

Aircraft Noise Measurement Report

Willow Hill Road

Annapolis, MD 21403

Prepared by Harris Miller Miller & Hanson, Inc.

August 2017

1. INTRODUCTION

This memorandum presents the measured aircraft noise levels for the period of July 10 to July 24, 2017 at Willow Hill Road Annapolis, MD 21403. This residence is located approximately 16.5 miles southeast of the southeastern end of Runway 15R/33L of Baltimore/Washington International Thurgood Marshall (BWI Marshall) Airport. Figure 1 shows the location of the measurement site (marked as BW250) relative to BWI Marshall. Measurement data were collected and analyzed on behalf of the Maryland Department of Transportation Aviation Administration (MAA) by Harris Miller Miller & Hanson (HMMH) and Straughan Environmental (SE). The equipment was regularly checked for function and calibrated during the measurements. With the exception of brief periods during calibration, noise levels were monitored continuously throughout the measurement period. The equipment experienced one variance from its expected operating parameters for up to two days. This is further discussed in Section 2 of this memorandum.



At the conclusion of the measurement period, data were uploaded to the MAA's Noise and Operations Monitoring System (NOMS). The NOMS compared the times of loud noise events to its database of aircraft radar flight paths. Loud noise events which occurred while aircraft were passing within the vicinity were identified as aircraft noise. This matching of noise events to individual aircraft flights makes possible the calculation of the total aircraft noise exposure over a particular hour or day as well as the full measurement period. Additionally, the relative contribution of different aircraft types (e.g. jet aircraft, propeller aircraft, helicopters) or operations (e.g. arrivals, departures) to the total noise exposure can be computed.

Section 2 of this memorandum describes the measurement location. Section 3 presents information about the aircraft operations during the measurement period. Section 4 summarizes the measured noise levels. Section 5 provides conclusions. The appendix titled "How Do We Describe Aircraft Noise" provides background information on acoustical terms used in this memorandum.

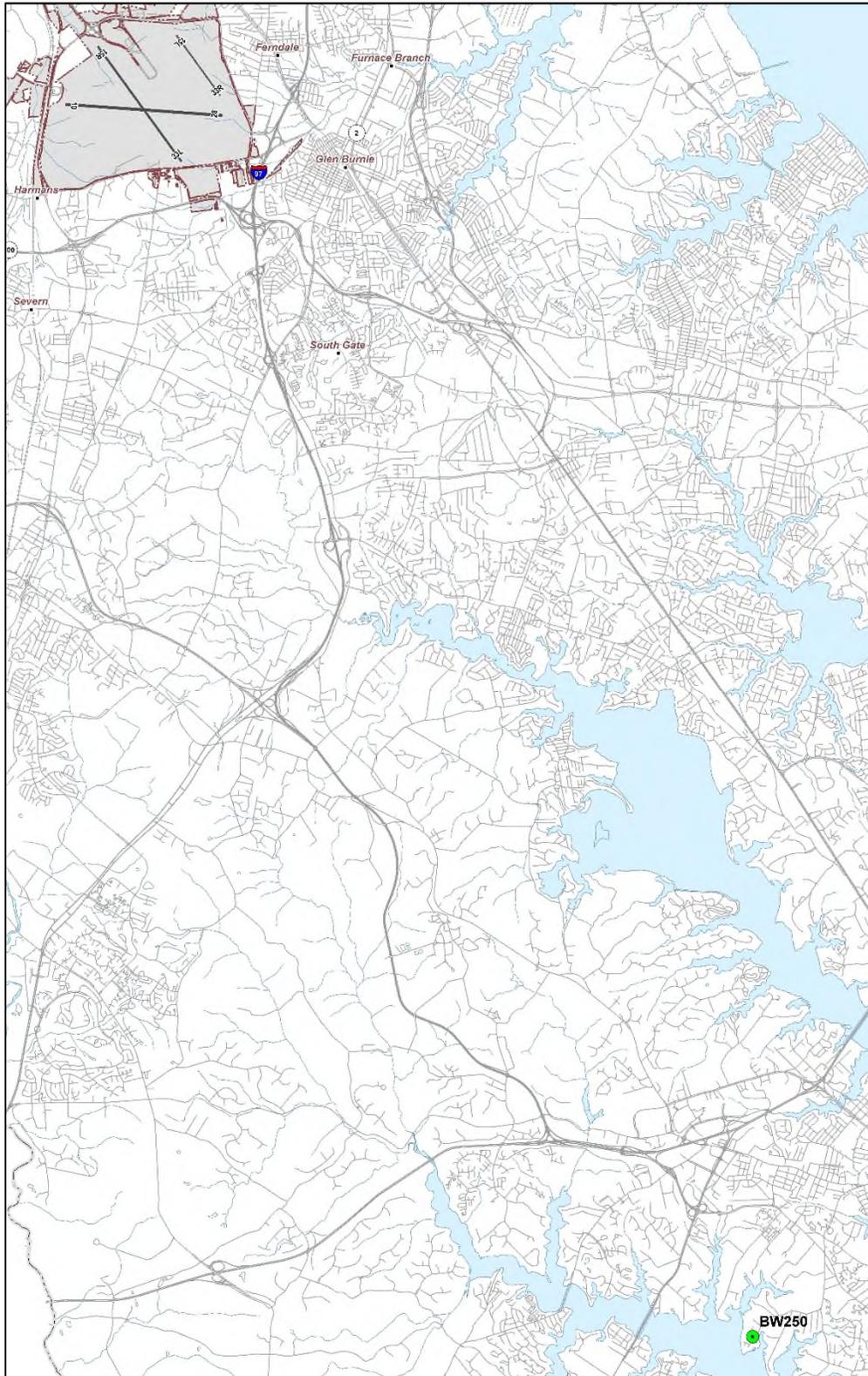


Figure 1. Noise Monitoring Location Map

2. MEASUREMENT SITE

Aircraft noise levels were measured from midday on July 10 through the early afternoon of July 24, 2017 at Willow Hill Road in Annapolis. The noise monitor was placed in the front yard of the residence. Figure 2 shows the placement of the noise monitoring equipment.

