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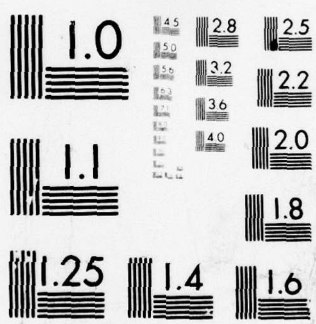

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ASSESSMENT OF THE ENVIRONMENTAL COMPATIBILITY OF DIFFERING HELICOPTER NOISE CERTIFICATION STANDARDS

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16. Abstract

Areas having the heaviest helicopter activity in the U.S. were visited and environmental noise measurements made in order to evaluate the impact of possible relaxed noise emission standards for helicopters restricted to remote regions. Measurement results showed that an average of 10 flyovers per hour produced a one-hour energy-averaged sound level (Leq) of 54.5 dBA, a level 2.5 dBA above ambient. An average of 34 events per hour adjacent to heliports produced a one-hour Leq of 63.1 dBA, which was 13.3 dBA above ambient. If emission levels were increased by 10 dBA, projected $Leq_{(24)}$ values of 57.0 and 71.2 dBA resulted for the flyover and heliport conditions, respectively. Sixty-four percent of those responding to a questionnaire stated that they had not experienced a problem from helicopter noise. The degree to which the remaining respondents were bothered ranged from "slightly" to "very annoyed" with no significant preference for either category.

67

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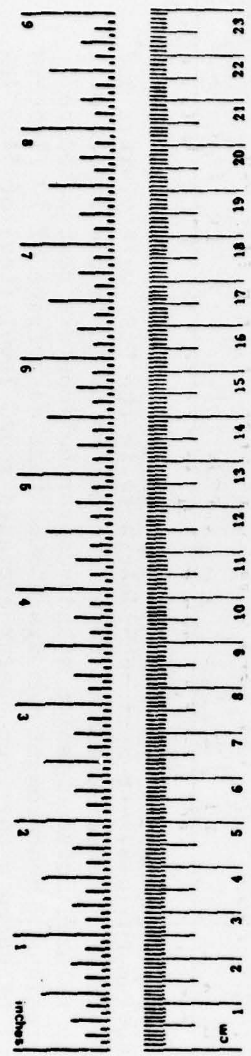
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

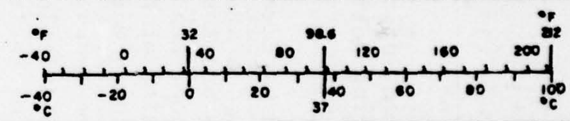
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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ABSTRACT

In order to evaluate the impact of relaxed noise emission standards for helicopters restricted to remote regions, areas along the Gulf Coast of Louisiana and Texas, identified as those in the U.S. characterized by the "heaviest of helicopter activity," were visited and environmental noise measurements made for miscellaneous helicopter flyovers and for activity adjacent to heliports. The instrumentation system employed sampled and stored A-weighted sound levels at the rate of 10 per second, and by using two independent systems, one of which rejected data any time a helicopter was audible, the contribution to ambient was established for the heaviest of existing civil helicopter activity. Questionnaires (272) were received from selected postmasters, wildlife refuge directors, forestry service employees, and national park superintendents in states having the highest helicopter densities (helicopters per 1,000 square miles). In addition, a brief study was performed at Aransas, Texas National Wildlife Refuge in which the responses of several species of wildlife were observed as a function of helicopter noise levels. Results showed that an average of 10 flyovers per hour produced a one-hour energy-averaged sound level (Leq) of 54.5 dBA, a level 2.5 dBA above ambient. An average of 34 events per hour adjacent to heliports produced a one-hour Leq of 63.1 dBA, which was 13.3 dBA above ambient. If emission levels were increased by 10 dBA projected $Leq_{(24)}$ values of 57.0 and 71.2 dBA resulted for the flyover and heliport conditions, respectively. Sixty-four percent of those responding to the questionnaire stated that they had not experienced a problem from helicopter noise. Of those that had experienced such a problem, interference with "rest and relaxation" and with "wildlife" were popular reasons. The degree to which these respondents were bothered ranged from "slightly" to "very annoyed" with no significant preference for either category. Seventy-two percent of those having a helicopter noise problem heard three or less per week, and 76 percent objected more to hearing them than to seeing them.

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Messrs. Stephen Labuda, Jr., Ken Butts, Steve Van Riper, and Frank Johnson, all of Aransas National Wildlife Refuge, enabled the study there of wildlife response to helicopter noise. In addition, the assistance from Mr. James Tiller in flying the Bell 47G helicopter and from Mrs. Bernice Barbour to document the animal behavior was appreciated.

Consultation was received from Jerry Speakman, John Cole, and Stan Harris of the Acoustics Branch, Biodynamics and Bionics Division, U.S.A.F. Aerospace Medical Research Laboratory at Wright-Patterson AFB, Ohio. Also, Mr. Robert Camp, Jr., of the Bioacoustics Division at Ft. Rucker, Alabama, and Joe McBryan of the Army's Construction Engineering Research Laboratory at Champaign, Illinois, were extremely helpful.

Mr. Henry Thomas, Director of the Standards and Regulations Division of EPA's Office of Noise Abatement and Control, Washington, offered assistance with much of the reference material.

Thanks to Jean Rose Howard of the Aerospace Industries Association for furnishing the "Directory of Helicopter Operators" and other information. The time extended by Robert Richardson of the Helicopter Association of America was appreciated.

During the field study along the Gulf Coast many commercial helicopter operators were extremely helpful. Among those were Carl Dougherty and Stan Clay of Petroleum Helicopters, Inc., Mr. Ray Champagne of Evergreen Helicopters, Inc., and Mr. Bill Thompson of Air Logistics.

Personnel at Bell and Hughes Helicopters were visited during the course of the study. Charles Cox and Bryan Edwards of the Acoustics Division at Bell Helicopter in Ft. Worth assisted by furnishing advice and also data for their craft. Stanley Spector and Edwin Cohen of Hughes Helicopters in Culver City, California were very beneficial, as was their colleague Bob Wagner. Mr. Wagner, Manager of Research and Development at Hughes (now retired) and also as Chairman of the HAA's Committee on Helicopter Acoustic Certification Standards, was certainly most helpful, and his assistance, advice, and gracious hospitality were truly appreciated.

Finally, the support by Mr. Richard Tedrick, Chief of the Noise Policy and Regulatory Branch of the FAA's Office of Environment and Energy, enabled the study to be performed. The authors acknowledge this support.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Figures | Page

LIST OF ILLUSTRATIONS (continued)

LIST OF TABLES

I. Introduction

The goal of the Federal Aviation Administration's Regulation 36 (FAR 36), promulgated in 1969, was to apply, consistent with legislative constraints, the maximum feasible use of noise control technology to fixed-wing aircraft, to be enforced by certification procedures. Application of a similar certification procedure to rotary-wing aircraft has been under consideration for some time. In addition to the FAA, the Committee on Aircraft Noise (CAN) of the International Civil Aviation Organization (ICAO), and the Helicopter Association of America's (HAA) Committee on Helicopter Acoustic Certification Standards has been concerned with the formulation of suitable procedures, limits, and criteria.

The HAA's Helicopter Acoustic Certification Standards Committee, in a letter dated November 21, 1977, (15)*, made several suggestions to the FAA in regard to Working Paper II, presented by the FAA at the ICAO CAN Working Group B meeting on June 29, 1977. Among the suggestions was "The adoption of a Certification category structure to recognize the demand of operation in sparsely populated areas". The following excerpt further states the feeling of the HAA Committee:

> "The helicopter is unique in that most of its operations are conducted in remote areas, away from people. Noise generated by helicopters, in this regard, is of importance, and hence must be limited, only when it is produced in populated areas. It follows therefore, that noise limits established to protect the health and welfare of the public need be applied only in areas where population exists and can be affected. Conversely, imposing these same limits on helicopters in sparcely populated areas serves no purpose in regard to protection of public health and welfare and is counterproductive to the essential growth of the helicopter industry and the related immeasurable benefits that can accrue to the public."

*Numbers in parenthesis refer to references.

A plan is proposed *"whereby noise limits are established in a manner similar to that required for fixed wing aircraft but recognizes the uniqueness of helicopter operations and the dictates of the Noise Control Act of 1972 in regard to "economic reasonableness and technological practicability".*

Specifically the plan proposes the establishment of one maximum noise level for densely populated areas and a higher maximum noise level for those sparsely populated. Variation of type certification operating parameter limits would be permitted to establish noise level limits for each category. One purpose of this approach would be to permit some noisier helicopters to continue to fly, but restrict their certification to "remote", sparsely populated areas.

The present study was undertaken in an effort to assess the environmental compatibility of such differing helicopter noise certification standards, i.e. what would be the potential effects on the environment of having one helicopter noise limit for densely populated areas and another (higher) limit for areas sparsely populated.

If one considers the scope of the problem undertaken, it becomes obvious very quickly that several important assumptions must be made at the outset. What is the definition of a "Sparsely Populated Area"? What is a "Densely Populated Area"? What is the proposed maximum noise level for "densely populated areas"? What is the increased noise level proposed for "sparsely populated areas"? What metric should be used to measure the helicopter noise? What, if any, degree of protection should be afforded animals as opposed to people? What "dose-response" relationship best represents man's response to helicopter noise; i.e., how much is too much, and what criteria do we use? The same questions can be asked for animals. It clearly becomes evident that any one of these questions could require extensive study to answer properly. In order for the present study to assess possible environmental consequences of a "dual certification standard", assumptions have been made, and these are listed throughout this report.

At the beginning of this study the authors visited with several researchers involved with helicopter acoustics, and also visited the acoustics groups of several helicopter manufacturers to review the problems associated with control and/or reduction of helicopter noise, and the difficulties that would be encountered if "overly restrictive" noise regulations were promulgated. Many of the considerations were set forth by Wagner (17) in his presentation "Helicopter Noise Regulations: An Industry Perspective" contained in the proceedings of the May, 1978 Helicopter Acoustics Symposium. "Helicopter External Noise Requirements -- FAA Perspective", presented at the same meeting by Foster (17), illustrated the need for helicopter noise control as viewed by the regulatory agency. Although the present study was limited to providing data regarding the potential impacts of the previously discussed "dual certification standard", i.e. limited in scope to the portion of the question related to "adequate protection of the environment", certainly the equally important consideration of technological feasibility and economic reasonableness must also be reflected in a final helicopter noise regulation.

The present study must be considered somewhat unique in its approach. Most of the literature addressing the question of helicopter external noise certification has been concerned with the appropriateness of the unit of measurement (EPNL, dBD, SEL, NEF, dBA, CNR, etc.), proper locations of microphones, flight path (angle and altitude) of craft relative to microphones, parameters of aircraft during the test (weight, speed, engine power, etc.), correction factors to reflect the effect of "blade slap", etc. While these are very important considerations for the certification procedure, they need not be addressed in a study involved with the impact of helicopter noise on the environment. Simply stated, the approach taken in the present study for field data was (1) to locate the areas in the United States having "heavy helicopter activity" (HHA), (2) travel to these areas and measure the actual cumulative noise energy impacting the environment, i.e. measure the amount by which the HHA increases the ambient noise levels,and (3) on the basis of this measurement, to assess the impact and project the impact that would result if the helicopter noise emission was increased by an assumed amount.

Those areas characterized by "heavy helicopter activity" were determined from data contained in the Aerospace Industries Association's (AIA) Directory of Helicopter Operators (9). The Gulf Coast area of Louisiana and Texas proved to be the U. S. area most densely populated with civil helicopters. This area was visited, and a novel method employed to yield the average (on an energy basis) sound levels, with and without helicopter activity, at selected points throughout the HAA region. At every selected location, the following two measurements were made: (1) the total energy averaged sound level including the contribution from helicopters, and (2) the energy averaged sound level excluding that from helicopters. The difference between these two measurements therefore represented the amount by which the "heavy helicopter activity" increased the local noise energy level.

The criteria used to assess helicopter noise impact was, for human exposure, based upon the Environmental Protection Agency's "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety"(22). The assessment of the potential effects of the various helicopter noise environments on wildlife and other animals is based upon some data gathered in the present study at Aransas (Texas) National Wildlife Refuge, and the two publications "Effects of Noise on Wildlife" (11) by Fletcher and Busnel and the EPA publication "Effects of Noise on Widlife and Other Animals" (12). Additional data on overall impact was provided by the questionnaires completed by 272 persons as a part of the present study, and by a previous study by the authors concerning helicopter noise in the area surrounding a large military helicopter base (4).

II. Study Procedures

As a matter of convenience, the procedures and results sections of the study are discussed in three distinct divisions:

1. Field Study. Referes to data gathered during the field trip to Alabama, Louisiana, and Texas.

2. Effects of Helicopter Noise on Wildlife. Refers to data gathered at Aransas National Wildlife Refuge, Texas.

3. Questionnaire.

A. Field Study

At the time the study was initiated, the 1977 Directory of Helicopter Operators (9) was the most recent compilation available to locate the distribution of civil helicopters throughout the United States. This directory divides the registrations into "Commercial", "Corporate", and "Civil Government" classifications. It was assumed the larger (and therefore noisier) helicopters would be mainly contained in the "commercial" classification, and for this reason only commercial craft were considered (a total of 3,327 was found in all 50 states). California had more commercial helicopters than any other state (438), but Louisiana had the highest helicopter "density" (helicopters per 1,000 square miles) - 8.05 compared to 2.76 for California. The national average was 1.61 helicopters per 1,000 square miles. Louisiana therefore had a helicopter density exactly five times greater than that of the average state. It was for this reason that Louisiana was chosen as the primary measurement site for the field study. Most of the helicopter activity in this state was found to be associated with the "offshore" petroleum industry, mainly for the transport of men and materials to and from offshore drilling operations. Inspection of maps locating such operations in the Gulf of Mexico revealed heavy concentrations all along the Louisiana Gulf, and south along the Texas Gulf Coast to Galveston. Field study sites thus included selected locations along the Gulf Coast from Louisiana to Aransas, Texas. Figure 1 shows the selected measurement locations.

At the time of planning for the field trips, it was uncertain how much helicopter activity would be encountered at the selected sites, therefore, in order to assure an "extreme" data point, i.e. one where there was almost continuous helicopter activity, one site selected was Ft. Rucker, Alabama, home of one of the Army's largest fleets of helicopters. Pilot training activities there afforded ample opportunity to record the environmental noise impact of near-continuous activity.

A very important consideration for the study involved the unit of measurement to be used. Several constraints limited the choice. The measurement had to be one that could be made easily in the field, that would adequately reflect the human perception of aircraft noise and that could be interpreted in concert with existing environmental noise criteria. The limited scope of the study further dictated that the measurement would have to be made at relatively low cost. These constraints, along with previous experience, pointed to the use of the equivalent, energy-averaged sound level, Leq, measured in units of dB(A).

