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AA VULNERABILITY CHARACTERISTICS OF EMERGENCY OPERATING CENTERS (EOC'S) IN BLAST-RISK AREAS DCPA WORK UNIT 1622A JANUARY 1977

FINAL REPORT

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by
CURTIS LANG

for
DEFENSE CIVIL PREPAREDNESS AGENCY
WASHINGTON, D.C. 20301

CONTRACT NO. DCPA 01-75-C-0337
DCPA WORK UNIT 1622A

AGBABIAN ASSOCIATES

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) VULNERABILITY CHARACTERISTICS OF EMERGENCY OPERATING CENTERS (EOC'S) IN BLAST-RISK AREAS		5. TYPE OF REPORT & PERIOD COVERED Final Report. June 1975 – November 1976
		6. PERFORMING ORG. REPORT NUMBER AA-R-7611-4314
7. AUTHOR(s) Curtis/Lang		8. CONTRACT OR GRANT NUMBER(s) DCPA01-75-C-0337
9. PERFORMING ORGANIZATION NAME AND ADDRESS Agbabian Associates, 250 North Nash Street, El Segundo, California 90245		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 1622A
11. CONTROLLING OFFICE NAME AND ADDRESS Defense Civil Preparedness Agency, Washington, D.C. 20301		12. REPORT DATE January 1977
		13. NUMBER OF PAGES 140
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 131p.		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

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

Emergency Operating Centers, Blast-resistant Characteristics, Vulnerability Characteristics, Vulnerability Reduction, Nuclear Weapons Effects, Upgrading Techniques, Cost Estimates of Upgrading, Statistical Inference

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

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20. ABSTRACT (continued)

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ACKNOWLEDGMENTS

The contents of this report have been enriched by contributions from sources other than the author. Guidance, suggestions, and direction were provided by Donald A. Bettge and George N. Sisson of the Hazard Evaluation and Vulnerability Reduction Division, Research and Engineering Directorate, DCPA. EOC data were acquired with the full support of the 8 DCPA Regional Offices, various state and county civil-preparedness agencies, and the officials of the 25 state and local EOCs that were visited and inspected. Technical support was given by several members of the staff of Agbabian Associates. H.S. Ts'ao reviewed the statistical approach used. The entire report was reviewed and critiqued by M.S. Agbabian and R.W. Anderson.

DETACHABLE SUMMARY

FINAL REPORT

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by
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FINAL REPORT
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The technical approach to obtain an estimate of the total cost for reducing the vulnerability of all Emergency Operating Centers (EOCs) to all nuclear-weapon effects except for radioactive fallout and EMP involved the following:

a. Establishing an appropriate statistical method

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c. Collecting data for the EOC sample

d. Performing vulnerability reductions for the sample EOCs

e. Estimating the costs of the vulnerability reductions of the sample EOCs

f. Obtaining by statistical inference the estimate of the total cost for the vulnerability reduction of all EOCs

Figure S-1 presents a flow chart highlighting the approach used.

Starting with the DCPA listing of all EOCs (i.e., 3616 EOCs), 143 EOCs were randomly selected from the EOCs located in "high risk" areas for a preliminary survey. Of these 143 EOCs, 18 EOCs no longer existed, given a net sample of 125 EOCs, with size distributions as shown in Figure S-2. From this sample of 125 EOCs, 25 EOCs were selected for in-detail inspection. Additionally, three hypothetical, but representative EOCs were chosen to cover the entire range of the EOCs with regard to EOC sizes and aboveground/belowground locations. Each of the 25 *belowground* EOCs of the 28-EOC sample was assessed as to its vulnerability and was upgraded to a 10-psi hardness, and the cost of such vulnerability reduction was estimated. Figure S-3 shows the unit upgrading costs for the 25 EOCs and presents a curve of point estimates of unit upgrading costs for all belowground EOCs located in "high risk" areas. For each of the three aboveground EOCs of the 28-EOC sample, preliminary designs for separate, belowground, hardened facilities (new construction) were developed and their costs estimated. Figure S-4 shows a curve of point estimates for the unit costs of such new EOC construction. By statistical inference the average unit cost of upgrading ($/ft^2) and the total cost of upgrading of the estimated 1333 EOCs located in "high risk" areas were deduced. The data shown in Figures S-2, S-3, and S-4, the ratio of aboveground to belowground EOCs, and the estimate of the number of existing EOCs located in "high-risk" areas constituted the base for inference.

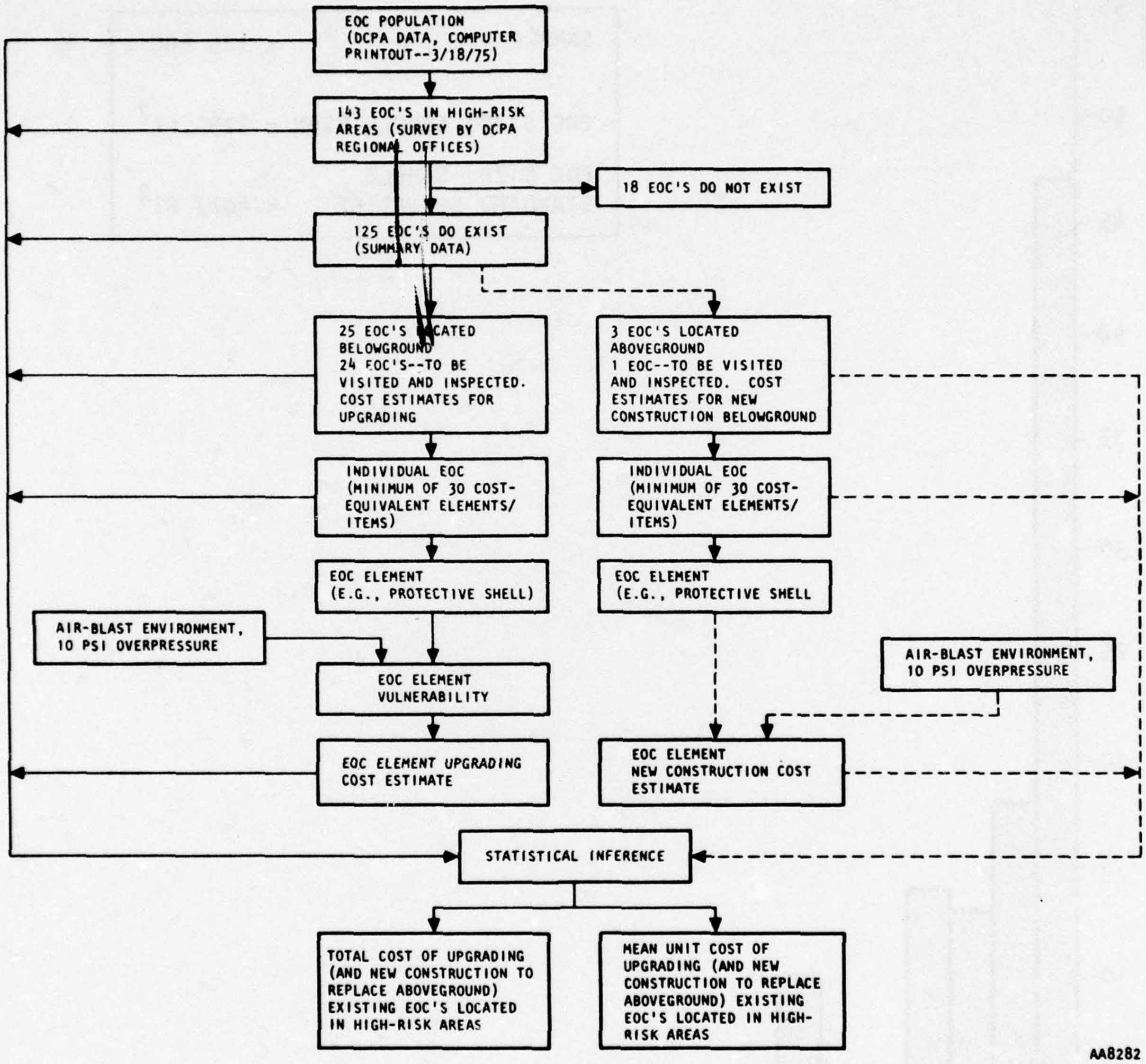
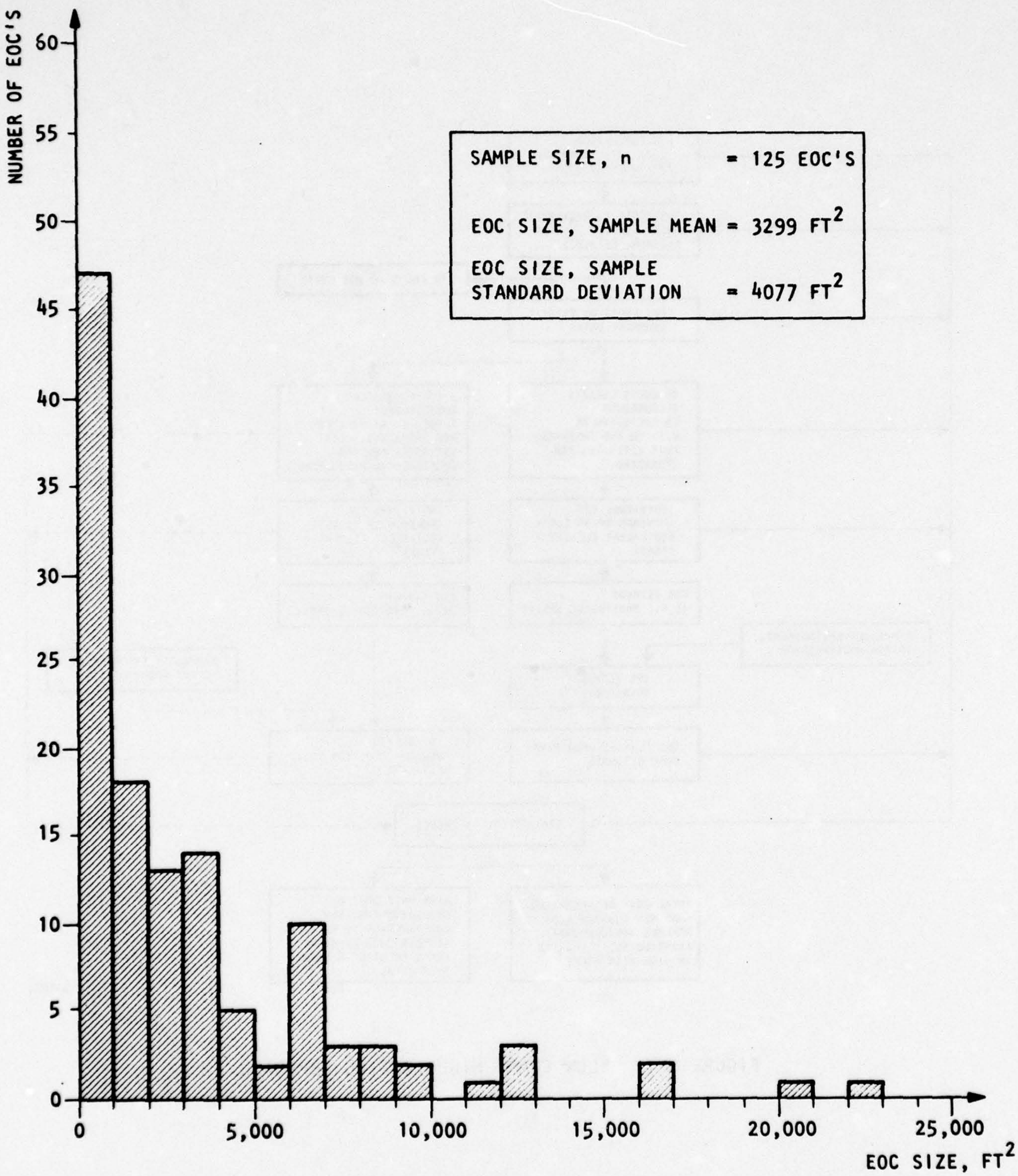


FIGURE S-1. FLOW CHART HIGHLIGHTING APPROACH



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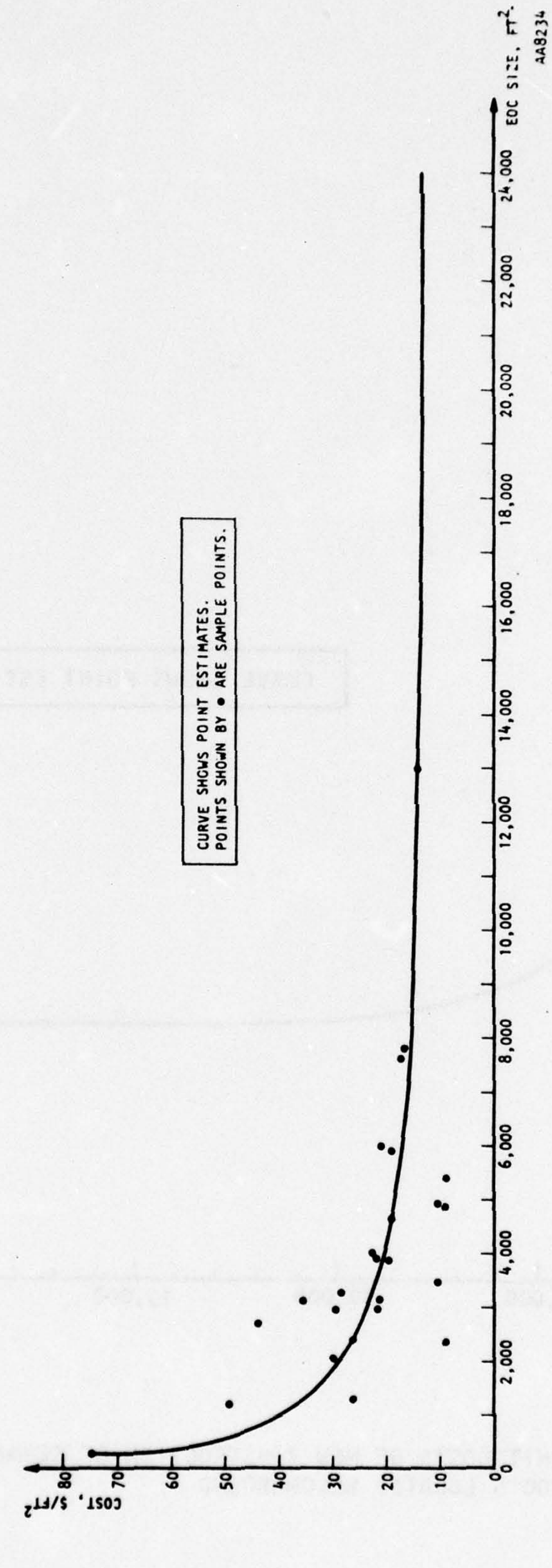

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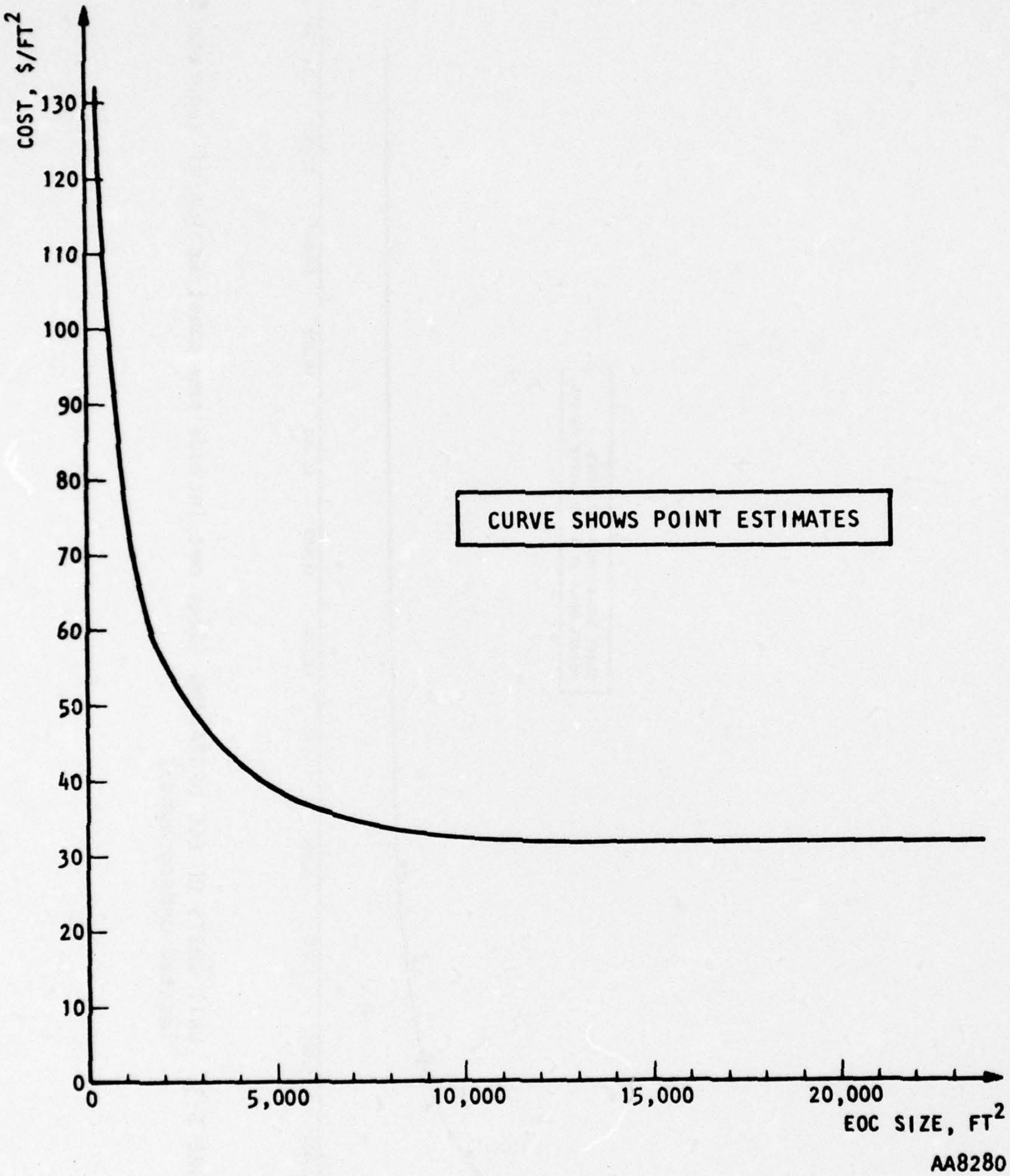

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CONCLUSIONS AND RECOMMENDATIONS

It is estimated that the unit costs (based on average 1975 construction costs) to reduce the vulnerability of all EOCs located in "high-risk" areas with expected air-blast overpressures of equal to or greater than 2 psi by upgrading to a 10-psi hardness level (without the consideration of the effects of nuclear fallout and EMP) are at 95% confidence--

a. Between $\$16/ft^2$ and $\$24/ft^2$ for belowground EOCs and aboveground EOCs to be relocated to belowground building spaces

b. Between $\$18/ft^2$ and $\$34/ft^2$ for belowground EOCs and aboveground EOCs to be replaced by new, hardened construction of separate EOC facilities located belowground

The corresponding total upgrading costs for all EOCs located in "high-risk" areas, i.e., an estimated 1333 EOCs, are estimated to be at 95% confidence--

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The 95% confidence intervals estimated for the EOC population upgrading costs could have been significantly reduced by simultaneous, appreciable increase (e.g., doubling) of the two sample sizes for the basic cost sample of 25 EOCs and 3 EOCs and the EOC size distribution sample of 125 EOCs. But the limited budget for this project effort did not permit this. However, the provided cost estimates, at 95% confidence, of $\$20/ft^2$ $\pm\$4/ft^2$ and \$87,500,000 ±\$17,500,000 for the upgrading approach defined in *a*, and of $\$26/ft^2$ $\pm\$8/ft^2$ and \$115,000,000 ±\$35,000,000 for the upgrading approach defined in *b*, reflecting estimate accuracies of approximately ±20% and ±30% at 95% confidence, respectively, can be considered reasonable estimates.

The following recommendations for additional work related to the material covered in this report are offered for consideration.

Program Plan

The development of a program plan (contingency plan) for the vulnerability reduction of the EOC population predicated in this report is recommended. Such a plan should address the following:

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EOC Seminar

Many local EOC officials are unrealistically optimistic about the operational survivability of their facilities. They do not have an appreciation of the possible nuclear-weapons effects and the associated protection

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Examples of Actual EOC Upgrading

The author's previous report, *Blast-Resistant Characteristics of State and Local Emergency Operating Centers (EOCs)*, as well as other DCPA guidelines and reference material, will provide a good starting point for the engineer faced with upgrading an individual EOC. But since EOCs and hardened structures are not everyday design problems with which he is thoroughly familiar, examples of actual EOC upgrading may be very valuable to him. These examples, covering the few most prevalent types of upgradable existing EOCs, would have to include the required design calculations, complete drawing packages (but not necessarily all shop and fabrication details), and cost estimates.

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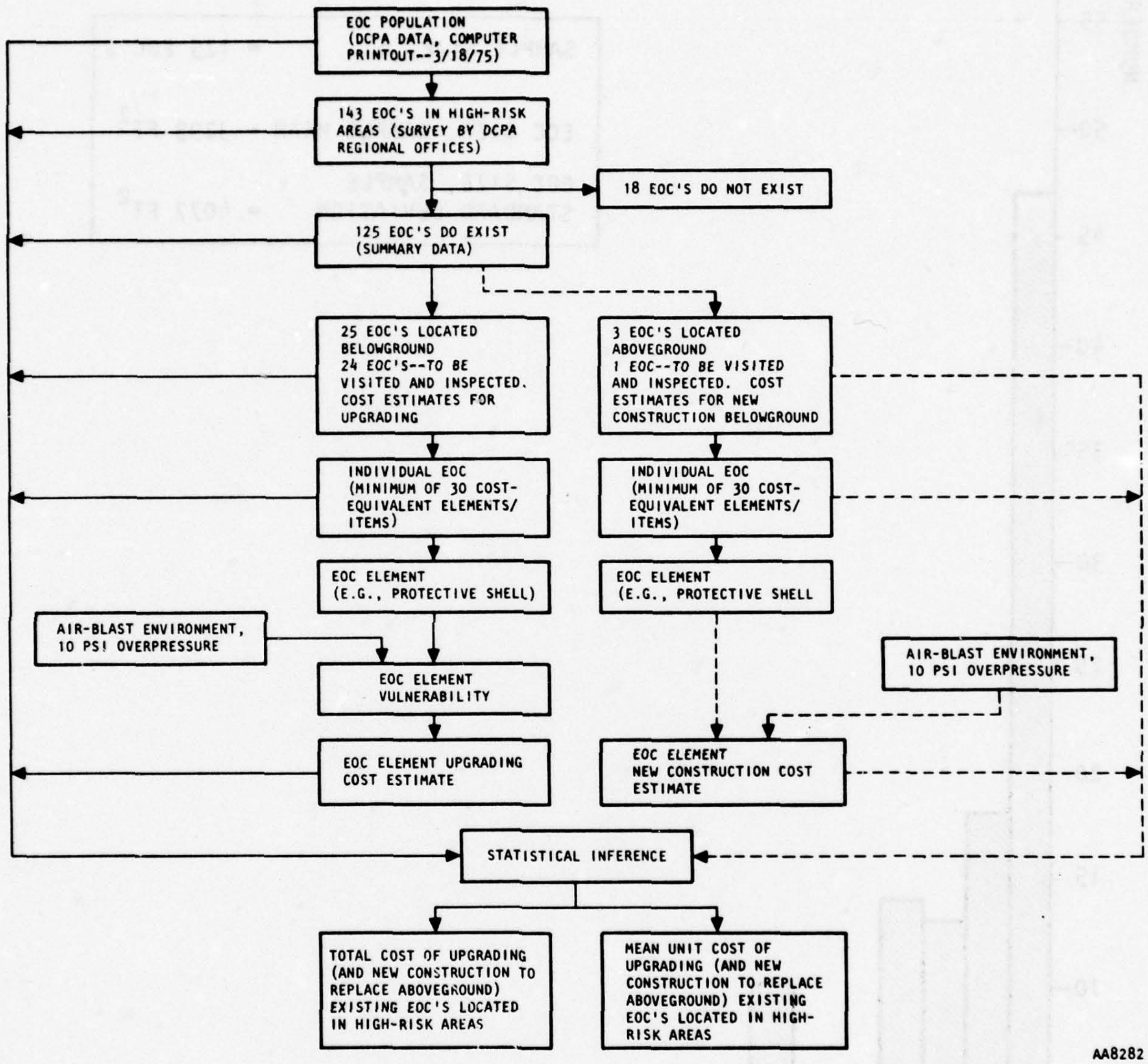

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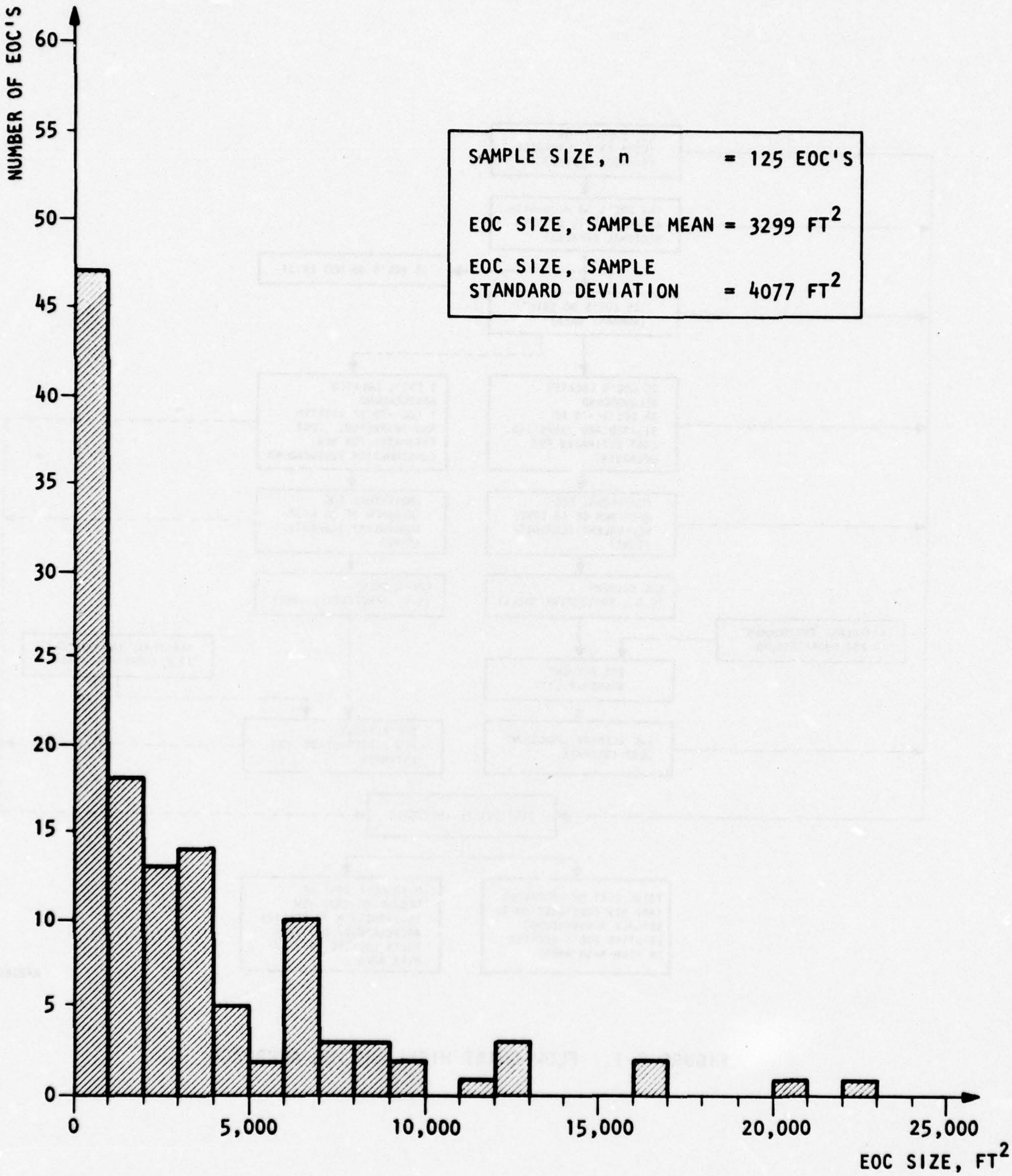

