ANALYSIS OF START-OF-TAKEOFF ROLL

AIRCRAFT NOISE LEVELS AT

BALTIMORE/WASHINGTON INTERNATIONAL AIRPORT

August 1990

HMMH Report No. 290600.1

Submitted to:

Mr. Robert Talbert
Manager, Aviation Noise Program
Office of Planning and Engineering
Maryland Aviation Administration
First Floor Terminal Building
Baltimore/Washington International Airport
Maryland 21240

Submitted by:

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Table of Contents

List of Tables

List of Figures

1. SUMMARY

This report analyzes 34 days of near continuous noise monitor data acquired at 851 Main Avenue, Linthicum, Maryland. The site is approximately 4000 feet north northeast of the threshold of Runway 15R at Baltimore/Washington International Airport (BWI); and the measured 34 day average Day/Night Average Sound Level (Ldn) was 67.9 decibels. This value includes all noise sources; not just departure and arrival noise from BWI. An analysis of the noise data, runway use records, and maintenance ground runup logs led to the conclusion that only 65.9 decibels of this total is related to departure and arrival noise at BWI. The remaining two decibels is equally divided between nighttime maintenance engine runups and intermittent high daytime sound levels that appear at first reading to be related to the instrument calibrations.

Tests were applied to determine whether or not the value of 65.9 decibels was indicative of long term average exposure. These tests used supplemental runway use data and long term noise monitor data from the BWI permanent noise monitor system to determine whether the use of Runway 15R/33L during the noise measurement period was typical of annual average conditions. The results of this analysis indicate that because of the large day-to-day Ldn variability and the small fraction of the year the noise levels were monitored, there is a four decibel range of uncertainty in the annual average value, and that 65.9 probably lies on the lower side of that range.

The entire range of uncertainty however is higher than the 61.2 decibels computed for this site by the Noise Zone computer model. Part of this discrepancy may be due, in part to another finding of this report: that the noise model can be underestimating the noise levels produced by individual aircraft departures in the vicinity of brake release and initial ground roll. Initial estimates from the available data suggest the underestimate may be on the order of 2 to 4 decibels for Stage 2 aircraft and 5 decibels for Stage 3 aircraft. Thus, as the fleet serving BWI transitions from Stage 2 to Stage 3 aircraft, future noise zone updates may further underestimate Noise Zone boundaries in areas around the airport where the noise environment is dominated by start-of-takeoff roll noise. Section 5 of this report provides recommendations for future action based on these findings.

2. INTRODUCTION

This report provides an analysis of aircraft noise levels measured by the Aviation Noise Program Office in the vicinity of runway thresholds at Baltimore/Washington International Airport, Maryland (BWI) during early 1990. The focal point of the study is 34 complete days of near continuous noise monitoring data obtained in the rear yard of a single family residence at 851 Main Avenue in Linthicum, MD from 4 January to 8 February, 1990. The noise levels were measured by a Metrosonics dB-604 Portable Noise Monitor which reported the average hourly noise level (Leq) during each hour of the noise monitor period. The monitor operated unattended for most of the noise monitor period.

The measured energy average Day/Night Average Sound Level (Ldn) at the 851 Main Avenue site was 67.9 decibels (dB). This value is considerably higher than the 61.2 decibels computed for this site in the latest noise zone update map. The purpose of this analysis is to reconcile this difference and provide recommendations for interpreting and acting on future noise measurements of a similar nature. The goal of the recommendations is ensuring the highest noise modelling accuracy in future Noise Zone updates.

Figure 1 shows the location of the noise monitor site in relation to Baltimore/Washington International Airport (BWI). The site is approximately 4000 feet north northeast of the threshold of Runway 15R. The noise levels at this site are dominated by the noise of commercial jet aircraft departing BWI on Runway 15R during east flow operations.

A complete listing of measured noise levels is presented in Appendix A. The listing shows hourly average (equivalent) noise levels (Leq) for the entire monitor period. These hourly levels were used to compute Ldn values for each measurement day with complete 24-hour data. These Ldn data are shown in graphical form in Figure 2 which plots the Ldn for each measurement day. Note that daily observations range from a low of 58 decibels to a high of nearly 74 decibels, a variation of almost 16 decibels. The solid horizontal line shows the energy average sound level for the measurement period.

Section 3 of this report describes the analysis procedure used to understand the reasons for the difference between the empirical and modeled Ldn values. Section 4 summarizes the conclusions, and Section 5 provides recommendations for interpreting short-term noise monitor data acquired in the future and methods for incorporating such information in the noise zone update process.

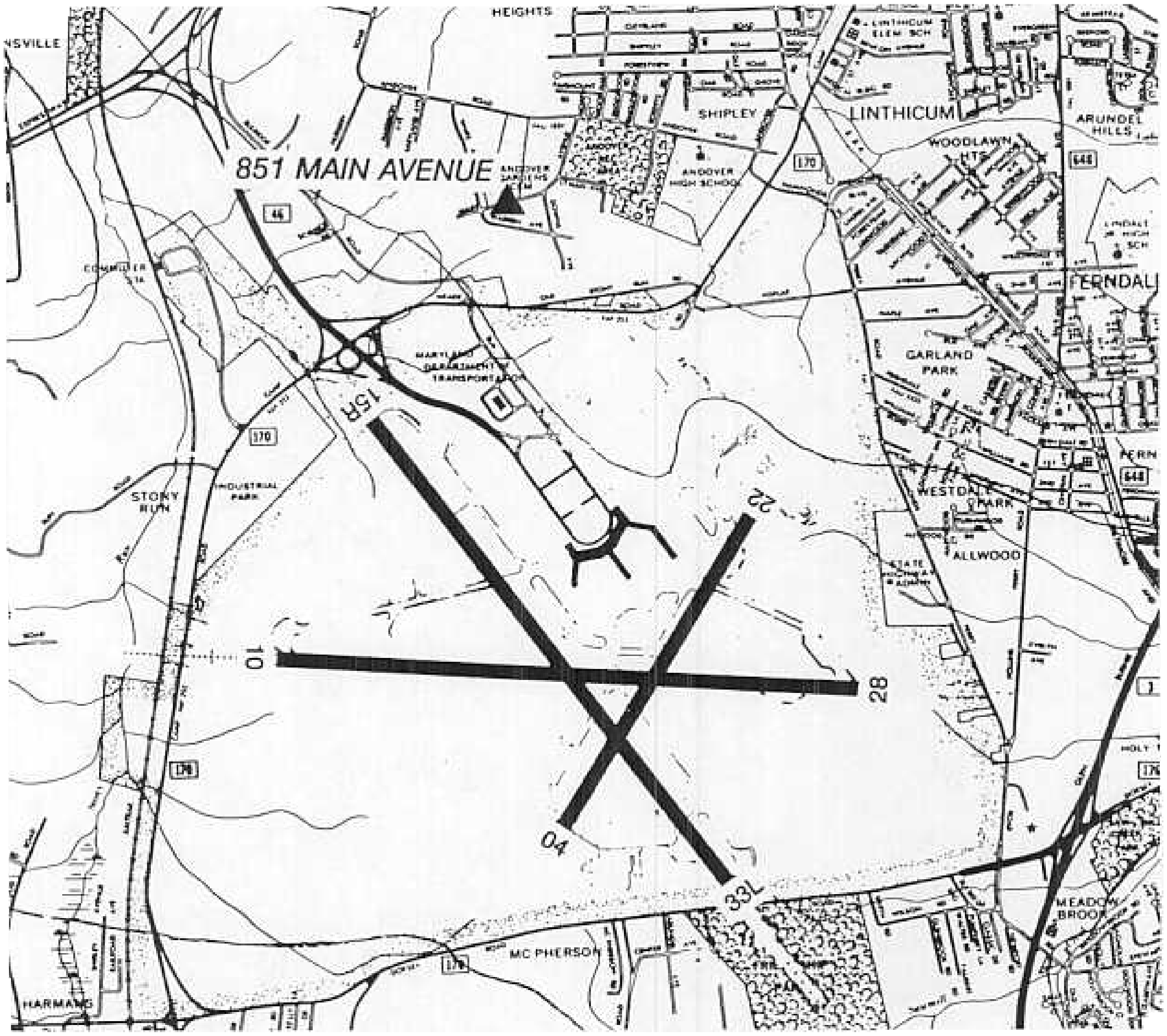


FIGURE 1. MEASUREMENT SITE LOCATION AT 851 MAIN AVENUE

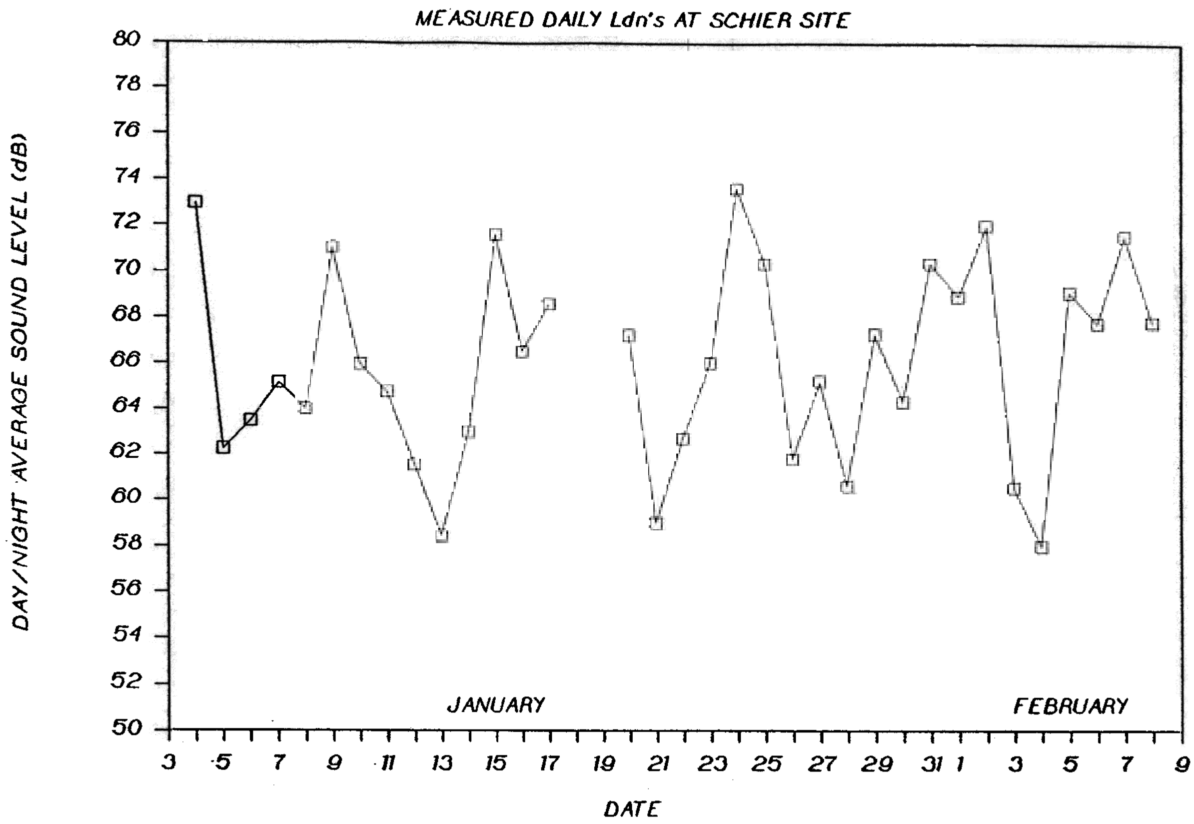


FIGURE 2. MEASURED DAY-NIGHT AVERAGE SOUND LEVELS AT 851 MAIN AVENUE

3. ANALYSIS PROCEDURE

The procedure used to analyze these data consisted of 4 steps:

(1) Analyze and quantify probable contributions to average measured Ldn by source,
(2) Estimate annual average aircraft noise Ldn from measured data,
(3) Compare measured and Noise Zone annual average Ldns,
(4) Explore effects of modelled versus measured single event levels on measurement versus modelling disparity.

3.1 Source Contributors to Measured Ldn

Four contributors were identified as potential contributors to the measured Ldn at 851 Main Avenue:

- local neighborhood background noise
- noise from apparent high level, non-aircraft sources during midday
- noise from maintenance engine runups
- noise from aircraft arriving and departing BWI

Each is discussed separately in the subsections below.

3.1.1 Contribution of Background Noise to Average Measured Ldn

While the background noise at 851 Main Avenue was not measured per se, an estimate was made by taking advantage of the continuous monitoring of average hourly noise levels (HNL's) and the intermittent use of Runway 15R during the measurement period. For each hour of the day, the 34 days of data were searched for the minimum measured HNL. These 24 minimum HNL's were then used to compute a Day/Night Average Sound Level (Ldn). The background Ldn estimated in this way is 55.3 decibels. Table 1 shows the minimum hourly levels and the Ldn computed.

TABLE 1. MINIMUM MEASURED HOURLY NOISE LEVELS (Leq)

Hour	(Leq)	Hour	(Leq)	Hour	(Leq)
1	37.9	9	52.1	17	54.8
2	36.6	10	58.0	18	51.2
3	37.0	11	51.3	19	49.3
4	36.1	12	54.1	20	53.9
5	37.4	13	45.9	21	54.9
6	48.3	14	46.6	22	45.6
7	55.8	15	52.2	23	40.5
8	54.8	16	56.6	24	37.6

Leq = 52.0   Ldn = 55.3

This value is consistent with methods developed by the EPA for predicting background noise Ldn based on population density. The empirically derived formula is:

$$\text{Ldn} = 10 \text{ Log (population / sq mi)} + 22 \text{ dB} \qquad (1$$

Substituting the Ldn of 55.3 in Equation 1 and solving for population density yields a value of approximately 2100 persons per square mile which seems reasonable for the area.

