runway-specific operations
3A	Biggest contributor to exterior DNL using equivalent annual operations and reference SELs	1	INM SC	All operations; whole airport	Medium	Low to medium level of effort; based on DNL	Based on single aircraft; not representative of entire fleet; not site specific; no adjustments (distance/atmospherics)	Based on all airport operations
3B	Biggest contributor to exterior DNL using detailed calculated contributions	1	INM SC	Runway ends; site-specific	Medium to High	Based on DNL; adjustments (distance, atmospherics); site specific	Based on single aircraft; not representative of entire fleet; requires access and ability to run noise study AEDT model	Based on runway-specific operations
4A	Spectrum by aircraft category	1 to 2	Derived from INM SC	n/a	Low	Uses spectra derived from INM SC for six (6) aircraft groupings; separate spectra for arrivals and departures	Not a standard approach; idea conceived by HMMH (analogous to Method 5); cannot be easily scaled to operations	The six (6) aircraft groupings are: turbofan, turbojet/business jet, turboprop, turboprop/piston, helicopter, and military.
5	Standardized spectrum	1	Other	n/a	Low	Low level of effort	Doesn't represent a specific aircraft, but rather a generalized transportation noise source; not scalable to operations	ASTM E1332
6A	Average (exterior) spectrum based on equivalent annual operations	Based on 100% of Annual Ops	INM SC	All operations; whole airport	Medium	Better accuracy	Higher level of effort; not site specific; no adjustments (distance/ atmospherics)	Spectra weighted by whole airport operations
6B	Average (exterior) spectrum based on equivalent annual operations and reference SELs	Based on 100% of Annual Ops	INM SC	All operations; whole airport	Medium to High	Better accuracy	Higher level of effort; not site specific; no adjustments (distance/ atmospherics)	Spectra weighted by whole airport operations and reference SEL
6C	Average (exterior) spectrum based on equivalent annual operations, reference SELs, and runway use	Based on 100% of Annual Ops	INM SC	Runway ends; site-specific	Medium to High	Better accuracy; site specific	Higher level of effort; no adjustments (distance/ atmospherics)	Scaled based on operations off runway ends
6D	Average (exterior) spectrum based on detailed calculated contributions	Based on 100% of Annual Ops	INM SC	Runway ends; site-specific	High	High accuracy; accounts for every aircraft operation and its contribution to DNL at a site	High level of effort; requires access and ability to run noise study AEDT model	Equivalent to Method 7
7 (Reference)	**All operations (adjusted & scaled) used to calculate interior DNL**	**Based on 100% of Annual Ops**	**INM SC**	**All operations; site-specific**	**High**	**High accuracy; accounts for every aircraft operation and its contribution to DNL at a site**	**High level of effort; requires access and ability to run noise study AEDT model**	**Method 7 was identified as the Reference Method against which the other Methods would be evaluated**
8	Simulated measurements weighted by equivalent annual runway operations	1 to 2	Other	20 to 30 operations for ARR flow on "Day 1"; 20 to 30 operations for DEP flow on "Day 2"	High	More "accessible" than INM SC data; site specific	Number of measurement sites; difficult to assess whether spectra are "representative"; unknown accuracy; does not address future fleet mix; extra effort to conduct measurements	Used RealContours to simulate a "measurement;" picked 2 days, 6 months apart, with a mix of arrivals & departures to/from a runway end

Notes: 1.) Potential disadvantages for all Methods that make use of the INM Spectral Class (SC) database are (i.) the availability and access to the INM SC data and (ii.) the frequency of updates to the INM SC data.

4 Detailed Results for a Representative Single-family Home at Study Airport A

This section demonstrates each of the evaluation methods and presents detailed NLR results for a representative single-family home in the vicinity of Study Airport A. Figure 17 in Appendix C shows the location of the home in relation to the runway with representative aircraft arrival flight tracks, while Figure 18 shows the home and the runway with departure flight tracks. The home is located approximately one mile from the runway end and approximately 300 feet east of the centerline of the extended runway. To maintain the anonymity of Study Airport A, the crosswind runway is not shown in either figure.

The OILR data for the single home are displayed in the graph of Figure 4 in 1/3-octave bands. This figure shows pre-construction and post-construction OILR data for each of four habitable rooms in the home, including the living room, the kitchen, bedroom 1, and bedroom 2. HMMH used linear interpolation and extrapolation to adjust the octave band OILR data measured for this home to one-third (1/3) octave bands.

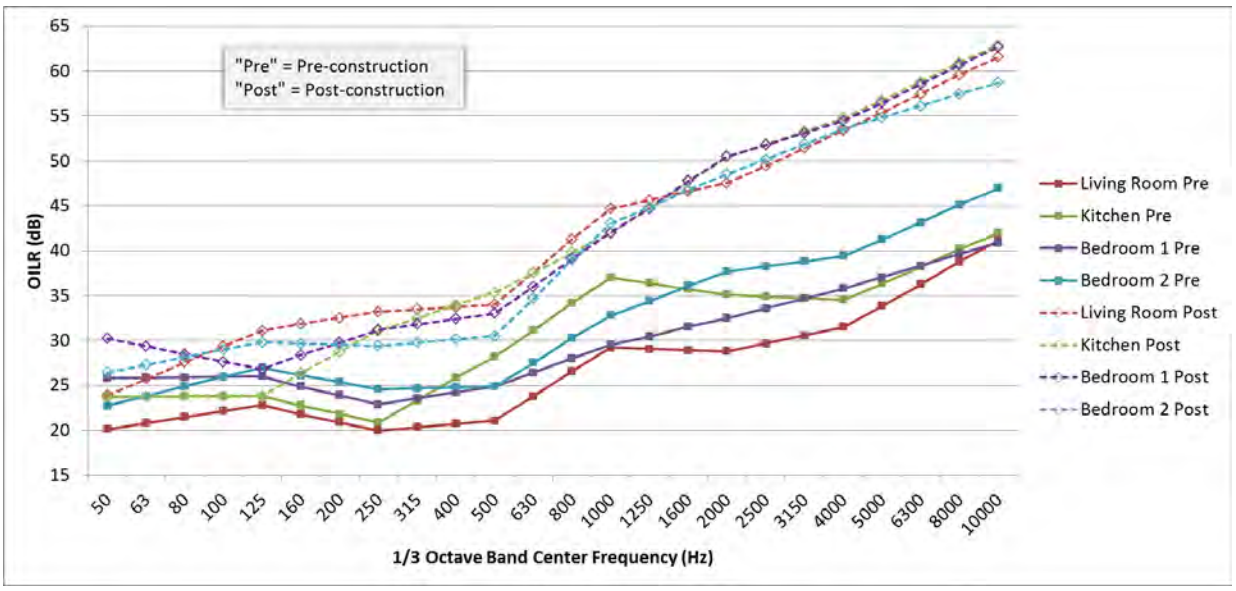

Figure 4. Equivalent 1/3 Octave Band Outdoor-Indoor Level Reduction (OILR) for Habitable Rooms in a Representative Single-family Home at Study Airport A

Sections 4.1 to 4.8 illustrate the outcome of the process used to select an aircraft noise spectrum for a representative single-family home at Study Airport A using each of the evaluation methods. Section 4.9 presents the calculated pre-construction and post-construction NLRs for each room, as well as the average NLR for the entire unit.

4.1 Method 1: Loudest Aircraft

- Method 1A is based on the loudest aircraft in operation at the airport using arrival and departure reference SELs computed in the INM at a distance typical for residences in airport sound insulation programs. For this particular residence, the loudest aircraft operating at the airport was a727Q15 departure, with only 0.9952 annual operations. The aircraft, with more than one operation per year, was a LEAR25 with 52.3263 annual operations.

- Method 1B is based on the loudest aircraft with arrival and/or departure operations off the runway that is closest to the house. In this particular case, the aircraft was a 727Q9 departure with 1.1699 annual operations.

Figure 5 is a plot of the aircraft noise spectra derived from Evaluation Methods 1A and 1B. The curve for each spectrum indicates the aircraft and its mode of operation, i.e. arrival (A) or departure (D). The spectra are normalized to a level of 70 dB at 1,000 Hz. The aircraft noise spectrum derived from Evaluation Method 7 is also shown in the graph for reference.

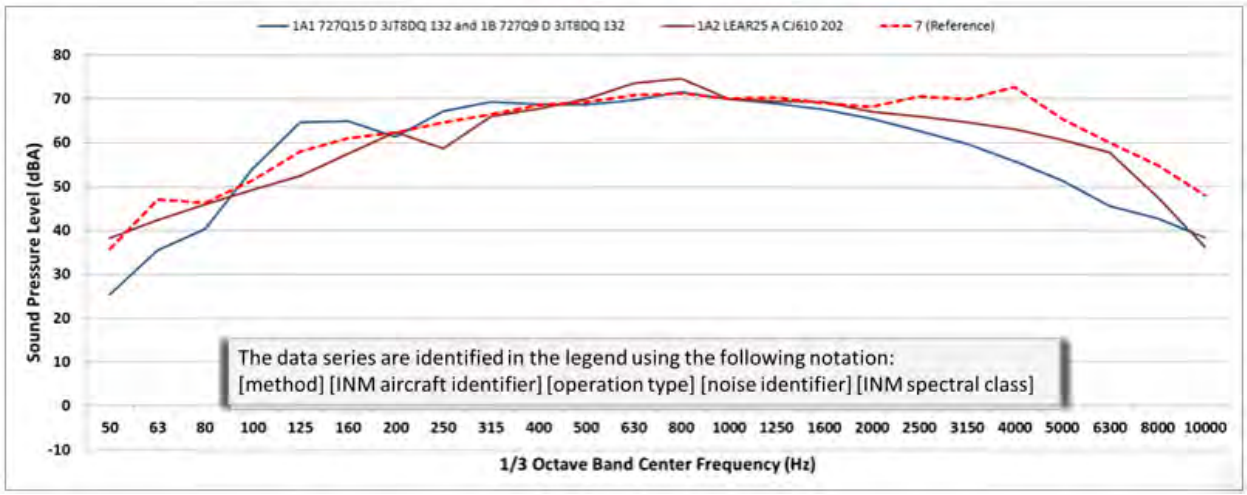

Figure 5. Aircraft Noise Spectra using Methods 1A and 1B Normalized to 70 dB at 1 kHz

4.2 Method 2: Most Frequently Operating Aircraft

- Method 2A is based on the most frequently operating aircraft at the airport. In this case, the 737700 had the most frequently occurring arrivals and departures for the entire airport.
- Method 2B is based on the most frequently operating aircraft off the runway that is closest to the parcel of interest. In this case, the most frequently occurring aircraft off the runway of interest also happens to be the 737700, since this runway is the most heavily used at the airport.
- The corresponding spectrum for the 737700 was used to calculate the NLR, separately for an arrival and a departure.

Figure 6 is a plot of the aircraft noise spectra derived from Evaluation Methods 2A and 2B. The curve for each spectrum indicates the aircraft and its mode of operation, i.e. arrival (A) or departure (D). The spectra are normalized to a level of 70 dB at 1,000 Hz. The aircraft noise spectrum derived from Evaluation Method 7 is also shown in the graph for reference.

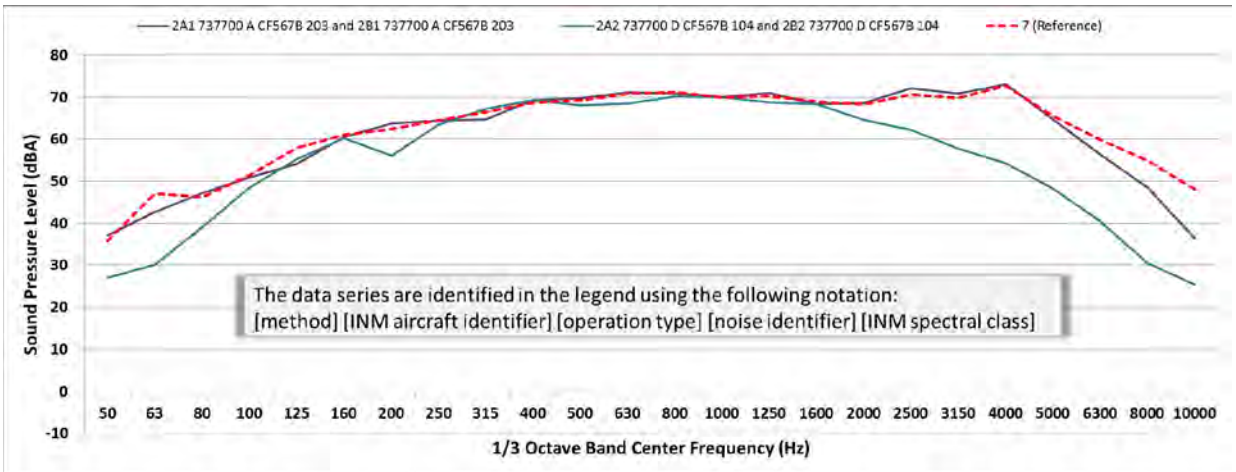

Figure 6. Aircraft Noise Spectra using Methods 2A and 2B Normalized to 70 dB at 1 kHz

4.3 Method 3: Largest Contributor to Exterior DNL

- Method 3A is based on the aircraft that is the largest contributor to exterior DNL on an airport-wide basis. Method 3A is based on the reference SELs for each aircraft, weighted by the number of annual operations.
- Method 3B is equivalent to Method 3A, but is based on the calculated SELs from the INM detailed grid analysis for each parcel of interest.
- For this airport, the largest contributor to exterior DNL for both methods 3A and 3B is also the most frequently operating aircraft, which is the 737700. Although often the case, it is not always the case that the most frequently occurring aircraft is the largest contributor to exterior DNL.

Figure 7 is a plot of the aircraft noise spectra derived from Evaluation Methods 3A and 3B. The curve for each spectrum indicates the aircraft and its mode of operation, i.e. arrival (A). The spectra were normalized to a level of 70 dB at 1,000 Hz. The aircraft noise spectrum derived from Evaluation Method 7 is also shown in the graph for reference.

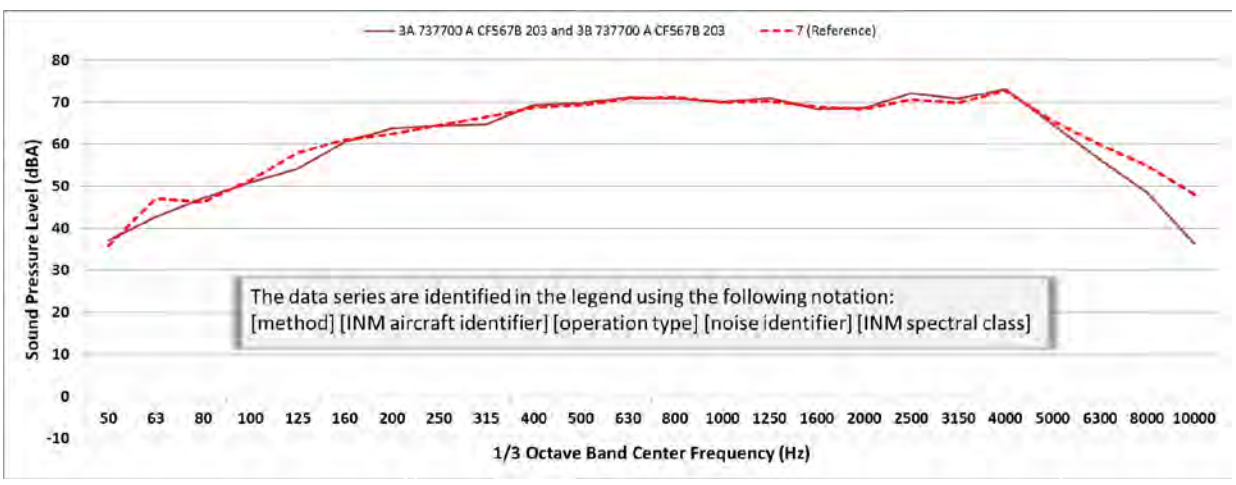

Figure 7. Aircraft Noise Spectra using Methods 3A and 3B Normalized to 70 dB at 1 kHz

4.4 Method 4A: Generalized Aircraft Noise Spectrum

Method 4A uses generalized aircraft noise spectra that were developed by HMMH from different aircraft groupings within the INM SC database.[iii] This method provides two generalized spectra for each aircraft grouping – one for an arrival aircraft and one for a departure aircraft.

The spectra for this method are displayed with the spectrum for Method 5 in figures in the following section. Additionally, Table 16 and Table 17 in Appendix E provide tables of the aircraft noise spectra derived for the different aircraft groupings that were identified for this method.

4.5 Method 5: ASTM Standard Noise Spectrum

Method 5 uses the noise source spectrum in ASTM Standard E1332 "Standard Classification for Rating Outdoor-Indoor Sound Attenuation."[iv] Note that Method 5 yields a single "generic" noise spectrum, i.e. there is no differentiation between arrivals and departures for Method 5.

Figure 8 and Figure 9 plot the noise spectra derived from Evaluation Methods 4A and 5. Figure 8 shows the noise spectra for Method 4A by aircraft grouping for arrivals (A), while Figure 9 shows the noise spectra for departures (D). In both figures, the spectra were normalized to a level of 70 dB at 1,000 Hz. The aircraft noise spectrum derived from Method 7 is also shown in both graphs for reference.

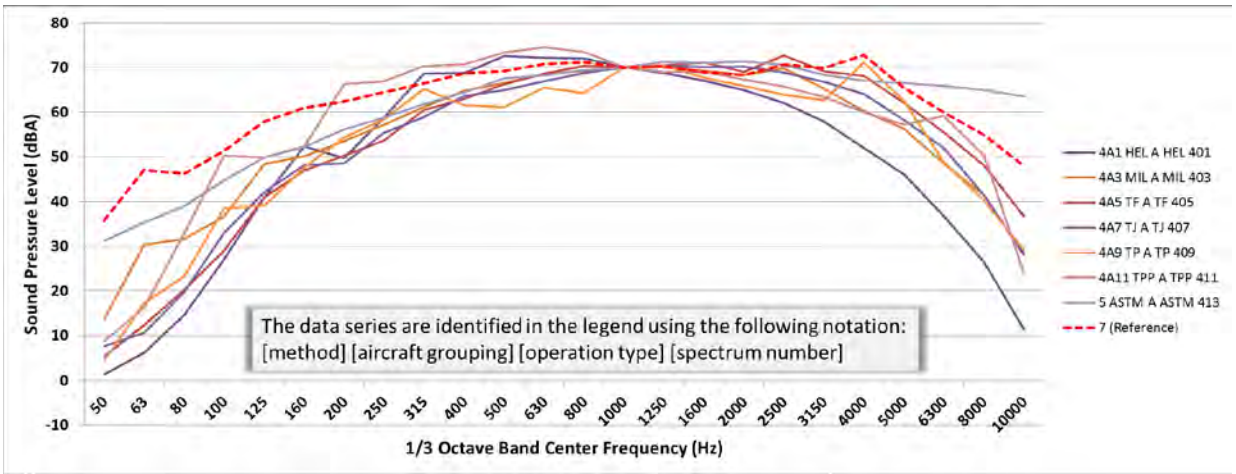

Figure 8. Noise Spectra for Arrivals using Methods 4A and 5 Normalized to 70 dB at 1 kHz

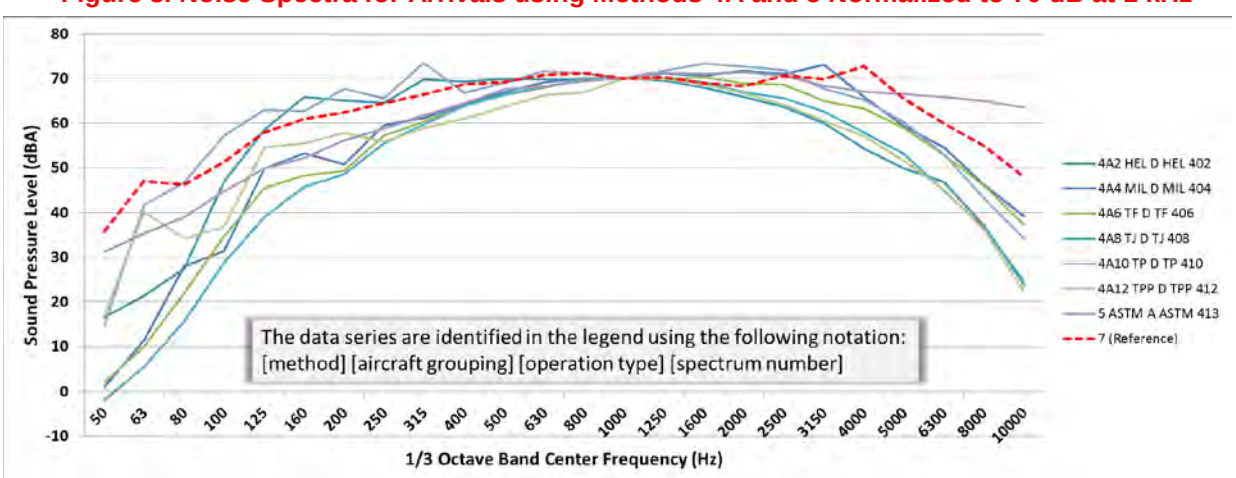

Figure 9. Noise Spectra for Departures using Methods 4A and 5 Normalized to 70 dB at 1 kHz

4.6 Method 6: Average Exterior Aircraft Noise Spectrum.

Methods 6A to 6D calculate an average (composite) exterior aircraft noise spectrum based on annual operations in slightly different ways, with an incrementally greater level of accuracy.