The response of a community to noise, whether physical (e.g. hearing loss) or psychological (e.g. annoyance), is as a generalization often

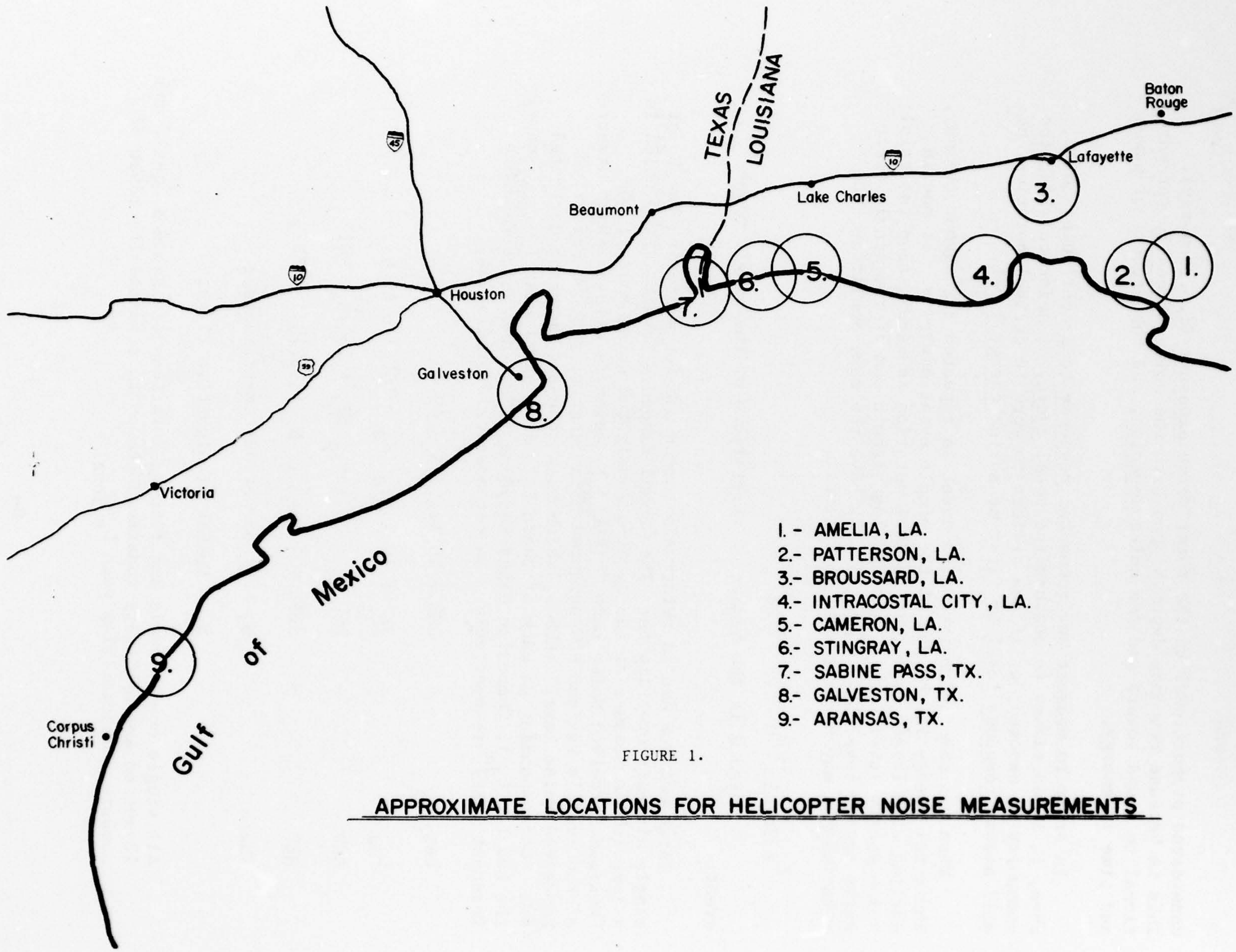


FIGURE 1.

APPROXIMATE LOCATIONS FOR HELICOPTER NOISE MEASUREMENTS considered proportional to the total noise <u>exposure</u> (i.e., energy). This is because response depends upon both the noise intensity (proportional to sound power) and the noise duration, and the product of power and time is energy.

In order to measure environmental response to a continuing noise, then, it is necessary to measure the total energy of noise to which the community is exposed; or if one prefers to work in decibel notation, he will assess response level by first measuring energy level.

When the same intrusive noise event is repeated throughout the day, the total energy is the sum of the single event energies. If one is working with levels (i.e., if decibel notation is used), then the total noise energy level $L_{e\ Total}$ is the logarithmic sum of the single event noise energy level L_e. When all L_e's have the same amplitude, the relationship may be expressed as follows:

$$L_{e\ Total} = L_e + 10 \log_{10} N$$

where N is the number of repetitions of the single noise event.

Three metrics are in relatively common use for measuring the L_e of single aircraft overflights: The "Sound Exposure Level" (SEL), which is a logarithmic measure of the event's A-weighted noise energy; the "Maximum Perceived Noise Level" (PNL_{max}), which is a logarithmic measure of the event's maximum NOY-weighted noise energy; and the Effective Perceived Noise Level" (EPNL), which is a tone-and-duration corrected PNL. Corresponding to each of these L_e's is a particular $L_{e\ Total}$ namely the Leq (or L_{dn}), Composite Noise Response (CNR), and Noise Exposure Forecast (NEF), respectively. In mathematical formulation,

$$Leq_{(24)} = SEL + 10 \log_{10} N - 49.4$$

$$L_{dn} = SEL + 10 \log_{10} (N_d + 10N_n) - 49.4$$

$$CNR = PNL_{max} + 10 \log_{10} (N_d + 16.7N_n) - 12$$

$$NEF = EPNL + 10 \log_{10} (N_d + 16.7N_n) - 88$$

Where N_d = Number of daytime flights

N_n = Number of nighttime flights

All single event levels and flyover durations are assumed equal, and 12 and 88 are arbitrary constants chosen to separate the range of numbers characterizing each $L_{e\ Total}$.

From these metrics, the Leq was chosen as the metric of choice for this investigation for the following reasons:

1. It is simple to measure with standard instrumentation, and therefore has the potential for accurate, yet inexpensive environmental assessments.

2. EPA recommends this metric for assessing the effects of environmental noise; it is recognized that FAA prefers use of the EPNL (and NEF) metric for aircraft certification purposes, but more data exist to relate community response to Leq than to NEF, and that was one purpose of the present study.

3. Many investigators, for example Hinterkeuser (20) and True (37), have demonstrated only minor differences in the shapes of dB(A), dB(D), and PNL curves (noise levels versus time).

4. The Leq is a direct measure of helicopter noise energy and includes the effect of blade slap by virtue of its response to the high-frequency components in each acoustic impulse.

Recent electronic advances have resulted in instruments that not only sample at rates up to 10 times per second, but also store all samples and perform statistical distribution analysis on such. The particular instrument chosen for use in this study was the Bruel and Kjaer Statistical Noise Level Analyzer (Model 4426).

Figure 2 shows photographs of typical instrumentation set-ups for field use. Two analyzers, as shown in the figure, were used at each location to obtain one set of data representing the total noise environment, including the contribution from helicopters, and another set of data, obtained during the same time interval, excluding any helicopter noise. The 4426 Analyzer is well suited for this "exclusion" measurement as it has a switch that can be placed in the "standby" mode, during which time data are simply not stored. During a measurement period, one analyzer would therefore store data continuously at the rate of 10 samples per second throughout the measurement period. The other analyzer would also store data at the same rate of 10 samples per second during the same measurement period except when a helicopter was audible, i.e., at the instant a helicopter was heard, the operator would place the function switch of this one analyzer from the "operate" to the "standby" mode, thereby ignoring all samples that contained helicopter noise, and as soon as the helicopter was no longer audible, he would place the function switch back to the "operate" mode, resuming the normal storage of data. By simply repeating this procedure every time a helicopter could be heard, the desired data were gathered -- one set containing all noise sources, the other excluding the helicopter noise. As shown in Figure 3, one microphone was required for use with each analyzer (B & K Model 4161). A time history (dBA versus time) was also recorded during all measurements by feeding the "A-Weighted" signal into a General

16

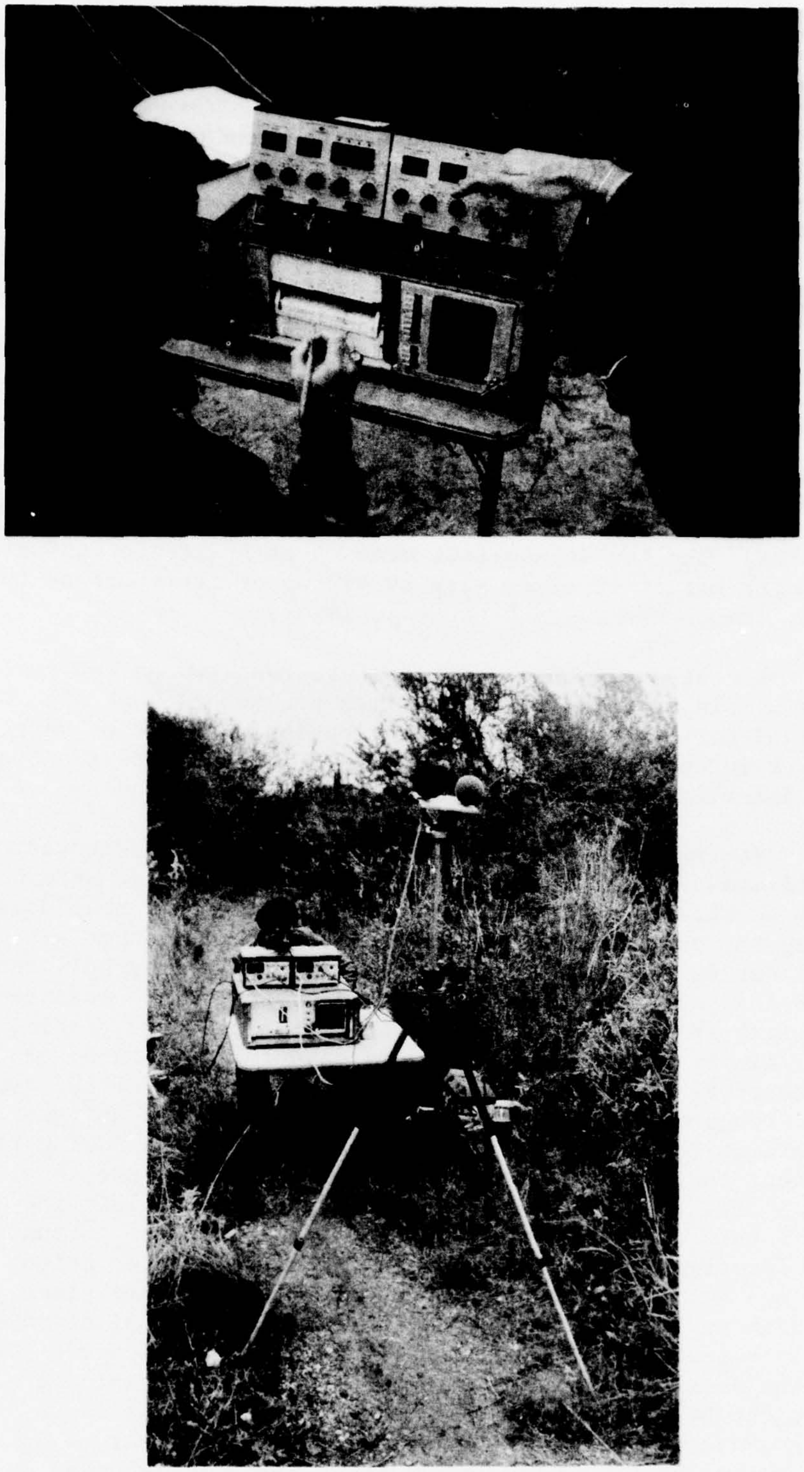


FIGURE 2. FIELD INSTRUMENTATION.

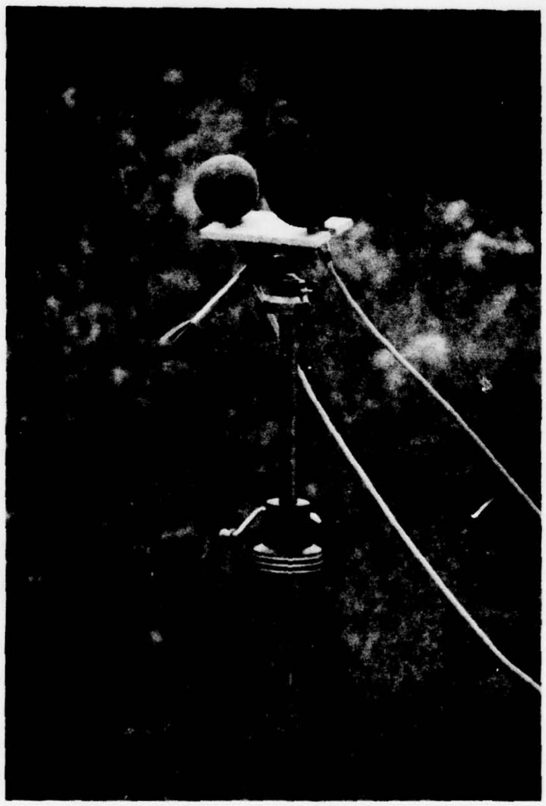


FIGURE 3. FIELD INSTRUMENTATION WITH
CLOSE-UP VIEW OF MICROPHONE ARRANGEMENT.

Radio graphic level recorder model 1523 with PIA preamplifier and inverter for use with DC power supply. In Figures 2 and 3, the recorder is located directly under the two analyzers.

In addition to the Leq, the analyzers also provide directly the "levels of exceedance" (L_1, L_{10}, L_{50}, L_{90}, L_{99}), which are simply the dB(A) levels exceeded 1, 10, 50, 90 and 99% of the time. The following example will illustrate use of this instrument for data collections:

Assuming that a sample period of 100 seconds and a sampling rate of 10 samples per second will be used, one can see that 1,000 samples will be stored in the analyzer at the end of the 100 second sample period. The instrument, after calibration, is switched to the "operate" mode to initiate the sample period, and 100 seconds later, the instrument indicates that the 1,000 samples have been stored. At this point the investigator may, by turning the "display" switch to the Leq position, ask the analyzer to display, via the LED digital readout, the Leq for the 1,000 samples. A reading of "58.1", for example, would mean that the acoustical energy in the 1,000 samples collected is equivalent to a constant (non time-varying) level of 58.1 dB(A) for 100 seconds. The Leq, therefore, is simply the average, on an energy basis, of the time varying signal. The "display" switch could now be turned to any of the L_1, L_{10}, L_{50}, L_{90}, or L_{99} positions. If, in the L_1 position, the digital readout indicated "73.4" this would simply mean that 1% of the samples, i.e. 1% of the 1,000 = 10 samples, had a magnitude greater than 73.4 dB(A). An L_{10} of 65.3 would mean that 100 samples (100 samples = 10%) were greater than 65.3 dB(A), etc. The L_1 is herein taken to indicate the average maximum helicopter noise contribution.

Since two analyzers were to be used in this study, and because data gathered by one were to be compared to that from the other, it was vital to demonstrate that the two instruments produced equal measurements for identical imputs. This was accomplished in the field by always collecting and comparing 3,000 samples immediately prior to, and immediately following, every data recording session. During these "calibration" periods, each analyzer was receiving the same ambient noise input and each was left in the "operate" mode for the entire 3,000 samples. Under such conditions, each analyzer should yield identical Leq, L_1, L_{10}, L_{50}, L_{90}, and L_{99} values (at least within 1 dBA, since this was the accuracy of the instrument). This proved to be the case, and therefore the comparison method was considered to be valid.

The procedure followed in the field for each data recording session was as follows:

The specific location was selected for exposure to maximum helicopter activity, either in the form of flyover, in those instances remote from heliports, or in the form of approach and takeoff, in which case the set-up was made adjacent to the heliport. For the case of "flyovers", the instrumentation was always set-up in an area removed from surface transportation or other "intrusive" noises. When locating adjacent to heliports, care was taken to locate such that any nearby surface transportation or other "intrusive" noises were minimal and the location was off the heliport property itself, but on an immediately adjacent piece of property. The attempt here was to locate at typical positions where homes could be located adjacent to heliports. This would represent sites of maximum helicopter noise exposure. It was usually possible to determine the hours of heaviest helicopter activity by inquiring of local helicopter operators. In the Gulf Coast area, where most helicopter activity is associated with offshore drilling, heavy periods of activity included the periods just after sunrise and just prior to sunset. For convenience, most measurement periods were chosen to be of 1 hour duration. Sampling rates were always 10 samples per second. Thirty six thousand samples were thus stored by the one analyzer operating continuously throughout the measurement period, while the other analyzer collected a number of samples less than 36,000 depending upon the amount of time helicopters were inaudible. For example, if helicopters were audible for 15 of the 60 minute measurement period, the second analyzer would collect 27,000 samples, since it would have been in the "standby" mode for 25% of the time. Both analyzers were always calibrated just prior to use by attaching a B & K Type 4230 Sound Level Calibrator to each microphone and adjusting the analyzer gain, if need be, to produce the proper output for the calibrated input. After this, the previously discussed 3,000 sample comparative data collection was always taken to assure that each analyzer produced the same Leq, L_1, L_{10}, L_{50}, L_{90} and L_{99} for the same input (ambient noise provided the input). Another 3,000 sample collection was always taken immediately after the 1 hour measurement period to check whether there had been calibration changes during the 1 hour test. The graphic level recorder was also calibrated with the 4230 Sound Level Calibrator before each use. The recorder was then placed in operation at the start of each 1 hour test and allowed to continuously record dB(A) versus time, thereby demonstrating each helicopter event.