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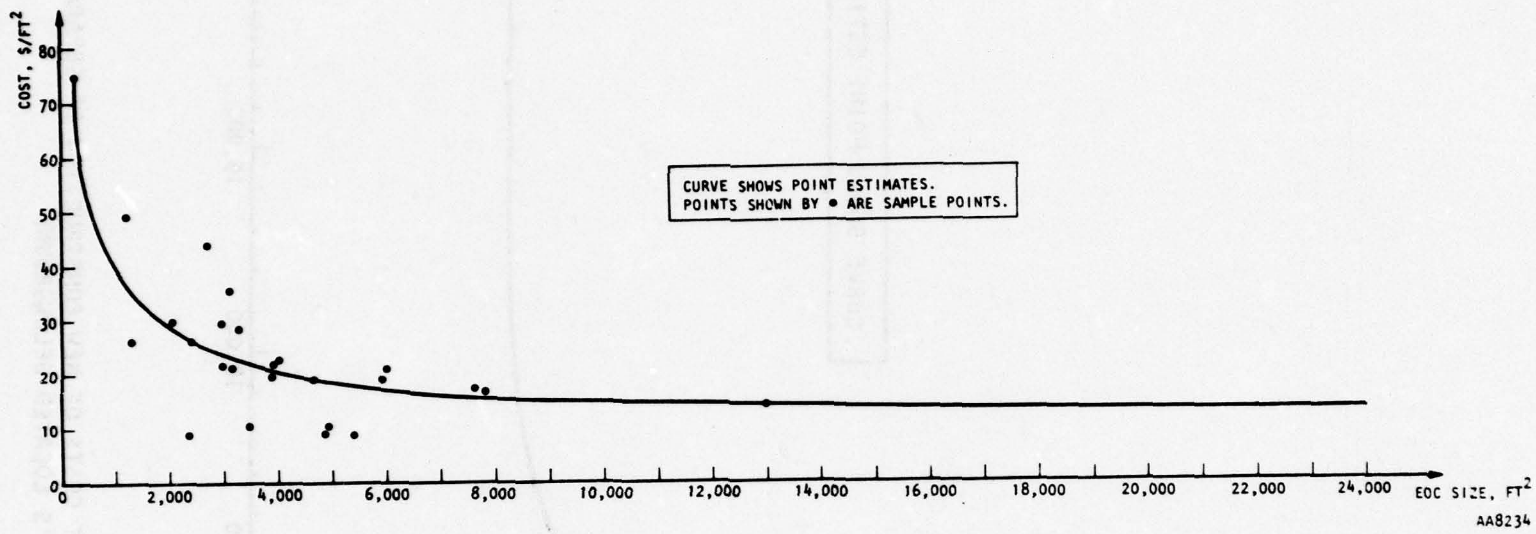

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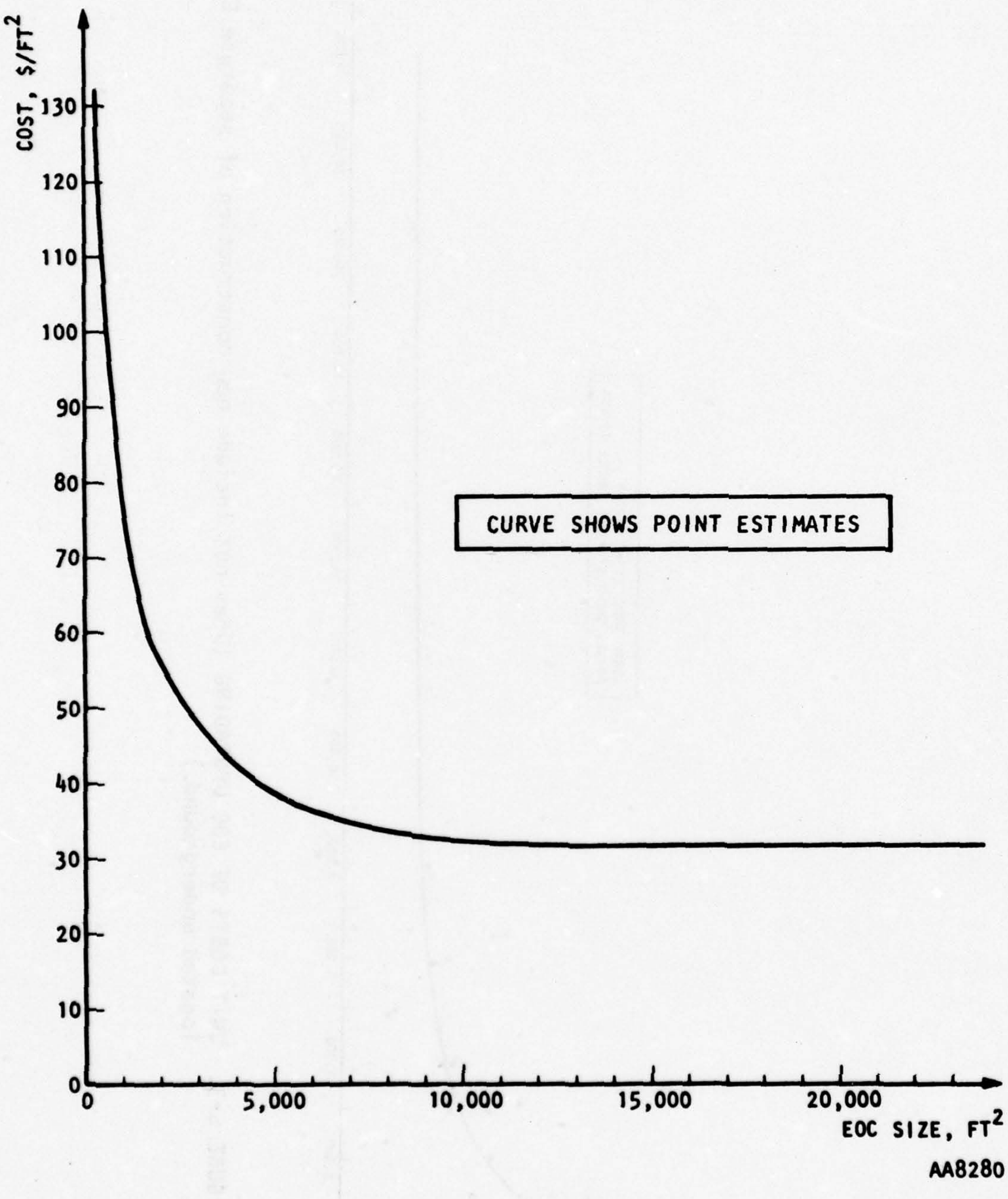

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CONTENTS

ILLUSTRATIONS

ILLUSTRATIONS (CONTINUED)

TABLES

SECTION 1

INTRODUCTION

This is the final report of the research work conducted by Agbabian Associates for the Defense Civil Preparedness Agency under Contract No. DCPA01-75-C-0337, entitled, *Vulnerability Characteristics of Emergency Operating Centers (EOCs).*

The objective of this project was to obtain an estimate of the total cost for reducing the vulnerability of all Emergency Operating Centers (EOCs) to all nuclear-weapon effects except radioactive fallout and EMP. Section 2 outlines the specific project objective and defines the scope of work.

Section 3 delineates the approach and methods used to reach the project objective. Section 4 discusses the research accomplished, and Section 5 presents conclusions and recommendations. The Appendix to this report provides additional EOC data in support of the conclusions reached.

SECTION 2

PROJECT OBJECTIVE AND SCOPE OF WORK

The objective of this project was to obtain an estimate of the total cost for reducing the vulnerability of all emergency operating centers to nuclear-weapon effects except radioactive fallout and EMP. By DCPA direction, this reduction of vulnerability was to be interpreted as the upgrading of all EOCs located in "high risk" areas (i.e., areas with expected air-blast overpressures equal to or exceeding 2 psi) to functionally resist the nuclear-weapon effects corresponding to a 10-psi air-blast overpressure caused by a 1-megaton surface burst.

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Working from data supplied by DCPA, Agbabian Associates selected a representative sample of the EOC population and collected all relevant data on that sample. Twenty-five sample EOCs were visited, and complete as-built drawing packages were obtained for each. With the aid of the collected data, the vulnerability reduction required for each sample EOC was assessed, and the cost of such modification was determined. By statistical inference from the individual costs for the sample EOCs, the total cost for reducing the vulnerability of all emergency operating centers was estimated.

SECTION 3

METHODS AND APPROACH

The technical approach to obtain an estimate of the total cost for reducing the vulnerability of all Emergency Operating Centers (EOCs) to all nuclear-weapon effects except for radioactive fallout and EMP involved the following:

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e. Estimating the costs of the vulnerability reductions of the sample EOCs

f. Obtaining by statistical inference the estimate of the total cost for the vulnerability reduction of all EOCs

Figure 1 presents a flow chart highlighting the approach used. Numbers of EOCs shown in some of the flow chart boxes indicate results or allocations by judgment, reflecting the conditional or evolutionary character of the approach. Referring to Figure 1, from the EOC population, a total of 3616 EOCs, as defined by DCPA data (computer printout dated 3/18/75), 143 EOCs located in "high risk" areas were selected by stratified random sampling. A survey of these 143 EOCs was conducted by the DCPA Regional Offices to obtain, among other data, verification of EOC existence, EOC size and EOC aboveground/belowground location. From the existing EOCs of this sample, 25 EOCs were selected (again by stratified random sampling means) for visit, inspection, vulnerability reduction and cost estimating of upgrading. Each one of the 25 EOCs was functionally divided into various EOC elements (e.g., protective

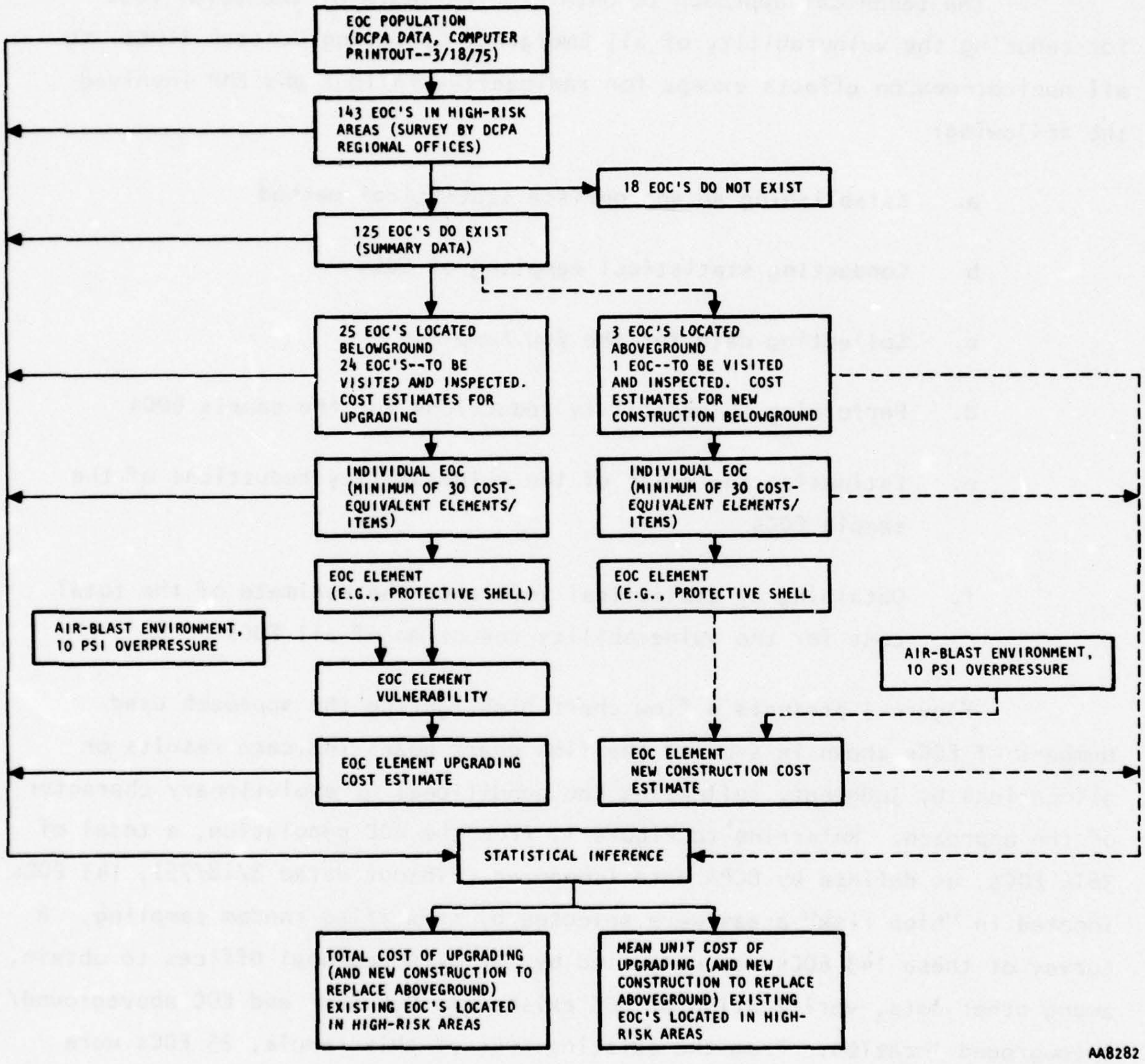

FIGURE 1. FLOW CHART HIGHLIGHTING APPROACH

shell). These elements were subjected to load environments corresponding to a 10-psi air-blast overpressure, thereby assessing their vulnerability. For each EOC element or subelement/item the required upgrading to 10-psi hardness was cost estimated. By statistical inference, using these cost data and population and sample characteristics, the total cost of upgrading and the mean unit cost of upgrading existing EOCs located in "high-risk" areas was established. The branch of the flow chart indicated by dotted connecting lines applies to presently aboveground EOCs that may have to be replaced by new construction of separate, belowground, hardened EOCs.

Two sets of total cost/average unit cost data were generated. The first set provides costs for upgrading belowground and partially exposed EOCs and for relocating totally aboveground EOCs to upgraded belowground spaces (i.e., basements of existing other buildings or belowground areas of future, conventionally constructed buildings). The second set of costs reflects upgrading of the belowground and partially exposed EOCs and new construction of separate, belowground, hardened EOCs to replace existing totally aboveground EOCs.

3.1 STATISTICAL METHOD

The following describes the statistical approach used and the statistical inference process applied in this project.

3.1.1 STATISTICAL APPROACH

Figures 2 and 3 not only depict a road map of the technical approach taken but also present the statistical model used. Figure 2 shows how the pertinent data such as EOC element/item cost, population and sample ratios, and sample distributions were derived. Figure 3 shows how these data were translated by statistical inference into the estimates of total cost and mean unit cost of upgrading existing EOCs located in "high-risk" areas.

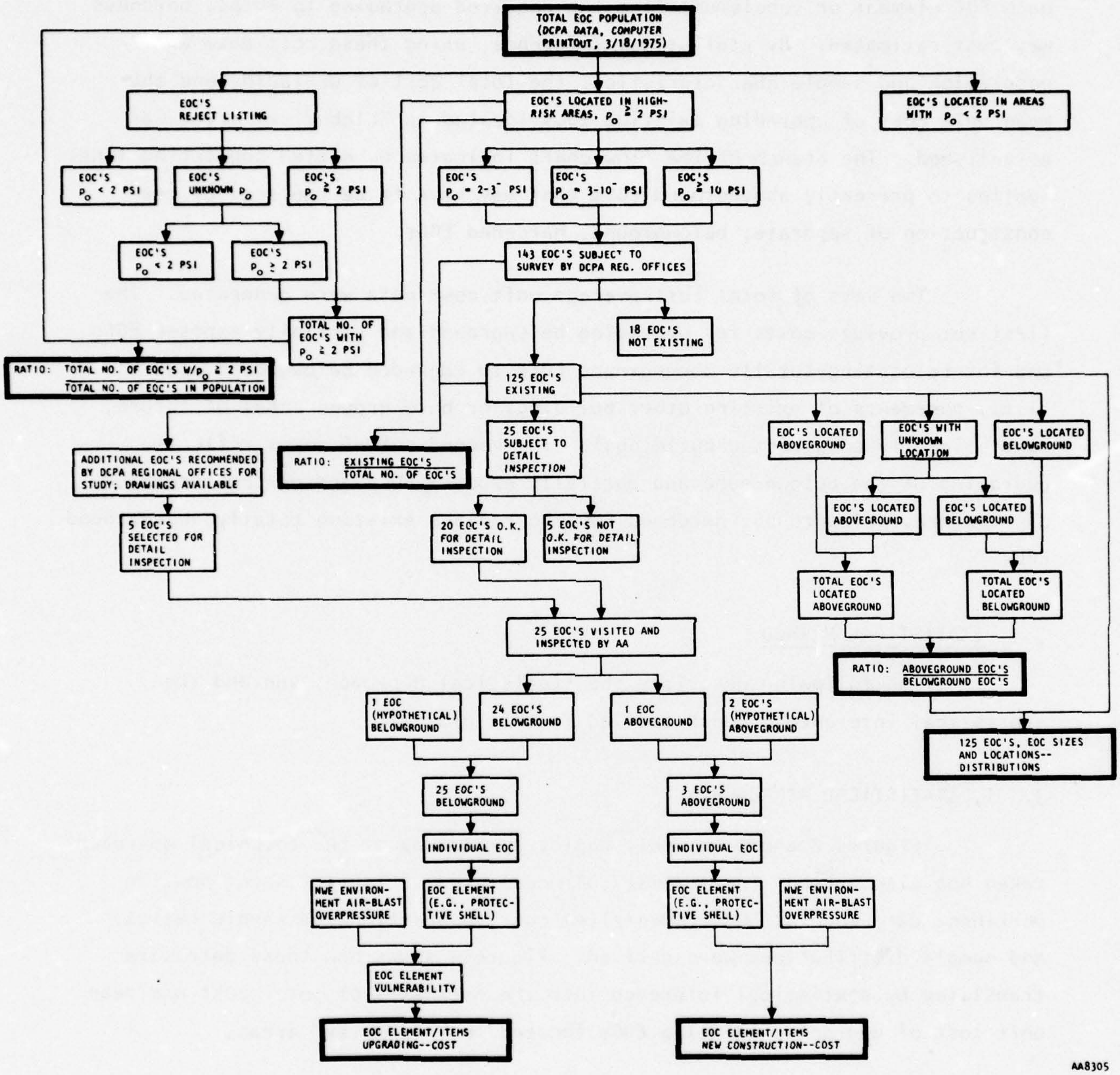

FIGURE 2. FLOW CHART OF APPROACH (Exclusive of statistical inference, which is delineated in Figure 3.)

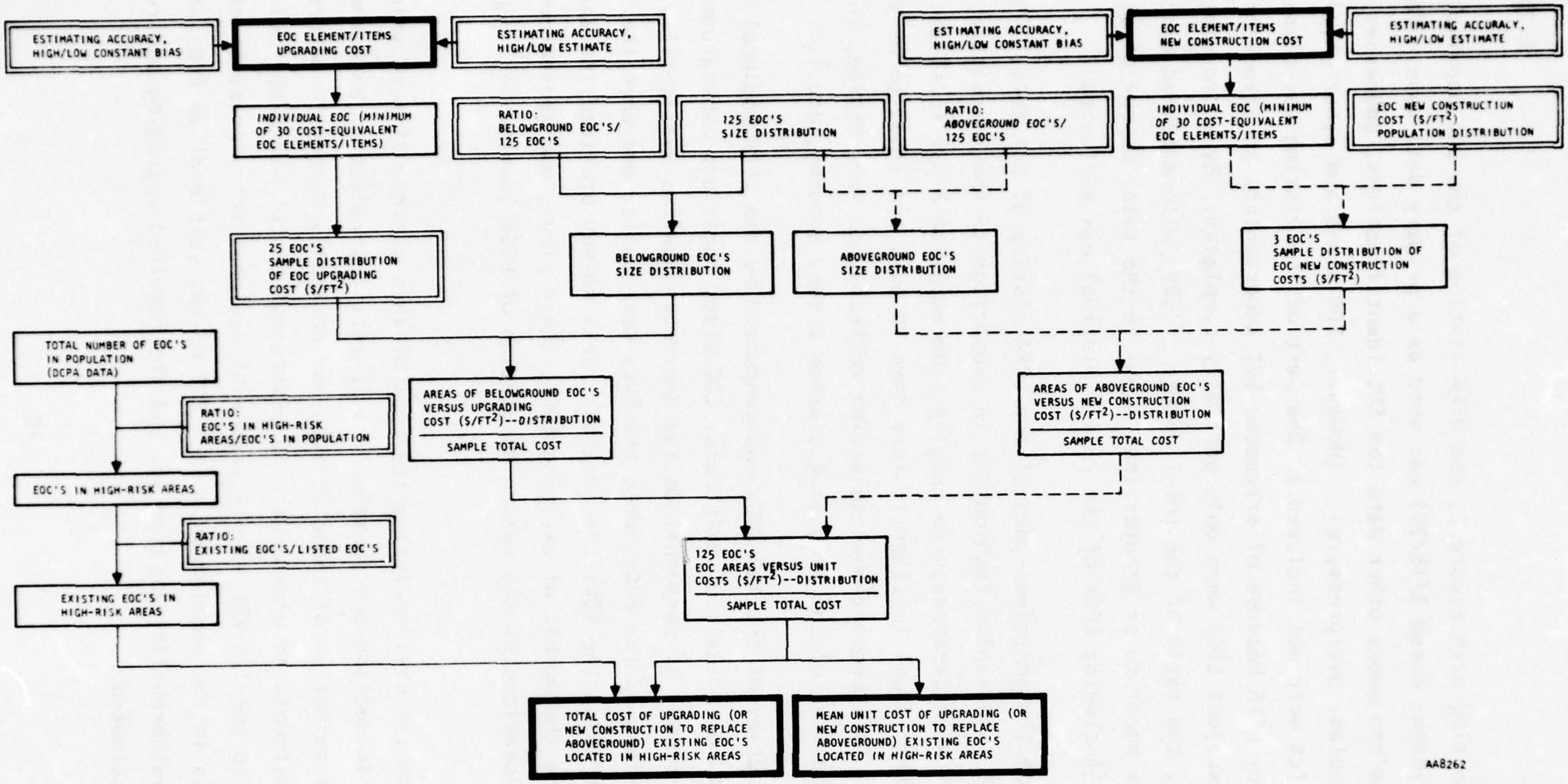

FIGURE 3. FLOW CHART OF STATISTICAL INFERENCE

Starting with Figure 2, the DCPA listing of the EOC population (computer printout dated 3/18/75) was used as a primary data base. This listing contained among other data the EOC identifications, addresses, and expected air-blast overpressures. (However, EOC sizes and other physical characteristics were not included.) One part of the listing was classified as "reject" by DCPA because of erroneous EOC geographical locations or because the subject EOCs were only partially completed. By appropriate apportioning, the ratio of the total number of EOCs with expected air-blast overpressures equal to or greater than 2 psi to the total number of all the listed EOCs (including EOCs of the reject listing) was estimated.

From the nonreject part of the DCPA listing of all EOCs, 143 EOCs were selected in a random fashion but in proportion to the 3 arbitrary categories: EOCs with overpressures ranging from equal to 2 psi to slightly less than 3 psi, from 3 psi to slightly less than 10 psi, and equal to or greater than 10 psi. This proportional selection reflects, to some degree, the geographical locations of the EOCs (e.g., urban areas, suburbs, etc.).

A survey of the 143 EOCs was conducted by the DCPA Regional Offices to obtain data on actual EOC existence, EOC size, locations aboveground or belowground, number of personnel on the emergency staffs, availability of as-built drawings of the EOCs, when the EOCs were built, and when the buildings were built in which the EOCs are located. This survey provided the data base for estimating the number of existing EOCs, their sizes, and aboveground/belowground locations of the entire population of EOCs located in "high-risk" areas.

From the still-existing 125 EOCs of this survey, 25 were selected for detailed inspection and subsequent vulnerability-reduction assessment and costing. The selection of these 25 EOCs was basically random in nature, but included adjustments to ensure both an assortment of EOC sizes/upgrading costs proportional to the 125-EOC sample, and a US regional representation of the number of EOCs in the population. Each EOC of the sample of 25 EOCs was subjected to a vulnerability assessment, and the required upgrading and related costs were estimated.

In order to obtain a better overall representation of the EOC total population, without adding significantly to survey and inspection costs, three hypothetical, but representative, EOCs were added to the sample of 25. Two were posited as totally aboveground EOCs, and one was posited to be a very small (287 sq ft) belowground EOC.

The contents of the heavily bordered boxes shown in Figure 2 present the parameters that, combined and interpreted by the statistical inference method, yielded the estimates of total costs for upgrading the EOC population.

3.1.2 STATISTICAL INFERENCE

Figure 3 delineates the statistical inference process used. Essentially, this process follows the same road map as the statistical approach but in the reverse direction, starting with upgrading costs for EOC elements/items and finishing with the total upgrading cost for the EOC population, integrating all values previously derived from measuring and counting population parameters, sampling, and calculating estimates.

Two sets of total-cost/average-unit-cost data were generated. The first set provides costs for upgrading belowground and partially exposed EOCs and for relocating totally aboveground EOCs to upgraded belowground spaces, such as basements of other existing buildings or belowground areas of future, conventionally constructed buildings. This set of data was established by considering only the items (boxes) connected by the solid lines shown in the flow chart of Figure 3 and following the solid-line arrows in the statistical-inference process. The second set of costs reflects upgrading of belowground and partially exposed EOCs and new construction of separate, hardened EOCs belowground to replace existing EOCs totally aboveground. These costs were generated by considering all items (boxes) shown in the flow chart and following along the solid and dotted lines in the inference process.

The double-lined boxes shown in the flow chart contain the variables (with associated point estimates and confidence intervals) that influence the accuracy of the cost estimates. These variables are defined in detail in Section 4.

To arrive at the total cost-estimating accuracies set as goals, allocation of allowable inaccuracies to the various segments of the estimating chain was judiciously exercised. This allocation was readjusted as required throughout the data acquisition phase.

3.2 SAMPLE EOC'S--VULNERABILITY REDUCTION AND ASSOCIATED COSTS

Twenty-five EOCs were inspected; and in most cases, complete as-built drawing packages were obtained. Each one of these EOCs was assessed for its vulnerability to an expected air-blast overpressure of 10 psi. This was accomplished by isolating the essential elements of an EOC, such as EOC protective shell, shell penetrations, interior structures, equipment, etc., and establishing their individual vulnerabilities. Next, preliminary upgrading designs to increase the EOC hardness to a 10-psi overpressure level were undertaken for each of the EOC elements. (Both vulnerability assessment and upgrading design were guided by the author's publication* and work by others listed in the bibliography of that publication.) Costs of such upgrading for each EOC element were estimated. Although each step was exercised without a great degree of detail, the depth of analysis and cost estimation was considered adequate in light of the array of other inaccuracies that influence the final EOC-population cost estimate.

One of the 25 EOCs was located entirely aboveground, and its upgrading was judged economically exorbitant. Two more cost-effective solutions were considered: (1) a relocation of the EOC to a belowground space of an existing other building (or a future, conventionally constructed building) and an upgrading of that space, and (2) the construction of a new, separate, belowground, and hardened EOC. Both alternatives were evaluated.

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*C. Lang, *Blast Resistant Characteristics of State and Local Emergency Operating Centers (EOCs)*, R-7427-1-3865, Agbabian Assoc., El Segundo, CA, Oct 1975. (AD A016 663).

In addition to the 25-EOC sample, three *hypothetical*, *but representative*, EOCs were examined. Two of these EOCs were assumed to be located aboveground, and one EOC was assumed to be located belowground and of very small size. The inclusion of these three additional EOCs was necessary to cover the spectrum of EOC sizes and to provide at least a minimum of data points for new construction costs of separate, hardened EOCs located belowground.

SECTION 4

DISCUSSION OF RESEARCH ACCOMPLISHED

Section 4 presents a discussion of the research accomplished. Specifically, this section summarizes DCPA's inventory listing of EOCs, highlights the results of a preliminary EOC survey conducted by the DCPA Regional Offices, and describes and discusses Agbabian Associates' EOC survey, individual EOC upgrading cost estimates, and the estimate of upgrading costs for the entire EOC population. Figures 2 and 3, depicting the technical approach and the statistical inference process used, provide an easy-to-follow frame of reference for this discussion.

4.1 DCPA INVENTORY OF EOC'S

The primary or starting point data base for this project was the DCPA inventory list of EOCs as given by the DCPA computer printout of 3/18/75. Table 1 summarizes the salient points of these data with regard to this project. A more detailed summary of these data is given in Appendix A-1.

4.2 PRELIMINARY SURVEY OF EOC'S

From the nonreject portion of the DCPA computer listing of EOCs, 143 EOCs located in "high-risk" areas with expected air-blast overpressures equal to or greater than 2 psi were selected at random but proportional to the number of EOCs in the three overpressure categories (2 to 3^- psi, 3 to 10^- psi, and equal to or greater than 10 psi). These 143 EOCs were surveyed by the DCPA Regional Offices (by record search and phone) in the summer of 1976. The pertinent data obtained by this survey are presented in Table 2. The names, addresses, geographical location codes, and facility numbers of these 143 EOCs are given in Appendix A-2.

Of the 143 EOCs surveyed, 18 EOCs either no longer existed, were no longer functional, or had been consolidated with other EOCs. This left a

TABLE 1. NUMBER AND RISK LOCATIONS OF EOC'S IN THE UNITED STATES
(Summary of DCPA data, computer printout dated 3/18/1975)

DCPA Region	Number of EOCs							
	≥10 psi*	3-10⁻ psi*	2-3⁻ psi*	≥2 psi*†	<2 psi*	Total‡	Reject Listing§	Grand Total**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	164	158	82	404	268	672	584	1256
2	25	15	8	48	61	109	205	314
3	36	18	9	63	137	200	67	267
4	43	15	4	62	59	121	354	475
5	63	55	20	138	394	532	30	562
6	30	33	12	75	219	294	103	397
7	98	29	8	135	84	219	25	244
8	15	7	1	23	56	79	22	101
Total	474	330	144	948	1278	2226	1390	3616

*Located in area of specified expected air-blast overpressure.