The noise monitor is a Type I sound level meter and is regularly calibrated. Additionally, the system was calibrated every two to four days during the measurements during equipment checks. These checks typically show small variances in the calibrated level of up to 1 dB. The equipment check on July 21 showed a variance of 2 dB. The calibration on the meter was reset and no further variances above 1 dB were observed during the measurements. The equipment was checked two days prior with no sign of malfunction. Given the small size and short period of the larger than expected variance, this data was not excluded from the analysis for this report. Apart from this issue, the equipment experienced no malfunctions and the meter was only stopped briefly for the periodic calibration checks.



Notable noise sources at this site include aircraft overflights, primarily arrivals to BWI Marshall and other overflight not associated with BWI Marshall, and typical suburban sounds including landscaping equipment, barking dogs, and nearby construction.

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Figure 2. Noise Measurement Microphone

3. AIRCRAFT OPERATIONS

The measurement site is located to the southeast of BWI Marshall and the primary aircraft noise events for this site are due to arrivals on BWI Marshall Runway 33L. Other less common aircraft noise events are due to other overflights not associated with BWI Marshall and arrivals on Runway 10.

During the measurement period, BWI Marshall operated in two configurations:

- departures on Runway 28 and arrivals on Runway 33L (west flow) and
- departures on Runway 15R and arrivals on Runway 10 (east flow).

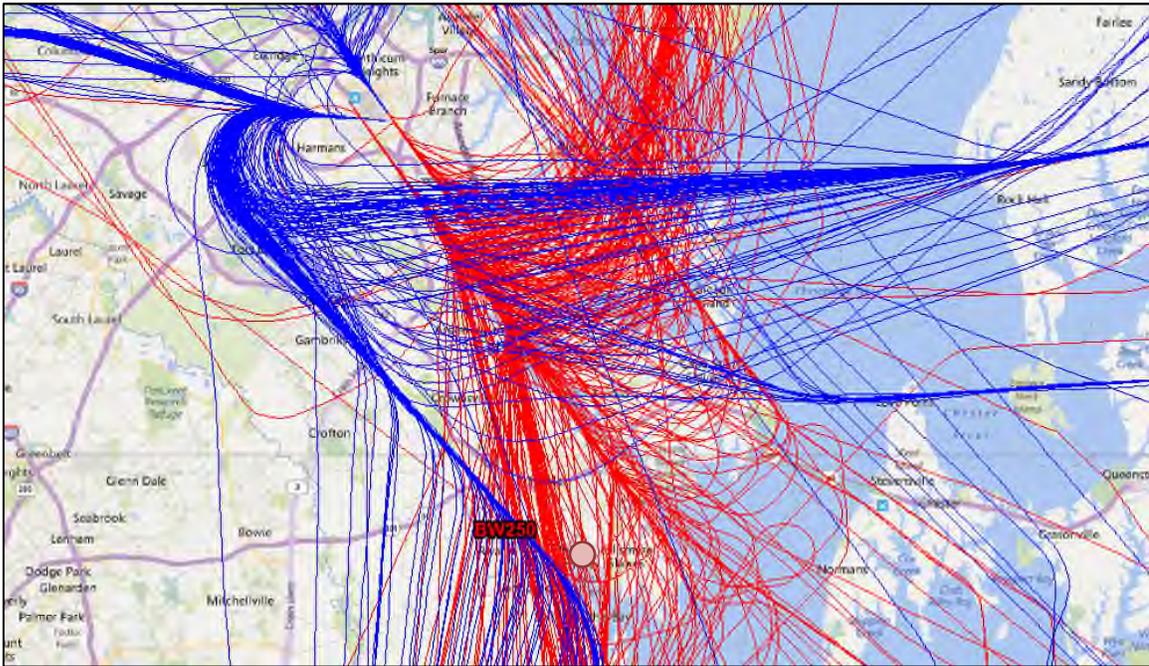
The most common configuration on an annual basis at BWI Marshall, departures on Runway 28 and arrivals on Runway 33L, was active for nine days during the measurement period. On six days, BWI Marshall operated in combinations of the two configurations above during different portions of the day. Table 1 in the Measured Noise Levels section includes a description of the primary arrival and departure runways for each day.



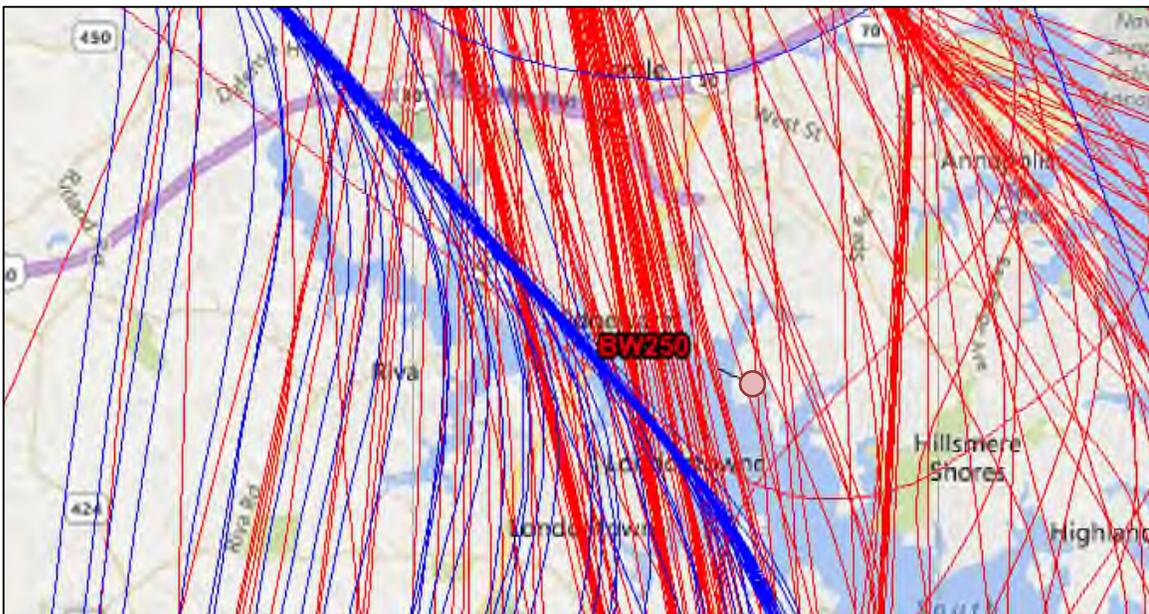
Figure 3 displays all BWI Marshall flight tracks for a typical day during the measurement period in west flow, which primarily utilizes Runway 28 for departures and Runway 33L for arrivals. The red flight tracks are arrivals and the blue flight tracks are departures. The location of the measurement site is marked with its unique identifier in the NOMS, “BW250”. Figure 4 displays the same west flow flight tracks at a larger scale. Again, the text “BW250” shows the location of the measurement site. In west flow, the primary BWI Marshall overflights were arrivals on Runway 33L. Arrivals on Runway 33L were 3,100 to 5,000 ft. above ground level at their point of closest approach to the measurement site, with the most common altitude being 4,100 ft. Note that Figure 3 and Figure 4 also show departures from Runway 28 near the measurement site. These departures are generally at a much higher altitude (over 10,000 ft. above ground level) than the operations discussed above.

