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Environmental Noise Assessment Hartsfield International Airport Atlanta, Georgia

ENVIRONMENTAL NOISE ASSESSMENT
HARTSFIELD INTERNATIONAL AIRPORT
ATLANTA, GEORGIA

by

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Atlanta, Georgia 30308

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This report has been reviewed by Region IV of EPA and approved for publication and release. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency. In addition, the mention of trade names and commercial products in no way constitutes an endorsement or recommendation of their use.

The identification of threshold noise exposure levels has been made on purely scientific terms in regard to the public health and welfare. No consideration was given relative to the availability of technology or the economic reasonableness of achieving such levels. Consequently, while L_{dn} = 55 dBA is a desirable long term goal, the necessity (in a statutory sense) of achieving it is not expressly stated or implied by this report.

Purpose

The information disseminated through the issuance of this report has been developed as a result of requests for current data on the noise environment adjacent to Hartsfield International Airport. These requests have come separately from Sixth District Congressman, John J. Flynt, Jr., Mr. George Berry of the City of Atlanta, the City Managers of College Park and Forest Park, Georgia, and the Mayor of Mountain View, Georgia. The U. S. Environmental Protection Agency, under Section 14 of the Noise Control Act of 1972, PL 92-574, was mandated to provide technical assistance to states and local governments, as well as individuals within the private sector. Included in this broad charge under Section 14 of the Act was the dissemination to the public of information on the effects of noise, acceptable noise levels, and techniques for the measurement of noise and noise control.

Thus, as a result of the aforementioned specific requests for technical assistance combined with the requirements of Section 14, PL 92-574, this report has been issued.

Abstract

This report contains information regarding the environmental noise levels in areas adjacent to Hartsfield International Airport in Atlanta, Georgia. Two separate studies were undertaken and incorporated into a single report. Continuous twenty-four hour field monitoring of the environmental noise levels was conducted at forty-two locations over a land area of approximately seven square miles, and for each of the sites surveyed the following minimum information was available on an hourly basis: the hourly equivalent sound level $L_{eq(1)}$, the maximum sound level for the period L_{max}, the sound level exceeded 50 percent of the time L_{50}, and L_{90}, the sound level exceeded 90 percent of the time. At certain of the locations even more detailed information was obtained. All data presented is in terms of an A-weighted descriptor. Due to the sheer volume of the data obtained (the monitoring time at individual sites varied from two days to thirty-five days), the hourly statistical information was reduced to daily or twenty-four hour time averages. As a result, the report addresses only $L_{eq(24)}$ and L_{dn} when identifying the noise exposure that exists in the study area. It does not consider the effect of intrusive single events which may lead to subjective reactions of varying degree depending on the exposure conditions.

To provide additional information in areas where monitoring could not be conducted because of resource constraints, analytical contours of average day-night sound level (L_{dn}) were developed from a grid of sound levels with a spacing of 1000 feet on a side. The contours were constructed employing operational data for 1977 level of operations and were done in 5 dBA increments from 55 dBA to 85 dBA. Because of the exceedingly large land areas involved, the graphics in this report extend only to L_{dn} = 65 dBA for complete closure of the contours, although some parts of the L_{dn} = 60 dBA contour are visible. The approximate land areas within these contours including off airport property are as follows:

Contour	Total area within contour (acres)	Area within contour exterior to airport boundary (acres)
L_{dn} = 85 dBA	1,900	160
L_{dn} = 80 dBA	4,200	1,500
L_{dn} = 75 dBA	8,600	5,600
L_{dn} = 70 dBA	19,900	16,500
L_{dn} = 65 dBA	49,200	45,800

The airport itself occupies some 3,750 acres. Unfortunately, as may be seen from the contours provided, considerable land (much of it residential) exists outside the airport boundary within the L_{dn} = 85 dBA and L_{dn} = 80 dBA contours.

To verify the information developed through the analytical prediction, sound levels identified with particular grid locations were compared with the data that resulted from the field monitoring. Since the contours were developed from an "average day" at the airport, the predicted L_{dn} was compared with an energy average of the daily L_{dn} obtained by measurement. Obviously, the more extensive the monitoring at a particular location, the better agreement one would expect between the field data and the prediction. This is because the short term energy average is likely to approach the "average day" prediction as time increases and more data is assessed. The results of this comparison are described in terms of the deviation between the analytically predicted L_{dn} and the measured L_{dn}. The average deviation from the prediction (without regard to whether it was positive or negative) is presented as a function of the number of days actually monitored at each site. For sites monitored three days or less the average deviation from the prediction is 1.55 dB, while for those sites monitored for nine days or more, the average deviation dropped to 0.85 dB. A summary of the findings and conclusions regarding the data and the degree of impact associated with the identified levels has been provided.

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I. Introduction

The degree of noise impact around many of the nation's larger airports has become an issue of increasing concern for local planners, airport proprietors, and the affected citizens as well. In addition, Agencies and Departments of the U. S. Government have realized the need for relief from this unwanted intrusion into the life style of individuals living in the near proximity of major hub airports. A report issued in 1973(1) quantified the extent of the problem by describing the effect of the spectacular growth of commercial air transportation in the past twenty-five years. Expansion of air traffic during that period brought with it an increased degree of noise pollution as new jet airplanes were introduced into the commercial fleet. The result of this expansion is that approximately sixteen million Americans are subjected to noise levels causing either annoyance or, in the extreme, risk of hearing loss. The acoustic threshold for this assessment (or response) is an average day-night level of 60 dBA; or some sixteen million Americans reside in areas where the noise level as a result of aircraft operations exceeds L_{dn} = 60 dBA. While it is true that the identification of potential annoyance has occurred for long term exposure to levels of L_{dn} = 55 dBA, it must be recognized that for such levels other sources of noise may be equal to or of greater importance than aircraft. In terms of the 1973 data(1) the number of people exposed to different levels of airport noise is:

Day-Night Avg. Sound Level L_{dn}	1972 Population Exposed (Millions of People)
Greater Than	
80	0.20
70	3.40
60	16.0

The entire issue of aircraft/airport noise is exceedingly complex, and the legal ramifications associated with various decisions of local airport proprietors regarding noise abatement remains unresolved. While it is true that much of the noise impact has resulted from the physical expansion of airport facilities and aircraft fleets, it is also true that encroachment has occurred because the airport proprietor has not had the zoning authority in areas adjacent to airport property. As a result, people "have come to a nuisance" with the airport not being liable in those cases, for damages to their property. This report is not an attempt to assess the blame for what has happened in the areas adjacent to

Atlanta's Hartsfield Airport. Its purpose is to provide the most recent up-to-date data on the degree of noise impact associated with the 1977 level of operations at the airport. It is hoped that the information, once made available, will be utilized by the proprietor and those federal agencies that have the authority to effect at least a partial solution to the problem.

II. Criteria for the Assessment of Impact

The measurements made and all the data presented are in terms of A-weighted sound levels. The A-weighted sound level has been selected by the Agency as being acceptable for assessing community noise and reaction to same. The rationale has been explained in the EPA Report 550/9-74-004, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety."(2) It has been found that with respect to both simplicity and adequacy of characterizing human response, a weighted sound level should be used in the evaluation of community noise. The A-weighted network, standardized in current sound level meter specifications, has been widely used for both transportation and community noise description. For many noises, the A-weighted sound level has been found to correlate as well with human responses as the more complex measures, such as perceived noise level and loudness level calculated from measurements of the acoustic spectrum.

The A-weighted sound levels considered in the results of this study do not in general correspond to instantaneous sound levels, but are rather equivalent or energy average sound levels. The utilization of energy average sound levels in the description of environmental noise exposure has been accepted by EPA through the development of the "Levels Document." Again quoting from that report:

> "A complete physical description of a sound must describe its magnitude, its frequency spectrum, and the variations of both of these parameters in time. However, one must choose between the ultimate refinement in measurement techniques and a practical approach that is no more complicated than necessary to predict the impact of noise on people. The Environmental Protection Agency's choice for the measurement of environmental noise is based on the following considerations:
>
> 1. The measure should be applicable to the evaluation of pervasive long-term noise in various defined areas and under various conditions over long periods of time.
>
> 2. The measure should correlate well with known effects of the noise environment on the individual and the public.
>
> 3. The measure should be simple, practical and accurate. In principal, it should be useful for planning as well as for enforcement or monitoring purposes.

4. The required measurement equipment, with standardized characteristics, should be commercially available.

5. The measure should be closely related to existing methods currently in use.

6. The single measure of noise at a given location should be predictable, within an acceptable tolerance, from knowledge of the physical events producing the noise."

"These considerations, when coupled with the physical attributes of sound that influence human response, lead EPA to the conclusion that the magnitude of sound is of most importance insofar as cumulative noise effects are concerned. Long-term average sound level, henceforth referred to as equivalent sound level (L_{eq}), is considered the best measure for the magnitude of environmental noise to fulfill the above six requirements. Several versions of equivalent sound level will be used for identifying levels of sound in specific places requisite to protect public health and welfare. These versions differ from each other primarily in the time intervals over which the sound levels are of interest, and the correction factor employed."

Equivalent A-weighted sound level is the constant sound level that, in a given situation and time period, conveys the same sound energy as the actual time-varying A-weighted sound. The basic unit of equivalent sound levels is the decibel, and the symbol for equivalent sound level is L_{eq}. Two sounds, one of which contains twice as much energy but lasts only half as long as the other, would be characterized by the same equivalent sound level; so would a sound with four times the energy lasting one-fourth as long. The relation is often called the equal-energy rule. A more complete discussion of the computation of equivalent sound level, its evolution and application to environmental noise problems, and its relationship to other measures used to characterize environmental noise is provided in Appendix A of the "Levels Document."

One of the most meaningful versions of equivalent sound level used in accommodating various modes of noise exposure is the equivalent level for twenty-four hours weighted for nighttime exposure, L_{dn} (average day-night sound level). This quantity is used to relate noise in residential environments to chronic annoyance by speech interference and in some part by sleep and activity interference. In determining the daily measure of environmental noise, it is important to account for the differences in response of people in residential areas to noises that occur during sleeping hours as compared to waking hours. During nighttime, exterior background noises generally drop in level from daytime values and further, the activity of most households decreases at night, lowering the internally generated levels. As a result, noise events of a specific intensity become more intrusive at night.

To account for this increase in the intrusive character of nighttime noise (nighttime is defined as the 9 hours from 10 p.m. to 7 a.m.), a 10 dB penalty or weighting is applied to noise levels during that time period. Thus, L_{dn} is defined as the A-weighted average sound level in decibels (re 20 micropascals) during a twenty-four hour period with a 10 dB weighting applied to nighttime sound levels.

The quantification of equivalent A-weighted sound level over a twenty-four hour period $L_{eq}(24)$ and the quantification of L_{dn} has been determined relative to hearing loss and activity interference and has been published in the "Levels Document." Table 1 shows the criteria against which measured noise levels may be compared. In the explanation of the identified level for hearing loss, the exposure period which should not result in hearing loss at the identified level is 40 years.

Table 1

SUMMARY OF NOISE LEVELS IDENTIFIED AS REQUISITE TO PROTECT PUBLIC HEALTH AND WELFARE WITH AN ADEQUATE MARGIN OF SAFETY

EFFECT	LEVEL	AREAS
Hearing Loss	$L_{eq}(24) \leq 70$ dB	All areas
Outdoor activity interference and annoyance	$L_{dn} \leq 55$ dB	Outdoors in residential areas and farms and other outdoor areas where people spend widely varying amounts of time and other places in which quiet is a basis for use.
	$L_{eq}(24) \leq 55$ dB	Outdoor areas where people spend limited amounts of time, such as school yards, playgrounds, etc.
Indoor activity interference and annoyance	$L_{dn} \leq 45$ dB	Indoor residential areas
	$L_{eq}(24) \leq 45$ dB	Other indoor areas with human activities such as schools, etc.

The utilization of the L_{dn}/L_{eq} descriptor in the assessment of noise impact has not been limited solely to this Agency. Other federal agencies involved in airport planning such as the Federal Aviation Administration (FAA), Housing and Urban Development (HUD), the Navy, and Air Force all either use these descriptors or accept their use. There should be great caution exercised, however, when threshold levels are identified in terms of cumulative measures. Table 1 identifies threshold criteria deemed requisite to protect public health and welfare with an adequate margin of safety over a forty year exposure period. They are not design goals. In the identification of these levels no consideration was given to technological feasibility, economic reasonableness or even whether it was completely desirable to achieve them. Consequently, their value lies primarily in their identification as long range planning goals for those communities able to adjust to the additional constraints of technological feasibility and economic reasonableness.

While the value of L_{dn} = 55 dBA has been identified by EPA solely in terms of a threshold criteria for health, it is important to understand that many federal agencies (HUD, EPA, FAA, Air Force, and Navy) appear to agree that contours of L_{dn} = 65 dBA should be plotted in all airport assessments. Within the areas so designated, ($L_{dn} \geq$ 65 dBA) development (commercial, institutional, residential) should not be allowed without noise mitigation.

III. Health and Welfare Implications of Noise Exposure

EPA Statutory Noise Authority

The Environmental Protection Agency derives its statutory noise authority from Public Law 92-574, the Noise Control Act of 1972. The Congress has declared that it is the policy of the United States to promote an environment for all Americans free from noise that jeopardizes their health or welfare. In that regard the Noise Control Act included a directive that the EPA Administrator shall develop and publish criteria with respect to noise. Such criteria was to reflect the scientific knowledge most useful in indicating the kind and extent of all identifiable effects on the public health or welfare which may be expected from differing quantities and qualities of noise. In addition, the EPA Administrator was then to publish information on the levels of environmental noise, the attainment and maintenance of which in defined areas under various conditions are requisite to protect the public health and welfare with an adequate margin of safety.

Implications and Effects of Noise Exposure

As a result of these directives and the publications resulting from same, consideration should be given to the terms "health and welfare." As used therein, "health and welfare" is defined as "complete physical, mental, and social well-being and not merely the absence of disease and infirmity." This definition takes into account subclinical and subjective responses (e.g., annoyance or other adverse psychological reactions) of the individual. All data to date indicates that the most serious clinical health and welfare effect caused by noise is interference with the ability to hear. The phrase "health and welfare" also includes personal comfort and well-being and the absence of mental anguish and annoyance. In fact, a considerable amount of the data available on the effects of noise is expressed in terms of annoyance. However, quoting from the "Levels Document," annoyance is a description of the human reaction to what is described as noise interference, and though annoyance appears to be statistically quantifiable, it is a subjective reaction to interference with some desired human activity." Many of the effects of noise and exposure to it are not readily quantifiable. That is, the quantification of the noise level and exposure time to that level necessary to produce observable effects in humans remains unresolved in a large number of instances. In any event, as part of a study designed to present information on the possible effects resulting from noise exposure, the following areas should be given consideration. (More detailed information may be found in EPA Publication 550/9-73-002, Public Health and Welfare Criteria for Noise.[3])

Stress Reactions

The degree to which a stimulus such as noise poses a threat to the health and welfare of an individual depends upon the exposure. If the noise stimulus is of a very brief duration (an impulsive sound evoking a startled response), the transient nature of the exposure allows the physical system to return to its normal state. If, however, the noise stimulus is continuous or consistently repeated, it has been observed that specific changes occur in neurosensory, circulatory, endocrine, sensory and digestive systems. These effects may be less transitory. If noise exposure is looked upon as being a stress, there is seldom an instance where a single stressing condition exists alone. Often when a combination of stresses occur of which noise is only one, the result is a response of fear or anger yielding an entirely different pattern of body responses. In this regard, the "Criteria Document" concludes "short and infrequent periods of stress are usually innocuous by virtue of there being an opportunity for the relevant opposing forces of the body to regain their balance as posing a potential danger to the health of an individual, this attitude being largely developed from extensive work on experimental animals. A major question that does not appear to have been resolved is with regard to the point at which a noise becomes a stressing agent in man, and what amount of exposure is necessary to cause long-lasting or permanent physiological changes."

