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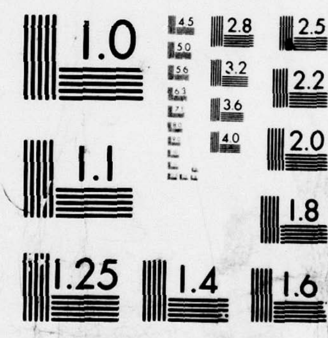

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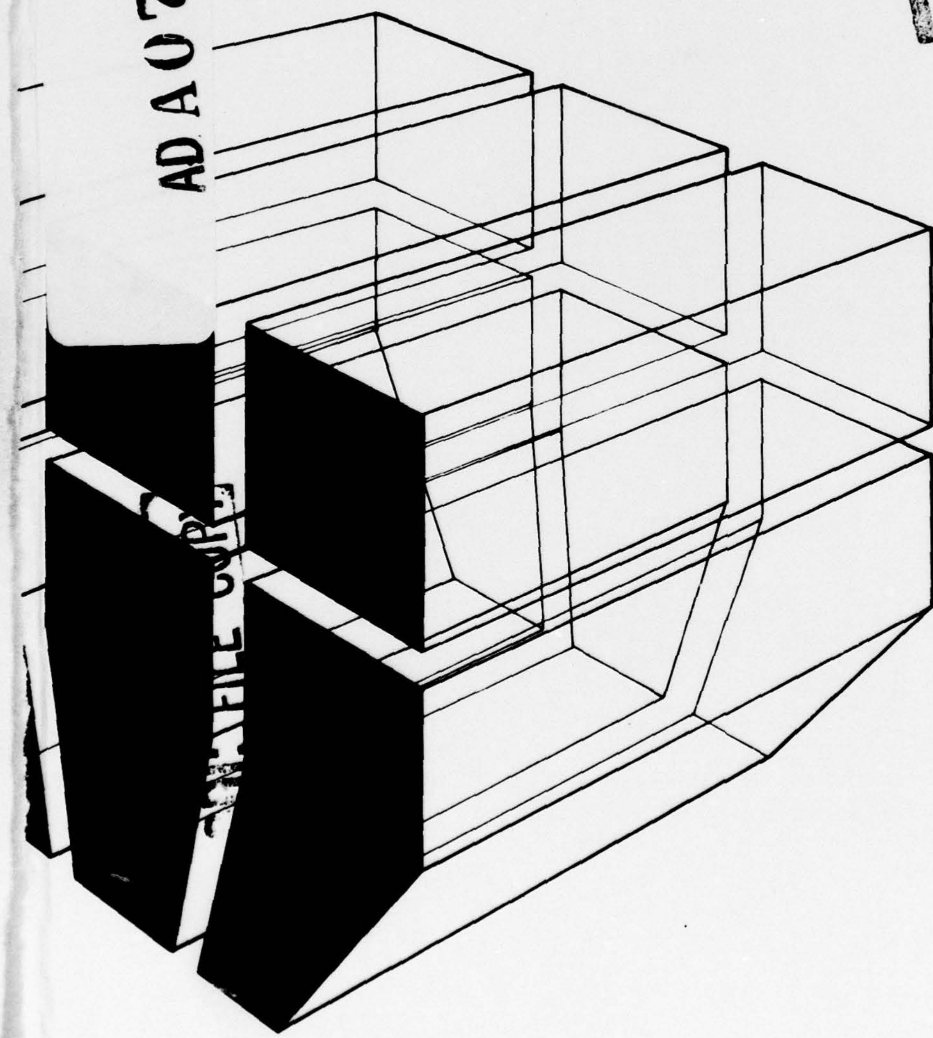
TECHNICAL REPORT N-76
September 1979

MITIGATION OF NOISE IMPACT VIA OPERATIONAL CHANGES



by
Richard Raspet

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER (14) CERL-TR-N-76	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* (6) MITIGATION OF NOISE IMPACT VIA OPERATIONAL CHANGES		5. TYPE OF REPORT & PERIOD COVERED (9) FINAL rept.,
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) Richard Raspet		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. ARMY CONSTRUCTION ENGINEERING RESEARCH LABORATORY P.O. Box 4005, Champaign, IL 61820		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS (16) 4A762720A896-B-023
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE (11) Sep[redacted]979
		13. NUMBER OF PAGES 22
14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)* (12) 26p.		15. SECURITY CLASS. *(of this report)* Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

Copies are obtainable from National Technical Information Service
Springfield, VA 22151

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Army operations
military facilities
noise reduction

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This report presents three case studies which can serve as a guide for using operational changes of artillery and demolition to reduce noise impacts at Army installations. In each case study, the initial and final noise impact is documented by computer-generated equal noise contours. The operational changes which produced the → next page

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reduction or shift in contours are described and their impact estimated. The case studies demonstrate, respectively:

1. A general reduction in operations,
2. A shift in operations away from noise sensitive areas; and
3. A concentration of operations toward the center of the installation.

The large effect night operations have on the C-weighted day and night average sound level is clearly shown by the examples. The relative importance of the larger weapons is also shown.

FOREWORD

This research was conducted for the Directorate of Military Programs, Office of the Chief of Engineers (OCE), under Project 4A76270A896, "Environmental Quality for Construction and Operation of Military Facilities"; Task B, "Source Reduction Control and Treatment"; Work Unit 023, "Noise Impact Mitigation Procedures for Army Facilities." The QCR number is 3.01.006. Mr. F. P. Beck, DAEN-MPE-I, is the OCE Technical Monitor.

The work was performed by the Environmental Division (EN), U.S. Army Construction Engineering Research Laboratory (CERL). Dr. R. K. Jain is Chief of EN.

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

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MITIGATION OF NOISE IMPACT VIA OPERATIONAL CHANGES

1 INTRODUCTION

Background

Noise from artillery, demolition, and helicopters is a major problem at Army installations. The magnitude of this problem is increasing because:

1. The land around Army bases is being developed for residential use at an estimated rate of 4 acres/day (2 hectares [ha]/day) in noise-impacted areas.

2. Training is being increased to maintain higher levels of combat readiness.

3. Larger, longer-range weapons such as the XM-1 tank and the XM-198 cannon are being developed. To fire safely, these weapons must be placed close to the installation boundary, where their noise impacts significantly on neighboring off-post housing areas. Their longer range also usually involves an increased noise level caused by increased charge.

The U.S. Army Construction Engineering Research Laboratory (CERL) has been developing methods for predicting noise levels, assessing noise impact, and reducing the impact of noise since 1971. The prediction of noise levels and the assessment of impacts is done by combining overlays of noise contours[1] generated by CERL computer program with land-use maps. If the noise level indicated by the contours exceeds the guidelines described in Army Technical Manual TM 5-803-2, *Environmental Protection: Planning in the Noise Environment* (1978), then the noise level must be reduced.

The reduction of noise impact is called mitigation. There are three different elements of mitigation:

1. The source can be quieted

2. The path over which the sound travels can be interrupted by a barrier

3. The receiver can be protected from noise.

Sources can be quieted in two ways. The first method reduces the actual noise produced by the source, e.g., burying explosives to reduce blast noise. The second method, operational changes, is widely applicable and is often the easiest to institute at an installation. The operational method does not reduce the actual noise emitted by the source, but only reduces the noise received at the noise-sensitive areas. Three common operational changes are (1) relocation of the source, (2) rescheduling of operations, and (3) reduction of the number of operations. Operational changes may be used to reduce the total area impacted, to reduce the noise level in a particular location, or to shift the impacted area away from the noise-sensitive areas.

Purpose

The objective of this report is to present case study examples which can serve as a guide for using operational changes to reduce noise impacts at Army installations.