†Total of Columns (1), (2), and (3).

‡Total of Columns (4) and (5).

§ Reject listing of EOCs (due to insufficiently identified location or only partial completion of subject EOCs).

**Total of all identifiable EOCs.

TABLE 2. 1975 DCPA SURVEY OF 143 EOC'S--SUMMARY

EOC No. (Net Response)	Region	EOC No. (Initial Request)	EOC Location, City, State	EOC Size, ft^2	Emergency Personnel, No.	Drawings Available (Yes/No)	EOC (Separate/ Sharing Building)	EOC (Above/ Below-ground)	Construction Date EOC	Construction Date Building
--	1	1[*]	Framington, CT	500	4	Yes	Shares	Partially	1972	1969
1	1	2	Meriden, CT	4,788	60	Yes	Shares	Below	1970	1969
2	1	3	Danbury, CT	3,750	50	Partially	Shares	Partially	1971	1970
3	1	4	Trumbull, CT	1,200	44	No	Shares	Partially	1971	1957
--	1	5	Barkhamsted, CT	INFORMATION NOT AVAILABLE						
--	1	6[†]	Auburn (Androsc. Co.), ME	9,000	40	Yes	Shares	Partially	1969	1856
4	1	7	Auburn (city), ME	3,900	50	Yes	Shares	Partially	1971	?
5	1	8	Westbrook, ME	2,200	30	Yes	Shares	Below	1972	1966
--	1	9[‡]	Agawam, MA	560	10	No	Shares	Below	1969	1942
6	1	10	Holden, MA	800	31	?	Shares	Below	1965	1957
7	1	11	W. Boylston, MA	400	22	?	?	?	?	?
8	1	12	Westford, MA	300	19	?	?	?	?	?
9	1	13	Marblehead, MA	360	25	?	Shares	Partially	1970	1856
10	1	14	Watertown, MA	1,920	50	No	Shares	Below	1972	1939
11	1	15	Dracut, MA	1,300	15	?	Shares	Below	?	1875
12	1	16	Fairhaven, MA	600	13	?	?	?	1971	?
13	1	17	N. Wilbraham, MA	1,200	20	?	?	?	1964	?
14	1	18	Brookfield, MA	900	21	?	Shares	Above	?	1893
15	1	19	Sutton, MA	500	10	?	?	?	1964	?
16	1	20	Northbridge, MA	648	30	Yes	Shares	Below	?	1930
17	1	21	Dighton, MA	200	9	?	?	?	?	?
18	1	22	Taunton, MA	1,300	30	?	?	?	1964	?
19	1	23	Littleton, MA	850	12	?	Shares	Below	1964	1950
20	1	24	Granby, MA	500	10	?	?	?	?	?
21	1	25	Hamilton, MA	990	15	?	Shares	Above	?	1957
22	1	26	Lunenburg, MA	400	10	?	Shares	Partially	1970	1952
23	1	27	Hadley, MA	400	8	?	?	?	?	?
--	1	28[§]	Northampton, MA	430	16	--	Shares	Partially	?	1895
24	1	29	Rochester, MA	120	25	?	?	?	?	?
25	1	30	Hopedale, MA	200	21	?	?	?	1964	?
26	1	31	Framingham, MA	300	6	?	?	?	1970	?
27	1	32	Ashland, MA	2,000	10	?	?	?	?	?
28	1	33	Wellesley, MA	400	8	No	Shares	Below	1962	1950
29	1	34	Randolph, MA	4,500	15	?	?	?	1966	?
30	1	35	Rockland, MA	400	15	?	?	?	1966	?
31	1	36	Bridgewater (B.Tn), MA	500	12	?	?	?	1964	?
32	1	37	Bridgewater (E.B.Tn), MA	600	10	?	?	?	1964	?
33	1	38	Litchfield, NH	2,500	6	?	?	?	1969	?
34	1	39	Greenland, NH	150	3	?	?	?	1965	?
35	1	40	Hampstead, NH	300	20	?	?	?	1965	?
36	1	41	Belleville, NJ	1,500	29	?	Shares	?	1971	?
37	1	42	E. Hanover, NJ	80	6	?	Separate ?	Above	1956 ?	1965 ?
38	1	43	Passaic, NJ	756	20	?	?	?	1954	?
39	1	44	Linden, NJ	760	60	?	Shares	?	1964	?
40	1	45	Emerson, NJ	2,000	10	?	Shares	?	1970	?
41	1	46	Cliffside Park, NJ	500	15	?	Shares	?	?	?

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*Not a functional EOC.
†This EOC consolidated with and into Auburn (city), ME.
‡This EOC does not exist anymore.
§No EOC at that location.

TABLE 2. (CONTINUED)

EOC No. (Net Response)	Region	EOC No. (Initial Request)	EOC Location, City, State	EOC Size, ft^2	Emergency Personnel, No.	Drawings Available (Yes/No)	EOC (Separate/ Sharing Building)	EOC (Above/ Below-ground)	Construction Date	
									EOC	Building
42	1	47	No. Haledon, NJ	250	15	?	?	?	1970	?
43	1	48	Trenton, NJ	6,460	76	Yes	Shares	Partially	1972	1972
44	1	49	Hamilton TWP, NJ	5,000	70	Yes	Shares	Below	1966	1966
45	1	50	Chathamboro, NJ	726	24	?	Shares	?	1965	?
46	1	51	Covent Sta., NJ	240	5	?	Shares	?	1971	1965
47	1	52	Fanwood, NJ	120	4	?	?	?	?	?
48	1	53	Princeton, NJ	3,300	32	Yes	Shares	Partially	1972	1967
49	1	54	Buffalo, NY	20,000	200	Yes	Shares	Below	1970	1929
50	1	55	Manhasset, NY	1,250	25	Yes	Shares	Below	1970	1950
--	1	56*	Staten Island, NY	5,600	60	--	Shares	Partially	1970	1938
51	1	57	Plattsburgh, NY	1,180	23	?	Shares	Above	1970	1917
52	1	58	Mt. Vernon, NY	3,200	64	Yes	Shares	Partially	1970	1928
53	1	59	Orchard Park, NY	16,393	216	Yes	Separate ?	Below	1971	1968 ?
54	1	60	Scituate, RI	400	14	?	?	?	1964	?
55	1	61	Jamestown, RI	1,000	12	?	?	?	1964	?
56	1	62	Portsmouth, RI	1,200	18	?	?	?	1964	?
57	1	63	Pascoag, RI	350	16	?	?	?	1970	?
58	2	1	Baltimore, MD	484	10	?	?	?	?	?
59	2	2	Hagerstown, MD	3,400	54	Yes	?	?	?	?
60	2	3	Garrison, MD	3,000	40	?	?	?	?	?
61	2	4	Philadelphia, PA	4,800	65	Yes	?	?	?	?
62	2	5	Virginia Beach, VA	2,313	31	Yes	?	?	?	?
63	3	1	Jacksonville, FL	12,000	120	Yes	Shares	Above	1960	1900
--	3	2	Tallahassee, FL	"THIS BUILDING CAN NO LONGER BE USED FOR AN EOC."						
--	3	3	Jackson, MS	"THE EOC HAS BEEN MOVED TO NEW CENTRAL FIRE STATION."						
64	4	1	Aurora, IL	5,415	65	No	Shares	Below	1966	1966
65	4	2	Springfield, IL	12,760	250	Yes	Shares	Partially	1967	1967
66	4	3	Madison, WI	6,070	84	Yes	Shares	Below	1968	1968
67	4	4	Waukesha, WI	6,070	84	Yes	Shares	Below	1968	1968
68	5	1	Conway, AR	1,400	20	Yes	Shares	Above	1967	?
69	5	2	Marion, AR	1,700	21	Yes	Shares	Above	1969	?
70	5	3	Little Rock, AR	4,600	25	Yes	Shares	Above	1969	?
71	5	4	Ft. Smith, AR	1,600	12	Yes	Shares	Partially	1969	?
72	5	5	Perryville, AR	1,800	23	Yes	Shares	Above	1969	?
73	5	6	Lafayette, LA	8,700	103	Yes	Shares	Below	1968	1968
--	5	7†	Baton Rouge, LA	12,200	151	Yes	Shares	Partially	1967	?
74	5	8	Baker, LA	2,200	31	Yes	Shares	Below	1967	1967
75	5	9	Waggaman, LA	1,120	15	Yes	Shares	Above	1963	?
76	5	10	Plaquemine, LA	3,200	35	Yes	Shares	Above	1968	?
77	5	11	West Lake, LA	300	4	Yes	Shares	Above	1963	?
78	5	12	Monroe, LA	400	5	No	Separate	Above	?	--
79	5	13	Shreveport, LA	900	12	Yes	Shares	Below	1964	?
80	5	14	St. Martinville, LA	800	14	Yes	Shares	Above	1963	?
81	5	15‡	Lawton, OK	6,400	85	Yes	Shares	Above	1974	1974
82	5	16	Oklahoma City, OK	2,500	40	Yes	Shares	Above	1969	?
--	5	17	Tulsa (Co.+City), OK	"NEW EOC IN PLANNING STAGE."						
83	5	18	Tulsa (OK St. Hwy), OK	340	4	Yes	Shares	Above	1970	1970
84	5	19	Altus, OK	3,700	66	Yes	Shares	Below	1969	1969

*No EOC at that location.
†This EOC will be abandoned.
‡Data for new location (new Comanche County Courthouse).

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TABLE 2. (CONCLUDED)

EOC No. (Net Response)	Region	EOC No. (Initial Request)	EOC Location, City, State	EOC Size, ft²	Emergency Personnel, No.	Drawings Available (Yes/No)	EOC (Separate/ Sharing Building)	EOC (Above/ Below-ground)	Construction Date	
									EOC	Building
85	5	20	Houston, TX	6,300	80	Yes	Shares	Below	1969	1969
86	5	21	San Angelo, TX	2,400	32	Yes	Shares	Below	1963	?
87	5	22	Sherman, TX	6,400	56	Yes	Shares	Below	1966	1966
88	5	23	Lubbock, TX	2,800	33	Yes	Shares	Below	1966	?
89	5	24	Brownsville, TX	2,400	50	Yes	Shares	Partially	1963	?
90	5	25	De Soto, TX	2,500	14	Yes	Shares	Above	1970	?
91	5	26	Sachse, TX	400	8	Yes	Shares	Above	1970	?
92	5	27	Tyler, TX	600	15	Yes	Shares	Below	1963	?
93	6	1	Boulder, CO	4,425	52	Yes	Shares	Below	?	1933
94	6	2	Greeley, CO	185	3	Yes	Shares	Below	?	1957
95	6	3	Littleton, CO	7,500	37	Yes	Shares	Below	?	1958
96	6	4	Davenport, IA	1,600	20	Yes	Shares	Below	?	1956
97	6	5	Leclaire, IA	360	22	No	Shares	Partially	?	1925
98	6	6	El Dorado, KS	7,400	36	Yes	Shares	Below	?	1965
99	6	7	Kansas City, MO	3,100	36	Yes	Shares	Below	?	1934
100	6	8	St. Joseph, MO	6,200	30	No	Shares	Below	?	1925
101	6	9	Kirkwood, MO	310	4	Yes	Shares	Partially	?	1932
102	6	10	Lincoln, NB	12,000	205	Yes	Separate	Below	?	1961
103	6	11	Cheyenne, WY	9,800	87	Yes	Shares	Below	?	1965
--	7	1*	Phoenix, AZ	10,700	126	Yes	Shares	Below	--	--
104	7	2	Stockton, CA	6,800	80	Yes	Shares	Above	?	1970
--	7	3†	Pacific Grove, CA	1,600	16	No	Shares	Partially	?	1911
105	7	4	Glendale, CA	3,060	36	Yes	Shares	Below	?	1957
106	7	5	Los Angeles (L.A. Co.), CA	8,500	100	Yes	Shares	Above	?	1930
107	7	6	Los Angeles (CA St. Region 1), CA	16,000	225	Yes	Shares	Below	?	1965
108	7	7	Santa Monica, CA	6,100	80	Yes	Shares	?	?	?
109	7	8	La Verne, CA	850	10	No	Shares	?	?	?
110	7	9	So. Pasadena, CA	3,595	60	Yes	Shares	Below	?	1967
111	7	10	Montebello, CA	11,810	140	Yes	Shares	Below	?	1969
112	7	11	Lynwood, CA	1,600	32	Yes	Shares	Above	?	1959
113	7	12	Downey, CA	22,300	150	Yes	Shares	Above	?	?
114	7	13	Paramount, CA	900	18	?	Shares	?	?	?
115	7	14	Hawthorne, CA	2,200	26	Yes	Shares	Above	?	?
116	7	15	Gardena, CA	3,400	40	No	Shares	Above	?	?
--	7	16†	Lawndale, CA	1,190	14	No	Shares	?	?	?
--	7	17†	Rolling Hills, CA	1,000	12	No	Shares	Above	?	?
--	7	18*	San Bernardino, CA	1,540	22	Yes	Shares	Below	?	?
117	7	19	National City, CA	7,000	104	Yes	Shares	Below	?	1967
118	7	20	El Cajon, CA	3,600	34	No	Shares	Above	?	?
--	7	21†	Oakland, CA	5,420	92	No	Shares	Partially	?	?
119	7	22	Richmond, CA	8,400	60	Yes	Shares	Below	?	1962
120	7	23	San Francisco, CA	2,500	41	Yes	Shares	Above	?	1963
121	7	24	Redwood City, CA	9,760	116	Yes	Shares	Below	?	1972
122	7	25	So. El Monte, CA	3,220	41	Yes	Shares	?	?	1969
--	7	26†	Burlingame, CA	800	16	No	Shares	Above	?	1967
--	7	27†	Campbell, CA	1,360	16	No	Shares	Above	?	?
123	7	28	Corona, CA	925	18	No	Shares	?	?	?
124	7	29	Delmar, CA	1,190	14	No	Shares	Above	?	?
125	8	1	Port Orchard, WA	6,000	80	Yes	Shares	Partially	1970	1949

*EOC relocated.
†No longer an EOC.

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net of 125 existing EOCs. Figure 4 shows the EOC size (measured in square feet) distribution of these 125 EOCs. Because of the large number of small EOCs and their upgrading cost implications, special attention was directed toward them. Figure 5 shows the size distribution of the 26 EOCs with areas equal to or smaller than 400 sq ft (i.e., of the sample of 125 EOCs). Figure 6 presents the distribution of total areas of the 125 EOCs with respect to EOC sizes. Figure 7 gives the distribution of total areas of the 26 smaller EOCs with respect to EOC sizes. Figures 8 through 13 address the aspects of aboveground and belowground EOCs of all 125 EOCs and of the 26 smaller EOCs.

Both EOC total area versus EOC size distribution and EOC locations (aboveground/belowground) are two parameters of the EOC population that have a significant impact on the EOC population upgrading cost. The statistical values shown in Figures 6, 7, 10, and 13 are direct inputs to the cost-estimating equations.

4.3 SURVEY OF 25 EOC'S

From the net 125 EOCs of the DCPA survey, 25 EOCs were selected for visit and in-detail inspection. The method of selection was basically random sampling, but was slightly adjusted to better represent EOC size/probable upgrading costs and U.S. regional differences. A not-minor factor of selection was the availability of EOC as-built drawings. Because of the later unavailability of drawing packages, 5 EOCs of the initial 25 EOCs chosen for visit and inspection had to be replaced. The survey of the 25 EOCs was conducted in the fall of 1975 and winter of 1975/1976. Figure 14 shows the approximate locations of the 25 EOCs visited and inspected. These EOCs are identified in Table 3, which is shown in subsection 4.6.1, and are described in Appendix A-3.

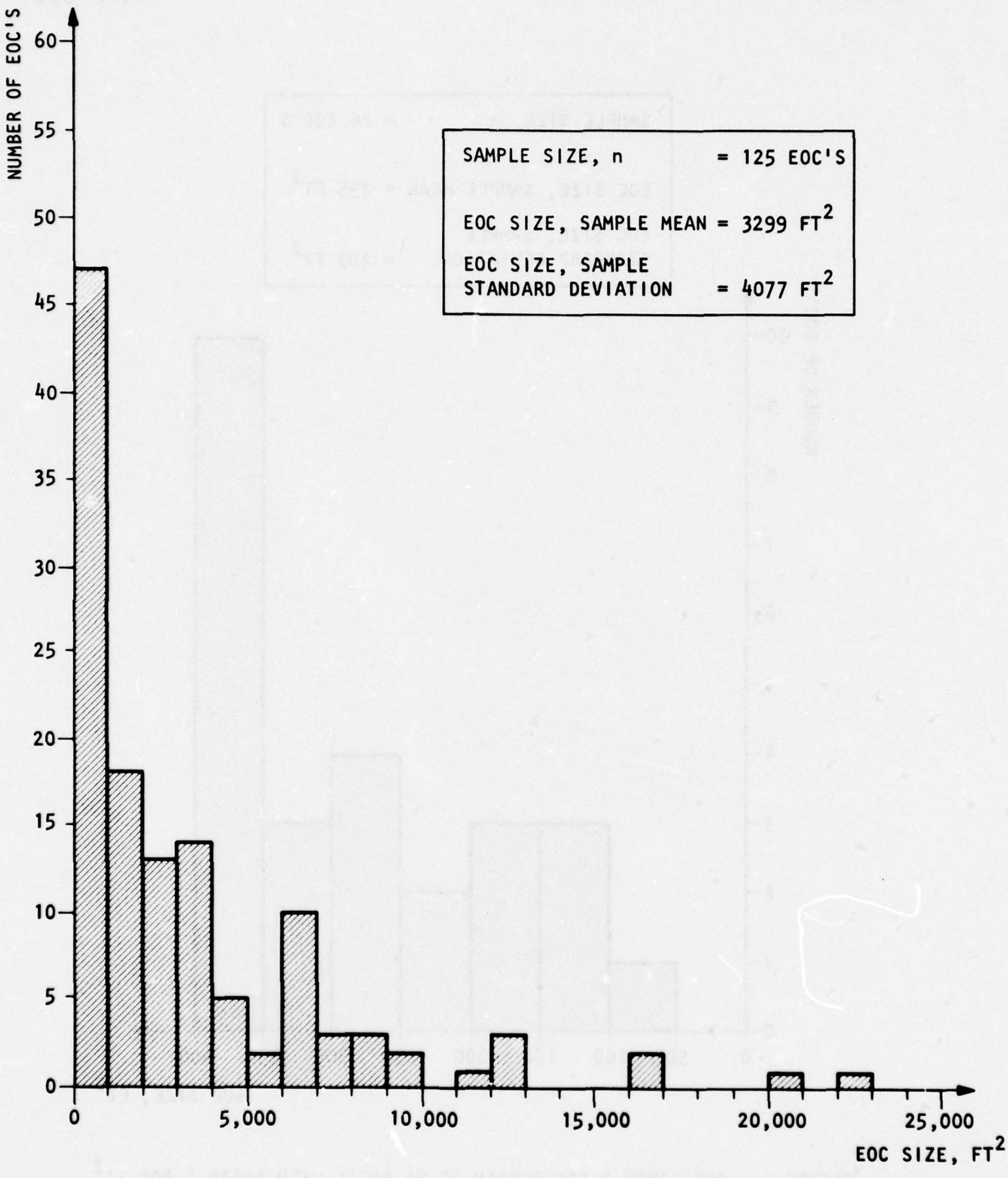


FIGURE 4. DCPA 1975 SURVEY OF 143 EOC'S: FREQUENCY DISTRIBUTION OF 125 EOC'S

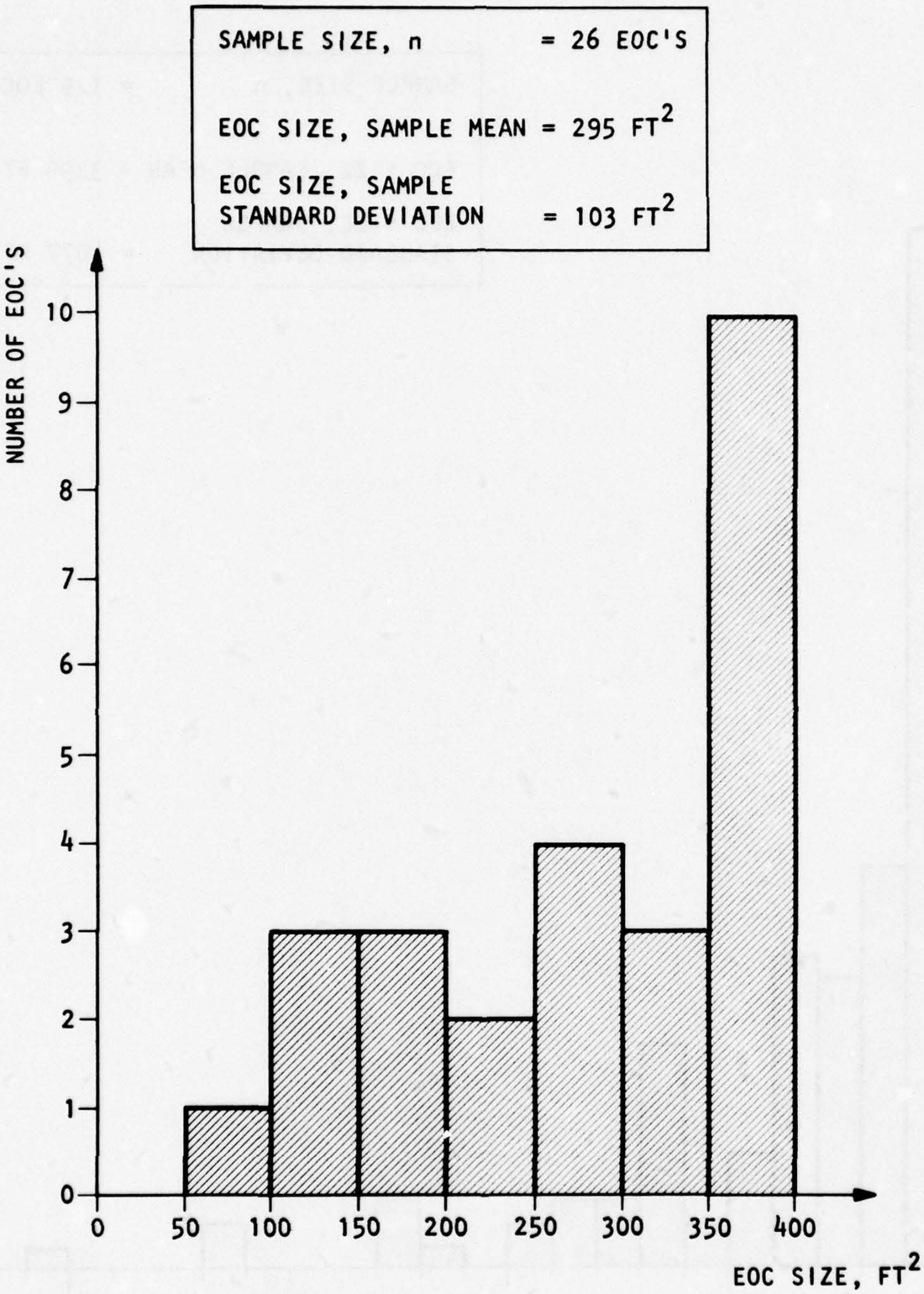


FIGURE 5. FREQUENCY DISTRIBUTION OF 26 EOC'S WITH AREAS ≦ 400 FT^2
(From DCPA 1975 survey of 143 EOCs)

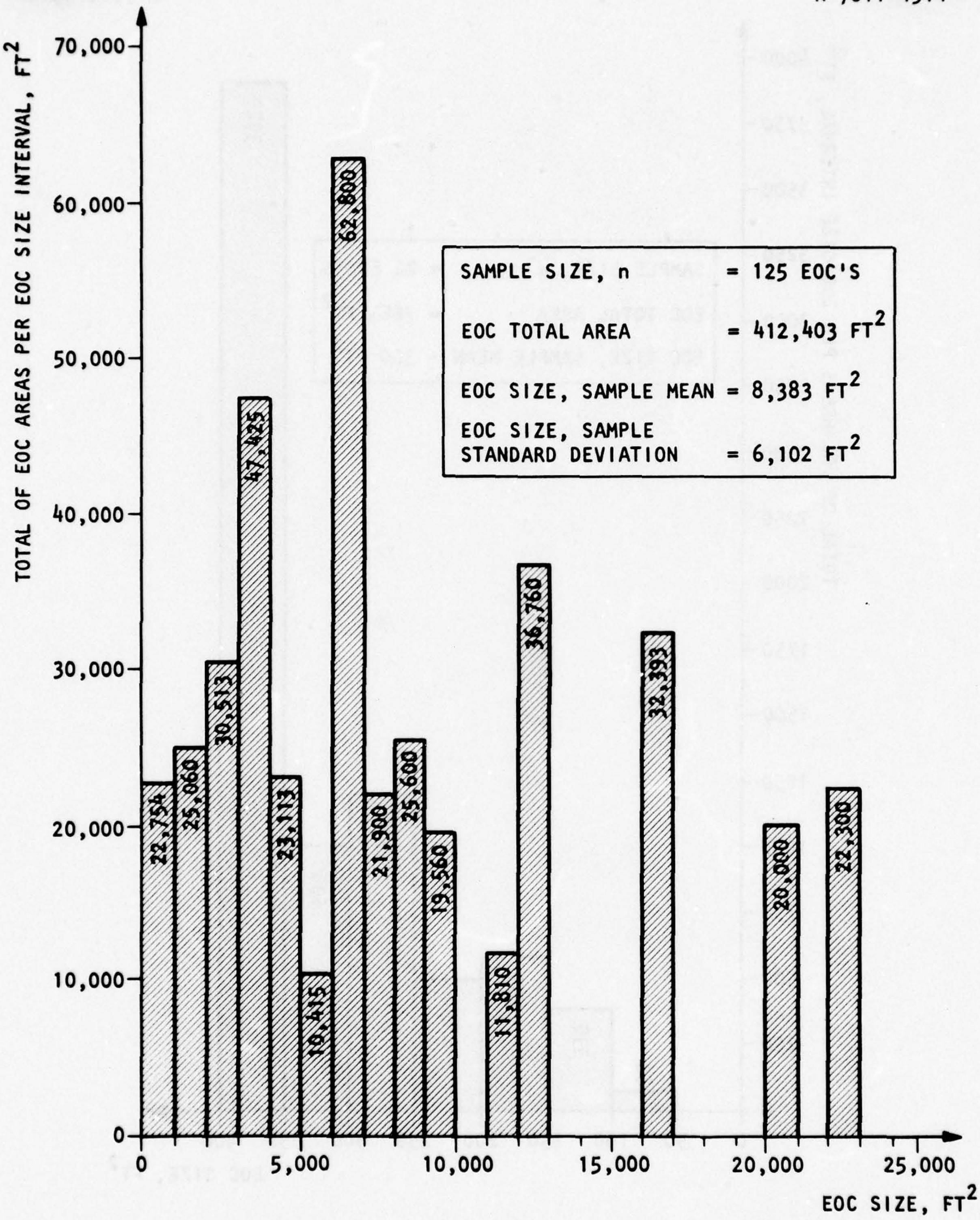


FIGURE 6. DISTRIBUTION OF TOTAL EOC AREAS VERSUS EOC SIZES (From DCPA 1975 survey of 143 EOCs)