B. Effects of Helicopter Noise on Wildlife

Although the scope of the study did not permit a detailed examination of the effects of helicopter noise on animals, it was thought that at least a cursory view was important to a broad assessment of environmental impact. The literature on helicopter noise impacts on animals is extremely scarce. Some literature deals with animals' response to "sonic boom", but helicopter noise is rarely addressed. In 1971, the Environmental Protection Agency published the report "Effects of Noise on Wildlife and Other Animals" (12) and in 1978 a book titled "Effects of Noise on Wildlife" (11) was edited by Fletcher and Busnel. While neither publication deals specifically with helicopter noise, some of the information was considered relevant.

To supplement this information, a short study of the effects of helicopter noise on wildlife was conducted at the Aransas National Wildlife Refuge, on the Gulf Coast near Corpus Christi, Texas. This refuge is home for abundant deer, peccary, wild boar, and several species of migratory water fowl including the endangered whooping crane.

Two sites were selected where species of interest could be observed (one is shown in Figure 4) and photographed from a blind or observation tower while a Bell 47G helicopter (Figure 5) flew over at several progressively lower altitudes. Noise measurements were made and concurrent wildlife responses were recorded.

Wildlife response to the helicopter noise was observed from two vantage points: a consulting biologist observed from either a blind or tower, and an Aransas wildlife biologist observed from the helicopter. From the fixed location at ground level, fewer species could be observed but their behavior could be studied in greater detail. From the air, only gross responses could be established, but it was possible to observe many additional species remote from the blind or tower locations (a five-minute flight over other areas of the refuge separated each overflight of the tower or blind so helicopter noise would drop to area ambient levels).

Each observer quantified the response of each observable species according to the following numerical code:

0 - No response
1 - Appear to notice, watch, or attend to the helicopter.
2 - Appear to be startled, flushed, or otherwise disturbed by the helicopter.
3 - Maximum response - seek cover or flee from the area.

In addition to these direct observations, extensive interviews were also conducted with the helicopter pilot who was previously a teacher of High School Biology and interested in wildlife. He was able to describe, from memory, how other species of animals, not located on the refuge, reacted to helicopter flight.

C. Questionnaire

To supplement the quantitative data gathered, subjective data were collected by means of a questionnaire. The authors had previously prepared a questionnaire for use in a study of the environmental consequences of a proposed military helicopter training mission (4), and had found the questionnaire results to be very helpful in evaluating the potential impact of the proposed effort.

FIGURE 4. THE VIEW FROM ONE WILDLIFE OBSERVATION POINT AT ARANSAS, TEXAS NATIONAL WILDLIFE REFUGE.

FIGURE 5. BELL 47G HELICOPTER USED AS NOISE SOURCE FOR ARANSAS STUDY.

A copy of the questionnaire for the present study can be found in the "Results" section. To expedite implementation of the questionnaire within the contract time constraints while conforming to Federal restrictions on government sponsored surveys, its distribution was limited to Federal employees. It was decided to send the questionnaire to four classifications of civil servants: (1) Postmasters, (2) Superintendents of National Parks, (3) National Wildlife Refuge Managers, and (4) Forestry Service employees. It was felt that the postamsters would be knowledgeable about rural and small town attitudes, while the other three classifications could reflect citizen attitudes in more remote or noise sensitive areas.

There were two primary questions on the first page. If respondents answered affirmative to either of these, they were then asked to complete additional questions. Even if they answered negative to both initial questions they were asked to so indicate and return the questionnaire with the remaining portions unanswered. Three hundred twelve questionnaires were mailed, and 272 were returned, for a very good return rate of 87 percent.

Questionnaires were sent to all 37 National Park Superintendents, to 93 Postmasters, 100 Refuge Managers, and to 82 Forestry Service employees. The AIA Helicopter Operators Directory was used to locate those areas of greatest helicopter activity, and selected postmasters, refuge managers, and forestry service employees in those areas were then mailed questionnaires. Rural postmasters were selected, and directories were obtained that listed locations and addresses of refuge managers and forestry service employees. The states found with the greatest helicopter density, and therefore those where the selected questionnaires were mailed, included Louisiana, California, Oregon, New Mexico, Arizona, Texas, Colorado, Florida, New Jersey, Oklahoma, Pennsylvania, and Washington.

III. Results.

A. Field Study.

Tables I through V contain, in tabular form, the results of the field study. As previously described, the data are divided into that involving helicopter "flyovers", labeled "Non-Heliport Data," and that involving measurements adjacent to heliports, labeled "Heliport Data." Throughout these tables, the designation "Analyzer A" refers to the instrument operated continuously during a measurement period, and "Analyzer B" refers to the one excluding helicopter noise during the same measurement period. A test designation number has been assigned to data gathered during each measurement period.

Table I lists, for each measurement period, the location, the number of samples registered by each analyzer, and the number of helicopter events occurring during the measurement. Tests # 1 and # 4 were made at Fort Rucker, considered the site of maximum activity; 92 events marked Test # 1, adjacent to the Hooper Field Heliport, and 21 "Flyovers" marked Test # 4; more distant from Hancy Field. The other three recordings adjacent to a heliport were made at Intercoastal City, La., and are identified as Tests # 7, # 8, and # 9. The remaining 13 tests were made at "flyover sites," as indicated at Amilia, Patterson, Broussard, Cameron, and Stingray, Louisiana, and at Galveston, Texas.

Table II is simply a listing of "calibration" information, presented in a manner similar to that of Table I. Note that there were no helicopter events during any calibration test except for # 2 where a special 18007 sample (rather than the usual 3,000) calibration test was performed during which there were 41 helicopter events.

Table III contains the analyzer data for all tests. For each analyzer the L_1, L_{10}, L_{50}, L_{90}, L_{99}, and Leq resulting from the number of samples shown in the Table I are listed. For example the test designated as # 23 included 17 helicopter "flyovers" at Cameron, Louisiana that, along with all other normal ambient noise, were recorded by Analyzer "A" to have an Leq of 58.0 dB(A). During this same time period Analyzer "B" showed an Leq of 55.6 dB(A). The difference of 2.4 dB(A) would represent the increase in overall noise level due to the helicopter. Notice for this same example that the L_{99} values differed only by 0.2 dB(A) between analyzers "A" and "B", i.e., the noise level exceeded 99% of the time was about the same for the two instruments (as it should be!), but that the L_1 values differed by 6.5 dB(A), reflecting the intrusive helicopter noise contribution contained in the data of Analyzer "A."

Table IV lists the "Calibration" data in the same format as Table III. As previously discussed, all of these tests were made by simply allowing each analyzer to continuously operate and have the same input, the object being to demonstrate that the analyzers were responding the same to identical inputs. Examination of this table clearly indicates that this was the case.

FAA HELICOPTER SURVEY DATA

NON-HELIPORT DATA

ANALYZER - A DATA
(INCLUDES HELICOPTER NOISE)
ANALYZER - B DATA
(EXCLUDES HELICOPTER DATA)

TEST #	LOCATION	ANALYZER	# ⁄SAMPLES A	B	# ⁄HELICOPTERS
4	FT RUCKER HANCHY		36000	24307	21
13	AMILIA LA		36000	21556	19
14	AMILIA LA		16428	11350	06
16	PATTERSON LA		36000	34107	02
17	PATTERSON LA		18259	16083	05
19	BROUSSARD LA		36000	28829	09
20	BROUSSARD LA		18002	13379	07
23	CAMERON LA		36000	21987	17
25	STINGRAY LA		36000	34535	02
26	STINGRAY LA		36000	35033	02
29	GALVESTON TX		36000	25910	07
30	GALVESTON TX		36000	29296	09
31	GALVESTON TX		36000	27375	08
32	GALVESTON TX		36000	28463	09

HELIPORT DATA

ANALYZER - A DATA
(INCLUDES HELICOPTER NOISE)
ANALYZER - B DATA
(EXCLUDES HELICOPTER DATA)

TEST #	LOCATION	ANALYZER	# ⁄SAMPLES A	B	# ⁄HELICOPTERS
1	FT RUCKER HOOPER		36000	06386	92
7	INTERCOASTAL CITY		36000	13357	20
8	INTERCOASTAL CITY		36000	24334	13
9	INTERCOASTAL CITY		36000	26361	13

TABLE I. NUMBER OF SAMPLES AND HELICOPTERS RECORDED AT EACH FIELD SITE.

CALIBRATION DATA

ANALYZER - A DATA
(INCLUDES HELICOPTER NOISE)
ANALYZER - B DATA
(EXCLUDES HELICOPTER DATA)

TEST			# ´SAMPLES		
#	LOCATION	ANALYZER	A	B	# ´HELICOPTERS
2	FT RUCKER HOOPER		18007	18007	41
3	FT RUCKER HANCHY		02000	02000	00
5	FT RUCKER HANCHY		02000	02000	00
6	INTERCOASTAL CITY		03000	03000	00
10	INTERCOASTAL CITY		03000	03000	00
11	AMILIA LA		03000	03000	00
12	AMILIA LA		18000	18000	00
15	PATTERSON LA		03000	03000	00
18	BROUSSARD LA		03000	03000	00
21	BROUSSARD LA		03000	03000	00
22	CAMERON LA		03000	03000	00
24	STINGRAY LA		03000	03000	00
27	STINGRAY LA		03000	03000	00
28	GALVESTON TX		03000	03000	00
33	GALVESTON TX		03000	03000	00
34	GALVESTON TX SW		03000	03000	00
35	GALVESTON TX SW		20090	20090	00
36	GALVESTON TX MSW		03000	03000	00

TABLE II. NUMBER OF SAMPLES AND HELICOPTERS RECORDED DURING EACH "CALIBRATION" TEST.

FAA HELICOPTER SURVEY DATA

NON-HELIPORT DATA
ANALYZER - A DATA (INCLUDES HELICOPTER NOISE)
ANALYZER - B DATA (EXCLUDES HELICOPTER NOISE)

LISTED BY LOCATION TEST #

	L1 DATA		L10 DATA		L50 DATA		L90 DATA		L99 DATA		LEQ DATA	
#	A	B	A	B	A	B	A	B	A	B	A	B
4	60.8	53.8	55.5	49.8	48.0	47.0	45.3	44.8	43.3	43.3	51.8	47.7
13	68.3	55.8	60.5	51.5	50.3	47.8	46.5	46.0	45.0	44.8	56.9	49.4
14	67.8	59.0	56.0	52.8	49.8	48.3	46.8	46.3	45.3	45.0	55.2	50.8
16	66.3	61.0	53.0	52.0	44.3	44.9	41.0	41.0	39.5	39.8	53.8	49.9
17	60.3	60.3	53.8	53.3	44.3	43.8	39.3	39.5	37.3	37.8	49.8	49.6
19	65.3	65.8	55.8	52.8	44.8	43.8	42.0	41.8	41.3	41.0	54.0	53.5
20	62.3	64.0	53.8	52.5	46.0	44.8	43.3	42.8	42.0	42.0	52.2	52.5
23	66.3	59.8	60.5	57.3	56.0	55.3	54.5	54.3	54.0	53.8	58.0	55.6
25	62.3	59.0	57.8	57.5	56.3	56.3	54.8	54.8	53.3	53.0	56.8	57.1
26	71.3	59.3	59.3	57.3	56.3	56.0	55.0	55.0	54.0	54.0	60.0	58.1
29	62.3	56.0	55.8	66.0	49.8	49.8	48.0	48.3	46.8	47.5	52.7	50.3
30	64.3	61.0	55.5	54.8	50.5	50.5	48.3	49.0	47.3	48.3	54.4	52.3
31	64.3	56.3	55.8	53.3	50.5	50.5	48.5	49.0	47.3	48.0	53.5	51.0
32	64.3	57.5	56.5	52.3	48.8	48.0	45.8	45.3	44.5	44.3	53.5	49.6

HELIPORT DATA
ANALYZER - A DATA (INCLUDES HELICOPTER NOISE)
ANALYZER - B DATA (EXCLUDES HELICOPTER NOISE)

LISTED BY LOCATION TEST #

	L1 DATA		L10 DATA		L50 DATA		L90 DATA		L99 DATA		LEQ DATA	
#	A	B	A	B	A	B	A	B	A	B	A	B
1	82.3	62.0	75.8	58.0	66.3	54.3	55.0	49.5	47.8	46.5	71.9	55.0
7	73.3	54.3	62.0	49.3	49.0	45.8	44.8	44.0	43.5	42.3	61.7	47.5
8	74.3	53.3	53.5	49.3	46.8	45.8	44.0	43.8	42.5	42.3	59.9	46.8
9	72.3	57.5	55.3	53.0	49.3	48.5	45.8	45.5	43.3	43.3	58.8	50.0

TABLE III. EXCEEDANCE LEVELS AND LEQ FIELD DATA.

CALIBRATION DATA

ANALYZER - A DATA (INCLUDES HELICOPTER NOISE)

ANALYZER - B DATA (EXCLUDES HELICOPTER NOISE)

LISTED BY LOCATION TEST #

	L1 DATA		L10 DATA		L50 DATA		L90 DATA		L99 DATA		LEQ DATA	
#	A	B	A	B	A	B	A	B	A	B	A	B
2	83.3	83.3	75.8	76.0	64.3	64.3	57.3	57.0	51.5	51.0	72.6	72.6
3	50.8	50.8	49.3	49.3	47.5	47.5	45.3	45.3	44.8	44.8	47.6	47.5
5	61.8	61.5	57.5	57.5	48.8	48.8	46.0	46.0	45.3	45.5	52.4	52.3
6	59.0	59.0	54.0	54.0	44.5	44.3	42.8	42.5	42.3	42.3	49.5	49.5
10	66.0	65.8	59.5	59.3	53.5	53.5	48.3	47.5	45.8	45.8	56.3	56.1
11	94.0	94.3	80.0	79.8	56.3	56.0	48.3	48.3	47.3	47.3	80.1	80.2
12	55.3	54.3	50.3	50.3	48.5	47.8	47.3	47.0	46.3	46.3	49.2	49.1
15	57.3	57.0	50.5	50.5	43.8	44.3	41.8	42.3	39.8	41.0	47.5	47.6
18	52.5	52.3	48.0	48.0	44.3	44.5	42.5	43.3	41.8	42.8	45.5	45.8
21	55.5	55.3	49.3	49.0	44.5	44.3	43.3	43.0	42.8	42.5	46.9	46.8
22	66.3	66.5	63.0	72.8	57.5	58.3	54.3	54.5	53.8	43.8	59.2	59.6
24	58.8	58.8	58.0	58.0	57.0	57.0	55.8	55.8	55.0	55.0	56.8	56.8
27	67.3	59.8	57.8	58.5	56.5	56.5	55.3	55.3	54.8	54.8	58.1	56.7
28	55.8	55.3	54.0	53.8	50.5	50.5	47.8	48.3	47.0	47.5	51.0	51.0
33	56.0	55.8	52.3	49.8	49.5	49.5	47.3	47.0	46.5	46.3	50.2	50.0
34	61.0	60.8	56.3	53.5	52.0	52.5	47.5	47.8	45.8	46.0	54.3	54.6
35	56.3	56.5	52.0	52.8	47.8	47.8	44.3	44.5	42.5	42.8	49.1	49.8
36	71.3	70.3	62.8	62.5	57.0	56.5	43.3	42.8	41.3	41.3	59.6	59.4

TABLE IV. EXCEEDANCE LEVELS AND LEQ FOR FIELD "CALIBRATION" DATA.

Means and standard deviations are tabulated in Table V. These data are derived directly from that of Table III.

Figures 6 and 7 contain the data of Table V in graphical form. Figure 6 corresponds to the "flyover" sites, Figure 7 to the "Heliport" sites. As would be expected, in each figure, the differences between the "A" and "B" Analyzer data, i.e., the difference between noise levels including and excluding helicopter contributions, are greatest for the L_1 exceedance levels (those exceeded 1% of the time), and decrease for increasing exceedance levels up to L_{99}, where, since this is essentially the background level, there is very little difference between analyzers. The Leq increase attributable to helicopter "flyover" activity was, on average, 2.5 dB(A), i.e., 54.5 minus 52.0 dB(A). On the other hand, the increase attributable to helicopter noise recorded near heliports was 13.3 dB(A), i.e., 63.1 dB(A) minus 49.8 dB(A). Thus, as might be expected, the effect of helicopter noise was much greater in areas adjacent to heliports.