The effect of this assumed background noise on the total Ldn can be estimated by energy subtracting the 55.3 decibels from 67.9 by

$$\text{Non-background Ldn} = 10 \log_{10}(10^{(67.9/10)} - 10^{(55.3/10)}) = 67.7 \text{ dB} \qquad (2)$$

It may be seen from Equation 2 that non-aircraft background noise probably had only a few tenths of a decibel impact on the total measured Ldn during the measurement period.

3.1.2 Contribution of High Hourly Noise Levels (Leq's)

High hourly Leq's (exceeding 75 dB) were observed in Table A-1 during five non-contiguous hours of the 34 day (816 hour) monitoring period. These high Leq's are shown in Table 2. The first two columns of the table show the date and time. The second two columns show the maximum A-weighted sound level which occurred during the hour and the hourly average noise level (Leq), respectively. The table is actually a rank-ordered list of the fifteen hours with the highest A-weighted sound pressure (momentary, not average) level during the measurement period.

TABLE 2. FIFTEEN HIGHEST HOURLY MAXIMUM A-WEIGHTED SOUND LEVELS

Date	Hour Ending At	Maximum A-Level (dB)	Hourly Noise Level (dB)
07-Feb	10:00	116.1	83.3
31-Jan	15:00	106.9	80.3
02-Feb	12:00	105.9	84.4
05-Feb	14:00	105.6	81.5
29-Jan	14:00	105.4	76.3
06-Feb	22:00	95.7	71.7
22-Jan	10:00	95.3	65.6
12-Jan	15:00	95.1	64.6
16-Jan	13:00	94.2	64.4
04-Jan	05:00	93.6	74.2
15-Jan	21:00	93.5	74.3
01-Feb	20:00	93.2	74.0
17-Jan	17:00	93.2	74.9
01-Feb	22:00	92.4	71.1
15-Jan	19:00	92.0	71.2

Note that the five high hourly Leq's emerge at the very top of the list. This suggests that the high Leq is probably the result of a very few high noise level events rather than a very large number of moderate noise level intrusions. A striking feature of the is the anomalous nature of the high levels: they are at least 10 decibels greater than any of the 811 remaining hours of the measurements. If these were aircraft related, it suggests that on a very infrequent basis aircraft which are at least 10 decibels louder levels than any other aircraft intrude on the measurement site. No ready explanation for how this could be so has been forthcoming. Alternate explanations of non-aircraft sources did not prove fruitful. These included potential construction noise and thunder.

Therefore it was decided to simply present these five data points in chronological order and estimate their contribution to the 34 day average Ldn. The method used is shown in Table 3. The top half of the table shows each of the five hours as a separate line item. The first three columns show the date, day of the week, and time at the end of the hour the data were measured. The next two columns show the hourly noise level (Leq) and maximum A-weighted sound level recorded by the noise monitor.

The right two columns of Table 3 show some inferred information about the magnitude of a single event which would be needed to generate the measured hourly noise level. The first number is the sound exposure level (SEL) of a single event which would generate the hourly noise level (sound energy uniformly spread equally over the hour). The second number is the duration of that noise event, assuming the measured maximum A-level were sustained during the entire event.

TABLE 3. EFFECT OF FIVE HIGH HOURLY NOISE LEVELS ON AVERAGE Ldn

	Raw Noise Monitor Data				Inferred Information	
Date	Day of Week	Hour Ending At	Hourly Noise Level (dB)	Hourly Maximum A-level (dB)	Equivalent SEL (dB)	Equivalent Continuous Duration (sec)
29-Jan	(Mon)	14:00	76.3	105.4	111.9	4.43
31-Jan	(Wed)	15:00	80.3	106.9	115.9	7.88
02-Feb	(Fri)	12:00	84.4	105.9	120.0	25.49
05-Feb	(Mon)	14:00	81.5	105.6	117.1	14.01
07-Feb	(Wed)	10:00	83.3	116.1	118.9	1.89
Energy Sum HNL			88.9			
-10 x Log(24 hrs)			-13.8			
Ldn (single day)			75.1			
-10 x Log(34 days) ...			-15.3			
Ldn (average day)			59.8	<-- Contribution to 34 day average measured Ldn		

The lower half of the table calculates the effect of these five hourly noise levels on the 34-day average Ldn. The energy sum HNL shows the total HNL energy for the five hours. Spreading this hourly energy uniformly over 34 days is shown as a two step process. In the first step, the energy is spread uniformly over a single day by subtracting ten times the logarithm of 24 hours (13.8 dB). In the second step, the energy is spread over the measurement period by subtracting ten times the logarithm of 34 days (15.3 dB). The result is a 59.8 decibel contribution to the average measured Ldn from these five hours.

Worthy of comment is the day of the week column, which shows some evidence of a Mon-Wed-Fri repeating sequence. Note also that the times-of-day are all mid day, during working hours, between 10am and 3pm. Other evidence of a Mon-Wed-Fri sequence was sought by reviewing the hourly noise level records in Appendix A. Table 4 shows the results of this review.

TABLE 4. OTHER MONDAY-WEDNESDAY-FRIDAY OBSERVATIONS

Date	Day of Week	Hour(s) Ending At	Observation
10-Jan	(Wed)	13:00-15:00	Missing data
12-Jan	(Fri)	16:00	Missing data
22-Jan	(Mon)	11:00	Missing data
24-Jan	(Wed)	13:00-14:00	Missing data
26-Jan	(Fri)	12:00-14:00	Missing data

This Mon-Wed-Fri pattern seems more than coincidental. One possible explanation may be that either electrical or acoustic noise is being added to the data during routine instrument calibration.

3.1.3 Contribution of Ground Runup Noise to Average Measured Ldn

Records of maintenance runups were supplied by the Aviation Noise Program office to assist in interpreting higher than expected aircraft noise HNL's during the early morning hours. Table 5 contains a tabular listing of these records for the noise monitoring period. The records show the date and approximate time the maintenance activity began. They also show aircraft identification information including the aircraft type. All of this maintenance activity took place between 10pm and 7am.

Using this information, the noise monitor records were examined for higher than normal hourly noise levels at the logged maintenance times. The hourly noise levels shown in Table 6 were found to correlate with the maintenance logs.

TABLE 5. GROUND RUNUP LOG DURING NOISE MONITORING

Date	Time From	Time To	Airline	Flight Number	A/C Number	A/C Type
1/4/90	3:50		US Air	5904	708	B727
1/8/90	3:40		American	195	N274	MD80
1/10/90	1:48		US Air	--	211	B737-200
1/10/90	3:22		American	--	226	MD80
1/10/90	3:56		US Air	--	518	B737-300
1/11/90	4:50		US Air	--	372	B737-300
1/14/90	2:50		American	195	--	--
1/14/90	6:06		US Air	2143	--	--
1/16/90	4:35		American	1111	--	--
1/17/90	4:51		US Air	--	N219US	B727-200
1/24/90	2:10		American	555	N879AA	B727-200
1/24/90	3:23		US Air	1071	N206US	B727-200
2/10/90	5:55	6:11	American	--	N709AA	B727
2/11/90	4:45	5:00	American	297	--	MD80
2/13/90	0:15		US Air	1735	--	--
2/17/90	6:00		US Air	1444	--	B737-300
2/18/90	22:30		US Air	351	--	B727

The contribution of ground runups to the 34 day average Ldn can be determined by averaging the noise energy over the 34 day period. The method used is shown in Table 6. The top half of the table shows five hourly noise levels which were noticeably above the ambient at the times identified in Table 5. The first three columns show the date, day of the week, and time at the end of the hour. The next two columns show the hourly noise level (Leq) and maximum A-weighted sound level recorded by the noise monitor.

The right two columns of Table 6 show some inferred information about the magnitude of a single event which would be needed to generate the measured hourly noise level. The first number is the sound exposure level (SEL) of a single event which would generate the hourly noise level (sound energy uniformly spread equally over the hour). The second number is the duration of that noise event, assuming the measured maximum A-level were sustained during the entire event.

TABLE 6. EFFECT OF GROUND RUNUP NOISE LEVELS ON AVERAGE Ldn

	Raw Noise Monitor Data				Inferred Information	
Date	Day of Week	Hour Ending At	Hourly Noise Level (dB)	Hourly Maximum A-level (dB)	Equivalent SEL (dB)	Equivalent Continuous Duration (sec)
04-Jan	(Thu)	5:00	74.2	93.6	109.8	41.33
10-Jan	(Wed)	0:20	64.9	85.8	100.5	29.26
10-Jan	(Wed)	3:20	64.5	89.6	100.1	11.13
16-Jan	(Tue)	5:00	62.4	75.4	98.0	180.43
17-Jan	(Wed)	5:00	59.0	75.0	94.6	90.43
24-Jan	(Wed)	3:00	73.1	90.0	108.7	73.50
24-Jan	(Wed)	4:00	73.5	89.9	109.1	82.47

Energy Sum HNL	78.9
Night Weighting	10.0
-10 x Log(24 hrs)	-13.8
Ldn (single day)	75.1
-10 x Log(34 days) ...	-15.3
Ldn (average day)	59.8 <-- Contribution to 34 day average measured Ldn

The lower half of the table calculates the effect of these hourly noise levels on the 34-day average Ldn. The energy sum HNL shows the total HNL energy for the seven hours. Spreading this hourly energy uniformly over 34 days is shown as a two step process. In the first step, the nighttime Ldn weighting factor of 10 decibels is added and the weighted energy is spread uniformly over a single day by subtracting ten times the logarithm of 24 hours (13.8 dB). In the second step, the weighted energy is spread over the measurement period by subtracting ten times the logarithm of 34 days (15.3 dB). The result is a 59.8 decibel contribution to the 34-day average measured Ldn.

3.1.4 Estimating Departure and Arrival Noise Contribution

Assuming that aircraft departure and arrival noise makes up the remainder of the measured Ldn, its component may be computed by subtracting the background, high daytime hourly levels, and runup noise levels from the total using Equation 4:

$$\text{Aircraft Ldn} = 10 \text{ Log } (10^{(67.9/10)} - 10^{(55.3/10)} - 10^{(59.8/10)} - 10^{(59.8/10)}) \qquad (4)$$

This equation yields a value of 65.9 dB. Table 7 summarizes the findings of this portion of the analysis by rank ordering the four contributing factors by Ldn.

TABLE 7. SUMMARY OF NOISE SOURCE CONTRIBUTION TO MEASURED Ldn

SOURCE	Ldn (dB)
Background	55.3
Unexplained high levels	59.8
Ground Runups	59.8
Aircraft	65.9
Total	67.9

3.2 Effect of Atypical East Flow Departures on Aircraft Ldn

Because the noise environment at 851 Main Avenue is dominated by departure noise from Runway 15R, the daily Ldn would be expected to correlate with the number of daily departures on this runway. Departures on Runway 15R occur when the airport is in East Flow operations: that is, when the prevailing winds are out of the East and approaching aircraft use Runway 10 and departing aircraft use Runway 15R. Hence, all other things being equal, measured average noise levels are likely to be typical of an annual average value if runway use during the period is also typical of annual average conditions.

Two independent means were employed to determine whether flight operations during the monitoring period were typical of annual average conditions, and if not by how much. The first method used runway use logs maintained by the FAA to estimate the percentage of east flow departures during the measurement period. These figures were then compared with estimates of annual average use developed during the recent BWI FAR Part 150 Study.

3.2.1 Runway Use Log Method

The runway use logs show times of day when traffic flow was changed at BWI (west to east, or east to west). One means for estimating percentage of east flow traffic is to count the total hours the airport was in east flow during the monitoring period. An analysis of the runway use logs indicates the airport was in east flow 30.2 percent of the time.

A potential shortcoming of this method is the absence of information showing whether heavy air traffic periods are equally represented during both east and west flow hours. That is, did east flow hours occur during heavy traffic periods and west flow hours during light traffic? To answer this question the March 1990 US Air departure schedule was used to represent a typical distribution of traffic over the day (US Air accounts for 70 to 75 percent of BWI daily traffic). The departure schedule shows departure times for all US Air flights leaving BWI. This schedule was matched on a day-by-day basis against the runway use log to determine the probable number of flights departing in east flow each day.

Table 8 presents the results of this analysis. The first two columns of the table show the date and day of the week. The next column shows the number of estimated east flow departures. The last column shows the total daily departures indicated in the schedule (This number varies somewhat depending on the day of the week). By totaling both columns and taking the ratio of east flow to total departures an estimated <u>30.9</u> percent were in east flow during the measurement period. Note that the estimate based only on numbers of hours agrees nicely with this figure.

To determine how well this figure represents a long term annual average, Table 6.4 of Volume II of the Part 150 report (HMMH Report 2503021.1) was consulted. Combining the runway 10 and 15R utilizations the percentage of east flow totals <u>29.7</u> percent. All other things being equal, the extent of the difference between 30.9 and 29.7 percent may be represented in decibels by:

$$10 \text{ Log } (30.9 / 29.7) = 0.2 \text{ dB} \tag{5}$$

Thus, the measurement period east flow appears to be in excellent agreement with estimated annual average values.