Figure 5 displays all BWI Marshall flight tracks for a typical day during the measurement period in east flow, which primarily utilizes Runway 15R for departures and Runway 10 for arrivals. Figure 6 displays the same flight tracks at a larger scale. In east flow, the primary BWI Marshall overflights were arrivals on Runway 10. These arrivals were 4,100 to 5,200 ft. above ground level at their point of closest approach to the measurement site, with the most common altitudes being 4,100 ft. and 5,100 ft.

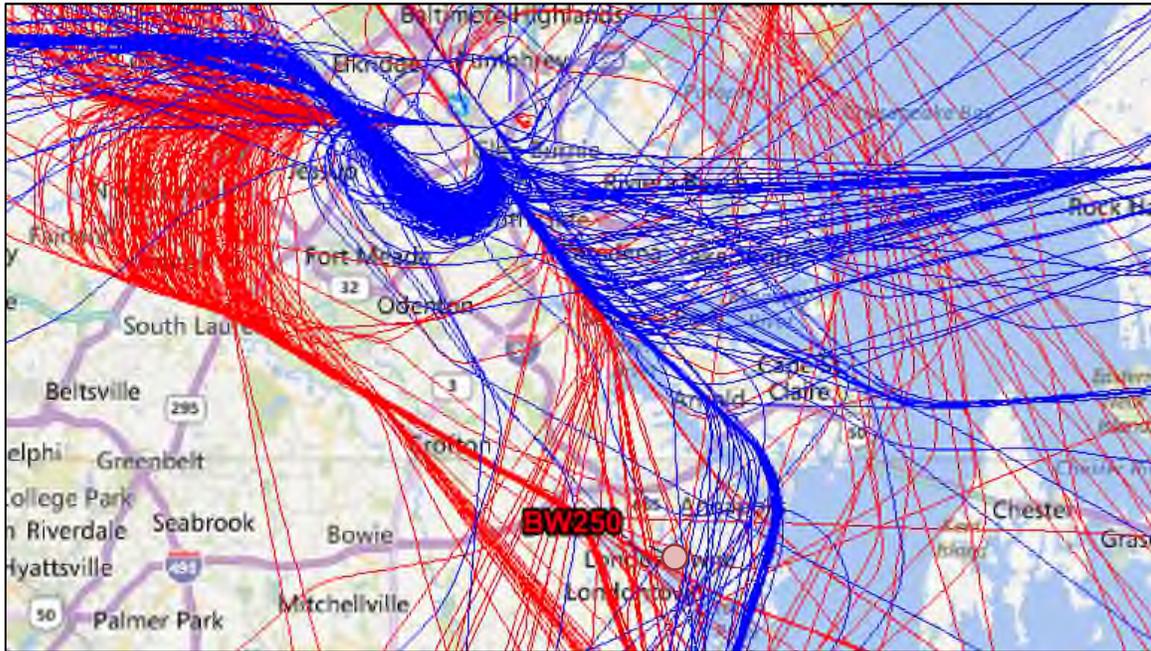
Figure 7 displays all overflights not associated with BWI Marshall for a typical day during the measurement period. Figure 8 displays the same flight tracks at a larger scale. The primary low altitude overflights in these figures are operations by light piston aircraft from nearby Lee Airport (1.9 miles to the west) and Freeway Airport (13.1 miles to the west). The flights from the more distant Freeway Airport pass the measurement site as part of a pattern from the airport to downtown Annapolis and back. These overflights were 400 to 6,200 ft. above ground level at their point of closest approach to the measurement site, with the most common altitude being 900 ft.



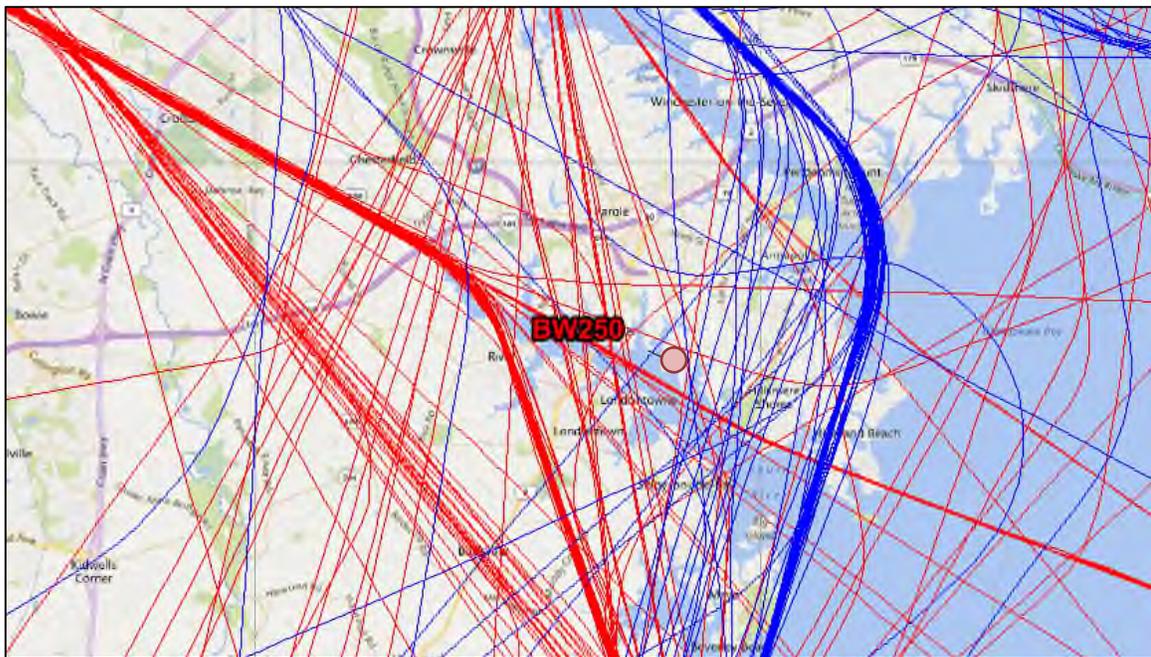
**Figure 3. All Flight Tracks for a West Flow Day – July 12, 2017
(red = arrivals, blue = departures)**