Figure 8 shows the increase in Leq attributable to helicopter noise versus the percentage of time helicopter activity is present. In this graph, all data are combined to express an overall relationship (a "least-squares" regression line) between these two variables.

Figures 9 through 12 show how noise energy would be increased if noise emissions were permitted to increase by 10 dBA, Figures 9 and 10 representing the "flyover" condition, and Figure 11 and 12 representing the heliports. In each of these figures the lower shaded area represents ambient Leq, while the upper shaded area represents the increase attributable to helicopter noise. There are four conditions, identified as 1, 2, 3, and 4, for each graph. The first of these represents the existing condition (one hour values) in Figures 9 and 11 and 24 hour values in Figures 10 and 12. This computation was made with the following assumptions:

1. The $Leq_{(1)}$ resulting from helicopter activity was assumed present for 12 of the 24 hours, i.e., it was assumed there were, on average, no flights between sundown and sunrise (this was in fact the case; pilots seldom flew at night for safety reasons).

2. The average L_{99} recorded durign the daylight hours was assumed to be the nighttime (10 pm to 6 am) ambient Leq. The daytime ambient was assumed to be the Leq, excluding helicopter noise. These daytime and nighttime ambients were combined to calculate the ambient $Leq_{(24)}$.

In each figure, the ambient level for condition 1 was assumed to also be the ambient for conditions 2, 3, and 4. Condition 2 of each figure represents the Leq increase that would occur if helicopter noise emissions were increased by a factor of 10 dBA (assuming the number of flights, ambient noise level, etc., remain the same). This amount was suggested in interviews with several helicopter manufacturers' representatives as being a maximum amount that any given helicopter might exceed any of the proposed noise limits if a certification exemption was permitted. Comparison of Figures 9 and 11 will show

FAA HELICOPTER STATISTICAL DATA

NON-HELIPORT DATA

ANALYZER - A DATA
(INCLUDES HELICOPTER NOISE)

	MEAN	STANDARD DEVIATION
L1	64.7	3
L10	56.4	2.3
L50	49.6	4.1
L90	47	4.9
L99	45.7	5.2
LEQ	54.4	2.6

ANALYZER - B DATA
(EXCLUDES HELICOPTER NOISE)

	MEAN	STANDARD DEVIATION
L1	59.1	3.2
L10	54.5	4
L50	48.9	4.3
L90	46.9	5
L99	45.9	5.1
LEQ	51.9	3.1

HELIPORT DATA

ANALYZER - A DATA
(INCLUDES HELICOPTER NOISE)

	MEAN	STANDARD DEVIATION
L1	75.5	4.5
L10	61.6	10.1
L50	52.8	9
L90	47.4	5.1
L99	44.2	2.3
LEQ	63	6

ANALYZER - B DATA
(EXCLUDES HELICOPTER NOISE)

	MEAN	STANDARD DEVIATION
L1	56.7	3.9
L10	52.4	4.1
L50	48.6	4
L90	45.7	2.6
L99	43.6	1.9
LEQ	49.8	3.7

TABLE V. MEAN AND STANDARD DEVIATION FOR EXCEEDANCE LEVELS AND LEQ.

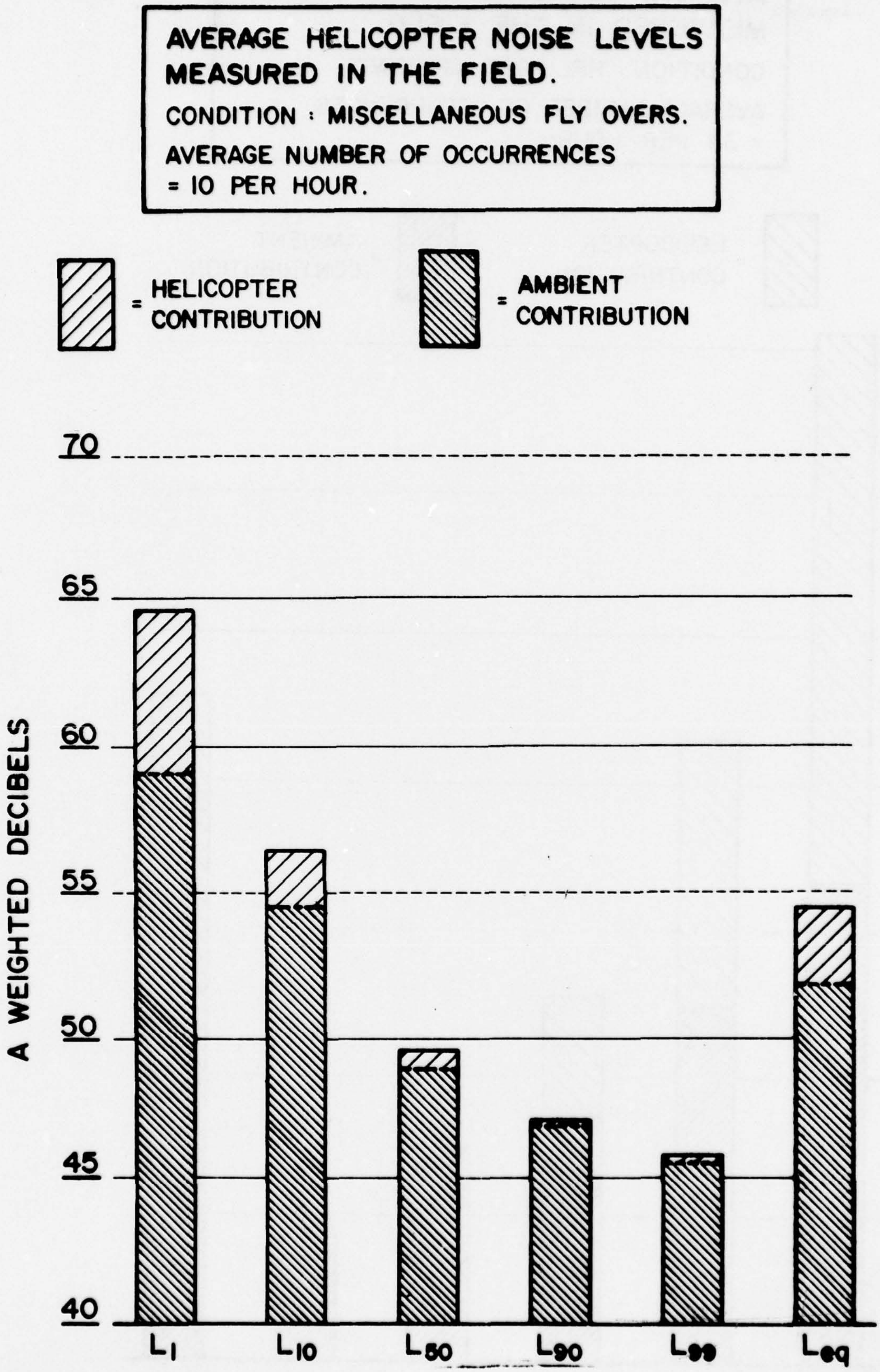


FIGURE 6. AVERAGE EXCEEDANCE LEVELS
AND LEQ FOR MISCELLANEOUS "FLYOVERS".

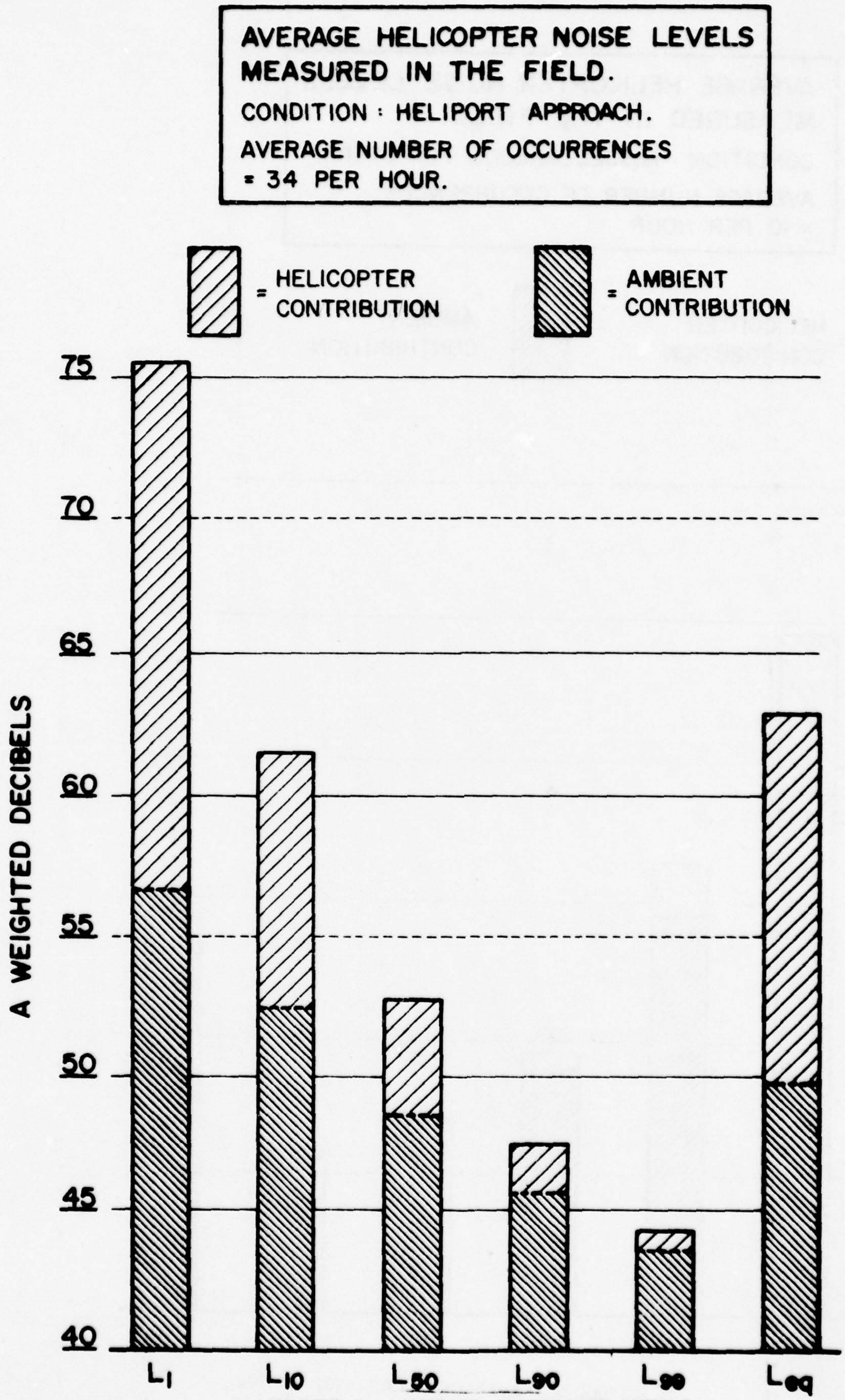


FIGURE 7. AVERAGE EXCEEDANCE LEVELS
AND LEQ MEASURED ADJACENT TO HELIPORTS.

FIGURE 8. RELATIONSHIP BETWEEN THE PERCENTAGE OF TIME HELICOPTERS ARE AUDIBLE AND THE RESULTING INCREASE IN AMBIENT LEQ.

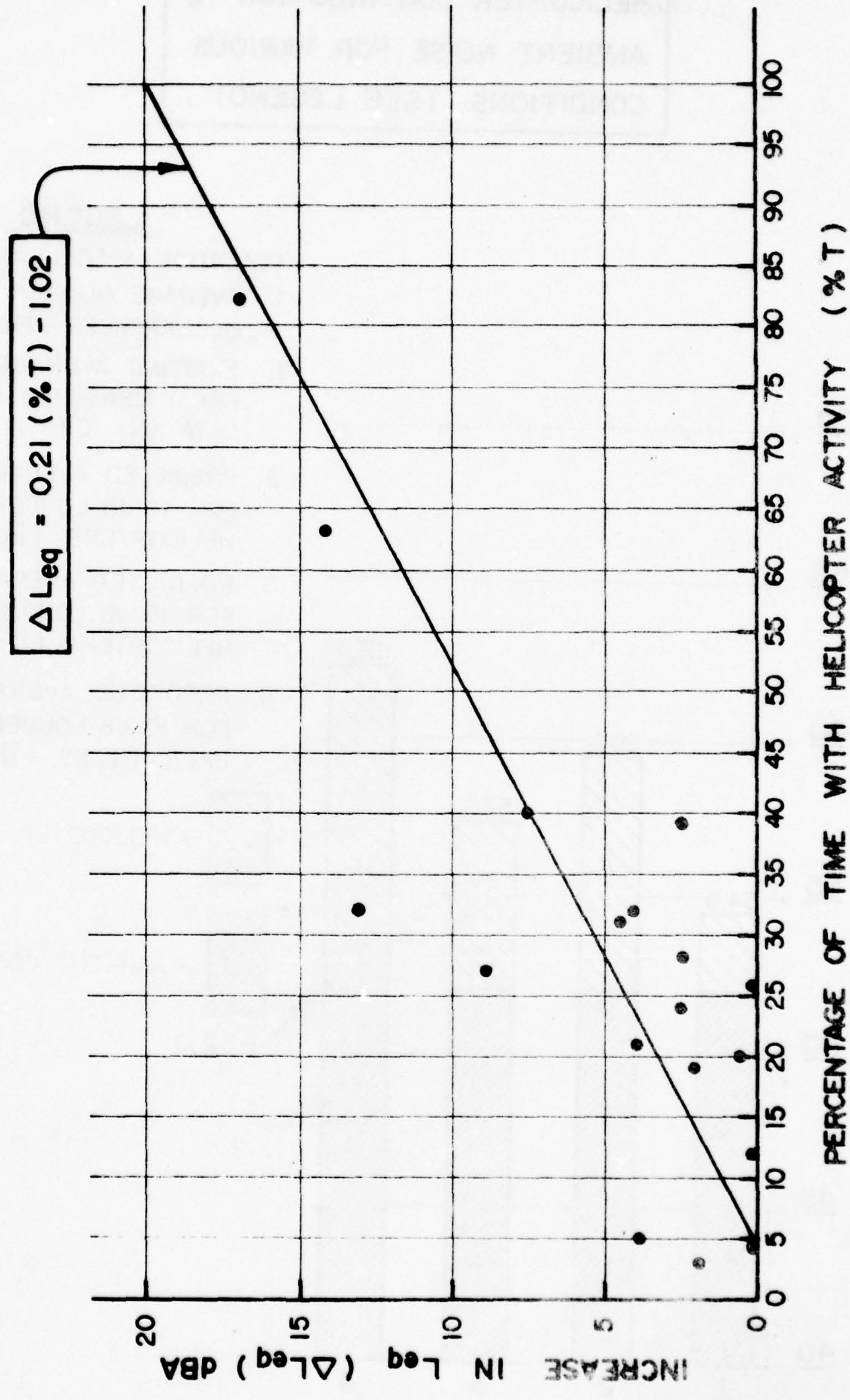


FIGURE 9

HELICOPTER CONTRIBUTION TO AMBIENT NOISE FOR VARIOUS CONDITIONS. (SEE LEGEND)