- Method 6A calculates an average exterior spectrum, weighted by the aircraft operations over a one year period for the entire airport.
- Method 6B calculates an average exterior spectrum, using reference SELs, weighted by the aircraft operations over a one year period.
- Method 6C calculates an average exterior spectrum, using reference SELs and runway use for the runway end of interest, weighted by the aircraft operations over a one year period.
- Method 6D calculates an average exterior spectrum based on detailed calculated exterior noise level contributions for all aircraft operations at the parcel of interest. In effect, this method is mathematically equivalent to Method 7, described below.

Figure 10 is a plot of the composite aircraft noise spectra derived from Methods 6A to 6D. The spectra were normalized to a level of 70 dB at 1,000 Hz. The aircraft noise spectrum derived from Method 7 is also shown in the graph.

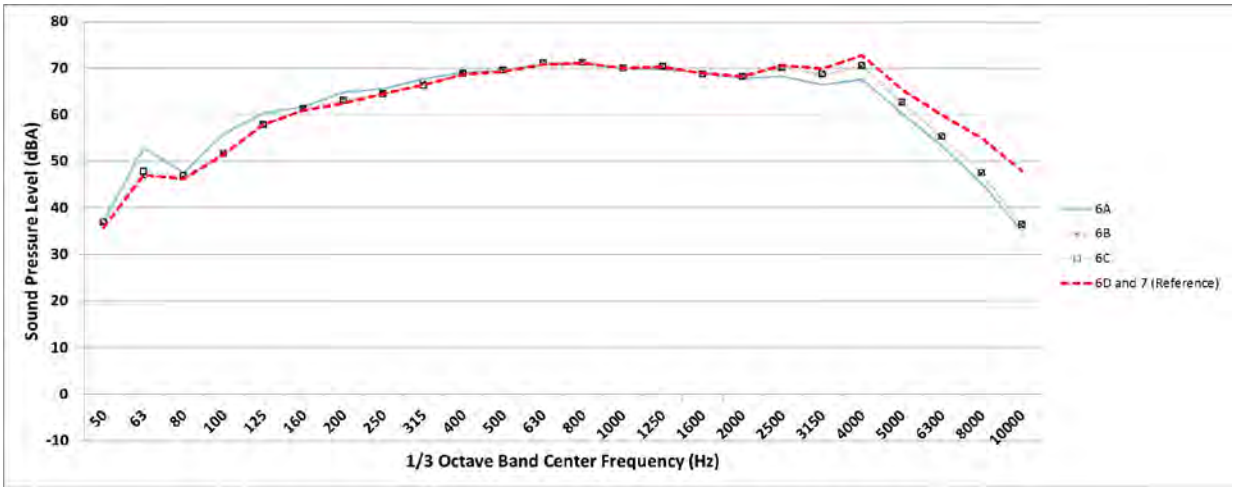

Figure 10. Composite Aircraft Noise Spectra using Methods 6A to 6D Normalized to 70 dB at 1 kHz

4.7 Method 7: Calculate NLR using all Aircraft Spectra

Method 7 is the **baseline reference method** and represents the best estimate of the overall NLR for a habitable structure. This method yields a composite NLR that includes contributions from all aircraft operations, including arrivals and departures. The objective of this study is to recommend a relatively straightforward method to develop an aircraft source spectrum that yields an NLR value that matches, as closely as possible, the composite NLR calculated using Method 7. Note that it is not the intent of this study to identify Method 7 as a recommended approach since this method directly utilizes measured OILR data within the computational process.

While an exterior aircraft noise spectrum is not explicitly calculated using Method 7, one can be derived from the process. The aircraft noise spectrum derived from Method 7 is effectively equivalent to the spectrum calculated using Method 6D. The spectrum derived from Method 7 for the representative single-family home at Study Airport A is shown in the graphs in Figure 5 to Figure 11 for reference purposes.

4.8 Method 8: Simulated Aircraft Sound Level Measurements

Since measurements were not included in the scope of work for this study, Method 8 is intended to simulate exterior noise spectrum determination methods that are based on aircraft sound level measurements in the communities surrounding an airport. Figure 11 is a plot of the composite aircraft noise spectra derived from Method 8. Each spectrum that is shown in the figure is based upon a mix of arrival and departure aircraft operations for the day of the simulated noise measurement. The curve labeled "8_1" was generated from the first day of simulated measurements, while the curve labeled "8_2" was generated from the second day. The aircraft noise spectra in the figure are normalized to a level of 70 dB at 1,000 Hz. The aircraft noise spectrum derived from Method 7 is also shown in the graph for reference.

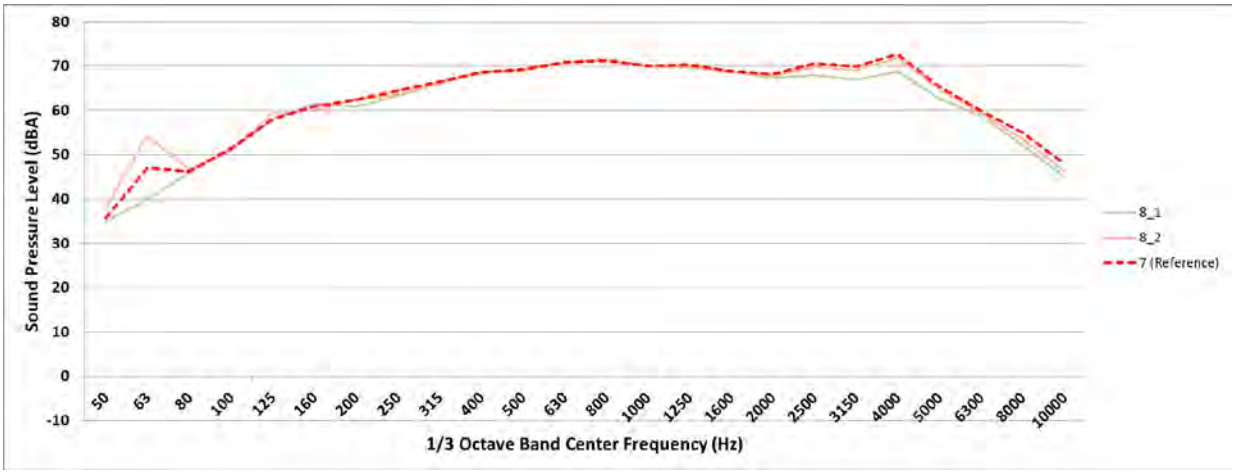

Figure 11. Composite Aircraft Noise Spectra using Method 8 Normalized to 70 dB at 1 kHz

4.9 Calculated NLRs for a Single-family Home at Study Airport A

Figure 12 shows the distribution of calculated NLRs for a representative single-family home at Study Airport A using Method 7. The distribution is based on an entire year of aircraft operations. Distributions of calculated NLRs are provided separately for each room for both pre-construction and post-construction scenarios. As shown in the figure, pre-construction NLRs range from 21 to 32 dB, while post-construction NLRs range from 25 to 42 dB. Figure 13 shows the distribution of calculated NLRs using Method 7 in terms of each aircraft's contribution to the exterior DNL.

As shown later in Table 5, Method 7 ultimately yields a single composite NLR for each room for both the pre-construction and post-construction scenarios. Then, the overall NLR is determined for the entire home by taking an arithmetic average of the room NLRs.

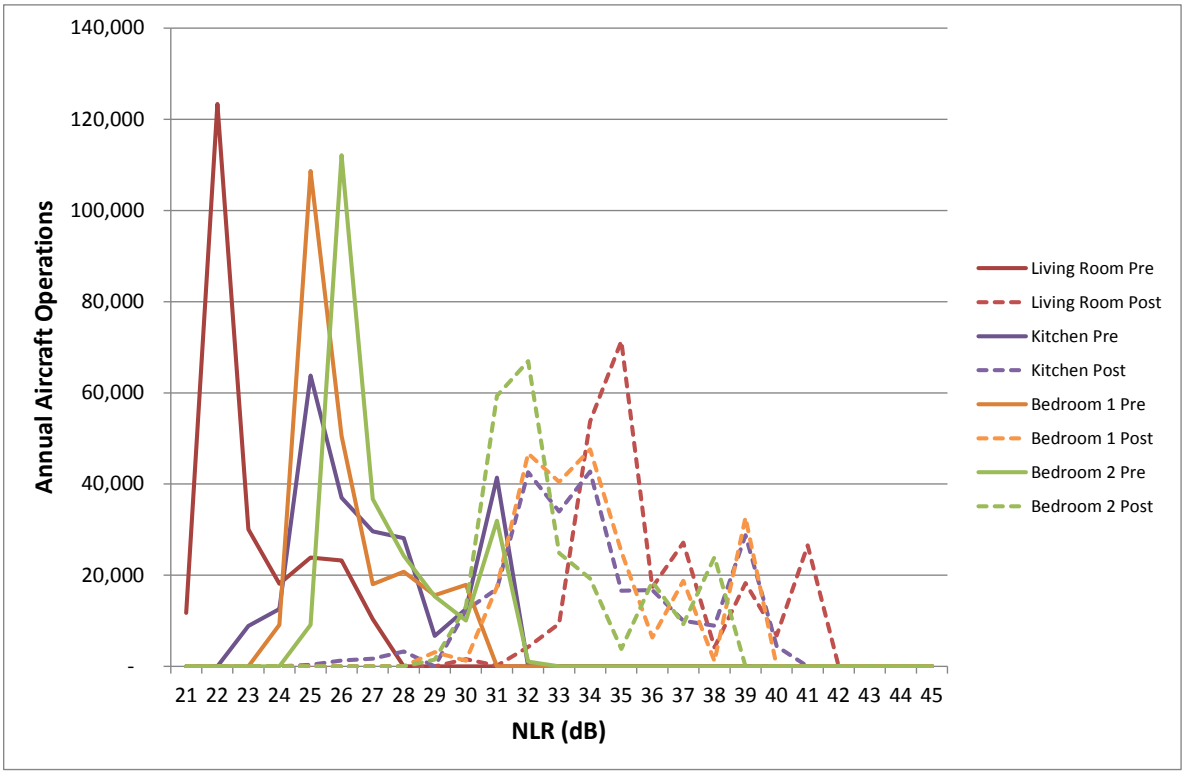

Figure 12. Distribution of Calculated NLRs for a Representative Single-family Home at Study Airport A based on Aircraft Operations for a One Year Period using Method 7

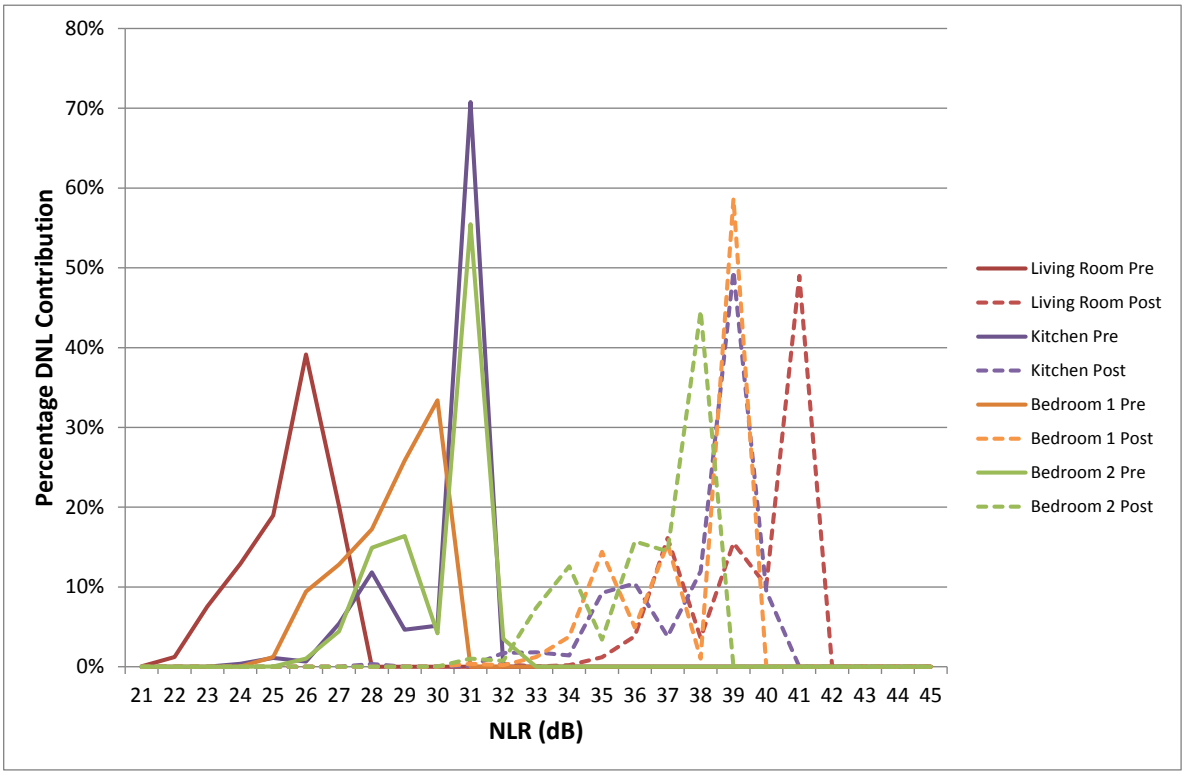

Figure 13. Distribution of Calculated NLRs for a Representative Single-family Home at Study Airport A based on Percent Contribution to Annual DNL using Method 7

Table 5 summarizes the calculated NLRs for each of the evaluation methods described in the previous section and summarized in Table 4. Table 5 shows the calculated pre-construction and post-construction NLR separately for each room, and for the entire residential unit (arithmetic average of calculated room NLRs). Method 7 is shown in red, bold text at the end of the table to distinguish it as the "baseline" or "reference" scenario. Table 5 also indicates the aircraft noise spectrum on which the calculated NLR values are based. In some cases, the NLR is based on a single aircraft noise spectrum (e.g. Methods 1, 2, 3, 4, and 5). In other cases, the NLR is based on a composite spectrum (e.g. Methods 6 and 8), or multiple spectra (e.g. Method 7).

Table 6 provides values of the calculated deviation in NLR (in dB) with respect to Method 7 for a representative single-family home at Study Airport A. As shown in Table 6, the calculated deviation in NLR for Method 6D is 0.0 dB for each room, for both the pre-construction and post-construction scenarios, as well as for the whole-house scenario. These results are as expected, since an aircraft noise spectrum generated using Method 6D is essentially equivalent to a spectrum derived from Method 7.

Table 5. Calculated NLRs (in dB) for a Representative Single-family Home at Study Airport A

Method	Spectrum[1]	Living Room Pre[2]	Living Room Post[2]	Kitchen Pre[2]	Kitchen Post[2]	Bedroom 1 Pre[2]	Bedroom 1 Post[2]	Bedroom 2 Pre[2]	Bedroom 2 Post[2]	Whole House[3] Pre[2]	Whole House[3] Post[2]
1A1	727Q15 D	23.5	36.3	27.2	33.5	26.4	34.1	27.7	33.2	26.2	34.3
1A2	LEAR25 A	24.7	38.3	30.3	37.4	27.4	36.7	28.8	35.3	27.8	36.9
1B	727Q9 D	23.5	36.3	27.2	33.5	26.4	34.1	27.7	33.2	26.2	34.3
2A1	737700 A	25.5	39.2	30.1	37.9	28.5	37.5	30.0	36.1	28.5	37.7
2A2	737700 D	23.9	37.2	28.5	36.0	26.8	35.5	28.1	34.0	26.8	35.7
2B1	737700 A	25.5	39.2	30.1	37.9	28.5	37.5	30.0	36.1	28.5	37.7
2B2	737700 D	23.9	37.2	28.5	36.0	26.8	35.5	28.1	34.0	26.8	35.7
3A	737700 A	25.5	39.2	30.1	37.9	28.5	37.5	30.0	36.1	28.5	37.7
3B	737700 A	25.5	39.2	30.1	37.9	28.5	37.5	30.0	36.1	28.5	37.7
4A1	HEL A	23.5	37.0	29.2	36.9	26.5	35.6	27.6	33.7	26.7	35.8
4A2	HEL D	23.3	36.3	27.3	34.3	26.3	34.3	27.5	33.1	26.1	34.5
4A3	MIL A	26.0	40.3	31.8	39.8	28.7	38.8	30.5	37.3	29.3	39.0
4A4	MIL D	26.9	41.6	32.5	41.0	29.7	40.2	31.7	38.7	30.2	40.4
4A5	TF A	27.1	41.9	33.0	41.7	29.8	40.6	31.9	39.1	30.4	40.8
4A6	TF D	26.3	40.7	32.2	40.3	28.9	39.3	30.8	37.8	29.6	39.5
4A7	TJ A	26.8	41.5	32.8	41.1	29.4	40.2	31.6	38.7	30.2	40.4
4A8	TJ D	25.9	40.1	32.1	39.8	28.5	38.7	30.3	37.1	29.2	38.9
4A9	TP A	26.7	41.1	31.3	40.2	29.3	39.6	31.4	38.1	29.7	39.7
4A10	TP D	24.4	37.6	28.1	35.4	27.3	35.7	28.9	34.5	27.2	35.8
4A11	TPP A	23.3	36.7	28.1	36.0	26.3	35.1	27.4	33.4	26.3	35.3
4A12	TPP D	26.3	40.3	31.7	38.5	28.7	38.5	30.8	37.6	29.4	38.7
5	ASTM E1332	26.9	41.4	32.5	40.8	29.7	40.0	31.7	38.5	30.2	40.2
6A	—	24.3	37.4	28.5	35.4	27.2	35.6	28.6	34.3	27.1	35.7
6B	—	24.9	38.4	29.5	36.8	27.8	36.6	29.2	35.3	27.9	36.8
6C	—	25.0	38.4	29.5	36.9	27.9	36.7	29.3	35.4	27.9	36.9
6D	—	25.4	39.0	29.9	37.4	28.3	37.3	29.8	35.9	28.4	37.4
8_1	—	24.9	38.4	29.6	36.8	27.7	36.6	29.2	35.3	27.9	36.7
8_2	—	25.2	38.6	29.9	37.0	28.2	37.0	29.6	35.7	28.2	37.1
7	**all aircraft**	**25.4**	**39.0**	**29.9**	**37.4**	**28.3**	**37.3**	**29.8**	**35.9**	**28.4**	**37.4**

Notes:
1.) "A" = Arrival; "D" = Departure; "HEL" = Helicopter; "MIL" = Military; "TF" = Turbofan; "TJ" = Turbojet; "TP" = Turboprop; "TPP" = Turboprop/Piston; "ASTM E1332" = noise source spectrum in ASTM Standard E1332.
2.) "Pre" = Pre-construction NLR (prior to installation of sound insulation treatments); "Post" = Post-construction NLR (after installation of sound insulation treatments).
3.) The whole-house NLR is simply the arithmetic average of the individual room NLRs.