**Figure 4. All Flight Tracks for a West Flow Day – July 12, 2017
(red = arrivals, blue = departures)**



**Figure 5. All Flight Tracks for an East Flow Day – July 17, 2017
(red = arrivals, blue = departures)**



**Figure 6. All Flight Tracks for an East Flow Day – July 17, 2017
(red = arrivals, blue = departures)**

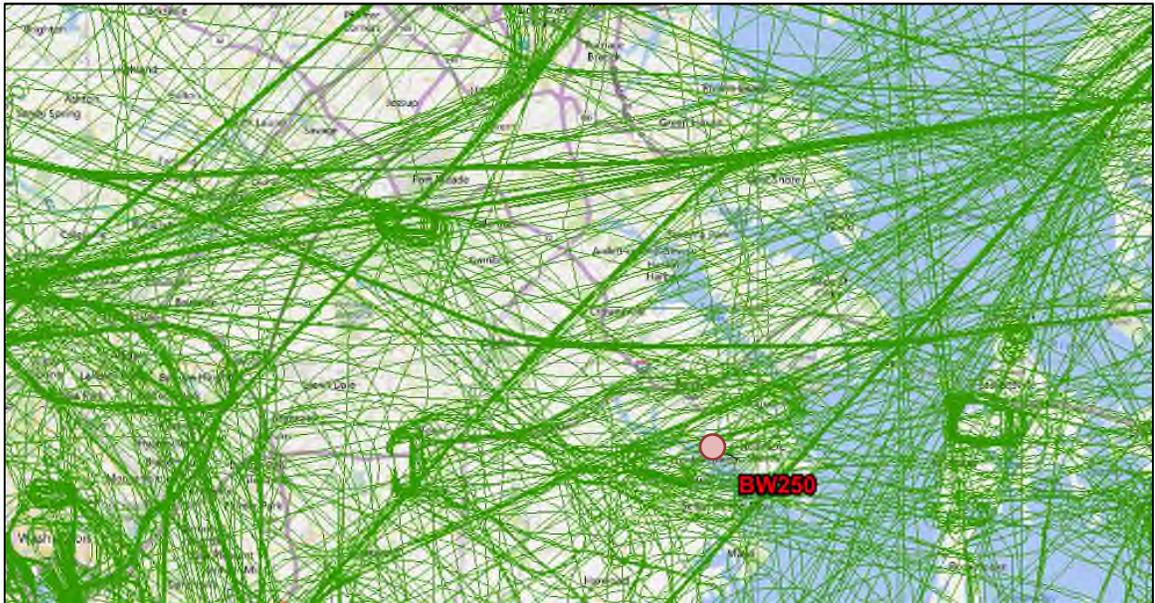


Figure 7. All Overflights not Associated with BWI Marshall – July 12, 2017

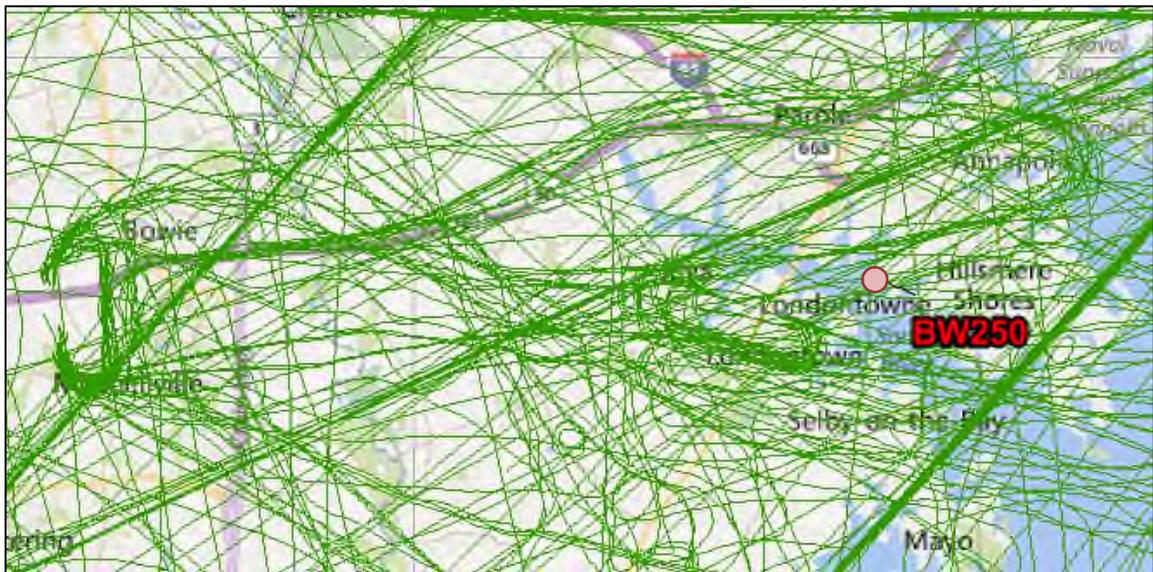


Figure 8. All Overflights not Associated with BWI Marshall – July 12, 2017

4. MEASURED NOISE LEVELS

This section provides an introduction to noise terminology, discusses the noise levels from individual aircraft noise events, and summarizes the cumulative noise exposure over the measurement period.

4.1 Aircraft Noise Terminology

There are several key metrics which are used to describe aircraft noise on a single-event and cumulative basis. The appendix titled “How Do We Describe Aircraft Noise” provides a more detailed overview of the metrics which are discussed in this section.