Circulatory System

Specific effects of noise on the circulatory system remain unresolved. Laboratory studies on the gross parameters of the circulatory system such as blood pressure, pulse rate, EKG, are apparently negligible at least up to sound intensities of 100 dB SPL. Associated with ongoing noise exposure, however, some researchers have found evidence of constriction of blood vessels in peripheral regions of the body such as fingers and toes. In extreme cases the effect has been found to represent changes as great as 40% from the resting value. Some observations have led to the conclusion that vascoconstriction does not completely adapt with time, either on a short-term or long-term basis, and the effects often persist for a considerable length of time after the noise exposure. Quantification of the levels necessary for this effect have been shown to begin above 70 dB SPL. The effect has been found to be proportioned to the number of decibels above 70 dB, up to 110 dB at least.

Sleep Interference

Although a thorough treatment of the subject is not possible here, there exists evidence that noise may interfere with sleep. High noise levels or intrusive noise events may awaken sleeping persons or prevent them from falling asleep. Additionally, lower levels of noise may be sufficient to shift a person's sleep from one stage into a less restful stage. Certain groups such as the old and sick are more sensitive to these intrusions. Since sleep is thought to be a restorative process during which the organs of the body renew their supply of energy and nutritive elements, noise as it affects sleep could be a health hazard. In any event, since survey data indicate that disturbance with sleep is often the principal reason given for noise annoyance and consequently, lowers the quality of life, interference with sleep by noise constitutes a health hazard within the framework of the "health and welfare" definition. Moreover, it is the opinion of some researchers that sleep interruption or sleep modification due to noise exposure is one of the most harmful conditions noise poses for an individual's overall health.

General Health and Welfare

In terms of adverse influences on the general health of individuals, many conditions have been attributed to noise exposure. These include:

Nausea
Headaches
Irritability
Instability
Argumentativeness
Reduction in Sexual Drive
Anxiety
Nervousness
Insomnia
Abnormal Somnolence
Loss of Appetite

The assessment of such claims are exceedingly difficult, one reason being their essentially subjective nature. In addition, the bulk of the data available that has resulted in the above expressions of discomfort has come from occupational environments where other factors exist that could possibly account for many of the symptoms with or without the influence of noise. Quantitative evidence in regard to the condition alluded to above is far from clear.

Performance and Efficiency

How noise affects performance and work efficiency may be a topic more germane to an occupational noise setting than it is to one considering environmental noise. However, in looking into the broad question of the effect of noise on public health and welfare, certain comments should be made relative to how extended exposures to intense noise levels may affect performance and efficiency. It has been found that continuous exposures to noise levels above 90 dBA appear to have potentially detrimental effects on human performances, especially on certain types of tasks. The effect of noise exposure on more routine tasks is less important. While quantification of the effect has been made at 90 dBA, levels less intense can be disruptive when intermittent, unexpected, or uncontrolled. Noise has not been found to influence the overall rate of work usually, but high noise levels can produce variability in the work rate. Accuracy is more likely to suffer rather than volume of work output and complex or demanding tasks are more likely to be adversely effected than simple tasks.

Normal Human Activities

Environmental noise may interfere with many normal human activities resulting in a degradation of public health and welfare. These activities include:

1. speech communication in conversation and teaching
2. telephone communication
3. listening to television and radio broadcasts
4. listening to music
5. concentration during mental activities
6. relaxation
7. sleep

Regarding certain specific listening situations, interference can be quantified in terms of the absolute level of the environmental noise and its characteristics. Speech communication is a normal activity readily interfered with by excessive environmental noise. As a result, it may become a source of annoyance that over an extended period of time is considered to affect individual as well as public health and welfare. Of particular note is the effect of noise on face to face conversation both indoors and outdoors, telephone use, and the enjoyment of radio or television. As part of the basis for establishing "levels of environmental noise requisite to protect public health and welfare with an adequate margin of safety," critical evaluation was made of the equivalent sound levels that allow outdoor communication with a normal voice when 95 percent sentence intelligibility is the criteria. Levels have been identified for both continuous and fluctuating noises and result in a criteria compatible with an exterior L_{dn} of 55 dBA.

The interference with normal human activities resulting from excessive noise intrusions can be seen in light of studies done in an airport environment (London's Heathrow) as reported in the "Levels Document - Appendix D." Specific activities relative to both sleep and domestic factors are identified in terms of the percentage of people disturbed as a function of the outdoor L_{dn}. (Figure numbers and reference numbers in the figure title refer to the "Levels Document.")

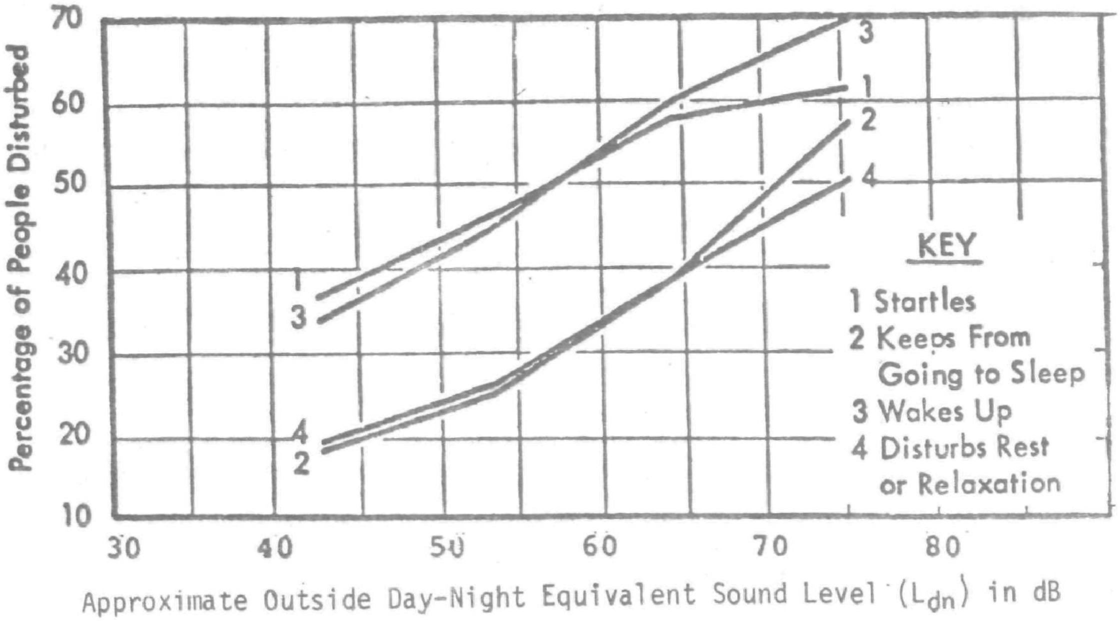


Figure D-5. Percentage of People Disturbed by Aircraft Noise for Various Types of Reasons Concerned With Rest And Sleep [D-6]

For any particular value of exterior L_{dn} and activity in question one can determine the percentage of people who feel that the activity has been significantly interfered with by the noise environment. For example, if the approximate outside day-night equivalent level was 60 dBA, about 58% of the people surveyed were disturbed by the interference with their conversation as caused by the primary source of noise responsible for establishing the L_{dn}; in this case, aircraft flyovers.

A study similar in nature done in the United States provides the information shown in Table D-4 vis-a-vis activity interference. The table gives the activity disturbance percentages of those who reported that they were extremely disturbed by the noise which accounts in part for the low percentage values. During the survey of about 4,000 people, it was reported that the daily activities of 98.6% of those questioned were disrupted one or more times by aircraft noise.

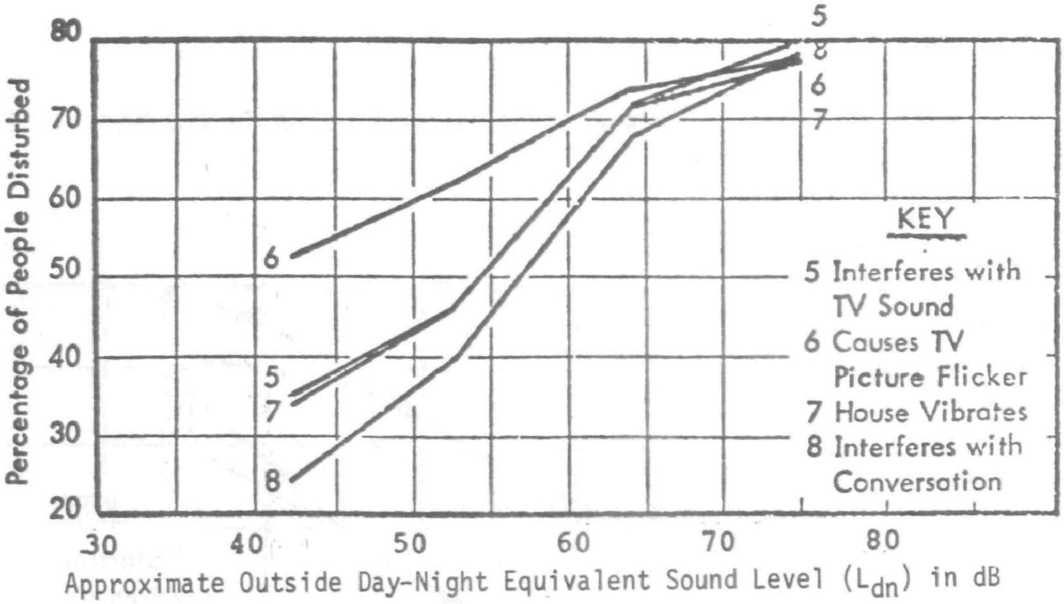


Figure D-6. Percentage of People Disturbed by Aircraft Noise for Various Types of Reasons Concerned with Domestic Factors[D-6]

Table D-4

PERCENT OF THOSE PEOPLE WHO WERE EXTREMELY DISTURBED BY AIRCRAFT NOISE*, BY ACTIVITY DISTURBED[D-7]

Activity	Percent
TV/Radio reception	20.6
Conversation	14.5
Telephone	13.8
Relaxing outside	12.5
Relaxing inside	10.7
Listening to records/tapes	9.1
Sleep	7.7
Reading	6.3
Eating	3.5

*Percent scoring 4 or 5 on a 1-5 scale.

Individuals' Reaction to Noise - Annoyance

Many studies have been conducted to assess the response of individuals, i.e., their feelings as well as their possible actions. In addition, surveys have been undertaken to try to gain insight into the relationship between word descriptors and day-night sound level. In regard to the Heathrow study, the two figures below present more information regarding likely feelings of residents living in an airport environment as a function of L_{dn}. The third figure represents the U. S. study (Table D-4), the first Heathrow study, and a second Heathrow study in the same general areas as the first. While some refinements were attempted in this second study, six years later, the results were generally the same. From these results it may be postulated that the percentage of annoyed people may be predicted as:

$$\% \text{ Highly Annoyed} = 2 (L_{dn} - 50)$$

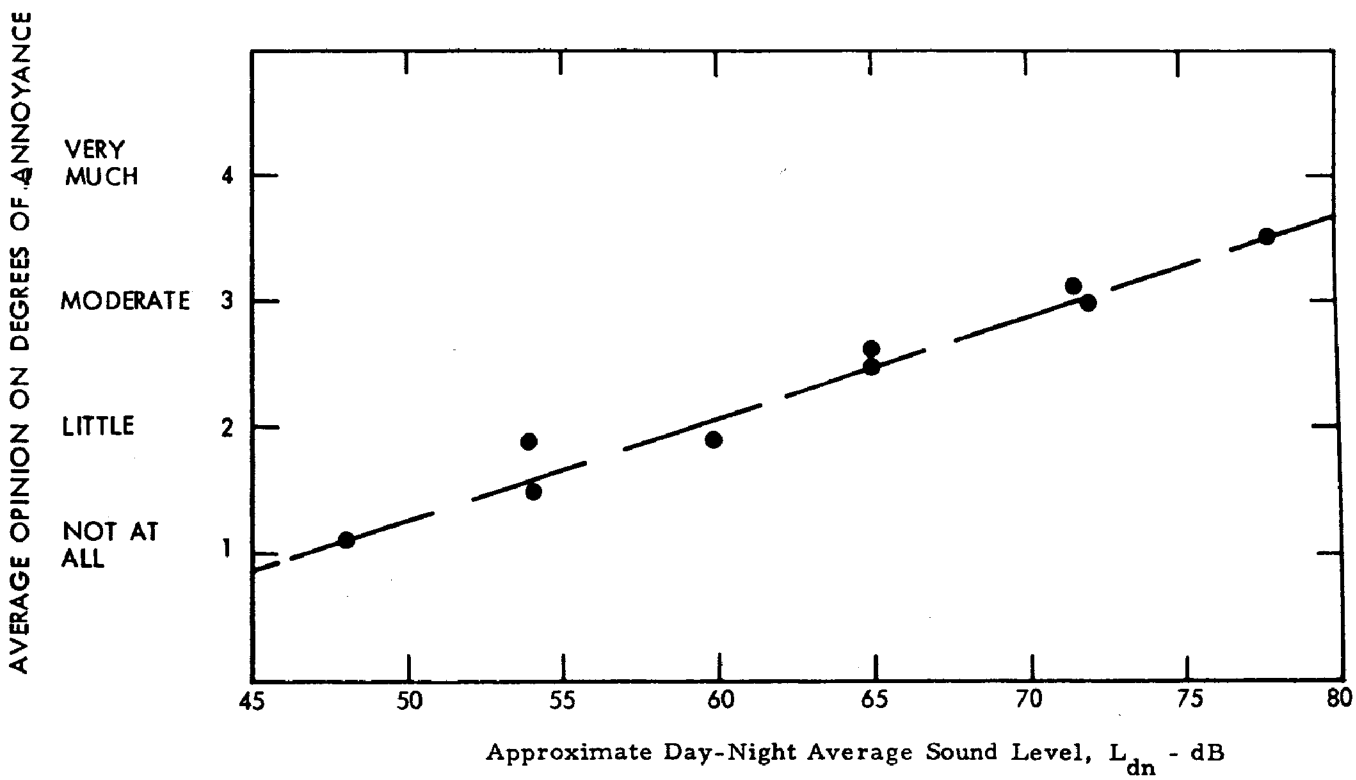


Figure D-9. Average Degree of Annoyance as a Function of the Approximate Day-Night Noise Level – Results of First London Heathrow Survey D-39 from D-6

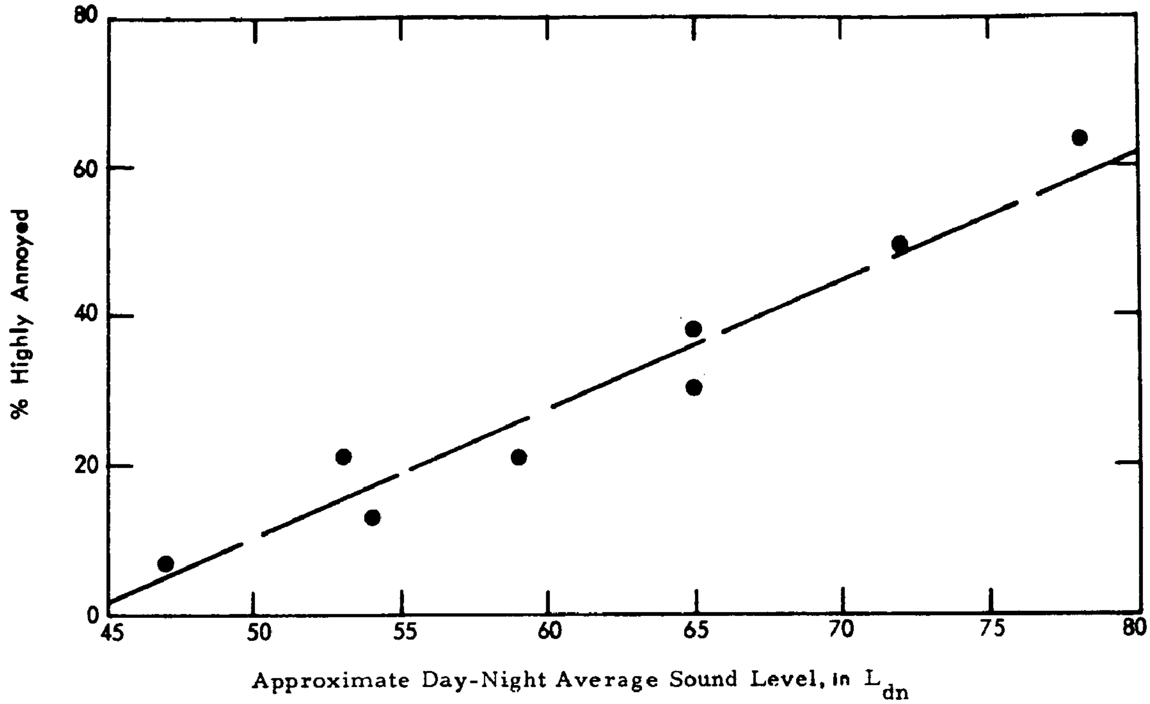


Figure D-10. Percentage Highly Annoyed as Function of Approximate Day-Night Noise Level – Results of First London Heathrow Survey[D-39 from D-6]