Table 6. Calculated Deviation in NLR (in dB) with respect to Method 7 for a Representative Single-family Home at Study Airport A

Method	Spectrum[1]	Living Room Pre[2]	Living Room Post[2]	Kitchen Pre[2]	Kitchen Post[2]	Bedroom 1 Pre[2]	Bedroom 1 Post[2]	Bedroom 2 Pre[2]	Bedroom 2 Post[2]	Whole House[3] Pre[2]	Whole House[3] Post[2]
1A1	727Q15 D	-1.9	-2.7	-2.7	-4.0	-2.0	-3.2	-2.2	-2.7	-2.2	-3.1
1A2	LEAR25 A	-0.7	-0.6	0.4	0.0	-0.9	-0.6	-1.0	-0.6	-0.6	-0.5
1B	727Q9 D	-1.9	-2.7	-2.7	-4.0	-2.0	-3.2	-2.2	-2.7	-2.2	-3.1
2A1	737700 A	0.1	0.2	0.2	0.5	0.2	0.3	0.2	0.2	0.2	0.3
2A2	737700 D	-1.5	-1.8	-1.4	-1.5	-1.6	-1.8	-1.8	-2.0	-1.6	-1.7
2B1	737700 A	0.1	0.2	0.2	0.5	0.2	0.3	0.2	0.2	0.2	0.3
2B2	737700 D	-1.5	-1.8	-1.4	-1.5	-1.6	-1.8	-1.8	-2.0	-1.6	-1.7
3A	737700 A	0.1	0.2	0.2	0.5	0.2	0.3	0.2	0.2	0.2	0.3
3B	737700 A	0.1	0.2	0.2	0.5	0.2	0.3	0.2	0.2	0.2	0.3
4A1	HEL A	-1.9	-2.0	-0.7	-0.5	-1.8	-1.7	-2.3	-2.3	-1.7	-1.6
4A2	HEL D	-2.1	-2.7	-2.6	-3.2	-2.0	-2.9	-2.3	-2.8	-2.3	-2.9
4A3	MIL A	0.7	1.3	1.9	2.3	0.4	1.6	0.7	1.4	0.9	1.6
4A4	MIL D	1.5	2.6	2.6	3.6	1.3	2.9	1.9	2.8	1.8	3.0
4A5	TF A	1.7	2.9	3.1	4.2	1.4	3.4	2.1	3.2	2.1	3.4
4A6	TF D	0.9	1.7	2.3	2.9	0.6	2.0	1.0	1.9	1.2	2.1
4A7	TJ A	1.4	2.5	2.9	3.7	1.1	2.9	1.8	2.8	1.8	3.0
4A8	TJ D	0.5	1.1	2.2	2.4	0.1	1.4	0.4	1.2	0.8	1.5
4A9	TP A	1.3	2.1	1.4	2.8	1.0	2.3	1.6	2.2	1.3	2.3
4A10	TP D	-1.0	-1.4	-1.8	-2.0	-1.0	-1.6	-0.9	-1.4	-1.2	-1.6
4A11	TPP A	-2.0	-2.3	-1.8	-1.5	-2.0	-2.2	-2.4	-2.6	-2.1	-2.1
4A12	TPP D	0.9	1.3	1.8	1.1	0.4	1.2	1.0	1.6	1.0	1.3
5	ASTM E1332	1.6	2.4	2.6	3.4	1.4	2.8	1.9	2.6	1.9	2.8
6A	—	-1.1	-1.6	-1.4	-2.0	-1.1	-1.7	-1.3	-1.6	-1.2	-1.7
6B	—	-0.5	-0.6	-0.4	-0.6	-0.5	-0.6	-0.6	-0.6	-0.5	-0.6
6C	—	-0.4	-0.5	-0.4	-0.5	-0.4	-0.6	-0.5	-0.6	-0.4	-0.6
6D	—	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8_1	—	-0.5	-0.6	-0.3	-0.7	-0.6	-0.7	-0.6	-0.6	-0.5	-0.7
8_2	—	-0.2	-0.3	0.0	-0.4	-0.2	-0.3	-0.2	-0.2	-0.1	-0.3
7	**all aircraft**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Notes:
1.) "A" = Arrival; "D" = Departure; "HEL" = Helicopter; "MIL" = Military; "TF" = Turbofan; "TJ" = Turbojet; "TP" = Turboprop; "TPP" = Turboprop/Piston; "ASTM E1332" = noise source spectrum in ASTM Standard E1332.
2.) "Pre" = Pre-construction NLR (prior to installation of sound insulation treatments); "Post" = Post-construction NLR (after installation of sound insulation treatments).

3.) The whole-house NLR is simply the arithmetic average of the individual room NLRs.

The results in Table 5 underscore the need for this study and demonstrate that care must be taken when selecting an aircraft noise spectrum. Using the results for the kitchen as an example, there is a 6-dB range in calculated pre-construction NLR values and an 8-dB range in the calculated post-construction NLR. The following observations can be made from the results shown in Table 5:

- For the living room, there is a 4-dB range in the calculated pre-construction NLR values and a 6-dB range in the post-construction NLR.
- For the bedroom 1, there is a 3-dB range in the calculated pre-construction NLR values and a 7-dB range in the post-construction NLR.
- For the bedroom 2, there is a 4-dB range in the calculated pre-construction NLR values and a 6-dB range in the post-construction NLR.
- Overall, there is a 4-dB range in the average pre-construction NLR values and a 7-dB range in the average post-construction NLR.

The following observations are made with respect to the results in Table 6:

- The most frequently operating aircraft at Study Airport A is the 737700. It is also the most frequently occurring aircraft on the runway that directly affects sound levels at the residential structure used in the calculations. As a result, Methods 2A and 2B yield the same results.
- Overall, the methods were found to be accurate to about +/- 3 dB. Note that results for individual rooms were shown to vary more widely than the average results for entire residential units.
- Methods 3A and 3B, which are based on the largest contributor to DNL, yield the same results as Methods 2A and 2B, since in all of these cases the aircraft spectrum is based on a 737700 arrival.
- The methods based on a “standardized” aircraft noise spectrum (Method 4A and 5) generally yield NLR values with larger deviations from Method 7. Note that the 737700 would fall in the “Turbofan” (TF) grouping, represented by Methods 4A5 and 4A6.
- These results are influenced by the 737700 noise spectrum that was used in the calculations. The differences in NLR across the evaluation methods may not be as apparent if a different aircraft noise spectrum was used.

Of course, the foregoing results are for a single residential structure at Study Airport A. As shown in the next section, the analysis was expanded to consider nine additional single-family homes at Study Airport A (representing a total of 60 habitable rooms within those homes), plus another 30 residential units at Study Airport B (representing a total of 60 habitable rooms within those residences).

5 Summary of Results for Both Study Airports

This section presents the results of the expanded analysis for all 40 residences at both of the study airports. Figure 19 and Figure 20 in Appendix C show each of the 10 single-family homes in the vicinity of Study Airport A, with representative arrival and departure flight tracks, respectively. Figure 21 and Figure 22 in the same appendix depict similar information for the 30 residences in the vicinity of Study Airport B.

Table 7 summarizes the resultant aircraft noise spectra for Methods 1A, 1B, 2A, 2B, 3A, and 3B, for each residential structure for both Study Airports. As shown in the table, Methods 1A and 1B yielded different aircraft spectra, depending upon the airport and the location of the home, while Methods 2A, 2B, 3A, and 3B all returned a noise spectrum for either a 737700 arrival, or a 737700 departure.

Table 18 in Appendix F provides the calculated average NLR values for each single-family home, at both study airports, by evaluation method, for pre-construction conditions. Table 19 in the same appendix tabulates similar results for post-construction conditions in each of the 40 residences. Figure 23 and Figure 24 in Appendix F plot the ranges of calculated NLRs by site against the corresponding reference NLR values from Method 7 using the data shown in Table 18 and Table 19, respectively.

Table 8 shows the calculated pre-construction decibel-offsets for different methods relative to Method 7, i.e. it shows the deviations in the calculated NLR for each method relative to Method 7. The individual cells in Table 8 have color-coded shading that is dependent upon the values in each cell. Shaded cells with cooler colors highlight cells with negative decibel offsets, i.e. the calculated NLR for that method was less than the reference NLR calculated using Method 7. Shaded cells with warmer colors highlight cells with positive decibel offsets. Table 9 shows corresponding decibel-offsets for post-construction conditions.

As shown in both Table 8 and Table 9, most of the Method 4A variations, as well as Method 5, yield decibel offsets that are positive. That is, these methods tend to over-estimate the reference NLR calculated using Method 7. Note that the spectra used in Methods 4A and 5 are not adjusted for distance or atmospheric effects, nor are they weighted by annualized aircraft operations.

Table 10 shows the distribution of calculated pre-construction decibel-offsets for different evaluation methods relative to Method 7. Similarly, Table 11 shows the distribution of calculated post-construction decibel-offsets for different evaluation methods relative to Method 7. We observe that there is slightly more scatter in the post-construction distributions shown in Table 11, when compared to the pre-construction distributions in Table 10.

Table 12 is a blend of the distributions shown in Table 10 and Table 11. That is, the distributions shown in Table 12 include decibel-offsets for both pre-construction and post-construction conditions combined.

Based on the distributions shown in Table 10 to Table 12, Method 6 shows very good overall agreement with Method 7. Note that Method 6D is mathematically equivalent to Method 7 and therefore is the most precise approach. In addition, the decibel-offsets calculated for Methods 6B and 6C are at most +/- 2 dB. Methods 2 and 3 also produced reasonably accurate decibel-offsets of at most +/- 2 to 3 dB since operations at both study airports are largely dominated by one aircraft type, however these methods may not be as applicable to other airports. The remaining evaluation methods generally yield decibel-offsets that are beyond this range of accuracy.

Note that the calculated NLRs using Method 8 also show good agreement with the calculated reference NLRs using Method 7. However, because Method 8 simulates a noise measurement, it excludes the effects of certain parameters that are inherent to noise measurements and that introduce variability into the measured data. For this reason, the results of Method 8 should not be interpreted as a validation of, or a recommendation for, noise measurements. See Section 5.1 for additional comments on Method 8.

Table 7. Resultant Aircraft Noise Spectrum and Operation from Methods 1A to 3B for both Study Airports

Site	1A-1 Aircraft	1A-1 A/D	1A-2 Aircraft	1A-2 A/D	1B Aircraft	1B A/D	2A-1 Aircraft	2A-1 A/D	2A-2 Aircraft	2A-2 A/D	2B-1 Aircraft	2B-1 A/D	2B-2 Aircraft	2B-2 A/D	3A Aircraft	3A A/D	3B Aircraft	3B A/D
A01	727Q15	D	LEAR25	A	727Q9	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	A
A02	727Q15	D	LEAR25	A	LEAR25	D	737700	D	737700	A	737700	D	737700	A	737700	A	767300	D
A03	727Q15	D	LEAR25	A	LEAR25	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	A
A04	727Q15	D	LEAR25	A	727Q9	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	A
A05	727Q15	D	LEAR25	A	727Q9	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	A
A06	727Q15	D	LEAR25	A	727Q9	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	A
A07	727Q15	D	LEAR25	A	727EM2	D	737700	D	737700	A	737700	D	737700	A	737700	A	767300	D
A08	727Q15	D	LEAR25	A	727EM2	D	737700	D	737700	A	737700	D	737700	A	737700	A	767300	D
A09	727Q15	D	LEAR25	A	LEAR25	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	A
A10	727Q15	D	LEAR25	A	DC9Q9	D	737700	D	737700	A	737700	D	737700	A	737700	A	767300	D
B01	LEAR25	D	74720B	A	727EM2	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	D
B02	LEAR25	D	74720B	A	727EM2	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	D
B03	LEAR25	D	74720B	A	727EM2	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	A
B04	LEAR25	D	74720B	A	727EM2	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	D
B05	LEAR25	D	74720B	A	727EM2	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	A
B06	LEAR25	D	74720B	A	727EM2	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	D
B07	LEAR25	D	74720B	A	LEAR25	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	D
B08	LEAR25	D	74720B	A	74720B	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	D
B09	LEAR25	D	74720B	A	74720B	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	D
B10	LEAR25	D	74720B	A	727EM2	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	A
B11	LEAR25	D	74720B	A	74720B	A	737700	D	737700	A	737700	D	737700	A	737700	A	737700	A
B12	LEAR25	D	74720B	A	727EM2	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	A
B13	LEAR25	D	74720B	A	74720B	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	D
B14	LEAR25	D	74720B	A	727EM2	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	D
B15	LEAR25	D	74720B	A	727EM2	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	D
B16	LEAR25	D	74720B	A	727EM2	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	A
B17	LEAR25	D	74720B	A	74720B	A	737700	D	737700	A	737700	D	737700	A	737700	A	737700	A
B18	LEAR25	D	74720B	A	727EM2	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	A
B19	LEAR25	D	74720B	A	74720B	A	737700	D	737700	A	737700	D	737700	A	737700	A	737700	A
B20	LEAR25	D	74720B	A	GIIB	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	D
B21	LEAR25	D	74720B	A	727EM2	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	D
B22	LEAR25	D	74720B	A	727EM2	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	A
B23	LEAR25	D	74720B	A	74720B	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	D
B24	LEAR25	D	74720B	A	727EM2	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	A
B25	LEAR25	D	74720B	A	74720B	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	D
B26	LEAR25	D	74720B	A	727EM2	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	D
B27	LEAR25	D	74720B	A	727EM2	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	D

Site	1A-1 Aircraft	1A-1 A/D	1A-2 Aircraft	1A-2 A/D	1B Aircraft	1B A/D	2A-1 Aircraft	2A-1 A/D	2A-2 Aircraft	2A-2 A/D	2B-1 Aircraft	2B-1 A/D	2B-2 Aircraft	2B-2 A/D	3A Aircraft	3A A/D	3B Aircraft	3B A/D
B28	LEAR25	D	74720B	A	727EM2	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	A
B29	LEAR25	D	74720B	A	74720B	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	D
B30	LEAR25	D	74720B	A	74720B	D	737700	D	737700	A	737700	D	737700	A	737700	A	737700	D

Source: HMMH, 2015.

Table 8. Calculated Pre-construction Decibel Offsets for Different Methods Relative to Method 7

Pre Construction

Site	1A1	1A2	1B	2A1	2A2	2B1	2B2	3A	3B	4A1	4A10	4A11	4A12	4A2	4A3	4A4	4A5	4A6	4A7	4A8	4A9	5	6A	6B	6C	6D	8_1	8_2
A01	-2	0	-2	-1	1	-1	1	1	1	-1	-1	-1	1	-2	1	2	2	1	2	1	2	2	-1	0	0	0	0	0
A02	0	1	0	0	2	0	2	2	1	0	1	0	2	0	2	3	3	2	3	2	3	3	0	1	1	0	0	0
A03	-3	0	-1	-2	0	-2	0	0	0	-1	-2	-2	1	-3	1	2	3	2	2	1	1	2	-2	-1	-1	0	0	0
A04	-3	-1	-3	-2	0	-2	0	0	0	-2	-2	-3	1	-3	1	2	3	1	2	1	1	2	-2	-1	-1	0	-1	0
A05	-2	-1	-2	-2	0	-2	0	0	0	-2	-1	-2	1	-2	1	2	2	1	2	1	1	2	-1	-1	0	0	-1	0
A06	-2	-1	-2	-2	0	-2	0	0	0	-2	-1	-2	1	-2	1	2	2	1	2	1	2	2	-1	-1	-1	0	-1	0
A07	-1	1	-1	0	2	0	2	2	0	0	0	0	2	-1	2	3	3	2	3	2	3	3	0	1	1	0	0	0
A08	0	1	0	0	1	0	1	1	1	0	1	0	2	0	2	2	2	2	2	1	2	2	0	1	1	0	0	0
A09	-3	0	-1	-2	0	-2	0	0	0	-1	-2	-2	1	-3	2	3	3	2	3	2	2	3	-2	-1	-1	0	0	0
A10	0	1	0	0	2	0	2	2	1	0	1	0	2	0	2	3	3	2	3	2	3	3	1	1	1	0	0	0
B01	0	1	-1	0	1	0	1	1	0	0	0	0	1	0	2	2	2	2	2	1	2	2	1	1	0	0	0	0
B02	1	2	-1	1	2	1	2	2	1	1	0	0	4	0	4	5	5	4	5	4	3	5	1	2	1	0	0	0
B03	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
B04	1	1	-1	0	1	0	1	1	0	1	0	0	2	0	2	2	2	2	2	2	2	2	1	1	0	0	0	0
B05	0	0	-1	-1	0	-1	0	0	0	0	-1	-1	0	-1	0	1	1	1	1	0	0	1	0	0	0	0	0	0
B06	1	1	0	0	1	0	1	1	0	1	0	0	1	0	1	2	2	2	2	1	1	2	0	1	0	0	0	0
B07	0	1	0	0	1	0	1	1	0	0	0	0	1	0	1	1	1	1	1	1	1	1	0	1	0	0	0	0
B08	0	1	1	0	1	0	1	1	0	0	0	0	1	0	1	2	2	1	2	1	1	2	0	1	0	0	0	0
B09	0	1	1	0	1	0	1	1	0	0	0	0	1	0	1	1	2	1	1	1	1	2	0	1	0	0	0	0
B10	-1	0	-2	-1	0	-1	0	0	0	-1	-1	-1	0	-2	0	1	1	1	1	0	1	1	-1	-1	0	0	0	-1
B11	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B12	0	0	-1	-1	0	-1	0	0	0	0	-1	-1	1	-1	1	1	1	1	1	1	0	1	0	0	0	0	0	0
B13	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0
B14	0	-2	0	0	-2	0	-2	-2	0	0	0	0	1	0	0	-1	-1	0	0	1	-2	-1	-1	-1	0	0	0	0
B15	1	2	-1	1	2	1	2	2	1	1	0	0	3	-1	3	4	4	3	4	3	3	4	1	2	1	0	0	0
B16	0	0	-1	0	0	0	0	0	0	0	0	0	1	-1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
B17	-1	0	0	-1	0	-1	0	0	0	-1	-1	-1	0	-2	1	1	1	1	1	1	0	0	-1	-1	0	0	0	0
B18	0	0	-1	0	0	0	0	0	0	0	-1	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B19	-1	0	0	-1	0	-1	0	0	0	0	-1	-1	0	-1	0	0	0	0	0	0	0	0	-1	0	0	0	0	0
B20	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0
B21	0	1	0	0	1	0	1	1	0	0	0	0	1	0	1	2	2	2	2	1	2	2	1	1	0	0	0	0
B22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
B23	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
B24	-1	0	-1	-1	0	-1	0	0	0	-1	-1	-1	0	-1	0	1	1	0	0	0	0	1	-1	0	0	0	0	0
B25	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0
B26	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0
B27	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	1	1	1	1	0	1	0	0	0	0	0	0
B28	-1	0	-2	-1	0	-1	0	0	0	-1	-2	-2	0	-2	0	0	1	0	0	0	0	0	-1	-1	-1	0	0	-1
B29	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0
B30	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Table 9. Calculated Post-construction Decibel Offsets for Different Methods Relative to Method 7

