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TECHNICAL BACKGROUND: INTERIM CRITERIA FOR PLANNING ROTARY-WING--ETC(
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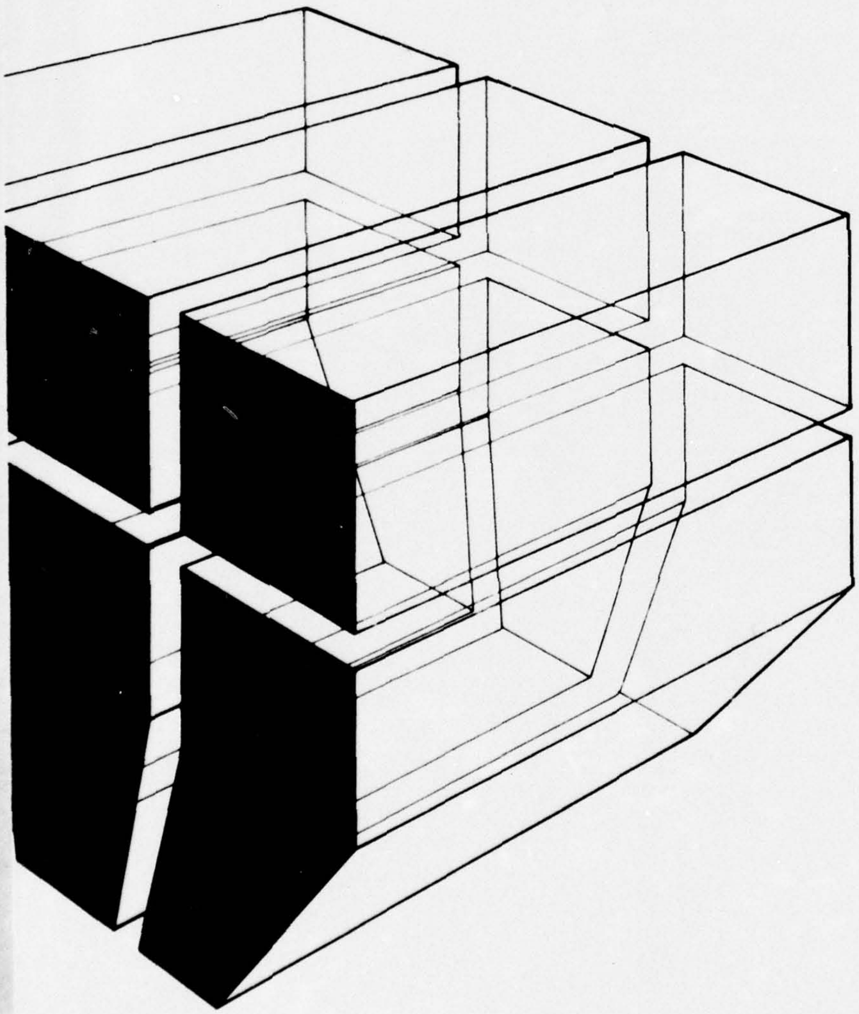
INTERIM REPORT N-9
September 1976
Prediction and Reduction of the Noise Impact Within and Adjacent to Army Facilities

TECHNICAL BACKGROUND: INTERIM CRITERIA FOR PLANNING ROTARY-WING AIRCRAFT TRAFFIC PATTERNS AND SITING NOISE-SENSITIVE LAND USES



by
P. D. Schomer
B. L. Homans

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This report presents interim criteria for locating rotary-wing aircraft traffic patterns and ingress and egress corridors into an airfield/heliport to avoid conflict with noise-sensitive land uses, and provides criteria for planners to site noise-sensitive land uses with respect to the established airfield/heliport and established flight corridors. These interim criteria are required because the "exact" Air Force technique for pre- (over)

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) dicting fixed-wing aircraft noise cannot currently be used due to the unpredictability of helicopter flight patterns; these criteria are the basis for interim procedures established in a companion report, *User Manual: Interim Procedure for Planning Rotary-Wing Aircraft Traffic Patterns and Siting Noise-Sensitive Land Uses* (Construction Engineering Research Laboratory Interim Report N-10, 1976).

FOREWORD

This research was conducted for the Directorate of Military Construction, Office of the Chief of Engineers (OCE), under Project 4A762720A896, "Environmental Quality for Construction and Operation of Military Facilities"; Task 02, "Pollution Control Technology"; Work Unit 008, "Prediction and Reduction of the Noise Impact Within and Adjacent to Army Facilities." The QCR number is 1.03.011.

Mr. F. P. Beck is the OCE Technical Monitor. Guidance was provided by Mr. J. L. Halligan of OCE.

This study was conducted by the Acoustics Team (Dr. P. D. Schomer, Acting Chief) of the Environmental Division (Dr. R. K. Jain, Chief), U.S. Army Construction Engineering Research Laboratory (CERL).

COL J. E. Hays is Commander and Director of CERL and Dr. L. R. Shaffer is Deputy Director.

CONTENTS

TECHNICAL BACKGROUND: INTERIM CRITERIA FOR PLANNING ROTARY-WING AIRCRAFT TRAFFIC PATTERNS AND SITING NOISE-SENSITIVE LAND USES

1 INTRODUCTION

Background

Urban development has been encroaching on military and civilian airfields in recent years. In particular, residential development has been occurring in areas subject to high noise levels which emanate from aircraft and airfield operations. The Army has an obligation to protect the well-being and safety of persons and property in Army airfield environments, as well as to use public funds judiciously in constructing facilities near airfields.