Approach

Equal-noise contours were generated using the CERL noise contour program. These contours were then superimposed on installation maps to identify noise-impacted areas in the cantonment area and outside the installation boundaries. Each case was analyzed in terms of the original impact, the reduction required, and how operational changes were used to meet these requirements. All impact was quantified in terms of area.[2]

Mode of Technology Transfer

The material in this report will be incorporated into a unified Technical Bulletin on Noise Mitigation and will be initially transmitted to the field via a cover letter from the Office of the Chief of Engineers (OCE), Installations and Site Development Branch (Engineering Division).

[1] R. J. Goff and E. W. Novak, *Environmental Noise Impact Analysis for Army Military Activities User Manual*, Technical Report N-30/ADA047969 (U.S. Army Construction Engineering Research Laboratory [CERL], November 1977).

[2] For more exact measurements of impact, see R. J. Goff and E. W. Novak, *Environmental Noise Impact Analysis for Army Military Activities: User Manual*, Technical Report N-30/ADA 045421 (CERL, September 1977).

2 NOISE CONTOURING AND OPERATIONAL CHANGES

C-Weighted Metric

The metric used to measure noise impact in this study is the C-weighted day/night level ($L_{C_{dn}}$) which best predicts the annoyance of impulsive source such as artillery or blast.

The $L_{C_{dn}}$ metric is a logarithmic average annual noise level from *all* sources. The $L_{C_{dn}}$ is a measure both of how loud the sources are (their single event level or SEL) and the number of times each source is heard.

In addition, the $L_{C_{dn}}$ includes a penalty for night operation, because people are more sensitive to noise at night. The $L_{C_{dn}}$ can be reduced by changing the SEL, by changing the number of operations, and by reducing the proportion of nighttime operations.

Table 1 is a summary of permissible levels for various activities from TM 5-803-2.

Table 1

Acceptable Land Uses Without Special Noise Insulation or Hearing Protection in $L_{C_{dn}}$*

Facility	Boundary Between Acceptable and Unacceptable Use
Residential, housing	65 dB
Classrooms	65 dB
Offices	70 dB
Hospitals	65 dB
Commercial and Repair	70 dB
Flightline operation	75 dB
Playgrounds, sports arenas	75 dB
Livestock	75 dB
Agricultural	80 dB

*Compiled from TM 5-803-2, *Environmental Protection: Planning in the Noise Environment* (Department of the Air Force, the Army and the Navy, June 1978).

Operational Changes—Single and/or Identical Sources

Relocation

For a single source (or several sources at the same location), the SEL decreases by about 7.2 dB for each doubling of distance (see Figure 1). For example, a source with an SEL of 120 dB at 400 m will have an SEL of 120 − 7.2 dB = 112.8 dB at 800 m; at 1600 m it would have an SEL of 105.6 dB. Therefore, the $L_{C_{dn}}$ at a location can be reduced by moving the sources away from the receiver.

The density of sources in an area can also affect the size of the noise-impacted area. Concentrating sources produces higher noise levels, but reduces the size of the impacted area; dispersing sources increases the impacted area, but reduces noise levels.

Rescheduling and Reduction of Operations

The number of operations affects the $L_{C_{dn}}$ value. Noise value is expressed in logarithmic terms. The formula for how variation in the number of operations affects $L_{C_{dn}}$ is as follows:

$$\text{Logarithm NT} = \text{Logarithm}(N_d + 10N_n) \quad \text{[Eq 1]}$$

where NT is the adjusted total number of operations
N_d is the number of day operations
N_n is the number of night operations.

There are two ways of changing $L_{C_{dn}}$.

1. Change the number of both day and night operations

2. Change the proportion of night operations; this method is the most significant, since night operations are multiplied by a factor of 10.

Example 1. Suppose an installation has 100 day operations and 10 night operations. To determine the increase in $L_{C_{dn}}$ if the number of operations is halved:

Step 1. Determine the initial and final adjusted number of operations.

$$\text{INITIAL NT} = 100 + (10 \times 10) = 200$$

$$\text{FINAL NT} = 50 + (10 \times 5) = 100$$

where NT = adjusted number of operations.

Step 2. Determine the reduction factor.

$$\text{REDUCTION FACTOR} = \frac{200}{100} = 2$$

Step 3. Use Figure 2 to determine the decrease in $L_{C_{dn}}$.

$$\text{DECREASE in } L_{C_{dn}} = 3\text{ dB}$$

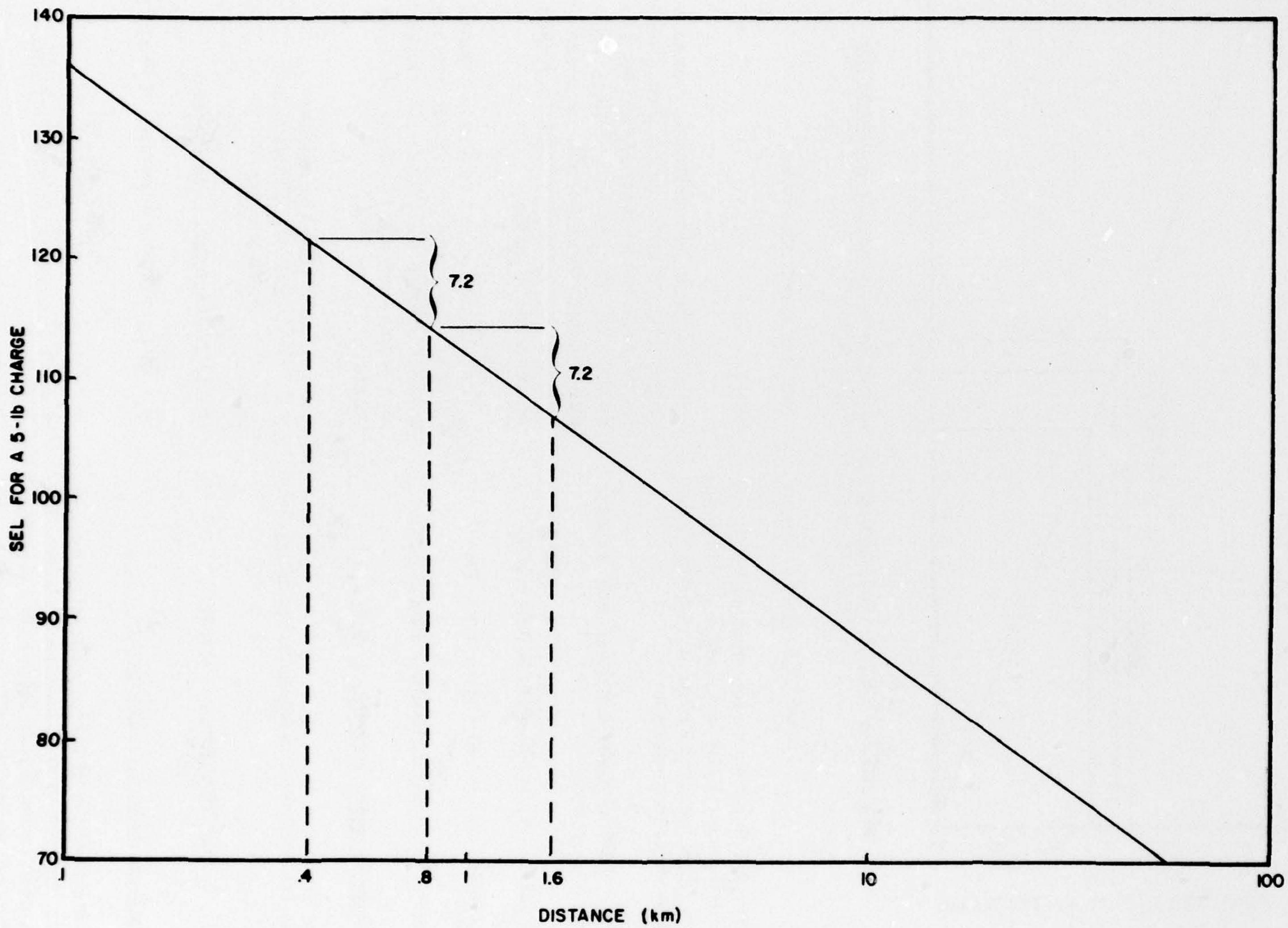

Figure 1. Single event level vs distance.

