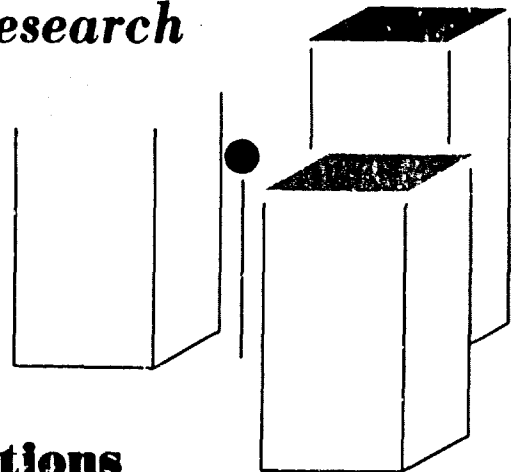


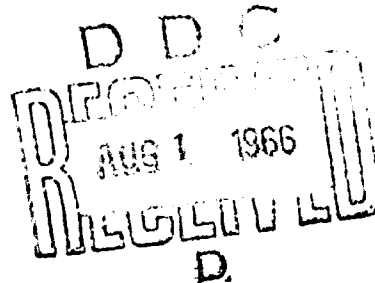
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FINAL REPORT***Radiological Recovery Requirements, Structures,
and Operations Research***

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**Volume I, General Considerations**

PREPARED FOR THE
OFFICE OF CIVIL DEFENSE
DEPARTMENT OF THE ARMY
WASHINGTON, D. C. 20310
OCD WORK UNIT NO. 3233B



by

**J. T. Ryan, T. Johnson,
and S. M. Walker**

UNDER

TECHNICAL MANAGEMENT OFFICE
U. S. NAVAL RADIOLOGICAL DEFENSE LABORATORY
SAN FRANCISCO, CALIFORNIA 94135
CONTRACT N228 (62479)-68153
RTI PROJECT OU-214

6 June 1966

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J. J. Ryan, J. Johnson, and S. M. Walker

Prepared for the
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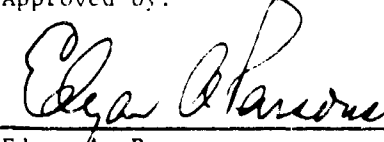
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6 June 1966

FOREWORD

This is Volume I of four separately bound volumes that report the research completed under the general terms of the Office of Civil Defense Subtask No. 3233B, "Radiological Recovery Requirements, Structures, and Operations Research." This volume describes the general aspects of the investigations and presents the conclusions and recommendations. The specific considerations and supporting material are contained in Volumes II, III, and IV. The abstract for each of the volumes is presented on the following pages.

The authors are pleased to acknowledge the valuable assistance of Ahmed Qadeer, Philip Rasberry, Philip McGill, Kenneth Willis, and Russell Lyday during the course of the project.

ABSTRACT FOR VOLUME I

General Considerations

Volume I is a comprehensive summary of the research conducted under OCD Sub-task 3233B. This research is reported in detail in Volumes II, III, and IV of this report. The abstracts for these volumes are on the following pages.

This study examines the application of decontamination strategies to extensive urban areas. Urban areas of various sizes (from a few acres to an interconnected system involving hundreds of acres) are examined with regard to decontaminating vital sections and their connecting links. The task of creating decontaminated "islands" or marshalling areas is determined to be feasible. The nature and scope of command and control system elements required for conducting effective decontamination in practical situations is determined together with the preattack and post-attack data required by such a system. Several models were developed during the course of the project and are discussed.

ABSTRACT FOR VOLUME II

Development of Analytical, Computer, and Systems Models in Support of Decontamination Analyses

Volume II contains six studies, five of which describe models developed during the course of the contract. These models can be used to determine the cost and effectiveness of decontaminating urban areas. The sixth is devoted to a study of the components of a command and control system for municipal decontamination. These studies cover the following subjects:

(1) A Feasibility Study of the Application of Analog Computers to the Analysis of Decontamination: This study examines the application of analog computers to the analysis of decontamination. The main features of analog computers are briefly described; a simplified analog model of the effect of a single decontamination effort is developed. Sample analog records of output from a prototype of this model are presented. The design of a more elaborate model requiring substantially more analog equipment is described and areas of possible application are indicated.

(2) A Circular Model for Approximating Gamma Ray Intensity at a Given Detector Location: A procedure for determining the gamma ray intensity, due to fallout radiation, at a detector location is investigated. A reasonably accurate model using circular annulus geometry was developed which includes the effects of gamma ray attenuation, build-up, backscatter, and skyshine. This model was based on NBS Monograph 42.