Since the prediction of rotary-wing aircraft noise impact is still under development, criteria which permit easy interpretation of existing published guidelines are needed. The *Construction Criteria Manual*[1] and the *Air Installations Compatible Use Zones*[2] are two Department of Defense (DOD) documents that define land-use restrictions. Both documents describe three zones which impose varying degrees of restriction on land use in order to insure its compatibility with the characteristics of Army operations.

The reason an exact prediction technique for rotary-wing aircraft noise does not exist is the unpredictable nature of helicopter flight. Unlike fixed-wing aircraft, helicopters are able to make tight turns and execute sharp maneuvers. Training procedures demand that helicopter pilots be proficient in this flexible form of flight. Fixed-wing aircraft, conversely, have more limited maneuverability; thus a straightforward methodology, such as that of the Air Force,[3] can be used in predicting noise impact. The Air Force procedure uses distinct flight paths and other operational information to predict noise impact; it has been found that this system does not work for rotary-wing aircraft because of the impossibility of defining flight paths with current records.

These problems notwithstanding, compatibility between land use and noise impact must be achieved to safeguard facilities' operational capabilities while providing satisfactory on- and off-post living environments. Installation master planners and airfield operations personnel must join forces to achieve this result.

Purpose

The purposes of this report are (1) to establish interim criteria for locating rotary-wing aircraft traffic patterns and ingress and egress corridors into an airfield/heliport to avoid conflict with noise-sensitive land uses, and (2) to provide criteria for planners to site noise-sensitive land uses with respect to the established airfield and flight corridor plan. The operations plan (the zones and corridors) established from these criteria will define the "noisy" and "quiet" areas to insure compatible development and future unimpeded airfield capability. This report provides the technical background for the planning manual entitled *User Manual: Interim Procedure for Planning Rotary-Wing Aircraft Traffic Patterns and Siting Noise-Sensitive Land Uses.*[4]

2 TECHNICAL BACKGROUND AND APPROACH

Measures of Noise Impact

Two measures of noise impact commonly used for aircraft noise are Noise Exposure Forecast and Day-Night Equivalent Level.

The Noise Exposure Forecast (NEF) uses Effective Perceived Noise Level (EPNL) as its basic noise measure for aircraft flyovers. EPNL and the number of operations during the day (0700 to 2200 hrs) and night (2200 to 0700 hrs) provide the information necessary to determine NEF at some specified location. As the number of events increases, NEF becomes larger.

Tables and graphs which show EPNL versus distance and allow easy determination of NEF for known aircraft types are available for fixed-wing aircraft but, due to the present state of helicopter prediction, not for rotary-wing aircraft.

[1] *Construction Criteria Manual*, DOD 4270.1-M (Department of Defense).

[2] *Air Installations Compatible Use Zones*, DOD Instruction 4165-57 (Department of Defense).

[3] R. D. Horonjeff, et al., *Community Noise Exposure Resulting From Aircraft Operations: Computer Program Description*, Report AD/A-004821 (Bolt, Beranek and Newman [BBN], 1974).

[4] P. D. Schomer and B. L. Homans, *User Manual: Interim Procedure for Planning Rotary-Wing Aircraft Traffic Patterns and Siting Noise-Sensitive Land Uses*, Interim Report N-10 (Construction Engineering Research Laboratory [CERL], 1976).

Because nighttime operations cause greater disturbance than daytime operations, the noise of each night event is penalized in the calculation procedure by 10 dB.[5] That is, for the same average number of aircraft operations per hour during the day and night periods, the NEF value for nighttime operations is 10 dB higher than for daytime operations.[6] Since the concept of NEF was introduced in the 1960s, the calculated NEF values around a given airfield have been lowered in absolute value by subtracting a constant (88) to avoid confusion with other noise measures such as the Composite Noise Rating (CNR) and the Community Noise Equivalent Level (CNEL).

The Day-Night Equivalent Level (L_{dn}) is also a measure of the 24-hour noise environment. L_{dn} uses the energy equivalent concept, which represents a fluctuating noise level in terms of a steady-state noise having the same amount of total energy. The specified time integration period is 24 hours.

In a similar although not absolutely equivalent fashion to NEF, a 10-dB correction is applied in the calculation of L_{dn} to account for the increased annoyance due to noise during the night.[7] The noise level is measured in A-weighted sound pressure level.[8]

The Air Force prediction program contains several items common to all noise prediction models. These considerations or input factors, inherent in any aircraft noise impact prediction, include total number of operations (number of takeoffs and landings), percentage of night operations (between 2200 and 0700 hrs), and fleet mix (the percentage of each type of aircraft in operation). These factors must be estimated before any prediction methodology can be used.

Definitions of Terms

1. AGL—Above Ground Level.

2. Conflict with a noise-sensitive land use—A day-night equivalent level (L_{dn}) in excess of 65. The previous section provides more detail.

3. Ground distance—Distance along the ground measured from the projection of the aircraft on the ground to the observer (Figure 1).

4. Ingress/egress corridors—Approach and departure corridors (and other traffic corridors) where flight altitudes are less than the altitude AGL required to maintain a day-night equivalent level not exceeding 65.

5. L_{AE}—A-weighted Sound Exposure Level.

6. Noise-sensitive area—An area containing one or more of the following: bachelor and family housing, temporary lodging, recreation, welfare and religious facilities designed for the assembly of groups of people, medical facilities, and school buildings.*

7. Operations
   a. In a traffic pattern, an operation is a takeoff or landing.
   b. In a corridor, an operation is a fly-by.
   c. Touch-and-go operations are counted as two operations.

8. Slant distance—The distance measured from the closest edge of the noise-sensitive facility to the center of the flight path (Figure 1).