In brief, noise can be described by A-Weighted Sound Level¹ and is expressed in decibels (noted as dB or dBA). This noise level rises and falls from second to second as noise becomes louder or quieter. The average noise level over some time period, such as an hour, is called the Equivalent Sound Level (Leq). For a particular noise event, such as an aircraft overflight, the loudest level at any instant during the event is the Maximum A-Weighted Sound Level (Lmax). The Lmax tends to correlate poorly to people’s perception of the total “noisiness” of an event because it neglects the duration. The Sound Exposure Level (SEL) accounts for both the level and duration of the noise and is the best measure of the “noisiness” of a single event. Finally, the noise exposure over a complete day is represented by the Day-Night Average Sound Level (DNL). This metric sums all of the noise exposure over the day with a ten decibel weighting for any noise which occurs during the nighttime (10 pm to 7 am) to account for the intrusive nature of these noise events.



4.2 Single Event Noise Levels

Figure 9 presents a count of noise events due to arrivals on Runways 33L and other overflights not associated with BWI Marshall at various Lmax values for the complete measurement period. For example, the tallest blue bar in the figure shows that 78 arrivals on Runway 33L had an Lmax of 56 dB. For typical conversational speech at a distance of approximately three feet, speech is interrupted by noise levels at or above 65 dB. Any noise events shown in this figure with a maximum level at or above 65 dB would, briefly for quieter events and longer for louder events, interrupt typical conversations outdoors.

Figure 10 shows counts of noise events at various Lmax values due to arrivals on Runway 10. Note that there were far fewer noise events due to these aircraft operations as compared to arrivals on Runway 33L and other overflights not associated with BWI Marshall and therefore the vertical scale of this figure is quite different from the scale in Figure 9.

Figure 11 and Figure 12 tell a similar story using the SEL metric which corresponds better to people’s judgment of the noisiness of an event. Arrivals on Runway 33L produced the largest number of loud noise events, followed by other overflights not associated with BWI Marshall. Noise events due to arrivals on Runway 10 were much less common.

Note that the noise events measured and presented in this report are those which can be clearly detected by the noise measurement equipment. Aircraft noise events with maximum levels at, near, or below the ambient noise levels from community noise sources are difficult, and sometimes impossible, to quantify and in most cases contribute little to the total noise exposure.

¹ A-Weighting simply refers to a method of computing the noise level which accounts for the particular response of the human ear. It is the standard for the vast majority of environmental noise analyses.

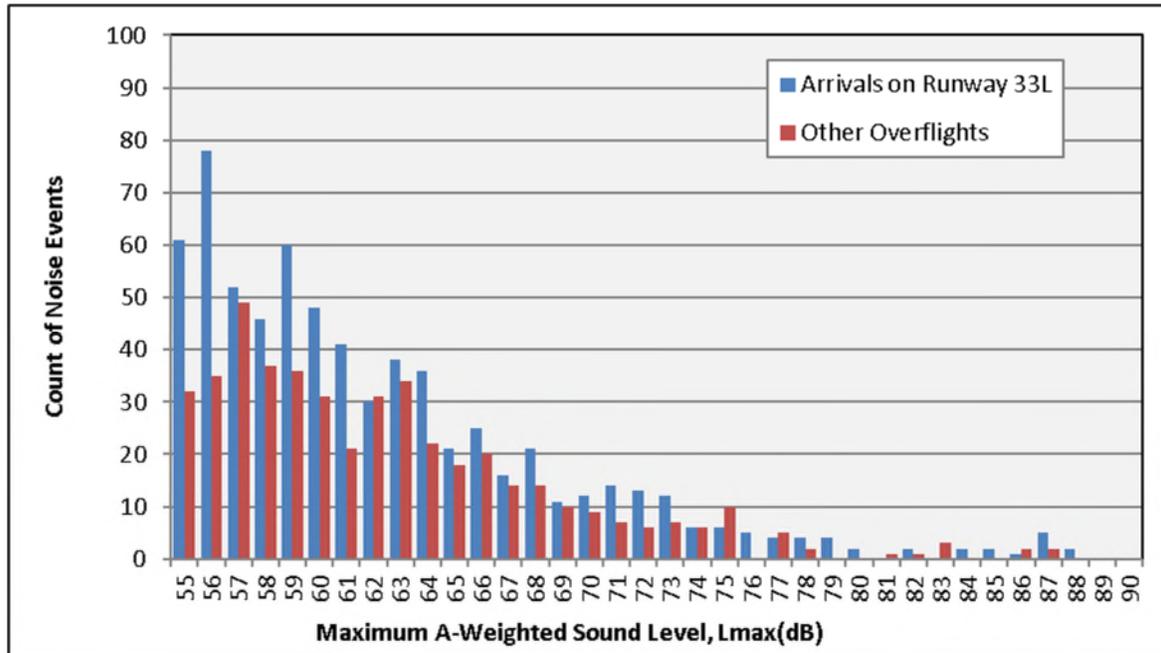


Figure 9. Counts of Maximum Noise Levels from Aircraft Overflights over the Full Measurement Period – Arrivals on Runway 33L and Other Overflights not Associated with BWI Marshall