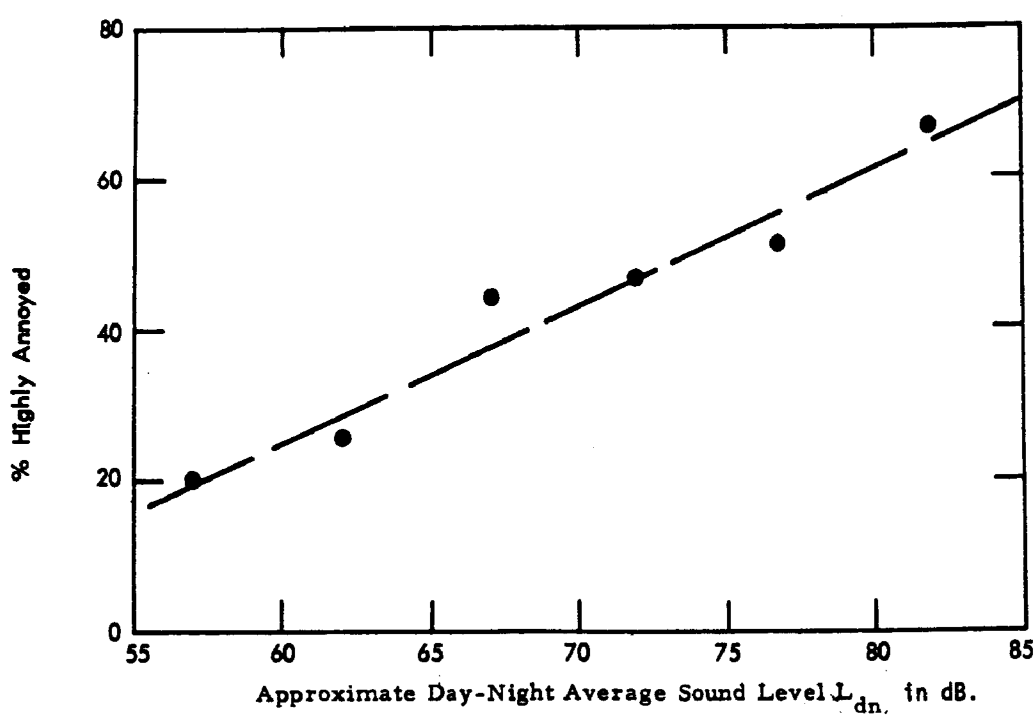


Figure D-13. Combined Results–British and U.S. Surveys[D-17]

In summarizing environmental noise interference with human activities and its resulting effect on public health and welfare, the primary effect is found to be the interference with speech communication. The levels that interfere with human activities which do not involve active listening cannot be quantified relative to the level of a desired sound, and the levels that are associated with annoyance depend upon local conditions and attitudes. The level identified for the protection of speech communication is 45 dB within the home, which can be extrapolated for residential areas to an outdoor L_{dn} of 55 dB.

The effects associated with an outdoor day-night sound level of 55 dB are summarized in Table D-11 (numbers correspond to original reference).

Table D-11

SUMMARY OF HUMAN EFFECTS
IN TERMS OF SPEECH COMMUNICATION, COMMUNITY REACTION, COMPLAINTS, ANNOYANCE AND ATTITUDE TOWARDS AREA ASSOCIATED WITH AN OUTDOOR DAY/NIGHT SOUND LEVEL OF 55 dB re 20 MICROPASCALS

Type of Effect	Magnitude of Effect
Speech – Indoors	100% sentence intelligibility (average) with a 5 dB margin of safety
– Outdoors	100% sentence intelligibility (average) at 0.35 meters
	99% sentence intelligibility (average) at 1.0 meters
	95% sentence intelligibility (average) at 3.5 meters
Average Community Reaction	None, 7 dB below level of significant "complaints and threats of legal action" and at least 16 dB below "vigorous action" (attitudes and other non-level related factors may affect this result)
Complaints	1% dependent on attitude and other non-level related factors
Annoyance	17% dependent on attitude and other non-acoustical factors
Attitudes Toward Area	Noise essentially least important of various factors

As the average day-night sound level increases above L_{dn} = 55 dBA, Figure D-16 illustrates "average community reaction."

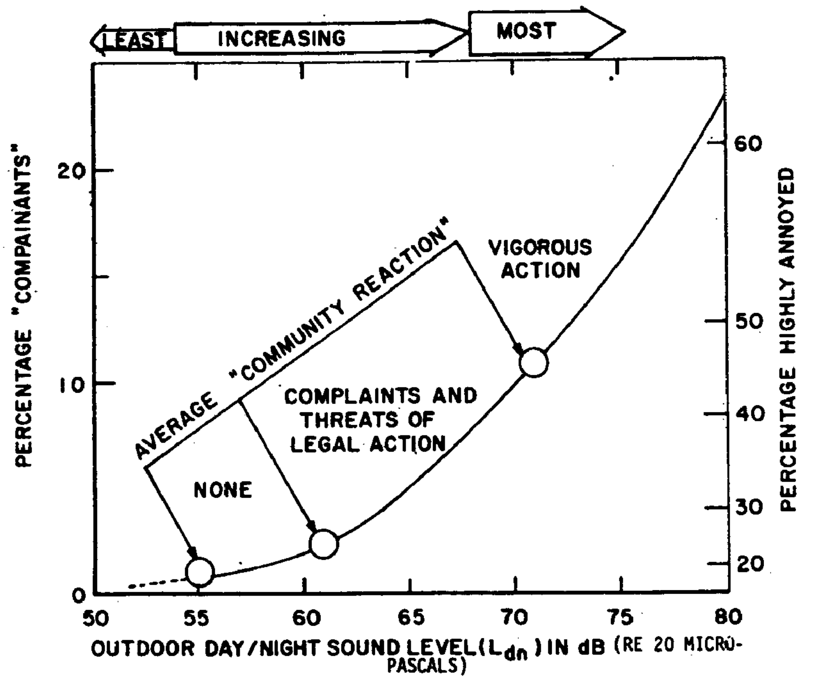


Figure D-16. Summary of Annoyance Survey and Community Reaction Results

It is important to keep in mind that the annoyance tolerance limits obtained from the social survey results have been found to be based on relatively well defined health and welfare criteria; the disturbance of essential daily activities.

Hearing Loss

Logically, it would be assumed that the specific health and welfare effect upon which most reliable data has been accumulated is that of noise induced hearing loss. Under certain conditions such as continuous and ongoing noise in an industrial setting, it has been proven that permanent hearing impairment may be sustained. The proof has been provided by the existence of audiograms for individuals being subjected to high noise levels over extended time periods. Noise is also known to cause temporary hearing loss and ringing in the ears (tinnitus). However, there is a relative lack of data about the effect of shorter-term intermittent or incomplete daily exposures. In situations of this type the effect of noise exposure has been postulated theoretically. One theory of note is the Equal-Energy Hypothesis, which postulates that hearing damage is determined by the total sound energy entering the ear on a daily basis. Since the acoustic energy is related to the sound level, determination of relationships between exposure times (or doses) may be obtained if the sound level is known. If criteria have been established for damage risk relative to a specific equivalent level on a daily basis, extrapolations may be made regarding the exposure times acceptable for progressively higher levels.

A second theory suggests that long-term hearing hazard is predicted by the average Temporary Threshold Shift (TTS) produced by daily noise exposures. That is, a Noise Induced Permanent Threshold Shift (NIPTS) can be predicted from daily TTS. Again drawing on industrial data and averaging the NIPTS predictions from various models gives a fairly dependable measure of hearing risk of noise exposed populations. Hearing damage has been noted at levels as low as 75 dBA after ten years.

The auditory effects as related to hearing loss may be summarized by saying that noise exposure can damage hearing and can lead to both NITTS and NIPTS. For both industrial settings and high intensity impulsive sounds the relationship between exposure and hearing loss is well understood. However, in the case of fluctuating or intermittent noise, data is lacking to the extent that extrapolations are necessary to estimate effects.

IV. Cumulative Measures of Aircraft Noise Impact

Because of the extremely large land areas involved in a comprehensive study of aircraft noise in communities adjacent to a major hub airport, the most cost effective way to study the problem is through the prediction of noise contours. Predictions of noise exposure, however, are only as reliable as the operational input data. Field monitoring of noise levels is of extreme value in assessing the accuracy of the input data through the verification of the noise contours at discrete locations. In either situation cumulative measures are employed in the analysis. A number of the more readily accepted cumulative descriptors are discussed below.

CNR

The development of noise contours has provided valuable information to land use planners around commercial airports for nearly fifteen years. When CNR contours (Composite Noise Rating)[4] were introduced for commercial jet operations in the early 1960's it was possible to assess the degree of noise impact through a matrix of expected community responses resulting from interviews with a statistically significant number of residents in the airport environment. The original method employed Perceived Noise Level (PNL) in decibels (PNdB) as the single event noise descriptor. To provide cumulative impact such factors as time of operation, number of operations, percent runway utilization, and aircraft type are considered. As a result, CNR Zones may be developed, and per Reference 4 the following responses may be expected.

Table 2

Expected Responses of Citizens Residing in Areas Described by the Composite Noise Rating Methodology

CNR Zone 1 ($PNdB < 100$; $CNR < 100$)
Essentially no complaints would be expected. The noise may, however, interfere occasionally with certain activities of the residents.

CNR Zone 2 ($100 \leq PNdB \leq 115$; $100 \leq CNR \leq 115$)
Individuals may complain, perhaps vigorously. Concerted group action is possible.

CNR Zone 3 ($PNdB > 115$; $CNR > 115$)
Individual reactions would likely include repeated, vigorous complaints. Concerted group action might be expected.

The methodology does have the limitation that it is not verificable by measurement. It will be seen later, however, that it is relatable to a measurable parameter within an acceptable degree of error. CNR contours are still used extensively in the development of Environmental Impact Statements (EIS) to illustrate and allow for mitigation of expected impact from present and future aircraft operations.

NEF

A second common method of describing the cumulative effect of aircraft noise is called the Noise Exposure Forecast (NEF). Developed from the basic CNR concepts the "new"methodology(5) appearing in 1967 addressed some of the technical criticisms of the 1964 CNR. The most significant change was the utilization of Effective Perceived Noise Level (EPNL) in decibels (EPNdb) as the basic single event descriptor of aircraft noise. This unit, currently used in the certification of individual aircraft for noise, resulted from the continued evolution of the PNL concept. EPNL expanded upon the PNL concept by including duration factors for the overflight and pure tone corrections since it was well known that the pure tone content of the noise led to increased annoyance. As was found for CNR, NEF requires information on the noise level for each aircraft, number of operations of each aircraft type, and time of operation among other things, to develop contours of noise exposure. More or less standardized responses (again based upon a statistically significant number of respondents) have been developed through social research with the following expected within each NEF Zone.

Table 3

Expected Responses of Citizens Residing in Areas Described by the Noise Exposure Forecast Methodology

NEF 30 (or less)
Essentially no complaints would be expected. The noise may, however, interfere occasionally with certain activities of the residents.

$30 < NEF < 40$
Individuals may complain, perhaps vigorously. Concerted group action is possible.

NEF 40 (or greater)
Individual reactions would likely include repeated, vigorous complaints. Concerted group action might be expected.

Noise Exposure Forecast, like Composite Noise Rating, is a cumulative, but not a physically measurable parameter. Its value is approximately related to the CNR value by a relationship to be discussed later.

L_{dn}

A third method, the one used in this study to portray aircraft impact, is based on the average day-night sound level, a measurable parameter. The average implied in this definition is an energy average rather than an arithmetic average. Because of the logarithmic nature of describing sound levels "average values" can be very misleading. Consider the following example: If two sound sources produce, at a given point, the sound levels shown for the time period given, what are the arithmetic and energy averages for the period?

Source 1 produces a constant level of 100 dB at Point A for five minutes

Source 2 produces a constant level of 70 dB at Point A for five minutes

Arithmetic Average: $\frac{100 + 70}{2} = \frac{170}{2} = 85$ dB

Energy Average: $10 \log_{10} \left[\frac{10^{\frac{100}{10}} + 10^{\frac{70}{10}}}{2} \right] = 96.99$ dB

Note how the energy average is dominated by the higher level since Source 1 has 1000 times the acoustic energy of Source 2. The point to be made is that sound levels do not add in a manner that one might customarily employ for addition processes.

A second issue to be understood when using L_{dn} as an aircraft noise descriptor is the distinction between a cumulative parameter and a parameter describing a single event. Because time is inherently a part of L_{dn} (24 hours is the time base) the single event descriptor used to formulate the predicted L_{dn} from aircraft operations is called the Sound Exposure Level (SEL). The SEL is the A-weighted sound level of a continuous one second signal which contains the same amount of acoustic energy as the actual noise event. Due to the fact that aircraft flyovers generally last longer than one second, the SEL for the event will in all likelihood be higher than the maximum A-weighted level for the same event. Typical acoustic instrumentation used for monitoring will display (and/or store) the maximum rms sound level associated with the event in question. This number is distinctly different from the average day-night sound level. For example, a location adjacent to the airport may be subjected to single events from takeoffs or landings as high as 110 dBA while the average day-night level may be approximately 85 dBA. It should be clear, however, from the previous discussion of energy average that a very few intense sound level events can contribute much more to the energy average than a large number of moderately loud intrusions.

In summary, the following aircraft rating schemes that are cumulative in nature employ the single event descriptor shown:

Table 4

Cumulative Noise Methodologies and Their Corresponding Single Event Descriptor

Methodology	Single Event
Composite Noise Rating (CNR)	Perceived Noise Level (PNL)
Noise Exposure Forecast (NEF)	Effective Perceived Noise Level (EPNL)
Average Day-Night Level (L_{dn})	Sound Exposure Level (SEL)

An approximate relationship exists between the cumulative descriptors. For a tolerance of 3 dB one may translate from one system to another by

$$L_{dn} \doteq NEF + 35 \doteq CNR - 35$$

INM (Integrated Noise Model)

Simply for completeness, a method initially entitled "Aircraft Sound Description System" will be briefly described. Originally developed by the Federal Aviation Administration as a planning tool, the format was to provide the following information. Contours could be developed which illustrate "time above," a particular sound level threshold. Early versions of the method allowed one to determine only contours (a line of constant value of time) for which 85 dBA was exceeded. It is now possible to determine contours for times above 65, 75, 85, 95, 105 and 115 dBA (both the daytime and night-time portions) through the use of the Integrated Noise Model (INM). The original work also allowed the determination of the situation index (SI), a single number representation, incorporating both time and area, of overall noise exposure in excess of 85 dBA. The concepts of Situation Index and "Time Above" are not directly and simply translatable to CNR, NEE or L_{dn}. More recent versions of this methodology are compatible with currently accepted prediction methods and it is now possible to use INM to develop NEF and L_{dn} contours, as well as the "Time Above" information described above.