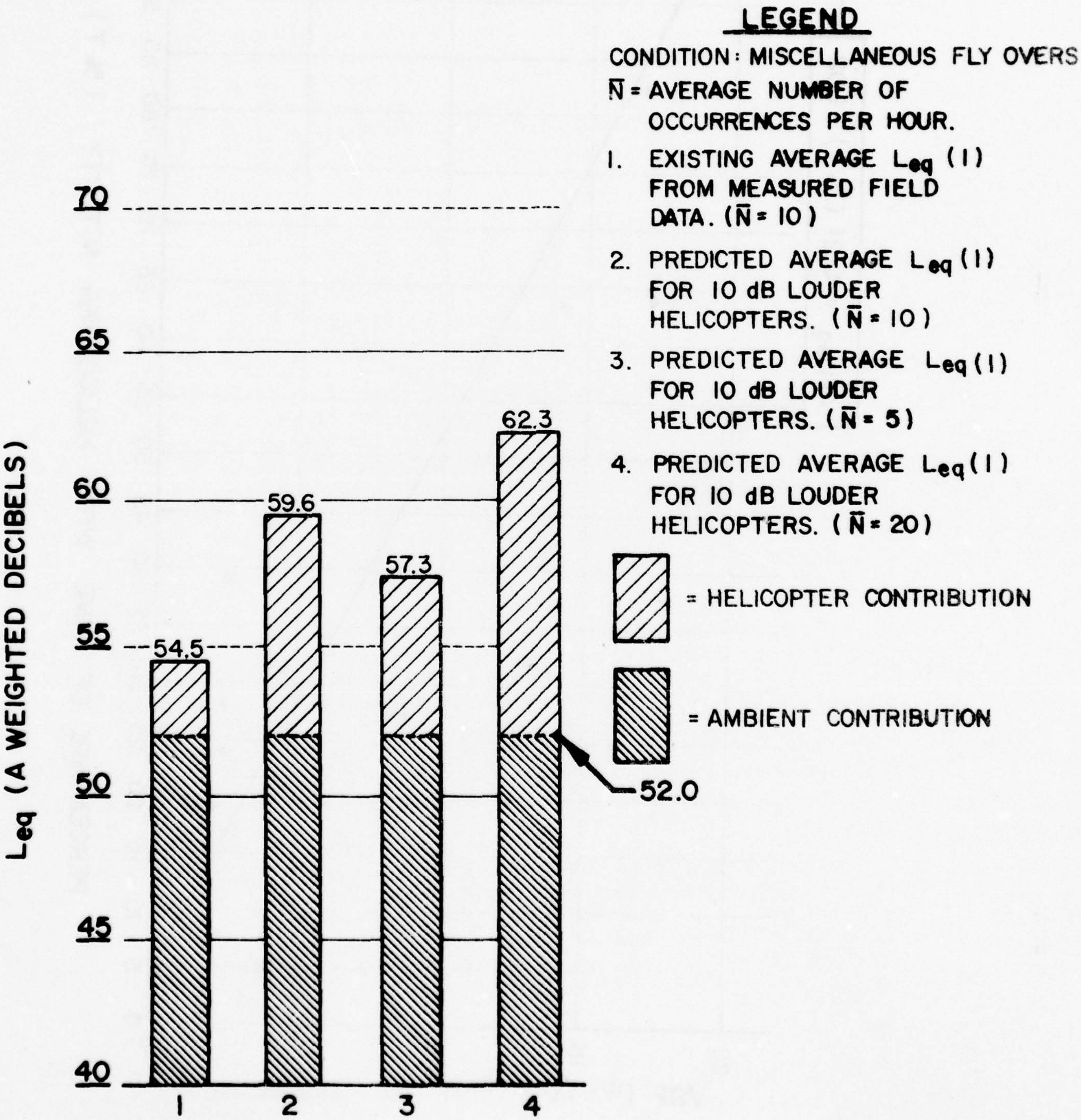


FIGURE 10

HELICOPTER CONTRIBUTION TO AMBIENT NOISE FOR VARIOUS CONDITIONS. (SEE LEGEND)

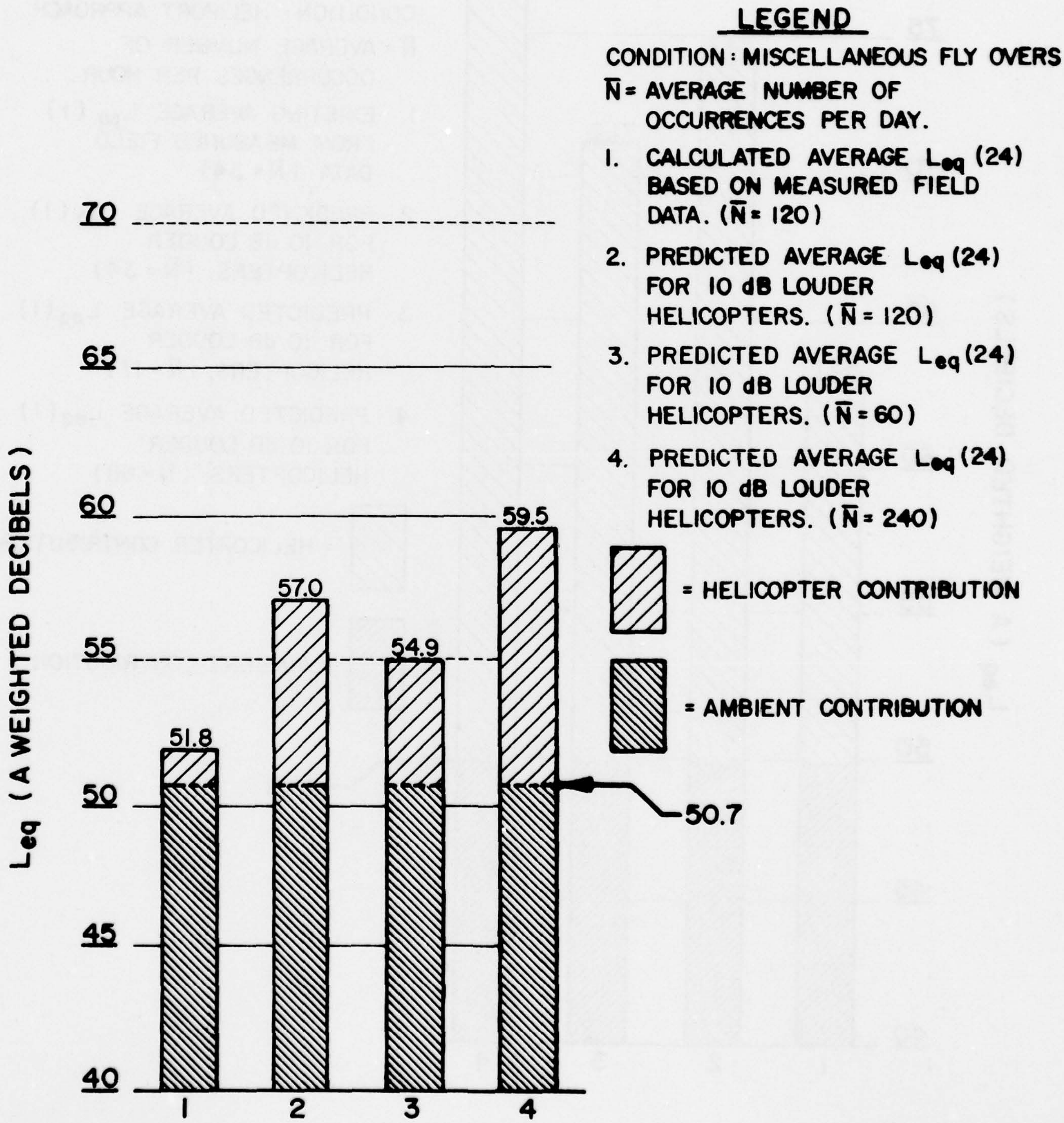
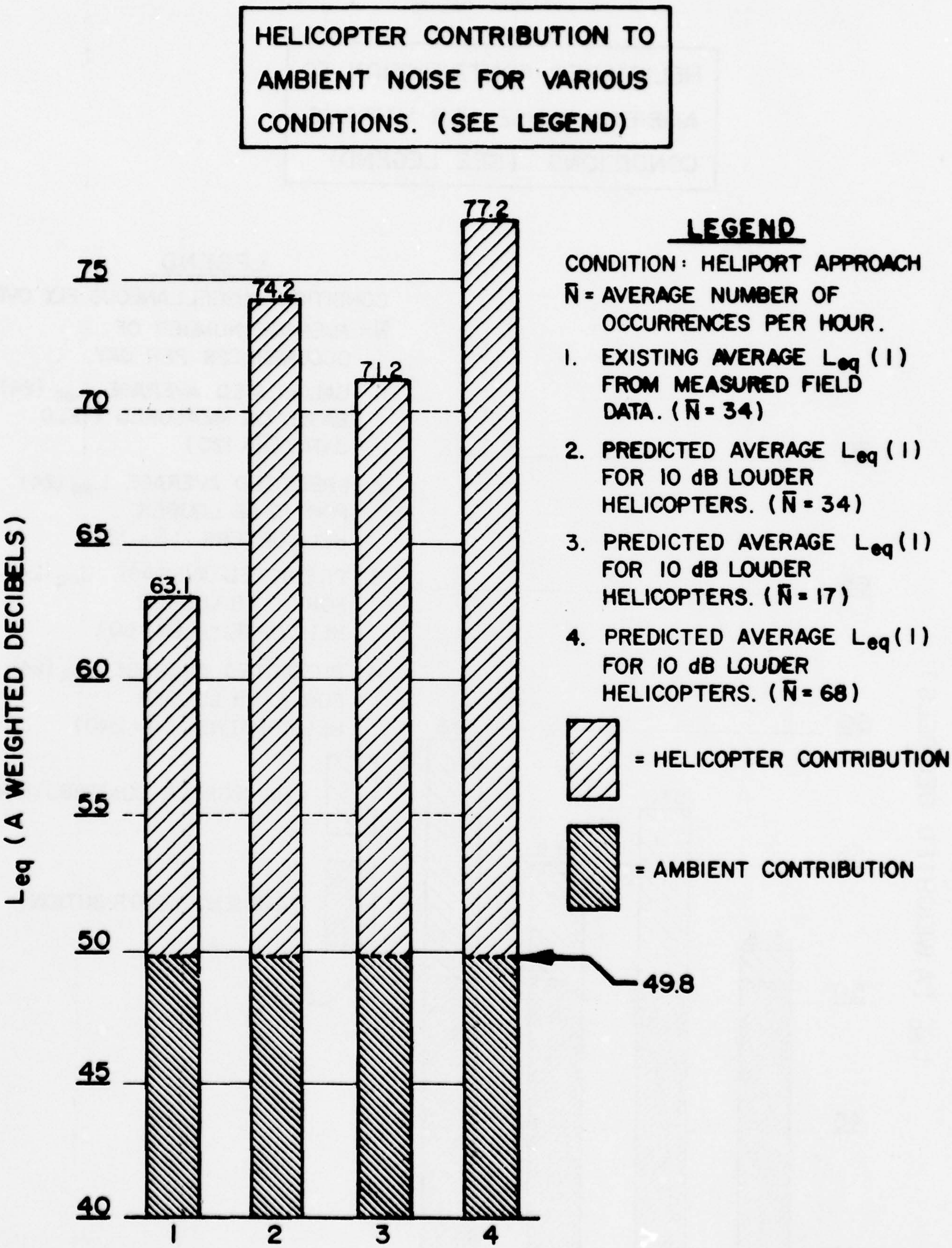
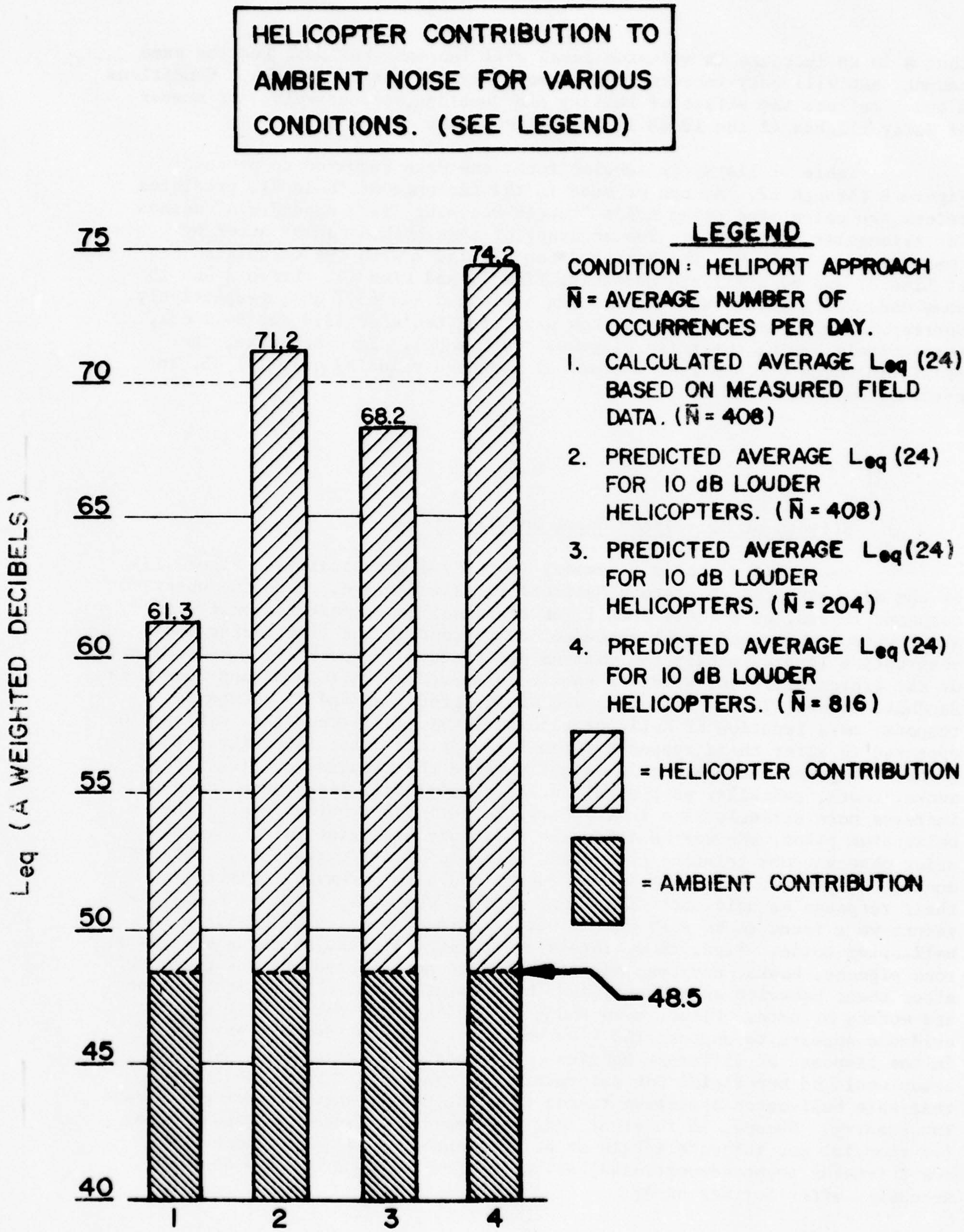


FIGURE 11


HELICOPTER CONTRIBUTION TO AMBIENT NOISE FOR VARIOUS CONDITIONS. (SEE LEGEND)
L_{eq} (A WEIGHTED DECIBELS)
75
70
65
60
55
50
45
40
63.1
74.2
71.2
77.2
49.8
1
2
3
4
LEGEND
CONDITION: HELIPORT APPROACH
$\bar{N}$ = AVERAGE NUMBER OF OCCURRENCES PER HOUR.
1. EXISTING AVERAGE L_{eq} (1) FROM MEASURED FIELD DATA. ($\bar{N}$ = 34)
2. PREDICTED AVERAGE L_{eq} (1) FOR 10 dB LOUDER HELICOPTERS. ($\bar{N}$ = 34)
3. PREDICTED AVERAGE L_{eq} (1) FOR 10 dB LOUDER HELICOPTERS. ($\bar{N}$ = 17)
4. PREDICTED AVERAGE L_{eq} (1) FOR 10 dB LOUDER HELICOPTERS. ($\bar{N}$ = 68)
= HELICOPTER CONTRIBUTION
= AMBIENT CONTRIBUTION


HELICOPTER CONTRIBUTION TO AMBIENT NOISE FOR VARIOUS CONDITIONS. (SEE LEGEND)
75
70
65
60
55
50
45
40
Leq (A WEIGHTED DECIBELS)
61.3
71.2
68.2
74.2
48.5
1
2
3
4
LEGEND
CONDITION: HELIPORT APPROACH
N̄ = AVERAGE NUMBER OF OCCURRENCES PER DAY.
1. CALCULATED AVERAGE Leq (24) BASED ON MEASURED FIELD DATA. (N̄ = 408)
2. PREDICTED AVERAGE Leq (24) FOR 10 dB LOUDER HELICOPTERS. (N̄ = 408)
3. PREDICTED AVERAGE Leq (24) FOR 10 dB LOUDER HELICOPTERS. (N̄ = 204)
4. PREDICTED AVERAGE Leq (24) FOR 10 dB LOUDER HELICOPTERS. (N̄ = 816)
= HELICOPTER CONTRIBUTION
= AMBIENT CONTRIBUTION

that a 10 dB increase in emission level will increase heliport Leq the same amount, but will only increase more remote flyover Leq by 5.1 dBA. Conditions 3 and 4 reflect the effect of halving and doubling, respectively, the number of daily flights of the 10 dB louder helicopters.