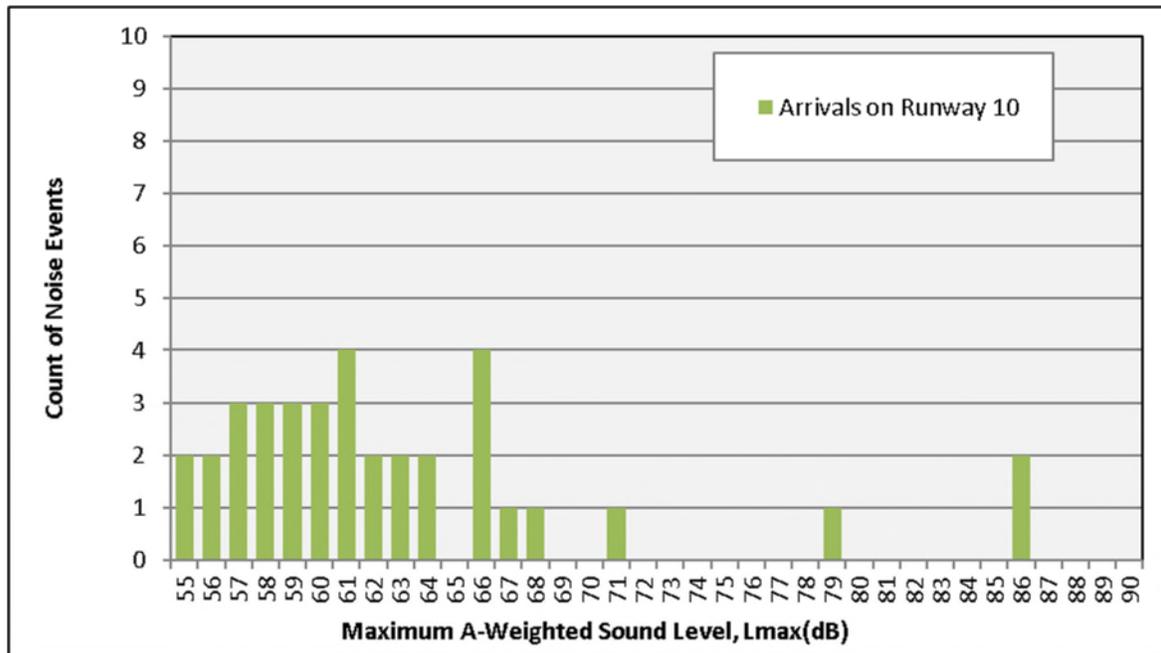


Figure 10. Counts of Maximum Noise Levels from Aircraft Overflights over the Full Measurement Period – Arrivals on Runway 10

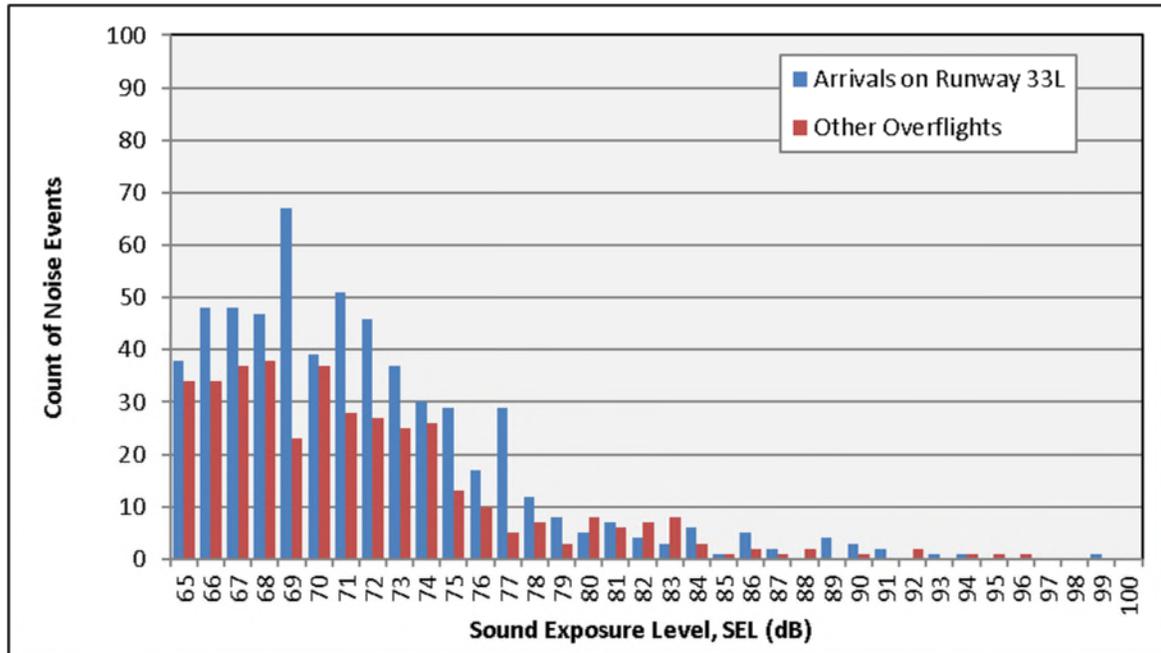


Figure 11. Counts of Sound Exposure Levels from Aircraft Overflights over the Full Measurement Period – Arrivals on Runway 33L and Other Overflights not Associated with BWI Marshall

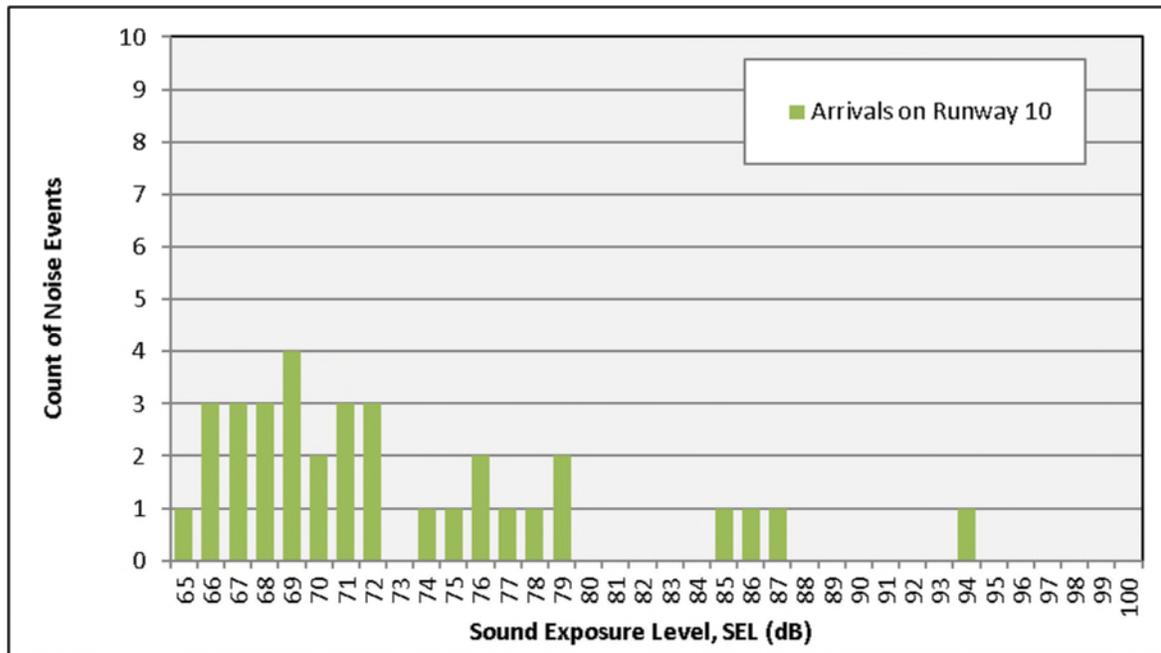


Figure 12. Counts of Sound Exposure Levels from Aircraft Overflights over the Full Measurement Period – Arrivals on Runway 10