V. Analytical Prediction of Aircraft Noise - L_{dn} Contours

Atlanta's Hartsfield International Airport is the world's second busiest air carrier airport in terms of total domestic scheduled passengers with over 1,400 daily scheduled operations of all types occurring in late 1977. Based on scheduled operations the peak hour corresponds to about 115 operations. For the determination of noise impact, the number of operations are divided among the three parallel east-west runways. The north runway used for both takeoffs and landings, is 10,000 feet in length, and is designated 8/26. The south runway pair is designated 9L/27R and 9R/27L. 9L/27R is 8,000 feet in length, located 4,000 feet south of 8/26 and is employed for takeoffs while 9R/27L is 9,000 feet in length and is utilized primarily for landings. The south runways are separated by 1,050 feet. Airport property comprises a land area of about 3,750 acres. To completely assess the noise impact of an operation as large and complex as this required the utilization of an analytical prediction (ie: the development of noise contours).

In order to make an accurate prediction of aircraft noise on the ground, considerable detailed information needs to be made available relative to airport operations. The runways must be specified geometrically relative to a coordinate system. Aircraft headings and flight tracks must be specified for each runway end. The location of touchdown for arrivals and the point where takeoff roll begins on departure is additional information required. The particular arrival and departure procedure, turn radius and location of Navigational Aids (inner, outer and middle markers) are all representative of physical data necessary in the analysis. Detailed information relative to the aircraft fleet is essential. The number of each aircraft type (eg: DC-9, B-727, etc.) flying into and out of the airport on a daily basis is required along with the time of day of the operation and the approximate weight of the aircraft (at least for departure). Finally, three crucial bits of information are necessary to complete the analysis. First the noise characteristics of each aircraft type for a particular weight and operational procedure needs to be known. This is a part of the data base for the Air Force's Noisemap Program used in this study. Second, an "average day" must be constructed. Because certain flights may not be scheduled for seven days a week, an "average day" is developed for the airport. If, for example, a particular flight is scheduled for only four days a week, its contribution to the "average day" is 4/7 of an operation. Thirdly, all aircraft traffic must be allocated to a particular runway (heading and flight track) for arrival and departure. The more accurately it is possible to forecast traffic allocation by runway and flight track, the more accurate will be the prediction. In summary, the information required for the analytical prediction of contours:

1. Geometry of runways.

2. Aircraft heading and flight tracks for each runway end.

3. Location of touchdown and point where takeoff roll begins for each runway end.

4. Arrival and departure procedures (eg: N.W. Orient, ATA, etc.)

5. Location of navigational aids (markers).

6. Turn radius on departure.

7. Aircraft fleet/number of operations of each aircraft type - daily.

8. Time of day of all scheduled operations - by aircraft type.

9. Approximate weight of departing aircraft.

10. Individual noise characteristics of each aircraft type and particular operational configuration as a function of slant range to points on the ground.

11. Formulation of an "average day" in terms of number of operations of each aircraft type including time of day.

12. Allocation of traffic by runway and heading for the "average day."

The parallel runway configuration at Hartsfield International Airport is utilized in the following manner. The 10,000 foot long north runway (8/26), S°89 52' 54" E True, is used for both landings and takeoffs. The northern most runway of the south parallel pair (9L/27R), S°89 52' 19" E True, is 8,000 feet in length and is the "takeoff runway." The remaining runway (9R/27L), S°89 52' 54" is 9,000 feet in length and is used by arriving aircraft. Aircraft no wind headings and visual flight tracks are shown in Figure 1, which is page 2 of a memorandum regarding a runway selection program for noise abatement initiated by the Chief of the Atlanta Traffic Control Tower, Federal Aviation Administration, May 6, 1975. This information is graphically displayed in Figure 2 entitled, Noise Abatement Visual Tracks.

Departing turbojet and four-engine piston-powered aircraft shall be assigned departure procedures as follows:

RUNWAY	NO WIND HEADING	VISUAL TRACK	DISTANCE OR ALTITUDE	
8	070°	I-285	4 mi.	4,000'
26	275°	Camp Creek Pky.	4 mi.	4,000'
9L	105°	Forest Pky.	4 mi.	4,000'
27R	240°	US-29/RR Track	4 mi.	4,000'
9R	105°	Forest Pky.	4 mi.	4,000'
27L	240°	US-29/RR Track	4 mi.	4,000'

Pilots, through a recent pilot bulletin, have been encouraged to supplement the above headings with visual tracks when visibility conditions permit. Under IFR conditions, headings only will be used. Noise abatement headings/tracks are to be assumed at the middle marker of the reciprocal runway. Controllers shall issue the following takeoff clearance.

"(Ident), at the middle marker, fly heading _______, cleared for takeoff."

Figure 1

Departure Headings and Visual Tracks for Noise Abatement

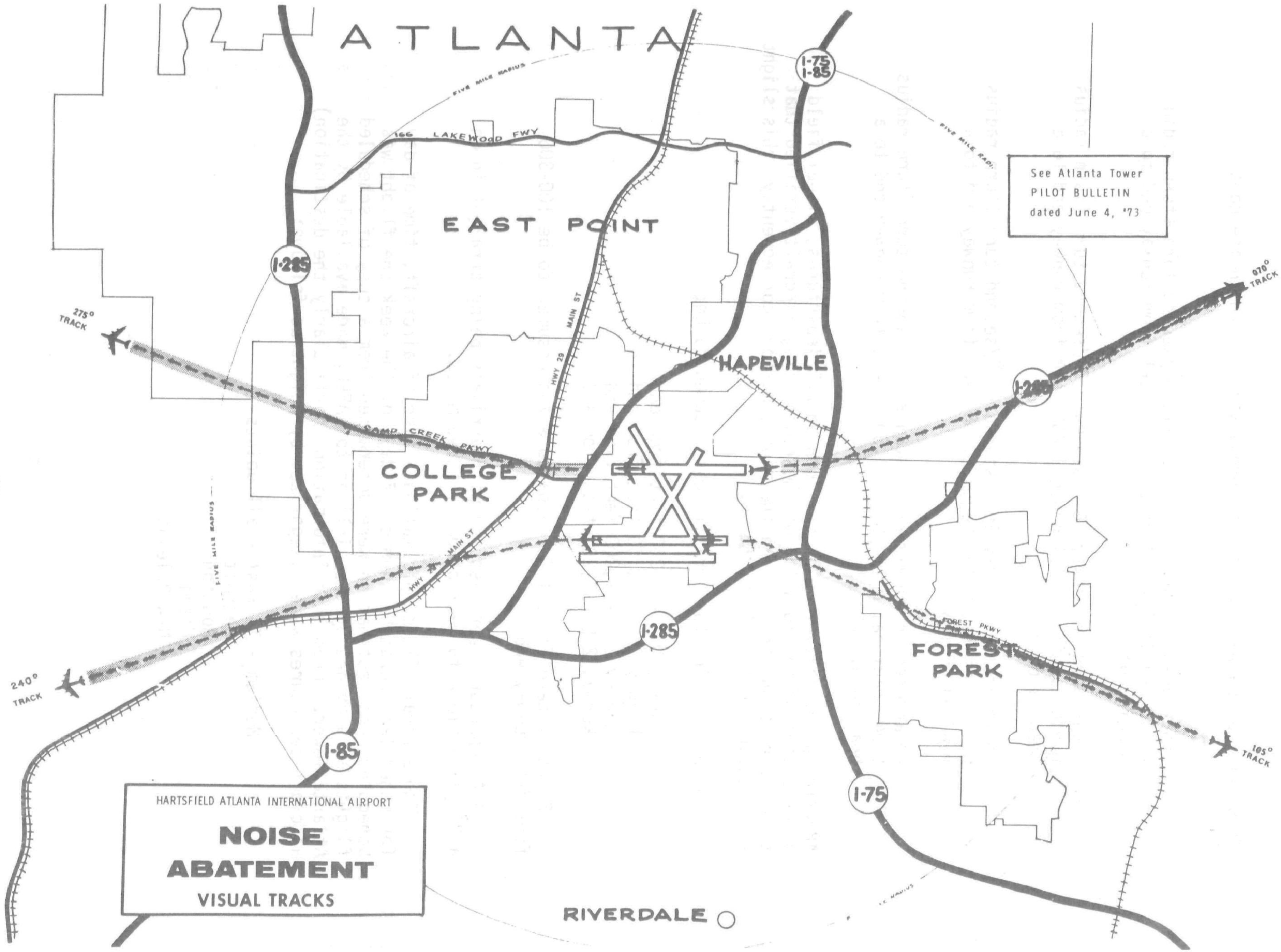

ATLANTA
I-75
I-85
FIVE MILE RADIUS
166 LAKEWOOD FWY
See Atlanta Tower
PILOT BULLETIN
dated June 4, '73
EAST POINT
I-285
275° TRACK
070° TRACK
MAIN ST
HWY 29
HAPEVILLE
CAMP CREEK PKWY
COLLEGE PARK
HWY MAIN ST
FOREST PKWY
FOREST PARK
240° TRACK
105° TRACK
I-85
I-75
HARTSFIELD ATLANTA INTERNATIONAL AIRPORT
NOISE
ABATEMENT
VISUAL TRACKS
RIVERDALE

Figure 2

This information was used in the preparation o' the noise contours as follows:

1. Departures on runway 8 - standard 3°/second turn (turn radius 0.940 nautical mile) begun 2,640 feet from runway end to a heading of 070°

2. Departures on runway 26 - standard 3°/second turn (turn radius 0.940 nautical mile) begun 3,260 feet from runway end to a heading of 275°

3. Departures on runway 9L - standard 3°/second turn (turn radius 0.940 nautical mile) begun 2,100 feet from runway end to a heading of 105°

4. Departures on runway 27R - standard 3°/second turn (turn radius 0.940 nautical mile) begun 1,500* feet from runway end to a heading of 240°

*Regarding the initiation of the turn on 27R departures, visual field observations of the location of these departing aircraft verified that turns were begun earlier than the middle marker; consequently, this slight modification in the flight track.

Touchdown point for arrivals was assumed to be:

Runway 8 - 1,250 feet from end
Runway 9R - 1,150 feet from end
Runway 26 - 1,200 feet from end
Runway 27L - 1,200 feet from end

Start of takeoff roll for departure was assumed to be 100-300 feet from runway end.

ATA departures were assumed with arrivals being straight in on a 3° glide slope for a minimum of three miles.

The aircraft fleet information - type of aircraft, time of day for scheduled operation, number of days of the week the flight was scheduled, and destination were determined from a copy of scheduled flights as provided by the airlines to NAFEC, made available by the Atlanta Tower. From this information (particularly the destination) aircraft departures were categorized by weight as follows:

Medium - To East - all points
Detroit
Houston
Miami
New Orleans

Light - To Alabama
Kentucky
Tampa
Jacksonville
South Carolina

Heavy - To Phoenix
Denver
All points westward
multi-stop medium runs (2 or more stops)
flights over oceans

Once the "average day" was formulated in terms of the number and times of operation of each aircraft type, the airplanes were allocated to flight tracks through the following traffic allocation procedure.

It was assumed that the airport operated in a West mode and East mode equally. That is, 50% of all operations were West (departures on 26 and 27R, arrivals on 26 and 27L) and 50% of all operations were East (departures on 8 and 9L, arrivals on 8 and 9R). In addition, it was assumed that 8/26 was involved in 50% of the total operations; with 9R/27L and 9L/27R responsible for the remaining 50%. In summary then the traffic allocation for the average day assumes the following form:

1. East-West operations divided 50% - 50%

2. All East departures are divided 50% on runway 8 and 50% on runway 9L.

3. All West departures are divided 50% on runway 26 and 50% on runway 27R.

4. All East arrivals are divided 50% on runway 8 and 50% on runway 9R.

5. All West arrivals are divided 50% on runway 27L and 50% on runway 26.

These assumptions are open to question, and although much of the information provided on this subject seemed in conflict, as a first approximation a 50% - 50% East-West allocation appears reasonable.

While it was possible to divide aircraft models into particular types (ie: 727-100, 727-200, etc.) when scheduling, this was not done in terms of noise characteristics. Consequently, a DC-9 and D9S were assumed to be the same acoustically. The same held true for other models and types as well, ie: DC-8 and D8S were both assumed to have the same noise characteristics, etc.

Day Arrivals

Runway → / # of operations ↓	8	9R	26	27L	Aircraft Type
	3.57143	3.57143	3.57143	3.57143	DC-8
	18.5357	18.5357	18.5357	18.5357	727
	37.6071	37.6071	37.6071	37.6071	72S

Night Arrivals

8	9R	26	27L	
5.7857	5.7857	5.7857	5.7857	D9S
3.00	3.00	3.00	3.00	L1011

Day Departures

8	9L	26	27R	
2.9285	2.9285	2.9285	2.9285	L.
10.9285	10.9285	10.9285	10.9285	M. 727
2.7857	2.7857	2.7857	2.7857	H.

Night Departures

8	9L	26	27R	
0.00	0.00	0.00	0.00	L.
0.500	0.500	0.500	0.500	M. DC-9
0.2143	0.2143	0.2143	0.2143	H.

Figure 3
Excerpt from "Average Day" and Flight Track Allocation

Summarizing the impact data for an "average day" by allocation of flight track, weight, and time of scheduled operation, typically the information would appear as shown in Figure 3, Excerpt from "Average Day" and Flight Track Allocation.

The results of using this information in the Noisemap Program are shown in Figure 4 - 1977 L_{dn} Contours, Hartsfield International Airport. The contours shown are for L_{dn} values of 85, 80, 75, 70, 65 and 60 dBA. The original contours were overlayed and reproduced on orthoquad negatives with a scale of one inch equals 2,000 feet. The 2:1 reduction in the figure yields a scale of one inch - 4,000 feet. The contours themselves are a result of determining the L_{dn} values from an orthogonal network with a grid spacing of 1,000 feet. Thus, the L_{dn} = 75 dBA contour is the locus of those grid points having an L_{dn} value of 75 dBA.

It is possible to determine the total area within these closed curves through various techniques. Due to the fact that the field monitoring program was basically constrained by resources to the areas of L_{dn} = 75 dBA or greater, this value will also be the lower limit in viewing the contour areas when field verification of the prediction is necessary. For the graphics in Figure 4, the following is the approximate land area within each contour.

Table 5

Land Area Encompassed by Specified L_{dn} Contour

Contour	Land Area - Acres	
	Total Area	Area Outside Airport Boundary
85 dBA	1,900	160
80 dBA	4,200	1,500
75 dBA	8,600	5,600
70 dBA	19,900	16,500
65 dBA	49,200	45,800

It is important to observe that much of the most heavily impacted land is property already owned by the airport (3,750 acres - current airport boundary). Consequently, these areas are not necessarily to be considered impacted by the airport's activities. However, the right hand column of Table 5 portrays the most telling information identifying more than 5,000 acres of impacted land within the L_{dn} = 75 dBA contour. It is this level of exposure that is given the highest priority by Federal agencies involved in airport noise issues. Consequently, future planning efforts on the part of the responsible jurisdictions should look immediately to the areas identified herein.

PAGE NOT

AVAILABLE

DIGITALLY

VI. Field Monitoring Methodology

Instrumentation

Depending upon the monitoring site in question one of the following instrumentation systems was employed in the field monitoring program.

- 1 ea. EPA/CERL non-commercial
- 1 ea. Metrosonics dB 602 Sound Level Analyzer
- 2 ea. Bruel and Kjaer Model SP-321 Digital Data System

All of the units made use of the Bruel and Kjaer Model 4921 outdoor microphone. The EPA/CERL system was built specifically for EPA by the Construction Engineering Research Laboratory (CERL) to the following specifications. Data could be obtained over a dynamic range of 80 dB with the upper and lower end selected as 40 dBA and 120 dBA for this study. The sampling rate was set at 10 samples per second. The data samples were classified into memory storage bins 1 dB wide over the 80 dB range if the ambient wind velocity did not exceed a predetermined level (13 mph). If at any time during the measurement period the windspeed exceeded this threshold, the data was classified into 16 bins, 5 dB in width, and the number of "windy samples" was likewise stored. Thus, for each individual measurement period (selected to be one hour in length), the following information was available: L_n, n = 99, 90-----00 the sound levels exceeded 99, 90, 50, 10, 1, 0.1, 0.01 percent of the time, the maximum level L_{OO}, the number of "Windy samples," the number of overscale samples (above 120 dBA), and the equivalent level for the hour. An hourly dump of this information was made onto a digital cassette tape in a Wang 600-14 Programmable Calculator. The data was available simply by removing the cassette as desired and inserting a blank tape for further data accumulation.