TABLE 8. ESTIMATED US AIR EAST FLOW DEPARTURES DURING NOISE MONITOR PERIOD

Date	Day of Week	Estim'd East Flow Departures	Estim'd Total Departures
04-Jan	(Thu)	0	151
05-Jan	(Fri)	0	151
06-Jan	(Sat)	0	151
07-Jan	(Sun)	0	144
08-Jan	(Mon)	46	148
09-Jan	(Tue)	27	151
10-Jan	(Wed)	0	151
11-Jan	(Thu)	33	151
12-Jan	(Fri)	0	151
13-Jan	(Sat)	0	144
14-Jan	(Sun)	74	148
15-Jan	(Mon)	87	151
16-Jan	(Tue)	0	151
17-Jan	(Wed)	85	151
18-Jan	(Thu)	--	--
19-Jan	(Fri)	--	--
20-Jan	(Sat)	144	148
21-Jan	(Sun)	27	151
22-Jan	(Mon)	0	151
23-Jan	(Tue)	74	151
24-Jan	(Wed)	17	151
25-Jan	(Thu)	149	144
26-Jan	(Fri)	0	148
27-Jan	(Sat)	67	151
28-Jan	(Sun)	74	151
29-Jan	(Mon)	133	151
30-Jan	(Tue)	0	151
31-Jan	(Wed)	53	144
01-Feb	(Thu)	66	148
02-Feb	(Fri)	41	151
03-Feb	(Sat)	144	151
04-Feb	(Sun)	74	151
05-Feb	(Mon)	0	151
06-Feb	(Tue)	39	144
07-Feb	(Wed)	11	148
08-Feb	(Thu)	103	151
Average		46.1	149.4

30.86% East flow departures

3.2.2 Comparison With Permanent Monitor System Data Method

The second method uses noise monitor data from the BWI permanent aircraft noise monitor system combined with the data from 851 Main Avenue to directly estimate the long term average Ldn at Main Avenue. The method involves computing two numbers: the long term energy average Ldn at a nearby permanent site from long term data and the Ldn difference between the permanent and short term sites during the short term measurements. Thus, the short term measurements are not used directly to infer a long term average, but instead used to establish a relationship between the temporary and long term sites. The computed inter-site difference is then added to the long term Ldn at the permanent site to predict the long term Ldn at Main Avenue. Error bounds are applied to the prediction based on the number of days of short term data and the degree of correlation between the noise levels at the two sites. The formula for this procedure may be expressed as follows:

$$\text{Estimated } Ldn(T)_{LT} = Ldn(P)_{LT} + (Ldn(T)_{ST} - Ldn(P)_{ST}) \quad (6)$$

where:
$Ldn(T)_{LT}$ = long term average Ldn at the temporary site
$Ldn(P)_{LT}$ = long term average Ldn at the permanent site
$Ldn(T)_{ST}$ = short term average Ldn at the temporary site
$Ldn(P)_{ST}$ = short term average Ldn at the permanent site

Candidate permanent noise monitoring sites for use in Equation 6 were remote monitoring site (RMS) numbers 11, 12 and 13. All of these sites are exposed to noise from the same aircraft departures that generate noise at the Main Avenue site. Table 9 shows the 34 day average and past 2 year average Ldn values at these sites. Figure 3 plots the measured daily Ldn's at sites 11 and 13 for the period of 1 August 1988 through 28 February 1990. These Ldn values were obtained directly from the BWI permanent noise monitoring system. They do not include background noise sources. Note that day-to-day variability is greater at RMS 13 than at RMS 11. This observation is almost certainly attributable to RMS 11's exposure to arrivals on Runway 33L as well as departures on Runway 15R, whereas RMS 13 is exposed only to 15R departures. Hence, approach noise "fills in the gaps" between departures at RMS 11, but not at RMS 13. Since the 851 Main Avenue noise environment is dominated by Runway 15R departures, RMS 13 Ldn values were felt to stand the best chance of correlating with those at 851 Main Avenue. RMS 12 suffers the same problem as RMS 11 with regards to arrivals on Runway 33L and was, therefore, also eliminated from consideration.

TABLE 9. LONG AND SHORT TERM AVERAGE Ldn VALUES AT PERMANENT MONITOR SITES

	RMS 11	RMS 12	RMS 13
Average of 8-1-88 to 4-21-89 and 6-15-89 to 2-28-90	74.6	64.9	62.4
Average during 34 short term days	73.9	65.0	60.8

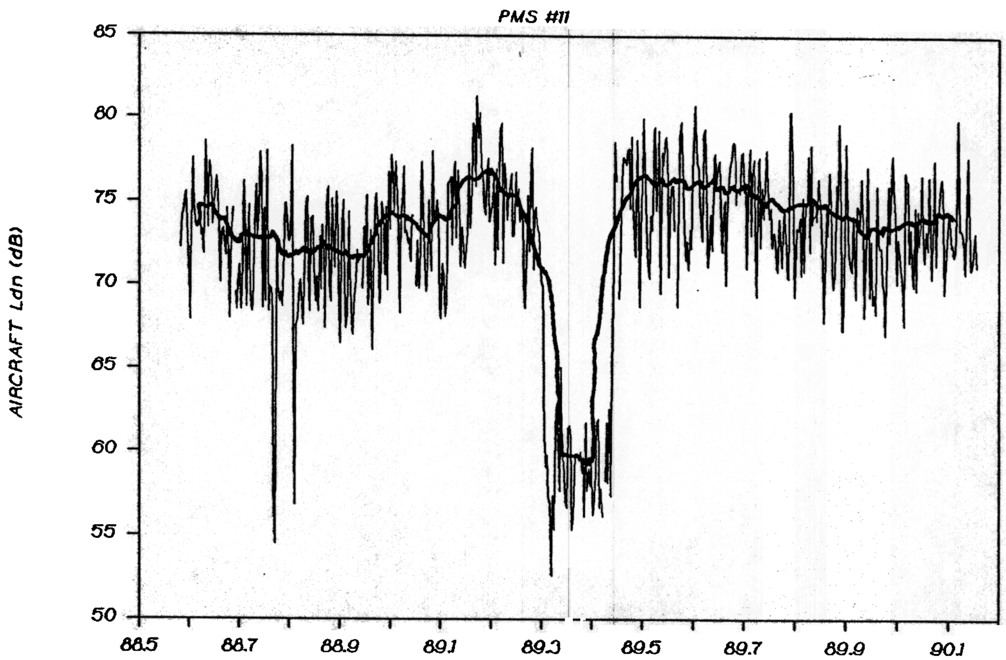
Digressing for a moment, Figure 3 illustrates a second important point. The heavy trend line running through the measurement data of both sites shows a running energy average Ldn value for a 30 day period. Ignoring the approximate two month period when Runway 15R/33L was obviously not in use, the 30 day average Ldn varies across a 5 decibel range at RMS 11 and over a 7 decibel range at RMS 13. This observation underscores the variability even in month long measurements and the importance of tieing short term measurements to a longer term point of reference in order to effectively use short term data for estimating long term average values.

Figure 4 illustrates the utility of using RMS 13 data for purposes of determining how representative the 851 Main Avenue time frame might be of annual average conditions. This figure plots daily aircraft-only Ldn's for both 851 Main Avenue and RMS 13 versus measurement date. Note that the general day-to-day trend is generally consistent across sites, but the ability to predict the Ldn at one site from measurements at the other is less than perfect. Figure 5 illustrates this point by replotting the same data in Figure 4 to show how the daily Ldn at one site correlates with that at the other.

Using Equation 6 and the values in Table 9 the long term Ldn at 851 Main Avenue is estimated at:

$$62.4 + (65.9 - 60.8) = \underline{67.5\ \text{dB}}$$

The 90 percent confidence interval on this estimate using the data points of Figure 5 is plus or minus 1.6 dB. Thus, all other things being equal, one would expect the true long term average value to lie somewhere between 65.9 and 69.1 dB. The question is, are all other things really equal? By this we mean, are there factors which could bias the short-term relationship of 65.9-60.8 so that it is <u>not</u> indicative of a long term average. Such factors would include the proportion of Runway 15R departure traffic making a left turn over RMS 13 and atmospheric conditions affecting overground sound propagation to a much more significant degree than air-to-ground propagation.