Post Construction

Site	1A1	1A2	1B	2A1	2A2	2B1	2B2	3A	3B	4A1	4A10	4A11	4A12	4A2	4A3	4A4	4A5	4A6	4A7	4A8	4A9	5	6A	6B	6C	6D	8_1	8_2
A01	-3	0	-3	-1	1	-1	1	1	1	0	-1	-1	2	-2	3	4	4	3	4	3	3	4	-1	0	0	0	-1	0
A02	-1	2	1	0	2	0	2	2	1	1	1	0	3	-1	3	5	5	4	5	3	4	5	1	2	1	0	0	-1
A03	-4	0	-1	-2	0	-2	0	0	0	-1	-2	-2	1	-3	2	3	3	2	3	2	2	3	-2	-1	-1	0	0	0
A04	-3	-1	-3	-2	0	-2	0	0	0	-3	-1	-3	1	-3	1	2	2	1	2	0	2	2	-2	-1	-1	0	-1	0
A05	-3	0	-3	-2	0	-2	0	0	0	-2	-2	-2	1	-3	2	3	3	2	3	2	2	3	-2	-1	-1	0	-1	0
A06	-4	0	-4	-2	0	-2	0	0	0	-1	-2	-2	1	-3	2	3	3	2	3	2	2	3	-2	-1	-1	0	-1	-1
A07	-1	2	-1	0	2	0	2	2	1	1	0	0	4	-1	4	5	6	5	6	4	5	5	0	2	2	0	0	0
A08	-1	1	-1	0	2	0	2	2	1	0	1	0	3	-1	3	4	5	4	4	3	4	4	0	1	1	0	0	0
A09	-4	0	-1	-1	0	-1	0	0	0	0	-2	-1	1	-3	2	3	3	2	3	2	2	3	-2	-1	-1	0	0	0
A10	-1	2	-1	1	3	1	3	3	1	1	1	0	3	-1	4	5	6	4	5	4	5	5	0	2	2	0	0	0
B01	1	3	-2	1	3	1	3	3	1	2	0	1	3	-1	5	5	6	5	6	5	5	5	1	2	1	0	0	0
B02	2	3	-2	1	3	1	3	3	1	4	0	2	3	-1	5	6	6	6	6	6	5	5	1	2	1	0	0	0
B03	-2	-1	-5	-3	-1	-3	-1	-1	-1	-1	-4	-3	-1	-4	0	1	2	1	1	1	0	1	-3	-2	-2	0	0	-1
B04	1	2	-1	1	2	1	2	2	1	1	0	0	2	-1	3	4	4	3	4	3	3	4	1	1	1	0	0	0
B05	-1	1	-3	-1	0	-1	0	0	0	0	-2	-1	2	-3	2	3	4	3	3	2	2	3	-1	0	0	0	0	-1
B06	1	2	0	1	2	1	2	2	1	1	1	1	2	0	2	3	3	2	3	2	2	3	1	1	1	0	0	0
B07	0	1	0	0	1	0	1	1	0	1	0	0	1	0	1	1	1	1	1	1	1	1	0	1	0	0	0	0
B08	1	2	1	1	2	1	2	2	1	2	0	1	2	-1	4	4	5	4	4	4	4	4	1	1	1	0	0	0
B09	1	2	1	0	2	0	2	2	0	0	1	0	2	0	2	3	4	3	3	2	3	3	1	1	1	0	0	0
B10	-2	0	-4	-2	0	-2	0	0	0	-1	-3	-2	0	-4	1	2	2	1	2	1	1	2	-2	-1	-1	0	0	-1
B11	-2	-1	-1	-3	-1	-3	-1	-1	-1	-2	-3	-3	0	-4	0	1	2	1	1	0	0	1	-2	-2	-1	0	0	-1
B12	-1	0	-3	-1	0	-1	0	0	0	0	-2	-1	0	-2	1	1	2	1	2	1	1	1	-1	-1	0	0	0	0
B13	1	3	2	1	3	1	3	3	1	2	0	1	4	-1	5	6	7	6	6	5	5	6	1	2	1	0	0	0
B14	1	2	-2	0	2	0	2	2	0	1	0	0	3	-1	3	5	5	4	5	3	4	4	1	1	0	0	0	0
B15	1	3	-1	1	3	1	3	3	1	2	0	1	4	-1	5	6	7	6	6	5	5	6	1	2	1	0	0	0
B16	0	1	-3	-1	1	-1	1	1	1	0	-1	-1	2	-2	3	4	5	4	4	3	3	4	-1	0	1	0	1	0
B17	-3	-1	-1	-3	-1	-3	-1	-1	-1	-2	-4	-3	0	-5	1	2	3	1	2	1	0	2	-3	-2	-2	0	0	-1
B18	-2	0	-2	-2	-1	-2	-1	-1	-1	-2	-2	-2	0	-2	0	1	1	0	0	0	0	1	-1	-1	-1	0	0	-1
B19	-1	0	0	-1	0	-1	0	0	0	-1	-1	-1	0	-2	0	0	1	0	1	0	0	1	-1	-1	-1	0	0	0
B20	1	3	1	1	2	1	2	2	1	2	0	1	3	-1	5	5	6	5	6	5	4	5	1	2	2	0	1	1
B21	1	2	-2	1	2	1	2	2	1	2	0	1	2	-1	4	4	5	4	4	4	4	4	1	1	1	0	0	0
B22	-2	0	-5	-2	-1	-2	-1	-1	-1	-1	-3	-2	0	-4	2	3	3	2	3	2	1	2	-2	-1	-1	0	0	-1
B23	1	2	1	1	2	1	2	2	1	2	0	1	2	-1	3	4	4	4	4	4	3	4	1	2	1	0	0	0
B24	-1	1	-2	-1	0	-1	0	0	0	0	-1	-1	1	-2	2	2	3	2	3	2	2	2	-1	0	0	0	0	-1
B25	1	1	1	0	1	0	1	1	0	1	0	0	2	-1	2	3	3	2	3	2	2	2	0	1	0	0	0	0
B26	1	3	0	1	3	1	3	3	1	1	1	1	3	0	3	4	5	4	4	3	4	4	1	2	1	0	0	0
B27	1	2	-1	1	2	1	2	2	1	3	0	1	3	-1	4	5	5	5	5	5	4	5	1	2	1	0	0	0
B28	-2	0	-5	-2	-1	-2	-1	-1	-1	-1	-3	-2	0	-4	1	2	3	2	2	2	1	2	-2	-1	-1	0	0	-1
B29	1	3	2	1	3	1	3	3	1	2	0	0	4	-1	5	6	7	6	6	5	4	6	1	2	1	0	0	0
B30	0	1	1	0	1	0	1	1	0	1	0	0	1	-1	2	2	2	2	2	2	2	2	0	1	0	0	0	0

Table 10. Distribution of Calculated Pre-construction Decibel Offsets for Different Methods Relative to Method 7

Pre Construction

Offset (dB)	1A1	1A2	1B	2A1	2A2	2B1	2B2	3A	3B	4A1	4A2	4A3	4A4	4A5	4A6	4A7	4A8	4A9	4A10	4A11	4A12	5	6A	6B	6C	6D	8_1	8_2
-10	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-9	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-8	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-3	8%	0%	3%	0%	0%	0%	0%	0%	0%	0%	8%	0%	0%	0%	0%	0%	0%	0%	0%	3%	0%	0%	0%	0%	0%	0%	0%	0%
-2	8%	3%	13%	13%	3%	13%	3%	3%	0%	8%	15%	0%	0%	0%	0%	0%	0%	3%	10%	13%	0%	0%	8%	0%	0%	0%	0%	0%
-1	15%	8%	30%	20%	0%	20%	0%	0%	0%	18%	20%	0%	3%	3%	0%	0%	0%	0%	25%	18%	0%	3%	23%	23%	13%	0%	8%	5%
0	60%	58%	48%	63%	63%	63%	63%	63%	85%	50%	58%	30%	23%	18%	25%	25%	20%	35%	58%	68%	25%	23%	55%	45%	73%	100%	93%	95%
1	10%	28%	8%	5%	23%	5%	23%	23%	15%	25%	0%	48%	33%	35%	45%	33%	63%	33%	8%	0%	58%	30%	15%	28%	15%	0%	0%	0%
2	0%	5%	0%	0%	13%	0%	13%	13%	0%	0%	0%	18%	28%	25%	25%	28%	13%	18%	0%	0%	13%	30%	0%	5%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	3%	10%	15%	3%	10%	3%	13%	0%	0%	3%	10%	0%	0%	0%	0%	0%	0%
4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	3%	3%	3%	3%	3%	3%	0%	0%	0%	3%	3%	0%	0%	0%	0%	0%	0%
5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	3%	3%	0%	3%	0%	0%	0%	0%	0%	3%	0%	0%	0%	0%	0%	0%
6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
8	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
9	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
10	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Table 11. Distribution of Calculated Post-construction Decibel Offsets for Different Methods Relative to Method 7

Post Construction

Offset (dB)	1A1	1A2	1B	2A1	2A2	2B1	2B2	3A	3B	4A1	4A2	4A3	4A4	4A5	4A6	4A7	4A8	4A9	4A10	4A11	4A12	5	6A	6B	6C	6D	8_1	8_2
-10	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-9	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-8	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-5	0%	0%	8%	0%	0%	0%	0%	0%	0%	0%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-4	8%	0%	5%	0%	0%	0%	0%	0%	0%	0%	13%	0%	0%	0%	0%	0%	0%	0%	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-3	10%	0%	15%	8%	0%	8%	0%	0%	0%	3%	15%	0%	0%	0%	0%	0%	0%	0%	10%	10%	0%	0%	5%	0%	0%	0%	0%	0%
-2	15%	0%	15%	20%	0%	20%	0%	0%	0%	10%	15%	0%	0%	0%	0%	0%	0%	0%	18%	18%	0%	0%	23%	8%	5%	0%	0%	0%
-1	20%	10%	25%	18%	15%	18%	15%	15%	15%	18%	45%	0%	0%	0%	0%	0%	0%	0%	13%	18%	3%	0%	18%	28%	28%	0%	10%	28%
0	8%	28%	10%	20%	25%	20%	25%	25%	38%	20%	10%	10%	3%	0%	5%	3%	10%	13%	40%	28%	20%	0%	15%	10%	20%	100%	85%	70%
1	38%	18%	18%	35%	13%	35%	13%	13%	48%	25%	0%	15%	13%	8%	18%	10%	13%	13%	15%	25%	20%	15%	40%	25%	40%	0%	5%	3%
2	3%	28%	5%	0%	30%	0%	30%	30%	0%	20%	0%	28%	15%	15%	25%	15%	30%	25%	0%	3%	25%	20%	0%	30%	8%	0%	0%	0%
3	0%	18%	0%	0%	18%	0%	18%	18%	0%	3%	0%	20%	23%	25%	10%	25%	18%	13%	0%	0%	23%	18%	0%	0%	0%	0%	0%	0%
4	0%	0%	0%	0%	0%	0%	0%	0%	0%	3%	0%	13%	20%	13%	23%	20%	13%	23%	0%	0%	10%	23%	0%	0%	0%	0%	0%	0%
5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	15%	18%	20%	10%	10%	15%	15%	0%	0%	0%	18%	0%	0%	0%	0%	0%	0%
6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	10%	13%	10%	18%	3%	0%	0%	0%	0%	8%	0%	0%	0%	0%	0%	0%
7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	8%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
8	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
9	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
10	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Table 12. Distribution of All Calculated Decibel Offsets for Different Methods Relative to Method 7

All

Offset (dB)	1A1	1A2	1B	2A1	2A2	2B1	2B2	3A	3B	4A1	4A2	4A3	4A4	4A5	4A6	4A7	4A8	4A9	4A10	4A11	4A12	5	6A	6B	6C	6D	8_1	8_2
-10	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-9	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-8	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-5	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-4	4%	0%	3%	0%	0%	0%	0%	0%	0%	0%	3%	0%	0%	6%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
-3	9%	0%	9%	4%	0%	4%	0%	0%	0%	1%	5%	6%	0%	11%	0%	0%	0%	0%	0%	0%	0%	0%	3%	0%	0%	0%	0%	0%
-2	11%	1%	14%	16%	1%	16%	1%	1%	0%	9%	14%	15%	0%	15%	0%	0%	0%	0%	0%	0%	1%	0%	15%	4%	3%	0%	0%	0%
-1	18%	9%	28%	19%	8%	19%	8%	8%	8%	18%	19%	18%	1%	33%	0%	1%	1%	0%	0%	0%	0%	1%	20%	25%	20%	0%	9%	16%
0	34%	43%	29%	41%	44%	41%	44%	44%	61%	35%	49%	48%	23%	34%	20%	13%	9%	15%	14%	15%	24%	11%	35%	28%	46%	100%	89%	83%
1	24%	23%	13%	20%	18%	20%	18%	18%	31%	25%	11%	13%	39%	0%	31%	23%	21%	31%	21%	38%	23%	23%	28%	26%	28%	0%	3%	1%
2	1%	16%	3%	0%	21%	0%	21%	21%	0%	10%	0%	1%	19%	0%	23%	21%	20%	25%	21%	21%	21%	25%	0%	18%	4%	0%	0%	0%
3	0%	9%	0%	0%	9%	0%	9%	9%	0%	1%	0%	0%	13%	0%	11%	16%	20%	6%	18%	10%	13%	14%	0%	0%	0%	0%	0%	0%
4	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	6%	0%	8%	11%	8%	13%	11%	8%	11%	13%	0%	0%	0%	0%	0%	0%
5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	8%	10%	11%	5%	6%	8%	8%	11%	0%	0%	0%	0%	0%	0%
6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%	6%	5%	9%	1%	0%	4%	0%	0%	0%	0%	0%	0%
7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
8	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
9	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
10	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

5.1 Additional Comments on Method 8

The data collection effort described in Section 2 confirms that some consultants are using field measurements to develop an aircraft noise spectrum to calculate the NLR of a residential structure. Since measurements were not included as part of the scope of work for this this study, Method 8 was intended to simulate a noise measurement program based on our understanding of the approaches used by other consultants. Because Method 8 simulates a noise measurement, it excludes the effects of certain parameters that are inherent to noise measurements and that introduce variability into measured data. The Method 8 results should not be interpreted as being representative of the results obtained from actual noise measurements, nor should they be considered an endorsement of actual noise measurements, for the following reasons:

- The simulated measurements of Method 8 do not properly account for the range of weather conditions that are inherent in measurements, e.g., it does not account for variability in wind speed and direction, temperature, and atmospheric absorption.
- The simulated measurements of Method 8 do not properly account for the effects of aircraft performance on measured noise levels.

The results of Table 10 to Table 12 are based on only two days of simulated noise measurements. The sampled aircraft operations on those measurement days matched the annual operations fairly well. Recall that annual operations at both study airports are dominated by a single INM aircraft type (737700). The following figure shows the distribution of decibel-offsets using Method 8 at six residences located adjacent to single runway end and to the north of Study Airport A. As shown in the figure, although there are strong central tendencies in the distributions (i.e. the decibel-offset equals 0 dB), the offsets range from -3 to 1 dB for pre-construction NLRs and from -4 to 2 dB for post-construction NLRs.

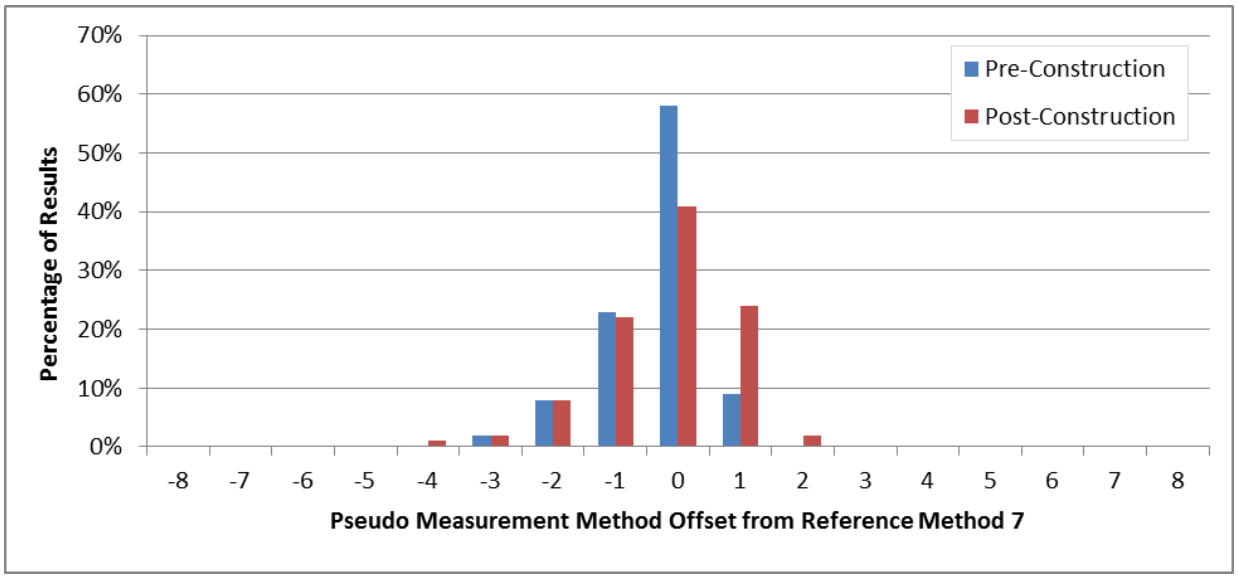

Figure 14. Distribution of Decibel Offsets for a Full Year using Method 8 at Six Locations Adjacent to a Single Runway End at Study Airport A

For these reasons, the results of Method 8 should not be interpreted as a validation of, or a recommendation for, noise measurements. There are several disadvantages to noise measurement programs as a means to determine an aircraft noise spectrum, not the least of which are the additional time and resources required to conduct a noise measurement program. Furthermore, noise measurement programs often raise issues associated with the repeatability of results and/or the required number of operations for a representative sample size. In addition, noise measurements do not ensure that the predominant aircraft types used in the calculation of DNL would be included, nor do they account for future fleet mix changes. Such issues would be better resolved through the study and analysis of noise measurement data collected for a number of airports.

The next section provides our recommendations for the development of an exterior aircraft spectrum that can be used to calculate the NLR of a structure in an airport SIP.

6 Conclusions and Recommendations

HMMH evaluated eight generalized methods for determining an exterior aircraft noise spectrum for use in airport SIPs that utilize the artificial sound source (i.e. loudspeaker) method as part of the Program's acoustical test plan. Each method was used to calculate NLR values for a total of 40 residential structures at two study airports. The results were compared with baseline NLR values calculated using Method 7, the reference method for our analysis, to investigate the overall accuracy of each of the other methods that were developed for this evaluation.

Based on the results presented in the previous section, HMMH found that Method 6 has the best overall accuracy. This approach incorporates spectra for all aircraft operations to determine an average exterior aircraft noise spectrum. Note that Methods 2 and 3, which each utilize a single aircraft spectrum, also produced reasonably accurate results since operations at both study airports are largely dominated by one aircraft type (737700). However, since Method 6 incorporates spectra for all operating aircraft, we anticipate that this method would be the most robust overall and also the most applicable to airports with operations that are not dominated by a single aircraft type. It should be noted that all of these evaluation methods make use of spectra included in the INM SC database. We expect that FAA would provide the relevant aircraft noise spectra to airport sponsors upon written request.

Given the current status of the INM and the Aviation Environmental Design Tool (AEDT) and at the request of FAA, HMMH suggests a tiered approach for implementing the recommendations discussed in this section. The tiered approach to implementation allows airports to balance the merits of those methods that are relatively straight-forward and easy to implement, but likely to be less accurate, against those methods that require a higher level of effort and/or more resources to implement, but offer increased accuracy. Although the methods that require a higher level of effort can be implemented at any time, we believe that the availability of a stand-alone tool that could be used with the INM/AEDT would make Method 6 more attractive to consultants and analysts. Furthermore, FAA may want to consider future revisions to the AEDT to implement the recommendations described herein.

Our recommendations include an interim approach and a long-term approach for identifying an aircraft noise spectrum. The Interim Approach uses Method 2B and is relatively straight-forward, requiring a low level of effort to implement. The Interim Approach yields reasonably accurate results for airports dominated by frequent commercial jet operations and may be used immediately. The Long-term Approach is based on Method 6C and/or Method 6D and requires a medium-high to high level of effort to implement. The Long-term Approach yields more accurate results and could also be implemented for immediate use. However, we believe the development of a stand-alone spreadsheet tool and/or future revisions to AEDT, as directed by FAA, would provide consistent and repeatable results.

6.1 Interim Approach based on Method 2B (Most Frequently Operating Aircraft)

HMMH recommends that airports determine a single INM aircraft type that is the most frequently operating aircraft (method number 2B above) for the runway ends adjacent to a particular community. The arrival and departure spectra for that aircraft type should be combined using a weighted average based on the relative numbers of equivalent annual runway operations (multiplier of 10 for nighttime ops) for the runway end(s) of interest. The resulting aircraft noise spectrum can then be used to calculate the NLR of structures within that community until the FAA is able to provide a tool that airports can use to generate a more comprehensive composite spectrum (refer to Section 6.2) for particular communities based on the DNL values from the FAA-approved NEM. Until such a tool exists, the FAA can provide airports with the appropriate arrival and departure spectra upon receipt of the single INM aircraft type for a particular community based on the NEM on record.

6.2 Long-term Approach based on Method 6 (Average Exterior Aircraft Spectrum)

HMMH evaluated four variations of Method 6 incorporating incrementally greater levels of detail. Our recommendation for on-going and completed Part 150 and EIS environmental studies is to utilize Method 6C. This approach incorporates annual aircraft operations, reference SEL levels for each aircraft type, and runway use information to calculate an average exterior aircraft spectrum.

HMMH recommends the development of a stand-alone spreadsheet or other software tool to implement Method 6C. We envision that the software utility would contain the INM SC database and the reference SEL levels for each aircraft type, as defaults. This information could remain hidden from the user of the software utility, if necessary. The user would enter annual operations and runway use information and then select the desired runway ends of interest for a particular community area. The utility would generate the appropriate exterior aircraft spectrum based on this user input. In addition, if all runway ends were selected within the utility, then the analysis method would essentially be equivalent to Method 6B.

For future Part 150 and EIS environmental studies, we suggest that Method 6D be incorporated directly into the AEDT model. Note that this approach is mathematically equivalent to Method 7 (except that measured OILR data are not needed) and therefore provides the highest level of accuracy overall. Method 6D also incorporates detailed distance scaling, which allows for determination of an average exterior aircraft spectrum that is specific to an individual grid point, such as a particular parcel or a representative community location. However, this analysis method is by far the most complicated and requires a wide array of inputs, therefore a stand-alone tool is likely not feasible.

Appendix A. Data Request Form

This appendix includes a copy of the data request form that was distributed to acoustical consulting firms that are actively working on airport SIPs throughout the country.