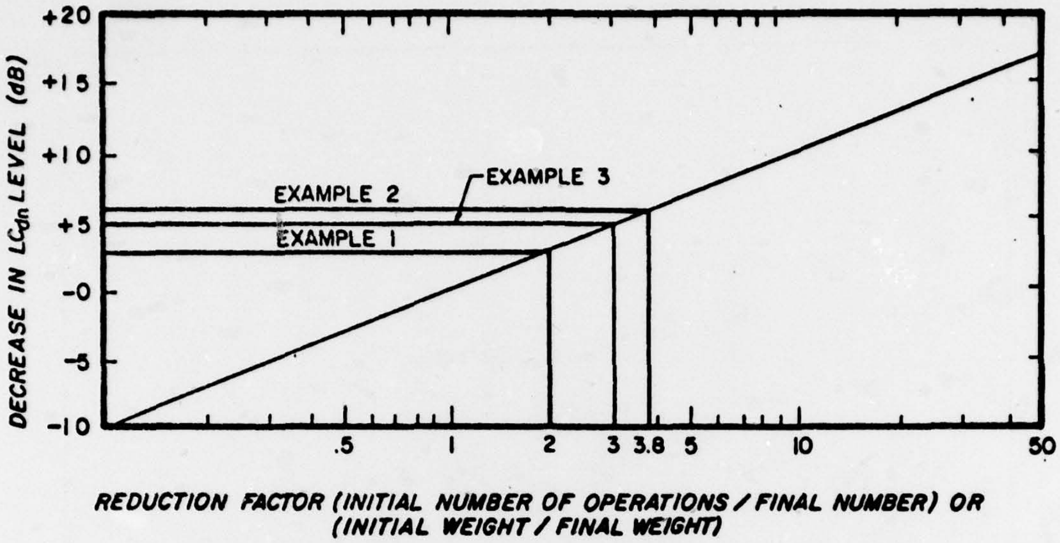

Figure 2. Change in C-weighted day-night level vs reduction factor.

Example 2. Suppose an installation has 100 firings in the daytime and 100 firings at night. To determine the noise-level reduction if 90 of the night operations are rescheduled to the daytime:

Step 1. Determine the initial and final adjusted number of operations.

$$\text{INITIAL NT} = 100 + (10 \times 100) = 1100$$

$$\text{FINAL NT} = 190 + (10 \times 10) = 290$$

Step 2. Determine the reduction factor.

$$\text{REDUCTION FACTOR} = \frac{1100}{290} = 3.8$$

Step 3. Use Figure 2 to determine the decrease in $L_{C_{dn}}$.

$$\text{DECREASE in } L_{C_{dn}} = 6 \text{ dB}$$

Operational Changes—Multiple Sources

To determine the effect of operational changes on an area impacted by noise produced by several different noise sources, it is necessary to find the difference between the initial and final combined $L_{C_{dn}}$ of the area.

Step 1

To find the initial combined $L_{C_{dn}}$ for an area with several different noise sources, first determine the $L_{C_{dn}}$ of each source which impacts the area. Next, rank the $L_{C_{dn}}$ from lowest to highest. The $L_{C_{dn}}$ are then summed logarithmically, beginning with the two lowest $L_{C_{dn}}$ and proceeding to the highest, which will be the last $L_{C_{dn}}$ added.

For example, suppose an area is impacted by the following noise sources: 155-mm howitzer, 8-in. howitzer, demolitions. After determining the $L_{C_{dn}}$ for each source, rank the $L_{C_{dn}}$ from the lowest to the highest:

50 dB — 8-in. howitzer
54 dB — 155-mm howitzer
60 dB — blasts

To find the combined $L_{C_{dn}}$ for the area:

$50 + 54L_{C_{dn}}$ = 4 value difference = 1 (from Table 2)

$$1 + 54L_{C_{dn}} = 55L_{C_{dn}}$$

$55 + 60L_{C_{dn}}$ = 5 value difference = 1 (from Table 2)

$1 + 60L_{C_{dn}} = 61L_{C_{dn}}$ (combined value of 50, 54 and $60L_{C_{dn}}$)

Table 2

Method for Addition of Logarithms

When Two $L_{C_{dn}}$ or SEL Values Differ By	Add the Following to the Higher Value
0 to 1 dB	3
2 to 3 dB	2
4 to 9 dB	1
10 or more dB	0

NOTE: To add more than two levels, start with lowest values.

Step 2

After operational changes are complete, redetermine the $L_{C_{dn}}$ for each noise source and recalculate the combined $L_{C_{dn}}$ as described in Step 1. Next, determine the difference between the initial and final $L_{C_{dn}}$.

Step 3

$$\text{REDUCTION} = \text{initial } L_{C_{dn}} - \text{final } L_{C_{dn}} \quad \text{[Eq 3]}$$

Using Charge Weight to Find the Difference in Combined $L_{C_{dn}}$

A quicker but less accurate way of estimating the change in the combined $L_{C_{dn}}$ is to examine the change in the weight of explosives. The $L_{C_{dn}}$ is approximately proportional to the logarithm of the total adjusted charge weight. For a single source or type of source, the total adjusted number of operations is used to calculate the reduction in noise. However, for a mix of different types of operation at a single location, the total adjusted charge weight is used to predict noise-level reductions. The total adjusted charge weight is given by:

$$WT = W_d + (10 \times W_n) \quad \text{[Eq 4]}$$

where: WT = total adjusted charge weight
W_d = total charge weight of day operations
W_n = total charge weight of night operations.

Note that the reduction factor is the ratio of the initial to final *charge weight* rather than the ratio of initial number of operations to final number of operations. Given this ratio, the noise-level reduction can be predicted using Figure 2 as illustrated below:

$$\frac{\text{Initial Wt}}{\text{Final Wt}} = \text{Ratio (see Figure 2)} = \text{Variation in } L_{C_{dn}}$$

where Wt = Charge Weight

For example, suppose the initial operations at a demolitions range involved firing twenty 1 lb (.453 kg) charges during the day and five 5 lb (2.27 kg) charges at night. If the operations are changed to twenty 1 lb (.453 kg) charges fired during the day and seven 1 lb (.453 kg) charges fired at night, how much reduction in $L_{C_{dn}}$ would occur?

Step 1. Calculate the Initial and Final Adjusted Total Charge Weight

Initial W_d = 20 × 1.0 lb = 20.0 lb (9.1 kg)
Initial W_n = 5 × 5.0 lb = 25.0 lb (11.3 kg)
Initial WT = 20.0 + 10 × 25.0 = 270 lb (122.3 kg)

Final W_d = 20 × 1.0 lb = 20.0 lb (9.1 kg)
Final W_n = 7 × 1.0 lb = 7.0 lb (3.2 kg)
Final WT = 20.0 lb + 10 × 7.0 lb = 90 lb (40.8 kg)

Step 2. Determine the Reduction Factor

$$\text{Reduction factor} = \frac{270}{90} = 3.0$$

Step 3. Use Figure 2 to Determine the Decrease in $L_{C_{dn}}$

Decrease in $L_{C_{dn}}$ = 5 dB

3 CASE STUDY A

Case study A demonstrates how a noise impact can be reduced by reducing the number of noise-producing operations.