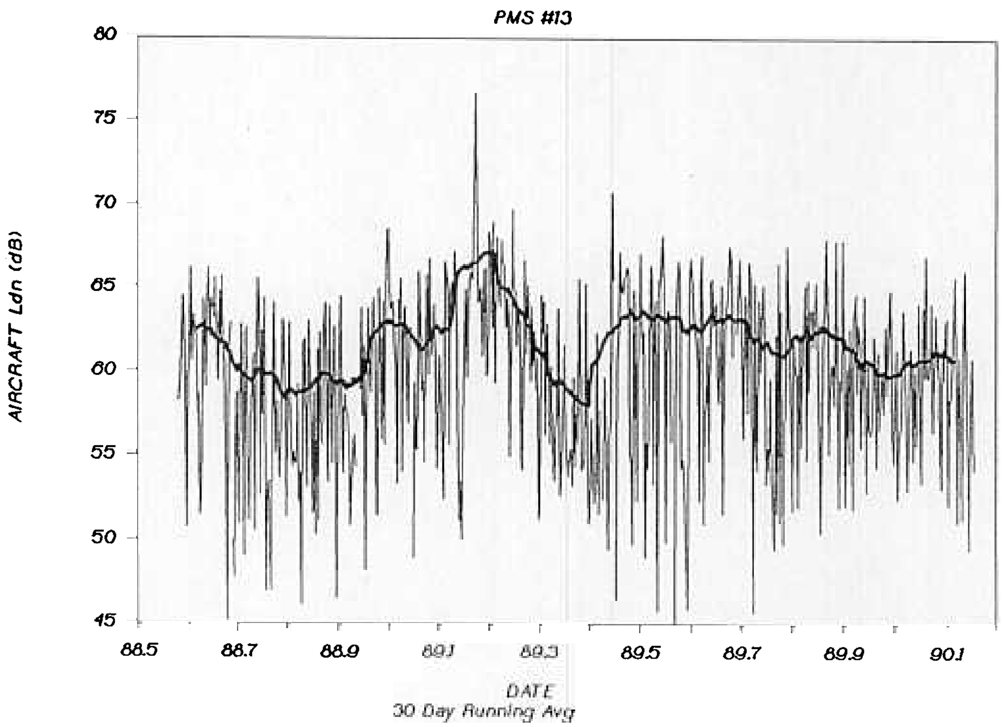


FIGURE 3. Ldn HISTORY AT REMOTE MONITOR SITES 11 AND 13

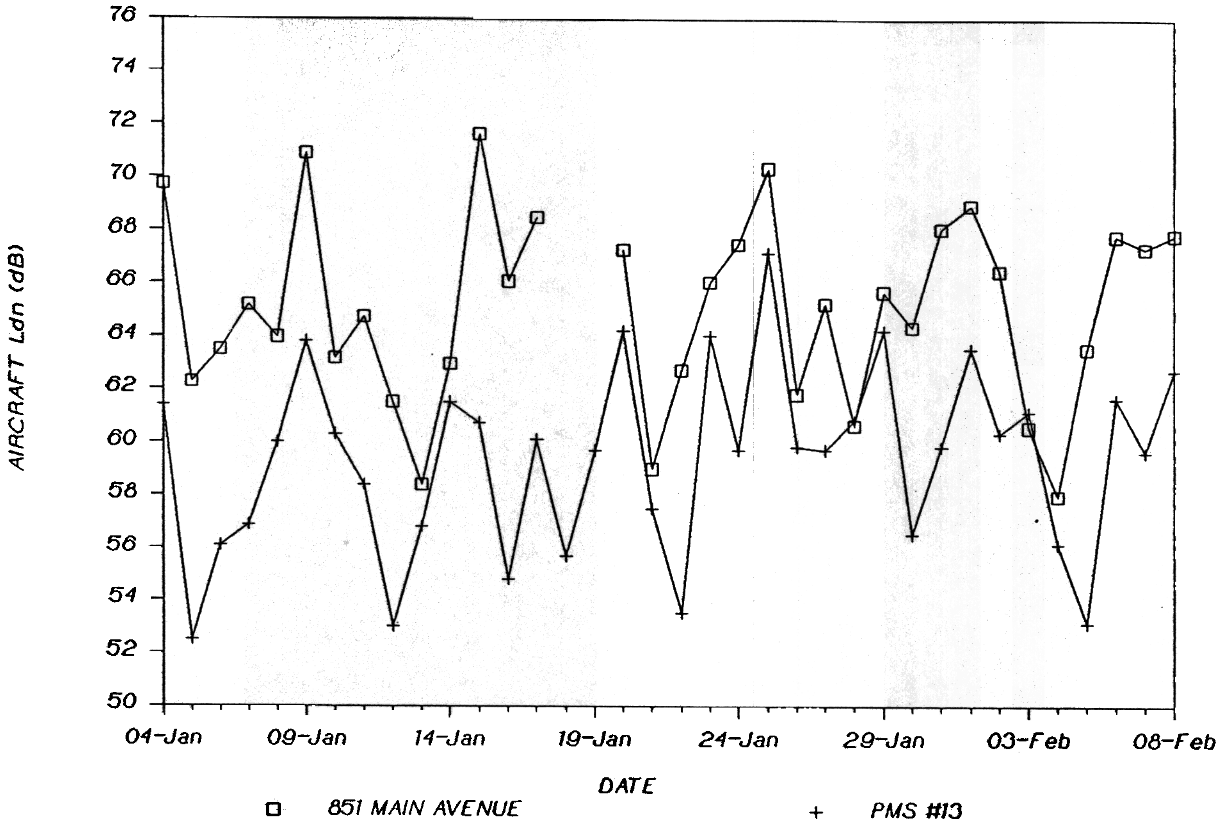


FIGURE 4. Ldn HISTORY AT REMOTE MONITOR SITE 11 AND 851 MAIN AVENUE

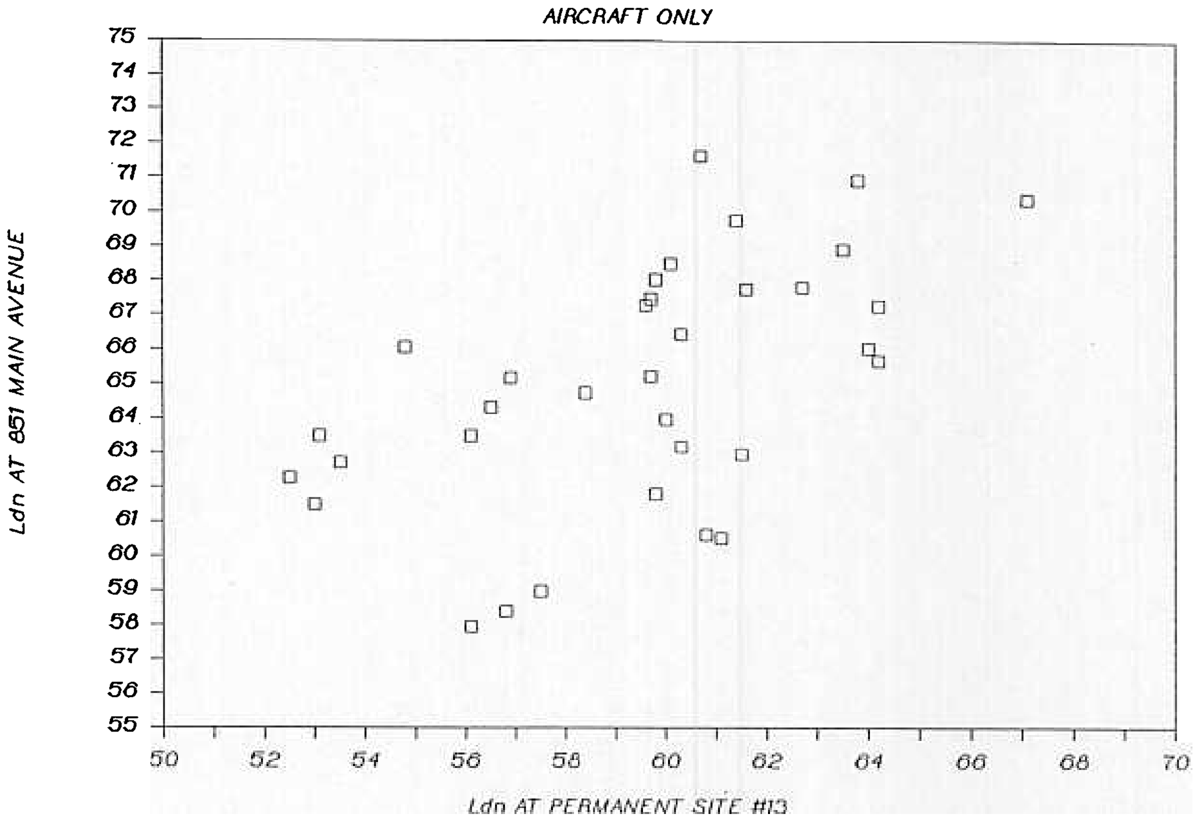


FIGURE 5. Ldn RELATIONSHIP BETWEEN MONITOR SITE 11 AND 851 MAIN AVENUE

3.3 Effect of Vagaries of Overground Sound Propagation

Perhaps one of the weakest areas of any airport noise prediction model (NOISEMAP or INM) is the prediction of aircraft sound levels in the vicinity of start-of-takeoff roll and along the runway sideline as aircraft accelerate to the liftoff point. The reasons are many and varied, but they all tend to have one element in common: there is far greater variability in measured single event noise levels in these geographic areas compared with overflight areas. This is so because there are a number of unique factors which affect noise levels in the vicinity of the runway which have a much smaller effect in areas exposed to overflights. These factors may be thought of in two categories: those influencing the duration of a noise event and those affecting the maximum sound level. Some of the more salient duration factors are:

Aircraft Load - This factor can influence the rate of acceleration and thus the amount of time the aircraft spends near the brake release end of the runway;

Runway Length - This factor may influence pilot decisions to hold the aircraft on its brakes until engines produce full thrust instead of allowing the aircraft to roll during engine spoolup;

Early Clearance - The point in time at which the pilot receives departure clearance can also influence whether the aircraft taxis onto the runway without stopping or whether it is held short for other aircraft movements and must accelerate from a standing start when clearance is received.

Factors affecting the maximum sound level include:

Directional characteristics - Jet aircraft have very pronounced sound directional characteristics and the location of the observer along a circular arc around the aircraft can have a major effect (10 decibels or more) on the maximum sound level:

Aircraft Source Level Assumptions - Aircraft source levels on the ground are not nearly as well refined in model databases as are aircraft source levels in flight;

Wind speed - This factor has been shown to have a very pronounced effect on sound propagation, and the key element is the wind speed component along a line connecting the sound source (aircraft) and the observer;

Temperature inversions - This factor can have ,under certain conditions, an effect of equal magnitude to wind speed;

Terrain - This factor includes the effect of all physical barriers between the source and receiver, such as hills, structures, or any obstacle that breaks the line of sight between sound source and receiver,

Foliage - This factor can have some effect on sound propagation, but generally 100 feet or more of dense planting is required to have a measurable effect.

This portion of the study chose to focus on two of the most important (and documentable) factors - source levels and wind speed.

3.3.1 Initial Comparison of Measured and Modelled Sound Exposure Levels

Sound exposure levels (SELs) resulting from individual aircraft departures were measured by Aviation Noise Program Office staff at 851 Main Avenue and two additional sites (with similar geometric relationships to the brake release end of the runway) during late January and early February, 1990. Aircraft types of each departure were visually determined by direct observation. Hourly atmospheric records (temperature, dew point, wind speed and direction) were obtained from the National Weather Service sensors at BWI.

Figure 6 shows the locations of these sites. Note that each of the sites is approximately the same distance from the runway end and that a line connecting each site with the runway end forms the same approximate angle with the runway centerline. This was done to ensure that propagation distance and directional characteristics of aircraft noise emissions did not become factors in comparative analyses between measurement sites. Data from the three sites were sorted by aircraft type and plotted to compare them with the SELs predicted by the FAA's Integrated Noise Model (INM).

Figures 7, 8 and 9 present these data for the three sites. In these figures the "X" plotting symbols show the measured SELs. The square plotting symbols show the energy average measured value and the triangular symbols indicate the SEL predicted by the INM. The figures illustrate two important points. First, there is a tremendous range in the measured SELs for any one aircraft type. In some cases this range exceeds 20 decibels. This range is almost certainly attributable to atmospheric effects on overground sound propagation.

The second point is that the measured energy average SELs exceed those predicted by the INM in most cases. Table 10 reports these comparisons in tabular form. With one exception, the measured SEL exceeded the modelled SEL.

TABLE 10. MEASURED AND MODELLED AVERAGE SELS BY AIRCRAFT TYPE

Aircraft	Hanover Avenue Meas'd	INM	Diff	851 Main Avenue Meas'd	INM	Diff	Ferndale Street Meas'd	INM	Diff
B727-200	90.1	82.9	7.2	92.0	90.0	2.0	90.6	87.8	2.8
B737-200	89.8	86.0	3.8	90.7	88.0	2.7	88.4	85.8	2.6
B737-300	76.1	71.1	5.0	78.3	73.1	5.2	77.8	70.8	7.0
DC-9	88.3	84.5	3.8	88.5	86.5	2.0	86.5	84.3	2.2
F28	83.0	83.8	-0.8	86.6	85.8	0.8	86.5	83.0	3.5
MD82	78.7	76.7	2.0	83.2	78.8	4.4	83.1	76.4	6.7