Table 1 summarizes the cumulative noise exposure over each of the fifteen days of recorded data within the measurement period using the DNL metric. DNL sums the noise from every aircraft noise event over the day. The formula for DNL gives an extra ten decibel weighting to nighttime noise events to account for the intrusive nature of these events. The DNL for the thirteen complete days, as shown in Table 1, ranged from 40 dB to 53 dB.



Table 1. Measured Daily Aircraft Noise Levels			
Date	Day-Night Average Sound Level, DNL (dB)	Hours Measured	Primary Aircraft Operations
7/10/2017	54*	11	10 Arr / 15R Dep 33L Arr / 28 Dep (before 7 AM and 3 PM to 6 PM)
7/11/2017	53	24	33L Arr / 28 Dep
7/12/2017	47	24	33L Arr / 28 Dep
7/13/2017	47	24	33L Arr / 28 Dep
7/14/2017	44	24	33L Arr / 28 Dep 10 Arr / 15R Dep (briefly around 3 PM)
7/15/2017	51	24	33L Arr / 28 Dep
7/16/2017	43	24	33L Arr / 28 Dep
7/17/2017	40	22	10 Arr / 15R Dep 33L Arr / 28 Dep (before 6 AM and briefly around 6 PM)
7/18/2017	45	24	33L Arr / 28 Dep 10 Arr / 15R Dep (after 1 PM)
7/19/2017	44**	24	10 Arr / 15R Dep 33L Arr / 28 Dep (9 AM to 4 PM)
7/20/2017	45**	24	33L Arr / 28 Dep
7/21/2017	46**	23	33L Arr / 28 Dep 10 Arr / 15R Dep (2 PM to 8 PM)
7/22/2017	46	24	33L Arr / 28 Dep
7/23/2017	51	24	33L Arr / 28 Dep
7/24/2017	54*	14	33L Arr / 28 Dep
Total	49	334	-

Notes:

* Measurements for a partial day may not represent the average noise level for the complete day.

** The equipment check on 7/21 showed a variance of 2 dB in the calibration. See Section 2 for further details.

As shown in the single event figures, Figure 9 through Figure 12, most of the loudest noise events at this site are from arrivals on Runway 33L. Arrivals on Runway 33L accounted for about fifty-nine percent of the DNL over the measurement period. Other overflights not associated with BWI Marshall contributed approximately thirty-six percent of the DNL over the period. Arrivals on Runway 10 accounted for approximately five percent of the DNL over the period. The small remainder of the DNL was due to arrivals and departures on other BWI Marshall runways.

5. CONCLUSION

The composite aircraft DNL over the full measurement period was 49 dB. The precise DNL over a full year will depend on the type and number of aircraft utilizing BWI Marshall and the percentage of time the airport spends in various operational configurations. Approximately seventy-eight percent of operations during the measurement period were in west flow and twenty-two percent were in east flow, which is more than the typical annual average of seventy percent west flow operations. Noise levels at this site are higher in west flow than in east flow. Based only on the measurements and a seventy percent annual west flow assumption, the annual DNL at the measurement site is likely similar to or slightly lower than the 49 dB that was measured for this period. Table 1 shows the primary runways in use each day of the measurement period.

As discussed in previous sections, the noise monitor experienced a greater than expected variance in calibration during one of the equipment checks. The composite DNL for the full measurement period with the two days of potentially effected data excluded was also 49 dB.



In Appendix A of 14 CFR Part 150, the Federal Aviation Administration provides guidelines for the compatibility of land uses with various annual DNL values. These guidelines consider residential land use to be incompatible when the DNL is 75 dB or greater. For noise levels between 65 dB and 75 dB DNL, residential land use is considered incompatible, but where the community determines that this land use must be allowed, measures to achieve greater than typical outdoor to indoor noise level reduction should be incorporated into building codes. The guidelines designate all land uses, including residential, as compatible for DNL values below 65 dB.

How do we Describe Aircraft Noise?

We use a number of terms to describe aircraft noise. These metrics form the basis for the majority of noise analyses conducted at most airports in the U.S.

The Decibel, dB

All sounds come from a source – a musical instrument, a voice speaking, an airplane. The energy that produces these sounds is transmitted through the air in waves, or sound pressures, which impinge on the ear, creating the sound we hear.

The decibel is a ratio that compares the sound pressure of the sound source of interest (e.g., the aircraft over flight) to a reference pressure (the quietest sound we can hear). Because the range of sound pressures is very large, we use logarithms to simplify the expression to a smaller range, and express the resulting value in decibels (dB). Two useful rules of thumb to remember when comparing individual noise sources are: (1) most of us perceive a six to ten dB increase to be about a doubling of loudness, and (2) changes of less than about three dB are not easily detected outside of a laboratory.

The A-Weighted Decibel, dB(A)

Frequency, or “pitch”, is an important characteristic of sound. When analyzing noise, we are interested in how much is low-, middle-, and high-frequency noise. This breakdown is important for two reasons. First, our ears are better equipped to hear mid- and high-frequencies; thus, we find mid- and high-frequency noise more annoying. Second, engineering solutions to noise problems are different for different frequency ranges. The “A” filter approximates the sensitivity of our ear and helps us to assess the relative loudness of various sounds.

Maximum A-weighted Sound Level, L_{max}

A-weighted sound levels vary with time. For example, the sound increases as an aircraft approaches, then falls and blends into the background as the aircraft recedes into the distance. Figure 1 illustrates this phenomenon. We often describe a particular noise “event” by its maximum sound level (L_{max}). Figure 2 shows typical L_{max} values for some common noise sources. In fact, two events with identical L_{max} may produce very different total exposures. One may be of very short duration, while the other may be much longer.