Aircraft Noise Spectrum Data Form

The FAA has contracted with Harris Miller Miller & Hanson Inc. (HMMH) to conduct a study with the purpose of:

- Compiling the various aircraft sound source spectra used throughout the numerous airport sound insulation programs
- Evaluating the sensitivity in the calculation of a building's Noise Level Reduction (NLR) using the various aircraft noise spectra compiled
- Recommending a preferred method(s) for the selection and use of exterior noise spectra for airport sound insulation programs being completed in accordance with AIP

By completing this form, you will assist in the first objective of the study. Please note that your response to this survey is voluntary. The information you provide below will be maintained as confidential – that is, neither the Program nor the person responding to this survey will be identified in report.

(1.) Enter name of Airport:

(2.) Does the Sound Insulation Program at the named airport use the artificial sound source method (with a loudspeaker), the fly-over method (with actual aircraft), or both methods? (check all that apply)

☐ Artificial sound source method (with loudspeaker)

☐ Fly-over method (with aircraft)

(3.) Does the Airport Sound Insulation Program use more than one aircraft noise spectrum?

☐ Yes (If "yes," please complete the following page for each aircraft noise spectrum)

☐ No

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Figure 15. Data Request Form Page 1

Aircraft Noise Spectrum Data Form

(4.) If the Program uses the artificial sound source method, what is the aircraft noise spectrum based on?

☐ Noise measurement data; ☐ Aircraft type in the INM database;
☐ Other (please describe): Click here to enter text.

(5.) What does the aircraft noise spectrum represent?

☐ Loudest aircraft at Airport; ☐ Most frequently operating aircraft;
☐ Aircraft that contributes most to DNL; ☐ "Annual average" aircraft;
☐ Other (please describe): Click here to enter text.

(6.) Does the aircraft noise spectrum represent an ☐ Arrival; or a ☐Departure; or
☐ Other (please describe): Click here to enter text.

(7.) Does the spectrum represent a particular aircraft? If so, which one? Click here to enter text.

(8.) Is the noise spectrum in full octave bands or 1/3 octave bands? (If the latter, please submit the aircraft noise spectrum in a separate document.) ☐ Full octave bands; ☐ 1/3 octave bands

Please provide the octave band sound pressure levels for the aircraft noise spectrum:

Name of Spectrum / Aircraft	Octave Band Sound Pressure Level							
	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 KHz
Is the Spectrum unweighted or A-weighted?	☐ unweighted; ☐A-weighted							

(9.) Please describe the process used to develop the aircraft noise spectrum shown in the table. Use another sheet, if necessary.

Click here to enter text.

(10.) Please identify the person responsible for providing this information. This information will be kept confidential and will be used only to track responses.

Click here to enter text.

Please submit your completed form to Chris Bajdek (HMMH) at the email address shown below. If you have any questions, please contact Chris at 781-229-0707 or cbajdek@hmmh.com.

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Figure 16. Data Request Form Page 2

Appendix B. Summary of Responses to Data Request

Table 13. Summary of Responses to Questions in Data Request Form

Question #	Summary of question
Response	**Summary of responses in data request form**
Question 1	**Enter Name of Airport**
Response	**The airport SIPs represented in the various responses to this data request are maintained as "confidential" or "anonymous."**
Question 2	**Does the Sound Insulation Program at the named airport use the artificial sound source method (with a loudspeaker), the fly-over method (with actual aircraft), or both methods?**
Response	Five respondents answered "artificial sound source method (with loudspeaker)" and one respondent answered "both."
Response	One respondent filled out three forms, i.e. one form for each of three SIPs
Response	One respondent filled out a single form for 20 SIPs
Question 3	**Does the Airport Sound Insulation Program use more than one aircraft noise spectrum?**
Response	Five respondents answered "No", while one answered "Yes". Historically, HMMH has not used more than one aircraft noise spectrum for acoustical testing using a loudspeaker.
Question 4	**If the Program uses the artificial sound source method, what is the aircraft noise spectrum based on?**
Response	Three respondents and HMMH make use Aircraft type in the INM database
Response	Noise measurement data and aircraft type in the INM database
Response	Noise measurement data
Response	IBANA standard aircraft spectrum
Question 5	**What does the aircraft noise spectrum represent?**
Response	The aircraft were selected to be representative of the loudest frequently-operated departure aircraft (Airbus 321) and the two most common arrival aircraft
Response	Loudest aircraft at airport
Response	Use of measured data in combination of Part 150 Study data to create an exterior spectrum to approximate the spectrum of the DNL/CNEL
Response	A mix of Chapter 2 and 3 jet aircraft
Response	"Annual average" aircraft; the spectrum is based upon measurements of arrivals at the school being tested.
Response	"Annual average" aircraft; the spectrum is based upon measurements of arrivals and departures at multiple locations around the airport.
Response	Stage 3 aircraft
Question 6	**Does the aircraft noise spectrum represent an Arrival, or a Departure, or Other (please describe)**
Response	Average of arrival and departure for one departure spectral class and two arrival spectral classes
Response	Departure
Response	Both, in the ratios as they occur at the airport
Response	Arrivals and Departures (2)
Response	Arrival
Response	One respondent answered "other" without providing additional details
Question 7	**Does the spectrum represent a particular aircraft?**
Response	Aircraft represented include: Embraer 190, Airbus 321, B727 (for 10 SIPs), Stage 3, B737, and ERJ-170, as well as an "average of all operating aircraft."
Response	One respondent answered "No."
Question 8	**Is the noise spectrum in full octave bands or 1/3 octave bands?**
Response	Three respondents answered "full octave bands", while two answered "1/3 octave bands," and one answered "1/3 octave bands" even though data were provided as full octave bands
Question 9	**Please describe the process used to develop the aircraft noise spectrum shown in the table. Use another sheet, if necessary**
Response	Departure Spectral Class 103 and Arrival SC's 202 and 205 were A-weighted and adjusted to the same overall A-weighted level. The Arrival spectra were averaged and the result then averaged with the departure spectrum.
Response	One respondent did not answer this question.

Question #	Summary of question
Response	**Summary of responses in data request form**
Response	A location in the community eligible for sound insulation treatments is selected. The SEL is measured of about 20 to 30 departures and 20 to 30 arrivals (around 50 operations total) on different days if necessary. Using the SELs, the L_{eq} is determined for departures and arrivals, and each are weighted in the ratios that they occur at a given airport to determine the overall L_{eq}. Sometimes we will normalize the spectrum to an A-weighted total such that the total matches a DNL/CNEL/L_{max}, etc. The relative spectral shape does not affect the NLR.*
Response	For a couple homes [at Survey Airport V], the flyover measurement method was not feasible due to elevated ambient (freeway) noise levels at the home. We conducted loudspeaker measurements at these homes; the project budget did not allow for a sampling of aircraft flyovers, so we used the IBANA standard spectrum.
Response	Measurements of arrivals were conducted at each campus being treated. The results were then averaged.
Response	Measurements of arrivals and departures were conducted at multiple locations in the neighborhoods being sound insulated. The results were then averaged.
Response	This spectrum was developed off of stage 3 aircraft

Notes:
* The last sentence of this response is vague. HMMH believes the intent of the last sentence is to state that the calculated NLR does not depend upon the reference A-weighted sound level that is chosen to normalize the spectral data.

Sources: Acentech; Andrew S. Harris, Inc.; BridgeNet International; CSDA Design Group; HMMH; and Landrum & Brown. Compiled by HMMH, 2015.

Appendix C. Figures Showing the Locations of Representative Residential Units in Relation to the Study Airports

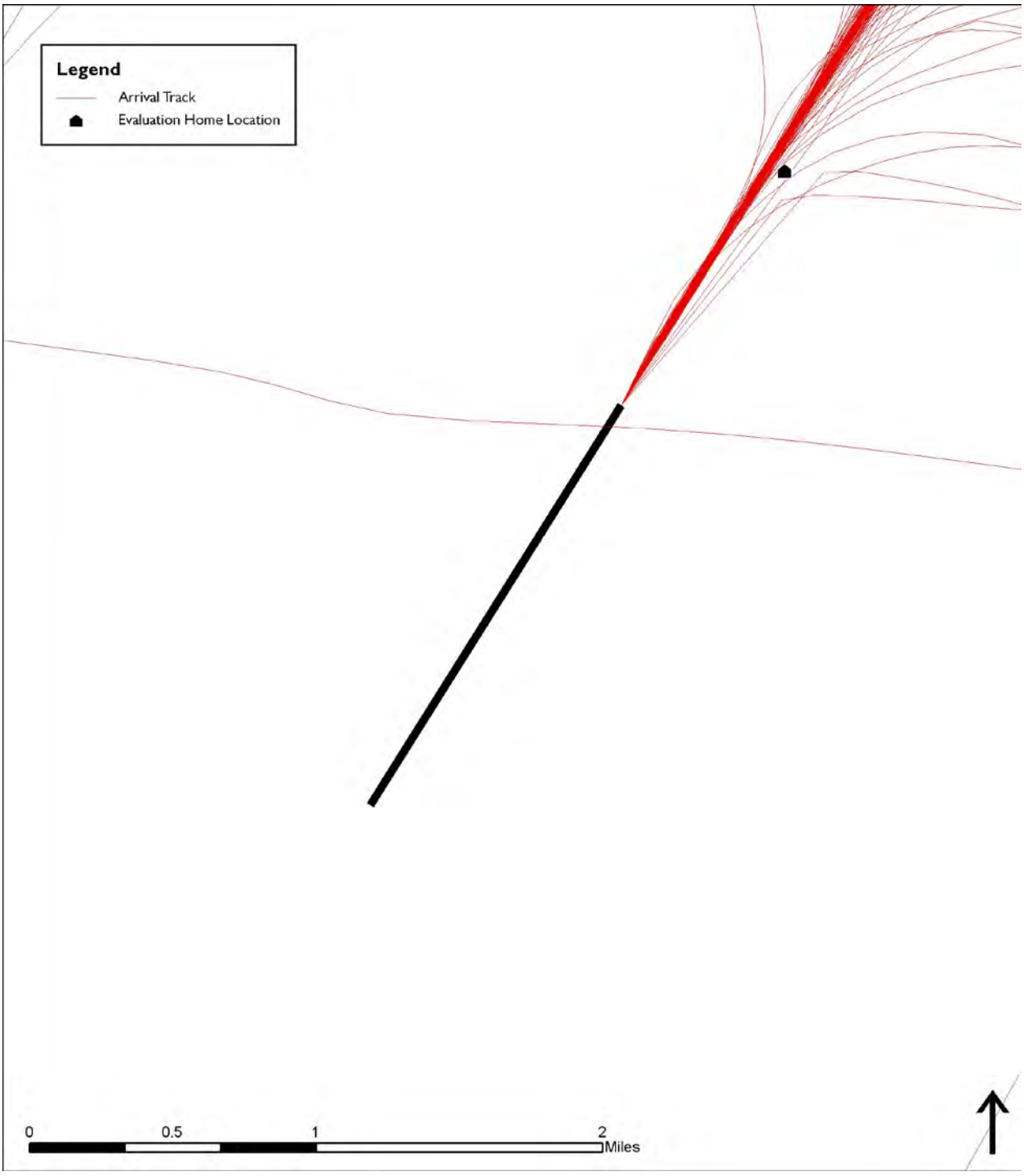

Figure 17. Single Residence in Relation to Study Airport A with Representative Arrival Flight Tracks

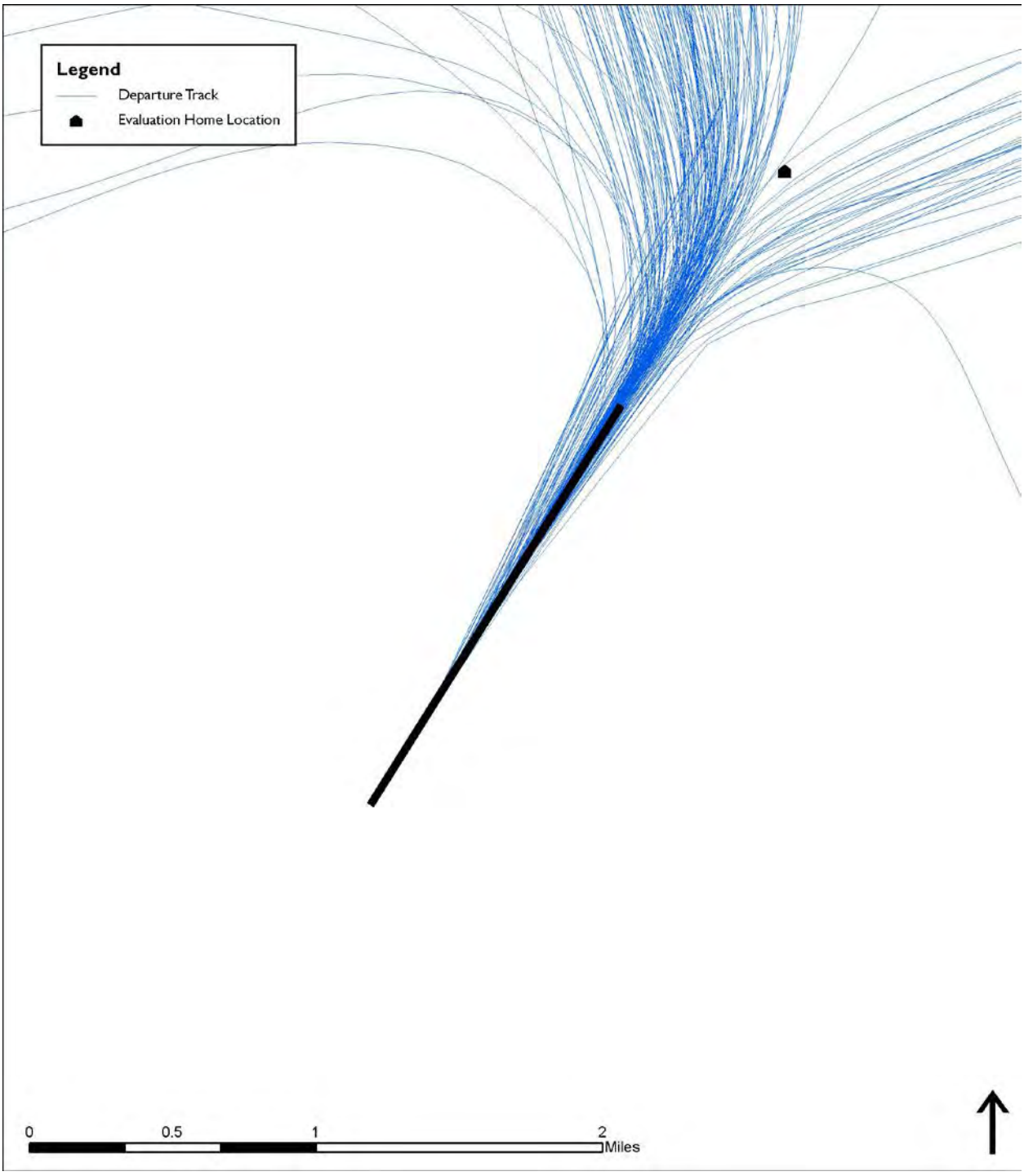

Figure 18. Single Residence in Relation to Study Airport A with Representative Departure Flight Tracks

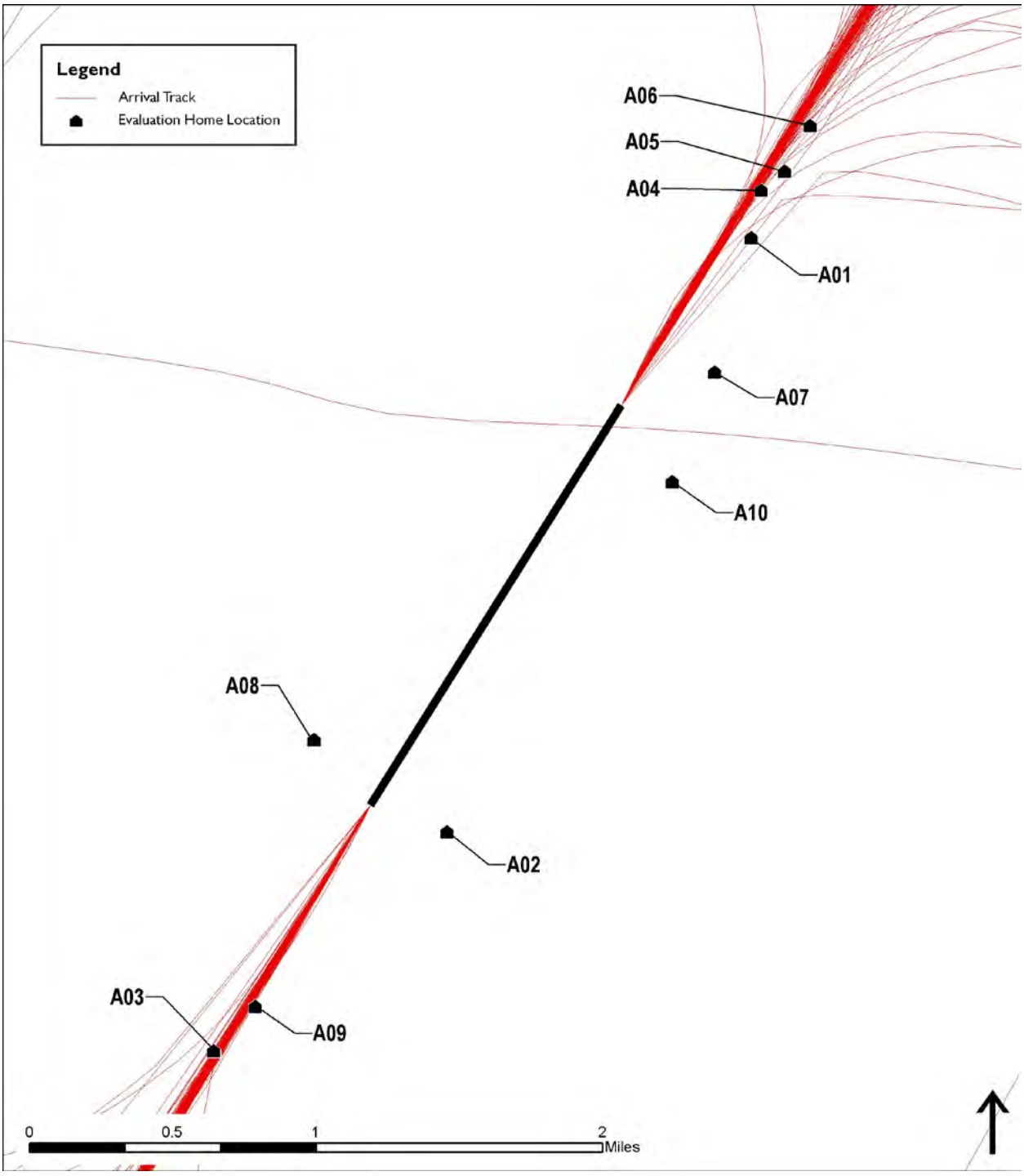

Figure 19. Residences for the Full Analysis in Relation to Study Airport A with Representative Arrival Flight Tracks