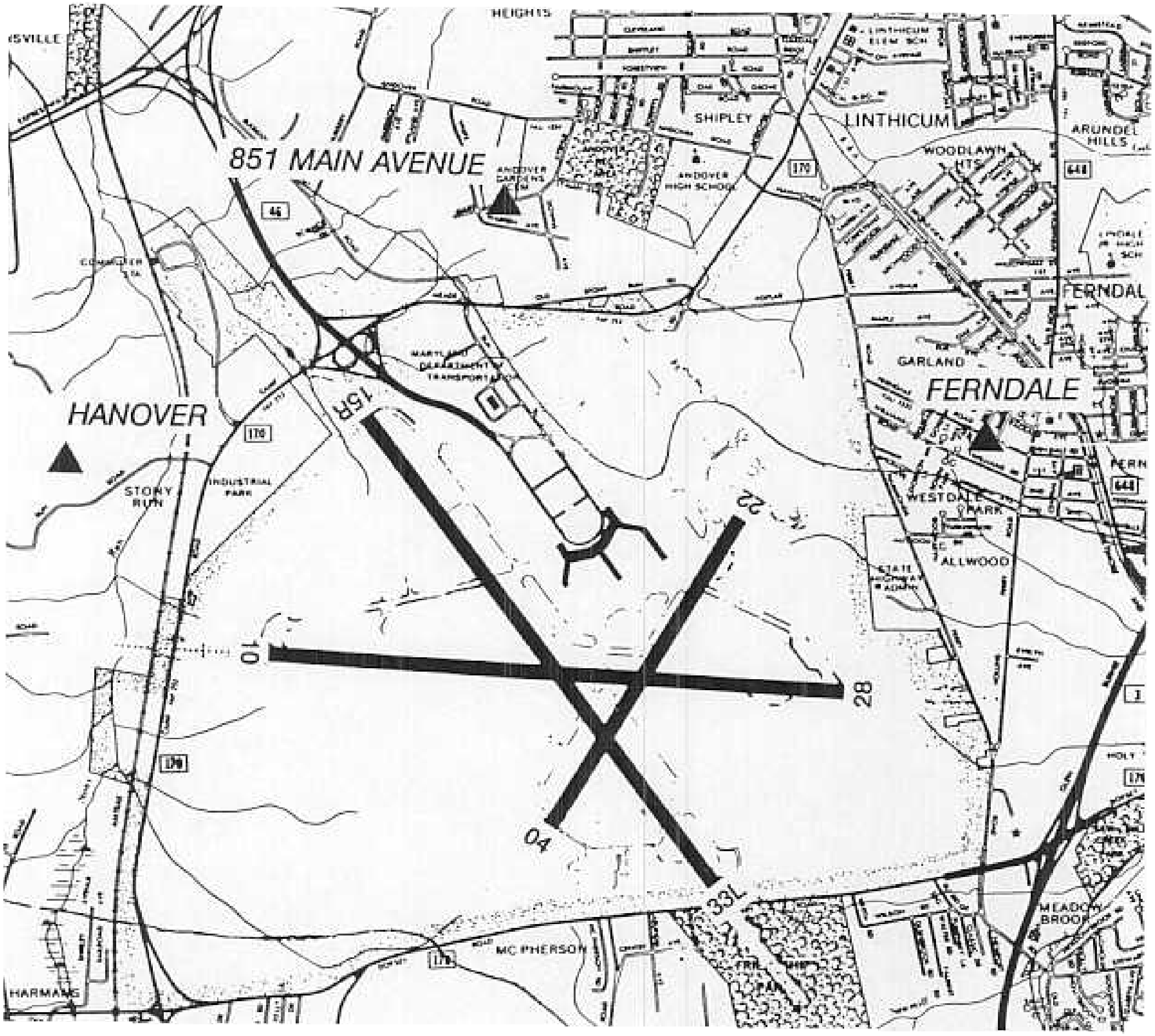


FIGURE 6. MEASUREMENT LOCATIONS FOR OVERGROUND SOUND PROPAGATION STUDY

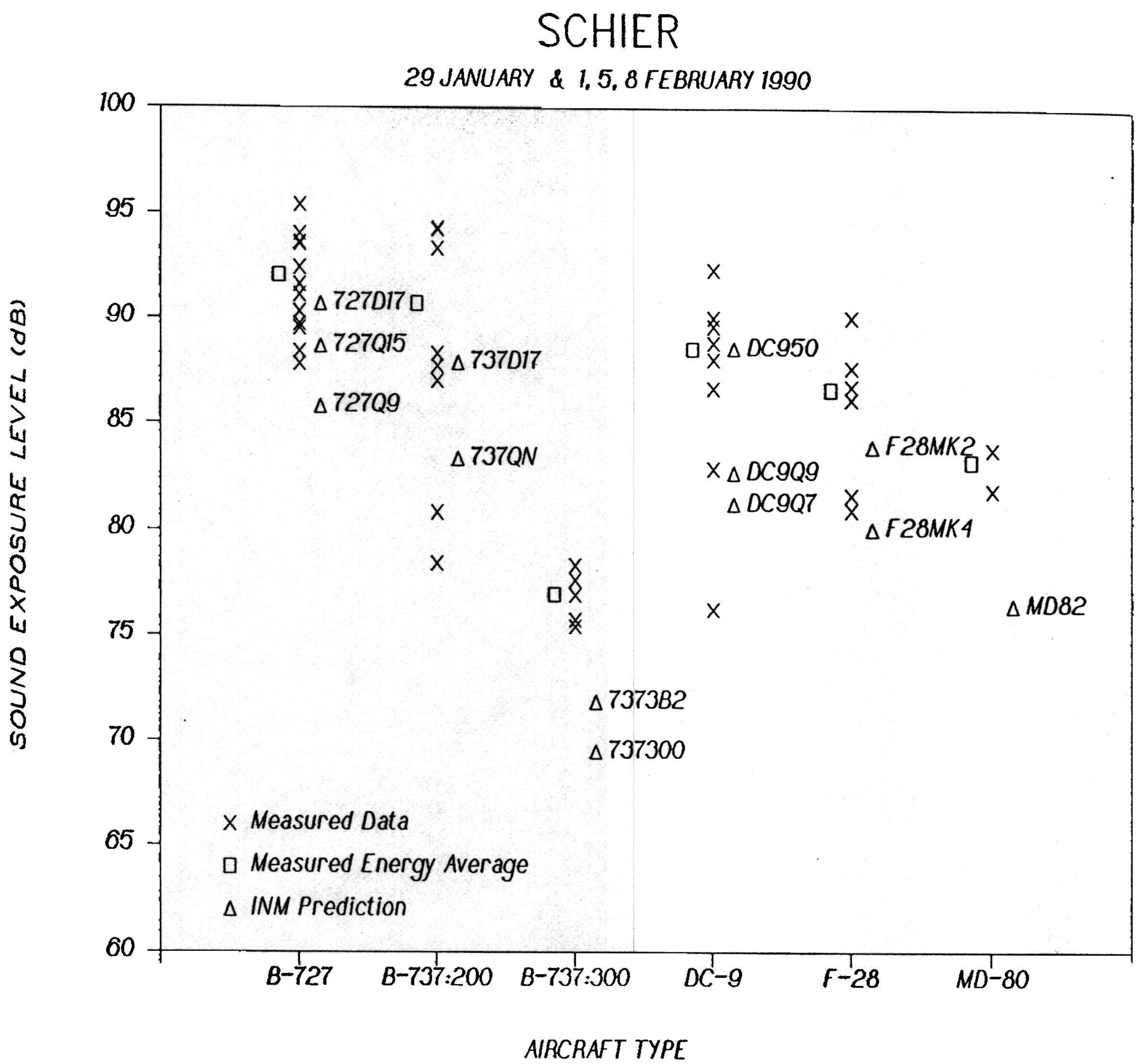


FIGURE 7. MEASURED SOUND EXPOSURE LEVELS AT 851 MAIN AVENUE

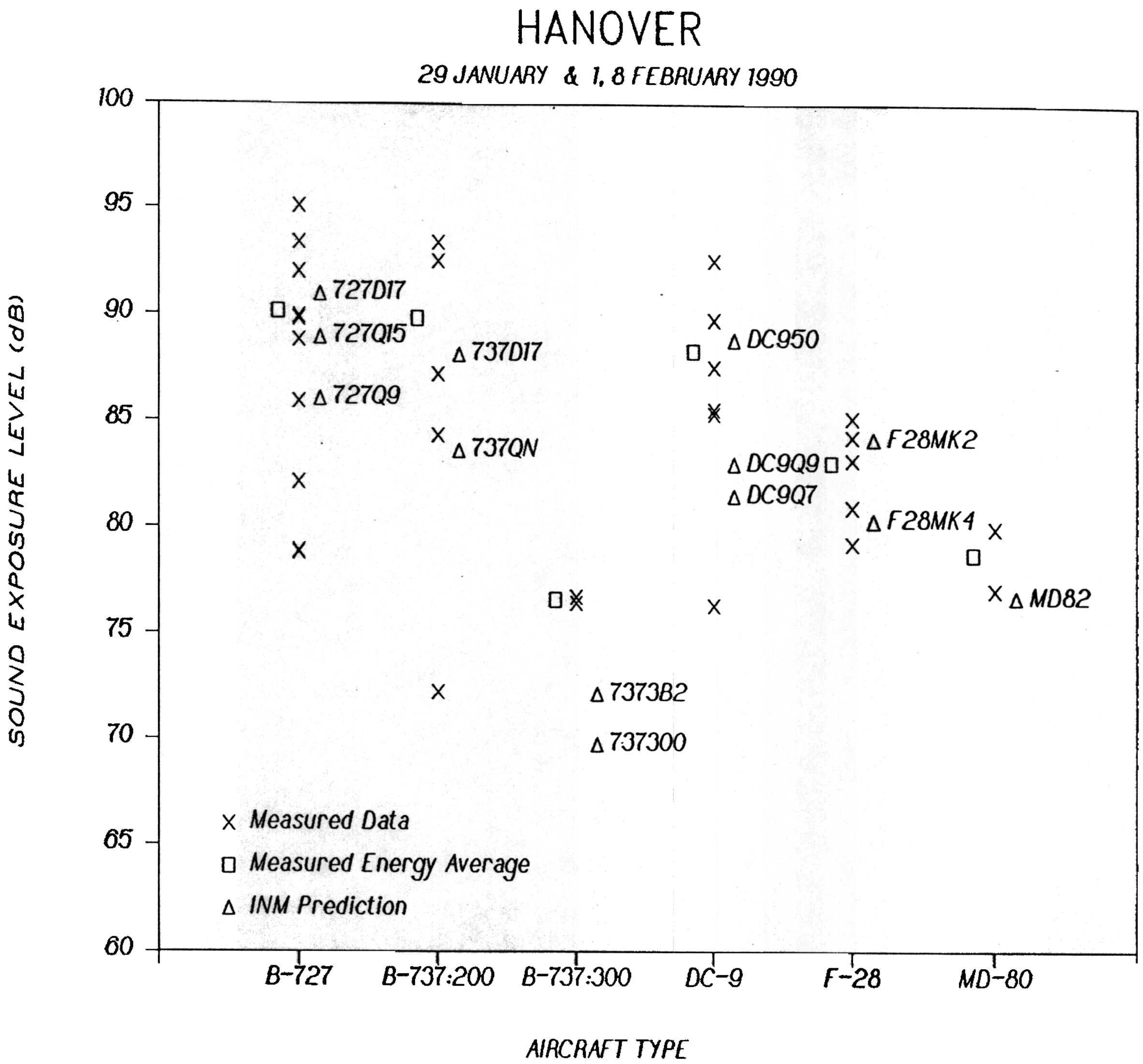


FIGURE 8. MEASURED SOUND EXPOSURE LEVELS AT HANOVER AVENUE

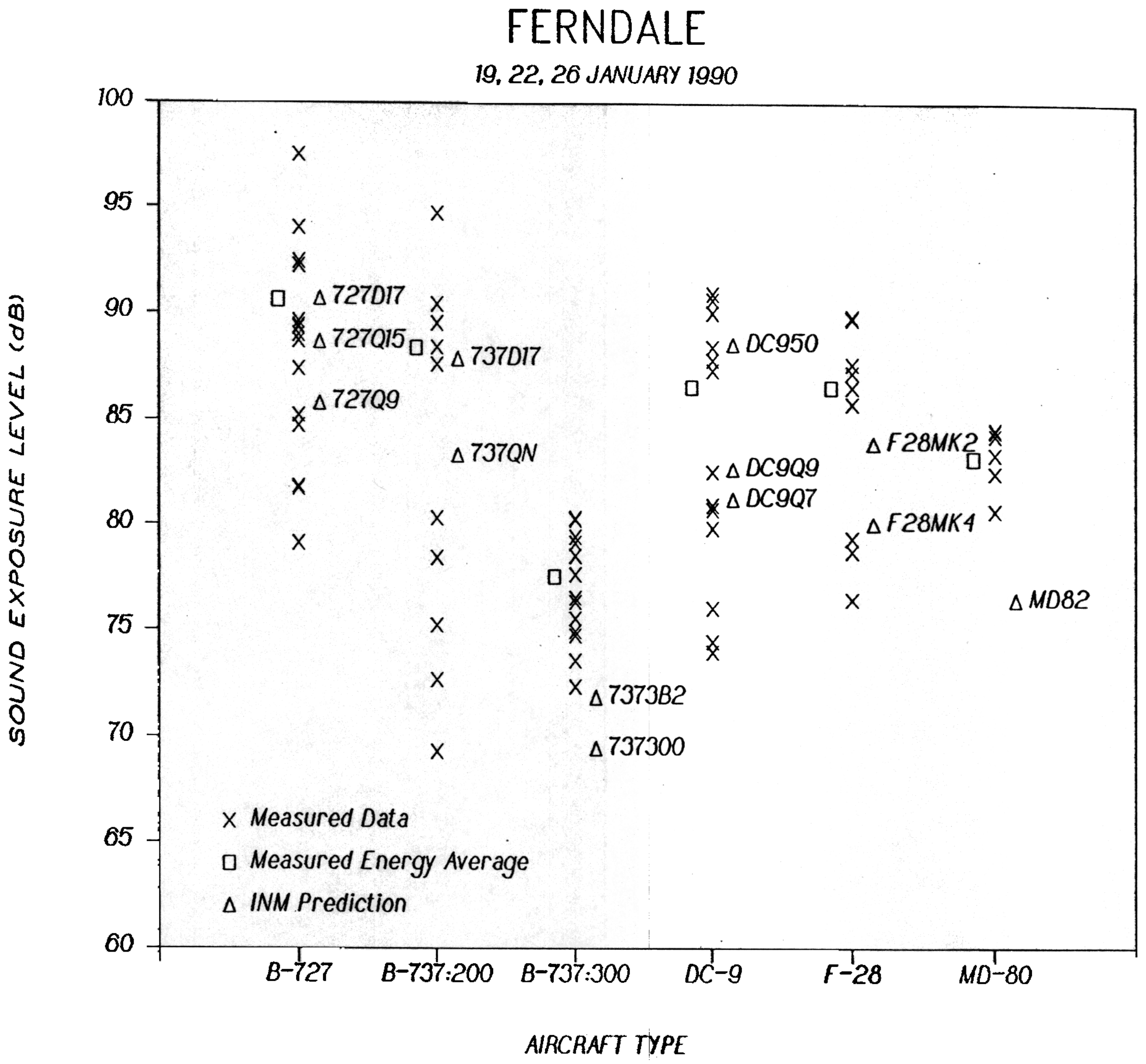


FIGURE 9. MEASURED SOUND EXPOSURE LEVELS AT FERNDALE AVENUE

3.3.2 Assessment of Wind Effects on Measured Sound Exposure Levels

In order to assess the effect of wind on the measured SELs the wind component velocity in the direction of the runway end to the measurement site was determined for each of the data points shown in Figures 7, 8, and 9. This was accomplished by matching the measurement dates and times of each event against the hourly weather records at BWI and interpolating between the hourly readings to estimate wind speed and direction at the time of the measurement. The wind direction was then compared to the sound propagation direction from the runway end (from which the highest noise level of the aircraft was assumed to emanate) to the measurement site, and the wind component speed in the later direction calculated.

Figures 10 through 15 replots the SELs shown in Figures 7, 8 and 9 against the estimated wind component speed at the time of the measurement. Each figure plots the data of a different aircraft type. The data points on the right half of the figures show measurements from downwind sound propagation conditions: that is, with the wind blowing in the same direction as the sound propagation from source to receiver. The data on the left side of the figures show measurements from upwind sound propagation conditions where the wind is blowing in the opposite direction, from the receiver to the source. For the sake of comparison all SELs were normalized to the Main Avenue site to account for small differences in propagation distance. The normalizations were two decibels or less, and were computed by taking the difference in the INM predicted SEL at Hanover or Ferndale and the SEL predicted at Main Avenue on an aircraft-by-aircraft basis.

All figures clearly show the effects of wind velocity on measured SELs and are consistent with findings of prior studies. Sound levels under upwind propagation conditions are consistently less than under downwind conditions. Note that the difference between upwind and downwind propagation is 8 to 10 decibels for Stage 2 aircraft (B727-200, B737-200, DC9 and F28) and 2 or 3 decibels for Stage 3 aircraft (B737-300 and MD80). This phenomenon is almost certainly due to the different spectral (frequency) composition of the noise produced by Stage 2 and Stage 3 aircraft. Stage 2 aircraft have, in general, a larger proportion of high frequency noise than Stage 3 aircraft. These higher frequency noise components are generally attenuated more readily by wind effects than are the lower frequency components.

Figures 10 through 15 also show the energy average sound levels for downwind propagation conditions only. It is our understanding that the intent of the INM is to predict SELs which are consistent with worst case, or downwind, propagation conditions. Table 11 compares these measured downwind SELs (normalized to Main Avenue) with the INM predicted levels at the same location. This table indicates that the INM seems to be underpredicting Stage 2 aircraft SELs by approximately 3 decibels and Stage 3 aircraft by approximately 6 decibels. No immediate reason for this underprediction is evident.