A single annulus model is described in order to show clearly the basic premises upon which the full "circular" model is based. The development of the multiple annular model is treated in a manner so as to show how each of the parameters involved is handled. An example demonstrating the use of the model is included.

(3) A Square-Grid Model for Approximating Gamma Ray Intensity at a Given Detector Location: This study describes a simple and practical procedure for determining the approximate fallout gamma ray intensity at a detector location as a function of the geometry of the contributing planes and related shielding. The

procedure described employs a "square-grid" technique for modeling the area of interest. This model is shown to be reasonably accurate and easily adapted to practical situations with the help of scaled overlays for city maps to be used in conjunction with the constructed tables and graphs. An example analysis is carried out to illustrate the mechanics of the procedure.

(4) A Point Source Model for Approximating Gamma Ray Intensity at a Given Detector Location (The Equivalent Planes Method): A method for analyzing the dose contributions from areas of fallout radiation is developed where each contaminated plane is treated as a weighted point source of radiation intensity. Only the area, the location of the center, the eccentricity of the approximating rectangle, and the intervening shielding need be considered. Limits are developed for the eccentricity of an area, centered over the detector, which can be represented by a square of the same area with an error of less than ten percent in dose rate contribution. Limits are also developed for the area of off-center contaminated areas such that the product of area times the dose rate contribution per unit area from the center is within ten percent of the true contribution from the area. A sample analysis is given.

A step-by-step procedure based on this model is presented. This procedure is called "The Equivalent Planes Method."

(5) A FORTRAN Program for Decontamination Analysis: This study describes a debugged and tested computer program written in FORTRAN to compute the effectiveness parameters used to analyze municipal decontamination. The program was written in FORTRAN 64 to be used on large scale computers such as the CDC 3600.

(6) The Nature and Scope of Command and Control System Elements Required for Conducting Effective Decontamination in Municipalities: This study serves to determine the nature and scope of command and control systems elements which are required to effect practical municipal decontamination. The preattack and postattack data requirements for decontamination are specified and the essential components of an information system for decontamination are identified and related. The influence of direct and indirect effects on the decontamination system is examined.

ABSTRACT FOR VOLUME III

Decontamination Analysis of Selected Sites and Facilities in San Jose, California

Volume III contains the cost and effectiveness data related to decontamination analyses of sixteen sites and facilities selected from San Jose, California. Costs are measured in team-hours of effort. Decontamination effectiveness is measured in terms of fractions of dose-rate remaining at specified detector locations and fractions of dose remaining for persons who perform functions requiring specified daily activity patterns at the sites and facilities chosen.

ABSTRACT FOR VOLUME IV

Decontamination Analysis of Selected Sites and Facilities in
Detroit, Michigan

Volume IV contains the cost and effectiveness data related to decontamination analyses of twelve sites and facilities selected from Detroit, Michigan. Costs are measured in team-hours of effort. Decontamination effectiveness is measured in terms of fractions of dose-rate remaining at specified detector locations and fractions of dose remaining for persons who perform functions requiring specified daily activity patterns at the sites and facilities chosen.

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Chapter 1

Introduction and Summary

I. GOVERNING OCD PROGRAM OBJECTIVE

The goals of the postattack decontamination research program, of which this subtask is a part, are to provide planners at all levels with the necessary analyses on which to base realistic planning, to implement effective training programs, to procure and preposition essential decontamination equipment and material, and to design a system for the coordination and control of decontamination measures. This includes the provision of information for planning guides and manuals for use by operating personnel in the postattack period.

II. BACKGROUND AND OBJECTIVES OF THIS RESEARCH

To meet partially the above broad objectives, the research reported herein was undertaken. This study is the second year's effort on OCD Subtask 3233B. The first year's effort was completed under OCD Contract OCD-PS-64-56. The basic conclusion of that study was that decontamination operations in a fallout environment are as vital to postattack recovery as shelters are to postattack survival. That study also recommended that decontamination analysis be extended in the context of a coordinated recovery of metropolitan areas. This recommendation led to the second year's effort which is summarized in this chapter.

The objective of the research^{1/} undertaken in this study was to determine for a broad spectrum of fallout conditions likely to be encountered in an early postattack nuclear environment:

- (1) The extent to which decontamination can aid the recovery of urban areas under various fallout environments.
- (2) The cost and effectiveness of decontamination in recovering urban areas.

^{1/} The language used here is basically the contract work statement. For completeness the entire technical part of the contract is reproduced in enclosure (1) to this volume.

- (3) The preattack and postattack data required for decontaminating urban areas with various levels of effort and/or capability.
- (4) The nature and scope of command and control system elements required for conducting effective decontamination in practical situations.
- (5) Those areas where existing experimental and/or theoretical data are insufficient for planning operations or assessing capabilities.