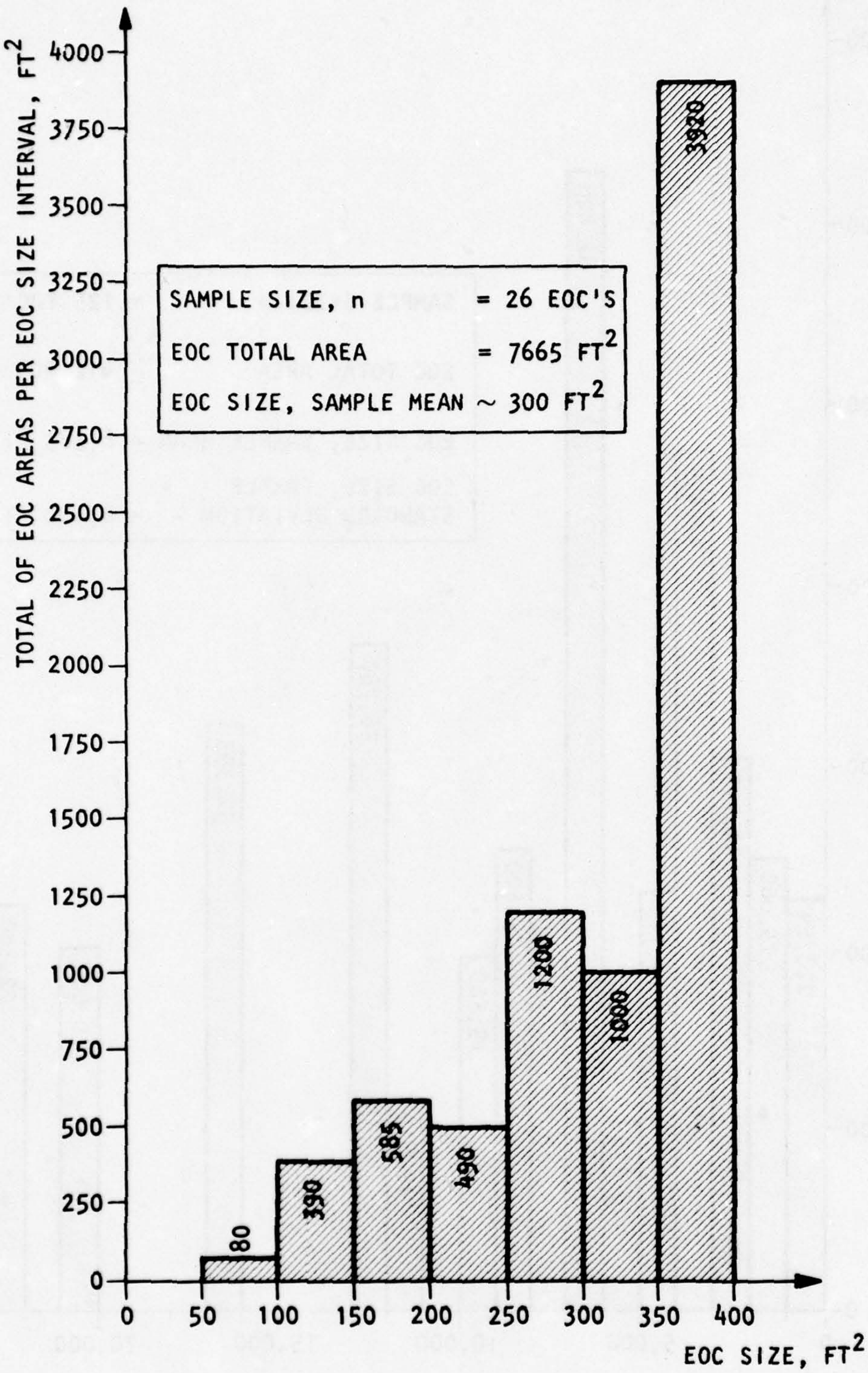


FIGURE 7. DISTRIBUTION OF TOTAL EOC AREAS VERSUS EOC SIZES FOR EOC'S WITH AREAS ≤ 400 FT^2 (From DCPA 1975 survey of 143 EOCs)

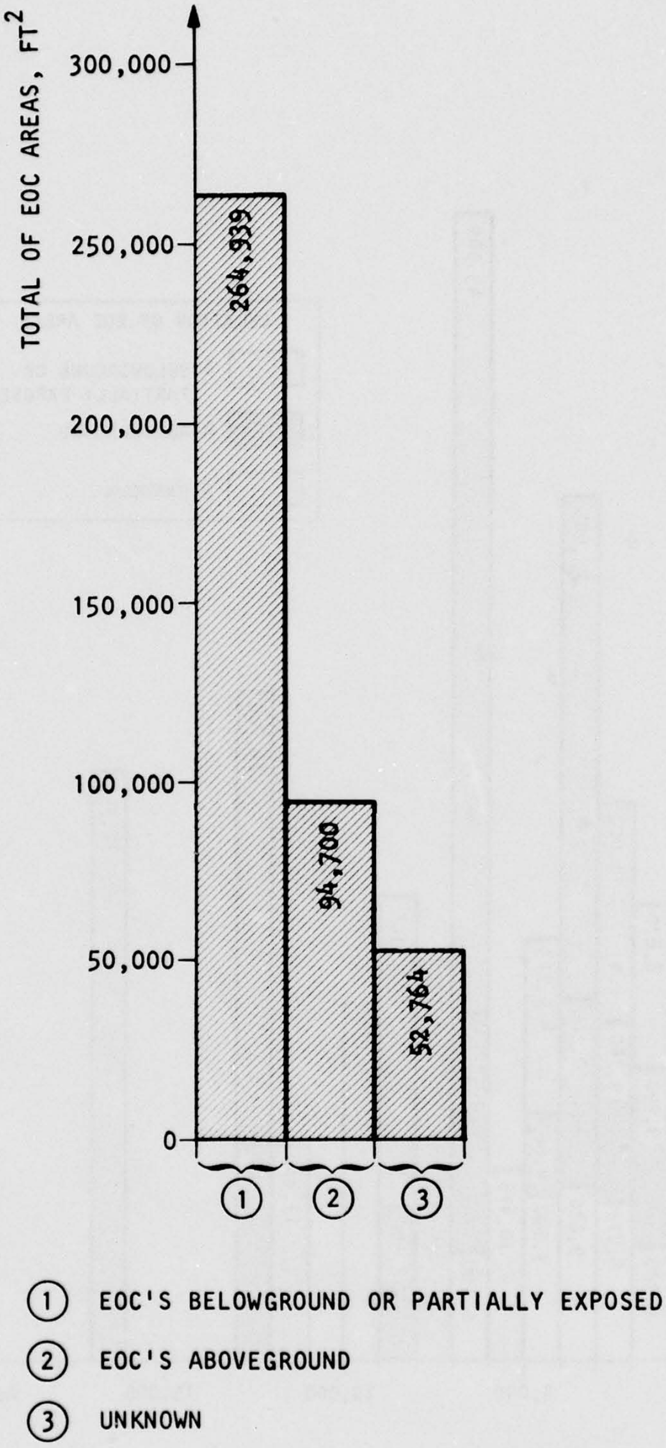


FIGURE 8. BELOW/ABOVEGROUND LOCATIONS OF 125 EOC'S
(From DCPA 1975 survey of 143 EOCs)

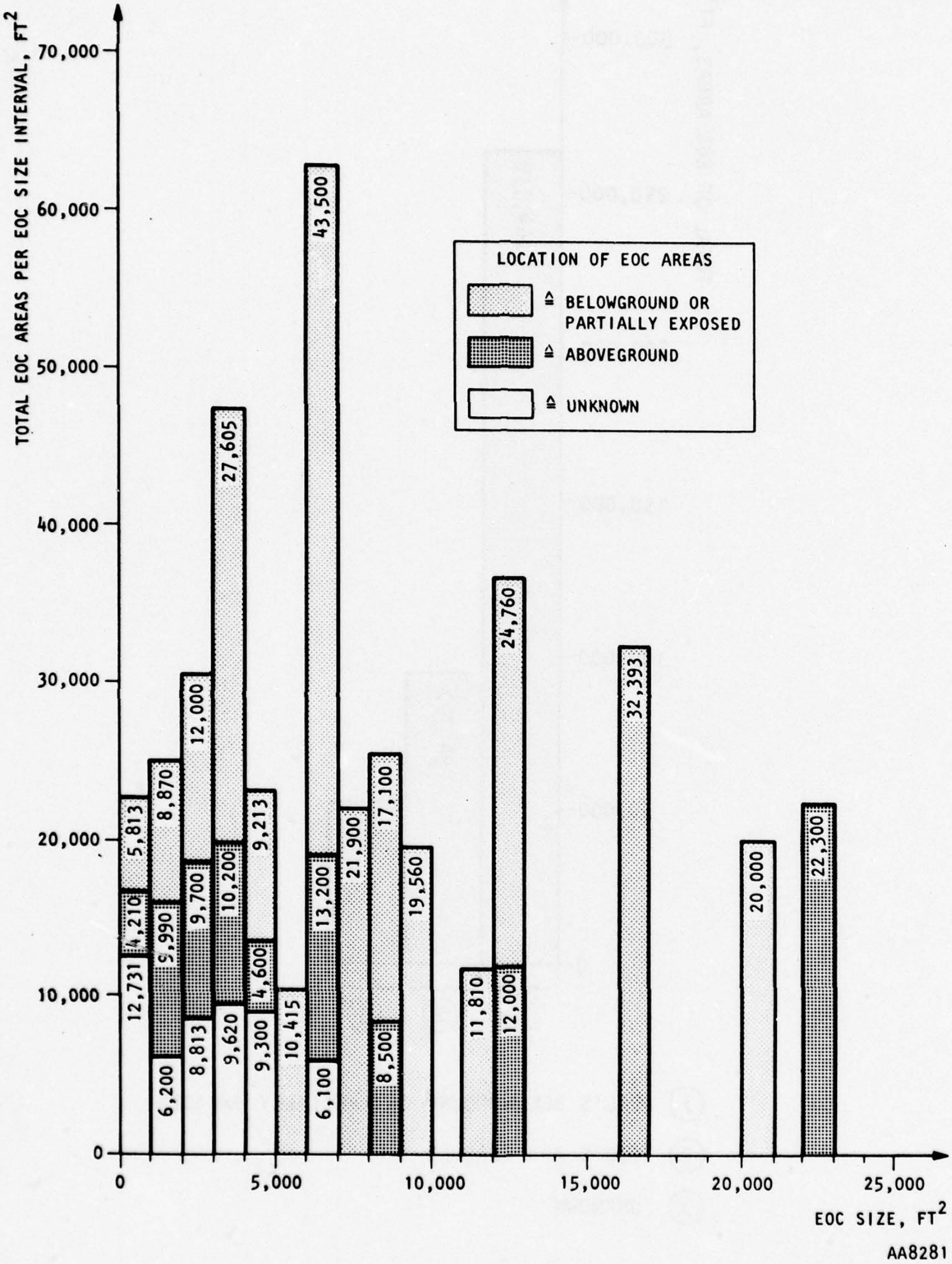


FIGURE 9. DISTRIBUTION OF 125 EOC'S--TOTAL EOC AREAS VERSUS EOC SIZES AND LOCATION (ABOVE/BELOWGROUND)

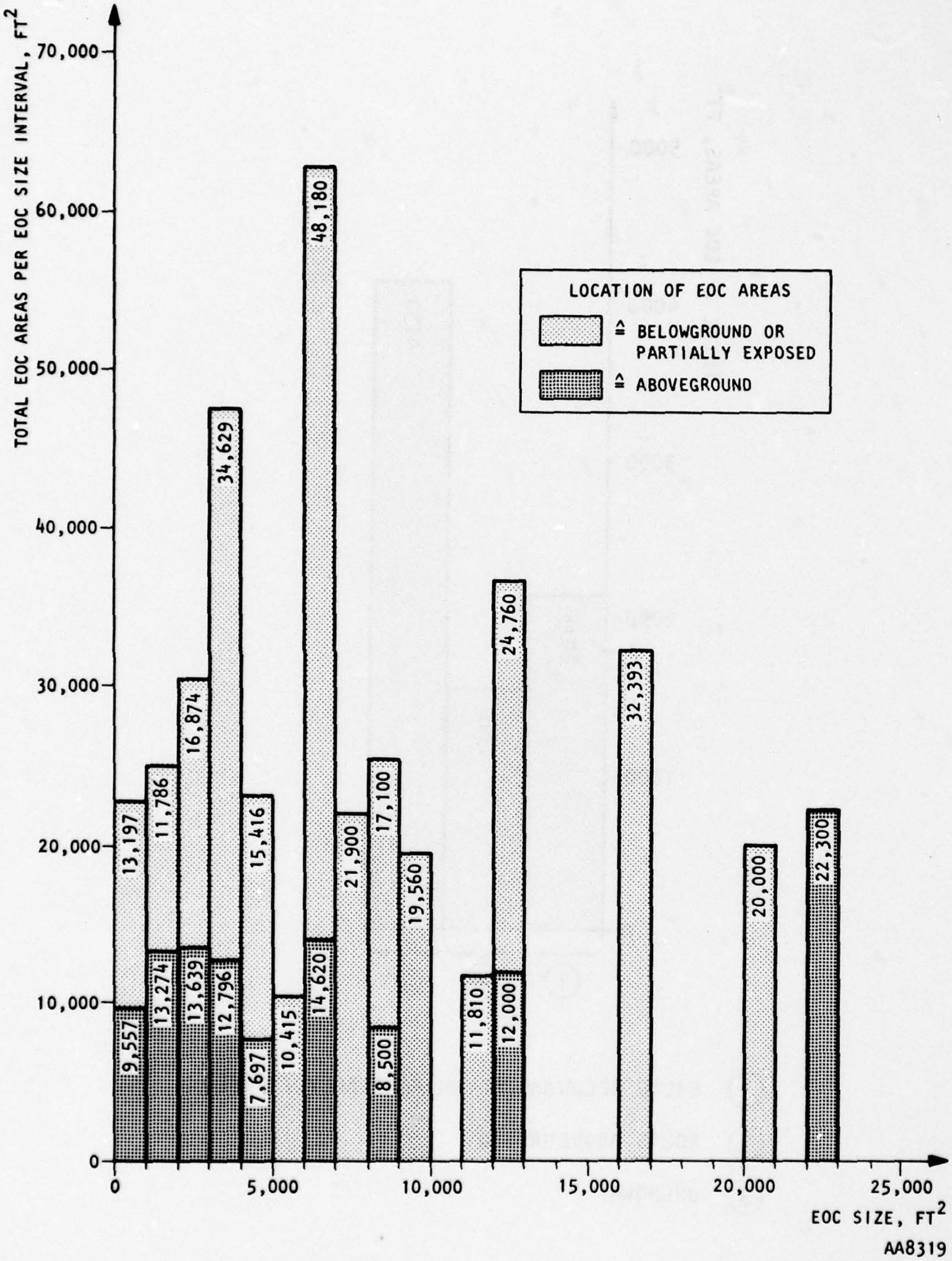
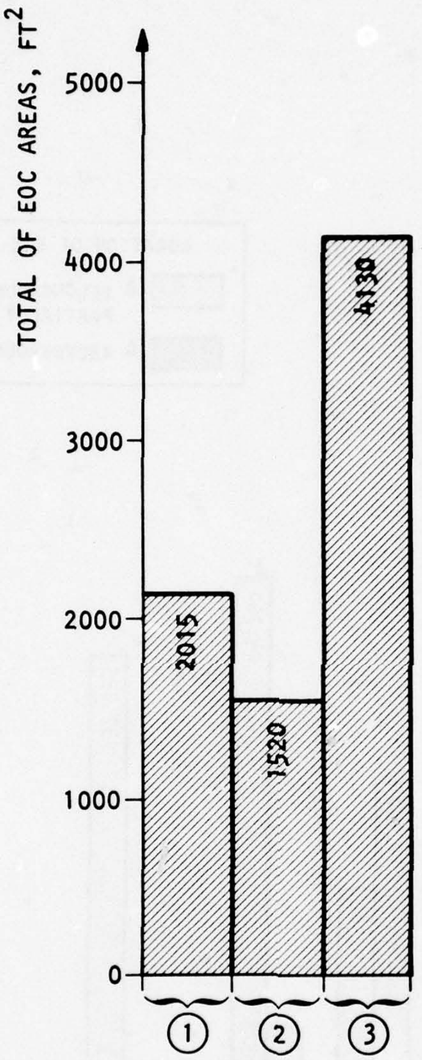


FIGURE 10. ESTIMATED DISTRIBUTION OF 125 EOC'S--TOTAL EOC AREAS VERSUS EOC SIZES AND LOCATIONS (Above/below ground)



(1) EOC'S BELOWGROUND OR PARTIALLY EXPOSED

(2) EOC'S ABOVEGROUND

(3) UNKNOWN

FIGURE 11. BELOW/ABOVEGROUND LOCATIONS OF 26 EOC'S WITH AREAS $\leqq$ 400 FT^2
(From DCPA 1975 survey of 143 EOCs)

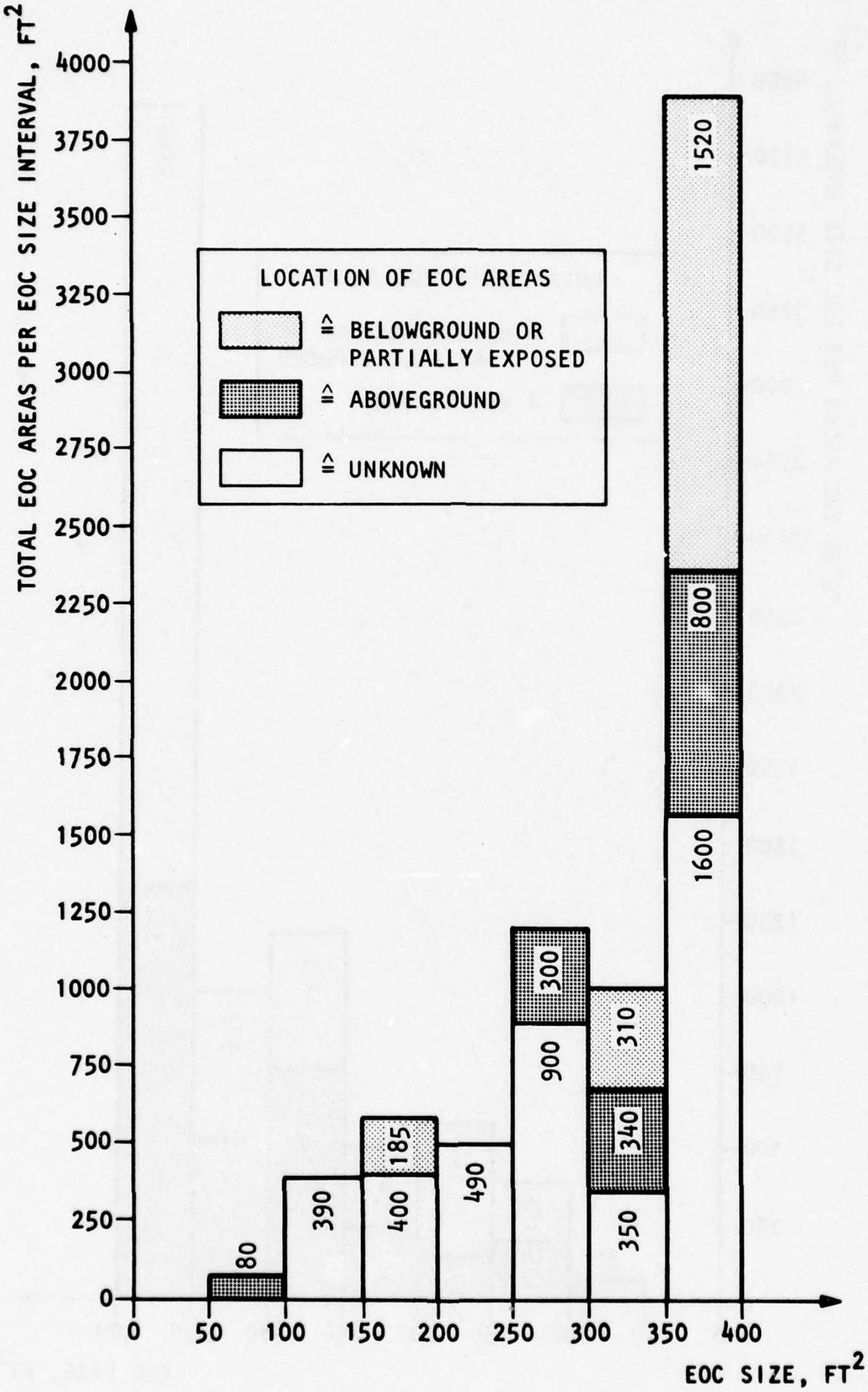


FIGURE 12. DISTRIBUTION OF 26 EOC'S--TOTAL EOC AREAS VERSUS EOC SIZES AND LOCATIONS (Above/below ground)

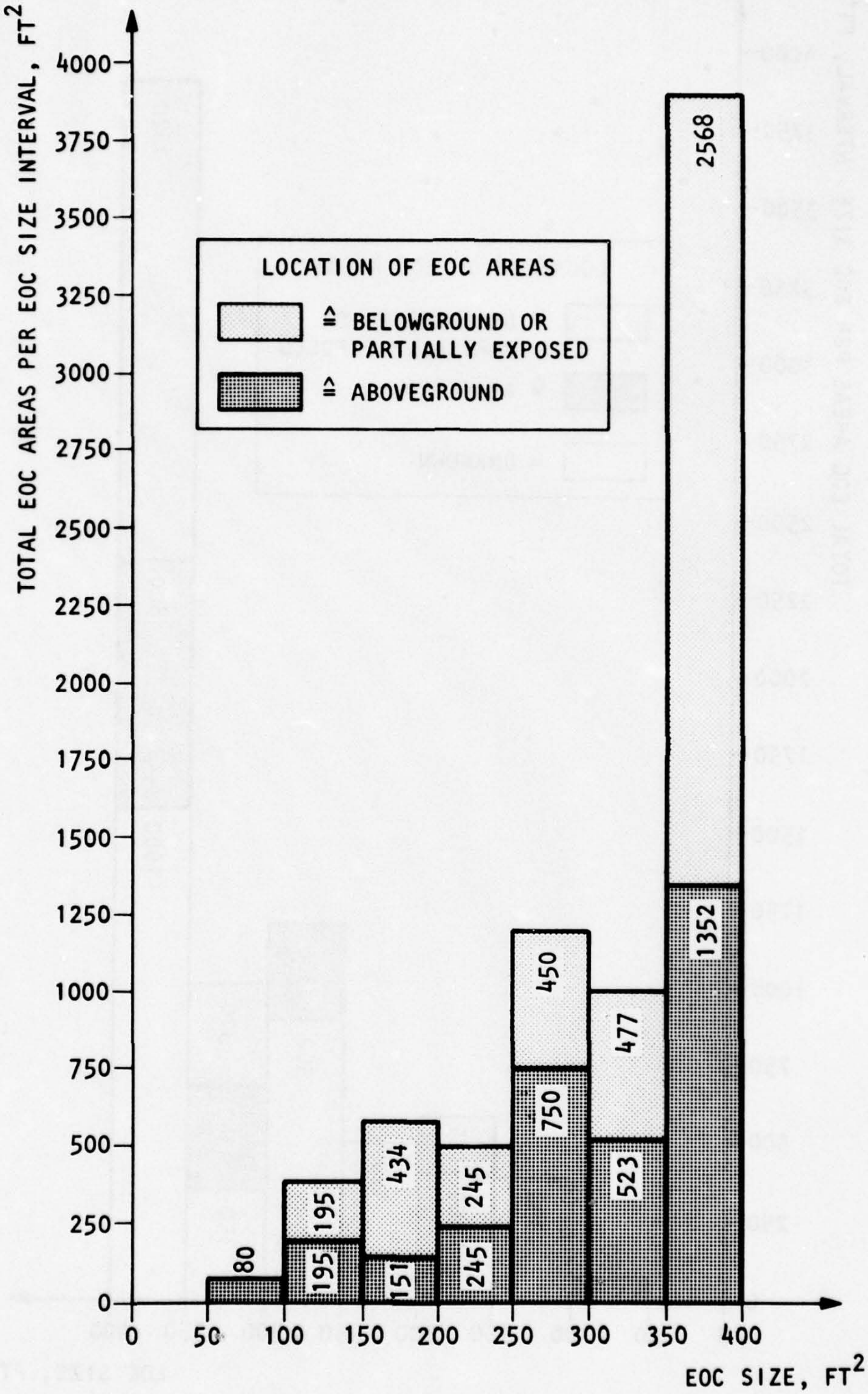


FIGURE 13. ESTIMATED DISTRIBUTION OF 26 EOC'S--TOTAL EOC AREAS VERSUS EOC SIZES AND LOCATIONS (Above/below ground)

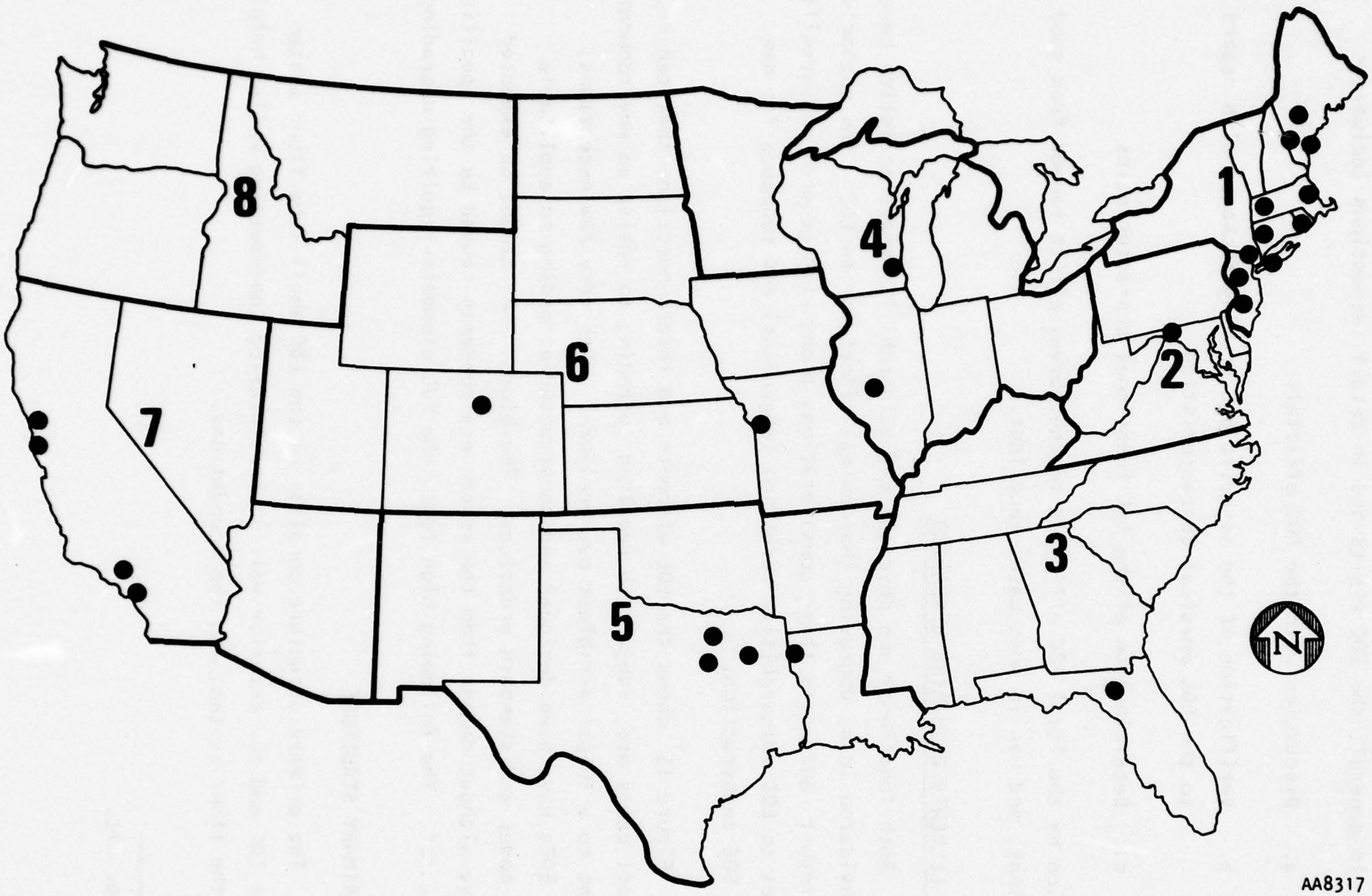


FIGURE 14. MAP OF THE UNITED STATES SHOWING THE EIGHT DCPA REGIONS AND THE LOCATION OF THE TWENTY-FIVE EOC'S VISITED AND ANALYZED. (NOT SHOWN ARE ALASKA, HAWAII, PUERTO RICO, AND THE VIRGIN ISLANDS)

In general, the EOC visits and in-detail inspections included--

a. Discussion with the EOC officials

b. Verification of the as-built EOC drawing packages with regard to the EOC physical characteristics

c. Determination of the EOC functional characteristics

Cooperation by the local EOC officials in the survey effort ranged from good to excellent, and was in most cases excellent.

4.4 EOC ELEMENTS REQUIRING UPGRADING

Both functional and physical EOC vulnerability characteristics have to be considered in an upgrading (hardening) effort for an EOC. The author's earlier report* addresses these considerations along with general and specific approaches to EOC vulnerability reduction (upgrading) and concepts for new, hardened EOC construction.

Figure 15* shows the EOC elements and interconnections that can be, and in most cases are, subject to required upgrading to resist an environment equivalent to a 10-psi air-blast overpressure. With very few exceptions, existing EOCs have been designed and constructed according to applicable building codes and standard practices. Therefore, they cannot be expected to survive without damage from the severe environments caused by the specified nuclear burst. The following highlights the EOC elements requiring upgrading.*

4.4.1 PRIMARY STRUCTURE

The primary structure consists of the EOC shell (the floor system above the EOC and the exterior walls); the interior load-bearing walls, helping support the floor system; and the foundations.

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*Lang, op. cit.