TABLE 11. COMPARISON OF DOWNWIND MEASURED AND PREDICTED SELS

Aircraft Category	Aircraft Type	Meas'd	INM	Diff
Stage 2	B727-200	93.0	90.0	3.0
	B737-200	92.1	88.0	4.1
	DC-9	89.7	86.5	3.2
	F28	88.4	85.8	2.6
	Stage 2 Average			3.2
Stage 3	B737-300	79.5	73.1	6.4
	MD80	84.9	78.8	6.1
	Stage 3 Average			6.3

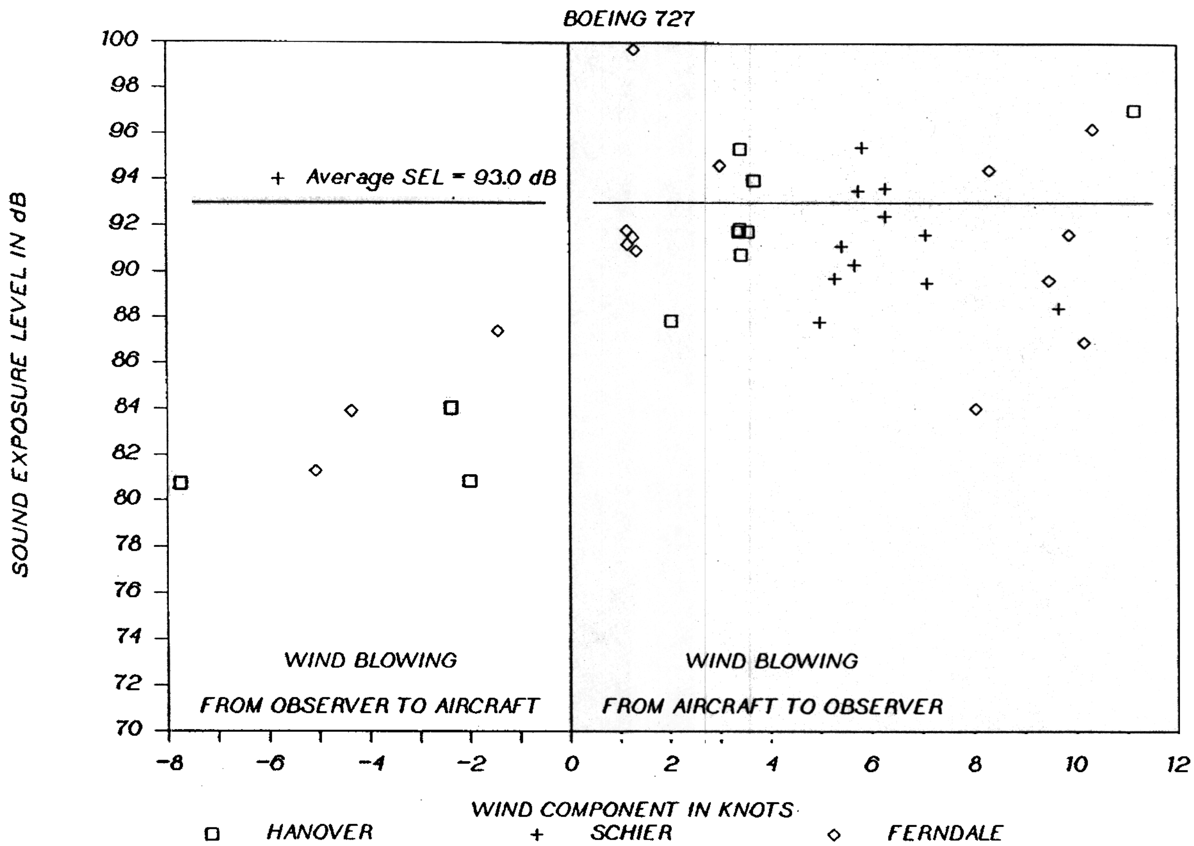


FIGURE 10. MEASURED SELS AS A FUNCTION OF WIND VELOCITY FOR B727-200

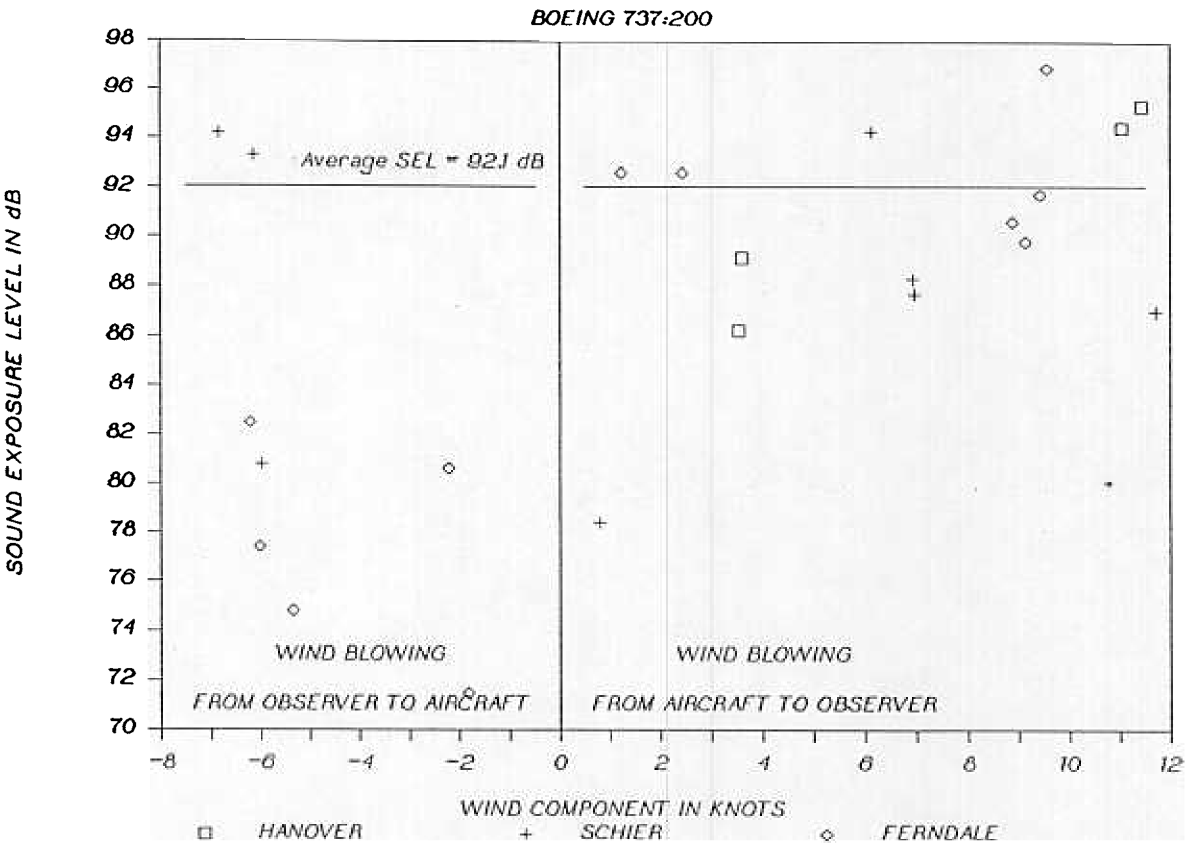


FIGURE 11. MEASURED SELS AS A FUNCTION OF WIND VELOCITY FOR B737-200

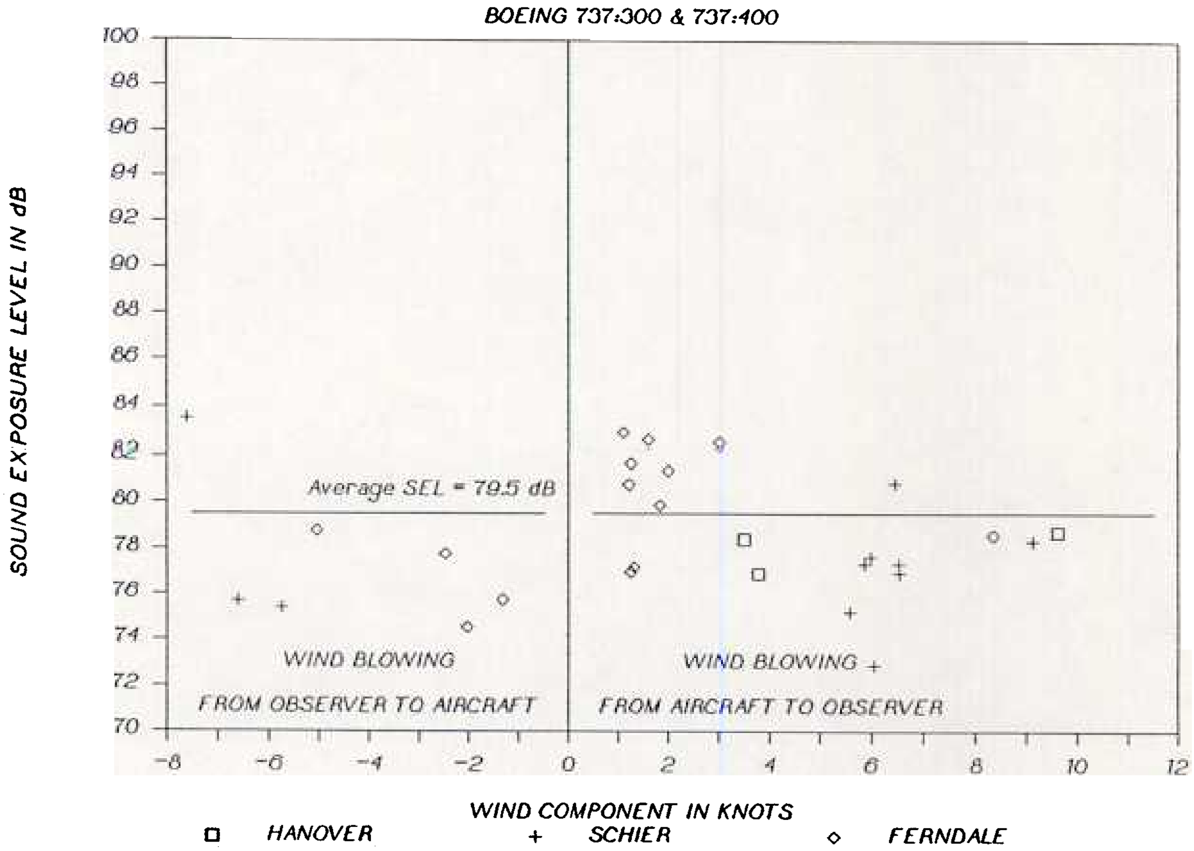


FIGURE 12. MEASURED SELS AS A FUNCTION OF WIND VELOCITY FOR B737-300

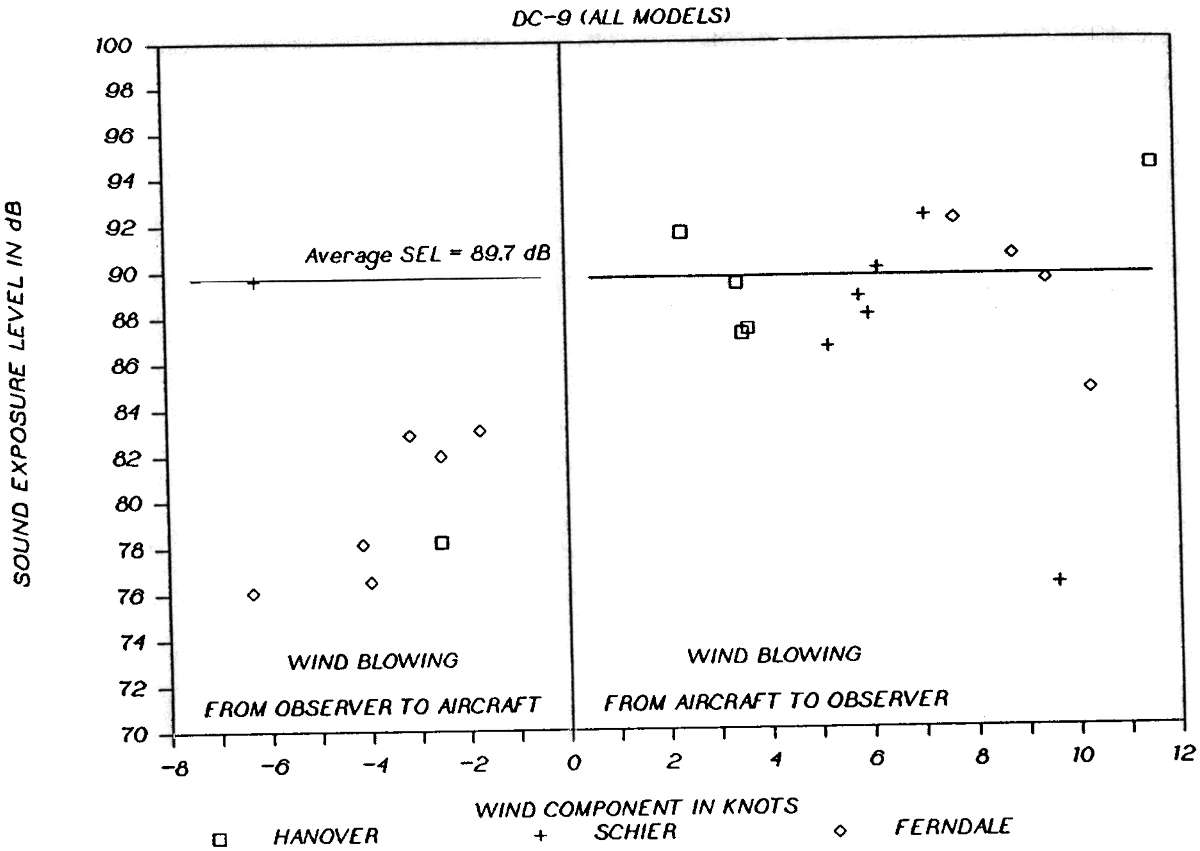


FIGURE 13. MEASURED SELS AS A FUNCTION OF WIND VELOCITY FOR DC9

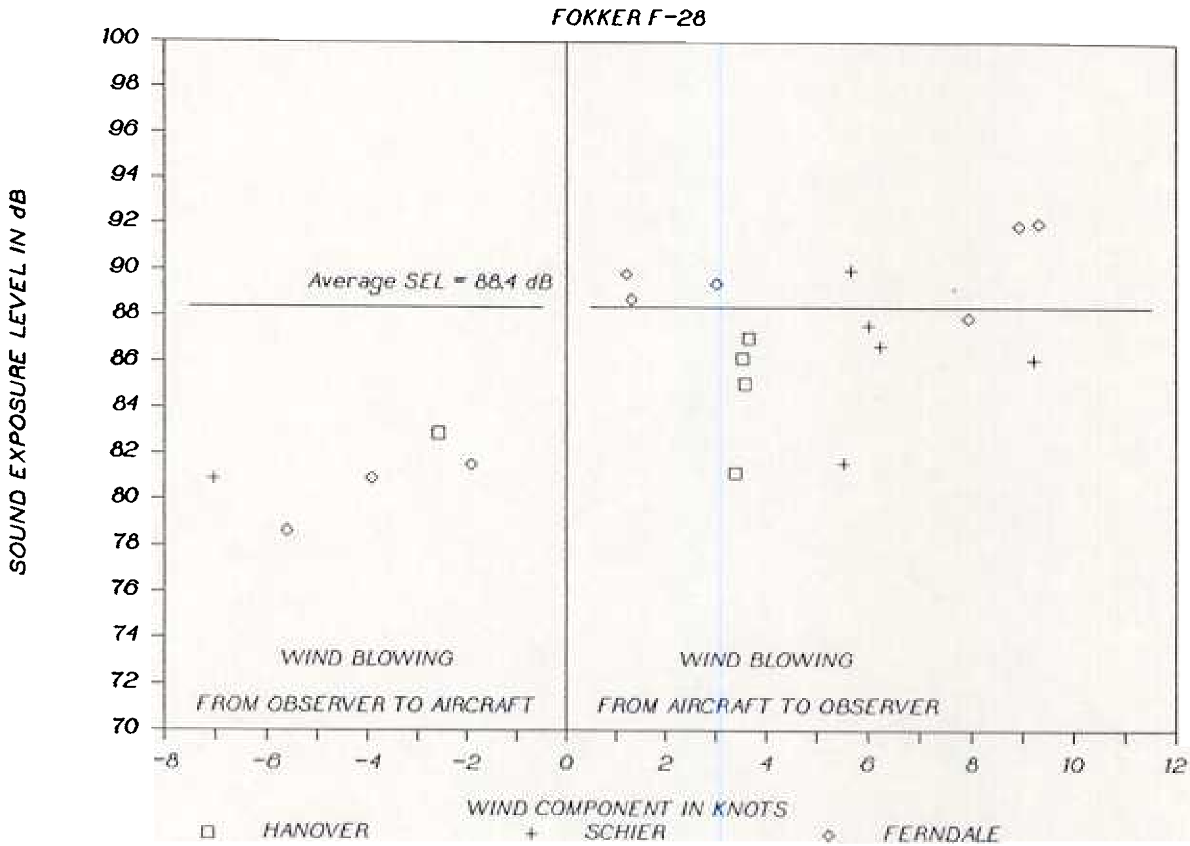


FIGURE 14. MEASURED SELS AS A FUNCTION OF WIND VELOCITY FOR F28

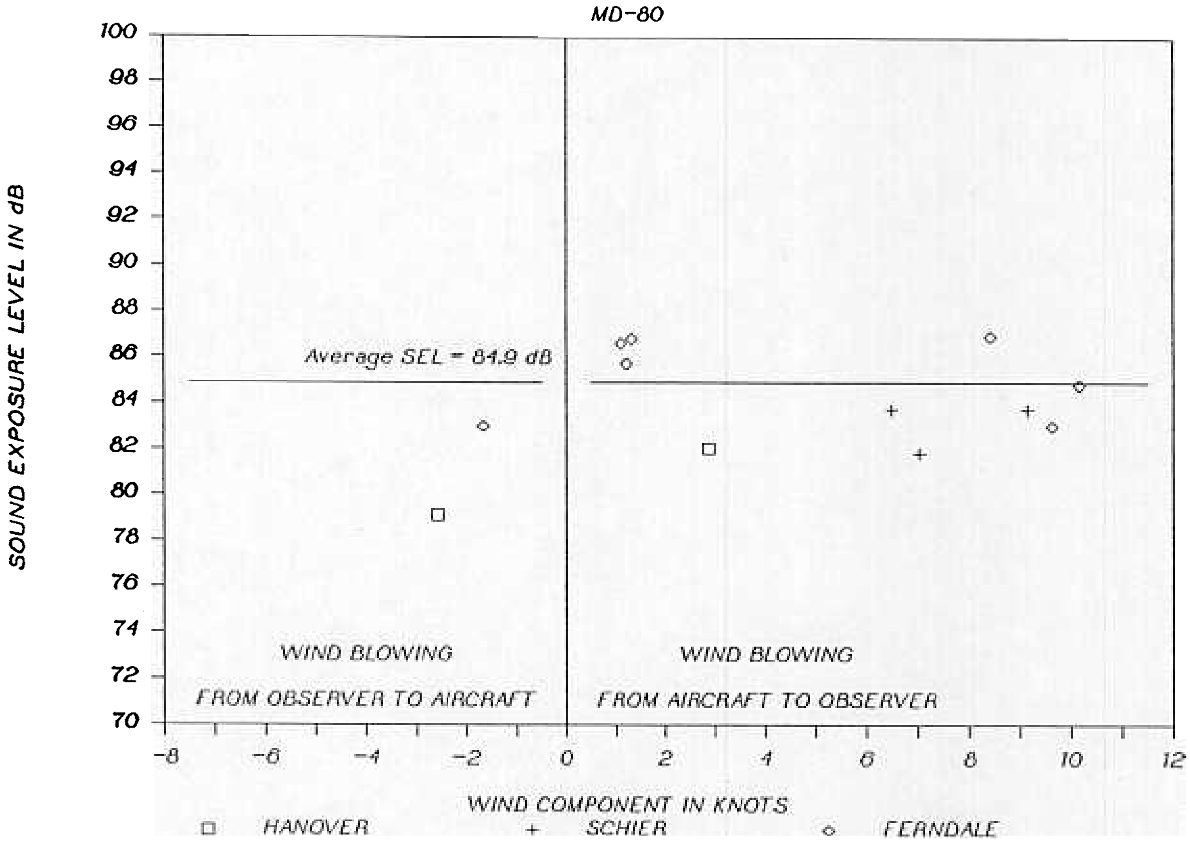


FIGURE 15. MEASURED SELS AS A FUNCTION OF WIND VELOCITY FOR MD80

4. CONCLUSIONS

This study reveals several important considerations with regards to estimating long term average Day/Night Average Sound Levels (Ldn) from short term noise measurements. Some have universal application at any location around the airport. Others are special considerations for measuring in the vicinity of the runway sideline or start-of-takeoff roll. The first consideration is the effect of background noise levels on measured Ldn's. This effect will be greater in low aircraft noise environments than in higher ones, but since the airport Noise Zone is not intended to include local noise sources, background noise should be excluded. To put the magnitude of this effect in some perspective, a typical residential background Ldn of 55 decibels would increase a measured Ldn of 60 by 1 decibel and a measured Ldn of 65 by 0.5 decibels.

The second consideration is ensuring that local, non-aircraft high noise level sources or calibration artifacts are adequately accounted for, either by guarding against them at the time of the measurements, or by removing them in some systematic and defensible way from measured levels. As this study showed, the effect of such artifacts was approximately 1 decibel on the average measured Ldn at the Main Avenue site.

A third item is the effect of maintenance ground runup noise which is not currently considered in the Noise Zone update process. Current maintenance engine runup records appeared to correlate well with all high nighttime hourly noise levels during the measurement period, thus allowing a relatively straightforward assessment of the runup contribution to the average Ldn during the measurement period. The fact that such engine maintenance (1) can generate moderate to high A-weighted sound levels, and (2) occurs during the night when noise receives the 10 decibel Ldn nighttime weighting, suggests that this element of BWI airport noise should receive attention in future Noise Zone updates. In this study, ground runup noise accounted for 1 decibel of the average Ldn over the measurement period at a distance of about one mile from the source. The study did not investigate whether the magnitude of this effect was typical of the site on an annual basis.

To the extent that the same level of maintenance activity can be successfully transferred to daytime hours (7am to 10pm) the impact would on the total Ldn would be lessened because the 10 decibel nighttime weighting penalty would not be introduced. For example, the measured engine runup Ldn of 59.8, when added to the aircraft noise component of 65.9, produces a total of 66.9 decibels (an increase of 1 decibel). If the same runups had occurred during the daytime hours the runup component would have been 10 decibels less, or 49.8, which when added to the aircraft noise component of 65.9 produces a total of 66.0 decibels (an increment of only 0.1 decibel).

A fourth element is the need for a reliable and defensible means by which short term noise monitor data can be effectively used to refine and improve Noise Zone contours in future updates. A critical question in this regard is how short term average values can be most reliably normalized to annual average conditions. Two approaches were used in this study: (1) adjusting on the basis of estimated runway use, and (2) adjusting on the basis of long term monitoring at a permanent monitor site. Both methods had limitations. The runway use limitation was due to the availability of only generalized runway use data during the measurement period and some uncertainty about the accuracy of the long term runway use estimate. The permanent monitor site reference method was limited by the lack of nearby, long term data which would correlate well with the measurement site. The permanent site chosen for correlation was the best available, but uncertainty on the order of 1.5 to 2 decibels still remained in the long term average value which was estimated for the Main Avenue site.

The fifth consideration is the ability of the model to accurately predict noise levels in the vicinity of the start-of-takeoff roll. While the evidence provided by this study is not conclusive, it suggests that the current start-of-takeoff roll noise environment (which is dominated by Stage 2 aircraft) may be underestimated by 2 to 4 decibels. The evidence further suggest that the underestimate may increase with time as the fleet transitions from Stage 2 to Stage 3 aircraft.

5. RECOMMENDATIONS

The conclusions of Section 4 lead to recommendations on two fronts: (1) opportunities for improving the quality of homeowner reports and (2) opportunities for using the data acquired in short term measurements to improve the accuracy of future BWI Noise Zone updates.

With regards to homeowners reports the following recommendations are made:

- Review Noise Monitor Calibration Procedures. The data suggest that either electrical or acoustic noise during noise monitor instrument calibration is being interpreted by the monitor as data. This may be due to instrument malfunction or a misunderstanding of how the instrument functions.