Background

Fort A is a relatively small installation (approximately 20 by 20 km) with artillery ranges, demolition ranges, and impact areas concentrated into one region. Three small towns lie on the installation boundary (Figure 3). Since noise impacts on all sides of the installation, relocating firing points and/or target areas would only increase the impact at one of the already impacted areas.

Initial Impact and Operations

Figure 3 shows noise levels exceeding 65 $L_{C_{dn}}$ in the towns of Jean, Helm, and portions of Allied. In addition, half of the cantonment area has levels of 65 dB or higher. A large, sparsely populated region west of the installation is also within the 65 dB contour. The total area impacted by an $L_{C_{dn}}$ of greater than 65 outside the installation is 8500 acres (3400 ha), which is separated into five different parcels. Of

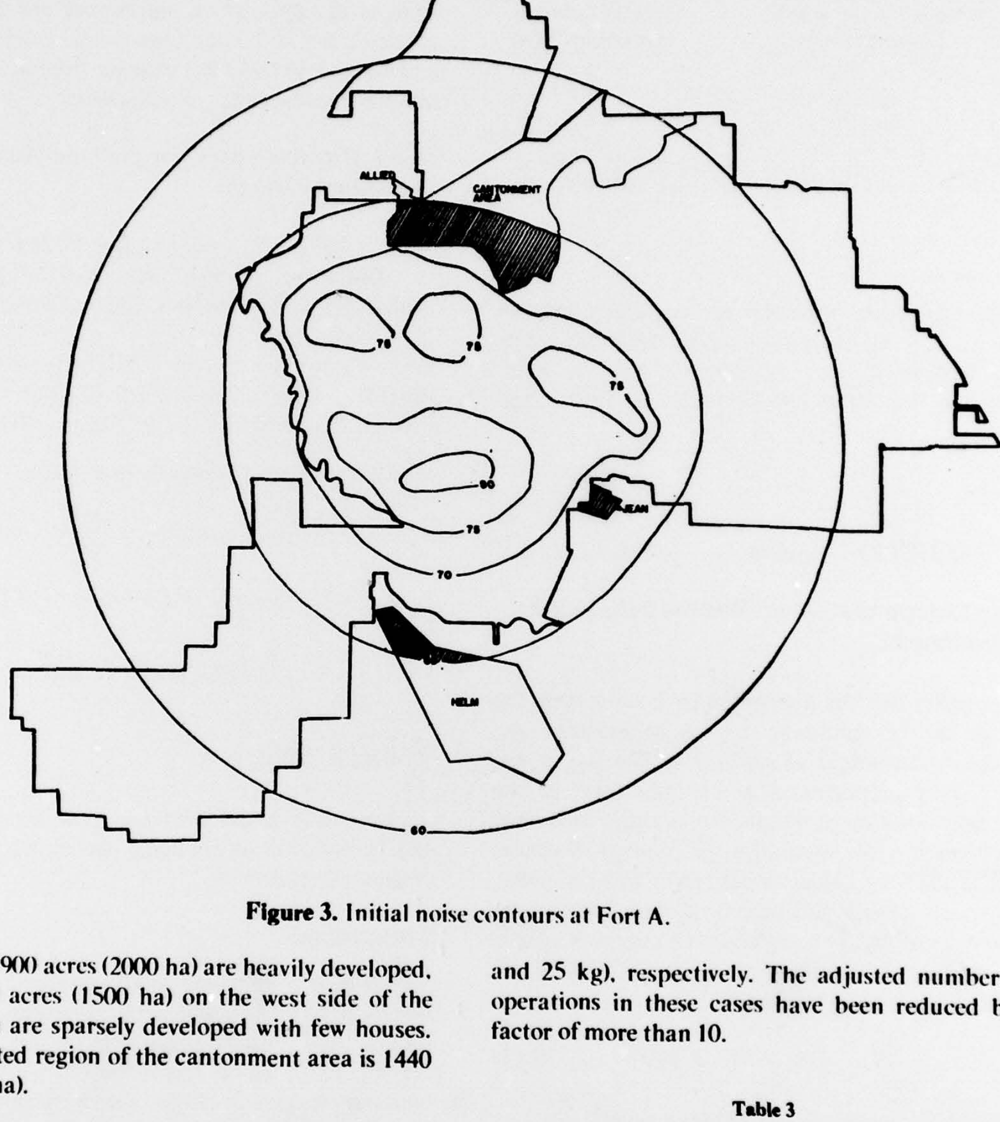

Figure 3. Initial noise contours at Fort A.

this total, 4900 acres (2000 ha) are heavily developed, while 3600 acres (1500 ha) on the west side of the installation are sparsely developed with few houses. The impacted region of the cantonment area is 1440 acres (580 ha).

So that the relative importance of each type of weapon used can be established, the average propellant weight and projectile charge weight are listed in Table 3. The initial and final numbers of daily operations for each type of weapon used at Fort A are listed in Table 4. The last column of Table 4 is the adjusted total number of operations. Although the change in total number of operations is not large, most of the change in operations is caused by reducing the firing of large weapons, i.e., the 155-mm and 8-in. howitzers. Table 3 shows the total charge weights (projectile and propellant) for a single firing of the 155-mm and 8-in. howitzers as 25 and 56 lb (11 and 25 kg), respectively. The adjusted numbers of operations in these cases have been reduced by a factor of more than 10.

Table 3

Average Propellant* and Projectile Weight for a Single Firing

Weapon	Propellant, lb (kg)	Projectile, lb (kg)
105-mm howitzer	1.6 (.7)	4.6 (2.1)
155-mm howitzer	10.0 (4.5)	15.4 (7.0)
8-in. howitzer	20.0 (9.0)	36.3 (16.0)
175-mm gun	40.0 (18.0)	31.3 (14.0)
60-mm mortar	.3 (.1)	.6 (.3)
66-mm mortar	.3 (.1)	.6 (.3)
81-mm mortar	.2 (.1)	2.3 (1.0)
107-mm mortar	.6 (.3)	8.5 (4.0)
90-mm recoilless rifle	1.2 (.5)	1.7 (.8)
106-mm recoilless rifle	7.6 (3.4)	2.7 (1.2)
2.75-in. rocket	.01 (4.53)	2.3 (1.0)

*Amount of propellant varies with range.

Table 4

Case A: Initial and Final Number of Operations Day/Night/Total Adjusted

Weapon	Initial (1976) Day/Night/ Adjusted Total	Final (1978) Day/Night/ Adjusted Total
105-mm howitzer	72/8/152	84/5/134
155-mm howitzer	27/8/107	9/.2/11
8-in. howitzer	21/1.5/36	1.5/—/1.5
60-mm mortar	—	12/.4/16
66-mm mortar	—	.7/0/.7
81-mm mortar	—	63/1.8/81
107-mm mortar	21/0/21	24/1/34
Demolition	7/0/7	—
Total	148/17.5/323	200.5/10.2/278.2

Table 5

Initial and Final Daily Adjusted Total Charges (lb), by Weapon*

	Initial (1976)	Final (1978)
105-mm howitzer	960	800
155-mm howitzer	2380	300
8-in. howitzer	1960	60
60-mm mortar		20
66-mm mortar		—
91-mm mortar	150	190
107-mm mortar	180	310
Demolition	710	
Total	5640	1680

*Metric Conversion: 1 lb = .453 592 kg

Reduced Operations and Final Noise Impact

To reduce noise impact to acceptable levels, it was necessary to reduce the $L_{C_{dn}}$ by about 5 dB in all directions. However, if all operations were reduced equally, a reduction factor of 3 would be required (an effective operational reduction of one third) (Figure 2). Therefore, instead of reducing all operations equally, only the firing of the large weapons was curtailed: firings of the 8-in. howitzer were almost eliminated, night firing of the 155-mm howitzer was reduced to a minimum, and 155-mm howitzer day operations were reduced by one-third. Table 5 shows the total adjusted charge weight for the initial and final operations. Note the large effect the reduction in firing has on the total charge weight of the 155-mm and 8-in. howitzers; 155-mm howitzer adjusted charge weight decreased from 2380 to 300 lb (1079 to 136 kg) and the charge weight of the 8-in. howitzer decreased from 1960 to 60 lb (889 to 27 kg) *daily*. These large changes decreased the total adjusted charge weight from 5,640 to 1,680 lb (2558 to 782 kg). The resulting overall noise reductions can be estimated using the methods described in Chapter 2:

Step 1

$$\text{Reduction Factor} = \frac{5{,}640 \text{ lb}}{1{,}680 \text{ lb}} = 3.35$$

Step 2

Use Figure 2 to find the decrease in decibel level.

$$\text{DECREASE IN } L_{C_{dn}} = 5.1 \text{ dB}$$

Results

Figure 4 demonstrates that the operational changes at Fort A generally reduced the size of the installation's equal-noise contours by 5 dB. With modified operations, only portions of the town of Jean are impacted by $L_{C_{dn}}$ levels of 65 or higher; the off-post impacted area in this parcel is only 200 acres (81 ha). And although a small portion of the 530 acres (210 ha) west of the installation is impacted, only a few houses exist in this region. The cantonment area lies entirely outside the 65 dB contour, with most of the area outside the 60 dB contour.

4 CASE STUDY B

Case Study B illustrates how noise levels can be selectively reduced.

Background

Fort B is an extended installation approximately 40 by 10 km. Since it is an extended installation, large changes in the shape of the contours can be established by relocating operations. The overall operations at Fort B have changed only slightly. Unlike Case A, which illustrated a general reduction, Case B shows that a major reduction in only one direction can be achieved by relocating operations. (Although the particular change in operations described in this chapter was not intended to reduce noise impact, it is a good example of the type of gains which can be achieved by relocating operations.)

Initial and Final Contours

The initial equal-noise contours for Fort B were generated for operations in the third quarter of

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Figure 4. Final noise contours at Fort A.

1974; the final contours were produced for the fourth quarter of 1974. These contours are shown in Figures 5 and 6, respectively. Note that the noise levels to the west of the installation were approximately 5 dB higher during the third quarter, a shift of one equal-noise contour.

Note that the initial contour had a large region (4300 acres [1740 ha]), with an off-post $L_{C_{dn}}$ of 75 or greater along the southern boundary, while in the fourth quarter, only a small region (900 acres [360 ha]) had noise levels exceeding 75.

Initial and Final Operations

The overall operations at Fort B have changed only slightly. The adjusted total number of operations increased from 1840 to 1900 daily operations. The total daily charge weight decreased from 15,800 to 14,600 lb (7166 to 6622 kg). To explain how operational changes caused the noise contours to shift to the east, it is necessary to examine the activities by regions grouped around the various impact areas (see Figure 7). The number of operations was divided among approximately three regions: 5 percent in the west, 70 percent in the central region, and 25 percent in the eastern region.

Western Region

If the mix of weapon types and the proportion of day/night operations are kept the same, the number of operations or the daily projectile weight should directly reflect the noise reduction resulting from a reduction in operations (see Figure 2).

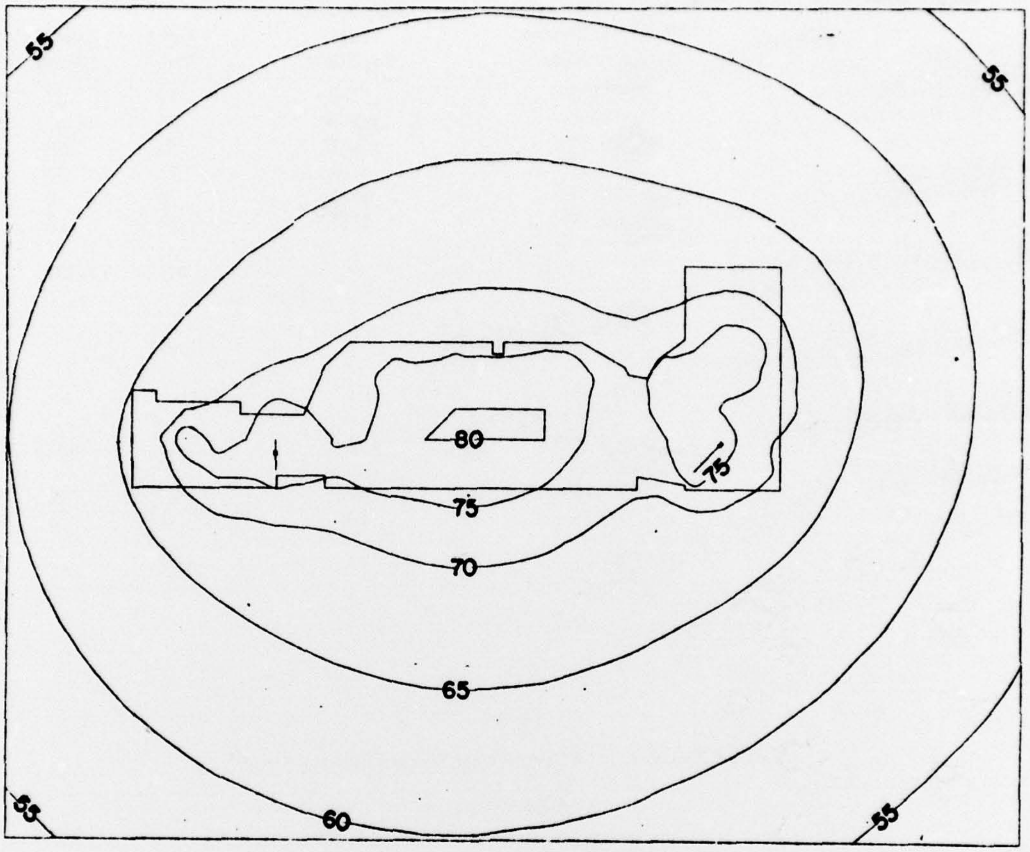


Figure 5. Initial noise contours at Fort B.

In the western region at Fort B, the mix of weapon types and proportion of day/night operations changed considerably from the third to the fourth quarter. The target weight increased from 430 to 680 lb (195 to 308 kg) daily. However, the surrounding noise contours *shrank* by approximately 5 dB. To account for this somewhat surprising result, it is necessary to carefully analyze western region operations by a detailed accounting of the following large weapons: 105-mm howitzer, 155-mm howitzer, 8-in. howitzer, 175-mm gun, 2.75-in. rocket, and the 107-mm mortar. Tables 6 and 7 total the number of western region operations using these weapons. (In the tables, the target or projectile operations are totaled separately, since some weapons firing in the western region impact in the central area and some weapons firing in the central area impact in the western region.)

Tables 6 and 7 identify the important operational differences between the third and fourth quarters at Fort B. The largest single contributor to the third-quarter noise was the 175-mm gun, which had an equivalent daily propellant weight of more than 2000 lb (907 kg). In the fourth quarter, firing of the 175-mm gun was eliminated. Comparison of the actual total weight with the equivalent total weight of propellant for the 175-mm gun demonstrates the significance of night firing; i.e., the *actual* weight fired was 660 lb (299 kg) daily, while the *equivalent* weight, which contains the night penalty, was more than 2000 lb (907 kg).