Two locations could be monitored simultaneously with Bruel and Kjaer Model SP-321 Digital Data Systems. These instruments have a dynamic range of 60 dB (set alternately from 50 dBA-110 dBA and 40 dBA-100 dBA during this study) and a maximum sampling rate of one sample per second. Again the data was classified into memory storage bins 1 dB in width. Detailed hourly information was obtained from these systems by analyzing a digital cassette with a Tektronix Model 31 Programmable Calculator. A direct printout of L_n and L_{eq} was available for each hour of operation. Because of the somewhat limited dynamic range, a compromise was necessary regarding the upper range of the data if lower levels were of interest as well. For most of the data the upper range was set at 100 dBA and, consequently, it was at times impossible to determine the absolute maximum sound level. In situations of this type one could determine that 100 dBA was indeed equalled or exceeded, but it was not possible to verify by how much.

A third automated system employed was the Metrosonics dB 602 operating in a multiple interval storage mode. The acoustic environment was sampled at sixteen times per second with the data being stored in computer memory over a 100 dB dynamic range (30 dBA-130 dBA). The storage registers were 1 dB wide. Four separate acoustic parameters were available for each hourly interval corresponding to an individual data block. The parameters selected to describe the environmental noise levels were the equivalent A-weighted sound level L_{eq}, the maximum sound level L_{00}, L_{50}, and L_{90}. Data was retrieved by recalling the computer memory hour by hour (L.E.D. display) and recording the four parameters described above.

All data obtained in the study corresponded to A-weighted sound levels, regardless of the parameter considered. The monitoring systems were calibrated daily (or in some instances every two days), employing Bruel and Kjaer Model 4230 Oscillator Type Calibrators or the internal reference signal on the outdoor microphones. The measurements were made on an "around-the-clock" basis at each site. The duration of the measurement period varied from site to site and ranged from a minimum of two days to over 30 days. At certain times during the monitoring program four sites were monitored simultaneously. This allows a determination of the spatial variation in aircraft impact resulting from the same (and assumed to be normal) aircraft operations.

Monitoring Sites

The sites selected were within the cities of Mountain View, Atlanta, and College Park. Forty-five locations provided the basic framework of the ground data. Instrumentation problems at two locations prevented data from being accumulated while vandalism eliminated data gathering at a third site. Data, consequently, is presented for forty-two sites with locations selected to provide a cross section of impact resulting from operations on all three parallel runways. Certain of the sites are more susceptable to takeoff noise than landing noise due to the fact that noise abatement tracks are specified on departure. As a result when monitored noise data is compared with the analytical prediction of L_{dn} the predominant direction of aircraft operations is an important consideration. The sites are all residential with the exception of four schools (two high schools and two elementary schools). See Table 6.

The information provided below is an attempt to place the sites physically with respect to the principle runway affecting the noise environment. The distances used in locating the sites are approximate but should be within 100 feet of the actual position of the microphone.

Table 6

Monitoring Sites and Their Physical Location with Respect to the Parallel Runways

Site #	Address	Physical Location with Respect To Runways
1	85 N. West Avenue	4,000 feet off end of 8/26 on centerline of 8/26.
2	3961 North Avenue	3,200 feet off end of 8/26, 100 feet south of 8/26.
3	215 Oak Street	6,900 feet off end of 9L/27R and approximately 400 feet north of 9L/27R.
4	251 Eason Drive	10,400 feet off end of 9L/27R and 700 feet south of 9L/27R.
5	Mt. View Elementary School College Street	3,800 feet off end of 8/26, 6,800 feet off end of 9L/27R, and 7,600 feet off end of 9R/27L.
6	3942 Atkins Avenue	2,400 feet off end of 8/26, 100 feet north of 8/26.
7	137 Conley Avenue	6,000 feet off end of 8/26, 1,700 feet south of centerline of 8/26.
8	114 Pine Street	7,200 feet off end of 9L/27R on centerline of 9L/27R. 8,000 feet off end of 9R/27L, 1,000 feet north of centerline of 9R/27L.
9	340 Kenwood Drive	8,100 feet off end of 9L/27R, 1,600 feet north of centerline of 9L/27R.
10	147 South West Street	3,400 feet off end of 8/26, 1,700 feet south of centerline of 8/26.
11	191 College Park Road	3,000 feet off end of 8/26, 2,250 feet south of centerline of 8/26.
12	250 Redmont Street	10,400 feet off end of 9L/27R, 2,250 feet south of centerline of 9L/27R.
13	102 Blalock Street	9,100 feet off end of 9L/27R, 1,700 feet north of centerline of 9L/27R.

Table 6 Cont'd.

Site #	Address	Physical Location With Respect To Runways
14	130 Morris Street	3,500 feet off end of 8/26, 250 feet north of centerline of 8/26.
15	4460 Walker Street	7,700 feet off end of 9L/27R, 600 feet south of centerline of 9L/27R.
16	16 Conley Road	5,100 feet off end of 8/26, 1,600 feet south of centerline of 8/26.
17	183 Pinehurst	6,200 feet off end of 9L/27R, 300 feet south of centerline of 9L/27R.
18	405 Alverstone Drive	690 feet north of centerline 8/26. 8,560 feet east of end of 8/26.
19	154 Celeste Drive	1,500 feet north of centerline 8/26. 6,375 feet east of end of 8/26.
20	178 Archcrest Drive	750 feet north of centerline 8/26. 6,500 feet east of end of 8/26.
21	356 Keystone Drive	1,625 feet north of centerline of 8/26. 8,125 feet east of end of 8/26.
22	327 Archcrest Drive	1,000 feet north of centerline of 8/26. 7,875 feet east of end of 8/26.
23	246 Gilbert Way	1,690 feet north of centerline of 8/26. 7,250 feet east of end of 8/26.
24	435 Archcrest Drive	1,000 feet north of centerline of 8/26. 8,940 feet east of end of 8/26.
25	Caroline Harper School 180 Poole Creek Rd., SE	2,125 feet north of centerline of 8/26. 6,625 feet east of end of 8/26.
26	3780 Kenway Drive	1,560 feet north of centerline of 8/26. 9,060 feet east of end of 8/26.

Table 6 Cont'd.

Site #	Address	Physical Location With Respect To Runways
27	2892 Arlington Road	2,100 feet north of centerline of 8/26. 13,100 feet off end of 8/26.
28	Eva L. Thomas High School 2075 Princeton Avenue	3,100 feet north of centerline of 8/26. 5,530 feet off end of 8/26.
29	2376 Brown Road	2,750 feet south of centerline of 8/26. 8,300 feet off end of 8/26.
30	2006 W. John Wesley	940 feet north of centerline of 8/26. 4,690 feet off end of 8/26.
31	3945 Oak Hill Drive	125 feet north of centerline of 8/26. 7,700 feet off end of 8/26.
32	4096 Alcott Place	1,200 feet south of centerline of 8/26. 7,950 feet off end of 8/26.
33	1820 E. Columbia Avenue	1,875 feet north of centerline of 8/26. 2,960 feet off end of 8/26.
34	2134 Lakeshore Drive Lakeshore High School	1,700 feet south of centerline of 8/26. 12,750 feet off end of 8/26.
35	2480 Paul D. West Drive Kathleen Mitchell E.S.	200 feet north of centerline of 8/26. 9,060 feet off end of 8/26.
36	4017 Oak Hill Drive	500 feet south of centerline of 8/26. 7,150 feet off end of 8/26.
37	2206 Draper Drive	2,400 feet south of centerline of 8/26. 6,700 feet off end of 8/26.
38	2023 Second Avenue	375 feet south of centerline of 8/26. 4,970 feet off end of 8/26.
39	2066 First Avenue	1,560 feet south of centerline of 8/26. 5,250 feet off end of 8/26.
40	3996 Northwest Drive	150 feet south of centerline of 8/26. 5,650 feet off end of 8/26.
41	4540 Hopewell Road	100 feet south of centerline of 9R/27L. 7,500 feet off end of 9R/27L.

Table 6 Cont'd.

Site #	Address	Physical Location With Respect To Runways
42	1986 W. Georgia Avenue	250 feet north of centerline of 8/26. 4,470 feet off end of 8/26.
43	4735 Winthrop Drive	2,250 feet south of centerline of 9R/27L. 8,900 feet off end of 9R/27L.
44	2650 Colonial Drive	375 feet north of centerline of 9L/27R. 9,780 feet off end of 9L/27R.
45	1950 W. Georgia Avenue	250 feet north of centerline of 8/26. 4,125 feet off end of 8/26.

VII. Data Summaries

Daily L_{dn} and L_{eq}

The daily summaries for L_{dn} and L_{eq} are ostensibly for twenty-four time periods. Due to the fact that time is required for calibration and the movement of instrumentation from site to site, some data is necessarily presented for less than that (eg: 22 hours, 13 daytime and 9 nighttime). This fact is implicit in the following table, however, no data will be presented for any site if less than 17 hours of data was obtained in the 24 hour time period of interest. If this point must be pursued further, the days for which less than 24 hours of data was available will be apparent by having the reader direct his attention to the time period for which L_{dn} and L_{eq} are representative (see Table 7).

Table 7

Daily Data Summaries

Threshold for Activity Interference/Annoyance $L_{dn} \leq 55$ dBA

Location	Time Period for Which L_{dn} and L_{eq} are Representative	L_{dn} dBA	$L_{eq}(24)$ dBA
104 N. West Ave.	1200 1/12/76 - 1200 1/13/76	85.73	78.68
Site #1	1200 1/13/76 - 1200 1/14/76	87.88	81.58
	1200 1/14/76 - 1200 1/15/76	81.88	77.84
	1200 1/15/76 - 1200 1/16/76	83.97	79.30
	1200 1/16/76 - 1200 1/17/76	86.39	80.31
	1200 1/17/76 - 1200 1/18/76	82.42	78.83
	1200 1/18/76 - 1200 1/19/76	84.32	78.67
	1200 1/19/76 - 1200 1/20/76	83.67	78.48
	1200 1/20/76 - 1200 1/21/76	83.81	78.66
	1200 1/21/76 - 1200 1/22/76	83.46	78.75

Table 7 Cont'd.

Location	Time Period for Which L_{dn} and L_{eq} are Representative	L_{dn} dBA	$L_{eq(24)}$ dBA
104 N. West Ave. Cont'd.	1200 1/22/76 - 1100 1/23/76	83.46	78.58
	1200 1/23/76 - 1200 1/24/76	84.53	79.39
	1200 1/25/76 - 1200 1/26/76	84.69	80.48
	1200 1/26/76 - 1200 1/27/76	87.21	82.23
	1200 1/27/76 - 1100 1/28/76	82.69	78.42
	1200 12/15/76 - 1200 12/16/76	85.63	80.17
	1200 12/16/76 - 0900 12/17/76	84.72	79.22
	1200 12/17/76 - 1200 12/18/76	85.57	79.56
	1200 12/18/76 - 1200 12/19/76	82.93	77.96
	1200 12/19/76 - 1200 12/20/76	84.84	79.94
	1200 12/20/76 - 1100 12/21/76	84.68	80.67
3961 North Ave.	1500 2/23/76 - 1200 2/24/76	82.41	76.87
Site #2	1200 2/24/76 - 1200 2/25/76	80.94	76.28
	1200 2/25/76 - 1200 2/26/76	82.70	77.98
	1200 2/26/76 - 1200 2/27/76	83.86	78.79
215 Oak Street	1600 2/27/76 - 1200 2/28/76	76.09	73.01
Site #3	1200 2/28/76 - 1200 2/29/76	74.75	69.88
	1200 2/29/76 - 1200 3/01/76	73.11	66.74
	1200 3/01/76 - 1200 3/02/76	76.22	69.64
251 Eason Drive	1600 3/02/76 - 1200 3/03/76	74.12	70.27
Site #4	1200 3/03/76 - 1200 3/04/76	75.08	70.85

Table 7 Cont'd.

Location	Time Period for Which L_{dn} and L_{eq} are Representative	L_{dn} dBA	$L_{eq(24)}$ dBA
Mt. View School 4251 College St.	1200 3/10/76 - 1200 3/11/76	76.21	72.77
Site #5	1200 3/11/76 - 1200 3/12/76	77.34	72.62
	1200 3/12/76 - 1200 3/13/76	77.85	74.14
	1200 3/13/76 - 1200 3/14/76	71.82	66.86
	1200 3/14/76 - 1200 3/15/76	74.34	70.25
3942 Atkins Ave.	1200 2/24/76 - 1200 2/25/76	83.96	78.66
Site #6	1200 2/25/76 - 1200 2/26/76	84.77	79.98
	1200 2/26/76 - 1200 2/27/76	84.73	79.47
	1600 2/27/76 - 1200 2/28/76	86.01	82.46
	1200 2/28/76 - 1200 2/29/76	86.09	81.12
	1200 2/29/76 - 0700 3/01/76	86.05	79.56
137 Conley Avenue	1500 3/02/76 - 1200 3/03/76	73.20	68.14
Site #7	1200 3/03/76 - 1200 3/04/76	70.97	64.45
114 Pine Street	1200 2/25/76 - 1200 2/26/76	75.52	70.72
Site #8	1200 2/26/76 - 1200 2/27/76	77.15	72.55
	1200 2/27/76 - 1200 2/28/76	77.27	75.30
	1200 2/28/76 - 1200 2/29/76	78.53	75.10
	1200 2/29/76 - 0800 3/01/76	75.82	71.52
340 Kenwood Drive	1200 12/02/76 - 0700 12/03/76	69.24	64.40
Site #9	1300 12/03/76 - 1100 12/04/76	75.63	71.17
	1200 12/04/76 - 1100 12/05/76	75.58	71.07

Table 7 Cont'd.

Location	Time Period for Which L_{dn} and L_{eq} are Representative	L_{dn} dBA	$L_{eq(24)}$ dBA
340 Kenwood Drive Cont'd.	1200 12/05/76 - 0900 12/06/76	76.13	71.24
	1200 12/06/76 - 1100 12/07/76	78.93	73.27
	1200 12/07/76 - 1100 12/08/76	72.87	67.56
147 South West St.	1200 12/08/76 - 1000 12/09/76	71.74	67.51
Site #10	1200 12/09/76 - 0900 12/10/76	77.57	72.46
	1400 12/10/76 - 1100 12/11/76	79.08	73.22
	1200 12/11/76 - 1100 12/12/76	77.69	72.41
191 College Park Rd.	1200 11/23/76 - 1200 11/24/76	76.88	69.84
Site #11	1300 11/24/76 - 1100 11/25/76	81.20	73.71
	1200 11/25/76 - 1100 11/26/76	74.53	69.83
	1400 11/26/76 - 1100 11/27/76	73.40	68.67
	1200 11/27/76 - 1100 11/28/76	77.17	70.30
	1200 11/28/76 - 1100 11/29/76	75.33	69.43
250 Redmont St.	1500 11/22/76 - 1200 11/23/76	71.95	67.16
Site #12	1300 11/23/76 - 1200 11/24/76	72.36	67.64
	1300 11/24/76 - 1200 11/25/76	76.03	70.50
	1300 11/25/76 - 1200 11/26/76	71.88	69.59
	1300 11/26/76 - 1200 11/27/76	74.04	70.03
	1300 11/27/76 - 1200 11/28/76	78.26	72.08
	1300 11/28/76 - 0800 11/29/76	75.84	71.14

Table 7 Cont'd.