Table VI lists, in tabular form, the data required to produce Figures 9 through 12. As can be seen in the footnote of Table VI, predicted values are calculated using EPA's "Levels Document (22) Appendix A" method for triangular wave forms. The accuracy of this method can be noted by comparing, in Table VI, the measured Leq of Line 2 with the calculated Leq of Line 3, and by similarly comparing Line 13 and Line 14. Lines 2 and 13 show measured flyover and heliport Leq's of 54.5 and 63.1 dBA, respectively. Correspondingly, Lines 3 and 14 show predicted Leq's of 53.4 and 64.2 dBA, respectively, using the triangular wave form model. For each case, the predicted value differs from the actual measured value by only 1.1 dB, an error of only about 2%.

B. Effects of Helicopter Noise on Wildlife

Table VII contains a summary (portrayed graphically in Figure 13) of the data gathered at Aransas National Wildlife Refuge. Here the observed response levels, on a scale from 1 (no response) to 4 (most response), are shown versus the sound level exceeded one percent of the time during the observation (approximately the maximum dBA produced by overflying helicopter). Of the eleven different wildlife species observed, five (Canada and Snow geese, Sandhill Cranes, Turkey Vultures, and Great Egrets) showed no change in response as a function of helicopter noise level, while the other six species appeared to alter their response depending upon the noise intensity. The grebes' response increased only slightly while the response of ring-necked ducks, coots, gadwalls, purple gallinules, and pintail ducks were found to increase more strongly as a function of the helicopter noise level. The helicopter pilot, who was additionally a trained biologist, also gave his prior observations relating helicopter noise to wildlife response. Turkeys, ducks, alligators, dove, quail, and rabbit had been observed to increase their response as helicopter noise increased. Chickens, turkeys, and alligators were found to be very sensitive, but horses not at all sensitive to helicopter noise. Pigs, cows, antelope, turkey vultures, bald eagles, goats, rock pigeons, hawks, coyotes, and peccary were not observed by the pilot to alter their behavior as a function of helicopter noise. Two generalizations are worthy of note. First, even though these data are not definitive, the evidence appears to support the view that there is considerable variation in the response of different species to helicopter noise; a more detailed study would be beneficial for determining thresholds for many species so that safe helicopter operating ranges could be established for refuges around the country. Second, it is clear that some species (Canada and Snow Geese, for example) may tolerate little or no helicopter noise (any tendency to adapt remains to be demonstrated) so that "off-limits" areas may be found necessary after further study.

TABLE VI. TABULAR LISTING OF DATA FROM WHICH FIGURE 10 THROUGH 13 WERE CONSTRUCTED.

Measured (M) or Predicted (P)	Average Number of Occurrences	Measurement Period	Peak Noise Level (L_1)	Including Helicopters(I) or Excluding Helicopters(E)	Average Time (Sec.) Above Peak Noise Minus 10 dB	Leq
Miscellaneous Flyovers:						
1. M	--	1 hour	----	E	----	52.0
2. M	10	1 hour	64.7	I	22.4	54.5
3. P	10	1 hour	64.7	I	22.4	53.4
4. P	10	1 hour	74.7	I	22.4	59.6
5. P	5	1 hour	74.7	I	22.4	57.3
6. P	20	1 hour	74.7	I	22.4	62.3
7. P	--	24 hour	----	E	----	50.7
8. P	120	24 hour	64.7	I	22.4	51.8
9. P	120	24 hour	74.7	I	22.4	57.0
10. P	60	24 hour	74.7	I	22.4	54.9
11. P	240	24 hour	74.7	I	22.4	59.5
Adjacent to Heliports:						
12. M	--	1 hour	----	E	----	49.8
13. M	34	1 hour	75.6	I	17.6	63.1
14. P	34	1 hour	75.6	I	17.6	64.2
15. P	34	1 hour	85.6	I	17.6	74.2
16. P	17	1 hour	85.6	I	17.6	71.2
17. P	68	1 hour	85.6	I	17.6	77.2
18. P	--	24 hour	----	E	----	48.5
19. P	408	24 hour	75.6	I	17.6	61.3
20. P	408	24 hour	85.6	I	17.6	71.2
21. P	204	24 hour	85.6	I	17.6	68.2
22. P	816	24 hour	85.6	I	17.6	74.2

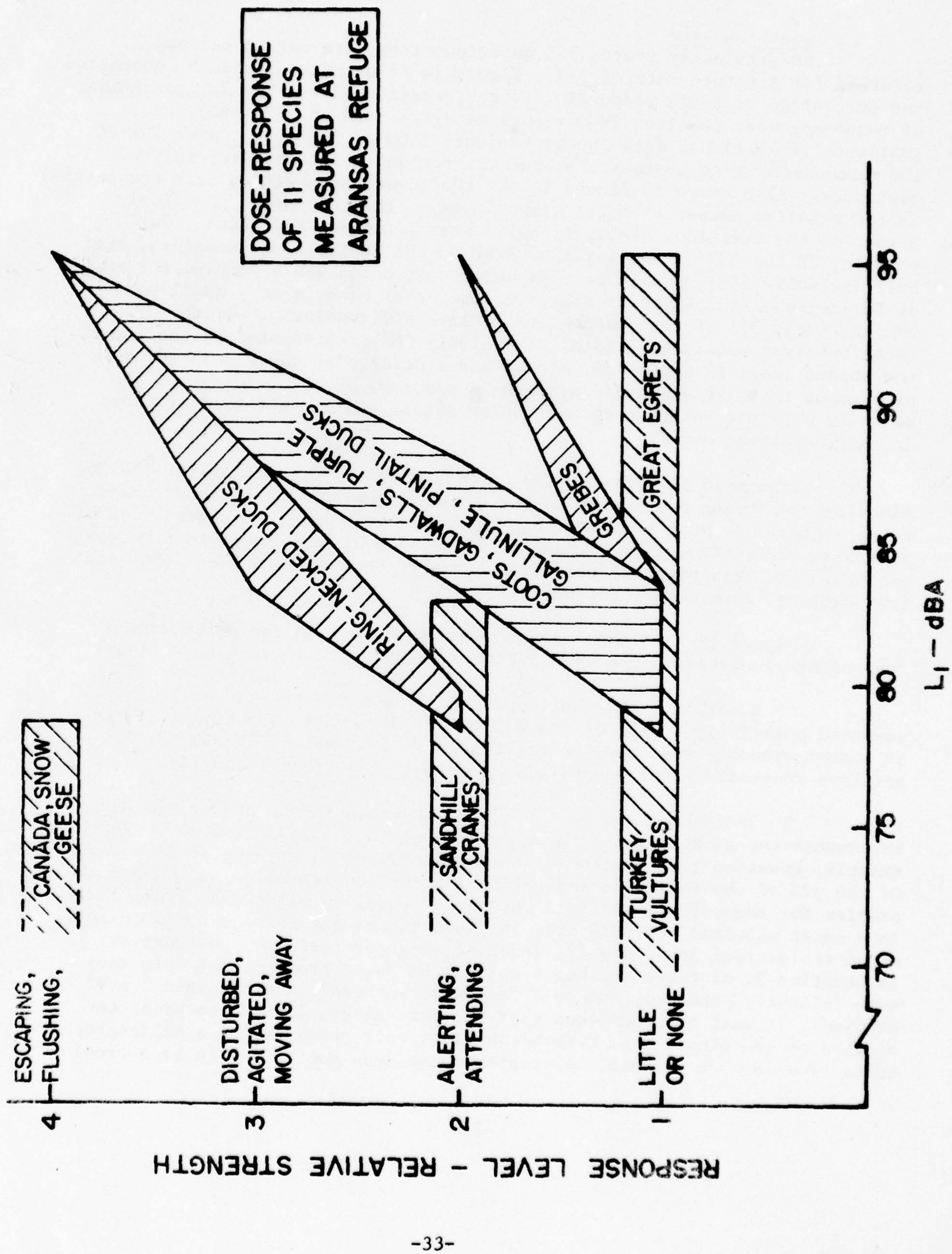
*Predicted values are based upon assumed triangular waveforms, and the method presented in Appendix A of the EPA's "Levels" Document (22).

TABLE VII. SUMMARY OF DATA RECORDED AT ARANSAS NATIONAL WILDLIFE REFUGE DURING FLYOVERS OF A BELL 47 G HELICOPTER AT SELECTED ALTITUDES ABOVE VARIOUS WILDLIFE SPECIES.

Area Designation	Approximate Helicopter Altitude	Peak dB(A)	L_I dB(A)	No Reaction 1	Alert-Looked Up 2	Agitated 3	Violent Left Area 4
Duck Blind	500'	78	78.3	G E GA C P PG	R		
	400'	80	79.8	G E GA C P PG	R		
	300'	83.3	83.3	G E P	GA PG C	R	
	200'	89.0	88.0	T E	P	GA R PG C	
	100'	96.0	95.3	T E	G		GA P R PG C
Fenced Area	100'	83.0	83.0	T	S		
	300'	81.0	81.3	T	S		
	500'	77.3	77.3	T	S		CG SG
	700'	75.5	75.5	T	S		CG SG
	1,000'	71.5	70.8		S		CG SG

LEGEND:
C - Coot
PG - Purple Gallinule
G - Pied-billed Grebe
E - Great Egret
CG - Canada Goose
SG - Snow Goose
GA - Gadwall
P - Pintail
R - Ring-Necked Duck
T - Turkey Vulture
S - Sandhill Crane

FIGURE 13. NOISE DOSE-RESPONSE RELATIONSHIP FOR 11 WILDLIFE SPECIES MEASURED AT ARANSAS, TEXAS WILDLIFE REFUGE.



C. Questionnaire

As previously stated 312 questionnaires were mailed out and 272 returned for a return rate of 87%. Figure 14 illustrates for each occupation the percentage of those responding to the questionnaire. The largest number of responses were received from refuge managers (33% of 272 = 90), the smallest from National Park Superintendents (10% of 272 = 27), with 30% of the respondents being postmasters, and the remaining 27% forestry service employees. Also shown in Figure 14 (by the shaded area within each occupation) is the relative number of total respondents that answered positively either of the questions asking if helicopter noise was a problem. For example, of the 33% of the total respondents that were refuge managers, over half (actually 54%), indicated that helicopter noise was a problem for them or for someone else in their area. On the other hand, a very small percentage (only 3%) of the postmasters replied affirmatively. Of the 272 questionnaires received, a total of 99 (only 36%), represented by the sum of the shaded areas in Figure 14, either had a helicopter noise problem, knew of someone in their area that had such a problem, or both. Clearly, the majority were not bothered by helicopter noise, and did not know of those in their area who were.

Figure 15 illustrates the distribution, by occupation, of the 36% minority responding positively to the question regarding helicopter noise being a problem. Most positive responses came from refuge managers (54% of 99 = 53), while the smallest number (3% of 99 = 3) were received from postmasters. The remaining 43% came from Forestry Service Employees (25%) and from National Park Superintendents (18%).

Figure 16 is a copy of the questionnaire with the percentage of respondents inserted in the answer blanks; major results were as follows:

Question I (Has helicopter noise every bothered you?) was answered positively by 32% of the 272 respondents, while Question II (Does it bother others?) was answered positively by 29% (68% of the 99 having positive responses answered positively to both questions I and II).

In Sections A and B, the number inserted in the answer blocks represents the percentage of those responding in the indicated way. For example, Question 1 of Section A could be answered in any one of five ways. Of the 32% of the total 272 indicating that helicopter noise had caused a problem for them, 70% lived in a very quiet rural or wilderness area, 13% in a quiet suburban or rural area, 4% in a normal suburban area, 1% in an urban residential area, and 12% in other areas of their own designation. In Question 2, of those who had a helicopter noise problem, 30% said they were "slightly" annoyed, 36% said "somewhat annoyed", and 34% said "very" annoyed. It must be remembered that the percentages listed represent the answers of the minority of respondents, i.e. only those having a helicopter noise problem. On balance, helicopter noise does not appear to be a problem

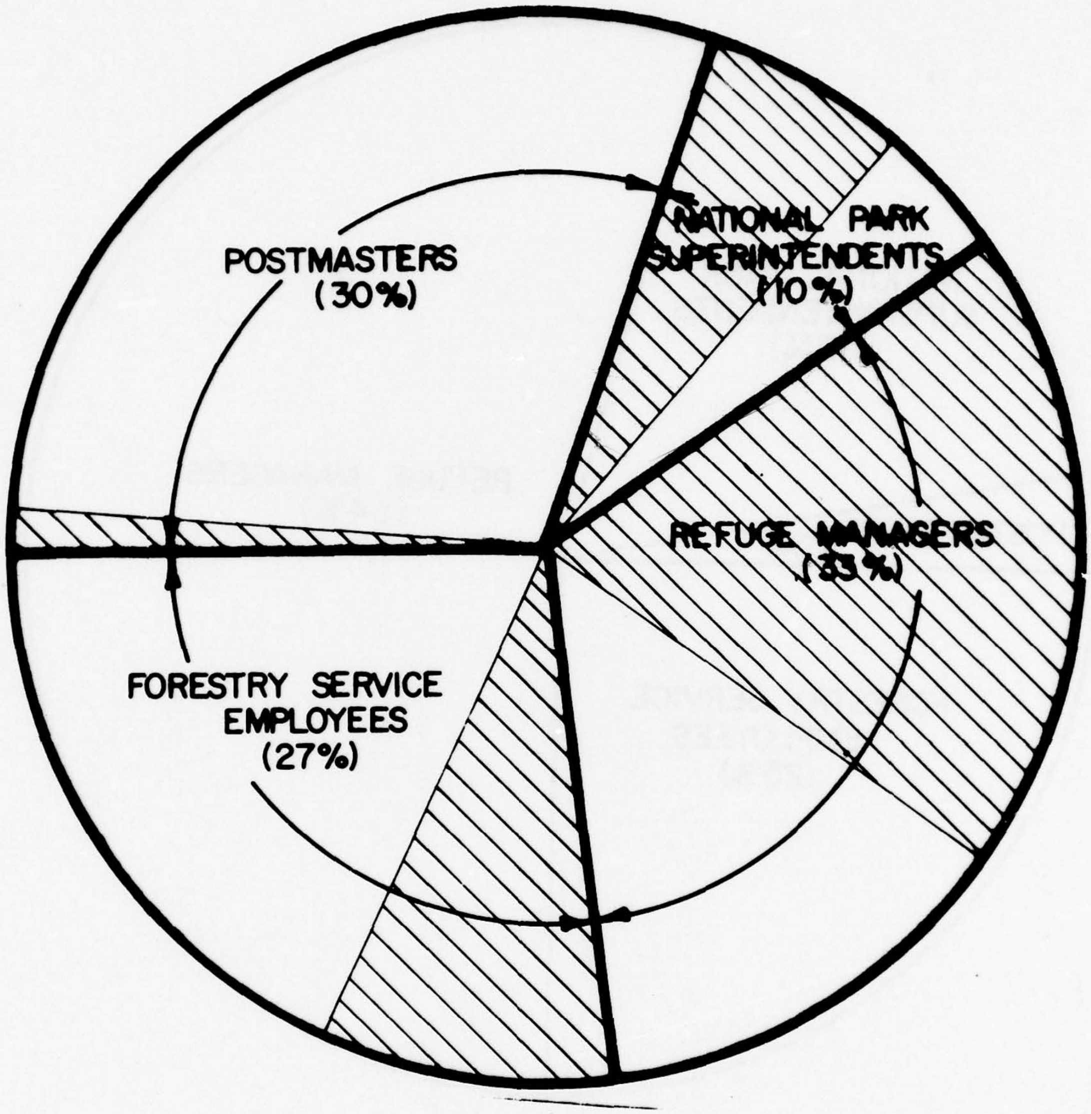


FIGURE 14.

OCCUPATIONS AND DISTRIBUTIONS OF THOSE RESPONDING TO QUESTIONNAIRE (100% = 272 QUESTIONNAIRES). SHADED AREA REPRESENTS, FOR EACH OCCUPATION, THE NUMBER OF POSITIVE RESPONSES TO THE QUESTION REGARDING HELICOPTER NOISE BEING A PROBLEM.