The projectile weights of the 8-in. howitzer show a similar relationship. While third-quarter operations increased from 580 to 1520, the noise impact increased only slightly, since the adjusted total charge

Table 6

Target Weights (lb) and Operations in Western Region of Fort B*

Weapon	Number of Operations During the Quarter Day/Night/Adjusted	Daily Average Weight Day/Night	Actual Total	Adjusted Total
Third Quarter				
105-mm howitzer	343/33/673	17/2	19	37
155-mm howitzer	365/57/935	63/10	73	163
8-in. howitzer	487/95/1437	196/38	234	576
175-mm gun	277/0/277	97/0	97	97
2.75-in. rocket	349/0/349	9/10	9	9
107-mm mortar	126/0/126	12/0	12	12
Total			444	897
Fourth Quarter				
105-mm howitzer	—	—	—	—
155-mm howitzer	—	—	—	—
8-in. howitzer	1520/0/1520	613/0	613	613
175-mm gun	—/—/—	—/—	—	—
2.75-in. rocket	1188/0/1188	30/0	30	30
107-mm mortar	79/0/79	8/0	8	8
Total			651	651

*Metric Conversion: 1 lb = .453 592 kg

Table 7

Propellant Weights (lb) and Operations in Western Region of Fort B*

Weapon	Number of Operations in Quarter Day/Night/Adjusted	Daily Average Weight Day/Night	Total	Adjusted Total
Third Quarter				
105-mm howitzer	221/33/551	1.2/.2	1.4	3
155-mm howitzer	224/224/2684	6/6	12	66
8-in. howitzer	209/60/809	14/4	18	54
175-mm gun	1950/573/7680	510/150	660	2010
2.75-in. rocket	349/0/349	.4/0	.4	.4
107-mm mortar	—	—	—	—
Total			690	2130
Fourth Quarter				
105-mm howitzer	—	—	—	—
155-mm howitzer	—	—	—	—
8-in. howitzer	745/0/745	50/0	50	50
175-mm gun	—/—/—	—/—	—	—
2.75-in. rocket	1188/0/1188	1.3/0	1.3	1.
3 107-mm mortar	—/—/—	—/—	—	—
Total			50	50

*Conversion factor: 1 lb = .452 592 kg

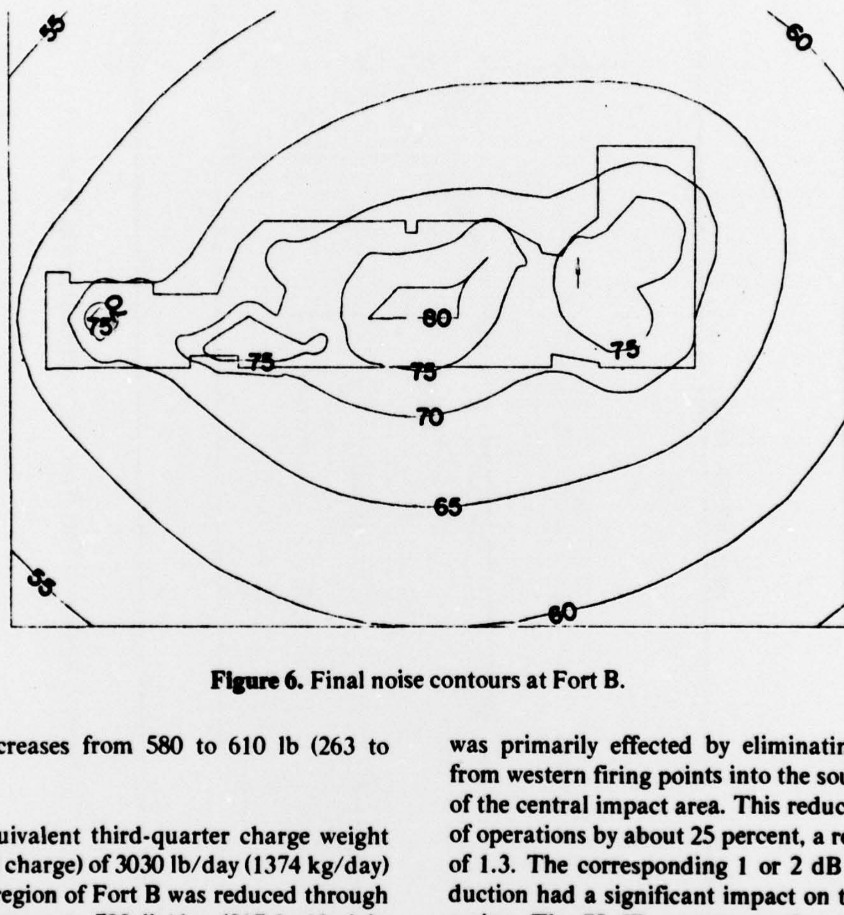


Figure 6. Final noise contours at Fort B.

weight only increases from 580 to 610 lb (263 to 276 kg).

The total equivalent third-quarter charge weight (propellant and charge) of 3030 lb/day (1374 kg/day) in the western region of Fort B was reduced through operational changes to 700 lb/day (317 kg/day) in the fourth quarter. This is a reduction factor of 4.3, a decrease of approximately 6 dB (see Figure 2). However, the actual overall noise-level reduction at any point is, of course, the sum of the contribution from all the areas.

Central and Eastern Region

Fort B instituted only small operational changes in the central and eastern regions from the third to fourth quarter. In the central region, the reduction was primarily effected by eliminating night firing from western firing points into the southwest section of the central impact area. This reduced the number of operations by about 25 percent, a reduction factor of 1.3. The corresponding 1 or 2 dB noise-level reduction had a significant impact on the $L_{C_{dn}}$ for the region. The 75 dB contour north and south in the central region shrank to almost within the base boundaries, reducing the off-post area impacted by 75 $L_{C_{dn}}$ (from 4300 to 900 acres [1700 to 360 ha]). (See Figure 6.)

The change in the central region contour, however, did not reduce noise levels in the noise-impacted area outside Fort B's *eastern* boundary. This is because the noise contour in that area considers the noise contribution of *both* Fort B's central and eastern region operations. In this case, even though

REGIONS OF FT B

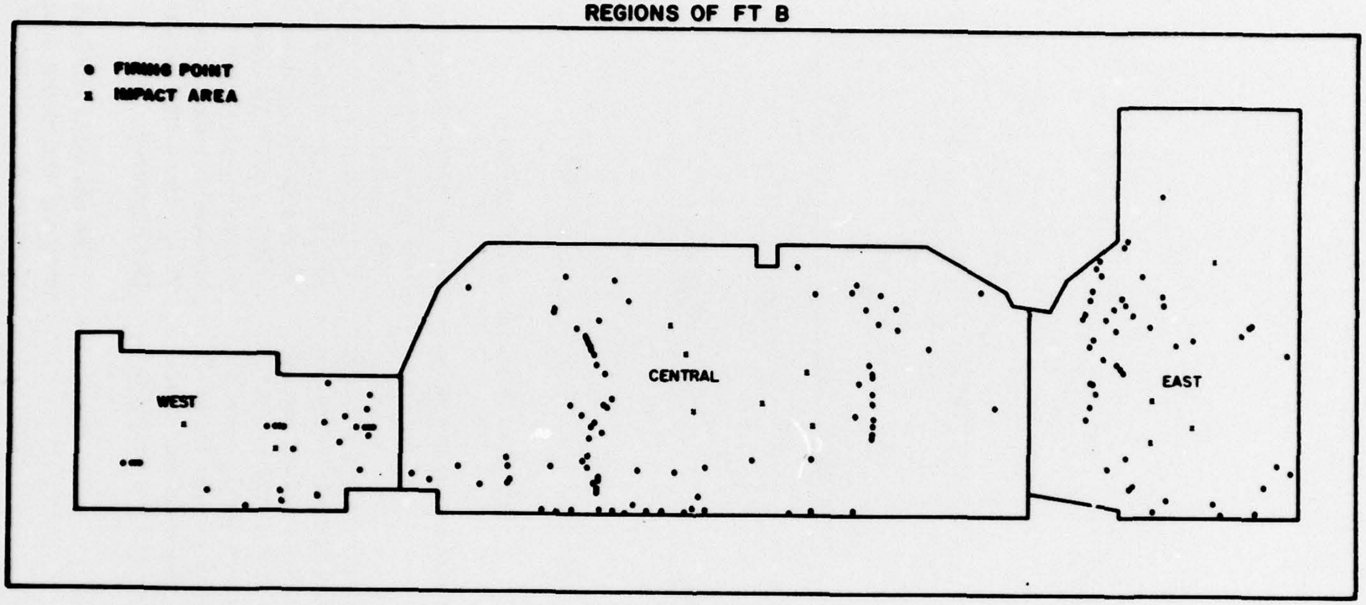


Figure 7. Regions of Fort B used in the operational analysis.

central region operations were reduced significantly, eastern region operations were increased enough to maintain pre-operational noise levels in that area.