9. Planning slant distance—The recommended slant distance which would insure that the noise-sensitive facility would not be subjected to an L_{dn} of greater than 65.

10. SEL—Sound Exposure Level is the time integral of the square of the acoustic pressure.

Approach

Originally, Construction Engineering Research Laboratory (CERL) researchers attempted to describe rotary-wing flight by using the computerized Air Force approach; that is, the flight tracks for each aircraft following each flight track were described using straight and curved arc sections. Alti-

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[5] *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare With an Adequate Margin of Safety,* Report 550/9-74-004 (Environmental Protection Agency [EPA], March 1974), pp A26-A28.

[6] K. S. Pearsons, et al., *Handbook of Noise Ratings,* Report N74-23275 (BBN, April 1974), pp 206-207.

[7] *Information on Levels of Environmental Noise,* pp A26-A28.

[8] K. S. Pearsons, et al., pp 224-225.

*This procedure should not preclude siting a school in a noise-sensitive area when the school subject relates directly to the noise source, such as a pilot-training classroom at an airfield. Proper acoustical considerations must be incorporated into the design of the school.

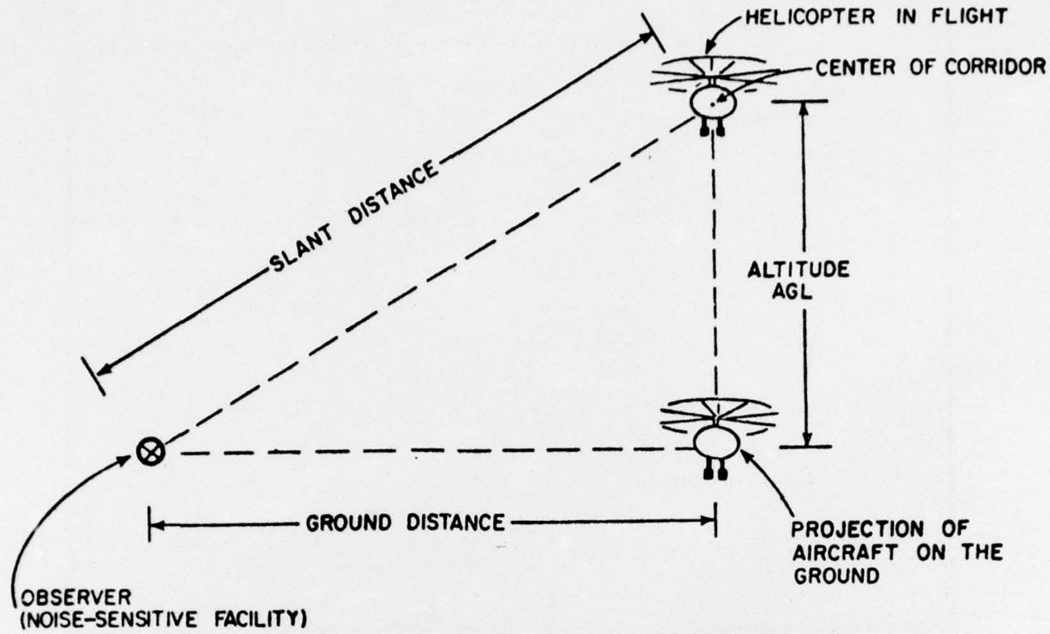

Figure 1. Illustration of the terms "ground distance" and "slant distance."

tude profiles and number of aircraft of each type following each flight track had to be specified.

The difficulty with using this procedure for helicopters was that it was extremely time-consuming. Since helicopters can, and do, fly almost anywhere, specific flight tracks must be defined for each helicopter path. Because of this position variability, a new approach was initiated.

Instead of detailing specific flight paths as in the computerized Air Force prediction procedure, it was decided in this study that distance criteria (based upon resulting L_{dn} and NEF values) for the placement of family housing and other noise-sensitive land uses would be developed from rotary-wing aircraft traffic patterns. These criteria could be easily understood and interpreted with the aid of the DOD documents discussed below.

The DOD *Air Installations Compatible Use Zones* (AICUZ) Instruction describes three zones of noise impact. *Zone 3*, the smallest and loudest, is the area in which the frequency of exposure and intensity are almost certain to produce difficulties in relation to some other possible use of the area, particularly where the use or proposed use is residential. *Zone 2* is a larger area in which similar problems with regard to other uses may occur. *Zone 1*, all land outside Zone 2, is an area in which essentially no such difficulties may be expected. NEF values above 40 are considered to be in Zone 3, values of 30 through 40 in Zone 2, and values below 30 in Zone 1.

The DOD *Construction Criteria Manual* recommends that bachelor and family housing, temporary lodging, recreation, welfare and religious facilities designed for the assembly of groups of people, and medical facilities should be sited in Zone 1. In addition, the Army requests that school facilities also be sited in Zone 1.*

The 15 October 1975 DOD letter, subject: *Air Installations Compatible Use Zone Noise Descriptors*[9] amends the above two documents. The first change is to compute L_{dn} in place of CNR or NEF.

*This procedure should not preclude siting a school in a noise-sensitive area when the school subject relates directly to the noise source, such as a pilot-training classroom at an airfield. Proper acoustical considerations must be incorporated into the design of the school.

[9]P. J. Fliakas, Deputy Assistant Secretary of Defense, Installations and Housing—ID, *Air Installations Compatible Use Zone Noise Descriptors*, letter of 15 October 1975.