Location	Time Period for Which L_{dn} and L_{eq} are Representative	L_{dn} dBA	$L_{eq(24)}$ dBA
102 Blalock St.	1300 12/01/76 - 1200 12/02/76	71.95	66.02
Site #13	1300 12/02/76 - 1200 12/03/76	67.28	65.51
	1300 12/03/76 - 1200 12/04/76	73.67	70.65
	1300 12/04/76 - 1200 12/05/76	73.67	70.52
	1300 12/05/76 - 0900 12/06/76	74.10	70.75
130 Morris St.	1300 12/01/76 - 1200 12/02/76	86.37	79.49
Site #14	1300 12/02/76 - 1200 12/03/76	82.26	77.84
	1300 12/03/76 - 1200 12/04/76	84.21	80.38
	1300 12/04/76 - 1200 12/05/76	83.78	80.16
	1300 12/05/76 - 0900 12/06/76	84.09	80.27
4460 Walker St.	No Data		
Site #15	Microphone Vandalized		
16 Conley Road	1500 11/22/76 - 1200 11/23/76	66.16	61.63
Site #16	1300 11/23/76 - 1200 11/24/76	66.55	61.66
	1300 11/24/76 - 1200 11/25/76	73.04	66.53
	1300 11/25/76 - 1200 11/26/76	70.12	68.05
	1300 11/26/76 - 1200 11/27/76	73.40	69.34
	1300 11/27/76 - 1200 11/28/76	76.03	70.06
	1300 11/28/76 - 0900 11/29/76	64.86	61.65

Table 7 Cont'd.

Location	Time Period for Which L_{dn} and L_{eq} are Representative	L_{dn} dBA	$L_{eq(24)}$ dBA
183 Pinehurst	1400 12/09/76 - 1200 12/10/76	82.92	80.34
Site #17	1300 12/10/76 - 1200 12/11/76	83.37	80.33
	1300 12/11/76 - 1200 12/12/76	81.37	79.20
	1300 12/12/76 - 0800 12/13/76	76.80	72.94
405 Alverston Dr.	1400 5/13/77 - 1100 5/14/77	73.33	68.19
Site #18	1200 5/14/77 - 1100 5/15/77	71.58	68.02
	1200 5/15/77 - 1100 5/16/77	80.22	74.64
	1200 5/16/77 - 1100 5/17/77	75.51	71.90
	1200 5/17/77 - 1100 5/18/77	73.72	70.50
	1200 5/18/77 - 1100 5/19/77	80.62	72.31
	1200 5/19/77 - 1100 5/20/77	74.70	72.19
	1200 5/20/77 - 1100 5/21/77	80.19	74.50
	1200 5/21/77 - 1100 5/22/77	78.56	72.76
	1200 5/22/77 - 1100 5/23/77	79.14	74.12
	1200 5/23/77 - 1100 5/24/77	78.89	73.00
	1200 5/24/77 - 1100 5/25/77	80.59	74.42
154 Celeste Drive	1800 5/27/77 - 1100 5/28/77	83.90	77.31
Site #19	1200 5/28/77 - 1100 5/29/77	79.92	75.42
	1200 5/29/77 - 1100 5/30/77	72.08	69.85
178 Archcrest Dr.	1400 5/31/77 - 1100 6/01/77	75.29	72.05
Site #20	1200 6/01/77 - 1100 6/02/77	72.73	67.83

Table 7 Cont'd.

Location	Time Period for Which L_{dn} and L_{eq} are Representative	L_{dn} dBA	$L_{eq(24)}$ dBA
178 Archcrest Dr. Cont'd.	1200 6/02/77 - 1100 6/03/77	73.45	70.41
	1200 6/03/77 - 1100 6/04/77	76.49	74.50
	1200 6/04/77 - 1100 6/05/77	74.10	71.96
	1200 6/05/77 - 1100 6/06/77	73.84	69.25
356 Keystone Dr.	1300 5/13/77 - 1100 5/14/77	67.84	62.47
Site #21	1200 5/14/77 - 1100 5/15/77	66.73	61.81
	1200 5/15/77 - 1100 5/16/77	80.85	76.56
	1200 5/10/77 - 1100 5/17/77	79.84	74.64
	1200 5/17/77 - 1000 5/18/77	78.42	71.34
	1200 5/18/77 - 1100 5/19/77	79.96	72.33
	1200 5/19/77 1100 5/20/77	78.52	73.47
	1200 5/20/77 - 1100 5/21/77	82.29	76.48
	1200 5/21/77 - 1100 5/22/77	80.68	75.43
	1200 5/22/77 - 1000 5/23/77	81.21	76.08
327 Archcrest Dr.	1300 5/23/77 - 1100 5/24/77	80.43	75.89
Site #22	1200 5/24/77 - 1100 5/25/77	81.51	76.74
	1200 5/25/77 - 1100 5/26/77	82.32	77.59
	1200 5/26/77 - 1100 5/27/77	81.77	76.97
	1300 5/27/77 - 1100 5/28/77	83.70	78.75
	1200 5/28/77 - 1100 5/29/77	79.19	76.03
	1200 5/29/77 - 1100 5/30/77	74.41	71.54
	1200 5/30/77 - 1100 5/31/77	81.30	76.31

Table 7 Cont'd.

Location	Time Period for Which L_{dn} and L_{eq} are Representative	L_{dn} dBA	$L_{eq(24)}$ dBA
246 Gilbert Way	1700 6/01/77 - 1100 6/02/77	67.23	60.64
Site #23	1200 6/02/77 - 1100 6/03/77	68.44	65.65
	1200 6/03/77 - 1100 6/04/77	73.74	72.44
	1200 6/04/77 - 1100 6/05/77	71.49	70.35
	1200 6/05/77 - 1100 6/06/77	68.44	61.35
435 Archcrest Dr.	1500 5/16/77 - 1100 5/17/77	80.84	71.93
Site #24	1200 5/17/77 - 1100 5/18/77	80.39	71.82
	1200 5/18/77 - 1100 5/19/77	79.06	72.73
	1200 5/19/77 - 1100 5/20/77	79.87	75.70
	1200 5/20/77 - 1100 5/21/77	80.01	70.34
	1200 5/21/77 - 1100 5/22/77	68.08	61.13
	1200 5/22/77 - 0400 5/23/77	70.05	62.37
180 Poole Creek Rd.	No Data		
Site #25			
3780 Kenway Dr.	1400 5/31/77 - 1100 6/01/77	72.99	71.86
Site #26	1200 6/01/77 - 1000 6/02/77	72.94	71.97
	1300 6/02/77 - 1100 6/03/77	71.54	70.26
	1200 6/03/77 - 1100 6/04/77	71.53	69.61
	1200 6/04/77 - 1100 6/05/77	69.34	67.47
	1200 6/05/77 - 1100 6/06/77	68.14	62.64

Table 7 Cont'd.

Location	Time Period for Which L_{dn} and L_{eq} are Representative	L_{dn} dBA	$L_{eq(24)}$ dBA
2892 Arlington Rd.	1200 7/11/77 - 1100 7/12/77	76.76	72.40
Site #27	1200 7/12/77 - 1100 7/13/77	76.91	72.01
	1200 7/13/77 - 1100 7/14/77	76.41	69.79
	1200 7/14/77 - 1000 7/15/77	74.31	67.91
	1200 7/15/77 - 1100 7/16/77	71.12	63.35
	1200 7/16/77 - 1100 7/17/77	68.09	64.78
	1200 7/17/77 - 1100 7/18/77	66.77	61.87
	1200 7/18/77 - 1100 7/19/77	69.51	63.16
2075 Princeton Ave.	1600 7/12/77 - 1100 7/13/77	75.33	68.96
Site #28	1200 7/13/77 - 1100 7/14/77	75.31	68.88
	1200 7/14/77 - 1100 7/15/77	74.29	65.88
	1200 7/15/77 - 1100 7/16/77	70.57	62.74
	1200 7/16/77 - 1100 7/17/77	69.17	62.19
	1200 7/17/77 - 1100 7/18/77	67.47	62.76
2376 Brown Road	1500 7/12/77 - 1100 7/13/77	74.14	70.19
Site #29	1400 7/14/77 - 1100 7/15/77	68.96	64.21
	1200 7/15/77 - 1100 7/16/77	61.96	58.04
	1200 7/16/77 - 1100 7/17/77	65.10	62.97
	1200 7/17/77 - 1100 7/18/77	60.92	57.24
	1200 7/19/77 - 1100 7/20/77	70.72	65.66
	1200 7/20/77 - 1100 7/21/77	74.12	70.87

Table 7 Cont'd.

Location	Time Period for Which L_{dn} and L_{eq} are Representative	L_{dn} dBA	$L_{eq(24)}$ dBA
2006 W. John Wesley	No Data		
Site #30			
3945 Oak Hill Dr.	1200 7/05/77 - 1100 7/06/77	82.25	77.38
Site #31	1200 7/06/77 - 1100 7/07/77	81.69	76.72
	1200 7/07/77 - 1100 7/08/77	80.79	76.73
	1200 7/08/77 - 1100 7/09/77	79.16	75.66
4096 Alcott Place	1200 6/28/77 - 1100 6/29/77	76.29	71.03
Site #32	1200 6/29/77 - 1100 6/30/77	76.89	71.54
	1200 6/30/77 - 1100 7/01/77	73.52	69.47
	1200 7/05/77 - 1100 7/06/77	78.28	72.21
	1200 7/06/77 - 1100 7/07/77	77.10	71.28
	1200 7/07/77 - 1100 7/08/77	75.86	70.72
	1200 7/08/77 - 0700 7/09/77	77.54	71.04
	1200 7/11/77 - 1100 7/12/77	76.96	71.26
1820 E. Columbia Ave.	1200 7/02/77 - 1100 7/03/77	77.17	72.94
Site #33	1200 7/03/77 - 1100 7/04/77	73.06	66.70
	1200 7/04/77 - 1100 7/05/77	73.19	68.04
	1200 7/05/77 - 1100 7/06/77	77.55	71.88
	1200 7/06/77 - 1100 7/07/77	77.57	71.98
	1200 7/07/77 - 1100 7/08/77	77.41	71.29
	1200 7/08/77 - 1100 7/09/77	81.56	74.06
	1200 7/09/77 - 1100 7/10/77	78.74	73.25
	1200 7/10/77 - 0900 7/11/77	79.20	73.12

Table 7 Cont'd.

Location	Time Period for Which L_{dn} and L_{eq} are Representative	L_{dn} dBA	$L_{eq(24)}$ dBA
2134 Lakeshore Dr.	1500 6/28/77 - 1100 6/29/77	73.80	68.30
Site #34	1200 6/29/77 - 1100 6/30/77	73.95	69.04
	1200 6/30/77 - 1100 7/01/77	70.99	67.89
2480 Paul D. West Dr.	1600 6/26/77 - 1100 6/27/77	78.38	74.39
Site #35	1200 6/27/77 - 1100 6/28/77	79.41	74.27
	1200 6/28/77 - 1100 6/29/77	79.37	74.79
	1200 6/29/77 - 1100 6/30/77	77.51	73.93
	1200 6/30/77 - 1100 7/01/77	82.68	75.67
	1200 7/01/77 - 1100 7/02/77	81.51	75.73
	1200 7/02/77 - 1100 7/03/77	77.25	71.95
	1200 7/03/77 - 1100 7/04/77	77.76	72.89
4017 Oak Hill Dr.	1500 6/06/77 - 1100 6/07/77	82.21	75.49
Site #36	1200 6/07/77 - 1100 6/08/77	82.30	76.17
	1200 6/08/77 - 1100 6/09/77	78.80	74.56
	1200 6/09/77 - 1100 6/10/77	80.84	75.64
	1200 6/10/77 - 1100 6/11/77	81.48	75.84
	1200 6/11/77 - 1100 6/12/77	77.61	75.81
	1200 6/12/77 - 1100 6/13/77	79.04	74.53
2206 Draper Drive	1200 6/07/77 - 1100 6/08/77	78.29	73.37
Site #37	1200 6/08/77 - 1000 6/09/77	76.60	72.53
	1200 6/09/77 - 1100 6/10/77	77.31	72.92

Table 7 Cont'd.

Location	Time Period for Which L_{dn} and L_{eq} are Representative	L_{dn} dBA	$L_{eq(24)}$ dBA
2206 Draper Drive Cont'd.	1300 6/14/77 - 1100 6/15/77	76.80	72.02
	1200 6/15/77 - 1100 6/16/77	77.66	73.31
	1200 6/16/77 - 1100 6/17/77	72.05	70.26
2073 Second Street	1500 6/13/77 - 1100 6/14/77	80.88	75.48
Site #38	1200 6/14/77 - 1100 6/15/77	83.06	77.71
	1200 6/15/77 - 1100 6/16/77	82.57	77.96
	1200 6/16/77 - 1100 6/17/77	80.75	76.11
	1200 6/17/77 - 1100 6/18/77	82.92	76.46
	1200 6/18/77 - 1100 6/19/77	80.61	76.88
	1200 6/19/77 - 1100 6/20/77	81.46	76.75
2066 First Street	1500 6/13/77 - 1100 6/14/77	76.53	69.94
Site #39	1200 6/14/77 - 1100 6/15/77	80.21	74.12
	1200 6/15/77 - 1100 6/16/77	79.76	74.17
	1200 6/16/77 - 1100 6/17/77	73.83	70.33
	1200 6/17/77 - 1100 6/18/77	78.27	71.48
	1200 6/18/77 - 1100 6/19/77	77.50	72.82
	1200 6/19/77 - 1100 6/20/77	77.60	72.71
3996 Northwest Dr.	1200 6/08/77 - 1100 6/09/77	83.14	78.55
Site #40	1200 6/09/77 - 1100 6/10/77	85.72	79.75
	1200 6/10/77 - 1100 6/11/77	86.25	79.80
	1200 6/13/77 - 1100 6/14/77	81.51	77.31
	1200 6/14/77 - 1100 6/15/77	85.46	79.18
	1200 6/15/77 - 1100 6/16/77	84.78	79.18

Table 7 Cont'd.

Location	Time Period for Which L_{dn} and L_{eq} are Representative	L_{dn} dBA	$L_{eq(24)}$ dBA
4540 Hopewell Rd.	1300 6/16/77 - 1100 6/17/77	74.54	78.37
Site #41	1200 6/17/77 - 1100 6/18/77	74.82	78.58
	1200 6/18/77 - 1100 6/19/77	74.29	76.17
	1200 6/19/77 - 1100 6/20/77	74.90	77.37
	1200 6/20/77 - 1000 6/21/77	73.74	75.94
	1200 6/23/77 - 1100 6/24/77	75.72	78.34
	1200 6/24/77 - 1100 6/25/77	75.76	78.85
	1200 6/25/77 - 1100 6/26/77	73.69	76.29
	1200 6/26/77 - 1100 6/27/77	74.41	77.82
	1200 6/27/77 - 0700 6/28/77	73.81	76.96
	1300 7/21/77 - 1000 7/22/77	72.37	75.08
	1400 7/26/77 - 1100 7/27/77	74.84	77.37
	1200 7/27/77 - 1100 7/28/77	77.40	80.84
	1200 7/28/77 - 1100 7/29/77	78.30	81.19
	1300 8/02/77 - 1100 8/03/77	78.02	80.63
	1200 8/03/77 - 1100 8/04/77	76.96	80.03
	1200 8/04/77 - 1100 8/05/77	75.87	79.33
	1200 8/05/77 - 1100 8/06/77	74.87	77.93
	1200 8/06/77 - 1100 8/07/77	74.65	76.94
	1200 8/09/77 - 1100 8/10/77	74.86	77.30
	1200 8/10/77 - 1100 8/11/77	74.67	76.90
	1200 8/16/77 - 1100 8/17/77	74.98	79.02
	1200 8/17/77 - 1100 8/18/77	74.96	77.29

Table 7 Cont'd.