Summary

For installations with distributed impact areas and firing points, off-base noise impact can be reduced by relocating operations. In the case of Fort B, noise impact was reduced by eliminating night firings and reducing operations in one region of the installation and by effecting an overall small shift of operations toward the east. The concentration of firing in the central and eastern regions at Fort B greatly reduced the impacted area, but did not require a large reduction in number of operations or total charge weight.

5 CASE STUDY C

Case study C demonstrates how larger installations can reduce off-post noise impacts by concentrating operations toward the center of the installation.

Background

Fort C is an irregularly shaped installation approximately 40 × 18 km. Most operations occur in a 30 by 18 km region west of the cantonment area. Case study C demonstrates what happens when the number of operations is uniformly reduced; i.e., when the ratio of day to night operations remains the same from the initial to final set of operations. In addition to the general reduction, firing points in the western and the eastern regions of Fort C were closed so that not only the size, but the shape of the contours changes.

Initial Impact

Fort C's initial noise contours from 1976 are shown in Figure 8. In this case, a large region of 12,500 acres (5050 ha) to the south and the west of the installation has noise levels higher than 70 dB. The towns of Rhett and Dewey and portions of Carlo are within this region. In addition, there are trailer courts and houses in the region adjacent to the southern boundary. A region of 5200 acres (2100 ha) in the cantonment area is within the 65 $L_{C_{dn}}$ contour. This region contains residential areas and the installation hospital.

Changes in Operations

To achieve acceptable noise levels in the western region towns and in the cantonment area, a large reduction in firing was required. Activities were concentrated toward the center of Fort C and firing points in the east and west were eliminated.

Figure 9a is a scattergram of third-quarter day operations at Fort C (each dot represents three operations); the scattergram of third quarter night operations is shown in Figure 9b (each dot represents 3 × 10 or 30 operations; also see Eq 1). As indicated in the figures, third quarter firing occurred in Fort C's far western region and adjacent to the cantonment area.

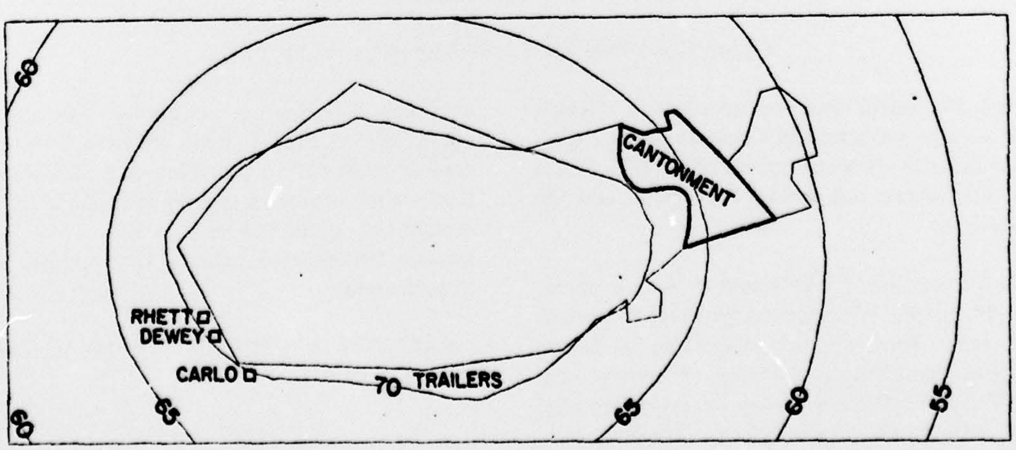
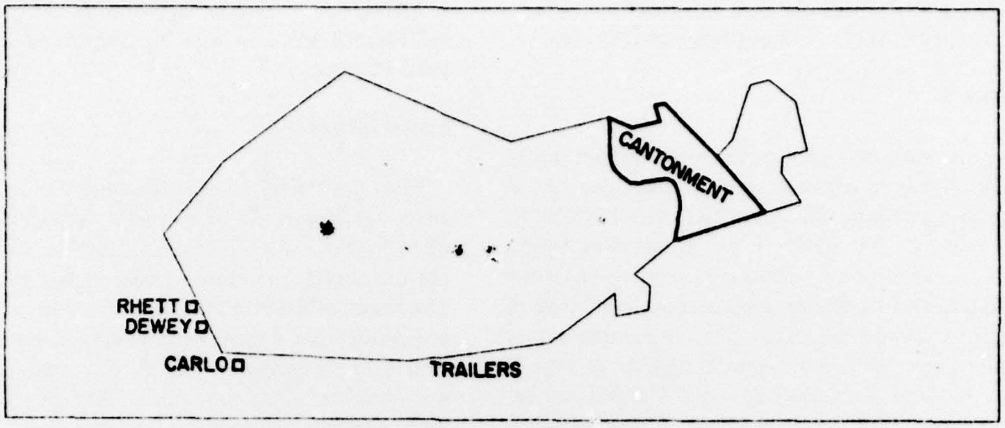
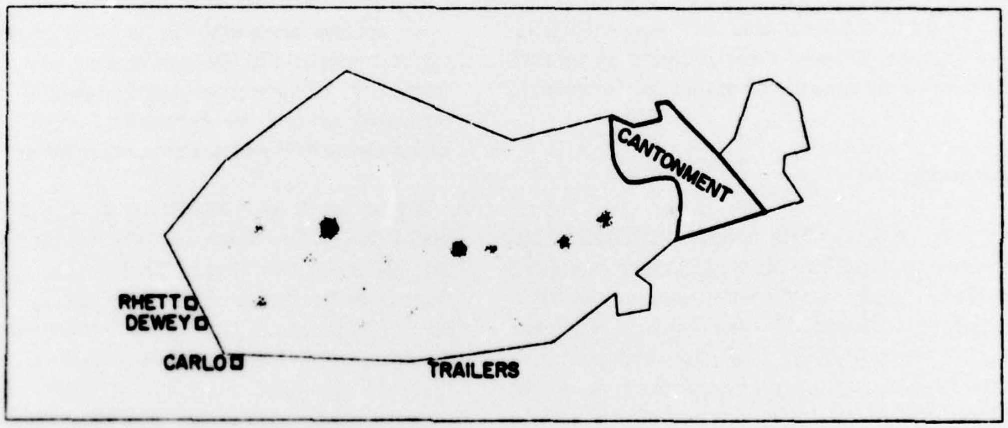


Figure 8. Initial noise contours at Fort C.



a. Day operations



b. Night operations

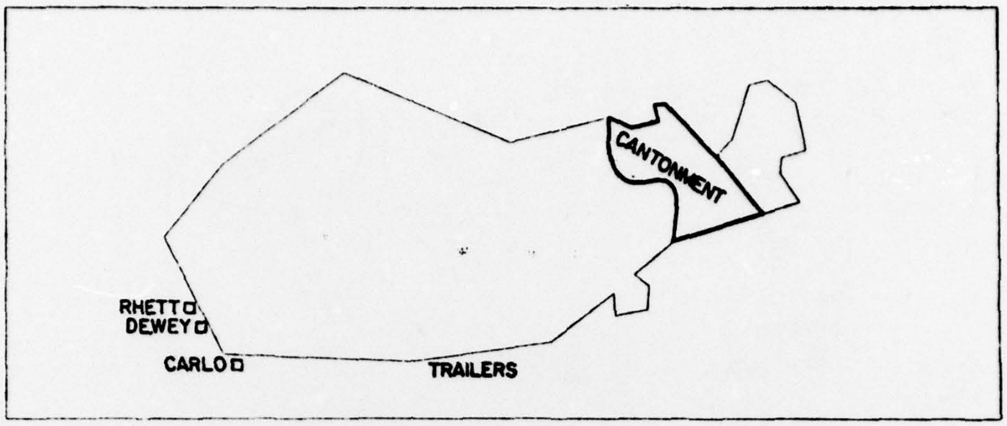
Figure 9. Scattergram of initial operations at Fort C.