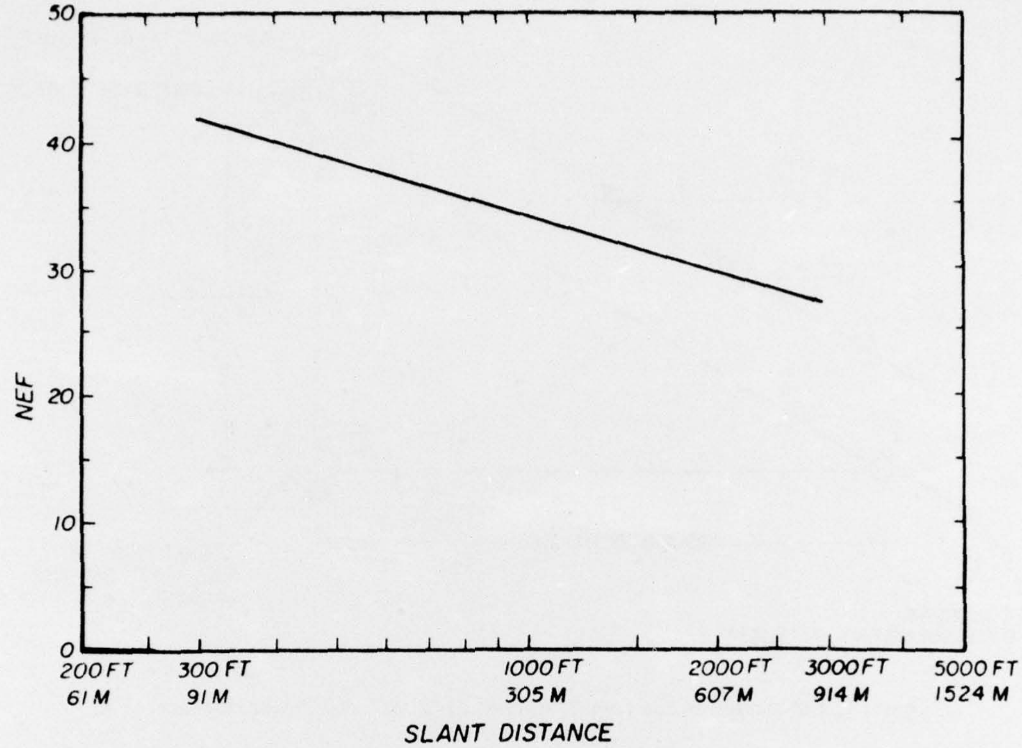

Figure 2. NEF vs slant distance plotted for distances between 300 and 3000 ft (91 and 914 m). The fleet mix is 80 UH-1s, 15 AH-IGs, and 5 CH-47s with 10 percent of operations flown during the night.

The second is a recommended correction of +7 dB to be added to meter readings when helicopter noise levels are measured. Guidelines are given for the interpretation of L_{dn} zones: in excess of 75 L_{dn} is equivalent in impact to CNR Zone 3; the range of 65 L_{dn} to 75 L_{dn} is equivalent to CNR Zone 2; and below 65 L_{dn} is equivalent to CNR Zone 1.

Noise Exposure Forecast (NEF) was calculated for a variety of distances using the maximum Perceived Noise Level (PNL) values* for each aircraft and the time that the signal was high (within 10 dB of the maximum PNL value) at each distance. The approximate EPNL was calculated from the maximum PNL and the effective duration, which was estimated from the total 10-dB down duration. Figure 2 shows a curve of NEF versus distance for 100 aircraft. From the curve, distance values at NEF 40, 35, and 30 were found.

L_{dn} was calculated using level flyover data measured by CERL.* Total Sound Exposure Level (L_{AE}) was calculated from the A-weighted peaks and the time interval to the points 10 dB down from the peak, called duration. L_{dn} was found from L_{AE} and the same operational data used for calculating NEF. As a check between the NEF and L_{dn}, distances were found for L_{dn} values of 75, 70, and 60. The two measures were found to be in close agreement.

Since no standard pattern exists, straight flight was assumed for estimation of time duration. In the traffic pattern, variations occur which can either increase or decrease the duration. It is felt that these factors generally cancel each other.

Appendix A discusses the calculations used in obtaining NEF and L_{dn}.

*Preliminary data for PNL curves were compiled from data from Bolt, Beranek and Newman (BBN), U.S. Army Environmental Hygiene Agency (AEHA), and CERL (CERL data, 1972).

*These data were gathered from detailed measurements in spring 1974 and are unrelated to the PNL data discussed.

Operational Considerations

Operational data used in the calculation of the traffic pattern criteria were for average operations at a typical airfield. Total number of operations, percentage of nighttime operations, and fleet mix were considered as in any prediction methodology. The total number of operations was chosen to be 100 per day. This number was made larger than traffic encountered in the normal pattern to allow for future growth. Table 1 gives NEF and L_{dn} values for greater numbers of operations.

The percentage of nighttime rotary-wing operations was chosen to be 10 percent. Previous experience indicates that this figure accurately describes operations between 2200 and 0700 hrs at the typical airfield. It should be noted that increasing nighttime operations to 20 percent would raise the noise impact by about 2 NEF or L_{dn} units.*

The last of the general considerations—fleet mix—approximates ownership of aircraft by the Army. Since the missions of most airfields are dissimilar, a typical fleet mix was difficult to arrive at. A mix of 80 percent UH-1s, 15 percent AH-1Gs, and 5 percent CH-47s was determined to be sufficient. Changes in this mix, e.g., to 40 percent UH-1s, 40 percent OH-58s, 15 percent AH-1Gs, and 5 percent CH-47s, would affect the noise impact only slightly.