- Eliminate background noise from measurements. This is especially critical in low aircraft noise level environments. Several satisfactory approaches may be used. One would be to assign a threshold level to the HNL measurements to discriminate against background noise. Simple guidelines could be developed for selecting the value of this threshold for any particular site. Another approach would be to measure the total noise environment, and then later subtract an assumed background level (eg. L_{90}) from each hourly noise level to determine the non-background component of the noise environment. The non-background noise hourly noise levels would then be summed to calculate the daily Ldn. This procedure could be quickly automated on a commercially available computer spreadsheet program (such as LOTUS, QUATRO, etc.).

- Separate the contribution of noise sources. If maintenance runups continue to occur at night, they may significantly contribute to the total aircraft noise environment. If so, their contribution to the measured Ldn should be identified. The procedure developed in Table 6 of this report provides one means for approaching the ground runup analysis. Unless there are other known special noise sources, aircraft departures and arrivals may be assumed to make up the balance of the measured Ldn.

- Compare average measured Ldn with probable long term average value. It is probably useful to estimate how the average measured Ldn compares with expected long term levels. This would serve a dual purpose: Afford the resident with information about how the noise monitor period likely compares to the long term, and provide information to the Aviation Noise Program Office on locations where the current Noise Zone may need future refinement. Expected long term levels may be estimated from the short term measurements by applying an "adjustment factor" to the measured data. The adjustment factor could be developed from accurate runway use data or from noise data from a nearby permanent noise monitor site whose data reliably correlates with the data at the short term site.

Current runway use data provides hours when east or west flow is in progress, but does not provide numbers of operations which are critical to the Ldn. The shorter the monitoring period, the more critical this factor becomes, since one anomalous day can materially affect the average measured Ldn. ARTS data monitoring would be an excellent means for resolving this issue.

The technique developed in Section 3.2.2 would serve well for developing an adjustment factor, provided the reference permanent monitor site were in close proximity to the short term site, and it was subject to the same number of aircraft movements as the short term site.

- Institute a systematic sampling plan at selected sites. Monitoring results obtained at some residences may identify potential noise model versus measurement discrepancies requiring an improved understanding for future Noise Zone updates. A systematic sampling plan of repeat measurement visits to these sites would provide the data needed to reduce the range of uncertainty in predicting annual average sound levels from measurement results. Since a great deal of the uncertainty lies in largely unknown seasonal effects, we recommend measurements at periodic intervals over a twelve month period. The exact measurement plan would naturally have to be based on the availability of monitoring resources consistent with other requirements, along with the nature of the discrepancy under study. For most situations, however, measurements for two to four weeks each quarter would be an appropriate level of monitoring.

- Advise resident of usefulness of his/her request. Some added text may be useful in the homeowners report to indicate how the information gathered at his residence will be used. Wording to the following effect would further demonstrate the Noise Program Offices commitment to the community: "The Noise Zone uses a nationally developed model. No current model accounts for specialized local effects, especially those of topography and wind conditions, which may affect noise levels in some areas. Because of your interest and concern we have learned that .... This provides us with valuable information to include in the next Noise Zone update."

- Consider sending a copy of this report to the FAA. As the current agency having charge of the Integrated Noise Model (INM), the FAA should be aware of the findings regarding the apparent underestimate of the model in predicting aircraft noise levels in the vicinity of start-of-takeoff roll. As future evidence becomes available, a refinement in the model or database may be warranted. The importance of the predictive model's accuracy should be emphasized as purchase assurance plans and home soundproofing programs become heavily reliant on the model for equitably distributing finite resources.

APPENDIX A. MEASURED HOURLY AND DAILY NOISE LEVELS AT 851 MAIN AVENUE

A-1. MEASURED HOURLY AND DAILY NOISE LEVELS

This appendix contains hourly noise level data provided by the BWI Aviation Noise Program Office. The data was acquired using a Metrosonics dB-604 Portable Noise Monitor. Day/Night Average Sound Levels (Ldn) were computed from the hourly noise levels and are shown at the bottom of the column for each day's hourly noise data. Twenty-four hour equivalent noise levels (Leq) are also shown (this value is calculated in an identical manner to Ldn, but without the 10 decibel nighttime weighting.

The original hourly noise level data file contained a small amount of missing data. In order to avoid underestimating the daily Ldn, the missing hourly noise levels were estimated using the arithmetic average of the two nearest adjacent hour's data. These estimates are shown clearly in the table by enclosing the numbers in parentheses ().