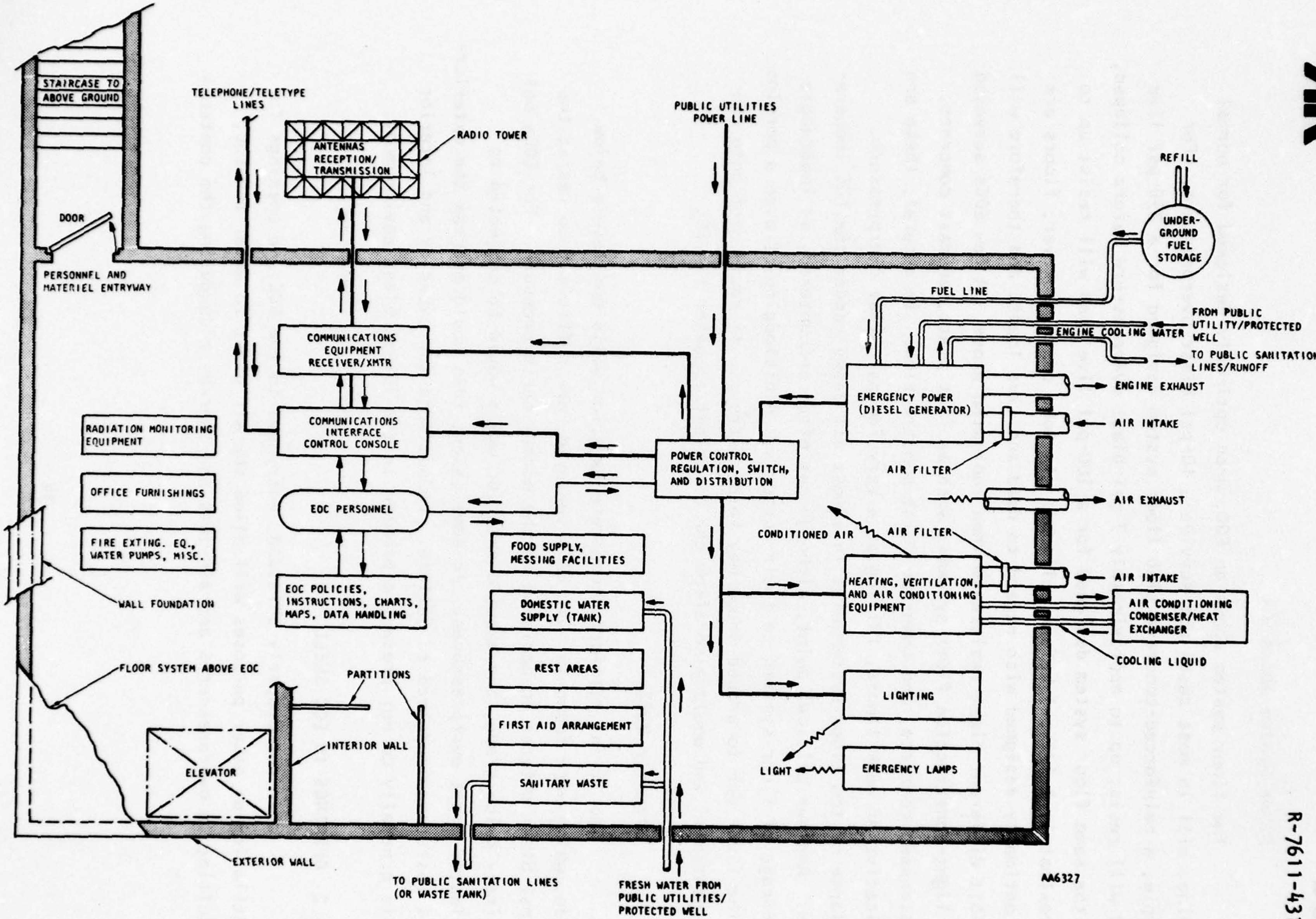

FIGURE 15. EOC ELEMENTS AND INTERCONNECTIONS

Floor System above EOC

The floor system above an EOC, when optimally designed for normal loading, will in most cases not survive a 10-psi blast overpressure. For example, a reinforced-concrete slab floor system designed for a 250-psf live load will resist up to approximately 7 psi blast overpressure before collapse, and the same floor system designed for a 100-psf live load will resist up to approximately 2-1/2 psi before collapse. In some cases, however, floors are not optimally designed with regard to dead and live loads, and therefore will exhibit different blast resistance than indicated above. A few EOCs surveyed had light-construction floor systems, such as flat plate, precast concrete, prestressed concrete, and open-web joist construction. In general, these are indicative of weak floors, failing at a very few psi blast overpressure. Collapse of the floor system will in almost all cases render the EOC inoperative. Another critical point, although not often encountered, is inadequate anchorage of floor systems to their supports. A dislodging of even a portion of the floor due to ground shock may be disastrous. It could drop onto the EOC contents, and would also allow the air blast to enter the EOC.

Exterior Walls

The 12-in. reinforced-concrete exterior walls completely below grade, which were found in most EOCs surveyed, are sufficient to resist the 10-psi blast effects in addition to the normal earth pressure. For EOCs not entirely below grade, the exposed exterior walls would be subjected to reflected blast overpressures. In some cases, this would overtax the exterior-wall resistance and lead to failure. Foundations for exterior and interior walls generally do not present a problem in the 10-psi blast environment.

4.4.2 OPENINGS IN EOC SHELL

When not properly shielded, entryways to the EOC and openings for ventilation or other purposes will allow the air blast to enter the EOC, resulting in overpressures and air jets and thereby endangering the contents of the EOC. Doors and closures, depending on their location and orientation, may be subjected to reflected overpressures of up to 25 psi for a blast overpressure of 10 psi, which is more than any standard door or cover can take.

4.4.3 SECONDARY STRUCTURES

Even though blast protected, the secondary structures inside EOCs, such as staircases, platforms, false floors, hung ceilings, nonload-bearing walls, and partitions are still subject to ground-shock motion. The possible response acceleration of the secondary structures due to ground-shock motion may reach 7g or more (at 10-psi blast overpressure), which will in many cases exceed their design strengths. Failure of some items may not be critical as long as they do not become falling objects, impacting with personnel and sensitive equipment; severing power cables, communication lines, and piping; or removing support from vital equipment.

4.4.4 EQUIPMENT

Survival of equipment--that is, the unimpaired operability of the equipment after a nuclear disaster--is a function of its resistance to the fraction of the air blast penetrating into the EOC and to ground shock; and, in some cases, of the survival of personnel and other equipment. Equipment outside the protected EOC faces an even severer environment.

In normal times, public utilities supply the needed power to the EOCs. Following a major disaster such as a nuclear explosion, this power source may be unavailable, or power cables to the source may be severed. Therefore, almost all EOCs are equipped with an emergency power source, usually a diesel generator. But these diesel generators may also be subject to damage. Diesel generators, vibration isolated at approximately 10 Hz in the vertical direction and very softly in the horizontal direction, often are not provided with excursion-limit stops. The strong ground shock associated with a blast overpressure level of 10 psi would in many instances knock the spring-mounted generator off its supports. Even differential displacements of a few inches may rupture pipes, cutting off fuel supply or cooling water. Additionally, air intake for the diesel engine may be endangered because of air filters clogged by the heavy dust load or air-blast destruction of air ducts and air filters, which allows the engine to take in dirty air.

Standby/control batteries not ruggedly mounted may slide or roll in all directions, breaking electrical connections and impacting against other equipment or walls. Power cables could be severed by falling objects or snapped by differential displacements.

Communications equipment may become inoperative due to lack of power or damaged components. Most vulnerable are the outside radio antennas, which generally are not designed to withstand the large drag forces resulting from air blast or impact by heavy, airborne debris. The receiver/transmitter equipment, located inside the EOC, is usually freestanding or only lightly fastened; it may wobble, topple, or slide and impact against other objects. Even for satisfactorily hard-mounted equipment, fragility levels may be exceeded in some cases, especially for older vintage equipment. The communications operator/equipment interface may be impeded by "personnel failure" or damaged units. Control consoles mounted, or just resting, on false floors that are also subject to failure, will become ineffective.

Lighting mounted in hung ceilings is also precarious, since hung ceilings are very apt to be damaged. Emergency lamps sitting on wall brackets or pedestals may drop to the floor and break, thereby precluding even emergency lighting.

Mechanical equipment, like electrical equipment, will also suffer in the disaster environment and affect the EOC operation. The air-conditioning equipment is very vulnerable. Parts of the air-conditioning system, such as condenser/heat exchanger, are usually located outside the EOC and aboveground; in most cases, they will not survive the blast effects. Standard air ducts connecting the outside world with the inside of the EOC would suffer blast damage. Most ventilation fans are not mounted securely enough to resist the ground-shock forces. And any air filters not damaged by the air blast will clog very rapidly under the heavy dust load, interrupting the air flow. Piping, unless provided with flexible connections to absorb differential displacements and properly supported by adequate pipe hangers, may be damaged, resulting in flooding of the EOC or fuel spillage and possibly fire. Tanks and containers not sufficiently restrained may also become dangerous objects. The underground fuel-storage tank would generally survive the disaster effects. Office furnishings subjected to ground-shock and air-blast penetration are also potential hazards to personnel and sensitive equipment.

Two conditions external to the EOC, flooding and fire, are of concern. External flooding could swamp the EOC interior with too much water for available pumps to handle. A fire could destroy the antennas and affect radio transmission; and could cause toxic gases, oxygen-depleted air, and heat to penetrate the EOC.

4.4.5 PERSONNEL

Personnel casualties could result from air blast penetrating the EOC, from ground shock, and from failure of the life-support system. Both the penetrating air blast and the ground shock may cause persons to collide with floors, walls, equipment, or other persons; or to be bombarded with falling or thrown objects. Nor would many survive without harm a total collapse of the floor system above the EOC. Toxic gases, oxygen depletion, and heat, resulting from a fire inside the EOC or from the effects conveyed from an external fire through the air-conditioning system, can also be paralyzing. In a nuclear disaster (10-psi blast overpressure level), most EOCs surveyed could, unless modified, be subject to the indicated personnel casualties, possibly to such an extent as to imperil the EOC mission.

4.5 EOC UPGRADING MEASURES

By DCPA direction, upgrading of existing EOCs located in high-risk areas to a 10-psi air-blast overpressure level was to be cost estimated. Although most EOCs surveyed did appear to be similar and had many elements and associated vulnerabilities in common, each EOC was unique and was treated as such.

Upgrading of aboveground EOCs was treated in two ways: (1) by relocating the EOCs to belowground spaces in existing buildings or future buildings and upgrading those spaces and (2) by replacing these EOCs by new construction of separate, belowground, hardened EOCs. For the first alternative of EOC relocation, upgrading was assumed to be identical to the upgrading of presently existing belowground EOCs. EOC relocation to future buildings should, where possible, entail EOC hardening in the design stage of these buildings.

Upgrading of belowground, or at least partially belowground, EOCs involved the hardening of the following EOC elements: primary structure, openings and closures, secondary structures, equipment, personnel, and external EOC surroundings. In general, the following upgrading measures were considered:

For the floor system above the EOC:

- Reduction of spans by adding members such as beams, support walls, and columns
- Strengthening of weak floor segments by adding thickness to the slab (concrete topping with wire mesh reinforcement)
- Replacement of weak floor segments with adequate ones
- Providing for structural continuity between floor system and supports, especially the exterior walls

For the exterior walls:

- Protection of partially exposed basement walls from reflected and dynamic pressures by earth berms of gentle slope
- Addition of pilasters to reduce horizontal spans
- Build-up of wall thicknesses
- Addition of interior structural walls, tied in with the exterior walls

For the interior load-bearing elements supporting the EOC shell:

- Increase of tie between elements and shell
- Addition of wall pilasters
- Build-up of wall thicknesses
- Build-up of column strengths
- Addition of columns

For openings and closures:

- Reduction of number and size of unprotected openings (permanent blockage, strong closures)
- Installation of simple blast valves for minimum air intake and exhaust openings that must remain open even during alert/disaster periods
- Blast-resistant wall encasement of elevator shafts and staircases

Secondary structures, such as nonload-bearing walls, partitions, interior staircases, and false floors and ceilings

- Secure anchorage
- Strengthening or removal
- Elimination of glass in partitions and doors

Equipment

- Storage of expedient (back-up) antennas
- Providing adequate cover for equipment located outside the EOC
- Secure mounting (including shock isolation)
- Introduction o. flexible connections
- Insertion of cut-off valves and power-off switches
- Strengthening of the air-conditioning system (including providing for redundant air flow by strategically located fans)

Personnel

- Providing for adequate water supply
- Providing for adequate food supply
- Providing for adequate sanitary facilities
- Providing for adequate first-aid facilities

EOC external surroundings:

- Protection against flooding caused by the nuclear weapon effects (dikes, water pumps)
- Elimination of fire hazards
- Reduction of possible blockage of air intake and exhaust passages

4.6 COST OF EOC UPGRADING

For belowground or partially exposed EOCs of the 25-EOC sample, each of the elements/items was assessed for upgrading to a 10-psi overpressure level, and such upgrading was cost estimated. The costs for upgrading the various elements/items of an EOC were totaled to arrive at the cost of upgrading the EOC. The set of 25-EOC total upgraging costs was used as the yardstick for upgrading unit costs ($\$/ft^2$) versus EOC sizes for belowground or partially exposed EOCs.

The same procedure was followed for EOCs subject to possible replacement by newly constructed separate, belowground EOCs, except that hardened new design was substituted for upgrade design. Because of the relatively high expense of such new construction (a cost-effectiveness issue) and because of the only partial impact of such new construction on the total cost for vulnerability reduction of the EOC population (based on the ratio of aboveground to belowground EOCs and the cost differential between EOC upgrading and new construction), combined with the lesser variability of new construction costs when compared with upgrading modification costs, a sample size of only three EOCs was chosen for new construction of separate EOCs located belowground. (This is a very small, but nevertheless adequate, sample size.)

Once the costs for the 25 EOCs (upgrading) and 3 EOCs (new construction), the total EOC areas versus EOC size distribution for 125 EOCs, and the number of existing EOCs located in "high-risk" areas were established, the total cost of upgrading the EOC population to a 10-psi hardness level was estimated.

Inaccuracies are associated with each of the estimated values (e.g., EOC element upgrading costs and EOC size distributions). These inaccuracies, either calculated or based on judgment, were expressed in terms of percentages of the estimated values, and they were combined by geometric addition (for example, the combination of A and B is equal to the square root of the sum of A^2 plus B^2).* Although some liberties were taken with statistical theory (that is, the use of approximations in some instances, instead of exact but lengthy solutions), the resulting "true" accuracies were not significantly compromised.

The following describes the details and sequence of the estimating process that yielded the total cost of EOC population upgrading.

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*The paper "Reliability Bases of Structural Safety and Design," by Alfredo H-S. Ang and C. Allin Cornell, published in *J. of the Structural Div., Proceedings of ASCE*, Sep 1974, presents a relevant discussion of this subject.

4.6.1 INDIVIDUAL SAMPLE EOC UPGRADING COSTS

For both upgrading by modification of existing EOCs and upgrading by new EOC construction, three basic considerations were made.

a. A minimum of 30 cost-equivalent EOC items were estimated, i.e., the largest cost item estimated as a single unit was equal to or less than the total EOC cost divided by 30.

b. A probability of a constant bias error of estimating, i.e., an "always high" or "always low" estimate, was assumed at ±10% of the estimate value at 95% confidence (a normal distribution).

c. A probability of random error in item estimating, i.e., some high and some low estimates, was assumed at a mean of zero and a standard deviation of 50% of the item estimate (a hybrid of normal distribution and adjusted log-normal distribution, but treated as normal distribution).

The resulting accuracy of a total EOC cost estimate is therefore at 95% confidence:

$$\frac{10\%\ (\pm)}{\sqrt{1}} \nleftrightarrow \frac{1.96 \times 50\%\ (\pm)}{\sqrt{30}} = 10\%\ (\pm) \nleftrightarrow 17.8\%\ (\pm) = \pm 20.4\% \quad *$$

(This figure of ±20.4% does not reflect any differences in regional construction costs, but is based on the national average of construction costs.)

Table 3 gives the cost estimates for the upgrading of 28 EOCs. 1975 average national construction costs are the basis for these estimates. The EOCs numbered 1 through 25 in this table are presently existing EOCs (which were visited and inspected in detail). The EOCs numbered 26 through 28 are hypothetical but representative EOCs. The costs for the EOCs numbered 17, 27, and 28 and "located aboveground" are based on new EOC construction of separate EOC facilities located belowground and hardened. All other listed EOCs are located belowground, and their upgrading is accomplished by modifications.

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*The symbol +→ stands for geometric addition. The value of 1.96 is the Z-value of the standard normal distribution for 95% confidence (two-tail critical area). The values under the √'s are: 1 for 1 estimator, 30 for 30 cost-equivalent EOC items.

TABLE 3. EOC UPGRADING COST SAMPLE
(Based on 1975 national average construction costs)

EOC No.	EOC Location City	State	DCPA Region	EOC Size, ft^2	Total Cost of EOC Upgrading, $	Cost of EOC Upgrading Per EOC Net Area, $\$/ft^2$
1	Portland	ME	1	3,898	77,200	19.82
2	Westbrook	ME	1	2,557	65,700	25.70
3	Auburn	ME	1	3,935	85,700	21.77
4	Quincy	MA	1	7,806	133,900	17.15
5	Chicopee	MA	1	3,948	86,400	21.89
6	North Kingstown	RI	1	3,326	93,400	28.09
7	Meriden	CT	1	4,888	45,300	9.27
8	Mt. Vernon	NY	1	3,154	68,200	21.63
9	Manhasset	NY	1	1,250	61,000	48.78
10	Princeton	NJ	1	3,018	67,400	22.33
11	Trenton	NJ	1	6,062	129,300	21.33
12	Hagerstown	MD	2	2,324	20,300	8.75
13	Gainesville	FL	3	2,959	88,700	29.97
14	Waukesha	WI	4	4,947	51,400	10.39
15	Springfield	IL	4	13,000	178,600	13.73
16	Sherman	TX	5	5,421	47,500	8.77
17*	De Soto	TX	5	1,300	80,800	62.14
18	Tyler	TX	5	2,700	117,000	43.35
19	Shreveport	LA	5	1,287	33,800	26.26
20	Kansas City	MO	6	3,100	109,600	35.35
21	Boulder	CO	6	4,693	89,200	19.01
22	Richmond	CA	7	7,676	136,800	17.82
23	San Francisco	CA	7	2,085	62,100	29.78
24	So. Pasadena	CA	7	5,911	111,100	18.79
25	Glendale	CA	7	3,493	37,200	10.66
26	EOC Design A			287	21,500	74.86
27*	EOC Design B			287	32,900	114.63
28*	EOC Design C			6,000	217,400	36.23

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*These EOCs are "presently" located aboveground. Their upgrading cost estimates are based on new construction of separate EOCs located underground. All other EOCs shown in this table are located underground or are only partially exposed aboveground.

4.6.2 EOC SAMPLE UPGRADING COSTS (25 EOCs and 3 EOCs)

Figures 16, 17, and 18 present the measured and estimated values of Table 3 in a graphical form. Figure 19 shows the 25 values of upgrading cost ($\$/ft^2$) versus EOC size ($ft^2$) for the belowground located sample EOCs and gives a curve of point estimates of upgrading costs for the entire range of EOC sizes. This curve was generated by the least-square method employed on the percentage cost differences (curve cost points versus sample cost points). Figure 20 presents the 95% confidence interval for the upgrading costs ($\$/ft^2$) versus EOC size ($ft^2$) for the belowground located EOCs. These confidence intervals include the statistically adjusted inaccuracies described in Section 4.6.1 and the effect of the distribution parameter of the sample 25 EOCs. The inaccuracy associated with the cost point estimates shown in Figure 19 is at 95% confidence.

$$\frac{10\%(\pm)}{\sqrt{1}} \leftrightarrow 17.8\%(\pm) \leftrightarrow 2.064 \times 33.3\%(\pm) = 10\%(\pm) \leftrightarrow 17.8\%(\pm)$$

$$\leftrightarrow 68.7\%(\pm) = \pm 71.7\% \quad ^*$$

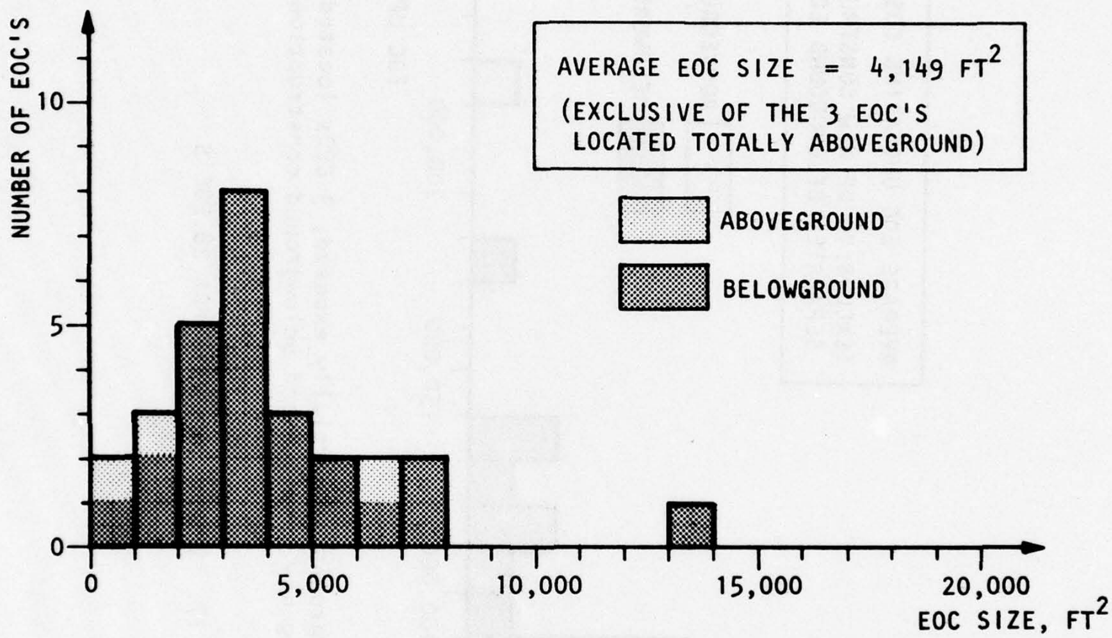
(This figure of ±71.7% does not reflect any differences in regional construction costs but is based on the national average construction costs. The 33.3% value in the geometric addition equation is the calculated standard deviation of cost distribution of the 25 EOCs).

Figure 21 shows the point estimate curve for cost ($\$/ft^2$) of new construction of separate EOCs located underground and hardened. Figure 22 gives the 95% confidence interval for those costs. The inaccuracy associated with the cost point estimates shown in Figure 21 is at 95% confidence:

$$\frac{10\%(\pm)}{\sqrt{1}} \leftrightarrow 17.8\%(\pm) \leftrightarrow 1.96 \times 20\%(\pm) = 10\%(\pm) \leftrightarrow 17.8\%(\pm) \leftrightarrow 39.2\%(\pm)$$

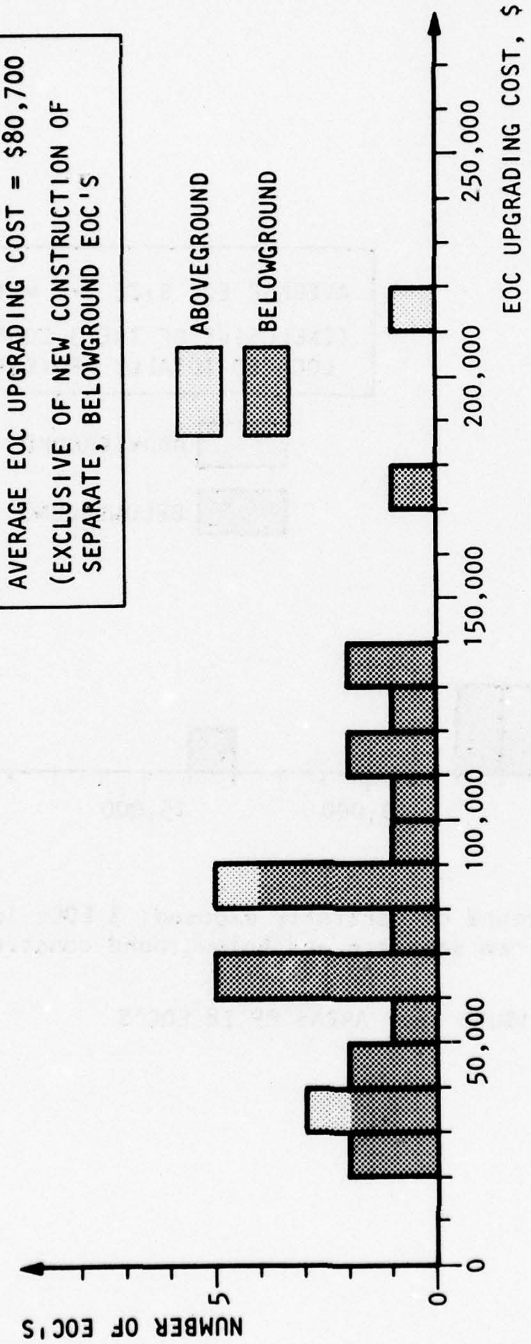
$$= \pm 44.2\%$$

*The value of 2.064 is the t-value of the Student's t distribution for 95% confidence (two-tail critical area) with a sample size of 25.



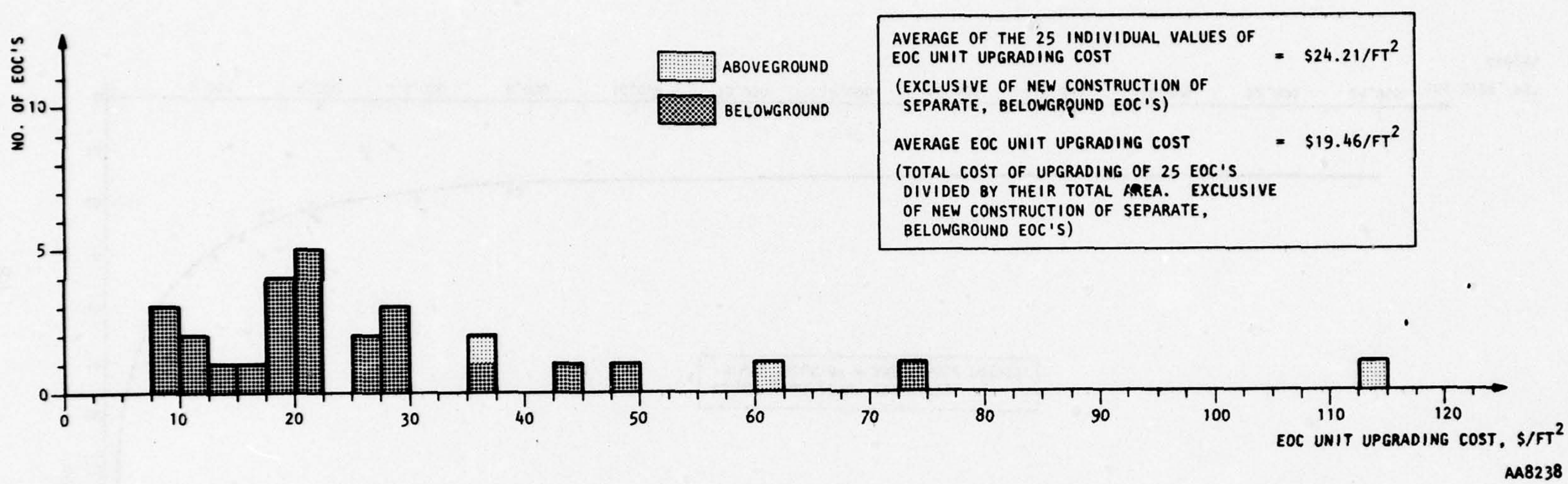
(25 EOCs located belowground or partially exposed; 3 EOCs located totally aboveground, requiring new separate and belowground construction)

FIGURE 16. AREAS OF 28 EOC'S



(25 EOCs located belowground or partially exposed; 3 EOCs located totally aboveground, requiring new separate and belowground construction)

FIGURE 17. UPGRADING COSTS FOR 28 EOC'S



(25 EOCs located belowground or partially exposed; 3 EOCs located totally aboveground, requiring new separate and belowground construction)

FIGURE 18. UNIT UPGRADING COSTS FOR 28 EOC'S

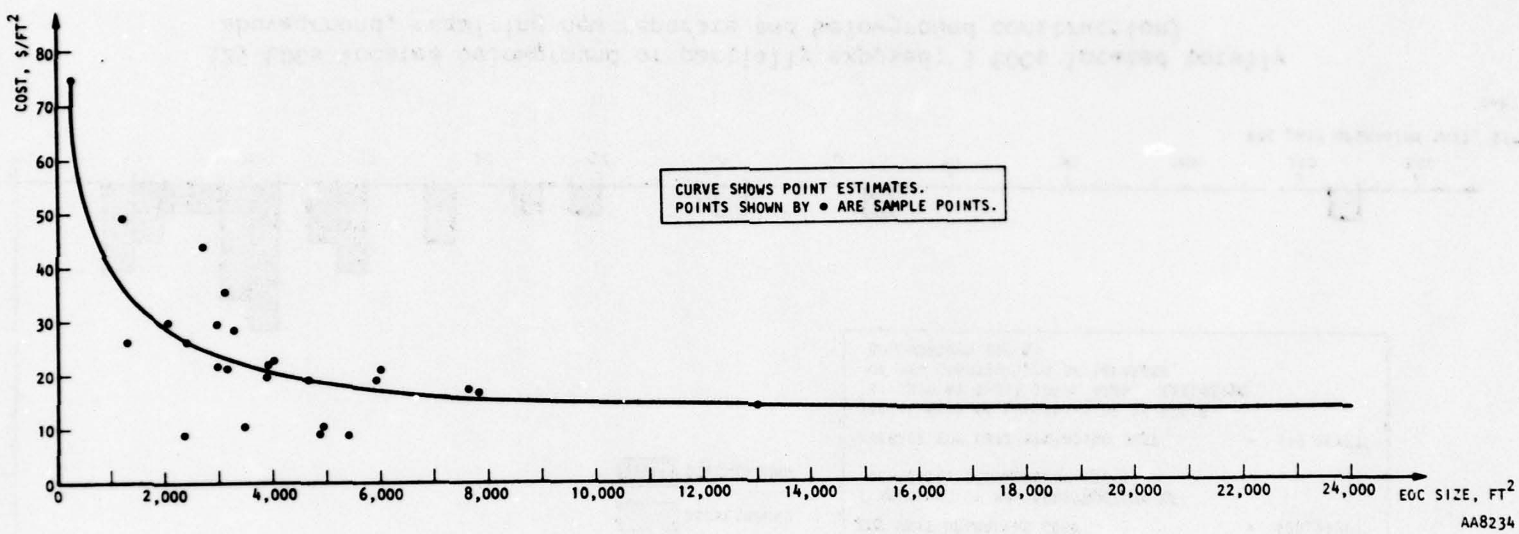


FIGURE 19. **UNIT COSTS OF EOC UPGRADING** (Does not include new construction of separate EOCs located underground.)