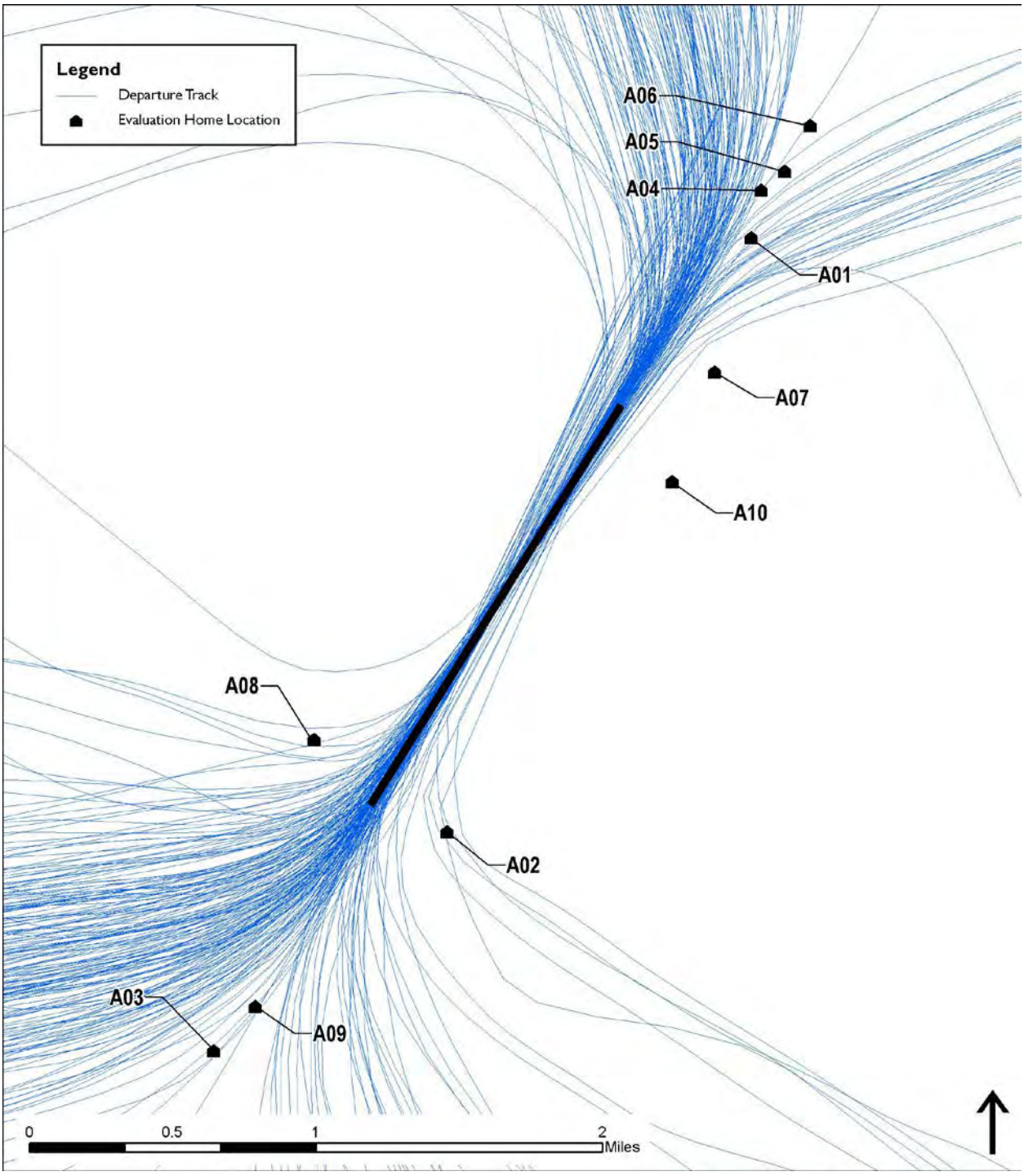

Figure 20. Residences for the Full Analysis in Relation to Study Airport A with Representative Departure Flight Tracks

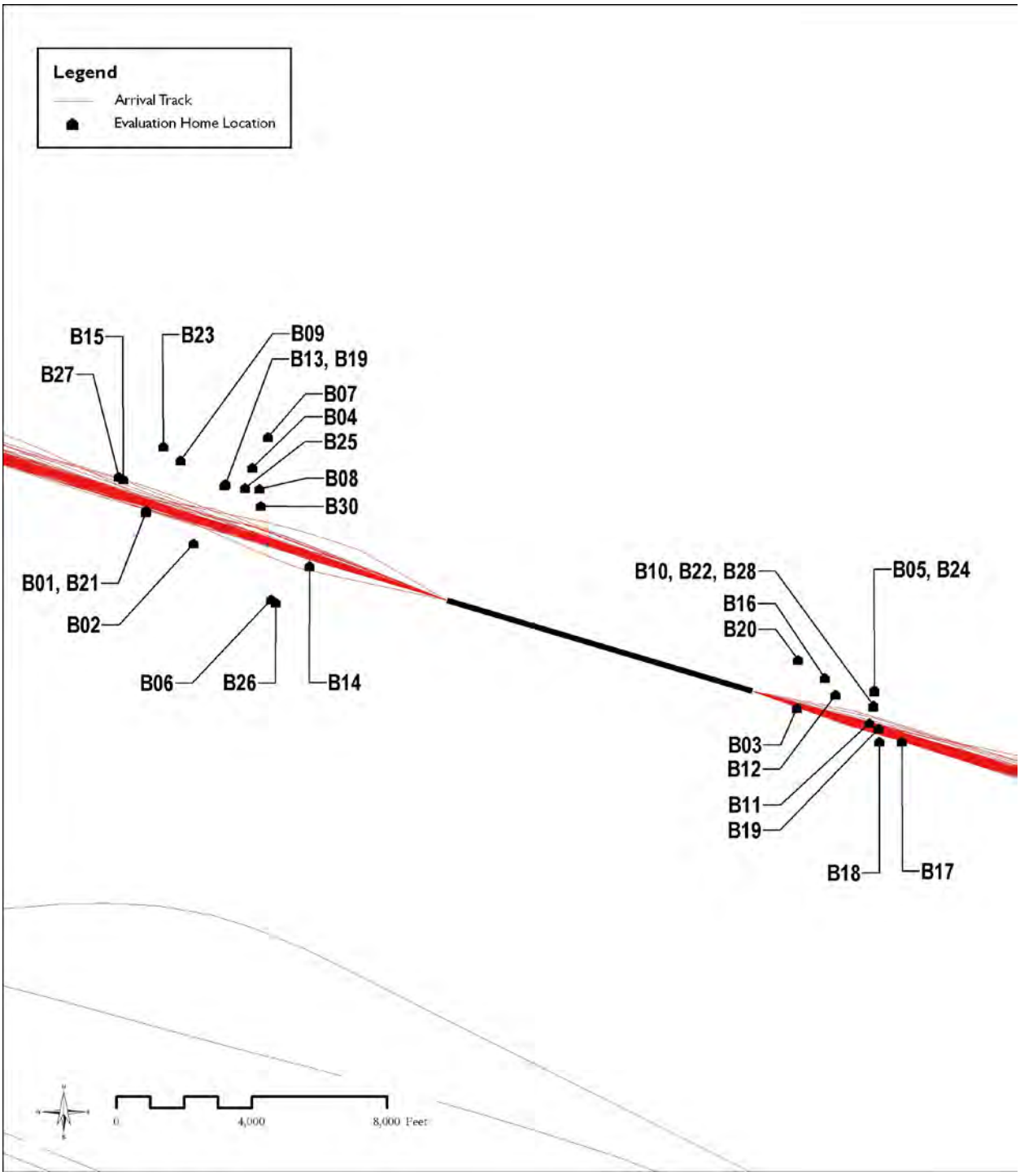

Figure 21. Residences for the Full Analysis in Relation to Study Airport B with Representative Arrival Flight Tracks

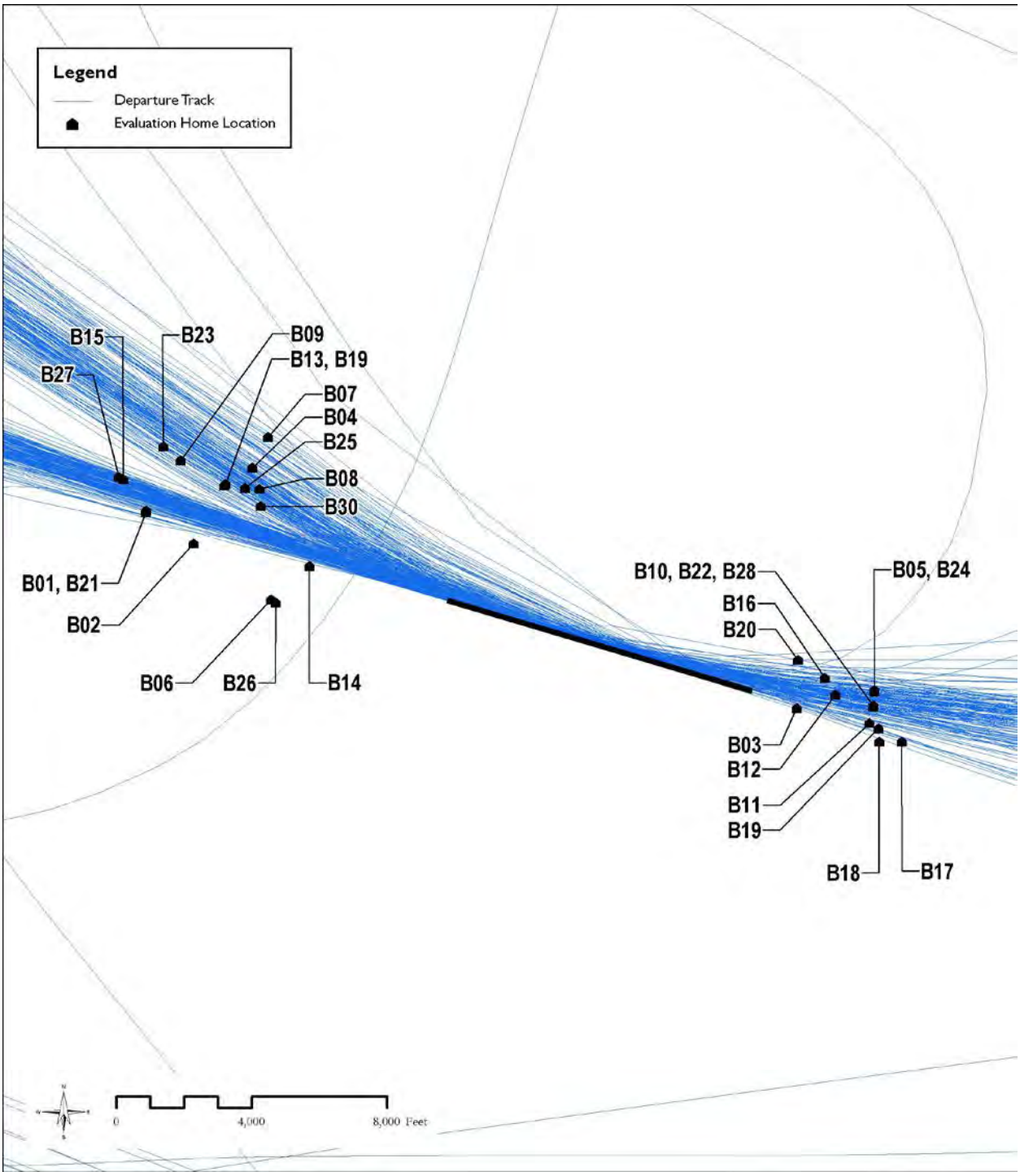

Figure 22. Residences for the Full Analysis in Relation to Study Airport B with Representative Departure Flight Tracks

Appendix D. Measured Outdoor-Indoor Level Reductions (OILRs)

Table 14. Measured Outdoor-Indoor Level Reductions (OILR) for 10 Homes at Study Airport A

House ID	Room	Measured OILR (dB) by Octave Band Center Frequency at 63 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 125 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 250 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 500 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 1000 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 2000 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 4000 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 8000 (Hz)
A01	Bedroom 1 Post	27.7	24.5	31.1	29.5	36.6	46.0	46.0	63.3
A01	Bedroom 1 Pre	25.8	24.0	21.6	21.4	26.0	27.0	31.6	31.1
A01	Bedroom 2 Post	24.5	22.7	34.9	37.5	44.4	52.2	55.2	67.2
A01	Bedroom 2 Pre	23.9	21.6	27.2	31.2	36.5	43.1	46.1	51.5
A01	Bedroom 3 Post	23.0	20.1	27.3	32.4	43.7	50.9	53.1	59.7
A01	Bedroom 3 Pre	17.2	20.0	22.3	26.3	34.3	39.0	43.7	46.5
A01	Dining Room Post	20.2	22.6	17.4	27.3	36.3	40.8	46.1	54.4
A01	Dining Room Pre	23.4	20.8	19.6	21.9	21.7	25.7	28.8	32.7
A01	Kitchen Post	22.7	27.8	30.5	28.2	33.9	41.1	44.4	49.8
A01	Kitchen Pre	24.8	25.2	23.9	24.5	25.0	30.0	30.0	30.7
A01	Living Room Post	18.5	17.3	28.3	29.7	37.0	46.9	47.7	54.2
A01	Living Room Pre	21.0	19.4	18.0	21.0	26.8	31.3	36.5	39.4
A02	Bedroom 1 Post	24.7	19.8	26.7	28.7	35.8	42.3	45.0	57.5
A02	Bedroom 1 Pre	25.9	23.6	20.7	16.6	27.8	32.8	31.0	34.6
A02	Bedroom 2 Post	26.5	25.3	23.4	29.8	37.3	47.8	55.1	62.9
A02	Bedroom 2 Pre	21.4	20.8	16.9	22.8	30.5	33.1	33.7	37.3
A02	Bedroom 3 Post	25.1	27.4	30.2	33.3	40.3	48.6	54.5	62.3
A02	Bedroom 3 Pre	17.4	21.3	19.7	23.4	28.8	35.0	36.3	35.2

House ID	Room	Measured OILR (dB) by Octave Band Center Frequency at 63 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 125 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 250 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 500 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 1000 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 2000 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 4000 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 8000 (Hz)
A02	Dining Room Post	24.2	25.9	28.2	26.5	34.3	37.0	38.6	46.8
A02	Dining Room Pre	20.7	23.3	24.1	24.4	25.6	25.2	25.4	31.9
A02	Kitchen Post	25.5	29.8	27.1	32.1	35.3	40.8	42.7	51.3
A02	Kitchen Pre	19.8	18.0	21.7	20.1	26.1	28.5	28.1	32.6
A02	Living Room Post	21.2	30.2	28.4	31.2	38.9	46.2	51.3	56.0
A02	Living Room Pre	19.3	21.5	17.1	20.4	25.4	24.2	25.7	29.2
A03	Bedroom 1 Post	23.9	19.5	31.6	32.6	38.4	44.5	50.4	61.3
A03	Bedroom 1 Pre	21.2	16.9	19.2	25.3	29.7	33.8	36.0	36.1
A03	Bedroom 2 Post	19.4	18.8	25.1	29.1	36.7	42.3	45.6	58.8
A03	Bedroom 2 Pre	13.9	15.3	15.1	22.5	25.5	28.7	29.6	28.7
A03	Bedroom 3 Post	20.4	25.6	34.5	38.4	39.6	46.0	50.6	70.0
A03	Bedroom 3 Pre	17.1	22.9	22.8	23.9	32.3	35.9	34.1	33.1
A03	Den Post	19.1	21.0	26.8	33.6	36.7	41.4	42.3	53.5
A03	Den Pre	15.6	14.9	12.7	16.1	26.8	28.0	26.2	30.2
A03	Dining Room Post	23.0	24.5	25.9	29.6	36.8	43.3	47.9	56.4
A03	Dining Room Pre	17.2	16.4	12.8	22.7	27.3	29.4	29.7	31.3
A03	Kitchen Post	21.0	22.6	26.9	27.0	36.9	41.6	43.3	45.8
A03	Kitchen Pre	17.5	21.4	18.4	25.6	26.4	29.7	31.2	30.7
A03	Living Room Post	21.7	18.2	27.3	32.1	38.8	43.0	45.8	55.3
A03	Living Room Pre	18.8	15.7	14.1	24.4	25.9	30.0	31.2	30.2
A04	Bedroom 1 Post	29.5	24.8	29.3	28.9	42.3	53.0	57.2	60.8

House ID	Room	Measured OILR (dB) by Octave Band Center Frequency at 63 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 125 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 250 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 500 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 1000 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 2000 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 4000 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 8000 (Hz)
A04	Bedroom 1 Pre	28.4	27.8	22.6	22.5	36.5	44.2	43.8	47.1
A04	Bedroom 2 Post	27.0	27.8	29.4	26.6	39.5	50.8	56.4	63.0
A04	Bedroom 2 Pre	24.8	28.6	23.6	24.3	34.0	43.1	47.8	48.8
A04	Bedroom 3 Post	30.9	28.2	30.1	26.7	38.2	52.9	56.0	58.2
A04	Bedroom 3 Pre	27.3	28.3	21.7	23.1	32.4	43.4	43.8	47.0
A04	Dining Room Post	20.7	24.2	29.4	25.9	36.2	41.7	48.5	57.5
A04	Dining Room Pre	20.0	23.9	18.1	21.7	33.5	39.8	40.6	47.0
A04	Kitchen Post	20.2	23.8	28.1	27.0	38.1	40.7	50.0	55.3
A04	Kitchen Pre	21.0	21.1	21.3	25.3	34.1	34.3	36.5	44.6
A04	Living Room Post	19.3	31.0	30.5	33.1	41.9	43.7	52.3	58.3
A04	Living Room Pre	22.6	27.1	21.1	26.6	34.7	36.4	38.8	38.0
A05	Bedroom 1 Post	29.4	26.8	31.2	33.0	42.0	50.5	54.5	60.7
A05	Bedroom 1 Pre	25.9	26.0	22.9	24.9	29.5	32.5	35.8	39.6
A05	Bedroom 2 Post	27.3	29.8	29.4	30.5	43.0	48.5	53.6	57.4
A05	Bedroom 2 Pre	23.8	27.0	24.6	24.9	32.8	37.7	39.4	45.1
A05	Kitchen Post	23.7	23.8	31.1	35.3	41.9	50.4	54.8	60.9
A05	Kitchen Pre	23.8	23.8	20.9	28.2	37.0	35.1	34.5	40.2
A05	Living Room Post	25.7	31.1	33.2	34.0	44.7	47.5	53.4	59.6
A05	Living Room Pre	20.8	22.8	20.0	21.1	29.2	28.8	31.5	38.8
A06	Bedroom 1 Post	23.4	20.9	27.4	32.4	42.8	48.1	56.0	65.6
A06	Bedroom 1 Pre	27.5	22.8	25.1	27.2	39.6	46.4	49.1	48.9
A06	Bedroom 2 Post	25.5	21.3	28.8	28.8	37.4	42.1	50.8	56.5

House ID	Room	Measured OILR (dB) by Octave Band Center Frequency at 63 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 125 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 250 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 500 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 1000 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 2000 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 4000 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 8000 (Hz)
A06	Bedroom 2 Pre	18.9	20.2	24.0	22.8	31.5	37.1	38.2	43.3
A06	Bedroom 3 Post	24.4	20.7	29.7	28.0	37.1	44.9	50.4	55.6
A06	Bedroom 3 Pre	21.6	22.2	25.7	21.4	32.5	34.9	36.6	41.6
A06	Family Room Post	23.6	25.9	31.0	32.6	41.7	50.1	55.4	63.0
A06	Family Room Pre	20.0	21.7	20.8	22.5	30.7	28.3	32.1	35.0
A06	Kitchen Post	19.2	21.5	29.4	32.7	39.6	43.0	52.3	58.5
A06	Kitchen Pre	18.8	20.3	24.6	26.8	34.2	29.5	30.2	35.7
A06	Living Room Post	22.6	22.1	28.8	29.9	37.8	41.1	48.0	56.2
A06	Living Room Pre	16.6	20.3	23.2	20.8	30.6	31.7	35.0	37.4
A07	Bedroom 1 Post	26.2	21.2	30.3	33.1	41.7	47.1	53.1	61.8
A07	Bedroom 1 Pre	18.8	19.1	24.9	27.7	32.4	31.4	33.5	37.1
A07	Bedroom 2 Post	23.7	27.6	32.5	35.2	44.4	50.5	56.0	59.4
A07	Bedroom 2 Pre	21.8	26.6	27.1	26.3	32.2	28.6	32.3	38.8
A07	Bedroom 3 Post	20.0	21.5	30.1	33.6	44.3	53.6	59.1	63.5
A07	Bedroom 3 Pre	17.1	24.7	19.8	22.9	20.3	21.0	23.2	29.7
A07	Dining Room Post	23.7	24.0	26.5	31.5	38.5	39.2	43.4	51.6
A07	Dining Room Pre	19.5	19.7	20.0	26.7	32.2	31.1	35.1	36.2
A07	Kitchen Post	20.9	22.4	23.1	30.4	38.0	41.4	45.1	52.7
A07	Kitchen Pre	19.9	23.1	21.8	24.1	33.1	36.6	39.6	39.7
A07	Living Room Post	26.0	30.5	27.6	34.2	45.1	45.6	53.1	59.8
A07	Living Room Pre	23.7	26.6	27.0	25.6	36.2	36.1	40.8	43.7