Location	Time Period for Which L_{dn} and L_{eq} are Representative	L_{dn} dBA	$L_{eq(24)}$ dBA
4540 Hopewell Rd. Cont'd.	1200 8/18/77 - 1100 8/19/77	75.52	78.93
	1200 8/19/77 - 1100 8/20/77	74.32	78.68
	1200 8/20/77 - 1100 8/21/77	73.82	76.84
	1200 8/21/77 - 1100 8/22/77	74.02	78.67
	1200 8/22/77 - 1100 8/23/77	75.88	79.13
	1200 8/23/77 - 1100 8/24/77	74.50	75.92
	1200 8/25/77 - 1100 8/26/77	76.23	79.59
	1200 8/29/77 - 1100 8/30/77	75.74	78.80
	1200 8/30/77 - 1100 8/31/77	74.86	79.20
	1200 8/31/77 - 1100 9/01/77	75.09	78.72
	1200 9/01/77 - 0800 9/02/77	74.57	78.88
1986 Georgia Avenue	1400 6/17/77 - 1100 6/18/77	80.06	87.12
Site #42	1200 6/18/77 - 1100 6/19/77	80.47	84.84
	1200 6/19/77 - 1100 6/20/77	80.04	85.19
	1200 6/20/77 - 1100 6/21/77	80.63	85.02
	1200 6/21/77 - 1100 6/22/77	80.69	85.60
	1200 6/22/77 - 1100 6/23/77	79.65	83.49
	1200 6/23/77 - 1100 6/24/77	81.11	86.41
4735 Winthrop Dr.	1400 6/20/77 - 1100 6/21/77	73.82	77.49
Site #43	1200 6/21/77 - 1100 6/22/77	74.16	77 70
	1200 6/22/77 - 1100 6/23/77	72.28	73.41

Table 7 Cont'd.

Location	Time Period for Which L_{dn} and L_{eq} are Representative	L_{dn} dBA	$L_{eq(24)}$ dBA
4735 Winthrop Dr. Cont'd.	1200 6/23/77 - 0900 6/24/77	75.25	77.44
	1300 6/24/77 - 1100 6/25/77	74.78	78.05
	1200 6/25/77 - 1100 6/26/77	73.27	76.17
	1200 6/26/77 - 1100 6/27/77	74.35	79.26
2650 Colonial Dr.	1200 6/20/77 - 1100 6/21/77	67.81	70.08
Site #44	1200 6/21/77 - 1100 6/22/77	70.47	75.73
	1200 6/22/77 - 1100 6/23/77	69.46	75.03
	1200 6/23/77 - 1100 6/24/77	70.33	73.66
	1200 6/24/77 - 1100 6/25/77	70.54	73.68
	1200 6/25/77 - 1100 6/26/77	69.26	72.58
	1200 6/26/77 - 1100 6/27/77	69.35	72.76
1950 W. Georgia Ave.	1400 6/24/77 - 1100 6/25/77	82.39	87.16
Site #45	1200 6/25/77 - 1100 6/26/77	81.22	85.46
	1200 6/26/77 - 1100 6/27/77	81.17	86.07
	1200 6/27/77 - 1100 6/28/77	81.24	85.71
	1200 6/28/77 - 1100 6/29/77	81.58	86.19
	1200 6/29/77 - 1100 6/30/77	81.96	86.07
	1200 6/30/77 - 1100 7/01/77	81.10	85.22
	1200 8/09/77 - 1100 8/10/77	80.71	86.27
	1200 8/10/77 - 1100 8/11/77	82.04	86.84
	1200 8/11/77 - 1100 8/12/77	82.32	86.68
	1200 8/12/77 - 1100 8/13/77	80.82	87.18

Table 7 Cont'd.

Location	Time Period for Which L_{dn} and L_{eq} are Representative	L_{dn} dBA	$L_{eq(24)}$ dBA
1950 W. Georgia Ave. Cont'd.	1200 8/13/77 - 1100 8/14/77	79.94	84.72
	1200 8/14/77 - 1100 8/15/77	78.85	84.19
	1200 8/15/77 - 1100 8/16/77	81.11	86.08
	1200 8/16/77 - 1100 8/17/77	81.80	87.24
	1200 8/17/77 - 1100 8/18/77	81.76	87.08
	1200 8/18/77 - 1100 8/19/77	80.78	85.56
	1200 8/19/77 - 1100 8/20/77	81.56	87.65
	1200 8/20/77 - 1100 8/21/77	80.64	84.77
	1200 8/21/77 - 1100 8/22/77	80.82	86.24
	1200 8/22/77 - 1100 8/23/77	81.54	86.44
	1200 8/23/77 - 1100 8/24/77	79.28	84.56
	1200 8/24/77 - 1100 8/25/77	81.85	86.58
	1200 8/25/77 - 1100 8/26/77	79.70	85.09
	1200 8/26/77 - 1100 8/27/77	80.52	86.99
	1200 8/27/77 - 1100 8/28/77	79.57	84.66
	1200 8/28/77 - 1100 8/29/77	79.62	85.36
	1200 8/29/77 - 1100 8/30/77	78.89	84.56
	1200 8/30/77 - 1100 8/31/77	78.58	84.26
	1200 8/31/77 - 1100 9/01/77	79.21	84.82
	1200 9/01/77 - 1100 9/02/77	79.63	85.73
	1200 9/02/77 - 1100 9/03/77	80.22	86.10
	1200 9/03/77 - 1100 9/04/77	78.62	83.74
	1200 9/04/77 - 1100 9/05/77	78.83	84.06
	1200 9/05/77 - 1000 9/06/77	79.06	84.51

Site Summaries - $\bar{L}_{dn}$

In addition to providing daily summaries, a site summary is also listed to present the energy average of the day-night sound level for the measurement period. Thus, if each daily L_{dn} is described by $L_{dn(i)}$ the energy average L_{dn} in the site summary described by L_{dn} is given by

$$L_{dn} = 10 \log_{10} \sum_{i=1}^{N} 10^{\frac{L_{dn(i)}}{10}} \text{ dBA}$$

Thus, $\bar{L}_{dn}$ portrays the energy average at a given site having N days of 17 hours of data or more. These site summaries are given in Table 8.

Table 8

Site Summaries

Threshold for Activity Interference/Annoyance $L_{dn} \leq 55$ dBA

Site Number	$\bar{L}_{dn}$ dbA	N (number of days - minimum 17 hours)
1	84.78	21
2	82.60	4
3	75.21	4
4	74.63	2
5	76.10	5
6	85.34	6
7	72.23	2
8	77.00	5
9	75.64	6
10	77.24	4

Table 8 Cont'd.

Site Number	$\bar{L}_{dn}$ dbA	N (number of days - minimum 17 hours)
11	77.23	6
12	74.96	7
13	72.71	5
14	84.35	5
15	No Data	-
16	71.72	6
17	81.75	4
18	78.21	12
19	80.79	3
20	74.50	6
21	79.48	10
22	81.19	8
23	70.57	5
24	78.75	7
25	No Data	-
26	71.42	6
27	73.98	8
28	73.02	6
29	70.44	7
30	No Data	-
31	81.12	4
32	76.74	8

Table 8 Cont'd.

Site Number	$\bar{L}_{dn}$ dbA	N (number of days - minimum 17 hours)
33	77.97	9
34	73.11	3
35	79.66	8
36	80.64	7
37	76.83	6
38	81.87	7
39	78.08	7
40	84.76	6
41	78.42	34
42	85.51	7
43	77.37	7
44	73.67	7
45	85.84	35

VIII. Comparison of Field Data with Analytical Model

Admittedly a number of assumptions were made in the development of the noise contours. The degree to which L_{dn} is predicted on the ground from such a formulation can be verified by establishing L_{dn} with field monitoring. As discussed in Section VI, data has been obtained at some 42 sites with individual sites being monitored for from two to 35 days. Since the contours are based on an "average day," it is of interest to determine how much data at a site is sufficient to approach the "average" noise level resulting from the level of operations occurring daily. From this limited amount of data some conclusions can be reached regarding the minimum sampling time for comparison with the "average day" when a certain degree of deviation is acceptable.

A second issue, which also necessarily bears on the average day assumption, is the site location relative to a specific type of aircraft operation. For example, sites 20, 23 and 26 are much more severely impacted by takeoffs to the East on runway 8 than by landings to the West on runway 26. This is a result of their physical location relative to the runway centerline (approximately 800-1600 feet north of 8/26 centerline) and the fact that East takeoffs turn north to 070° at the middle marker while landings are straight in. Consequently, if the airport is in a West configuration over the time period when field data is being acquired, the measured L_{dn} will be significantly lower than the L_{dn} grid prediction. But of course, an "average day" over the course of a year's time period is not all West operations, thus the field data simply was not taken over a long enough time period to represent all types of operations. In general, this was found to be the explanation whenever the field data disagreed materially with the analytical prediction. A phone call to the FAA Control Tower verified the direction of operations and gave further confidence in the analytical results.

The comparison between the data obtained through the monitoring program and that derived from the prediction is shown below in Table 9. The physical data is the energy average for site, specifying N, the number of days included in the average (17 hours of data the minimum to be considered), while the analytical data was obtained from the 1000 x 1000 foot L_{dn} grid used to generate the contours.

Table 9

Comparison of Field Data with Analytical Model

Site #	Field Data N = , $\overline{L}_{dn}(N)$ =	Analytical Prediction
1	N = 21, $\overline{L}_{dn}$ = 84.78 dBA	85.0 dBA
2	N = 4, $\overline{L}_{dn}$ = 82.60 dBA	86.0 dBA
3	N = 4, $\overline{L}_{dn}$ = 75.21 dBA	79.2 dBA
4	N = 2, $\overline{L}_{dn}$ = 74.63 dBA	77.1 dBA
5	N = 5, $\overline{L}_{dn}$ = 76.10 dBA	77.6 dBA
6	N = 6, $\overline{L}_{dn}$ = 85.34 dBA	86.6 dBA
7	N = 2, $\overline{L}_{dn}$ = 72.23 dBA	76.1 dBA
8	N = 5, $\overline{L}_{dn}$ = 77.00 dBA	80.6 dBA
9	N = 6, $\overline{L}_{dn}$ = 75.64 dBA	76.7 dBA
10	N = 4, $\overline{L}_{dn}$ = 77.24 dBA	79.2 dBA
11	N = 6, $\overline{L}_{dn}$ = 77.23 dBA	79.0 dBA
12	N = 7, $\overline{L}_{dn}$ = 74.96 dBA	76.1 dBA
13	N = 5, $\overline{L}_{dn}$ = 72.71 dBA	75.7 dBA
14	N = 5, $\overline{L}_{dn}$ = 84.35 dBA	84.5 dBA
15	No Data	80.6 dBA
16	N = 6, $\overline{L}_{dn}$ = 71.72 dBA	77.7 dBA
17	N = 4, $\overline{L}_{dn}$ = 81.75 dBA	83.4 dBA
18	N = 12, $\overline{L}_{dn}$ = 78.21 dBA	78.8 dBA
✓19	N = 3, $\overline{L}_{dn}$ = 80.79 dBA	79.7 dBA
20	N = 6, $\overline{L}_{dn}$ = 74.50 dBA	81.4 dBA
✓21	N = 10, $\overline{L}_{dn}$ = 79.48 dBA	78.6 dBA

Table 9 Cont'd.

Site #	Field Data N = , $\bar{L}_{dn}(N)$ =	Analytical Prediction
✓ 22	N = 8, $\bar{L}_{dn}$ = 81.19 dBA	79.7 dBA
23	N = 5, $\bar{L}_{dn}$ = 70.57 dBA	79.8 dBA
✓ 24	N = 7, $\bar{L}_{dn}$ = 78.75 dBA	78.0 dBA
25	No Data	78.3 dBA
26	N = 6, $\bar{L}_{dn}$ = 71.42 dBA	78.0 dBA
27	N = 8, $\bar{L}_{dn}$ = 73.98 dBA	74.2 dBA
28	N = 6, $\bar{L}_{dn}$ = 73.02 dBA	74.2 dBA
29	N = 7, $\bar{L}_{dn}$ = 70.44 dBA	75.0 dBA
30	No Data	81.1 dBA
31	N = 4, $\bar{L}_{dn}$ = 81.12 dBA	81.9 dBA
32	N = 8, $\bar{L}_{dn}$ = 76.74 dBA	77.5 dBA
33	N = 9, $\bar{L}_{dn}$ = 77.97 dBA	78.3 dBA
✓ 34	N = 3, $\bar{L}_{dn}$ = 73.11 dBA	72.8 dBA
35	N = 8, $\bar{L}_{dn}$ = 79.66 dBA	79.2 dBA
36	N = 7, $\bar{L}_{dn}$ = 80.64 dBA	80.2 dBA
37	N = 6, $\bar{L}_{dn}$ = 76.83 dBA	77.0 dBA
38	N = 7, $\bar{L}_{dn}$ = 81.87 dBA	83.3 dBA
39	N = 7, $\bar{L}_{dn}$ = 78.08 dBA	79.8 dBA
✓ 40	N = 6, $\bar{L}_{dn}$ = 84.76 dBA	83.4 dBA
41	N = 34, $\bar{L}_{dn}$ = 78.42 dBA	77.1 dBA
✓ 42	N = 7, $\bar{L}_{dn}$ = 85.51 dBA	84.3 dBA
43	N = 7, $\bar{L}_{dn}$ = 77.37 dBA	77.0 dBA
44	N = 7, $\bar{L}_{dn}$ = 73.67 dBA	73.8 dBA
✓ 45	N = 35, $\bar{L}_{dn}$ = 85.84 dBA	84.0 dBA

From a review of Table 9, it can be seen that sites 20, 23 and 26 all were characterized by a situation in which the prediction exceeded the field measured L_{dn}. However, as discussed earlier, these sites are much more sensitive to East takeoffs on runway 8 than West landings on runway 26. During the time period in question, a check with the control tower showed that virtually all operations were West, so it is not surprising that the predicted level exceeded the field data to a considerable degree.

Two other sites show a similar disagreement, ie: 3.50 - 4.00 dBA. Sites 3 and 8 are within a few hundred feet of the extended centerline of runway 9L/27R, the South takeoff runway. These sites are considerably (though not to the extent of sites 20, 23 and 26) more impacted by East takeoffs on 9L than by landings to the West on the southernmost runway 27L. Again, the information received from the control tower identified that the airport was in a West configuration during all but four hours of this time period. Consequently, the lack of agreement is not surprising when viewed in light of the "average day" concept.

Site 7 shows a discrepancy of nearly 4.0 dBA between the predicted and measured L_{dn}. However, since N = 2 days, it seems obvious that it is very unlikely to be in position to monitor an "average day" with only two monitoring days randomly selected out of 365. More data would be necessary at this location for extensive verification.