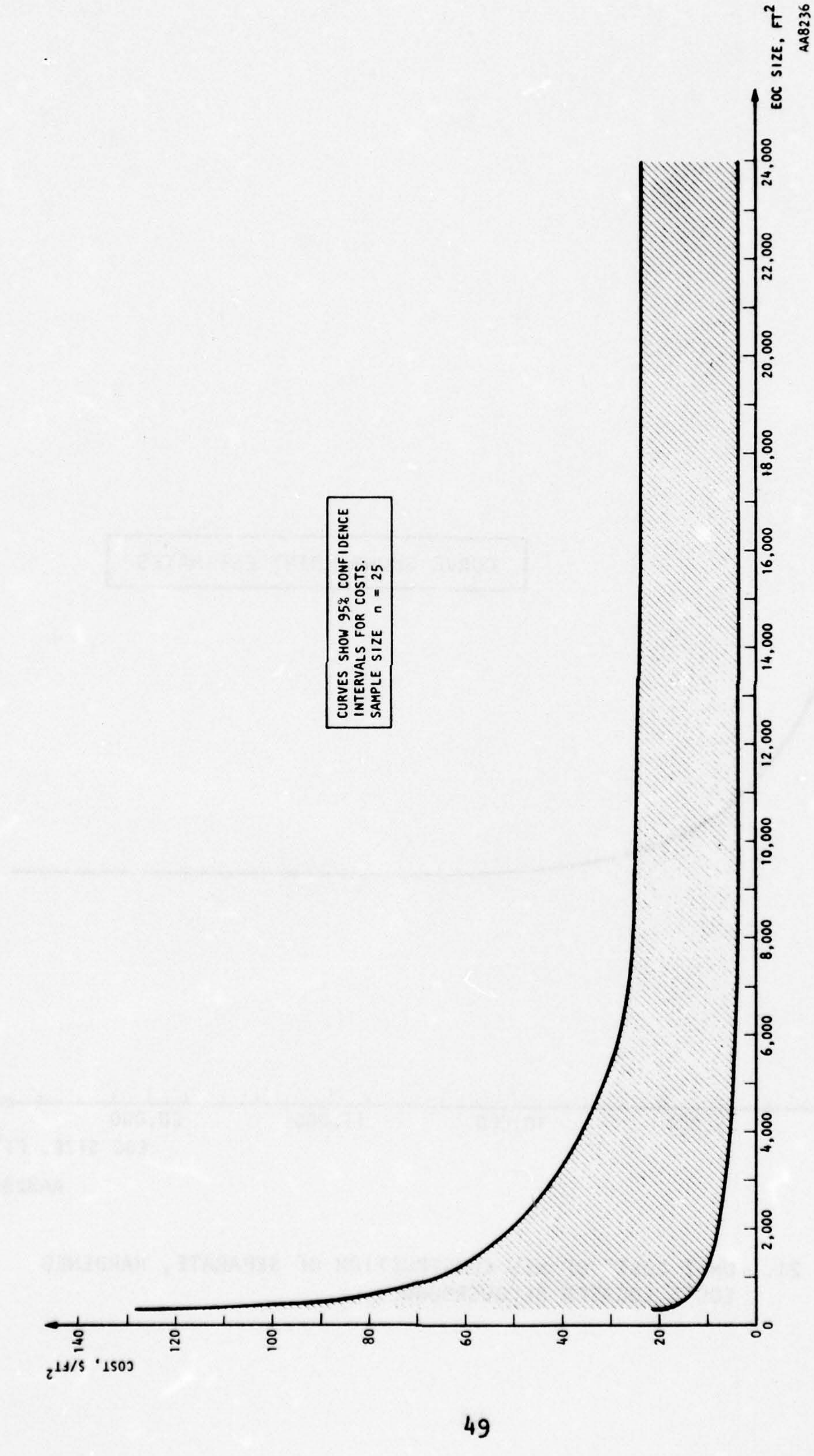


FIGURE 20. UNIT COSTS OF EOC UPGRADING (Does not include new construction of separate EOCs located underground)

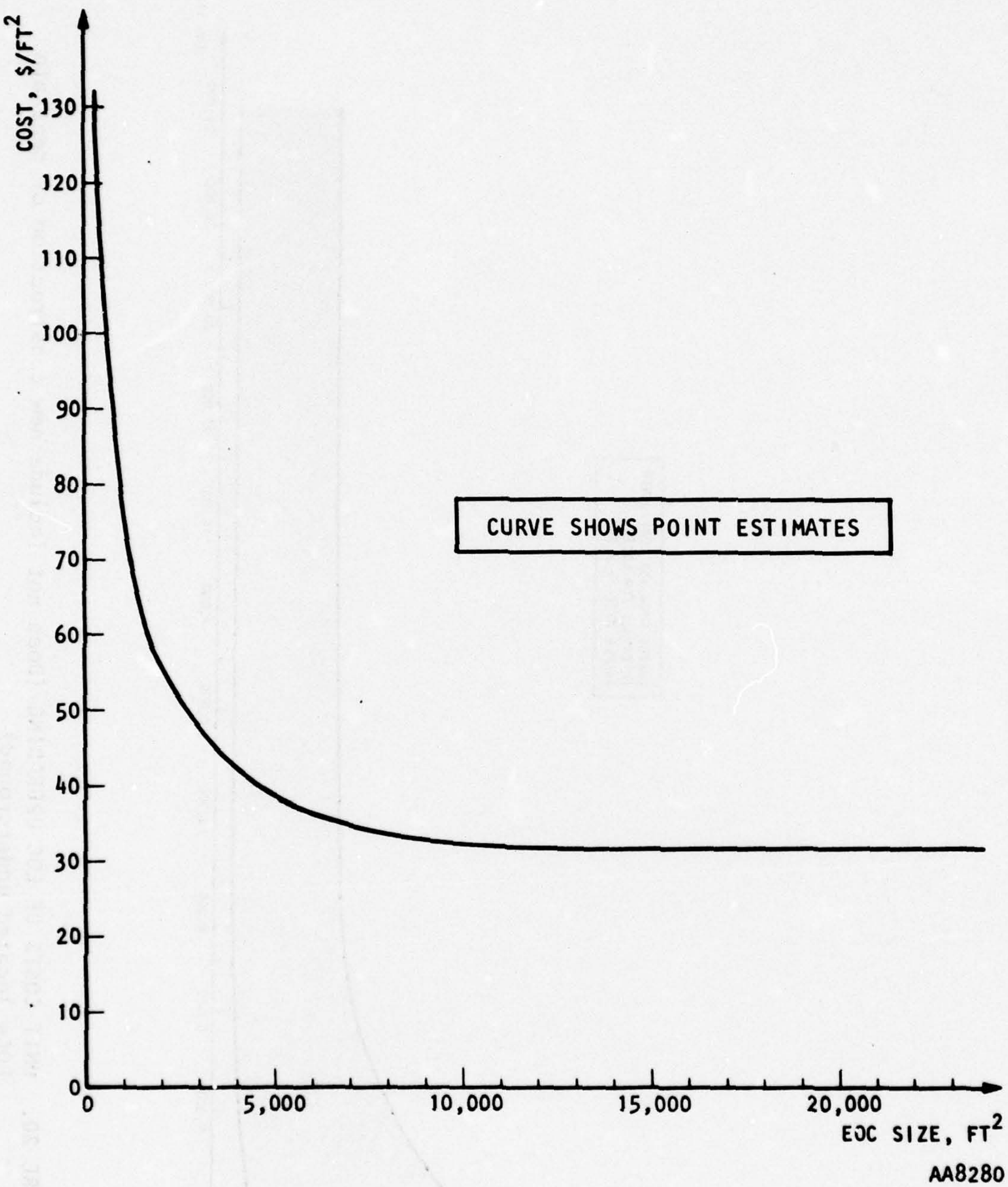


FIGURE 21. UNIT COSTS OF NEW CONSTRUCTION OF SEPARATE, HARDENED EOC'S LOCATED BELOWGROUND

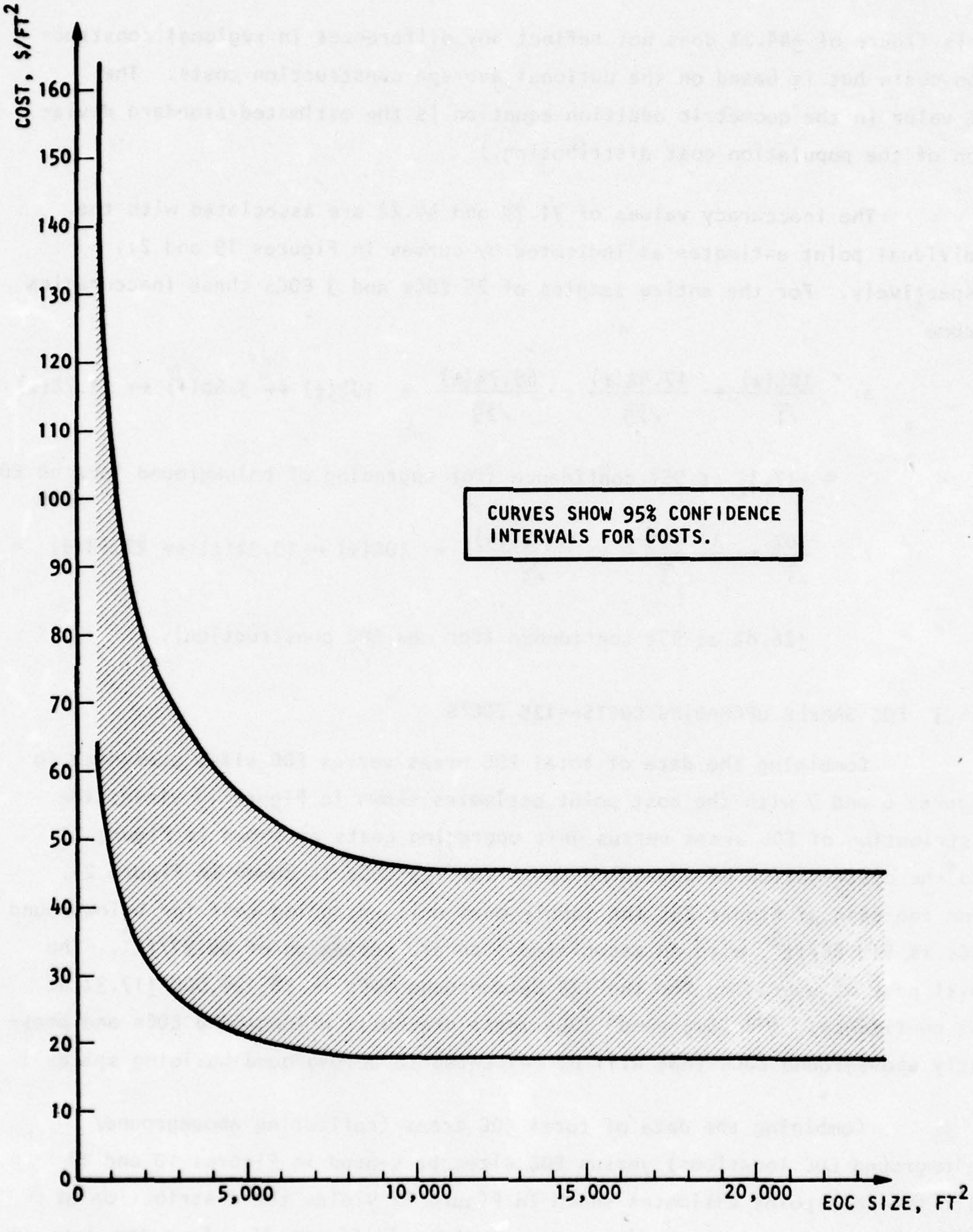


FIGURE 22. UNIT COSTS OF NEW CONSTRUCTION OF SEPARATE, HARDENED EOC'S LOCATED BELOWGROUND

(This figure of ±44.2% does not reflect any differences in regional construction costs but is based on the national average construction costs. The 20% value in the geometric addition equation is the estimated standard deviation of the population cost distribution.)

The inaccuracy values of 71.7% and 44.2% are associated with the individual point estimates as indicated by curves in Figures 19 and 21, respectively. For the entire samples of 25 EOCs and 3 EOCs these inaccuracies become

a. $$\frac{10\%(\pm)}{\sqrt{1}} \leftrightarrow \frac{17.8\%(\pm)}{\sqrt{25}} \leftrightarrow \frac{68.7\%(\pm)}{\sqrt{25}} = 10\%(\pm) \leftrightarrow 3.6\%(+) \leftrightarrow 13.7\%(\pm) =$$

±17.3% at 95% confidence (for upgrading of belowground located EOCs)

b. $$\frac{10\%}{\sqrt{1}} \leftrightarrow \frac{17.8\%(\pm)}{\sqrt{3}} \leftrightarrow \frac{39.2\%(\pm)}{\sqrt{3}} = 10\%(\pm) \leftrightarrow 10.3\%(\pm) \leftrightarrow 22.6\%(\pm) =$$

±26.8% at 95% confidence (for new EOC construction).

4.6.3 EOC SAMPLE UPGRADING COSTS--125 EOC'S

Combining the data of total EOC areas versus EOC sizes presented in Figures 6 and 7 with the cost point estimates shown in Figure 19 yields the distribution of EOC areas versus unit upgrading costs as shown in Figure 23 and the distribution of upgrading costs for 125 EOCs as shown in Figure 24. From the data of Figure 23, the sample mean unit upgrading cost for belowground EOCs is $19.86/ft^2, with an associated standard deviation of $8.97/ft^2. The total cost of upgrading for the 125 belowground EOCs is $8,190,000 ±17.3% at 95% confidence. ("Belowground" EOCs means presently belowground EOCs and presently aboveground EOCs that will be relocated to belowground building spaces.)

Combining the data of total EOC areas (reflecting aboveground/belowground EOC locations) versus EOC sizes presented in Figures 10 and 13 with the cost point estimates shown in Figure 21 yields the distribution of EOC areas versus unit upgrading costs as shown in Figure 25. From the data of

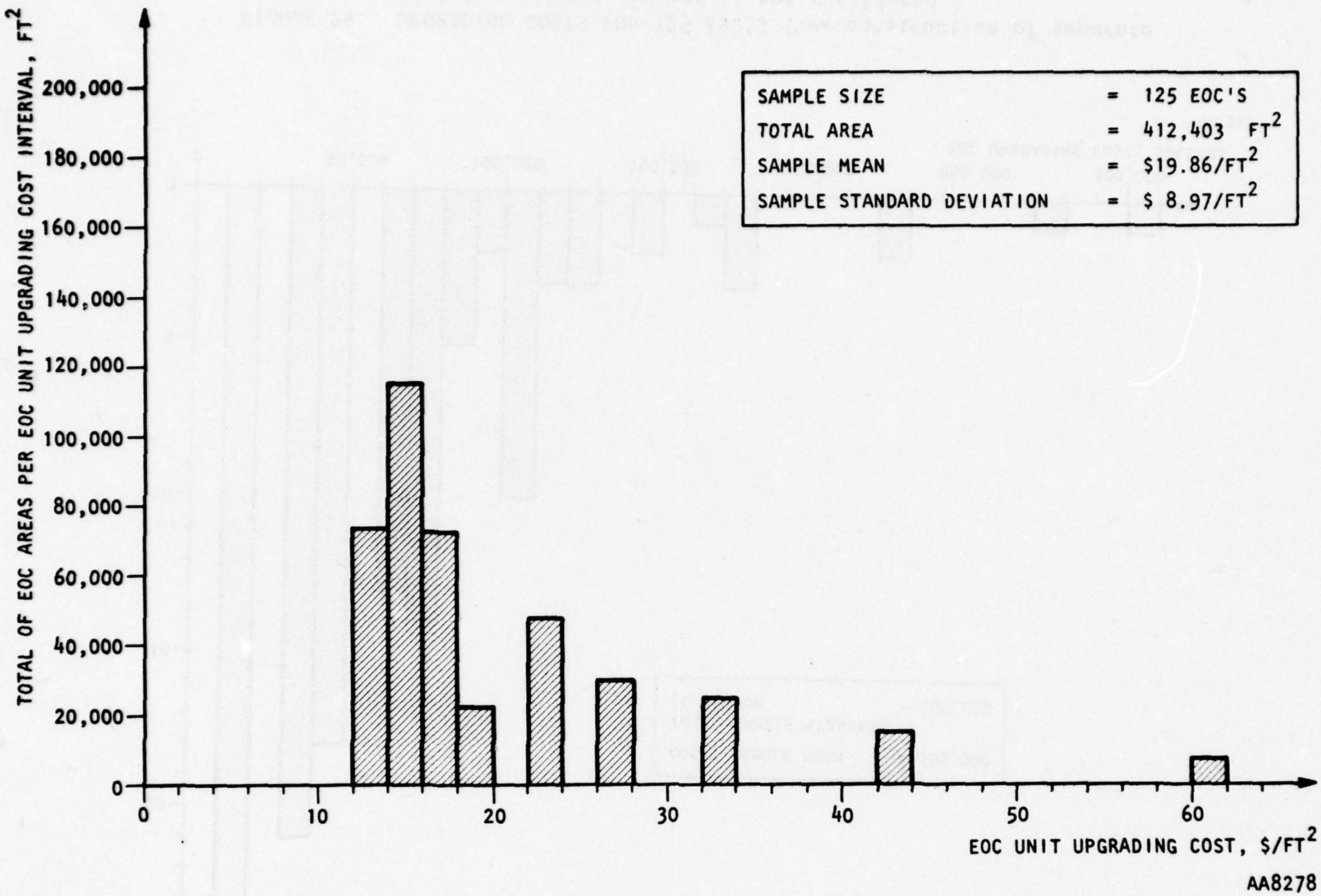


FIGURE 23. EOC AREAS VERSUS UNIT UPGRADING COSTS (New construction of separate EOCs located underground is not considered.)

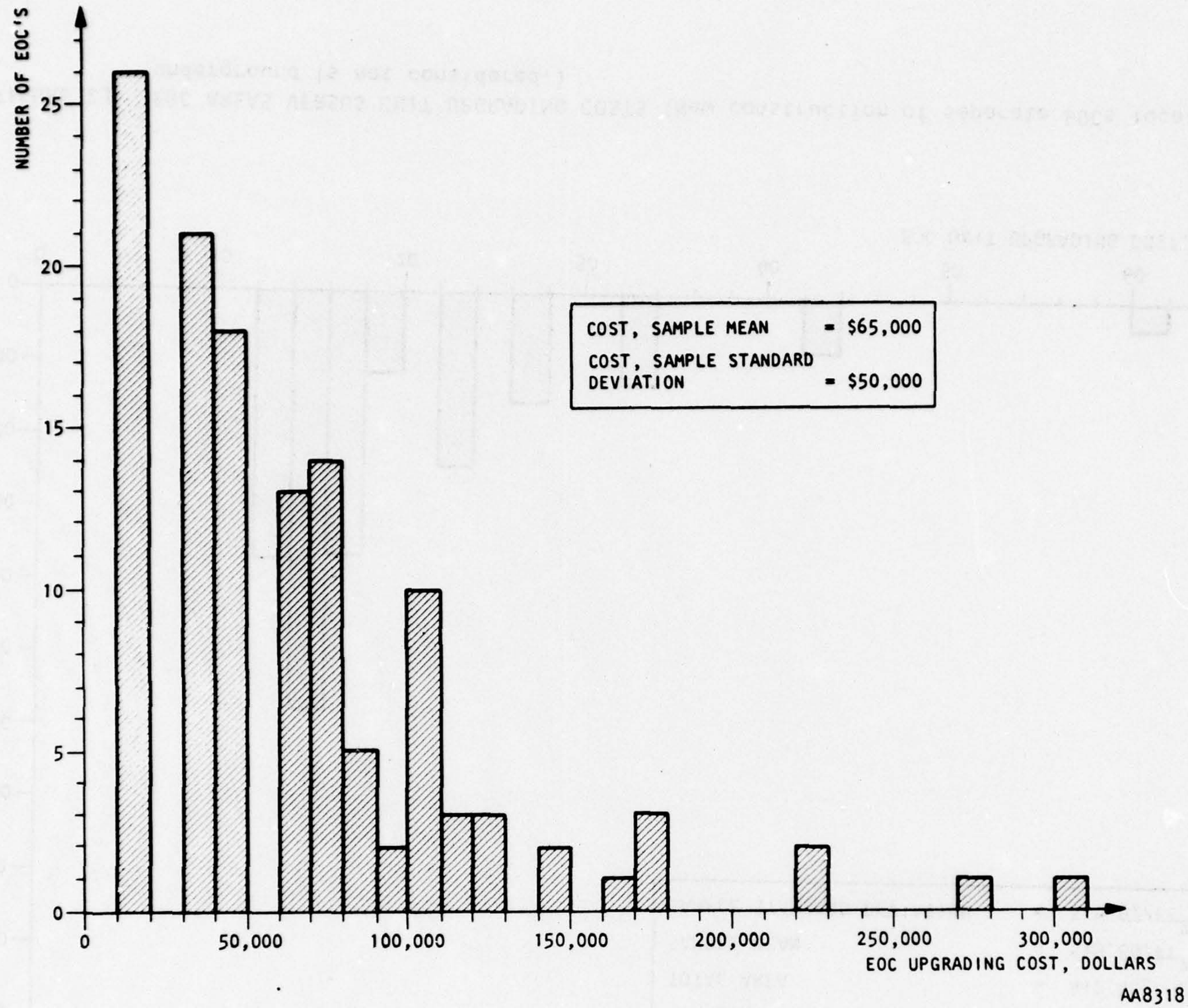


FIGURE 24. UPGRADING COSTS FOR 125 EOC'S (New construction of separate EOCs located underground is not considered.)

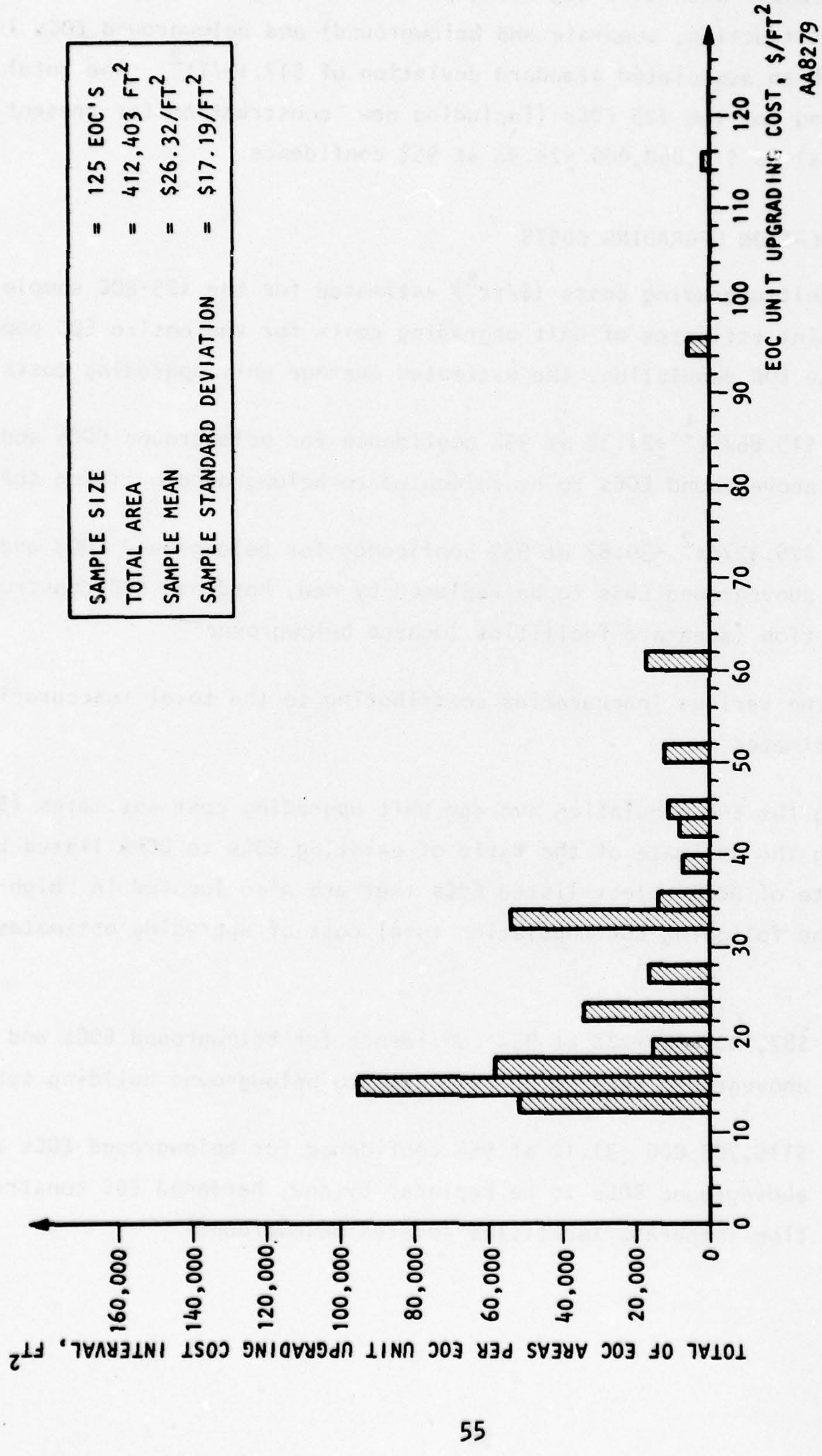


FIGURE 25. EOC AREAS VERSUS UNIT UPGRADING COSTS (New construction of separate EOCs located underground is included.)

Figure 25, the sample mean unit upgrading cost for aboveground EOCs (new hardened EOC construction, separate and belowground) and belowground EOCs is $\$26.32/ft^2$, with an associated standard deviation of $\$17.19/ft^2$. The total cost of upgrading for the 125 EOCs (including new construction for presently aboveground EOCs) is \$10,850,000 ±24.9% at 95% confidence.

4.6.4 EOC POPULATION UPGRADING COSTS

The unit upgrading costs ($\$/ft^2$) estimated for the 125-EOC sample are also the point estimates of unit upgrading costs for the entire EOC population. For the EOC population, the estimated average unit upgrading costs are--

a. $\$19.86/ft^2$ ±21.3% at 95% confidence for belowground EOCs and aboveground EOCs to be relocated to belowground building spaces

b. $\$26.32/ft^2$ ±30.6% at 95% confidence for belowground EOCs and aboveground EOCs to be replaced by new, hardened EOC construction (separate facilities located belowground)

Table 4 shows the various inaccuracies contributing to the total inaccuracies of the cost estimates.

Using the EOC population average unit upgrading cost estimates ($\$/ft^2$) and considering the estimate of the ratio of existing EOCs to DCPA listed EOCs and the estimate of DCPA reject-listed EOCs that are also located in "high-risk" areas, the following EOC population total cost of upgrading estimates were made.

a. \$87,300,000 ±22% at 95% confidence for belowground EOCs and aboveground EOCs to be relocated to belowground building spaces

b. \$115,700,000 ±31.1% at 95% confidence for belowground EOCs and aboveground EOCs to be replaced by new, hardened EOC construction (separate facilities located belowground)

TABLE 4. EOC UPGRADING TO RESIST A 10-PSI AIR-BLAST OVERPRESSURE: ELEMENTS CONTRIBUTING TO THE INACCURACY OF THE AVERAGE $/FT^2 COST ESTIMATE FOR THE EOC POPULATION (AT 95% CONFIDENCE)

Inaccuracy Attributable to:	EOC Upgrading Only. No New Construction/ Separate and Belowground		EOC Upgrading and New Construction/Separate and Belowground	
	Inaccuracy, %	Contribution to Total Inaccuracy, %	Inaccuracy, %	Contribution to Total Inaccuracy, %
Consistency of cost estimating error ("always high" or "always low" estimate)	10.0	22.1	10.0	10.7
Individual EOC cost-estimating error	3.6	2.9	6.8	4.9
EOC cost sample distribution, \$/ft^2 curve (n = 25 for upgrading only, n = 3 for N/C)	13.7	41.5	18.0	34.5
Ratio of aboveground EOCs to belowground/partially exposed EOCs	--	--	12.3	16.1
EOC cost sample distribution reflecting EOC size distribution (n = 125)	12.3	33.5	17.8	33.8
TOTAL	21.3*	100.0†	30.6*	100.0†

*Geometric sum
†Arithmetic sum

Both cost estimates were based on an estimated total of 1333 existing EOCs in "high-risk" areas with expected air-blast overpressures equal to or greater than 2 psi. Table 5 shows the various inaccuracies contributing to the total inaccuracies of the estimates.