The contract was later extended in scope (see enclosure (2)). This additional work was to be directed primarily to providing OCD Five-City Study results dependent upon precise attack information provided by other component studies. Inasmuch as the Five-City Study did not proceed as rapidly as anticipated, precise attack information was unavailable. Therefore, these additional funds were spent to include more sites and facilities in the urban area analyses and to consider the residual effects of blast and fire on municipal decontamination systems. This work supports the additional contract scope to "evaluate alternative decontamination strategies for specific situations taking into account all of the aspects of the precisely specified postattack environments including the residual effects of blast, fire, etc."

III. SUMMARY OF ACCOMPLISHMENTS

A. Approach

As stated in Section I, decontamination operations were analyzed in the previous year to determine their potential contribution to accelerating recovery in an early postattack environment. That study concentrated on developing the appropriate theoretical basis and on testing it by analyzing alternative decontamination procedures applied to several NFSS structures. (See References 1 and 2.)

Extending last year's research, decontamination of urban areas and facilities of various sizes is examined. These include several multi-building complexes, selected from business (downtown), industrial, and suburban areas located in two of the cities in the Five-City Study (San Jose, California, and Detroit, Michigan).

Vital elements and connecting links are included. These include such critical facilities as power plants, water pumping stations, sewage treatment plants, and hospitals as well as typical neighborhood buildings such as school buildings and gasoline stations. Further, the feasibility of creating marshalling areas or "islands" through decontamination is determined. A shopping center is studied as well as a number of large indoor areas (e.g., a school gymnasium, a legislative amphitheater, etc.). These analyses are summarized in Section III-E below.

When this work began, it seemed that extensive multi-building complexes could not be analyzed quickly and efficiently with the analysis techniques commonly used for single-facility shielding analysis. To meet this apparent need, a number of models were developed for approximating gamma ray intensity at a detector in the presence of complex contaminated plane configurations. These are discussed briefly in Section III-B below. This work, although used only to develop the approach and make sample computations during the course of this contract, has significant potential uses. These uses are also discussed below in Section III-B.

Paralleling the development of the analytical models, two computer programs written in FORTRAN for the CDC 3600 computer were completed and debugged. These programs perform most of the computations required to analyze decontamination operations. These programs are described briefly in Section III-C below. A complete description of the models and the above-mentioned computer programs is included in Volume II, Development of Analytical, Computer and Systems Models in Support of Decontamination Analysis.

The nature and scope of the command and control system elements required to effect practical decontamination are determined, including the influence of direct weapons effects on the decontamination system. This work is described in Section III-D below.

B. Model Development

Four models for approximating gamma ray intensity at a detector location were developed during the course of the contract. These models are described in detail in Volume II of this report. Briefly described, these models are:

1. The Analog Model

A feasibility study was conducted on the applicability of analog computers for analyzing decontamination effectiveness. The results of this study show that the decontamination process is amenable to an analog computer analysis since:

- (1) The decontamination process can be described by differential equations (e.g., decontamination efficiency, ERD, etc.),
- (2) Functions involved in the analyses can be generated by analog components (e.g., the $t^{-1.2}$ decay law, etc.),
- (3) The output desired consists of a graphical time history of dose and dose-rate associated with individuals and/or detector locations.

Analog models, typically smaller in scope than digital models, faster running, and more easily changed, were a natural choice for decontamination analysis. Investigation of the utility of analog computers led to the development of an exploratory model - a simplified approximate simulation of a single detector location and one plane of contamination. A small 10-amplifier Donner Computer was used. The following variables were simulated by this model:

- (1) the size of the contaminated plane and its distance from the detector,
- (2) all intervening shielding,
- (3) the time when decontamination is begun and the amount of time to decontaminate,
- (4) the decontamination efficiency,
- (5) the time interval over which dose is computed, and
- (6) the decay constant.

Test runs indicate the general feasibility of the model. Additional equipment will be required to make the techniques generally useful in more complex situations. Continuation of this work should be directed towards an analog model of larger size. A TR-48 Pace Electronic Analog Computer would allow simulation of as many as 10 contaminated planes affecting six detector locations simultaneously. Such a model could be quite valuable as a training device for persons responsible for planning and conducting decontamination.

2. The Circular Model

An effort was made to develop a model which would yield a simple procedure for approximating the gamma ray intensity at a detector in a complex of finite contaminated planes such as might be found in an urban area. Such a model was developed and is referred to as the Circular Model.

This model includes the effects of gamma ray attenuation, build-up, back-scatter, and skyshine, by employing the results of NBS Monograph 42. (Spencer, Reference 3). The model furnishes radiation contributions from various planes of contamination at different heights with or without barrier shielding. The planes of contamination are divided into azimuthal sectors with the detector located in each instance at the origin of a polar coordinate system.