To obtain a feel for how well the prediction actually modeled Hartsfield International Airport, consider the following analysis. Since it is clear why sites 3, 8, 20, 23 and 26 predict low (see previous discussion), they will be eliminated in the further discussion. In addition, two days is not an adequate time period to expect to find an "average day," so arbitrarily omit sites unless at least three days of data is available. (Note: three days may be insufficient as well, but the cutoff must be made somewhere.) Finally, define D to be the deviation from the predicted level; that is, $D = L_{dn_{predicted}} - L_{dn_{measured}}$, and additionally, let Class 1, Class 2 and Class 3 sites be defined as follows:

Class 1 site - site with more than 2 days but less than 5 days of data

Class 2 site - site with 5 or more days but less than 9 days of data

Class 3 site - site with more than 9 days of data

It is of interest to observe the "average deviation" as a function of the class of site being considered. The "average deviation" is defined as follows:

$$\bar{D} = \sum_{i=1}^{N} \frac{|D_i|}{N}$$

Table 10

Individual Deviations and Average Deviations from Analytical Prediction - Class 1, Class 2, and Class 3 Sites

Class 1 Sites - Sites with more than 2 but less than 5 days of data

Site #	Predicted L_{dn}	Measured L_{dn}	D_i
2	86.0 dBA	82.6 dBA	3.40
10	79.3 dBA	77.2 dBA	2.10
17	83.4 dBA	81.8 dBA	1.60
19	79.7 dBA	80.8 dBA	-1.10
31	81.9 dBA	81.1 dBA	0.80
34	72.8 dBA	73.1 dBA	-0.30

$$\bar{D} = \sum_{i=1}^{N} \frac{|D_i|}{N} = \frac{9.30}{6} = 1.55 \text{ dB}$$

Class 2 Sites - Sites with 5 or more days but less than 9 days of data

Site #	Predicted L_{dn}	Measured L_{dn}	D_i
5	77.6 dBA	76.10 dBA	1.50
6	86.6 dBA	85.34 dBA	1.26
9	76.7 dBA	75.6 dBA	1.10
11	79.0 dBA	77.2 dBA	1.80
12	76.1 dBA	74.96 dBA	1.14
13	75.7 dBA	72.7 dBA	2.99
14	84.5 dBA	84.35 dBA	0.15
16	77.7 dBA	71.7 dBA	6.00
22	79.7 dBA	81.2 dBA	-1.50
24	78.0 dBA	78.8 dBA	-0.80
27	74.2 dBA	74.0 dBA	0.20
28	74.2 dBA	73.0 dBA	1.18
29	75.0 dBA	70.4 dBA	4.60
32	77.5 dBA	76.7 dBA	0.80
35	79.2 dBA	79.7 dBA	-0.50
36	80.2 dBA	80.6 dBA	-0.40
37	77.0 dBA	76.8 dBA	0.20
38	83.3 dBA	81.9 dBA	1.40
39	79.8 dBA	78.1 dBA	1.70
40	83.4 dBA	84.8 dBA	-1.40
42	84.3 dBA	85.5 dBA	-1.20
43	77.0 dBA	77.4 dBA	-0.40
44	73.8 dBA	73.7 dBA	0.10

Table 10 Cont'd.

$$\bar{D} = \sum_{i=1}^{N} \frac{|D_i|}{N} = \frac{32.32}{23} = 1.41 \text{ dB}$$

Class 3 Sites - Sites with 9 or more days of data

Site #	Predicted L_{dn}	Measured L_{dn}	D_i
1	85.0 dBA	84.8 dBA	0.20
21	78.6 dBA	79.5 dBA	-0.90
18	78.8 dBA	78.2 dBA	0.60
33	78.3 dBA	78.0 dBA	0.30
41	77.1 dBA	78.4 dBA	-1.30
45	84.0 dBA	85.8 dBA	-1.80

$$\bar{D} = \sum_{i=1}^{N} \frac{|D_i|}{N} = \frac{5.10}{6} = 0.85 \text{ dB}$$

In summary then

Class 1 Sites, 5 days $> T > 2$ days, $\bar{D} = 1.55$ dB
Class 2 Sites, 9 days $> T \geq 5$ days, $\bar{D} = 1.41$ dB
Class 3 Sites, $T \geq 9$ days, $\bar{D} = 0.85$ dB

It is certain that too little data has been provided herein to recommend an optimum monitoring strategy for airport environments. Certainly, two days or less does not even allow for weekday to weekend variations to be observed if they in fact occur, and, consequently, is entirely insufficient. Good agreement with an "average day" analytical prediction would most likely be chance for such a short monitoring period.

However, as the monitoring period is extended one would expect to see increasing accuracy within the limitations of the model and as the duration of monitoring exceeds a week this is indeed seen to be the case. Because of the tremendous traffic volume at this airport, the average day is not significantly different from any day selected at random. As a result, the major deviation results at those sites more critically affected by a particular type of operation (takeoffs to the east, for example); an operation that occurs only infrequently during the monitoring period.

For the data presented, Class 3 sites ($T \geq 9$ days) show less than 1 dB variation in L_{dn} when compared to the "average day" prediction. This is exceptionally good agreement on the average and provides a basis for making decisions resulting from the analytical formulation. The conclusion to be reached from this assembly of data is that regardless of the assumptions made in the allocation of traffic by flight track, (admittedly a weak point in this analysis) the model more than adequately predicts the aircraft noise exposure on the ground. Obviously, even better predictions will be forthcoming as the quality of this particular type of input data is increased.

One final point should be addressed when discussing the model and how it relates to what is physically measurable. All the field data presented was obtained in areas with L_{dn} nominally 75 dBA or greater. There has been no attempt made to verify the prediction in areas where aircraft noise exposure is less severe. The degree to which the prediction was verified by field data for $L_{dn} \geq 75$ dBA is encouraging, however, and it is likely (though unproven) that such good agreement would continue beyond the contour of L_{dn} = 65 dBA. If those areas are of particular interest, a new study should be undertaken to again verify the model.

IX. Summary and Conclusions

Summary

Field Monitoring Study

The results of field monitoring at 42 sites (residential and institutional land uses) over a land area of approximately seven square miles were presented. Twenty-four sites covering a land area of approximately two square miles were analyzed east of the airport (Mountain View and Poole Creek) while 18 sites covering five square miles were investigated to the west of the airport in College Park. Aircraft noise, however, permeates communities and disrupts the activities of residents far beyond such limited boundaries. As a result, an analysis much less site specific than field monitoring is required to address large land areas. Consequently, noise contours have been provided to bridge this informational gap, and once the contours have been verified by physical measurement, extrapolation to other locations where no monitoring has been done is a logical extension of the overall analysis.

In determining the extent and resulting impact of the measured and predicted noise levels on the "public health and welfare," this study has employed the broad definition, "complete physical, mental and social well-being and not merely the absence of disease and infirmity." The criteria used in the quantification of the exposure has been the average day/night sound level L_{dn}; that is for $L_{dn} \leq 55$ dBA there would not be a significant community reaction to the noise environment (see Table D-11 and Figure D-16 in Section III).

Of the 42 locations for which data is presented, the categorization of exposures to the "energy average" of the daily average day/night sound level (L_{dn}) is: 3 sites with $L_{dn} > 85$ dBA, 13 sites with $L_{dn} > 80$ dBA, 29 sites with $L_{dn} > 75$ dBA, and all 42 sites with $L_{dn} > 70$ dBA.

In light of the definition of "public health and welfare," and consideration that activity interference may become a source of long-term annoyance, clearly in that context, a significant "health effect" has been identified. The extent of this effect varies from location to location as may be readily seen from the pictorial representation in Figure 4. The variation in the data obtained by monitoring exceeds 15 dBA from one site to another, again illustrating the non-uniformity of noise exposure over the survey area. A second issue that affects the ability of such a study to identify specific impacts is the individual's response and susceptability to intense noise intrusions. The sensitivity of individuals to noise varies greatly from one person to another, however, a statistically large number of people can give rise to a predictable subjective response. In this study, the data indicates an acoustic environment (at least within the areas monitored) that over a long period of time would likely cause adverse reactions, vigorous complaints, possible litigation, and possible damage to the physical well-being of the residents.

The previous discussion has dealt with criteria for activity interference and annoyance and its associated relationship to the measured average day/night sound levels. Quantification, at least in a subjective sense has been realized through research and social surveys. (See Figures D-5, D-6, D-9, D-10, D-13 and D-16.) Considerations on how general health and welfare is affected by noise is exceedingly difficult to quantify, i.e., nausea, headaches, irritability, anxiety, nervousness, insomnia, etc. One effect of noise exposure that has been well quantified and does not fall into any of the above categories, including activity interference/annoyance, is hearing loss. In addition to the activity interference/annoyance criteria ($L_{dn} \leq$ 55 dBA), EPA has identified levels adequate to protect the public from measurable hearing loss over a forty year exposure. Two such criteria have been established, $L_{eq(8)}$ = 75 dBA with an extension to twenty-four hours, $L_{eq(24)}$ = 70 dBA. The twenty-four hour hearing loss threshold of 70 dBA has the following margins of safety.

1. The level protects at the frequency where the ear is most sensitive (4000 Hz).

2. It protects virtually the entire population from exceeding 5 dB NIPTS (Noise Induced Permanent Threshold Shift).

3. It rounds off in the direction of hearing conservation (downward) to provide in part for uncertainties in analyzing the data.

In addition, it should be noted that the exposure period which results in no hearing loss at the identified level is a period of 40 years.

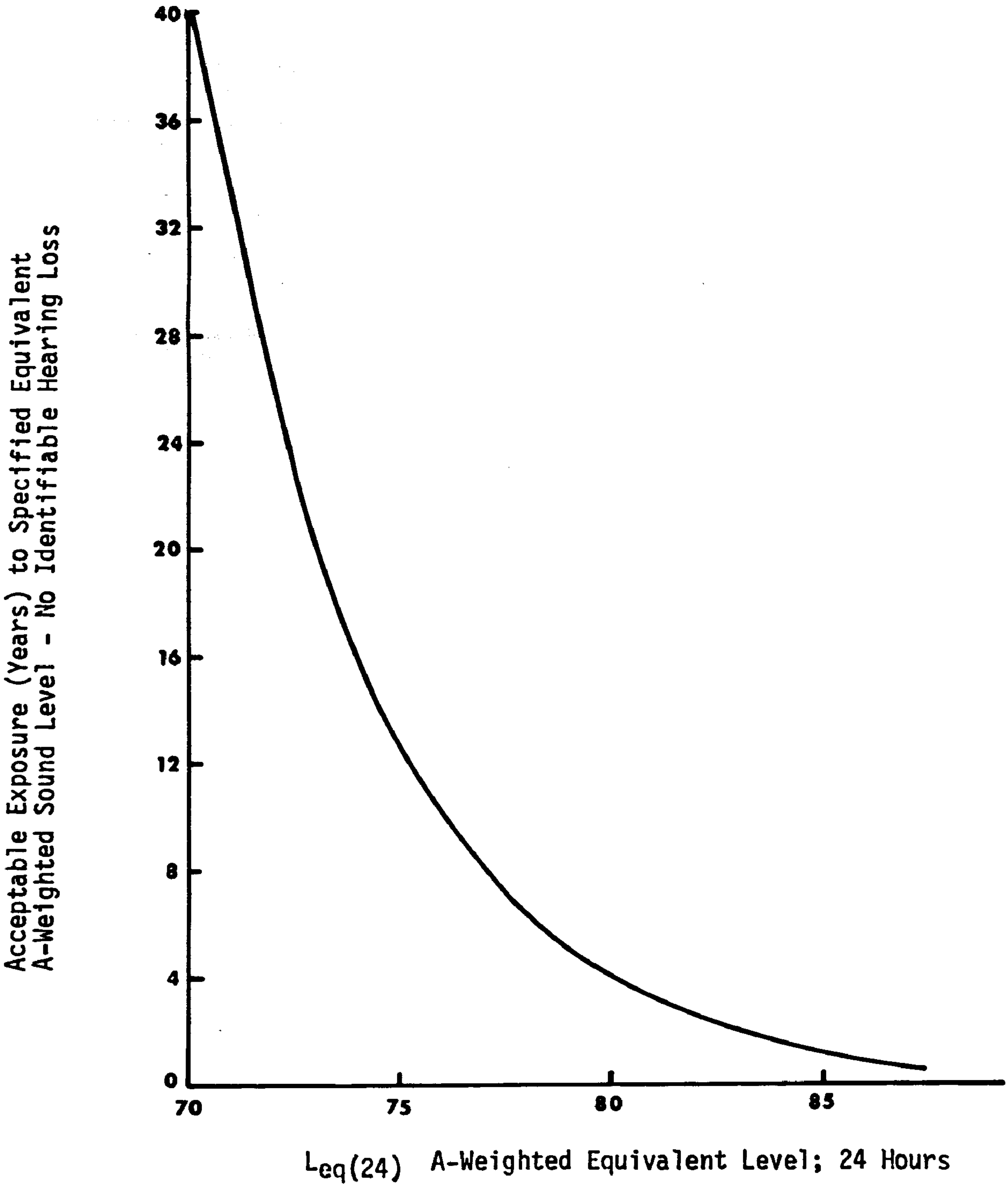
During the physical monitoring of the acoustic environment in this study, it was possible to obtain $L_{eq(24)}$ at all the sites surveyed. These data were obtained by outdoor measurements and correspond to the exterior L_{eq} and not necessarily the exposure and the noise dose of individuals living in the area. Thus, extreme care should be taken in attempting to draw specific conclusions regarding any possible hearing damage as a result of these exterior sound levels. However, since the levels do generally exceed $L_{eq(24)}$ = 70 dBA, potential effects should be investigated.

Sound levels in decibels are logarithmically related, the result being that an hourly equivalent sound level of 80 dBA contains ten times the acoustic energy one would find in an hourly equivalent level of 70 dBA. In the further extreme, an equivalent sound level of 90 dBA contains one hundred times the acoustic energy of an equivalent sound level of 70 dBA measured over the same time increment. The importance of these facts should be readily apparent when one views possible hearing loss from the concept of the equal energy hypothesis. Using an example to clarify this relationship, a 40 year exposure to $L_{eq(24)}$ = 70 dBA would be equivalent in acoustic energy received to a four year exposure to $L_{eq(24)}$ = 80 dBA. Again, it should be stressed that the key word is <u>exposure</u> and not simply the measured $L_{eq(24)}$. If, however, individuals were actually exposed to the exterior levels obtained in this study, they would receive a safe 40 year dose in a considerably shorter period of time. Figure 5 illustrates the equal energy relationship and the reduction in acceptable exposure times vis-a-vis no hearing loss over extended exposure times. The energy average $L_{eq}(24)$ computed from the daily $L_{eq}(24)$ shown for each site in Table 7, Section VII, may be consulted and combined with the information in Figure 5 to obtain acceptable exposure times. (Example: Site 17, energy average of daily $L_{eq}(24)$ based on four days = 79.02 dBA, equivalent 40 year exposure dose from Figure 5 would be approximately five years.)

Because dosimeters were not used in the study, the actual exposure and resulting noise doses for area residents were not obtained. Consequently, it is not possible to specifically identify individuals receiving dangerously high noise doses on a daily basis. It seems clear, however, from the field data presented that it is not possible to dismiss possible hearing loss a priori from consideration of health effects resulting from aircraft overflights.

Analytical Model

The field monitoring made it possible to assess the validity of the analytical prediction at 42 separate spatial locations and for various time periods. The agreement between field data and the predictive model based on the "average day" assumption is good - average deviation for all sites less than 2 dBA. While this comparison is only for sites nominally within the L_{dn} = 75 dBA contour, extrapolation outside the monitoring area seems reasonable. It appears certain that interpolation between contours inside L_{dn} = 75 dBA is likely to produce results with less than 2 dBA variation. Regardless of the fact that certain of the assumptions on flight track traffic allocation were not precise, the information provided by the model appears to make additional monitoring unnecessary.



*Extrapolation below 40 year exposure based on equal energy hypothesis

Figure 5 - Hearing Loss Criteria as Extrapolated from EPA "Levels Document" - Equal Energy Hypothesis Assumed

Conclusions

Considering initially the information within the area identified as $L_{dn} \geq 75$ dBA, (5,600 acres)

1. Activity Interference/Annoyance - Data indicates an acoustic environment that over an extended time period would very likely cause adverse reactions, vigorous complaints, litigation, and potential damage to the physical well-being of the residents.

2. Hearing Loss - Data indicates an acoustic environment that, with considerable outdoor activity identified, is of such a nature that one could not rule out the possibility of potential hearing loss over the long term.

3. Analytical Model - The model predicts the field measured L_{dn} at all sites with an average deviation of less than 2 dBA and in most cases, better. This is considered to be excellent agreement under the circumstances.

The contours as applied to regions where $65 \leq L_{dn} \leq 75$, (43,000 acres) may certainly be viewed for planning purposes and the identification of potential future problems. Further study of the entire airport environment should be initiated with appropriate land use planning actions being instituted by the local authorities responsible for the operation of the airport. This study should encompass future operations with projected airport growth as well as documentation of existing conditions using refined flight track and traffic allocation information. Strategies should be evaluated to mitigate the problem as it currently exists and a long-range plan for future land use compatibility should be developed.

X. References

1. "Report on Aircraft-Airport Noise," Report of the Administrator of the Environmental Protection Agency to the Committee on Public Works, U. S. Senate

2. EPA 550/9-74-004 - "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety"

3. EPA 550/9-73-002 - "Public Health and Welfare Criteria for Noise"

4. Land Use Planning with Respect to Aircraft Noise. AFM 86-5, TM 5-365, NAVDOCKS P-98, U. S. Department of Defense, October 1, 1964

5. D. E. Bishop, R. D. Horonjeff, "Procedures for Developing Noise Exposure Forecast Areas for Aircraft Flight Operations," FAA DS-67-10, August 1967

6. Williams, Kent C., "Environmental Noise Assessment, Mountain View, Georgia," EPA 504/9-77-021