During the fourth quarter, operational changes effected a large reduction in firing at Fort C. (Figures 10a and 10b are scattergrams of Fort C's fourth quarter operations and update Figures 9a and 9b, respectively.)

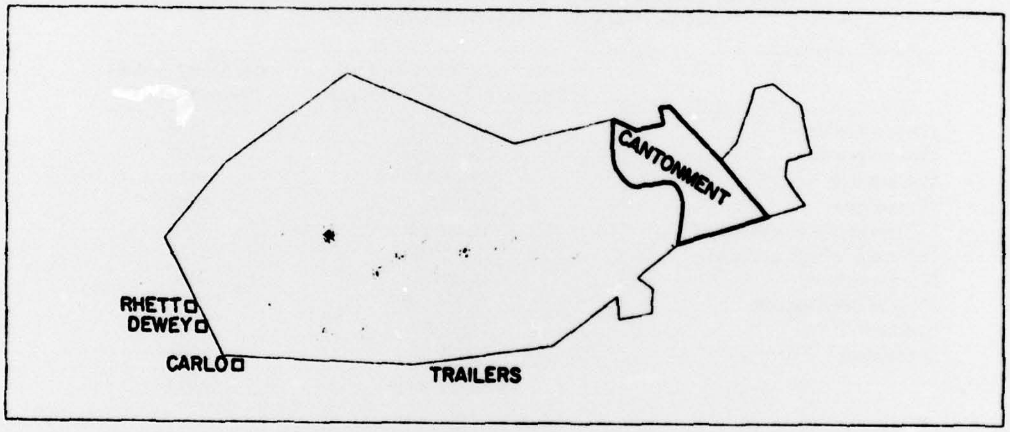
Table 8 charts Fort C's 1976 and 1978 *daily* operations and lists total adjusted charge weights for each weapon type. Note that the proportion of day to night operations changed only slightly. In the initial case (1976), the ratio of total day operations to total night operations was 455/102 = 4.6; the final ratio was 166/34 = 4.8. Since the day-to-night ratio did not change significantly, noise-impact reduction was achieved by reducing operations. The number of operations at Fort C from 1976 to 1978 has decreased from 567 to 200. The reduction in adjusted total weight was even greater than the reduction in number of operations because the number of large weapon firings were reduced by a greater amount than the total:

$$\text{REDUCTION FACTOR} = 26{,}930/7{,}210 = 3.7 \qquad \text{[Eq 5]}$$

Figure 2 shows this corresponds to a 6 dB noise-level reduction.



a. Day operations



b. Night operations

Figure 10. Scattergram of final operations at Fort C.

Final Contours

Figure 11, the final Fort C contour, shows the predicted general noise-level shift (approximately 6 dB). The new 55 dB contour falls slightly inside of the old 60 dB contour to the east and west of the installation and coincides with the old contour in the south and north.

The new 60 dB contour is less elongated than the old contour because Fort C's extreme east and west firing points were eliminated. The shape of the higher-level contours, the old 65 dB and the new 60 dB, is more sensitive to the change in distribution of firing points since these contours are closer to the noise sources. For these higher-level contours, the new contour lies *outside* the old contour north and south of Fort C, but *inside* the old contour in the east and west. This change in the contour shape is beneficial to towns near Fort C's western boundary and cantonment area. However, the new contour bulges in the area containing houses and trailers along the southern boundary of Fort C, indicating an increase in noise impact.

Results

The noise impact from the 1978 operations places 10,500 acres (4200 ha) within the level of 65 dB or higher to the south of Fort C. A small portion of this

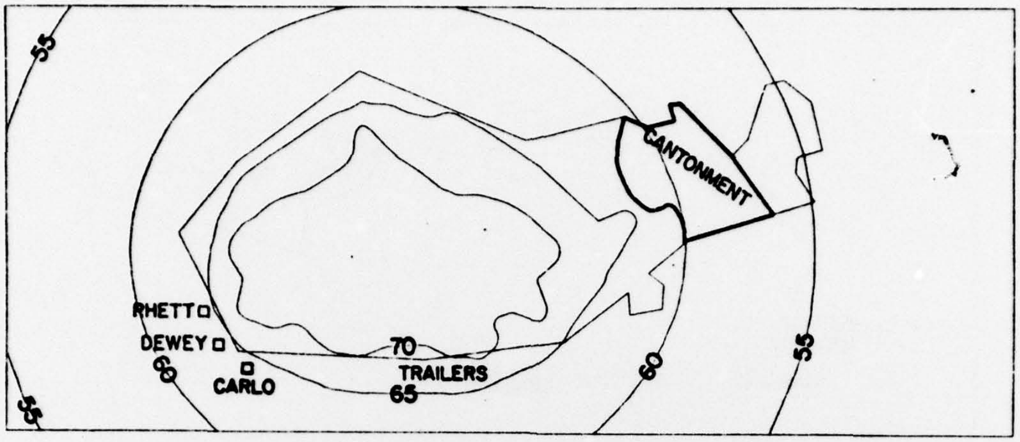


Figure 11. Final noise contours at Fort C.

Table 8

Initial and Final Day/Night/Adjusted Total Number of Operations and Total Adjusted Charge Weights for Fort C

	Day/Night/Adjusted Total Number of Daily Operations	Total Adjusted Daily Charge Weight*
105-mm howitzer	175/32/495	2450
155-mm howitzer	125/24/365	8200
8-in. howitzer	24/7/94	5430
175-mm gun	33/5/83	5850
152-mm gun (armor piercing)	10/2.5/35	560
152-mm gun (high explosive)	21/7/90	1110
107-mm mortar	49/19/241	2040
105-mm recoilless rifle	12.5/.5/18	190
M60 tank	14.5/5/65	900
Demolitions	1.5/0/1.5	200
	465/102/1488	26930
	Final	
105-mm howitzer	44/8.2/126	830
155-mm howitzer	58/17/230	5150
152-mm gun (armor piercing)	6/5/55	910
81-mm mortar	24/3.8/61	150
2.75-in. rocket	31/0/31	160
90-mm recoilless rifle	3/0/3	10
	166/34/506	7210

*WT = W_d + (10 × W_n); metric conversion: 1 lb = .453 592 kg.

region (370 acres [150 ha] is within the 70 dB or higher range.

6 CONCLUSIONS

1. The choice of the type of operational change used to reduce noise impact depends on the configuration of the installation. For small installations surrounded by noise-sensitive regions, noise levels must be reduced in general (Case A). Installations which are spread out with widely separated impact areas can move operations away from noise-sensitive areas (Case B). Larger installations can reduce off-post impacts by concentrating operations toward the center of the installation (Case C).

2. General reduction of noise impacts is significantly effected by two factors: night firing, and firing of larger weapons. Although not an exact measure, the total adjusted charge weight can be used to predict the change in noise levels which will result from a change of operations.

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