3 DERIVATION OF CRITERIA AND RESULTS

Calculation Procedures

Distance criteria were calculated using both NEF and L_{dn} as cross-checks of each other and of the procedure. Since EPNLs were unavailable for rotary-wing aircraft, PNLs were corrected as explained in Appendix A. Eq 1 was used in the calculation of NEF for each event.

$$NEF_i = \{EPNL_i + 10 \log [N_{di} + 16.67 (N_{ni})]\} - 88 + 7 \qquad \text{[Eq 1]}$$

where $EPNL_i$ = Effective Perceived Noise Level of event i

N = Number of events per day (d) and night (n).

*Changes in nighttime operational levels are considered in Appendix B.

Table 1

Calculated NEF and L_{dn} Values With Corresponding Slant and Planning Slant Distances*

NEF		L_{dn}		
NEF	**Slant Distance**	**L_{dn}**	**Slant Distance**	**Planning Slant Distance**
a. 100 Average Daily Operations				
40	350 ft (107 m)	75	300 ft (91 m)	325 ft (99 m)
35	850 ft (259 m)	70	750 ft (229 m)	800 ft (244 m)
30	1800 ft (549 m)	65	1800 ft (549 m)	1800 ft (549 m)
b. 150 Average Daily Operations				
40	550 ft (183 m)	75	400 ft (122 m)	475 ft (152 m)
35	1100 ft (335 m)	70	1100 ft (335 m)	1100 ft (335 m)
30	2300 ft (701 m)	65	2500 ft (762 m)	2400 ft (732 m)
c. 200 Average Daily Operations				
40	650 ft (198 m)	75	500 ft (152 m)	575 ft (175 m)
35	1300 ft (396 m)	70	1400 ft (427 m)	1350 ft (411 m)
30	2900 ft (884 m)	65	3000 ft (914 m)	2950 ft (899 m)
d. 300 Average Daily Operations**				
40	800 ft (244 m)	75	750 ft (213 m)	775 ft (236 m)
35	1900 ft (579 m)	70	1800 ft (549 m)	1850 ft (564 m)

*Values based on fleet mix of 80 percent UH-1s, 15 percent AH-1Gs, and 5 percent CH-47s per 24-hour period with 10 percent of operations flown at night. Cruise speed is 80 to 90 kt (148 to 167 km/hr).

**This procedure is not intended for extremely large numbers of operations such as 300 or more. CERL should be consulted before applying these criteria in such cases.

The total NEF at a given ground position was determined by summing all the individual NEF_i values on an energy basis, as in Eq 2.

$$NEF = 10 \log \sum_{i=1}^{n} \left(10^{NEF_i/10}\right) \qquad \text{[Eq 2]}$$

A correction factor of +7 dB was added to NEF to account for the relative annoyance of the spectrum of the helicopter and the fact that helicopters are usually turning and/or ascending or descending while in a traffic pattern or an ingress or egress corridor. (Appendix A provides a more detailed explanation.) Various slant distances were tried until NEF values of 40, 35, and 30 were obtained.

L_{dn} was calculated from CERL flyover data for the slant distances that were found to produce NEF values of 40, 35, and 30. The total A-weighted sound exposure level (L$_{AE}$) for each flyover was calculated using

$$L_{AE} = \text{Max} - 4.25 + 10 \log T_o \qquad \text{[Eq 3]}$$

where Max = A-weighted, slow, maximum level for the level flyover

T_o = Duration in seconds between the 10-dB down points from the maximum.

Eq 3 assumes a triangular approximation to the helicopter time history as explained in Appendix A. L_{dn} was calculated using

$$L_{dn} = [\sum_{i=1}^{n} (E_i + 10 \log N_d) + \sum_{i=1}^{n} (E_i + 10 \log N_n + 10)] - 10 \log 86400 + 7 \qquad \text{[Eq 4]}$$

where E_i = L_{AE} for event i

N = Number of events per day (d) and night (n)

86400 = Seconds per 24-hour period.

Appendix B shows sample calculations for NEF and L_{dn}.

Results

Table 1, which summarizes the calculation results for NEF and L_{dn}, shows NEF values of 40, 35, and 30 and L_{dn} values of 75, 70, and 65 with the corresponding distances found from calculations for various numbers of operations. Recommended planning slant distances to be used by planners are shown for the above NEF and L_{dn} values. As an example, it is recommended that an NEF of 35 (L_{dn} of 70) not be exceeded at a proposed building site located 800 ft (244 m) from a helicopter traffic pattern. The choice of these L_{dn} values is based on the AICUZ instruction and the DOD *Construction Criteria Manual* described earlier in this report.

The Environmental Protection Agency (EPA) states that for most environmental noise, NEF and L_{dn} are separated by 35 ±2 dB.[10] The calculated NEF and L_{dn} values therefore closely agree within these limits.

Applicability of Results

Corridors should be created for the anticipated maximum average daily number of operations. Table 1 gives recommended planning distances versus L_{dn} and NEF for 100, 150, 200, and 300 operations per day. It is felt that 100 is the minimum number of operations that should be used for planning purposes when actual daily operations exceed 10. Less than 10 operations per day should be ignored. The lower limit is designed to allow for landing pads at the hospital or base headquarters to be excluded from the planning requirements. This limit notwithstanding, patterns associated with main airfield or heliport operations in the vicinity of the airfield/heliport itself must be assessed.