House ID	Room	Measured OILR (dB) by Octave Band Center Frequency at 63 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 125 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 250 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 500 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 1000 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 2000 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 4000 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 8000 (Hz)
A07	Sitting Room Post	22.4	21.1	23.3	23.5	35.8	41.3	43.5	47.1
A07	Sitting Room Pre	20.4	21.0	17.9	19.2	29.5	29.4	32.4	37.6
A08	Bedroom 1 Post	23.4	28.7	32.5	30.4	35.6	44.3	53.9	64.5
A08	Bedroom 1 Pre	23.3	25.3	26.1	24.3	32.0	34.2	36.7	39.0
A08	Bedroom 2 Post	30.8	30.1	31.6	34.2	40.9	47.9	52.2	62.4
A08	Bedroom 2 Pre	23.7	27.5	31.0	30.3	35.8	32.0	31.0	37.8
A08	Den Post	19.1	21.7	29.7	27.7	36.6	42.5	48.9	55.0
A08	Den Pre	20.8	25.5	25.1	25.6	26.5	30.6	33.1	41.5
A08	Dining Room Post	25.1	24.7	25.6	32.1	37.8	44.3	50.8	61.0
A08	Dining Room Pre	23.1	22.9	20.1	21.1	30.5	29.3	30.0	38.8
A08	Kitchen Post	23.4	27.2	28.8	32.3	37.9	41.3	45.9	54.0
A08	Kitchen Pre	22.7	23.0	22.8	20.4	26.7	24.9	25.3	35.1
A08	Living Room Post	18.7	29.5	30.8	33.8	40.6	44.1	50.9	58.2
A08	Living Room Pre	16.8	20.4	21.0	21.9	29.7	28.9	29.6	34.6
A09	Bedroom 1 Post	26.8	27.2	35.7	37.8	44.8	46.6	52.4	59.8
A09	Bedroom 1 Pre	23.7	17.5	24.9	27.9	36.9	37.0	40.5	44.4
A09	Bedroom 2 Post	24.4	21.5	31.2	35.6	36.0	33.8	36.6	44.1
A09	Bedroom 2 Pre	21.2	16.2	20.0	21.9	30.1	30.6	34.1	37.8
A09	Bedroom 3 Post	27.5	23.4	35.5	38.8	42.9	51.0	55.3	64.9
A09	Bedroom 3 Pre	24.1	22.5	27.0	30.7	37.6	44.0	43.2	46.2
A09	Dining Room Post	20.6	24.0	30.2	34.4	43.1	46.5	48.5	55.4

House ID	Room	Measured OILR (dB) by Octave Band Center Frequency at 63 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 125 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 250 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 500 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 1000 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 2000 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 4000 (Hz)	Measured OILR (dB) by Octave Band Center Frequency at 8000 (Hz)
A09	Dining Room Pre	23.5	14.7	18.5	27.9	33.1	31.7	34.5	41.8
A09	Kitchen Post	22.1	23.1	29.3	30.2	36.7	42.5	44.0	41.9
A09	Kitchen Pre	20.0	18.1	17.7	20.9	29.0	31.3	32.1	35.7
A09	Living Room Post	23.2	23.6	28.8	34.5	44.5	47.7	50.7	59.4
A09	Living Room Pre	18.2	19.8	19.5	24.5	35.5	35.5	36.3	45.6
A10	Bedroom 1 Post	26.4	24.8	33.1	33.7	41.6	47.6	51.0	57.2
A10	Bedroom 1 Pre	27.5	24.2	22.2	22.2	31.5	37.7	38.2	40.6
A10	Bedroom 2 Post	21.9	24.9	32.6	37.0	45.1	51.0	56.6	62.8
A10	Bedroom 2 Pre	18.0	19.5	23.3	24.7	25.9	31.6	32.9	33.1
A10	Bedroom 3 Post	20.2	26.1	31.7	30.5	39.1	45.5	51.7	56.9
A10	Bedroom 3 Pre	15.9	16.6	18.9	23.0	25.6	31.3	31.5	34.2
A10	Dining Room Post	20.9	23.7	28.2	31.3	40.4	44.0	45.0	51.1
A10	Dining Room Pre	20.4	18.8	22.9	24.2	22.9	28.1	31.1	38.1
A10	Kitchen Post	27.8	22.5	29.1	31.0	38.3	42.2	46.7	52.4
A10	Kitchen Pre	19.4	19.8	24.3	22.4	18.3	26.1	28.5	32.7
A10	Living Room Post	21.2	27.9	30.5	36.4	43.4	44.0	50.4	56.9
A10	Living Room Pre	21.3	22.0	23.0	23.3	36.2	37.2	37.5	40.3

Table 15. Measured Outdoor-Indoor Level Reductions (OILR) for 30 Units at Study Airport B

House ID	Room	Pre-/Post-Treatment	Measured OILR (dB) by Octave Band Center Freq. at 63 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 125 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 250 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 500 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 1000 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 2000 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 4000 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 8000 (Hz)
B01	Bedroom 2	Post	16.3	18.0	26.8	31.8	36.1	39.7	43.5	53.0
B01	Bedroom 2	Pre	18.4	19.0	21.5	25.0	25.6	28.4	29.4	30.1
B01	Living Room	Post	18.6	19.9	28.3	34.0	40.6	41.5	41.8	47.8
B01	Living Room	Pre	16.3	19.2	22.7	24.9	27.5	28.6	28.0	30.7
B02	Bedroom 2	Post	19.1	22.7	33.0	39.0	41.9	43.1	44.5	51.9
B02	Bedroom 2	Pre	16.1	23.5	14.6	23.6	28.0	33.0	35.2	34.6
B02	Living Room	Post	17.5	17.2	26.4	35.7	39.9	39.5	41.4	52.0
B02	Living Room	Pre	17.8	16.5	16.2	22.9	29.0	29.7	27.7	33.5
B03	Bedroom 1	Post	21.2	24.4	29.2	37.9	43.3	42.4	45.7	53.2
B03	Bedroom 1	Pre	14.8	17.7	20.6	20.7	23.4	19.9	19.2	25.1
B03	Dining Room	Post	15.3	19.8	27.6	33.0	33.2	38.8	40.6	49.2
B03	Dining Room	Pre	12.6	17.2	18.7	20.0	21.9	18.4	20.6	18.3
B04	Bedroom 3	Post	22.8	21.9	24.3	30.7	35.6	38.1	38.3	40.8
B04	Bedroom 3	Pre	16.3	19.8	20.0	24.2	27.7	29.1	29.1	28.3
B04	Living Room	Post	20.2	19.6	22.9	27.1	30.2	30.7	31.3	33.1
B04	Living Room	Pre	16.5	16.6	17.9	22.2	24.9	23.7	22.9	21.4
B05	Bedroom 1	Post	18.5	23.3	26.0	32.8	38.0	39.4	38.5	42.4
B05	Bedroom 1	Pre	15.0	23.9	19.0	24.2	24.2	25.8	28.5	30.6
B05	Living Room	Post	18.2	24.6	22.5	32.4	37.0	39.4	38.7	38.8
B05	Living Room	Pre	16.6	22.3	19.8	25.2	25.6	26.6	24.2	30.1
B06	Bedroom 2	Post	19.7	25.7	29.9	32.4	30.5	37.5	40.9	48.2
B06	Bedroom 2	Pre	7.9	11.9	18.6	19.4	21.3	19.7	20.4	19.7
B06	Family Room	Post	22.9	25.8	24.0	32.1	32.5	35.3	37.7	43.6
B06	Family Room	Pre	11.2	15.2	17.9	21.2	22.4	26.5	23.6	23.5
B07	Bedroom 3	Post	19.4	22.5	27.3	30.5	32.9	29.4	30.5	34.6
B07	Bedroom 3	Pre	13.8	17.5	20.6	22.2	22.7	25.8	24.1	27.9
B07	Family Room	Post	19.7	21.2	27.1	26.7	29.4	28.7	29.6	30.9

House ID	Room	Pre-/Post-Treatment	Measured OILR (dB) by Octave Band Center Freq. at 63 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 125 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 250 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 500 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 1000 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 2000 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 4000 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 8000 (Hz)
B07	Family Room	Pre	13.6	16.2	18.6	18.1	22.4	19.5	20.7	24.6
B08	Bedroom 3	Post	15.2	15.6	21.8	29.8	31.1	33.4	39.8	47.4
B08	Bedroom 3	Pre	15.7	16.1	17.5	19.9	20.5	21.8	20.9	24.1
B08	Living Room	Post	14.4	16.3	24.3	29.6	32.2	35.5	33.5	33.7
B08	Living Room	Pre	13.8	12.9	18.0	21.2	23.5	25.1	23.4	24.3
B09	Bedroom 1	Post	16.8	22.3	31.8	31.1	36.9	41.2	42.8	46.3
B09	Bedroom 1	Pre	13.3	16.6	19.8	22.2	23.6	25.1	24.5	26.7
B09	Dining Room	Post	20.8	26.1	30.5	29.3	33.7	36.7	39.6	42.0
B09	Dining Room	Pre	17.4	20.7	20.8	20.3	23.2	24.4	24.2	25.1
B10	Bedroom 1	Post	21.3	21.5	26.7	31.7	34.1	38.7	39.4	43.3
B10	Bedroom 1	Pre	14.6	16.9	20.5	25.3	29.5	30.4	29.8	28.5
B10	Living Room	Post	19.2	21.9	19.8	31.3	36.3	37.3	36.1	46.3
B10	Living Room	Pre	14.1	16.5	19.6	20.5	23.5	23.3	25.2	31.7
B11	Kitchen	Post	20.0	25.4	28.4	32.0	37.5	40.8	36.8	44.4
B11	Kitchen	Pre	13.8	19.7	20.1	21.5	21.4	21.2	22.7	22.3
B11	Living Area	Post	23.9	24.3	25.3	31.3	37.6	42.3	41.6	43.2
B11	Living Area	Pre	19.2	19.2	20.8	22.6	22.2	21.9	18.9	21.2
B12	Bedroom 1	Post	20.5	21.2	26.9	37.6	39.7	42.5	43.6	53.2
B12	Bedroom 1	Pre	16.7	18.3	18.5	22.7	25.8	27.6	27.4	28.4
B12	Living Room	Post	15.5	19.8	24.8	27.0	28.1	26.4	26.2	30.6
B12	Living Room	Pre	16.3	17.7	18.1	19.9	21.7	22.6	18.7	21.6
B13	Bedroom 1	Post	20.8	22.5	24.5	29.8	46.1	47.0	45.9	57.3
B13	Bedroom 1	Pre	12.1	18.1	19.4	20.7	24.1	25.9	22.5	29.8
B13	Living Room	Post	20.7	23.0	26.5	35.4	42.8	43.6	40.7	48.2
B13	Living Room	Pre	13.9	18.4	19.1	23.3	24.7	24.6	21.7	27.3
B14	Bedroom 2	Post	20.2	20.8	25.4	29.6	35.4	40.0	41.3	46.3
B14	Bedroom 2	Pre	15.3	19.8	19.9	20.8	25.7	22.1	16.7	16.7
B14	Dining Room	Post	20.2	20.9	26.3	31.8	36.6	41.4	43.1	50.2
B14	Dining	Pre	14.3	18.2	18.5	19.3	23.7	22.4	14.7	22.5

House ID	Room	Pre-/Post-Treatment	Measured OILR (dB) by Octave Band Center Freq. at 63 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 125 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 250 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 500 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 1000 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 2000 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 4000 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 8000 (Hz)
	Room									
B15	Bedroom 2	Post	19.3	21.5	21.3	33.2	38.9	46.5	47.9	50.2
B15	Bedroom 2	Pre	16.3	14.7	16.6	24.5	26.8	25.9	28.1	33.8
B15	Living Room	Post	19.4	20.7	19.7	27.1	32.2	38.8	41.5	48.2
B15	Living Room	Pre	15.7	18.1	15.6	22.6	26.7	26.7	30.8	37.5
B16	Bedroom 1	Post	19.7	20.9	27.3	34.6	43.2	50.0	50.7	48.3
B16	Bedroom 1	Pre	17.6	19.5	17.6	22.1	23.6	21.7	24.4	29.3
B16	Living Room	Post	25.3	24.3	26.3	32.7	36.4	39.6	40.3	44.8
B16	Living Room	Pre	19.9	22.4	19.6	23.4	29.9	27.5	23.6	31.9
B17	Bedroom 1	Post	21.1	25.5	25.7	38.6	43.2	44.7	45.7	53.6
B17	Bedroom 1	Pre	12.6	15.6	17.2	21.1	23.4	22.1	21.0	23.4
B17	Living Room	Post	22.5	23.9	22.5	28.3	37.2	38.1	37.5	40.8
B17	Living Room	Pre	8.6	12.0	9.4	15.7	19.1	23.5	20.4	14.4
B18	Bedroom 1	Post	20.1	24.2	25.3	29.2	34.9	38.1	37.0	39.5
B18	Bedroom 1	Pre	19.8	20.8	19.1	23.9	26.4	25.3	23.8	28.6
B18	Living Room	Post	22.7	25.5	23.7	26.9	27.6	27.9	30.7	34.3
B18	Living Room	Pre	16.5	16.1	17.8	21.1	19.7	19.8	20.0	23.2
B19	Bedroom 1	Post	25.5	25.2	26.3	32.5	36.0	34.0	31.4	33.6
B19	Bedroom 1	Pre	11.1	15.9	18.0	21.5	23.5	25.4	25.7	23.0
B19	Living Room	Post	23.1	25.4	25.1	27.6	29.1	32.1	34.2	35.6
B19	Living Room	Pre	15.7	19.2	16.7	22.7	22.5	20.3	20.7	20.7
B20	Bedroom 2	Post	24.9	26.1	31.4	39.2	45.6	47.9	51.1	55.7
B20	Bedroom 2	Pre	17.6	18.7	19.7	24.0	28.6	27.2	27.3	31.7
B20	Living Room	Post	21.5	22.5	30.3	38.4	41.2	42.3	46.4	43.3
B20	Living Room	Pre	14.4	19.7	20.1	21.8	24.5	18.3	21.3	27.5
B21	Bedroom 2	Post	13.6	16.2	20.1	23.0	26.0	27.0	27.2	30.4
B21	Bedroom 2	Pre	14.9	16.4	17.9	19.6	19.6	23.3	24.7	24.3
B21	Living Room	Post	21.8	18.1	29.7	36.4	39.8	42.7	41.8	45.6

House ID	Room	Pre-/Post-Treatment	Measured OILR (dB) by Octave Band Center Freq. at 63 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 125 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 250 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 500 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 1000 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 2000 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 4000 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 8000 (Hz)
B21	Living Room	Pre	17.6	17.8	19.4	21.5	27.0	24.6	28.2	32.6
B22	Bedroom 1	Post	20.7	22.8	29.5	38.5	41.3	46.4	47.4	54.0
B22	Bedroom 1	Pre	17.4	14.1	18.0	22.3	22.5	18.6	17.0	27.8
B22	Living Room	Post	18.8	22.4	23.7	33.2	37.7	42.2	41.8	50.7
B22	Living Room	Pre	14.2	18.4	19.0	14.9	18.4	21.6	21.6	25.6
B23	Bedroom 2	Post	19.7	23.4	29.2	38.3	41.9	45.8	47.5	56.7
B23	Bedroom 2	Pre	16.8	21.2	17.4	22.1	23.4	19.5	23.3	25.5
B23	Living Room	Post	21.8	23.6	27.9	34.9	34.0	32.8	36.0	33.4
B23	Living Room	Pre	17.8	20.7	19.7	24.1	25.6	22.8	21.5	19.9
B24	Bedroom 1	Post	19.6	24.8	26.8	31.6	36.3	37.8	35.8	33.3
B24	Bedroom 1	Pre	13.7	21.2	20.3	25.4	26.7	27.9	32.9	36.5
B24	Living Room	Post	18.0	26.6	24.4	32.4	36.6	38.8	38.0	39.2
B24	Living Room	Pre	13.9	20.2	20.1	22.7	21.4	20.1	26.7	29.9
B25	Bedroom 1	Post	16.3	23.4	24.4	31.2	35.5	36.5	37.9	43.1
B25	Bedroom 1	Pre	9.6	17.0	14.3	15.7	18.3	20.9	19.9	15.4
B25	Living Room	Post	22.9	25.6	26.5	32.7	34.1	31.4	32.2	29.8
B25	Living Room	Pre	18.4	21.6	20.0	23.4	24.8	20.2	23.0	19.4
B26	Bedroom 5	Post	23.1	26.9	30.3	33.9	36.1	41.3	42.7	43.4
B26	Bedroom 5	Pre	14.7	17.6	19.4	22.3	25.2	22.5	23.0	19.5
B26	Dining Room	Post	22.8	25.1	25.7	32.2	36.1	41.4	43.9	44.7
B26	Dining Room	Pre	13.9	19.7	20.0	21.0	21.0	24.1	20.7	20.1
B27	Bedroom 3	Post	25.3	26.9	28.3	39.9	44.3	42.0	42.5	48.7
B27	Bedroom 3	Pre	20.2	21.3	20.5	25.3	27.0	28.7	28.7	32.3
B27	Living Room	Post	20.3	20.7	26.8	33.8	38.0	37.4	38.4	45.9
B27	Living Room	Pre	16.4	17.4	17.4	20.6	20.9	17.0	15.0	20.5
B28	Bedroom 1	Post	21.8	23.5	30.7	35.9	42.4	45.6	44.2	50.2
B28	Bedroom 1	Pre	14.7	18.9	17.6	22.7	27.5	30.0	33.7	28.3
B28	Living	Post	21.4	24.3	20.6	32.7	36.2	36.5	40.1	48.6

House ID	Room	Pre-/Post-Treatment	Measured OILR (dB) by Octave Band Center Freq. at 63 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 125 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 250 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 500 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 1000 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 2000 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 4000 (Hz)	Measured OILR (dB) by Octave Band Center Freq. at 8000 (Hz)
	Room									
B28	Living Room	Pre	13.1	16.0	17.0	18.0	20.3	17.2	21.3	22.9
B29	Bedroom 1	Post	21.6	22.6	23.8	30.0	44.6	46.5	45.4	54.0
B29	Bedroom 1	Pre	13.3	17.5	17.0	18.4	19.9	21.2	18.3	24.8
B29	Living Room	Post	22.1	24.6	25.9	35.1	41.9	43.7	41.9	46.9
B29	Living Room	Pre	11.4	17.9	17.5	20.8	21.7	23.3	18.8	23.1
B30	Bedroom 5	Post	24.8	27.3	29.1	34.4	36.9	41.6	42.8	39.6
B30	Bedroom 5	Pre	16.1	19.3	18.3	22.0	20.4	21.4	21.0	20.6
B30	Living Room	Post	19.1	23.8	25.7	30.9	31.5	29.8	30.1	33.9
B30	Living Room	Pre	13.7	16.8	19.3	22.6	26.8	20.2	20.1	22.3

Appendix E. Noise Spectra for Aircraft Groupings used in Method 4A

Table 16. Spectra for Arrival Aircraft Groupings used in Method 4A, Normalized to 70 dB at 1 kHz

Spectrum	HEL A	MIL A	TF A	TJ A	TP A	TPP A
1/3 OBCF (Hz)	Sound Pressure Levels (dBA) by 1/3 OBCF	Sound Pressure Levels (dBA) by 1/3 OBCF	Sound Pressure Levels (dBA) by 1/3 OBCF	Sound Pressure Levels (dBA) by 1/3 OBCF	Sound Pressure Levels (dBA) by 1/3 OBCF	Sound Pressure Levels (dBA) by 1/3 OBCF
50	1.4	13.8	5.4	7.6	4.5	8.9
63	6.2	30.3	12.4	10.7	17.3	16.3
80	14.6	31.6	20.3	19.7	23.3	32.8
100	27.0	36.6	29.0	33.0	38.5	50.3
125	41.0	48.4	40.9	42.1	39.2	49.9
160	52.4	50.1	47.0	48.2	47.7	52.4
200	49.7	53.5	50.3	48.5	54.4	66.2
250	58.8	57.2	53.7	55.4	58.4	67.0
315	68.6	61.2	60.5	58.9	65.2	70.3
400	68.8	64.8	63.0	63.7	61.5	70.8
500	72.6	66.5	66.3	64.9	61.1	73.4
630	72.1	68.5	68.6	66.9	65.5	74.5
800	72.0	69.2	70.3	68.7	64.3	73.5
1,000	70.0	70.0	70.0	70.0	70.0	70.0
1,250	68.8	70.0	70.5	70.5	70.4	69.0
1,600	67.0	69.2	71.2	70.0	67.7	69.0
2,000	65.0	68.3	69.0	70.2	65.8	67.4
2,500	62.0	69.8	72.7	68.9	63.9	65.7
3,150	57.8	65.2	69.2	66.8	62.8	63.3
4,000	51.9	60.2	68.1	64.0	71.1	60.0
5,000	46.1	56.3	62.1	58.2	62.4	57.2
6,300	36.7	48.5	55.4	52.0	48.8	59.2

Source:
Based on Table 2 in FAA, "Spectral Classes for FAA's Integrated Noise Model Version 6.0," DTS-34-FA065-LR1, December 7, 1999. Compiled by HMMH, 2015.