TABLE 5. EOC UPGRADING TO RESIST A 10-PSI AIR-BLAST OVERPRESSURE: ELEMENTS CONTRIBUTING TO THE INACCURACY OF TOTAL COST ESTIMATE FOR THE EOC POPULATION (AT 95% CONFIDENCE)

Inaccuracy Attributable to:	EOC Upgrading Only. No New Construction/ Separate and Belowground		EOC Upgrading and New Construction/Separate and Belowground	
	Inaccuracy, %	Contribution to Total Inaccuracy, %	Inaccuracy, %	Contribution to Total Inaccuracy, %
Consistency of cost estimating error ("always high" or "always low" estimate)	10.0	20.7	10.0	10.3
Individual EOC cost estimating error	3.6	2.7	6.8	4.8
EOC cost sample distribution, $\$/ft^2$ curve (n = 25 for upgrading only, n = 3 for N/C)	13.7	38.9	18.0	33.4
Ratio of aboveground EOCs to belowground/partially exposed EOCs	--	--	12.3	15.6
EOC cost sample distribution reflecting EOC size distribution (n = 125)	12.3	31.3	17.8	32.7
Ratio of nonexisting (but listed in DCPA data) to existing EOCs (n = 143)	5.3	5.8	5.3	2.9
Estimate of reject-listed EOCs that are located in "high-risk" areas	1.7	0.6	1.7	0.3
TOTAL	22.0*	100.0÷	31.1*	100.0÷

*Geometric sum
÷Arithmetic sum

SECTION 5
CONCLUSIONS AND RECOMMENDATIONS

It is estimated that the unit costs (based on average 1975 construction costs) to reduce the vulnerability of all EOCs located in "high-risk" areas with expected air-blast overpressures of equal to or greater than 2 psi by upgrading to a 10-psi hardness level (without the consideration of the effects of nuclear fallout and EMP) are at 95% confidence--

a. Between $\$16/ft^2$ and $\$24/ft^2$ for belowground EOCs and aboveground EOCs to be relocated to belowground building spaces

b. Between $\$18/ft^2$ and $\$34/ft^2$ for belowground EOCs and aboveground EOCs to be replaced by new, hardened construction of separate EOC facilities located belowground

The corresponding total upgrading costs for all EOCs located in "high-risk" areas, i.e., an estimated 1333 EOCs, are estimated to be at 95% confidence--

a. Between $70,000,000 and $105,000,000 for belowground EOCs and aboveground EOCs to be relocated to belowground building spaces

b. Between $80,000,000 and $150,000,000 for belowground EOCs and aboveground EOCs to be replaced by new, hardened construction of separate EOC facilities located belowground

The 95% confidence intervals estimated for the EOC population upgrading costs could have been significantly reduced by simultaneous, appreciable increase (e.g., doubling) of the two sample sizes for the basic cost sample of 25 EOCs and 3 EOCs and the EOC size distribution sample of 125 EOCs.

But the limited budget for this project effort did not permit this. However, the provided cost estimates, at 95% confidence, of $\$20/ft^2 \pm \$4/ft^2$ and \$87,500,000 ±\$17,500,000 for the upgrading approach defined in *a*, and of $\$26/ft^2 \pm \$8/ft^2$ and \$115,000,000 ±\$35,000,000 for the upgrading approach defined in *b*, reflecting estimate accuracies of approximately ±20% and ±30% at 95% confidence, respectively, can be considered reasonable estimates.

The following recommendations for additional work related to the material covered in this report are offered for consideration.

Program Plan

The development of a program plan (contingency plan) for the vulnerability reduction of the EOC population predicated in this report is recommended. Such a plan should address the following:

a. Schedule of implementation

b. Required total funding and schedule-phased budgetary allocations

c. Necessary activities by and responsibilities of the participating organizations, e.g., DCPA and its regional offices, and the state and local civil preparedness organizations

d. Transfer of upgrading technology to the local entities (governmental and private) that would accomplish the physical upgrading effort

EOC Seminar

Many local EOC officials are unrealistically optimistic about the operational survivability of their facilities. They do not have an appreciation of the possible nuclear-weapons effects and the associated protection

requirements. They consider EOC upgrading an unnecessary, and therefore unjustifiable expense. Local EOC officials are in most cases unaware of the research and development work being accomplished by DCPA. They feel that they do not receive full benefit from DCPA's efforts. They express that better communication up and down the line would improve "attitudes" and, more importantly, the effectiveness of their operations.

A DCPA-sponsored seminar would accomplish the following:

a. Provide a forum for an interchange of ideas between DCPA and local EOC officials.

b. Inform local EOC officials of the latest DCPA policies and approach to our civil defense.

c. Convey latest DCPA research and development findings (in more usable form) to local EOC officials and interested parties of the private sector (i.e., engineers and architects).

d. Show how local EOC officials and interested parties can obtain specific information from DCPA.

e. Receive feedback from local EOC officials.

EOC Standard Elements and Standardized Designs

Because of the large number of existing EOCs to be upgraded and new EOCs to be constructed, it may be economically beneficial to introduce standard designs for EOC elements, such as austere but adequate blast doors and simple blast valves. Going one step further, multiple-source supply of these EOC elements could be arranged. For new EOC construction, standardized, complete designs, used in their entirety or adapted to fit individual needs, could be developed. These standardized designs, which are few in number, would be optimized solutions for the physical makeup of EOCs, reflecting the particular functional needs and environmental conditions.

Examples of Actual EOC Upgrading

The author's previous report, *Blast-Resistant Characteristics of State and Local Emergency Operating Centers (EOCs)*, as well as other DCPA guidelines and reference material, will provide a good starting point for the engineer faced with upgrading an individual EOC. But since EOCs and hardened structures are not everyday design problems with which he is thoroughly familiar, examples of actual EOC upgrading may be very valuable to him. These examples, covering the few most prevalent types of upgradable existing EOCs, would have to include the required design calculations, complete drawing packages (but not necessarily all shop and fabrication details), and cost estimates.

SECTION 6

BIBLIOGRAPHY

In addition to standard reference books in the fields of civil/structural engineering, mechanical and electrical engineering, and statistics, the following publications were extensively used in the project effort.

Lang, C. *Blast-Resistant Characteristics of State and Local Emergency Operating Centers (EOC'S)*, R-7427-1-3865. El Segundo, CA: Agbabian Assoc., Oct 1975 (AD A016 663)

Amer. Soc. of Civil Eng. (ASCE). *Design of Structures to Resist Nuclear Weapons Effects*, ASCE Manuals of Eng. Practice No. 42. New York: ASCE, 1964.

Robert Snow Means Co. (Means). *Building Construction Cost Data 1975.* Duxbury, MA: Means, 1975.

Natrella, M.G. *Experimental Statistics*, NBS Handbook 91. Washington, DC: USGPO, 1963.

Engineering News Record, 1975 issues reviewed.

See also the bibliography in the Lang report shown above for additional general and specific background for this project.

Appendix A-1

Summary of DCPA Computer Printout of 3/18/1975: Number and Risk Locations of EOCs in Each Region

TABLE A-1. NUMBER AND RISK LOCATIONS OF EOC'S IN DCPA REGION 1
(Summary of DCPA data, computer printout dated 3/18/1975)

State	Number of EOCs							
	≧10 psi*	$3-10^-$ psi*	$2-3^-$ psi*	≧2 psi*†	<2 psi*	Total‡	Reject Listing§	Grand Total**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Virgin Islands							1	1
Connecticut	20	17	3	40	10	50	12	62
Maine	2	4	3	9	48	57	33	90
Massachusetts	57	80	47	184	90	274	30	304
New Hampshire	4	6	9	19	30	49	70	119
New Jersey	42	24	7	73	19	92	331	423
New York	23	13	7	43	56	99	20	119
Rhode Island	15	12	6	33	7	40	6	46
Vermont	1	2		3	8	11	81	92
Total	164	158	82	404	268	672	584	1256

*Located in area of specified expected air-blast overpressure.

†Total of Columns (1), (2), and (3).

‡Total of Columns (4) and (5).

§ Reject listing of EOCs (due to insufficiently identified location or only partial completion of subject EOCs).

**Total of all identifiable EOCs.

TABLE A-2. NUMBER AND RISK LOCATIONS OF EOC'S IN DCPA REGION 2
(Summary of DCPA data, computer printout dated 3/18/1975)

State	Number of EOCs							
	≥10 psi*	3-10⁻ psi*	2-3⁻ psi*	≥2 psi*†	<2 psi*	Total‡	Reject Listing§	Grand Total**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Puerto Rico					18	18	62	80
Delaware	1	2		3	1	4	1	5
District of Columbia							1	1
Maryland	10	4	2	16	5	21	11	32
Pennsylvania	10	6	4	20	22	42	108	150
Virginia	4	3	2	9	13	22	18	40
West Virginia					2	2	4	6
Total	25	15	8	48	61	109	205	314

*Located in area of specified expected air-blast overpressure.

†Total of Columns (1), (2), and (3).

‡Total of Columns (4) and (5).

§ Reject listing of EOCs (due to insufficiently identified location or only partial completion of subject EOCs).

**Total of all identifiable EOCs.

TABLE A-3. NUMBER AND RISK LOCATIONS OF EOC'S IN DCPA REGION 3
(Summary of DCPA data, computer printout dated 3/18/1975)

State	Number of EOCs							
	$\geqq$10 psi*	3-10⁻ psi*	2-3⁻ psi*	$\geqq$2 psi*†	<2 psi*	Total‡	Reject Listing§	Grand Total**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Alabama	4	7	4	15	22	37	3	40
Florida	8	4	3	15	24	39	8	47
Georgia	5	1		6	18	24	4	28
Mississippi	4	3		7	13	20	8	28
North Carolina	6	2	1	9	33	42	6	48
South Carolina	6		1	7	16	23	5	28
Tennessee	2	1		3	11	14	13	27
Kentucky	1			1		1	20	21
Total	36	18	9	63	137	200	67	267

*Located in area of specified expected air-blast overpressure.

†Total of Columns (1), (2), and (3).

‡Total of Columns (4) and (5).

§ Reject listing of EOCs (due to insufficiently identified location or only partial completion of subject EOCs).

**Total of all identifiable EOCs.

TABLE A-4. NUMBER AND RISK LOCATIONS OF EOC'S IN DCPA REGION 4
(Summary of DCPA data, computer printout dated 3/18/1975)

State	Number of EOCs							
	≥10 psi*	3-10⁻ psi*	2-3⁻ psi*	≥2 psi*†	<2 psi*	Total‡	Reject Listing§	Grand Total**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Illinois	8	4	1	13	5	18	83	101
Indiana	2		1	3	3	6	52	58
Michigan	7	2		9	11	20	38	58
Minnesota	5	3		8	14	22	103	125
Wisconsin	19	3	2	24	20	44	56	100
Ohio	2	3		5	5	10	22	32
Canal Zone					1	1		1
Total	43	15	4	62	59	121	354	475

*Located in area of specified expected air-blast overpressure.

†Total of Columns (1), (2), and (3).

‡Total of Columns (4) and (5).

§ Reject listing of EOCs (due to insufficiently identified location or only partial completion of subject EOCs).

**Total of all identifiable EOCs.

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JAN 77 C LANG DCPA01-75-C-0337
UNCLASSIFIED AA-R-7611-4314 NL

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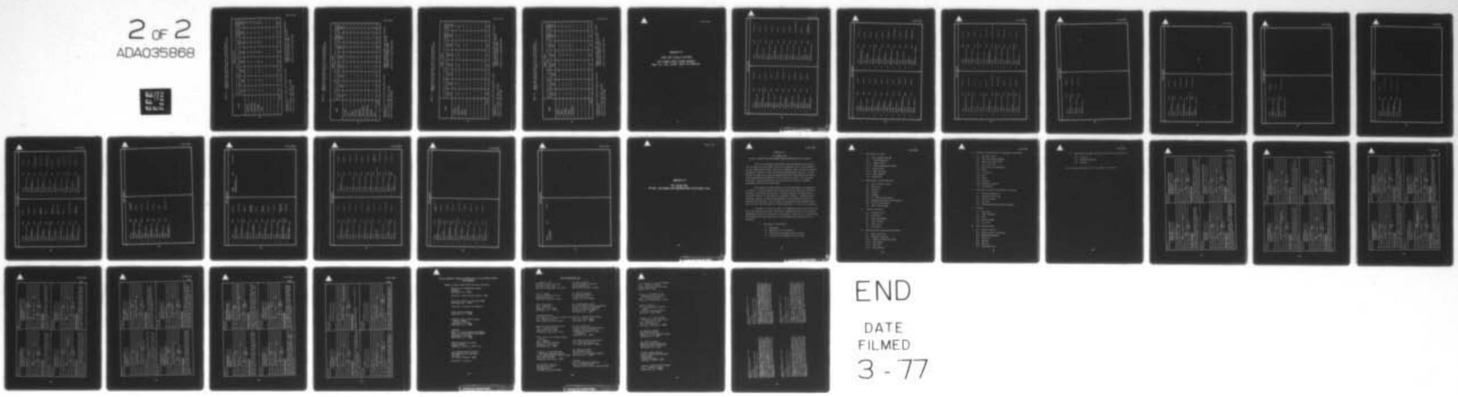

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TABLE A-5. NUMBER AND RISK LOCATIONS OF EOC'S IN DCPA REGION 5
(Summary of DCPA data, computer printout dated 3/18/1975)

State	Number of EOCs							
	≧10 psi*	3-10⁻ psi*	2-3⁻ psi*	≧2 psi*†	<2 psi*	Total‡	Reject Listing§	Grand Total**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Arkansas	8	7	2	17	70	87	6	93
Louisiana	8	9	3	20	32	52	3	55
New Mexico	2	1		3	26	29	1	30
Oklahoma	8	9	2	19	88	107	8	115
Texas	37	29	13	79	178	257	12	269
Total	63	55	20	138	394	532	30	562

*Located in area of specified expected air-blast overpressure.

†Total of Columns (1), (2), and (3).

‡Total of Columns (4) and (5).

§ Reject listing of EOCs (due to insufficiently identified location or only partial completion of subject EOCs).

**Total of all identifiable EOCs.

TABLE A-6. NUMBER AND RISK LOCATIONS OF EOC'S IN DCPA REGION 6
(Summary of DCPA data, computer printout dated 3/18/75)

State	Number of EOCs							
	$\geq$10 psi*	3-10⁻ psi*	2-3⁻ psi*	$\geq$2 psi*†	<2 psi*	Total‡	Reject Listing§	Grand Total**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Colorado	8	4	4	16	37	53	3	56
Iowa	4	2		6	35	41	32	73
Kansas	2	5	2	9	43	52	5	57
Missouri	9	11	2	22	27	49	10	59
Nebraska	2	5	1	8	31	39	5	44
North Dakota		2		2	8	10	13	23
South Dakota	3	2	1	6	21	27	30	57
Wyoming	1		1	2	6	8	2	10
Utah	1	2	1	4	11	15	3	18
Total	30	33	12	75	219	294	103	397

*Located in area of specified expected air-blast overpressure.

†Total of Columns (1), (2), and (3).

‡Total of Columns (4) and (5).

§ Reject listing of EOCs (due to insufficiently identified location or only partial completion of subject EOCs).

**Total of all identifiable EOCs.

TABLE A-7. NUMBER AND RISK LOCATIONS OF EOC'S IN DCPA REGION 7
(Summary of DCPA data, computer printout dated 3/18/75)

State	Number of EOCs							
	≥10 psi*	3-10⁻ psi*	2-3⁻ psi*	≥2 psi*†	<2 psi*	Total‡	Reject Listing§	Grand Total**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Arizona		2	1	3	11	14	4	18
California	96	26	7	129	66	195	11	206
Hawaii							9	9
Nevada	2	1		3	7	10	1	11
Total	98	29	8	135	84	219	25	244

*Located in area of specified expected air-blast overpressure.

†Total of Columns (1), (2), and (3).

‡Total of Columns (4) and (5).

§ Reject listing of EOCs (due to insufficiently identified location or only partial completion of subject EOCs).

**Total of all identifiable EOCs.

TABLE A-8. NUMBER AND RISK LOCATIONS OF EOC'S IN DCPA REGION 8
(Summary of DCPA data, computer printout dated 3/18/75)

State	Number of EOCs							
	≧10 psi*	3-10⁻ psi*	2-3⁻ psi*	≧2 psi*†	<2 psi*	Total‡	Reject Listing§	Grand Total**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Alaska							4	4
Idaho		2		2	12	14	5	19
Montana	5	1		6	10	16	6	22
Oregon	3	2		5	17	22	3	25
Washington	7	2	1	10	17	27	4	31
Total	15	7	1	23	56	79	22	101

*Located in area of specified expected air-blast overpressure.

†Total of Columns (1), (2), and (3).

‡Total of Columns (4) and (5).

§ Reject listing of EOCs (due to insufficiently identified location or only partial completion of subject EOCs).

**Total of all identifiable EOCs.

Appendix A-2

DCPA 1975 Survey of 143 EOCs

EOC Location Codes, Facility Numbers, Types (i.e., City, County, State), and Addresses

DCPA REGION 1

1.	11210116	03030	Farmington Tn	New Town Hall	Monteith Dr, Framington Ct
2.	11310008	03103	Meriden Cy	Fire Station	E. Main St./Pomeroy Ave., Meriden Ct
3.	11G10039	03162	Danbury Cy	City Hall	155 Deerhill Av, Danbury Ct
4.	11110059	00327	Trumbull Tn	Town Hall	5866 Main St, Trumbull Ct
5.	11H20002	00000	Barkhamsted Tn	Town Hall	Rte 181, Barkhamsted Ct
6.	12110001	01005	Androscoggin Co	County Courthse	2 Turner St, Auburn Me
7.	12110001	01540	Auburn Cy	Fire Station	Minot Ave, Auburn Me
8.	12210029	01031	Westbrook Cy	Mun Bldg	790 Main St, Westbrook Me
9.	13A10055	00500	Agawam Tn	Town Hall	Main St, Agawam Ma
10.	13B10040	01501	Holden Tn	Fire Dept	N Main St, Holden Ma
11.	13B10041	03330	W Boylston Tn	Light Co Bldg	2 Crescent St, W Boylston Ma
12.	13J20018	05330	Westford Tn	Town Hall	Main St, Westford Ma
13.	13110050	05030	Marblehead Tn	Abbott Hall	Washington St, Marblehead Ma
14.	13120116	03805	Watertown Tn	Municipal Garage	128 Orchard, Watertown Ma
15.	13610029	09920	Dracut Tn	Town Hall	62 Arlington St, Dracut Ma
16.	13710034	03160	Fairhaven Tn	Water Dept	6 Bridge St, Fairhaven Ma
17.	13A10052	02730	Wilbraham Tn	Town Bldg	4 Maple St, N Wilbraham, Ma
18.	13B10037	02702	North Brookfield Tn	Library	Main St, N Brookfield Ma
19.	13B10061	06130	Sutton Tn	Fire Sta	Manchaug Rd, Sutton Ma
20.	13B10062	02625	Mass Sector 3B + Northbridge Tn	Post Office	44 Church St, Northbridge Ma

DCPA REGION 1

21. 13I10002 Town Hall Rte 138, Dighton Ma	02801	Dighton Tn	
22. 13I10006 CD Bldg Leonard Crt, Taunton Ma	03530	Taunton Cy	
23. 13J20013 Town House Foster St, Littleton Ma	03501	Littleton Tn	
24. 13L20005 Kellogg Hall State St, Granby Ma	03130	Granby Tn	
25. 13I10022 Fire and Pol Sta Bay Rd, Hamilton Ma	05811	Hamilton Tn	
26. 13420008 Jr Sr High Sch Mass Ave, Lunenburg Ma	01701	Lunenburg Tn	
27. 13A20002 Fire Sta West St, Hadley Ma	01530	Hadley Tn	
28. 13A20004 Da Sullivan Sch 290 Main St, Northampton Ma	03330	Northampton Cy	
29. 13120009 Town Hall Hartley Rd, Rochester Ma	09960	Rochester Tn	
30. 13M10015 Fire Sta Dutcher St, Hopedale Ma	01504	Hopedale Tn	

31. 13120142 Womens Correctional Inst Western Ave, Framingham MA	04212	Mass Sector 1 B	
32. 13120146 Community House Main St, Ashland MA	04630	Ashland Tn	
33. 13130028 Police Sta 485 Washington St, Wellesley MA	03147	Wellesley Tn	
34. 13130058 Nike Adm Bldg 500 Middle St, Randolph MA	04310	Randolph Tn	
35. 13140004 Town Off Bldg Union St, Rockland MA	03831	Rockland Tn	
36. 13230013 Academy Bldg Bedford St, Bridgewater MA	00530	Bridgewater Tn	
37. 13230015 Fire Sta West St, E Bridewater MA	02130	East Bridgewater Tn	
38. 14G10007 Fire Sta Rte 3A, Litchfield NH	03410	Litchfield Tn	
39. 14G20010 Fire Sta Greenland NH	05605	Greenland Town	
40. 14G20001 Fire Sta Emerson Ave/Rt 121, Hamstead NH	04901	Hampstead Town of	

DCPA REGION 1

41. 15410146 00037 Belleville Cy
    Police Sta Town Hall
    152 Washington Ave, Belleville NJ

42. 15420019 09990 East Hanover Tn
    Mun Bldg
    415 Ridgedale Ave, East Hanover NJ

43. 15420041 03634 Passaic Tn
    Elm St Sch
    Elm St, Passaic NJ

44. 15430049 04902 Linden Tn
    Fire Dept
    4 W St and George Ave, Linden NJ

45. 15510020 06951 Emerson Bor
    Municipal Bldg
    Linwood Ave, Emerson NJ

46. 15510112 00958 Cliffside Park Bor
    Fire Hdqtrs
    661 Anderson Ave, Cliffside Park NJ

47. 15520058 00000 North Haledon Bor
    Mun Bldg
    103 Overlook Ave, No Haledon NJ

48. 15710020 02120 Trenton Cy
    Police Hq
    N Clinton Av + Perry St, Trenton NJ

49. 15710028 05297 Hamilton Twp
    Police Hdqtrs
    Whitehorse Mercervle Rd, Hamilton Twp

50. 15420028 04281 Chatham Bor
    Jr High Sch
    52 Fairmount Ave, Chatham Boro NJ

51. 15420033 09990 Morris Twp
    Police Hq
    49 Woodland Ave, Convent Sta NJ

52. 15430087 09990 Fanwood Bor
    Boro Hall
    130 Watson Rd, Fanwood NJ

53. 15710042 09990 Princeton Bor
    Borough Hall
    Bayard Lane, Stockton St, Princeton NJ

54. 16310072 07372 Buffalo Cy
    Cy Hall
    Niagara Sq, Buffalo NY

55. 16430018 00033 Nassau Co Zone 2
    N Hempstead Town Hall
    Plandome Rd, Manhasset NY

56. 16460035 03502 New York Cy-Richmond
    Public Sch 45
    58 Lawrence Ave, Staten Island NY

57. 16110010 00004 Plattsburgh Cy
    City Hall
    City Hall Pl, Plattsburgh NY

58. 16490012 00698 Mount Vernon Cy
    City Hall
    Roosevelt Sq, Mount Vernon NY

59. 16310142 04205 Erie Co
    EOC
    Chestnut Ridge Park, Orchard Park NY

60. 17G20002 00000 Scituate Tn
    Town Hall
    Main St, Scituate RI

DCPA REGION 1

61. 17230001 01608 Jamestown Tn

Town Hall
71 Narragansett Av, Jamestown RI

62. 17H10001 01008 Portsmouth Tn

Town Hall
East Main Rd, Portsmouth RI

63. 17240118 08504 Burrillville Tn

Police Sta
No Main St, Pascoag RI

DCPA REGION 2

1.	24130060	00793	Baltimore City
	North Dist Police Sta Keskeswick and 34 St, Baltimore MD		
2.	24J20015	01004	Washington Co
	Wash Co Courthouse Summit Av, Hagerstown MD		
3.	24120073	02035	Baltimore County
	Garrison Police Sta Reisterstown Rd, Garrison MD		
4.	26750357	05502	Philadelphia City
	Germantown Hall Germantown Ave + Haines, Philadelphia PA		
5.	27320007	99999	Virginia Beach Cy
	Va Beach EOC S. Plaza Trail, Virginia Beach VA		

DCPA REGION 3

1. 32210010 03021 Duval Co, Jacksonville Cy

   Lanier Bldg
   107 Market Street, Jacksonville FL

2. 32J30015 00115 Florida St

   State Supreme Court Bldg
   400 South Duval Street, Tallahassee FL

3. 34110050 00216 Hinds Co, Jackson Cy

   City Hall
   205 S President Street, Jackson MS

DCPA REGION 4

1. 41230006 04302 Aurora Cy

   City Hall
   44 E. Downers Place, Aurora IL

2. 41810022 01452 Illinois St-Ill SCMAA

   Old Power Plant
   East Monroe, Springfield IL

3. 45410031 09990 Wisconsin St Area

   District Headquarters
   Hwy 151 and 190-94, Madison WI

4. 45520019 09953 Wisc State Area

   Wisc State Patrol Dist 2
   US Hwy 18 and I-94, Waukesha WI

DCPA REGION 5

1.	51R70004	09007	Conway Cy	City Hall Oak at Chestnut, Conway AR
2.	51S40006	03004	Crittenden Co	County Courthouse Jackson Ave, Marion AR
3.	51210001	00068	Pulaski Co	County Courthouse 407 W Markham, Little Rock AR
4.	51110009	01384	Sebastian Co, Ft Smith Cy	County Courthouse 35 S 6th, Ft Smith AR
5.	51RE0002	00001	Perry Co	County Courthouse Courthouse Square, Perryville AR
6.	52S90012	06694	St Area 6, Lafayette Par Cy	Parish Courthouse W. Main, Lafayette LA
7.	52110013	00572	East Baton Rouge Parish	Publicworks Bldg 1100 Laurel, Baton Rouge LA
8.	52110045	02364	Baker Cy	City Hall 3325 Groom Rd, Baker LA
9.	52410013	01024	Jefferson Parish No 2	CD Headquarters 5743 River Road, Waggaman LA
10.	52S70001	00102	Iberville Par, Plaquemine Cy	Parish Courthouse Railroad Ave, Plaquemine LA
11.	52210010	01026	West Lake Cy	City Hall 701 Johnson, West Lake, LA
12.	52310008	00001	State Area 4	Old Fire Station 400 Stone Ave, Monroe LA
13.	52520010	02184	St Area 2, Caddo, Bossier Par	CD Office 1238 Murphy, Shreveport LA
14.	52SC0005	06528	St Martin Parish	Parish Courthouse 420 S Main, St Martinville LA
15.	54110008	02803	Okla St Dist 5, Comanche Co, Lawton	Police Sta 4th at A St, Lawton OK
16.	54230037	07805	Oklahoma Co	Courthouse Annex 320 W Kerr, Okla City OK
17.	54330025	00670	Okla St Dist 2, Tulsa Co-Cy	City Hall 200 Civic Center, Tulsa OK
18.	54330095	00001	Oklahoma State Hwy	Okla Hwy Div 8 4802 Mingo Valley Express, Tulsa OK
19.	54130001	01109	Jackson Co, Altus Cy	Fire Sub Station N Main St, Altus OK
20.	55B10073	07234	State Area 2A	Dept Pub Safety Reg Office NW Hwy at Dacoma, Houston TX

DCPA REGION 5

21.	55G10010 Polic Bldg 401 E Beauregard, San Angelo TX	09906	Tom Green Co, San Angelo Cy
22.	55U60007 Police Station Cherry at Travis, Sherman TX	00001	Sherman Cy
23.	55D10007 City Hall 916 Texas, Lubbock TX	06038	Lubbock Cy
24.	55510021 Police Station Ft Brown, Brownsville TX	00381	Brownsville Cy
25.	55720215 Police, Fire Bldg 116 W Belt Line, De Soto TX	00001	De Soto Cy
26.	55720231 City Hall Highway 78, Sachse TX	00001	Sachse Cy
27.	55J10005 County Courthouse 100 N Broadway, Tyler TX	05070	Smith Co, Tyler Cy

DCPA REGION 6

1. 61230002 01025 Boulder Co

   County Courthouse
   1321 Pearl St, Boulder CO

2. 61RE0017 01301 Colorado State

   State Patrol Bldg
   14th Ave and 2nd Street, Greeley CO

3. 61220037 03704 Arapahoe Co

   Welfare Bldg
   5606 S Court Pl, Littleton CO

4. 62210001 02014 Scott County, Davenport Cy

   Scott County Courthouse
   432 W Fourth, Davenport IA

5. 62210030 03032 Scott Co

   Fire Station
   105 N Cody Dr, Leclaire IA

6. 63U40006 02654 Butler Co, El Dorado Cy

   Dept Public Safety
   220 E First Ave, El Dorado KS

7. 64120027 01441 Kansas City

   City Hall
   414 E Twelfth St, Kansas City MO

8. 64210004 05025 St Joseph Cy

   City Hall
   11 Frederick St, St Joseph MO

9. 64330116 05506 Missouri State Highway Comm.