4 CONCLUSION

The interim criteria presented in this report will closely identify the noise impact areas (those areas with an L_{dn} of 65 or greater) of existing or proposed helicopter traffic corridors and the ingress and egress patterns of airfields, heliports, or frequently used helipads. It is essential that the criteria and guidance presented in this report and its companion report, *User Manual: Interim Procedure for Planning Rotary-Wing Aircraft Traffic Patterns and Siting Noise-Sensitive Land Uses*, be used by the installation commands which support Army aviation activities. Proper master planning of compatible land use areas on and adjacent to the installations depends on adoption of the guidelines and criteria provided in these reports. Excess free land area around an existing airfield or heliport should not be used as an excuse for not implementing these guidelines and criteria.

[10] *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare With an Adequate Margin of Safety*, Report 550/9-74-004 (EPA, March 1974).

APPENDIX A:

DISCUSSION OF CALCULATIONS

NEF

NEF was calculated using PNL data from helicopter overflights. Since EPNL is used in the calculation of NEF, it is necessary to convert maximum PNL and a measure of the duration to an approximation of EPNL.

Assuming a triangular shape of the PNL time history for values within 10 dB of the maximum value, the average value on an energy basis is about 4.25 dB below the maximum value. Considering the standard 10-sec duration used to calculate EPNL, this implies that

$$EPNL = (Max\ PNL - 4.25) + 10 \log_{10} T_0/10 \quad \text{[Eq A1]}$$

where T_0 = the time duration between the points 10 dB below the maximum PNL point.

Within the primary range of interest, CERL data indicate approximate 10-dB down durations at 300 ft (91 m), 360 ft (110 m), and 500 ft (152 m) of 10 sec, 12 sec, and 17 to 18 sec, respectively, for a cruise speed of about 80 to 90 kt (148 to 167 km/hr). These values closely fit expected theoretical values. Calculations show that absorptive effects cause the duration relation to depart from theory significantly only at short distances (less than 300 ft [91 m]) and long distances (greater than 3000 ft [914 m]). In the middle distances, the relative absorption changes between the maximum value and the values at the 10-dB down point are almost identical (Figure A1).

A correction factor of +7 is added to all results to account for helicopter noisiness and turns. The helicopter spectrum includes impulsive blade slap and other phenomena which make rotary-wing aircraft more annoying than fixed-wing aircraft. The DOD letter of 15 October 1975, Subject: *Air Installations Compatible Use Zone Noise Descriptors* requires use of the 7-dB factor.

It was assumed that helicopters, while in a traffic pattern or ingress or egress corridor, would usually be turning and/or changing altitude rather than being in level flight. Since no published data are available on turns versus level cruise, CERL data were consulted. Tentative results from this analysis show that turns increase the A-weighted, slow, maximum reading by 4 to 5 dB. Therefore, the total addition factor to NEF and L_{dn} could be 4 or 5 dB if the added noise from turns only was considered, or could be as high as 12 dB if the combined effects of impulsiveness and turning were taken into account. A total correction factor of +7 dB seems to reflect a conservative compromise between the limits.

L_{dn}

In the calculation of L_{dn}, A-weighted, slow, maximum levels from two pairs of sideline microphones at slant distances of 360 and 500 ft (110 and 152 m) were corrected for the three distances that yielded NEF values of 40, 35, and 30. Assuming a triangular approximation of the time pattern shape of the helicopter time history within 10 dB of the maximum level, it is estimated that the average level is 4.25 dB below the maximum. L_{AE} and L_{dn} were calculated on an energy basis using Eq 3 and Eq 4. The total correction factor of +7 has been included as shown in Eq 4.