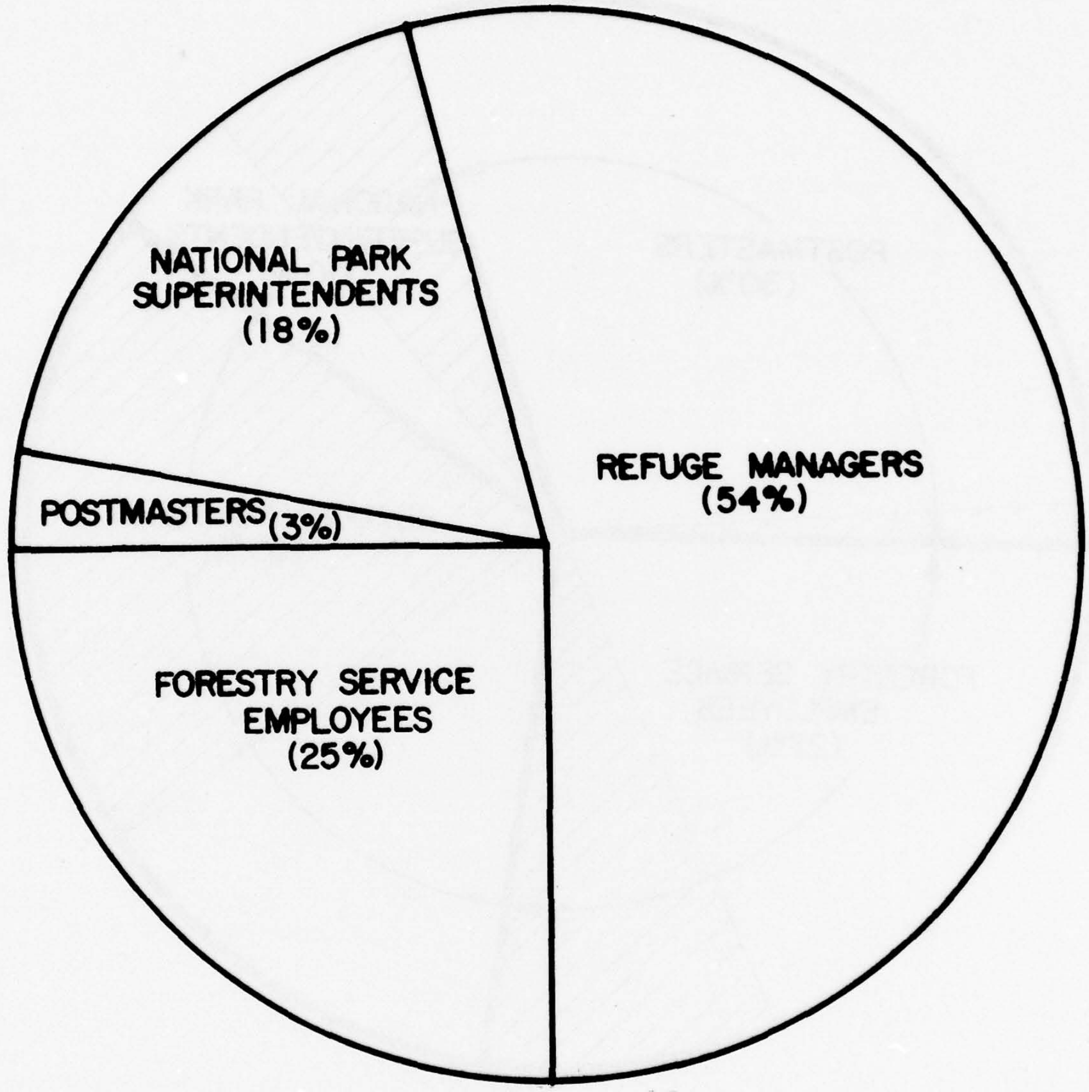


FIGURE 15.

OCCUPATIONS AND DISTRIBUTIONS OF THOSE RESPONDING POSITIVELY TO THE QUESTION REGARDING HELICOPTER NOISE BEING A PROBLEM (100% = 99 QUESTIONNAIRES

MASTER

QUESTIONNAIRE - 100%

The answers to the following questions are sought by the FAA to assess opinions of the impact of helicopter noise. Please answer the questions to the best of your ability:

I. Has helicopter noise ever caused a problem for you, or bothered you in any way?

/32%/ Yes /68%/ No

II. Do you know of anyone else who has commented about or complained of helicopter noise in your area?

/29%/ Yes /71%/ No

If your answers to both Questions I and II were "No", please return the questionnaire in the attached envelope. Thanks for your help!

If one or both of your answers was "Yes", please proceed as follows:

If your response to Question I was "Yes" - please answer the questions in Section A.

If your response to Question II was "Yes" - please answer the questions in Section B.

If your response to Questions I and II were both "Yes" - please answer the questions in both Sections A and B.

FIGURE 16. QUESTIONNAIRE RESULTS.

SECTION A - 32%

Please check the boxes most appropriate to your attitude about helicopter noise.

1. Which of the following best describes the area in which you work:

/70/ very quiet rural or wilderness area

/13/ quiet suburban or rural area remote cities, industry, etc.

/4/ normal suburban, not near industry

/1/ urban residential, not near busy road or industry

/12/ other - specify ____________

2. How much are you annoyed by helicopter noise?

/30/ slightly, just a little /36/ somewhat annoyed /34/ very annoyed

3. Check the appropriate box for each of the following ways in which helicopter noise affects you.

	A Lot, Very Much	Somewhat	Very Little	Not At All	Does Not Apply
A. It frightens people.	/1/	/16/	/30/	/33/	/19/
B. It interferes with rest and relaxation.	/32/	/29/	/26/	/3/	/11/
C. It interferes with the ability to carry on conversations.	/8/	/38/	/28/	/13/	/14/
D. It affects farm crops.	/0/	/1/	/6/	/33/	/60/
E. It affects farm livestock	/7/	/21/	/22/	/7/	/43/
F. It affects hunting and fishing in the area.	/20/	/32/	/20/	/8/	/21/
G. It affects wildlife in the area.	/54/	/27/	/12/	/2/	/5/
H. Other - Specify ____________					

4. On the average, how close to you do helicopters fly?

/38/ very close (500 feet or less) /54/ 500 to 2,000 feet /8/ distant (2,000 feet or more)

5. On the average, how frequently do you hear helicopters?

/72/ 3 or less per week

/10/ 2 - 10 per day

/16/ 1 or 2 per day

/1/ more than 10 per day

6. Have you ever complained about helicopter noise?

/47/ Yes

/53/ No

6A. If the answer to Question 6 is "Yes", to whom did you complain?

____

7. What, in your opinion, is the solution to the problem?

/30/ make them fly higher

/2/ do not fly them at all

/13/ make them fly farther away

/4/ there is no problem, make no change at all

/23/ make them fly elsewhere, not over me

/27/ make the helicopter quieter

8. Do you believe that your attitude about helicopter noise is shared by other people in your area?

/76/ probably yes

/21/ I don't know

/2/ probably no

SECTION B - 29%

Please check the boxes most appropriate to your knowledge of the attitude of others in your area towards helicopter noise.

1. Classify the area in which most of the people live who have complained about helicopter noise.

/55/ very quiet rural or wilderness area

/17/ quiet suburban or rural area remote from cities, industry, etc.

/ 9/ Normal suburban, not near industry

/ 9/ urban residential, not near busy road or industry

/ 9/ other - specify ______________

2. Approximately how many people that you know have complained about helicopter noise?

/49/ between 1 and 5 /30/ between 5 and 20 /20/ more than 20

3. Check the appropriate boxes for each of the ways in which people have stated that helicopter noise affects them.

	A Lot, Very Much	Somewhat	Very Little	Not At All
A. It frightens them.	/ 0/	/18/	/32/	/50/
B. It interferes with their rest, relaxation.	/36/	/44/	/11/	/ 8/
C. It interferes with their ability to carry on a conversation.	/10/	/36/	/34/	/19/
D. It interferes with radio, TV listening.	/ 2/	/22/	/30/	/46/
E. It affects farm crops.	/ 2/	/ 0/	/ 8/	/90/
F. It affects farm livestock.	/10/	/24/	/23/	/44/
G. It affects wildlife in the area.	/46/	/35/	/ 7/	/12/
H. It affects hunting and fishing in the area.	/26/	/35/	/15/	/24/

I. Other effects - specify

____

____

4. Do you believe that the people in your area typically object more to hearing helicopter activity than to seeing them?

/46/ yes, they definitely object more to hearing them than to seeing them

/30/ they probably object more to hearing them than to seeing them

/ 4 / no, they object more to seeing them than to hearing them

/20/ they object to both hearing and seeing them

/ 0/ don't know

5. Do you believe that the people in your area who complain about helicopter noise are aware of the beneficial effect of helicopters, (e.g., forest management, fire fighting, aid to injured people, a tool in law enforcement, etc.)?

/83/ yes, I believe they understand this

/ 6/ I don't know

/11/ no, I don't beieve they are aware of this

6. Would you say that the overall attitude of the people in your area about helicopters is

/40/ positive /26/ indifferent /13/ negative /21/ I don't know about their overall attitude

7. Do the people who complain about helicopter noise believe that the noise affects the value of their property?

/16/ yes, they do /45/ I don't know /39/ no, they do not

8. Do you believe that the people in your area would like to see something done about the helicopter noise?

/33/ yes, definitely they would

/47/ possibly

/ 1/ definitely not

/18/ they are probably indifferent, I don't think it matters to them

Please enclose this questionnaire in the return envelope and mail. Thank you for your participation.

for the majority of respondents, but it is a problem for park and wildlife interests in the most remote areas.

The following paragraphs summarize the detailed results of the questionnaire. Percentages superscripted with an asterisk are statistically significant answers.

Positive answers to Questions I and/or II (36% of respondents responded positively to these questions).

Section A**

1. 70%* work in a "very quiet rural or wilderness area".

2. Respondents were about evenly divided as to "how much bothered by helicopter noise" - slightly 30%, somewhat 36%, very 34%.

3. Helicopter noise affects people as follows:

a. Most are frightened very little (30%*) or not at all (33%*).

b. 32%*suffer "very much" interference with rest and relaxation.

c. 38%*suffer "only somewhat" from interference with conversations.

d. 33%*do not judge that helicopters affect farm crops.

e. Results on the question regarding the effect on livestock were indeterminate.

f. 32%*suffered "somewhat" from effects on hunting and fishing.

g. 54%*judged "very much" of an effect on wildlife.

4. Most helicopters were judged to fly between 500 and 2,000 feet (54%*). Significantly fewer (8%*) said they did fly farther than 2,000 feet.

5. Most (72%*) hear 3 or less helicopters per week. Significantly fewer(1%*)reported hearing more than 10 per day.

** Percentages reflect the portion of positive responses; for example, 70% of those who answered "yes" to Question I and/or II work in "very quiet, rural or wilderness areas".

6. Respondents were about evenly divided in reporting that they had complained about helicopter noise.

7. Regarding a solution to the problem, most (96%*) respondents (by responding to this section of the Questionnaire) agreed that helicopter noise does create a problem. A significant proportion of these indicated they believed the solution was "to make them fly higher" (30%*) or "make them quieter" (27%*). Only 2%* said "do not fly them at all".

8. 76%* thought their attitude about helicopter noise was shared by others in the area.

Section B

1. Most people who respondents had known to complain about helicopter noise lived in a "very quiet rural or wildernesss area" (55%*).

2. 49%* of respondents knew between one and five persons who complained.

3. Respondents believe other people were affected by helicopter noise as follows:

a. 50% were not frightened.

b. It interferes with rest and relaxation very much (36%*).

c. It interferes with conversation only somewhat (36%*).

d. It does not interfere with radio or television (46%*).

e.-f. It does not affect farm crops (90%*) or livestock (49%*).

g. It interferes with wildlife very much (46%*).

h. It does not significantly affect hunting and fishing.

4. People were believed to object more (76%*) to hearing helicopters than to seeing them.

5. Most people (83%*) are believed to be aware of the beneficial uses of helicopters.

6. The overall attitude of the people toward helicopters is believed to be decidedly positive (40%*).

7. The people are believed not to know (45%*) if helicopter noise affects their property.

8. Few respondents reported that people would like to see "nothing done" about helicopter noise (1%*). However, they do not feel that all would like to see something done. Most (46%*) replied that "possibly" complainants would like to see something done.

A public questionnaire related to proposed military helicopter training activity (nap-of-the-earth-type) over a 2,500 square mile area was conducted by the authors in 1974 (4). Since a portion of the questionnaire was concerned with helicoper noise impact, and since this type of data is relatively scarce. The following comments summarize several appropriate comparisons between the 2 studies:

1. The respondents in the current study (FAA) lived mostly in "very quiet rural or wilderness areas", whereas those from the military study (MS) lived mostly in "quiet suburban or rural areas". It would be concluded that the FAA respondents lived in more remote areas than did the MS respondents.

2. Those questioned in the FAA study "didn't know if helicopter activity affects property values", while those in the MS said "helicopter activity defintely does <u>not</u> affect property values".

3. The FAA study found that farm crops were "not at all" affected by helicopter activity, and so did the MS.

4. In the FAA study, livestock was perceived as not being affected, while the MS respondents had no definite opinion on this.

5. The FAA respondents concluded that helicopter noise affects rest and relaxation "quite a bit", while those from the MS found, to the contrary, that there was no affect on rest and relaxation.

6. Hunting and fishing were believed affected by helicopter noise "somewhat" in the FAA study, but "not at all" in the MS.

IV. DISCUSSION

The results of this study indicate that except near heliports, average noise levels from both the present civil helicopter fleet and those from an assumed 10 dBA louder fleet fall within the range of levels identified by the EPA criteria for annoyance as that which should not adversely impact man. However, more than a third of those individuals responding to the survey indicated a helicopter noise problem. The data from both the present investigation and prior related studies are insufficient to allow a definitive evaluation of the impact on wildlife, although indications are that present levels of helicopter noise may impact many species, some quiet strongly, and that increased emission levels would likely affect additional species.

Apart from the animal question, one major adverse environmental impact of present and proposed louder helicopter noise levels appears to be at locations close by heliports. Once away from the heliport, there appears little evidence that the normal dispersion of flight patterns would be characterized by noise levels that would affect man's normal outdoor activities. It is important to realize, however, that areas such as parks, wildlife refuge areas, certain animal farms (turkey, chicken, etc.), are presently impacted by the presence of even a single helicopter event. This point was dramatically illustrated in the questionnaire results where 64% of the National Park Superintendents reported a helicopter noise problem. It would seem advisable that for such noise sensitive areas, helicopter overflights should simply be prohibited, since there appears to be little hope that technology will ever advance to the point where a helicopter's acoustic signature would not degrade the "wilderness experience" one seeks at a National Park, at a wildlife refuge, or similar environs where quietness is one of the key ingredients of an enjoyable visit.

Since this study collected data on present environmental noise levels from the heaviest helicopter activity in the U.S., the results herein may be considered to be on the conservative side, i.e., one would certainly expect much less impact in areas of lesser helicopter densities. In fact, a Kentucky environmental noise study just completed (5) showed that, for Kentucky, there was 1/14 of a helicopter event per hour compared to the 10 per hour average recorded from overflights along the Gulf Coast. Thus, on average, the Gulf Coast area had greater helicopter activity than Kentucky by a factor of 140.

The criteria used in this study to define the noise limits for annoyance and hearing loss are those set forth in the EPA "Levels Document" (22). That document identified levels of 55 and 70 dBA as maximum 24 hour average levels to avoid noise annoyance and hearing loss, respectively, with an adequate margin of safety. These criteria do not, however, consider the effect that background (ambient) noise might have upon the annoyance limit. For example, recurring helicopter activity that in and of itself produced an $Leq_{(24)}$ of 53 dB(A) might be expected to produce little, if any, annoyance to man if the background noise level was somewhere close, say greater than 45 dB(A), to the 53 dB(A) of the helicopter. On the other hand, if the background noise was substantially less, the helicopter noise might be perceived as much more instrusive and annoying. This could, in part, account for the fact that even though the average noise level produced by helicopters flying overhead was found to be only 51.8 dB(A), 34% of those responding to the questionnaire indicated that helicopter noise was a problem for them. Unfortunately, the scope of the present investigation did not permit a definitive study of these types of interactions between noise sources (helicopters) and the existing background, or ambient, noise levels.