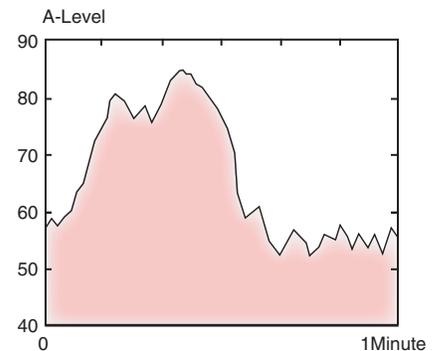


Figure 1. A-weighted Sound Levels Over Time

Sound Exposure Level, SEL

The most common measure of cumulative noise exposure for a single aircraft flyover is the Sound Exposure Level (SEL). Mathematically, it is the sum of the sound energy over the duration of a noise event – one can think of it as an equivalent noise event with a one-second duration. Figure 3 shows that portion of the sound energy included in this event. Because the SEL is normalized to one second, it will almost always be larger in magnitude than the L_{max} for the event. In fact, for most aircraft events, the SEL is about 7 to 12 dB higher than the L_{max}. Also, the fact that it is cumulative measure means that a higher SEL can result from either a louder or longer event, or some combination.

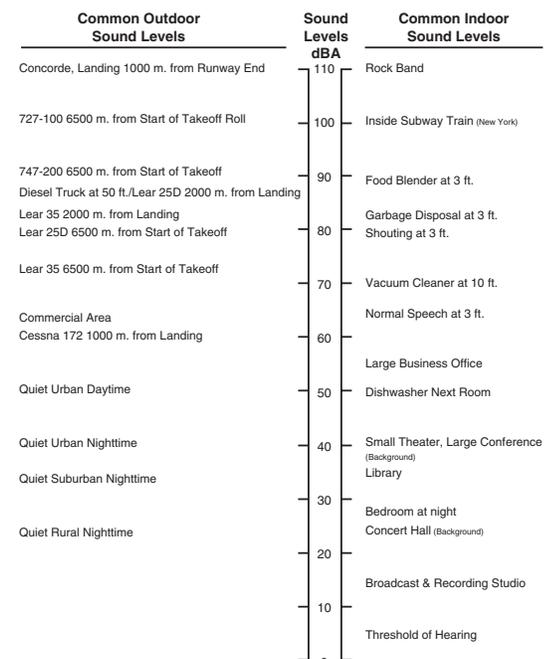


Figure 2. Common Environmental Sound Levels

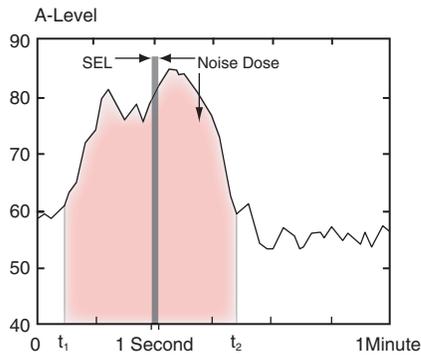


Figure 3. Sound Exposure Level

SEL provides a comprehensive way to describe noise events for use in modeling and comparing noise environments. Computer noise models base their computations on SEL values.

Day-Night Average Sound Level, DNL

The Day-Night Average Sound Level (DNL) represents noise as it occurs over a 24-hour period, with the assumption noise events occurring at night (10 p.m. to 7 a.m.) are 10 dB louder than they really are. This 10 dB penalty is applied to account for greater sensitivity to nighttime noise, and the fact that events at night are often perceived to be more intrusive because nighttime ambient noise is less than daytime ambient noise.

Figure 4 depicts a hypothetical daily noise dose. The top frame repeats the one-minute noise exposure that was shown in Figure 1. The center frame includes this one-minute interval within a full hour; now the shaded area represents the noise during that hour with 16 noise events, each producing an SEL. Finally, the bottom frame includes the one-hour interval within a full 24 hours. Here the shaded area represents the listener's noise dose over a full day.

DNL normally can be measured with standard monitoring equipment or predicted with computer models.

Most aircraft noise studies utilize computer-generated estimates of DNL, determined by accounting for all of the SELs from individual events which comprise the total noise dose at a given location on the ground.

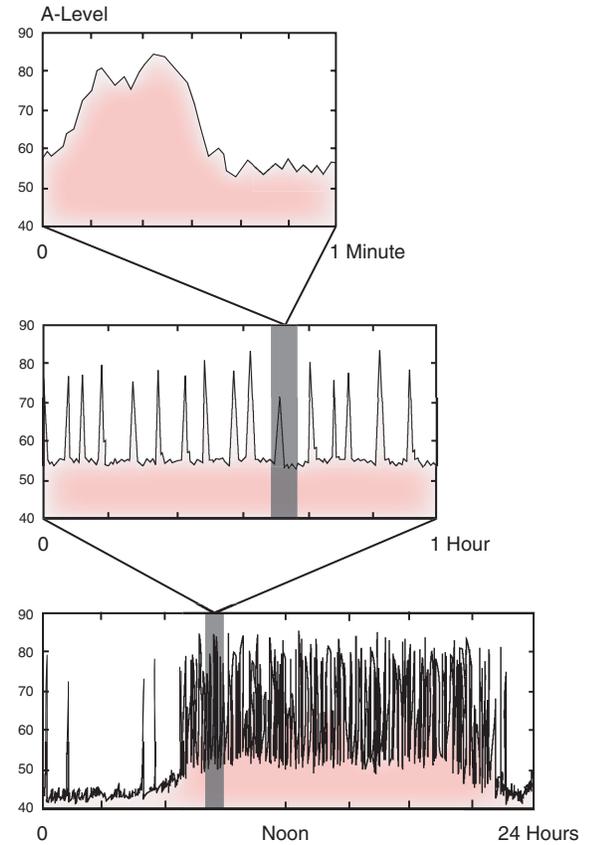


Figure 4. Daily Noise Dose

Computed values of DNL are often depicted as noise contours reflecting lines of equal exposure around an airport (much as topographic maps indicate contours of equal elevation). DNL contours usually reflect annual average operating conditions, taking into account the average number of flights each day, how often each runway is used throughout the year, and where over the surrounding communities the aircraft normally fly.



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