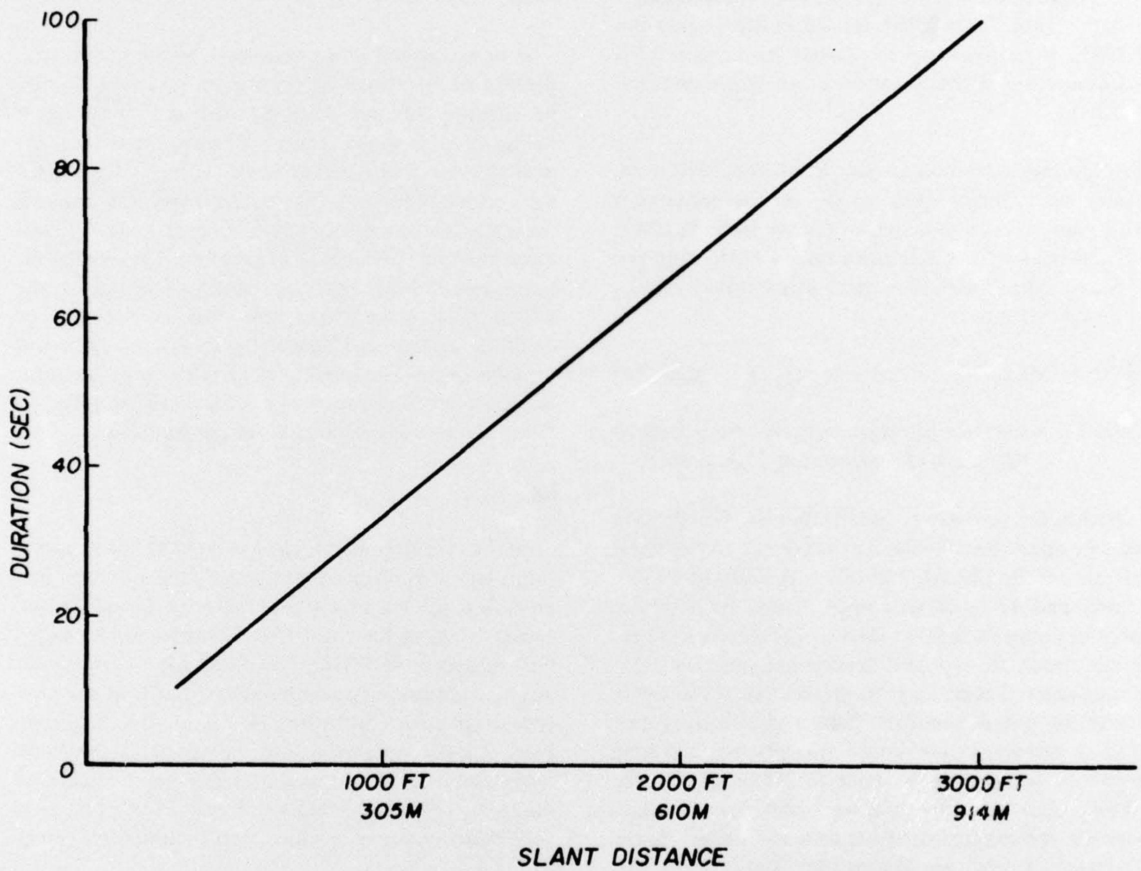

Figure A1. Expected duration between the points 10 dB down the maximum, slow, A-weighted level vs slant distance. Absorptive effects cause departure from theory below 300 ft (91 m) and above 3000 ft (914 m) slant distance.

APPENDIX B:

SAMPLE CALCULATIONS

Calculation of NEF

A simple example will demonstrate the calculation of NEF. Calculations will be performed for 100 total operations per 24-hour period with 10 percent of the flights during the night hours. Of the 100 operations, 80 will be UH-1s, 15 AH-1Gs, and 5 CH-47s (Table B1).

Table B1

Listing of Aircraft Used in Fleet Mix

Aircraft	Number of Aircraft per 24-Hour Period	
	Day (0700-2200 hrs)	Night (2200-0700 hrs)
UH-1	72.0	8.0
AH-1G	13.5	1.5
CH-47	4.5	0.5

Graphs of Perceived Noise Levels for level flight versus each aircraft type at a distance of 350 ft (107 m) were consulted. These levels will later be corrected for turns. EPNL can be found (as indicated in Appendix A) by using the PNL versus distance curves.

For this example, NEF will be calculated at 350 ft (197 m). By using Eq A1, PNL curves for each aircraft, and the durations plotted in Table A1, EPNL can be found as shown in Table B2 and the following calculations.

For

UH-1: $\text{EPNL} = 97 - 4.25 + 10 \log 11/10 = 93$
AH-1G: $\text{EPNL} = 107 - 4.25 + 10 \log 11/10 = 103$
CH-47: $\text{EPNL} = 98 - 4.25 + 10 \log 11/10 = 94$

With this information, it is possible to calculate NEF from Eq 1:

$$\text{NEF} = [93 + 10 \log (72 + 16.67 (8))]$$
$$+ [103 + 10 \log (13.5 + 16.67 (1.5))]$$
$$+ [94 + 10 \log (4.5 + 16.67 (0.5))] - 88 + 7$$
$$\text{NEF} = [116 + 119 + 105] - 88 + 7$$

Table B2

EPNL Values Calculated from PNL Data at 350 ft (107 m)

Aircraft	PNL at 350 ft (107 m)	EPNL at 350 ft (107 m)
UH-1	97	93
AH-1G	107	103
CH-47	98	94

Adding the numbers in brackets on an energy basis according to Eq 2 yields:

$$\text{NEF} = 121 - 88 + 7$$
$$\text{NEF} = 40$$

Similar calculations have been performed for a number of slant distances; the results are graphed in Figure 2. As can be seen, a slant distance of 350 ft (107 m) yields an NEF of 40. Table B3 demonstrates the change in noise impact given different percentages of night operations. This table demonstrates a relative insensitivity to the percentage of night operations in the range of 1 to 30 percent. Modification for this factor is not required.

Table B3

Approximate Modification to NEF or L_{dn} for a Change in the Percentage of Night (2200-0700 hrs) Operations to be Added to Values in Table 1

Percentage of Night Operations	Unit Correction to NEF or L_{dn}
0	−4
10	0
20	+2
30	+3
50	+5
100	+8

NOTE: This table demonstrates a relative insensitivity to the percentage of night operations in the range of 1 to 30 percent. Modification for this factor is not required.

Calculation of L_{dn}

L_{dn} was calculated from CERL flyover data (instead of tables) to produce similar results as for NEF.

For this example, the same total number of operations (100), percentage of night operations (10 percent), and fleet mix (80 percent UH-1s, 15 percent

AH-1Gs, and 5 percent CH-47s) will be used as for the NEF example. An L_{dn} at a slant distance of 750 ft (229 m) will be calculated. Aircraft were flying at 300 ft (91 m) AGL and data will be taken from one sideline microphone located at a ground distance of 400 ft (122 m) from the centerline (slant distance = 500 ft [152 m]).

The A-weighted, slow, maximum levels at 500 ft (152 m) slant distance can be normalized to any distance using Eq B1.

$$L_D = L_R - 20 \log (D/R) - \int_R^D a(s)ds \quad \text{[Eq B1]}$$

where D = Desired distance
R = Reference distance
a = Absorption per unit distance of the A-weighted spectrum (i.e., absorption is a function of spectrum which changes with distance).

At 750 ft (229 m), for example, it is estimated that the weighted absorption is 1 dB/1000 ft (0.0033 dB/m) for the helicopter spectrum. The level becomes

$$L_D = L_R - 20 \log (750/500) - (1.0/1000)(750\text{-}500)$$

$$L_D = L_R - 3.8$$

Table B4 presents the A-weighted, slow, maximum values at 500 and 750 ft (152 and 229 m) determined using the above correction. Figure B1 presents the maximum level relative to 500 ft (152 m) versus slant distance, including an estimation of the absorption effects.