TABLE A-1. HOURLY AND DAILY NOISE LEVELS FROM 851 MAIN AVENUE MONITOR SITE

	03-Jan	04-Jan	05-Jan	06-Jan	07-Jan	08-Jan	09-Jan	10-Jan	11-Jan	12-Jan	
Hour	(Wed)	(Thu)	(Fri)	(Sat)	(Sun)	(Mon)	(Tue)	(Wed)	(Thu)	(Fri)	Hour
1	--	58.1	44.0	51.0	48.4	57.3	59.4	63.3	53.7	50.9	1
2	--	57.6	52.3	46.5	44.2	45.9	57.8	52.4	45.2	40.7	2
3	--	59.2	49.9	47.6	45.4	46.9	56.2	60.1	48.3	50.2	3
4	--	56.7	45.3	48.7	50.3	46.5	55.4	62.8	47.9	43.3	4
5	--	74.2	48.4	58.0	53.1	51.2	58.2	51.5	55.6	48.6	5
6	--	64.1	52.1	60.3	56.8	57.6	66.2	58.6	59.6	54.7	6
7	--	68.5	57.0	63.3	62.9	61.0	69.0	62.3	62.7	59.1	7
8	--	69.5	56.2	59.0	65.4	66.2	67.1	62.4	66.6	58.1	8
9	--	71.8	58.5	62.6	68.6	65.9	68.4	61.6	66.8	60.9	9
10	--	72.6	59.6	60.3	64.2	58.2	69.5	62.2	67.0	60.1	10
11	--	68.7	53.5	59.4	58.6	62.1	65.4	60.3	61.2	57.7	11
12	--	66.4	57.5	58.3	61.3	59.9	64.8	58.9	65.3	57.7	12
13	--	66.0	60.2	59.6	62.2	61.8	65.4	(59.3)	64.1	61.7	13
14	52.1	63.0	53.8	53.9	55.7	62.3	64.5	(59.3)	61.4	54.2	14
15	58.4	66.5	55.3	57.0	59.2	55.1	64.7	(59.3)	60.7	64.6	15
16	66.7	66.9	61.2	62.7	64.0	58.7	66.7	59.6	64.3	(62.8)	16
17	68.2	66.1	60.9	59.0	66.9	59.9	69.0	61.2	64.9	61.0	17
18	66.9	63.1	57.4	51.2	60.0	57.7	71.4	54.2	61.6	56.1	18
19	65.4	64.5	59.7	51.5	61.1	54.8	71.8	56.6	57.2	56.7	19
20	66.1	66.6	64.0	56.0	67.2	55.4	69.9	59.2	57.1	58.5	20
21	64.6	63.7	63.5	58.2	62.8	58.6	71.0	60.8	59.2	61.3	21
22	61.1	61.2	58.0	51.9	56.9	59.4	70.2	54.3	53.2	51.5	22
23	61.4	56.3	59.6	46.1	58.7	59.1	64.3	49.8	51.2	53.3	23
24	58.6	53.7	58.4	49.3	58.6	57.7	62.4	51.7	50.4	53.7	24
Leq	61.1	67.2	58.4	58.0	62.2	59.9	67.3	59.7	61.9	58.5	Leq
Ldn	63.2	73.0	62.3	63.5	65.2	64.0	71.0	66.0	64.7	61.5	Ldn

NOTES: (1) Measurements obtained during calendar year 1990.
(2) Sound levels include both aircraft and community noise sources.
(3) Leq = 24 hour average equivalent sound level, in decibels.
Ldn = Day/Night Average Sound Level, in decibels.
(4) Hourly Noise Levels in brackets () are estimates in place of missing data.

TABLE A-1 (CON'T). HOURLY AND DAILY NOISE LEVELS FROM 851 MAIN AVENUE MONITOR SITE

	13-Jan	14-Jan	15-Jan	16-Jan	17-Jan	18-Jan	19-Jan	20-Jan	21-Jan	22-Jan	
Hour	(Sat)	(Sun)	(Mon)	(Tue)	(Wed)	(Thu)	(Fri)	(Sat)	(Sun)	(Mon)	Hour
1	44.6	43.1	43.5	52.8	55.3	53.8	--	48.8	46.7	49.0	1
2	40.4	42.5	45.3	50.1	52.2	46.8	--	48.4	36.6	47.6	2
3	44.6	47.2	48.9	54.3	54.7	51.7	--	45.3	38.7	51.9	3
4	45.2	49.2	49.0	53.9	50.0	47.0	--	45.9	36.1	52.1	4
5	50.5	49.1	51.7	62.4	59.0	54.6	--	50.2	37.4	49.6	5
6	51.7	54.0	69.9	62.2	61.3	58.4	--	60.1	52.4	55.1	6
7	57.3	57.4	70.9	64.4	62.5	61.7	--	66.8	58.2	59.5	7
8	54.8	58.9	69.9	65.5	64.9	61.9	--	61.2	61.4	61.7	8
9	57.9	58.7	68.8	65.2	64.8	63.2	--	66.7	52.1	63.5	9
10	59.1	58.0	71.3	62.8	64.4	62.2	--	69.5	59.6	65.6	10
11	53.1	53.1	60.6	55.7	63.5	--	--	63.3	57.3	(62.4)	11
12	54.1	54.3	60.3	57.7	61.6	--	--	66.1	57.8	59.2	12
13	57.9	58.8	61.4	64.4	65.0	--	--	68.0	59.0	60.0	13
14	51.2	52.6	54.7	54.7	59.5	--	--	59.9	58.0	55.1	14
15	54.5	61.9	60.9	56.0	60.5	--	54.2	64.9	57.3	60.6	15
16	62.1	65.1	64.1	63.0	71.1	--	59.3	68.6	58.7	62.0	16
17	56.1	67.1	62.8	63.1	74.9	--	58.1	70.4	59.2	64.1	17
18	53.4	61.9	66.6	61.5	69.9	--	53.8	59.0	55.2	60.9	18
19	52.7	67.0	71.2	62.9	71.8	--	49.3	58.6	53.6	63.2	19
20	54.9	69.4	74.6	63.5	73.8	--	56.6	60.7	57.9	65.3	20
21	56.9	64.5	74.3	63.2	63.5	--	65.0	61.1	58.9	57.8	21
22	47.3	57.5	63.1	60.3	59.2	--	58.4	60.3	48.2	54.5	22
23	49.3	56.1	57.7	59.5	59.0	--	58.1	59.1	48.3	53.1	23
24	43.6	48.3	52.5	54.9	55.2	--	54.3	54.7	41.3	50.1	24
Leq	55.0	61.5	67.6	61.5	67.0	55.4	54.8	64.1	56.3	60.4	Leq
Ldn	58.4	63.0	71.6	66.5	68.6	61.6	58.1	67.2	59.0	62.7	Ldn

NOTES: (1) Measurements obtained during calendar year 1990.
(2) Sound levels include both aircraft and community noise sources.
(3) Leq = 24 hour average equivalent sound level, in decibels.
Ldn = Day/Night Average Sound Level, in decibels.
(4) Hourly Noise Levels in brackets () are estimates in place of missing data.

TABLE A-1 (CON'T). HOURLY AND DAILY NOISE LEVELS FROM 851 MAIN AVENUE MONITOR SITE

	23-Jan	24-Jan	25-Jan	26-Jan	27-Jan	28-Jan	29-Jan	30-Jan	31-Jan	01-Feb	
Hour	(Tue)	(Wed)	(Thu)	(Fri)	(Sat)	(Sun)	(Mon)	(Tue)	(Wed)	(Thu)	Hour
1	46.1	56.0	54.8	51.2	49.5	55.6	37.9	50.6	56.2	56.7	1
2	44.1	49.8	51.7	49.8	48.3	51.5	38.3	51.3	56.6	53.7	2
3	52.7	73.1	53.5	48.1	46.2	50.6	39.1	55.2	56.7	53.6	3
4	50.0	73.5	52.0	43.8	51.0	51.2	41.7	54.2	54.8	52.5	4
5	54.7	61.2	59.5	50.1	53.9	50.8	41.8	51.0	53.3	57.5	5
6	55.7	63.7	62.8	55.4	56.0	56.0	54.3	55.1	64.7	60.7	6
7	59.1	65.5	68.9	59.8	61.0	59.1	62.0	61.0	59.5	63.6	7
8	58.8	66.0	68.1	65.2	62.4	58.9	62.6	58.1	56.2	66.4	8
9	60.2	66.9	69.9	58.3	64.8	59.8	64.3	59.9	54.3	68.0	9
10	59.3	63.9	70.1	63.8	61.6	60.8	63.6	61.7	60.7	63.5	10
11	59.6	58.4	66.7	56.8	56.7	51.3	59.9	54.7	57.5	62.3	11
12	60.2	58.8	65.5	(56.4)	56.9	56.4	60.6	55.5	65.6	63.8	12
13	67.3	(58.9)	67.1	(56.4)	59.7	56.4	63.7	58.6	66.1	64.1	13
14	53.8	(58.9)	61.5	(56.4)	54.7	49.6	76.3	57.5	57.1	59.5	14
15	59.8	58.9	64.9	55.9	59.3	52.5	64.9	58.8	80.3	59.9	15
16	67.1	64.1	68.9	59.6	66.5	57.0	67.9	61.8	57.6	63.1	16
17	69.3	63.0	67.4	59.9	67.7	59.7	67.7	60.0	65.8	71.4	17
18	66.9	62.1	67.3	56.7	63.5	51.3	66.9	54.9	63.2	69.9	18
19	64.4	64.0	71.7	57.2	67.9	50.5	66.3	56.3	66.5	70.4	19
20	69.5	69.5	72.9	58.9	70.1	54.5	72.9	62.2	74.4	74.0	20
21	69.0	64.0	73.2	59.0	69.7	54.9	63.3	64.6	73.6	73.3	21
22	65.0	60.6	70.1	53.5	54.5	45.6	58.9	63.1	62.4	71.1	22
23	60.2	59.1	60.8	55.9	58.1	42.7	56.7	63.0	61.8	60.4	23
24	61.6	56.3	56.2	52.8	54.8	38.4	55.4	55.6	57.2	57.8	24
Leq	63.7	65.6	67.7	58.1	63.3	55.6	66.3	59.3	69.0	67.1	Leq
Ldn	66.0	73.6	70.3	61.8	65.2	60.6	67.3	64.3	70.3	68.9	Ldn

NOTES: (1) Measurements obtained during calendar year 1990.
(2) Sound levels include both aircraft and community noise sources.
(3) Leq = 24 hour average equivalent sound level, in decibels.
Ldn = Day/Night Average Sound Level, in decibels.
(4) Hourly Noise Levels in brackets () are estimates in place of missing data.

TABLE A-1 (CON'T). HOURLY AND DAILY NOISE LEVELS FROM 851 MAIN AVENUE MONITOR SITE

Hour	02-Feb (Fri)	03-Feb (Sat)	04-Feb (Sun)	05-Feb (Mon)	06-Feb (Tue)	07-Feb (Wed)	08-Feb (Thu)	09-Feb (Fri)	10-Feb (Sat)	11-Feb (Sun)	Hour
1	52.1	42.7	42.3	39.7	57.2	58.7	45.9	59.4	--	--	1
2	49.0	40.2	38.9	44.2	53.8	57.0	48.8	55.5	--	--	2
3	50.8	38.2	37.0	43.2	52.4	58.9	50.2	56.5	--	--	3
4	50.0	39.9	45.8	42.6	52.2	56.0	46.6	54.5	--	--	4
5	60.0	51.8	41.4	44.1	57.8	59.2	55.7	61.2	--	--	5
6	60.6	53.6	48.3	49.6	58.6	62.5	57.5	63.9	--	--	6
7	66.1	57.6	55.8	55.9	62.8	66.9	61.9	64.0	--	--	7
8	69.5	56.5	61.0	60.6	61.7	72.1	63.3	65.8	--	--	8
9	69.4	57.1	53.2	56.1	59.6	64.0	63.5	66.2	--	--	9
10	66.9	58.4	59.9	59.5	59.7	83.3	59.2	--	--	--	10
11	62.6	59.1	63.8	55.5	55.9	55.9	59.6	--	--	--	11
12	84.4	62.1	55.3	55.7	58.0	55.9	63.3	--	--	--	12
13	64.4	62.4	45.9	58.7	56.9	57.5	64.3	--	--	--	13
14	60.7	58.0	46.6	81.5	50.0	56.3	61.1	--	--	--	14
15	59.8	62.2	53.8	58.2	53.3	52.2	62.5	--	--	--	15
16	57.9	61.2	56.6	58.1	57.2	58.2	67.0	--	--	--	16
17	56.6	63.7	54.8	57.0	56.7	59.0	68.9	--	--	--	17
18	57.8	58.9	51.3	56.9	65.7	55.8	68.7	--	--	--	18
19	56.5	60.1	52.8	61.0	67.9	52.9	69.2	--	--	--	19
20	58.5	62.7	53.9	64.4	73.0	60.6	73.7	--	--	--	20
21	58.5	61.4	59.8	65.4	72.5	58.9	72.4	--	--	--	21
22	53.4	46.7	53.0	62.9	71.7	55.8	68.2	--	--	--	22
23	53.9	40.5	50.3	64.0	63.6	53.2	62.8	--	--	--	23
24	47.8	37.6	47.9	58.1	58.7	47.5	58.8	--	--	--	24
Leq	71.2	58.7	55.6	68.3	65.0	70.2	66.0	58.3	0.0	0.0	Leq
Ldn	72.0	60.5	58.0	69.1	67.7	71.5	67.8	65.8	6.4	6.4	Ldn

NOTES: (1) Measurements obtained during calendar year 1990.
(2) Sound levels include both aircraft and community noise sources.
(3) Leq = 24 hour average equivalent sound level, in decibels.
Ldn = Day/Night Average Sound Level, in decibels.
(4) Hourly Noise Levels in brackets () are estimates in place of missing data.