Table 17. Spectra for Departure Aircraft Groupings used in Method 4A, Normalized to 70 dB at 1 kHz

Spectrum	HEL D	MIL D	TF D	TJ D	TP D	TPP D
1/3 OBCF (Hz)	Sound Pressure Levels (dBA) by 1/3 OBCF	Sound Pressure Levels (dBA) by 1/3 OBCF	Sound Pressure Levels (dBA) by 1/3 OBCF	Sound Pressure Levels (dBA) by 1/3 OBCF	Sound Pressure Levels (dBA) by 1/3 OBCF	Sound Pressure Levels (dBA) by 1/3 OBCF
50	16.5	1.0	2.0	-1.9	14.6	17.3
63	21.4	11.4	10.2	5.5	41.8	40.2
80	27.5	27.9	22.0	15.7	46.7	34.3
100	46.8	31.4	34.7	28.8	57.2	36.8
125	58.5	49.9	45.5	39.0	63.0	54.5
160	65.8	53.3	48.2	45.8	62.7	55.5
200	65.1	50.8	49.3	48.5	67.7	57.9
250	64.6	59.5	57.1	55.5	65.6	55.9
315	69.8	61.2	60.4	59.7	73.4	58.9
400	69.3	64.3	63.9	63.9	66.8	61.0
500	69.9	67.0	66.3	66.4	69.0	63.7
630	69.8	69.1	68.0	68.2	71.6	66.3
800	69.8	70.1	70.0	69.7	71.1	67.0
1,000	70.0	70.0	70.0	70.0	70.0	70.0
1,250	69.5	71.2	69.8	70.1	71.8	69.9
1,600	67.9	70.6	70.3	69.1	73.3	68.7
2,000	65.8	71.8	68.9	66.9	72.7	66.7
2,500	63.7	71.0	68.7	65.6	71.8	64.2
3,150	59.9	73.1	64.9	62.6	67.7	60.5
4,000	54.3	65.8	63.2	57.8	65.2	57.1
5,000	49.9	59.3	58.9	53.1	60.2	51.6
6,300	46.9	54.5	53.0	44.9	53.0	45.1

Source:
Based on Table 2 in FAA, "Spectral Classes for FAA's Integrated Noise Model Version 6.0," DTS-34-FA065-LR1, December 7, 1999. Compiled by HMMH, 2015.

Appendix F. Calculated NLRs by Method for Each Residential Unit at Both Study Airports

Table 18. Calculated Pre-construction Average NLR by Evaluation Method for Both Study Airports

Site	1A-1	1A-2	1B	2A-1	2A-2	2B-1	2B-2	3A	3B	4A-1	4A-2	4A-3	4A-4	4A-5	4A-6	4A-7	4A-8	4A-9	4A-10	4A-11	4A-12	5	6A	6B	6C	6D / 7[1]	8_1	8_2
A01	25	26	25	26	27	26	27	27	27	26	25	28	29	29	28	28	28	28	26	25	27	29	26	27	27	27	26	27
A02	23	24	23	23	25	23	25	25	24	23	23	25	26	26	26	26	25	26	24	23	25	26	24	24	24	23	23	23
A03	22	24	23	23	25	23	25	25	25	23	22	26	27	27	26	27	26	26	23	23	26	27	23	24	24	25	25	24
A04	26	28	26	27	29	27	29	29	29	26	26	30	31	31	30	31	30	30	27	26	30	31	27	28	28	29	28	29
A05	26	28	26	27	29	27	29	29	29	27	26	29	30	30	30	30	29	30	27	26	29	30	27	28	28	28	28	28
A06	26	28	26	27	28	27	28	28	28	26	26	29	30	30	29	30	29	30	27	26	29	30	27	28	28	28	28	28
A07	26	27	26	26	28	26	28	28	27	26	26	28	29	29	28	29	28	29	26	26	28	29	26	27	27	26	26	26
A08	26	27	26	26	27	26	27	27	27	26	26	28	28	29	28	28	28	28	27	26	28	29	27	27	27	26	26	26
A09	25	28	27	27	29	27	29	29	29	27	25	30	31	31	30	31	30	30	27	26	29	31	27	28	28	28	28	28
A10	24	25	24	24	26	24	26	26	25	24	24	26	27	27	27	27	26	27	25	24	26	27	25	25	26	24	24	24
B01	25	26	24	25	26	25	26	26	25	25	25	27	27	27	27	27	26	27	25	25	26	27	25	26	25	25	25	25
B02	23	25	22	23	25	23	25	25	23	24	22	26	27	27	27	27	26	26	23	23	26	27	23	24	23	22	22	22
B03	21	20	20	21	20	21	20	20	20	21	20	21	20	20	21	21	21	21	20	21	21	20	20	20	20	20	20	20
B04	24	24	23	23	24	23	24	24	23	24	23	25	25	25	25	25	25	25	23	23	25	25	24	24	24	23	23	23
B05	24	25	24	24	25	24	25	25	25	24	24	25	25	25	25	25	25	25	24	24	25	25	24	24	25	25	25	24
B06	21	21	20	21	21	21	21	21	21	21	20	22	22	22	22	22	22	22	20	20	21	22	21	21	21	20	20	20
B07	21	22	21	21	22	21	22	22	21	21	21	22	22	22	22	22	22	22	21	21	22	22	21	21	21	21	21	21
B08	21	21	21	21	21	21	21	21	21	21	20	22	22	22	22	22	22	22	21	21	22	22	21	21	21	20	20	20
B09	22	23	23	22	23	22	23	23	22	22	22	23	24	24	23	23	23	23	22	22	23	24	22	23	22	22	22	22
B10	24	25	23	24	25	24	25	25	25	24	23	25	26	26	25	26	25	25	23	23	25	26	24	24	24	25	25	24
B11	22	21	21	22	21	22	21	21	21	22	21	22	21	21	22	22	22	21	21	22	22	21	21	21	21	21	21	21
B12	22	22	21	22	22	22	22	22	22	22	21	23	23	23	23	23	23	23	22	22	23	23	22	22	22	22	22	22
B13	23	23	23	23	23	23	23	23	23	23	22	24	24	24	24	24	24	23	22	22	24	24	23	23	23	22	22	22
B14	21	19	21	21	20	21	20	20	21	21	21	21	21	21	21	21	22	20	21	21	22	20	21	20	21	21	21	21
B15	23	24	21	23	24	23	24	24	23	23	22	25	26	26	25	26	25	25	22	22	25	26	23	24	23	22	22	22
B16	23	24	23	23	24	23	24	24	24	23	23	24	24	24	24	25	25	24	23	23	24	25	23	24	24	23	24	23
B17	19	19	19	18	19	18	19	19	19	19	18	20	20	21	20	21	20	20	18	18	20	20	19	19	19	20	20	19
B18	22	22	21	22	22	22	22	22	22	22	21	22	22	22	22	22	22	22	22	22	22	23	22	22	22	22	22	22
B19	22	22	22	21	22	21	22	22	22	22	21	22	22	23	22	22	22	22	21	21	22	22	21	22	22	22	22	22
B20	23	23	23	23	23	23	23	23	23	23	23	24	24	24	24	24	24	24	23	23	24	24	23	23	23	23	23	23
B21	22	23	21	21	23	21	23	23	21	21	21	23	23	23	23	23	23	23	22	21	22	23	22	22	22	21	21	21
B22	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	20	19	19	19	19	19	19
B23	22	22	22	22	22	22	22	22	22	23	22	23	22	22	23	22	23	22	22	22	23	22	22	22	22	22	22	22
B24	23	25	23	23	24	23	24	24	24	24	23	24	25	25	24	24	24	25	23	23	24	25	24	24	24	24	24	24
B25	20	20	20	20	20	20	20	20	20	20	20	20	20	21	20	20	20	21	20	20	20	20	20	20	20	20	20	20
B26	22	22	21	22	22	22	22	22	22	22	22	22	22	23	23	23	23	22	22	22	22	22	22	22	22	22	22	22
B27	22	22	22	22	22	22	22	22	22	23	22	23	22	23	23	23	23	22	22	22	23	23	22	22	22	22	22	22
B28	21	22	20	21	22	21	22	22	22	21	20	22	23	23	23	23	22	23	21	21	22	23	21	22	22	22	22	22
B29	20	20	20	20	20	20	20	20	20	20	20	21	21	21	21	21	21	20	20	20	21	21	20	20	20	20	20	20
B30	22	21	21	22	21	22	21	21	22	22	21	22	21	21	22	22	22	21	21	22	22	21	21	21	21	21	21	21

Notes: 1.) Methods 6 D and 7 are mathematically equivalent and so yield the same NLR results.

Table 19. Calculated Post-construction Average NLR by Evaluation Method for Both Study Airports

Site	1A-1	1A-2	1B	2A-1	2A-2	2B-1	2B-2	3A	3B	4A-1	4A-2	4A-3	4A-4	4A-5	4A-6	4A-7	4A-8	4A-9	4A-10	4A-11	4A-12	5	6A	6B	6C	6D / 7[1]	8_1	8_2
A01	30	33	30	32	34	32	34	34	34	33	31	36	37	38	36	37	36	36	32	32	35	37	32	33	33	33	33	33
A02	31	33	32	32	34	32	34	34	33	32	31	35	36	37	35	36	35	36	32	32	35	36	32	33	33	32	32	31
A03	30	34	33	33	34	33	34	34	34	33	31	36	37	37	36	37	36	36	32	33	35	37	32	33	33	34	34	34
A04	31	33	31	32	34	32	34	34	34	31	31	35	36	37	35	36	35	36	33	31	35	36	32	33	33	34	34	34
A05	34	37	34	36	38	36	38	38	38	36	34	39	40	41	40	40	39	40	36	35	39	40	36	37	37	37	37	37
A06	31	34	31	33	35	33	35	35	35	33	31	36	37	38	37	37	36	37	33	33	35	37	33	34	34	34	34	34
A07	31	35	31	33	35	33	35	35	33	34	32	37	38	39	37	38	37	37	33	33	36	38	33	34	34	33	33	33
A08	33	35	33	34	36	34	36	36	34	34	33	37	38	38	37	38	36	37	34	33	36	38	34	35	35	33	34	33
A09	33	37	36	36	37	36	37	37	37	37	34	39	40	40	39	40	39	39	35	36	38	40	35	36	36	37	37	37
A10	33	36	33	35	37	35	37	37	35	35	34	38	40	40	39	40	38	39	35	35	38	39	35	36	36	34	35	34
B01	33	34	29	32	34	32	34	34	32	34	30	36	37	37	36	37	36	36	31	33	34	37	32	33	32	31	32	32
B02	35	37	31	35	36	35	36	36	35	37	32	39	39	40	39	40	39	39	33	35	36	39	34	35	34	34	34	34
B03	34	36	31	34	35	34	35	35	35	35	32	37	38	38	37	38	37	37	33	34	36	38	34	35	35	37	36	36
B04	29	30	27	29	30	29	30	30	29	30	28	31	32	32	32	32	31	31	29	29	31	32	29	30	29	28	28	28
B05	32	33	30	32	33	32	33	33	33	33	30	35	36	36	35	36	35	35	31	31	34	36	32	33	33	33	33	32
B06	31	33	30	31	33	31	33	33	31	32	30	33	34	34	33	33	33	33	31	31	32	34	32	32	31	31	31	31
B07	29	29	29	29	29	29	29	29	29	29	28	30	30	30	30	30	30	30	29	29	30	30	29	29	29	29	29	28
B08	29	30	29	28	30	28	30	30	28	30	26	31	32	32	31	32	31	31	27	28	30	32	28	29	28	28	27	27
B09	33	34	33	32	34	32	34	34	32	32	32	34	35	36	35	35	34	35	33	32	34	35	33	33	33	32	32	32
B10	30	32	28	30	32	30	32	32	32	31	29	33	34	35	34	34	33	33	30	30	33	34	30	31	31	32	32	31
B11	33	34	34	33	34	33	34	34	34	33	31	35	36	37	36	36	35	35	32	32	35	36	33	33	34	35	35	34
B12	31	31	28	30	31	30	31	31	31	32	29	33	33	33	33	33	33	32	29	31	32	33	30	31	31	31	31	31
B13	33	35	34	33	34	33	34	34	33	34	31	37	38	39	38	38	37	37	32	32	36	38	33	34	33	32	32	32
B14	31	33	29	31	33	31	33	33	31	32	30	34	35	36	35	35	34	35	31	31	34	35	31	32	31	31	31	31
B15	29	31	27	29	31	29	31	31	29	30	27	33	34	35	33	34	33	32	28	28	32	34	29	30	29	28	28	28
B16	34	35	31	33	35	33	35	35	35	34	31	37	38	39	37	38	37	37	32	33	36	38	33	34	35	34	34	34
B17	32	34	34	32	34	32	34	34	34	33	31	36	37	38	37	37	36	35	31	32	35	37	32	33	34	35	35	34
B18	29	30	28	29	30	29	30	30	30	29	28	30	31	31	31	31	30	31	29	28	30	31	29	29	30	30	30	30
B19	30	31	31	30	31	30	31	31	31	30	29	32	32	32	32	32	32	31	30	30	31	32	30	31	31	31	31	31
B20	37	39	37	37	39	37	39	39	37	39	35	41	42	42	41	42	41	41	36	37	39	41	37	38	38	36	38	37
B21	29	30	26	29	30	29	30	30	29	30	27	32	32	33	32	32	32	32	28	29	30	32	29	29	29	28	28	28
B22	34	36	31	34	35	34	35	35	35	35	32	38	39	39	38	39	38	37	33	34	36	39	34	35	35	36	36	35
B23	35	36	35	34	35	34	35	35	34	36	33	37	37	38	37	37	37	37	33	34	36	37	34	35	34	33	33	33
B24	32	33	31	32	33	32	33	33	33	33	31	35	35	36	35	35	35	34	32	32	34	35	32	33	33	33	33	32
B25	31	32	32	31	32	31	32	32	31	32	30	33	33	34	33	33	33	33	31	31	33	33	31	32	31	31	31	31
B26	33	35	32	33	35	33	35	35	33	34	32	36	37	37	36	37	36	36	33	33	35	37	34	34	33	32	32	33
B27	35	36	32	35	36	35	36	36	35	36	33	38	38	39	38	39	38	38	34	35	37	38	35	35	35	34	34	34
B28	33	35	31	33	35	33	35	35	35	34	31	37	37	38	37	38	37	36	32	33	36	37	33	34	34	35	35	34
B29	33	34	34	32	34	32	34	34	32	34	31	37	38	39	37	38	37	36	32	32	36	37	33	34	32	32	32	32
B30	32	33	33	32	33	32	33	33	32	33	31	34	34	34	34	34	34	34	32	32	33	34	32	33	32	32	32	32

Notes: 1.) Methods 6 D and 7 are mathematically equivalent and so yield the same NLR results.

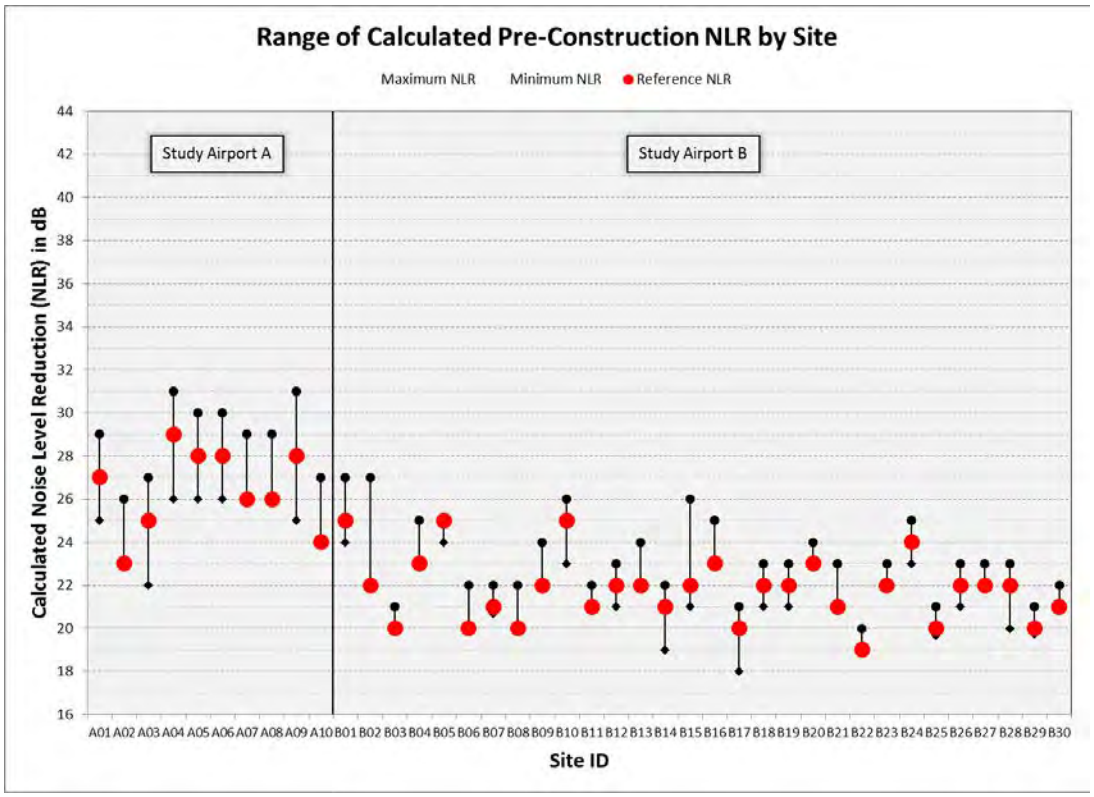

Figure 23. Ranges of Calculated Pre-construction NLR by Site

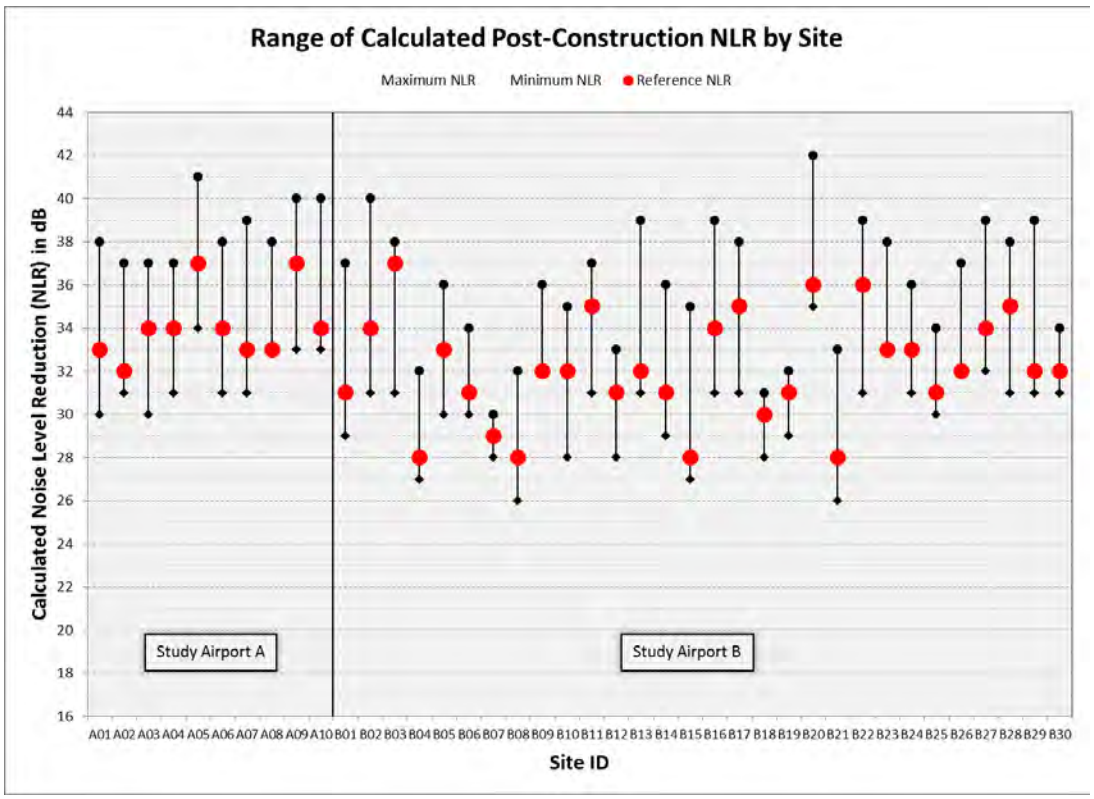

Figure 24. Ranges of Calculated Post-construction NLR by Site

References and Endnotes

[i] FAA Order 5100.38D, "Airport Improvement Program Handbook," Effective September 30, 2014.
[ii] See http://tc.gc.ca/eng/civilaviation/standards/aerodromeairnav-standards-noise-ibana-922.htm#.
[iii] FAA, "Spectral Classes for FAA's Integrated Noise Model Version 6.0," DTS-34-FA065-LR1, December 7, 1999.
[iv] ASTM Standard E1332, "Standard Classification for Rating Outdoor-Indoor Sound Attenuation," effective date.