Table B4

A-Weighted, Slow, Maximum Levels for the Aircraft Used

Aircraft	A-Weighted, Slow, Maximum Level 500 ft (152 m) Slant Distance	750 ft (229 m) Slant Distance
UH-1	82.5	79
AH-1G	87	83
CH-47	87	83

The typical duration between the point 10 dB down from the A-weighted, slow, maximum level at 500 ft (152 m), as found from CERL data, is about 16 sec, which indicates a 25-sec duration at 750 ft (229 m), as shown in Figure A1.

The time integral of the square of pressure (L_{AE}) can then be calculated for each aircraft at 750 ft (229 m) using Eq 3:

UH-1: $L_{AE} = 79 - 4.25 + 10 \log (25) = 89$

AH-1G: $L_{AE} = 83 - 4.25 + 10 \log (25) = 93$

CH-47: $L_{AE} = 83 - 4.25 + 10 \log (25) = 93$

where $L_{AE} = 1/t_o \int_T P_A^2 (t)dt \qquad (t_o = 1 \text{ sec})$

L_{dn} can be easily calculated using the number of aircraft from Table B1 and Eq 4:

$$L_{dn} = [\sum_{i=1}^{n} (L_{AE} + 10 \log N_d) + \sum_{i=1}^{n} (L_{AEi} + 10 \log N_n + 10)] - 10 \log 86400 + 7$$

Substituting,

$$L_{dn} = [(89 + 10 \log(144)) + (93 + 10 \log(27)) + (93 + 10 \log(9)) + (89 + 10 \log(16) + 10) + (93 + 10 \log(3) + 10) + (93 + 10 \log(0.1) + 10)] - 10 \log 86400 + 7$$

yields

$$L_{dn} = [108 + 104 + 100 + 108 + 105 + 100] - 10 \log 86400 + 7$$

Adding the numbers in brackets on an energy basis according to Eq 2 yields:

$$L_{dn} = 113 - 10 \log 86400 + 7$$

$$L_{dn} = 70$$

After 35 is subtracted (as suggested by the EPA), this L_{dn} value is in close agreement with NEF results calculated from published data.

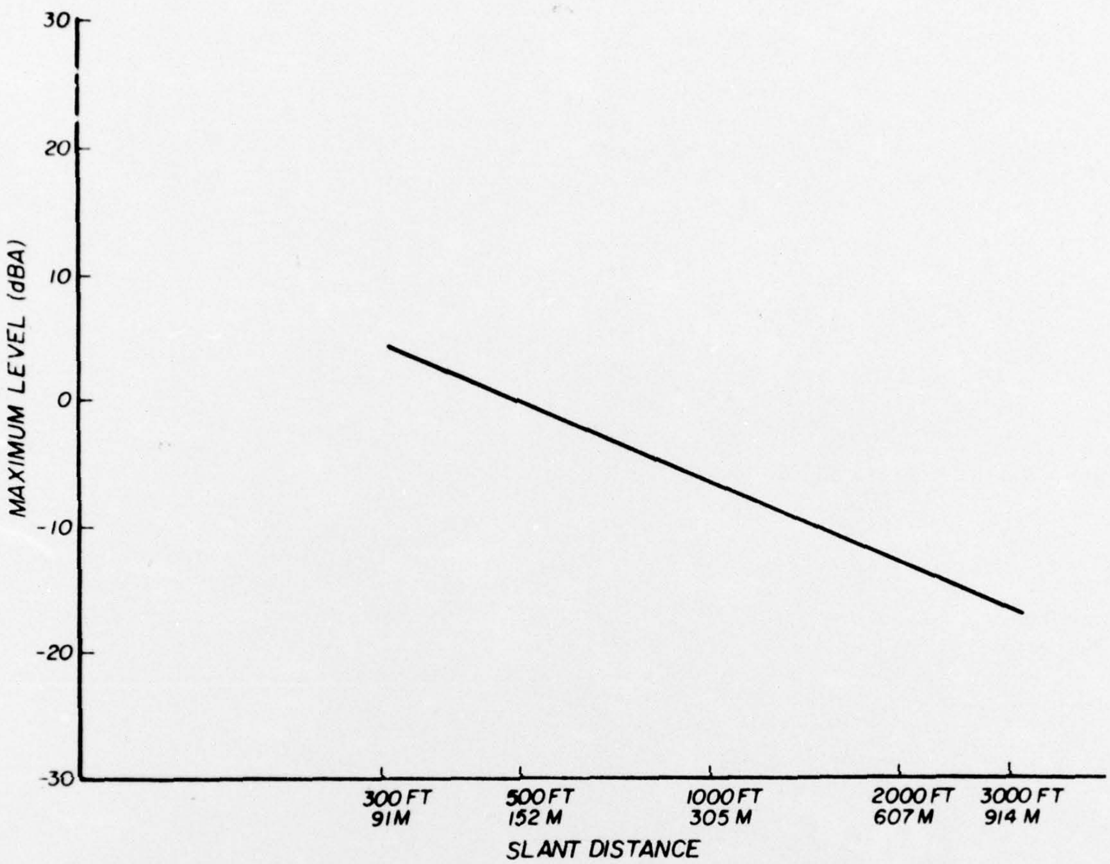

Figure B1. Estimation of the maximum, slow, A-weighted level relative to 500 ft (152 m) vs slant distance for rotary-wing aircraft.

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