   Highway Dist No 6 Bldg
   329 South Kirkwood Rd, Kirkwood MO

10. 65110005 00383 Nebraska State

    Nebraska State EOC
    1300 Military Road, Lincoln NB

11. 68H20006 09000 Wyoming, State of

    National Guard Armory
    5500 Bishop Blvd, Cheyenne WY

DCPA REGION 7

1. 71110069 00306 Arizona St
   Capitol Building
   17th and Washington, Phoenix AZ

2. 72A10002 02077 Stockton City
   Police Hqs and EOC
   El Dorado and Washington, Stockton CA

3. 72L10016 02000 Pacific Grove Cy
   City Hall
   Forest and Laurel, Pacific Grove CA

4. 72310063 02589 Glendale Cy
   City Hall
   613 E Broadway, Glendale CA

5. 72310442 01196 Los Angeles County
   Sheriff Dept Jail
   441 Bauchet St, Los Angeles CA

6. 72310449 01659 California State Region I
   State Bldg
   107 South Broadway, Los Angeles CA

7. 72310827 05312 Santa Monica Cy
   Civic Auditorium
   Santa Monica CA

8. 72310877 00233 La Verne Cy
   City Hall
   2061 Third St, La Verne CA

9. 72311000 04101 South Pasadena Cy
   City Hall-EOC
   1416 Mission St, So. Pasadena CA

10. 72311058 00217 Montebello Cy
    Police Bldg
    1600 Beverly Blvd, Montebello CA

11. 72311113 00002 Lynwood Cy
    Police Station
    11330 Bullis Road, Lynwood CA

12. 72311157 00231 Downey Cy
    City Hall
    Downey CA

13. 72311186 00010 Paramount Cy
    City Hall
    16420 Colorado St, Paramount CA

14. 72311232 00225 Hawthorne City
    City Hall
    4460 W 126th St, Hawthorne CA

15. 72311244 03022 Gardena Cy
    City Hall
    1700 West 162 St, Gardena CA

16. 72311252 00000 Lawndale Cy
    City Hall
    16706 Hawthorne Blvd, Lawndale CA

17. 72311272 00001 Rolling Hills Estates Cy
    City Hall
    26940 Rolling Hills Rd, Rolling Hills CA

18. 72520017 00018 San Bernardino Cy
    City Hall
    422 Third St, San Bernardino CA

19. 72610171 01708 National City Cy
    Civic Center
    1243 National Ave, National City CA

20. 72610212 05806 El Cajon City
    Fire Station
    210 Highland Ave, El Cajon CA

DCPA REGION 7

21.	72710095	00074	Oakland Cy Calif St Area 2	Ampitheatre 3304 Joaquin Miller Road, Oakland CA
22.	72720012	07403	Richmond City	Hall of Justice 429 Twenty Seventh St, Richmond CA
23.	72740109	01601	San Fransisco Co - Cy	Youth Guidance Center 375 Woodside Ave, San Fransisco CA
24.	72750077	05213	San Mateo Co	Hall of Justic Annex Marshall at Hamilton, Redwood City CA
25.	72310977	00010	South El Monte Cy	City Administration 1415 Tyler, S El Monte CA
26.	72750051	00420	Burlingame Cy	Police Station 1220 Howard St, Burlingame CA
27.	72810055	00000	Campbell City	Fire Station 51 No Central, Campbell CA
28.	72510034	03403	Corona City	City Hall Civic Center, Corona CA
29.	72610226	00034	Del Mar City	Fire Station 2200 Jimmy Durante Blvd, Del Mar CA

DCPA REGION 8

1. 85120030 03273 Kitsap Co

Kitsap Courthouse
Port Orchard WA

Appendix A-3

EOC Sample Data
28 EOCs--Descriptions and Upgrading/New Construction Costs

APPENDIX A-3

EOC SAMPLE DATA

28 EOC'S--DESCRIPTIONS AND UPGRADING/NEW CONSTRUCTION COST ESTIMATES

This section presents descriptions and upgrading/new construction cost estimates for the 25 EOCs visited and inspected and for three hypothetical, but representative EOCs, which were included to cover the entire spectrum of EOCs with regard to sizes and aboveground/belowground locations. Of the 28 EOCs, 25 EOCs were located belowground and their upgrading was considered to be accomplished by hardening of the existing facilities. For the other three EOCs, located aboveground, new construction of separate, hardened, belowground facilities was envisioned.

The estimates of EOC hardening to resist the effects corresponding to a 10-psi air-blast overpressure concentrated on the functional survival of the EOCs at that overpressure level. Secondary failures not affecting the functional survival of the EOCs were considered tolerable. Upgrading was by permanent measures, including EOC restoration to an acceptable level after hardening modifications. Not included in the upgrading cost estimates were costs arising from disturbances of normal operations, if any, during upgrading.

Included in the cost estimates for upgrading and for new construction were labor and material costs, contractors' overhead and profit, and required professional services by architects and engineers. Specifically, the following EOC elements/items were considered in the upgrading/new construction cost estimates:

1. EOC External Surroundings

   1.1 Antenna(s)
   1.2 Reduction of Fire Potential
   1.3 Minimizing of Exposed Vertical Surfaces
   1.4 Prevention of Blockage of Air Passages

2. EOC Protective Shell

2.1 Floor System above EOC

2.1.1 Plate/Slab/Joists

2.1.2 Support Beams

2.1.3 Columns/Load-bearing Walls

2.2 Exterior Walls

2.2.1 Wall Thickness

2.2.2 Wall supports

2.3 Foundations

3. Penetrations through EOC Shell

3.1 Doors and Door Frames

3.2 Staircases

3.3 Elevators

3.4 Windows

3.5 Areaways

3.6 Air Intakes and Exhausts

3.7 Emergency Generator Engine Exhaust

3.8 Piping Feed-throughs

3.9 Cable Feed-throughs

4. Interior Structures

4.1 Permanent Walls

4.2 Partitions

4.3 Doors and Windows

4.4 False Ceilings

4.5 False Floors

4.6 Staircases

5. Mechanical/Electromechanical Equipment

5.1 Public Utilities

5.2 Emergency Generator

5.2.1 Engine and Generator (E/G)

5.2.2 E/G Support

5.2.3 Batteries

5.2.4 Fuel Daytank

5. Mechanical/Electromechanical Equipment (continued)

   5.3 Switchover Gear
   5.4 Power Distribution/Cables
   5.5 Piping (fuel and water)
   5.6 Air Filter Units
   5.7 A/C Unit(s) and Condensers
   5.8 Heater
   5.9 Air Ducting
   5.10 Fans
   5.11 Motors
   5.12 Lighting
   5.13 Emergency Lighting
   5.14 Sump Pump(s)

6. Electronics Equipment and Operator Interface

   6.1 Transmitter/Receiver
   6.2 Telephone Switch Gear
   6.3 Control Consoles
   6.4 Teletype
   6.5 Telephones/Microphones/Loud Speakers

7. Storage

   7.1 Fuel Tank
   7.2 Water Tank/Well
   7.3 Food
   7.4 Sanitary Waste
   7.5 First Aid

8. Facilities/Furniture

   8.1 Office Furniture
   8.2 Operator Stalls and Chairs
   8.3 Mapping/Blackboards
   8.4 Billeting
   8.5 Messing
   8.6 Sanitary
   8.7 Decontamination

9. Required Professional Services by Architects and Engineers

   9.1 Architect

   9.2 Designer/Draftsman

   9.3 Engineer

The following addresses each of the 28 EOCs individually.

EOC NO. 1

EOC Address Bramhall Square Fire Station
Bramhall Square
Portland, ME

EOC serving City of Portland, ME

EOC serving a population of ~70,000

No. of EOC emergency personnel 40

EOC built in 1966

Building (in which EOC is located) built in 1966

EOC net area, ft^2 3898

Total cost of EOC upgrading, $ 77,240

Unit cost of EOC upgrading, $ 19.82 /ft^2

EOC main characteristics:
(vulnerability/upgrading)

Located partially belowground--three walls belowground and one wall fully exposed. Floor above EOC (concrete slab) needs underpinning. Exposed wall needs strengthening. Many EOC openings which require blast protection (blast doors, staircase enclosure).

EOC NO. 2

EOC Address Westbrook City Municipal Building
790 Main Street
Westbrook, ME

EOC serving City of Westbrook, ME

EOC serving a population of 15,000

No. of EOC emergency personnel ~25

EOC built in 1968

Building (in which EOC is located) built in 1966

EOC net area, ft^2 2557

Total cost of EOC upgrading, $ 65,720

Unit cost of EOC upgrading, $ 25.70 /ft^2

EOC main characteristics:
(vulnerability/upgrading)

Located belowground, in basement of building. Floor system above EOC is 4-in. reinforced concrete slab on steel beams. Requires extensive underpinning. Exterior walls need strengthening. Openings are few; mainly one staircase and one entrance at the basement floor level. Air intake and exhaust openings are subject to blockage.

EOC NO. 3

EOC Address Fire Station
Minot Avenue
Auburn, ME

EOC serving City of Auburn and Co. of Androscoggin, ME

EOC serving a population of ~90,000

No. of EOC emergency personnel 95

EOC built in 1971

Building (in which EOC is located) built in 1971

EOC net area, ft^2 3935

Total cost of EOC upgrading, $ 85,660

Unit cost of EOC upgrading, $ 21.77 /ft^2

EOC main characteristics:
(vulnerability/upgrading)

EOC located in basement of fire station. Three walls belowground, one wall fully exposed (no berming possible). Floor system above EOC (weak prestressed concrete slab) requires underpinning. Emergency generator heat exchanger located outside, unprotected. Air intake and exhaust openings subject to blockage.

EOC NO. 4

EOC Address Public Works Complex, Administration Building
55 Sea Street
Quincy, MA

EOC serving City of Quincy, MA

EOC serving a population of 90,000

No. of EOC emergency personnel 85

EOC built in 1967

Building (in which EOC is located) built in 1967

EOC net area, ft^2 7806

Total cost of EOC upgrading, $ 133,890

Unit cost of EOC upgrading, $ 17.15 /ft^2

EOC main characteristics:
(vulnerability/upgrading)

EOC located belowground, in basement of multiuse building. Reinforced concrete construction. Floor system above EOC: 9 1/2-in. slab on capitals, square columns; but not strong enough, requiring underpinning. Diesel generator located outside of protective EOC shell, but sufficiently protected. Three staircases and five doors need to be blast-protected.

AA8290

EOC NO. 5

EOC Address Public Safety Complex
Church Street/Grove Street
Chicopee, MA

EOC serving City of Chicopee

EOC serving a population of 70,000

No. of EOC emergency personnel 57

EOC built in Construction Started in 1975

Building (in which EOC is located) built in Construction Started in 1975

EOC net area, ft^2 3948

Total cost of EOC upgrading, $ 86,440

Unit cost of EOC upgrading, $ 21.89 $/ft^2$

EOC main characteristics:
(vulnerability/upgrading)

EOC located in basement of multiuse building. Two walls shared with adjoining buildings, one wall completely above ground. Floor system above EOC: 8-in. R/C slab on concrete beams; needs underpinning in some areas. Three walls have to be strengthened to resist reflected air-blast overpressures. Few openings after modifications. Four doors need to be blast-protected.

EOC NO. 6

EOC Address Police Station
8166 Post Road (State Highway-Route 1)
North Kingstown, R.I.

EOC serving City of North Kingstown, R.I.

EOC serving a population of 30,000

No. of EOC emergency personnel 35

EOC built in 1972

Building (in which EOC is located) built in 1972

EOC net area, ft^2 3326

Total cost of EOC upgrading, $ 93,420

Unit cost of EOC upgrading, $ 28.09 $/ft^2$

EOC main characteristics:
(vulnerability/upgrading)

EOC located in lower level of the police station. Three of four exterior walls are entirely exposed, requiring strengthening. The floor system above the EOC: 8-in. R/C slab is too weak, necessitating heavy underpinning. EOC has many openings (one staircase, four entryways/doors, plus openings for air intakes and exhausts).

EOC NO. 7

EOC Address Fire Station
1075 E. Main Street
Meriden, CT

EOC serving City of Meriden, CT

EOC serving a population of 65,000

No. of EOC emergency personnel 30

EOC built in 1967

Building (in which EOC is located) built in 1967

EOC net area, ft^2 4888

Total cost of EOC upgrading, $ 45,330

Unit cost of EOC upgrading, $ 9.27 $/ft^2$

EOC main characteristics:
(vulnerability/upgrading)

EOC located completely underground, a separate facility (except for fire station above a portion of the EOC). Floor system above EOC: R/C slab/beam/girder construction. 12 in. lightly reinforced concrete exterior walls. Very few openings for access and air intake and exhaust.

EOC NO. 8

EOC Address Mt. Vernon City Hall
Roosevelt Square
Mt. Vernon, NY

EOC serving City of Mt. Vernon

EOC serving a population of 74,000

No. of EOC emergency personnel 55

EOC built in (Occupied in) 1970

Building (in which EOC is located) built in 1928

EOC net area, ft^2 3154

Total cost of EOC upgrading, $ 68,230

Unit cost of EOC upgrading, $ 21.63 $/ft^2$

EOC main characteristics:
(vulnerability/upgrading)

EOC located belowground, in basement of the municipal building. Weak floor above the EOC (slag-block filler and concrete rib construction). Exterior walls are strong. EOC must be partitioned from rest of basement, requiring strong "partition" walls. Very few openings after modifications.

AA8291

EOC NO. 9

EOC Address North Hempstead Town Hall
220 Plandome Road
Manhasset, NY

EOC serving Naussau Co., Zone 2, NY

EOC serving a population of 238,000

No. of EOC emergency personnel 15

EOC built in (Occupied in) 1970

Building (in which EOC is located) built in 1950

EOC net area, ft^2 1250

Total cost of EOC upgrading, $ 60,980

Unit cost of EOC upgrading, $ 48.78 /ft^2

EOC main characteristics:
(vulnerability/upgrading)

EOC only partially belowground, one long side completely exposed. EOC occupies only part of basement. Floor system above EOC is R/C construction (slab), requires underpinning. Exterior walls need strengthening. Diesel generator is located outside, needs some protection. Cost-effective upgrading requires consolidation of EOC space, a lot of rework.

EOC NO. 10

EOC Address Borough Hall
Bayard Lane, Stockton Street
Princeton, NJ

EOC serving Borough and Township of Princeton, NJ

EOC serving a population of 25,000

No. of EOC emergency personnel 25 to 30

EOC built in (Occupied in) 1972

Building (in which EOC is located) built in 1967

EOC net area, ft^2 3018

Total cost of EOC upgrading, $ 67,400

Unit cost of EOC upgrading, $ 22.33 /ft^2

EOC main characteristics:
(vulnerability/upgrading)

EOC located in basement of multiuse building, mostly belowground (up to 4-ft exposure aboveground). Floor system above EOC: 8 in. R/C slab (too weak because of large spans). 12 in. R/C exterior walls. EOC shares basement space with other departments. Strong "partition" walls required. Very few openings after partitioning.

EOC NO. 11

EOC Address Police Headquarters
N. Clinton Ave. & Perry Street
Trenton, NJ

EOC serving City of Trenton

EOC serving a population of 105,000

No. of EOC emergency personnel 75 (plus their families for a total of 200 people)

EOC built in 1972

Building (in which EOC is located) built in 1972

EOC net area, ft^2 6062

Total cost of EOC upgrading, $ 129,300

Unit cost of EOC upgrading, $ 21.33 /ft^2

EOC main characteristics:
(vulnerability/upgrading)

EOC located in basement of multistory police building. Shares basement with other police functions. Too expensive to harden entire basement (over 12,000 sq ft). EOC must be partitioned from rest of basement. Floor above EOC: 6 1/2 in. lightly R/C slab on beams and columns, must be strengthened. 12 in. R/C exterior walls. Many openings to EOC will be eliminated by suggested partitions.

EOC NO. 12

EOC Address Washington Co. Courthouse
Summit Avenue
Hagerstown, MD

EOC serving County of Washington

EOC serving a population of 106,000

No. of EOC emergency personnel 50

EOC built in 1962

Building (in which EOC is located) built in 1962

EOC net area, ft^2 2324

Total cost of EOC upgrading, $ 20,340

Unit cost of EOC upgrading, $ 8.75 /ft^2

EOC main characteristics:
(vulnerability/upgrading)

EOC located in basement of multiuse building, but EOC built as separate facility with extra strong protective shell of 2-ft thick R/C floor slab above EOC and walls. Very few openings (one entrance door and small air intake and exhaust).

AA8292

EOC NO. 13

EOC Address Alachua County Courthouse
Main Street/University Avenue
Gainesville, FL

EOC serving Alachua County

EOC serving a population of 115,000

No. of EOC emergency personnel 24

EOC built in 1963

Building (in which EOC is located) built in 1963

EOC net area, ft^2 2959

Total cost of EOC upgrading, $ 88,680

Unit cost of EOC upgrading, $ 29.97 /ft^2

EOC main characteristics:
(vulnerability/upgrading)

EOC located belowground in basement of court building. Floor system above EOC: concrete joist construction on beams and square columns. EOC occupies part of basement. Strong partitioning walls required to separate EOC from rest of basement. Very few openings after partitioning of basement.

EOC NO. 14

EOC Address Wisconsin State Patrol District 2
21115 US Highway 18
Waukesha, WI

EOC serving State District 2 of Wisconsin

EOC serving a population of 1,900,000

No. of EOC emergency personnel 80

EOC built in 1967

Building (in which EOC is located) built in 1967

EOC net area, ft^2 4947

Total cost of EOC upgrading, $ 51,380

Unit cost of EOC upgrading, $ 10.39 /ft^2

EOC main characteristics:
(vulnerability/upgrading)

EOC located belowground, in basement of a one-story government building. R/C construction. Some areas of floor system above EOC (slab) need underpinning. Very few openings (two staircases and small air intake and exhaust openings).

EOC NO. 15

EOC Address Old Power Plant
East Monroe Street
Springfield, IL

EOC serving State of Illinois

EOC serving a population of 12,000,000

No. of EOC emergency personnel 250

EOC built in 1967

Building (in which EOC is located) built in 1923 and Before

EOC net area, ft^2 13,000

Total cost of EOC upgrading, $ 178,550

Unit cost of EOC upgrading, $ 13.73 /ft^2

EOC main characteristics:
(vulnerability/upgrading)

After modification for proposed blast-hardening, EOC will be completely belowground, in basement of existing multiuse building and in long tunnel. Floor system above EOC (basement): 4 in. R/C slab on steel beams and girders, requires strengthening. Moderate amount of openings, which need blast protection. Usage (proposed) of tunnel requires a lot of E/M equipment.

EOC NO. 16

EOC Address Police Station
Cherry/Travis
Sherman, TX

EOC serving City of Sherman, TX

EOC serving a population of 33,000

No. of EOC emergency personnel 48

EOC built in 1966

Building (in which EOC is located) built in 1966

EOC net area, ft^2 5421

Total cost of EOC upgrading, $ 47,530

Unit cost of EOC upgrading, $ 8.77 /ft^2

EOC main characteristics:
(vulnerability/upgrading)

EOC located belowground, in basement of police station. R/C construction. 12 in. and 15 in. thick walls. Floor system above EOC: 12 in. thick slab on columns (w/o capitals) and beams. Two staircases lead into basement. Air intake and exhaust openings subject to blockage.

AA8293

EOC NO. 17

EOC Address Police, Fire Building
116 West Belt Line
De Soto, TX

EOC serving City of De Soto, TX

EOC serving a population of 13,000

No. of EOC emergency personnel 14

EOC built in 1975 (Hypothetically)

Building (in which EOC is located) built in N/A

EOC net area, ft^2 1300

Total cost of new EOC construction, $ 80,780

Unit cost of new EOC construction, $ 62.14 $/ft^2$

EOC main characteristics:

Present "EOC" basically does not exist (no emergency plans). DCPA records show EOC at the firehouse/police station, which are of very light construction, entirely aboveground.

Construction of a new, hardened, belowground EOC (separate facility) was cost-estimated. Space for such a facility is available in the municipal center near the present police/fire building. (No land costs are included in the cost-estimate.)

EOC NO. 18

EOC Address County Courthouse
100 N. Broadway
Tyler, TX

EOC serving Smith County and City of Tyler, TX

EOC serving a population of 106,000

No. of EOC emergency personnel 45

EOC built in 1963 (Modifications in 1974)

Building (in which EOC is located) built in 1954

EOC net area, ft^2 2700

Total cost of EOC upgrading, $ 117,050

Unit cost of EOC upgrading, $ 43.35 $/ft^2$

EOC main characteristics:
(vulnerability/upgrading)

EOC located belowground, in the very large basement of a three-to six-story government building. Floor system above the EOC is concrete joist. Walls are concrete, 12 in. and more, surrounding the entire basement, which has some large openings (two garage entryways). EOC would have to be rebuilt, in parts completely.

EOC NO. 19

EOC Address Civil Defense Office
1238 Murphy Street
Shreveport, LA

EOC serving Cities of Shreveport and Bossier City and Parishes of Caddo-Bossier

EOC serving a population of 310,000

No. of EOC emergency personnel 40

EOC built in 1941 (and Later Modifications)

Building (in which EOC is located) built in 1941

EOC net area, ft^2 1287

Total cost of EOC upgrading, $ 33,800

Unit cost of EOC upgrading, $ 26.26 $/ft^2$

EOC main characteristics:
(vulnerability/upgrading)

EOC located in basement of multiuse building, partially exposed above-ground (3 to 5 ft). Weak slab/beam/girder construction, needs under-pinning. Diesel generator and fuel supply located outdoors, unprotected. Very few openings in EOC shell, except for staircase leading into EOC.

EOC NO. 20

EOC Address City Hall
414 E. Twelfth Street
Kansas City, MO

EOC serving City of Kansas City

EOC serving a population of 550,000

No. of EOC emergency personnel 40

EOC built in (occupied in) 1972/1973

Building (in which EOC is located) built in 1936

EOC net area, ft^2 3100

Total cost of EOC upgrading, $ 109,600

Unit cost of EOC upgrading, $ 35.35 $/ft^2$

EOC main characteristics:
(vulnerability/upgrading)

EOC located in basement of 30-story city hall, partially exposed above-ground (approximately 5 ft). EOC shares basement with other functions, needs to be partitioned off from rest of basement by strong walls. Floor system above EOC: R/C joist construction needs underpinning. After EOC modifications very few openings. Emergency generator is located outside the EOC; requires local protection.

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EOC NO. 21

EOC Address County Courthouse
1321 Pearl Street
Boulder, CO

EOC serving Boulder County, CO

EOC serving a population of 122,500

No. of EOC emergency personnel 51

EOC built in 1962 (occupied)

Building (in which EOC is located) built in 1961

EOC net area, ft^2 4693

Total cost of EOC upgrading, $ 89,220

Unit cost of EOC upgrading, $ 19.01 /ft^2

EOC main characteristics:
(vulnerability/upgrading)

EOC located in basement of multiuse building, partially exposed above-ground (2 to 3 ft). R/C construction. 8" exterior walls, 8" thick slab on R/C columns over EOC. EOC has two elevators, two staircases, and a tunnel leading to it. Has also large openings for air flow.

EOC NO. 22

EOC Address Hall of Justice
429 Twenty-Seventh Street
Richmond, CA

EOC serving City of Richmond

EOC serving a population of 85,000

No. of EOC emergency personnel 65

EOC built in (occupied in) 1964, later moved to penthouse of building.

Building (in which EOC is located) built in 1949

EOC net area, ft^2 7676

Total cost of EOC upgrading, $ 136,820

Unit cost of EOC upgrading, $ 17.82 /ft^2

EOC main characteristics:
(vulnerability/upgrading)

EOC presently located in penthouse of government building. But could be moved again into basement. Then, EOC would be belowground, sharing basement with other functions. EOC must be partitioned off from rest of basement. Openings can thereby be reduced to a minimum. Floor system above EOC: 9-1/2" R/C slab on columns with capitals, large spans, requires underpinning.

EOC NO. 23

EOC Address Youth Guidance Center
375 Woodside Avenue
San Francisco, CA

EOC serving County and City of San Francisco, CA

EOC serving a population of ~700,000

No. of EOC emergency personnel 41

EOC built in (occupied after) 1963

Building (in which EOC is located) built in 1948

EOC net area, ft^2 2085

Total cost of EOC upgrading, $ 62,130

Unit cost of EOC upgrading, $ 29.78 /ft^2

EOC main characteristics:
(vulnerability/upgrading)

EOC located mostly belowground, in basement of building. Floor system above EOC: concrete joist construction on R/C beams. 10" lightly reinforced concrete exterior walls. Moderate amount of openings: One exterior door, one interior staircase, two medium-sized windows. Emergency generator is located in different building (in basement, but requires local protection).

EOC NO. 24

EOC Address City Hall
1416 Mission Street
So. Pasadena, CA

EOC serving City of So. Pasadena, CA

EOC serving a population of 23,400

No. of EOC emergency personnel 12 plus

EOC built in 1967

Building (in which EOC is located) built in 1967

EOC net area, ft^2 5911

Total cost of EOC upgrading, $ 111,080

Unit cost of EOC upgrading, $ 18.79/ft^2

EOC main characteristics:
(vulnerability/upgrading)

EOC located belowground in basement of fire/police building complex. Floor system above EOC: 8", 5-1/2", and 3" slab supported by steel joists, very weak, needs underpinning. Exterior walls require some local reinforcement. Three staircases leading into EOC. Moderate openings for air intake and exhaust.

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EOC NO. 25
EOC Address City Hall
613 E. Broadway
Glendale, CA

EOC serving City of Glendale
EOC serving a population of 140,000
No. of EOC emergency personnel 36
EOC built in 1957
Building (in which EOC is located) built in 1957
EOC net area, ft^2 3493
Total cost of EOC upgrading, \$ 37,240
Unit cost of EOC upgrading, \$ 10.66 $/ft^2$

EOC main characteristics:
(vulnerability/upgrading)

EOC located belowground, in basement of municipal building. R/C construction. 16" thick exterior walls, 16" slab on beams and columns above EOC. Moderate amount of openings: Three staircases plus medium-sized air intake and exhaust openings.

EOC NO. 26
EOC Address N/A

EOC serving --
EOC serving a population of --
No. of EOC emergency personnel ~ 4
EOC built in 1975 (hypothetically)
Building (in which EOC is located) built in Before 1975 (hypothetical)
EOC net area, ft^2 287
Total cost of EOC upgrading, \$ 21,500
Unit cost of EOC upgrading, \$ 74.86 $/ft^2$

EOC main characteristics:
(vulnerability/upgrading)

Assumed representative characteristics of EOCs located belowground, in basements of multiuse buildings.

EOC NO. 27
EOC Address N/A

EOC serving --
EOC serving a population of --
No. of EOC emergency personnel ~ 4
EOC built in 1975 (hypothetically)
Building (in which EOC is located) built in N/A
EOC net area, ft^2 287
Total cost of new EOC construction, \$ 32,900
Unit cost of new EOC construction, \$ 114.63 $/ft^2$

EOC main characteristics:

New construction of a hardened, belowground, separate EOC facility. (No land costs are included in the cost estimate.) Assumed representative EOC layout and contents; reinforced concrete construction.

EOC NO. 28
EOC Address N/A

EOC serving --
EOC serving a population of --
No. of EOC emergency personnel ~ 80
EOC built in 1975 (hypothetically)
Building (in which EOC is located) built in N/A
EOC net area, ft^2 6000
Total cost of new EOC construction, \$ 217,400
Unit cost of new EOC construction, \$ 36.23 $/ft^2$

EOC main characteristics:

New construction of a hardened, belowground, separate EOC facility. (No land costs are included in the cost estimate.) Assumed representative EOC layout and contents; reinforced concrete construction.

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VULNERABILITY CHARACTERISTICS OF EMERGENCY OPERATING CENTERS (EOC'S) IN BLAST-RISK AREAS (UNCLASSIFIED)

By: Curtis Lang

Agbabian Associates, El Segundo, California 90245
January 1977, 140 pages

Contract No. DCPA01-75-C-0337, Work Unit 1622A

Estimates were obtained of the total cost and the average unit cost ($/ft^2) for reducing the vulnerability of all Emergency Operating Centers (EOCs) to nuclear-weapon effects except for radioactive fallout and EMP. The reduction of vulnerability was interpreted as an upgrading of all EOCs located in "high risk" areas (i.e., areas with expected air-blast overpressures equal to or exceeding 2 psi) to functionally resist the nuclear-weapon effects corresponding to a 10-psi air-blast overpressure caused by a 1-megaton surface burst. Two sets of total cost/average unit cost data were generated. The first set provides costs for upgrading belowground and partially exposed EOCs and for relocating totally aboveground EOCs to upgraded belowground spaces (i.e., basements of existing other buildings). The second set of costs reflects upgrading of belowground and partially exposed EOCs and new construction of separate, belowground, hardened EOCs to replace existing totally aboveground EOCs.

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