Data of the present study do not refute the HAA's proposed establishment of one maximum helicopter noise level for densely populated areas and a second, increased level for "sparsely" populated areas so long as the following are observed:

1. The "sparsely populated area " restriction should also be supplemented, for purposes of this consideration, by a "high ambient noise" restriction, that is,one based upon ambient noise level rather than human population density, e.g. certain noisy areas might have $Leq_{(24)}$'s exceeding 70-clearly a hazardous level, high enough to even induce hearing loss. For such an area, any additional noise contribution should be avoided, even from those helicopters certificated for the "densely populated" area, which means that such a helicopter would necessarily have to, of itself, produce an $Leq_{(24)}$ of at least 10dBA less than the ambient level in order to contribute less than one half decibel to the existing level. It has been from this type of setting, i.e. in "densely" populated urban areas, where many of the complaints and problems associated with helicopter noise have arisen. Busy heliports located in "downtown" areas having narrow approach and departure corridors have given rise to complaints and even litigation from adjacent residences and businesses. As pointed out by Spector (17), by 1985 it is estimated that half of all helicopter operations will be "urban operations". Thus, the most pressing need for helicopter noise control, either by source reduction, by operational parameters, or, preferably, by both, would certainly appear to be associated with areas nearby heliports, particularly urban heliports because of their increased potential for impacting man.

2. Moreover, the term "sparsely populated" should be understood to exclude parks, wildlife refuges, and other "quiet resources". Such areas should be "off limits" to any helicopter exceeding FAA proposed limits; and further study may suggest that existing helicopter activity in these areas should be reduced, except where specific permission is given by the area impacted.

V. Conclusions.

The data of this study, together with those from appropriate prior studies, lead to the following conclusions:

1. On a 24-hour basis, present helicopter "flyover" activity (i.e., that which is not adjacent to heliports) only increases ambient noise levels ($Leq_{(24)}$) by an average of 1.1 dBA. These data were recorded from selected locations in the state having the highest "helicopter density," some five times greater than the national average, where the average $Leq_{(24)}$ including the helicopter noise was 51.8 dB(A), some 3.2 dB(A) below the 55 dB(A) annoyance limit suggested by the EPA to protect health and welfare with an adequate margin of safety.

2. If all helicopter noise emissions were suddenly increased 10 dB(A)*, then the heaviest flyover activity (away from heliports) would result in an $Leq_{(24)}$ of 57.0 dB(A), an increase above ambient of 6.3 dB(A). Since this is only 2 dB above the EPA's 55 dB(A) annoyance limit (which includes a margin of safety) and since it is for the extreme condition, i.e., for all helicopters and for locations of maximum U.S. helicopter density, it is concluded that such an increased emission level may have only a marginal impact on man.

3. If, in addition to the 10 dBA increased noise emission, there were a doubling in the number of flyover events, the resulting $Leq_{(24)}$ is predicted to be 59.5 dB(A), a level that would likely begin to adversely impact man. As indicated by the EPA (22), this level would be at the threshold between "no" community reaction and "complaints and threats of legal action."

4. Adjacent to heliports and narrow corridors for take-off and landing activity, the existing energy averaged sound level was found to be 12.8 dB(A) greater than ambient, at an average level for 24 hours of 61.3 dB(A). Such a level would be expected to begin to invoke "complaints and threats of legal action" from the community, to "highly annoy" approximately 30% of the populace so exposed, to reduce property value, and would result in "increasing" relative importance of aircraft as a factor causing people to dislike their area or want to move (from EPA's "Levels Document" Figure D-16, Reference 22).

5. An increase in the present helicopters' noise emissions of 10 dBA would jump the $Leq_{(24)}$ adjacent to heliports and narrow take-off and landing corridors to 71.2 dBA, a level high enough to cause possible hearing loss to those continuously exposed. In addition, this level would result in "Vigorous" community reaction, would "highly annoy" approximately 50% of those exposed, and would rank as being of the "most" relative importance as a factor causing people to dislike their area or want to move (22).

*A "worst-case" situation should "remote area helicopters" be permitted an exemption on noise emission controls.

6. Quantitative data are, at present, insufficient to permit definitive assessments of the effects on animals of either current or projected helicopter noise levels. Limited data from the present study indicate that over half the species did not alter their observable responses as a function of helicopter noise intensity. Some animals, for example geese and alligators, appeared very sensitive to helicopter noise, while others, such as turkey vultures, horses, and great egrets, showed little or no response to even the highest noise levels produced by flyovers at 100' altitude. It appears safe to say that most wildlife would be aware of, and therefore possibly adversely impacted by, present noise levels produced by helicopter overflights, and that more species would be involved at elevated noise emission levels. It should be particularly noted that the range of $Leq_{(1)}$ for helicopter flyovers was from 49.8 to 60.0 dBA, with the average being 54.5 dBA. In his discussion of the interaction between wildlife and noise produced by electric power transmission equipment, Ellis (11) concludes:

> *"...it appears that many wildlife species are not disturbed by transmission line audible noise of up to 60 dBA. The temporal pattern of noise is as important as the volume. A person breaking a stick or clapping his hands may frighten nearby deer or elk, when a relatively constant noise of this same volume would produce no response in the same animals."*

Thus the 54.5 dB(A) average level recorded in the present study might present no problem whatever to many wildlife species if the noise were non-time-varying, but because it is not, and because of the intrusive nature of the aperiodic helicopter noise event, such a conclusion cannot be made.

7. The effect on wildlife of helicopter noise around heliports would appear to be, for existing heliports, a moot point. Certainly most noise-sensitive wildlife would choose **not to** live near heliport locations, largely because of the usual presence there of human activity. In addition, it is known that certain species can readily adapt to such unusual environments, as was the case with some birds, presumably coots, observed in the present study in a pond adjacent to the heliport at Intercoastal City, Louisiana. Here, during three hours of observation, 46 helicopter events were recorded to which little heed was paid by them as they swam about the pond. It appears equally clear, however, that new heliports should not be sited near wildlife refuges or other noise-sensitive areas.

8. Sixty-four percent of those participating in the questionnaire replied that helicopter noise was not a problem for them or for anyone they knew in their area. Twelve percent said they were bothered "very much" by helicopter noise. Since these questionnaires were sent only to areas of high helicopter densities, it is concluded that helicopter noise is not a problem for the majority of people.

9. Questions 3E and 3G of the questionnaire related directly to the effects of helicopter noise on animals. Among the 36% minority responding that they had a helicopter noise problem, there was no significant consensus

of opinion relative to farm livestock*, but a significant 54% said helicopter noise affects wildlife"very much", while another 27% answered "somewhat". Thus a strong majority (81%) of the respondents believed that present levels of helicopter noise affect wildlife either "somewhat" or "a lot, very much".

10. That the answers received were dependent upon the occupation and/or living area of the respondent was clearly demonstrated when 64% of the National Park Superintendents responded that helicopter noise was a problem, while only 4% of the postmasters answered affirmatively.

11. Most people hear less than 1 helicopter per day. Even in the heavy helicopter activity regions, most (72%) of those having a helicopter noise problem said they heard 3 or fewer helicopters per week! Only 1% of those with a helicopter noise problem reported hearing more than ten per day.

12. A comparison of the data from the questionnaire of the present study, where most respondents lived in a "very quiet or wilderness" area, with that from a prior study, where respondents lived in a "quiet rural or suburban areas", shows that those living in the wilderness area thought helicopter noise affected rest and relaxation "quite a bit" and hunting and fishing "somewhat", while the suburban respondent thought these activities were not at all affected by helicopter noise. Therefore, helicopters appear to be more of a problem in the most remote areas, especially where parks or wildlife may be affected.

*In the previous study at Fort Campbell, there were a few strong complaints about helicopter flights over such noise-sensitive, commercially raised animals as mink and turkeys.

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APPENDIX A

Summary of Questionnaire Findings

General

Due to governmental restrictions concerning sampling, this survey was taken from a limited group of people, government employees. It is possible that the data contained herein are biased in this regard.

Government employees sampled were postmasters, national park superintendents, wildlife refuge managers, and forestry service employees.

Taken together, a significant proportion of the respondents reported that they are not bothered by helicopter noise (hcn) and that they did not know of anybody who is (x^2 = 214.36)*. Correspondingly, significantly fewer of the respondents reported "yes", that they are bothered by hcn (x^2 = 53.59).

When analyzed by job, the above conclusion was true for postmasters (x^2 = 227.57) and for forestry workers (x^2 = 14.02). Wildlife refuge managers, on the other hand, showed slightly (but non-significantly) more "yes I was bothered by helicopters" responses, (51 yes, 30 no). National park superintendents reported "yes, I am bothered by hcn" significantly more than they said no (x^2 = 23.04).

Questionnaire A - Filled out by those who reported "yes, I am bothered by helicopter noise."

1. Most respondents live in a wilderness area (x^2 = 157.71).
2. The degree to which they are bothered ranged from "slightly" to "very annoyed" with no significant preference for either category.

3. The ways in which helicopter noise affects people are as follows:

It affects rest and relaxation "very much"	(x^2 = 6.03)
It affects wildlife in the area "very much"	(x^2 = 59.17)
It interferes with conversation only "somewhat"	(x^2 = 13.78)
It affects hunting and fishing in the area "somewhat"	(x^2 = 6.36)

Helicopter noise was judged to frighten people "not at all" (x^2 = 7.663) or "very little" (x^2 = 4.699). It affects farm crops "not at all" (x^2 = 6.890) and no relationship was in evidence between helicopter noise and farm livestock (x^2 = 22.29).

4. Most helicopters were judged to fly between 500 feet and 2000 feet away (x^2 = 17.70) at less than 500 feet (x^2 = 6.35). (From the answers, I would

* x^2 = Chi-Square. A statistic used to assess frequency data. All values reported here are statistically significant. Critical values of x^2 are: for .50 level 3.841 (for 1 df), 5.991 (for 2 df), 7.815 (for 3 df), and 9.488 (for 4 df).

guess they fly around 500 feet). However, significantly fewer fly more than 2000 feet away.

5. Most respondents hear relatively few helicopters, 3 or less per week (x^2 = 101.72) while significantly fewer report that more than 10/day are heard (x^2 = 26.06).

6. Responses are about equally split as to whether they have complained about helicopter noise (38 yes, 43 no, $x^2 < 1.0$ nonsignificant).

7. Regarding a solution to the problem, most respondents do agree that helicopter noise does create a noise problem (x^2 = 14.25). A significant proportion indicated that the solution was to "make them fly higher" (x^2 = 15.49) or "make the helicopters quieter" (x^2 = 10.32).

8. Most of the respondents believed that their attitude about helicopter noise is shared by others in their area (x^2 = 71.27).

Section B - Attitudes of Others in Your Area

1. Most people in the area live in a rural or wilderness area (x^2 = 73.77). Significantly fewer live in urban residential (x^2 = 7.16) or normal suberban (x^2 = 7.16).

2. Respondents report that they know between 1 and 5 people who have complained about helicopter noise (x^2 = 9.12). (This is possibly due to the relatively desolate area in which they live.)

3. The ways in which people have been affected by helicopter noise were as follows:

(a) It interferes with rest and relaxation "very much" (x^2 = 4.75) and only "somewhat", however there was no significant (x^2 = 14.25) difference between these alternatives.

(b) It interferes with wildlife in the area "very much". (x^2 = 17.32) Very few believe that wildlife is unaffected. (x^2 = 6.87)

(c) It interferes with conversation only "somewhat". (x^2 = 4.18) (The above are all consistent with Part A.)

(d) Helicopter noise was judged to frustrate people "not at all". (x^2 = 33.0)

(e) Neither does it affect farm crops or farm livestock at all. (x^2 = 43.94) (x^2 = 11.37)

(f) There was no consistent feeling about how helicopter noise affects hunting and fishing in the area. No significant preference for any one response category employed.

4. The noise that helicopters produce is more aversive than the visual aspects of the aircraft. People seem to object more to <u>hearing</u> hcn noise than to <u>seeing them</u> (x^2 = 32.26).

5. Respondents believe that people in the area are aware of the potentially beneficial effects of helicopters. The overall attitude is decidedly positive (x^2 = 9.16) despite the aversive qualities of the noise involved.

6. They "do not know" whether helicopter noise affects the value of their property (x^2 = 4.45).

8. Few respondents reported that people would like to see "nothing done about helicopter noise" (x^2 = 23.40). However, they do not feel that all would like to see something done. Most replied that "possibly" complaintents would like to see something done (x^2 = 20.93).

APPENDIX A - 2

Summary of Comparison Between the Fort Campbell Military Survey (MS) and the FAA Survey

1. At the outset, it should be noted that the data come from two entirely different groups of people. This is not simply a geographical distinction, but perhaps an attitudinal one as well. The FAA survey contains data only from individuals who judged helicopter noise to be aversive. The MS survey, on the other hand, probably represents a more random sample since no preliminary screening process was in effect when the data were collected. Also, it should be mentioned that many of the MS survey respondents included people who work at Fort Campbell, Kentucky. This may have colored their responses. Finally, the MS was taken several years ago. Perhaps helicopter activity has increased since that time. Any or all of these obvious differences may account for any discrepancies betwene the two sets of data. Also, the data collection methods were different, i.e. the FAA survey was done by mail, the MS by interviews.

2. With the above distinctions in mind, two sets of comparisons were made between the responses to the two instruments: First, the surveys were compared directly on items which they shared; i.e., on items which appeared in virtually an identical way in both instruments. Second, they were compared indirectly with respect to answers given to similar items. It was thought that this category might enable the assessment of general attitudes, which because of the differences in wording of specifications involved, were not attainable by direct statistical comparisons.

Direct Comparison

1. Both surveys contained questions regarding the area in which the respondents live. A significant proportion of the FAA survey came from "very quiet rural or wilderness areas" ($x^2 = 157.71$). The majority of the FTC input came from "quiet suburban or rural areas" ($x^2 = 10.88$). While there is some overlap in these two categories it seems likely that the two samples were drawn from essentially different environments.

2. "Does helicopter activity affect the value of your property?" The two sets of data are not distributed the same way. The MS survey reports that helicopter definitely do not affect property values ($x^2 = 232.5$) while the FAA respondents are less certain and reply that they "don't know" if property values are affected ($x^2 = 4.45$).

3. "Does helicopter noise affect farm crops?" The overall x^2 comparing FAA and MS responses to this question was non-significant. This indicates that the distribution of responses was not different. Therefore, we can conclude that the findings were similar regarding this question. Both report that helicopter noise affects farm crops "not at all" ($x^2 = 60.29$ for MS data, $x^2 = 6.89$ for FAA).

4. "Does helicopter noise affect farm livestock?" The overall x^2 was significant for this item, indicates that the two groups responded differently to the question. The FAA respondents reported that helicopter noise affects livestock "not at all" (x^2 = 22.29), where the MS survey indicates no significant preference for any of the answer categories, i.e., they had no opinion.

5. "Does helicopter noise affect personal rest and relaxation?" The comparison test indicates that the two surveys were very different on the question (x^2 = 77.33). The FAA respondents answered that helicopter noise affects their rest and relaxation "quite a bit" (x^2 = 6.03) while the MS respondents reported that helicopter noise does not affect rest and relaxation at all (x^2 = 33.95).

6. "Does helicopter noise affect hunting and fishing in the area?" Responses on this question were again significantly different (x^2 = 57.60). the FAA data shows that helicopter noise affects hunting and fishing "somewhat" (x^2 = 6.36), while the MS survey indicates that hunting and fishing is affected "not at all" (x^2 = 29.07).

Related Items

1. FAA data and FTC data agree that helicopter noise does not affect farm crops. In addition, the MS survey contained a question about flight over farm land. The respondents were asked to rate how they felt about this. The overwhelming report was that flight "does not matter" regarding farm activity (x^2 = 176.60). Thus, the two are consistent on the issue.

2. The FAA study revealed that despite the fact helicopter noise is aversive, the overall attitude about helicopters is positive; i.e., they understand about the potentially beneficial effects of helicopters.

The MS survey included a related item: "What about your attitude about the use of helicopters for medical evacuations, rescue, traffic safety, etc." The MS respondents also indicated an overwhelming positive attitude about the beneficial effects of helicopters, (x^2 = 378.73).

3. The FAA survey included an item which asked whether people object more to seeing or to hearing the helicopter activity. The response was that it is the auditory impact of helicopters that contributes to their averseness; people did not seem toobject to seeing helicopters.

4. The MS survey included a related item "Would you object to seeing helicopters?" The analysis concluded quite sharply that the respondents did not object to seeing helicopters. The MS and the FAA data are in agreement on this point.