Two characteristics of decontamination analysis make the circular model nonapplicable for practical usage:

- (1) Several off-center locations for a given facility must often be examined, and,
- (2) The circular geometry is a poor approximation for rectangular planes of urban areas and multi-structure complexes.

3. The Square-Grid Model

The square-grid model furnishes contributions to gamma ray intensity from square areas. Again, the effects of gamma ray attenuation, build-up back-

scatter, and skyshine are included by employing the results of Spencer's NBS Monograph.

It is shown that the square-grid model can easily be applied to a number of arbitrarily selected detector locations with the use of simple overlay maps. These rectangular grid overlays are used to collect the contaminated plane data from an urban area map. The contributions associated with each square grid are readily obtained from the model. This model has been tested and is accurate for many practical situations. This is discussed in Volume II.

4. The Point-Source Model or the Equivalent Planes Method

The point-source model is similar to the square-grid model in that the area consisting of the contaminated planes is modeled by a rectangular grid system. Each contaminated plane is treated as a weighted point source of contamination. Error is controlled by refining the grid to keep the eccentricity (ratio of length of width), size (relative to the distance from the detector), and orientation of each of the rectangular areas (representing planes) within prescribed bounds.

A hand computation procedure based on this model was developed and partially tested. This procedure is called the Equivalent Planes Method. The error bounds provided are based on the Engineering Manual procedure for protection factor computation. A rigorous error analysis of the Equivalent Planes Method has not yet been performed.

C. Computer Programs

Two computer programs written in FORTRAN for the CDC 3600 computer were used to perform most of the computations necessary to analyze municipal decontamination. The first of these was written and debugged under a separate contract by RTI for the Office of Civil Defense. This program computes the separate contributions to the intensity at specified detector locations from each of the contributing planes of contamination. A complete description of this program is given in RM-OU-205-1,

Protection Analysis and Construction Evaluation System, by E. L. Hill, F. A. Bryan, B. W. Howard, T. Johnson, R. O. Lyday, P. S. McMullan and M. D. Wright. (Reference 4.)

The second program was written and debugged under this contract. It computes both the reductions in dose-rate at specified detector locations and the reductions in total dose for persons spending prescribed amounts of times at specified detector locations where the level of decontamination is prescribed. This program also computes the fraction of the intensity received at a detector location from each of the contributing planes of contamination. This program is described in more detail in chapter 2 of this volume.

D. Command and Control Considerations

The nature and scope of command and control system elements required to effect practical municipal decontamination are determined. Emphasis is placed on decontamination within municipalities. The five questions (basic to decontamination analysis) upon which this aspect of the research focuses are:

- (1) What are the preattack and postattack data required to effect decontamination operations?
- (2) What are the essential components of the information system needed to effect decontamination operations?
- (3) How should trained personnel and decontamination equipment be prepositioned, organized, and controlled?
- (4) How can a decontamination system in a municipality be evaluated?
- (5) How can a decontamination system in a municipality be most effectively modeled to provide a ready vehicle for systems analysis?

Each of these questions was examined for various levels of decontamination capabilities, requirements, and attack environments. The various components of a decontamination system in a municipality are identified and embodied in the general command and control system framework. It is shown that a command and control system for decontamination operations must provide for decisions on whether

or not to undertake a mission, for decontamination and manpower resource commitment and for allocation decisions. These decision functions require an elaborate information subsystem consisting of organized data files containing prestored (preattack) data and postattack assessments (including system feedback).

The detailed characteristics of the individual components in each of the essential subsystems of a decontamination command and control system are studied. The interrelationships among the individual subsystem components are identified and displayed.

In order to determine the command and control system elements required to accomplish practical decontamination missions in a municipality, the environment (including direct weapons effects) and the system goals are reviewed and analyzed. Basic system evaluation criteria are also discussed and the essential decontamination system elements are identified.

Recommendations and guides leading to the design of a basic command and control system for municipal decontamination are indicated. This aspect of the research is described in detail in Volume II of this report.

E. Analyses of Real Cities

The cities selected for analysis from the Five-City Study are San Jose, California, and Detroit, Michigan. In all, twenty-eight sites and facilities were selected for analysis from these two cities. For each of these sites and facilities, the individual gamma radiation contributions from all contributing planes of contamination were computed for specified detector locations using the computer program described in reference 4. These contributions were then used to compute the fraction of dose-rate removed by specified strategies of decontamination around the site or facility. The second computer program described in Volume II, Appendix E, was used for this and subsequent computations related to the cost and effectiveness of decontamination. The decontamination strategies are specified by indicating (1) the method of fallout removal (e.g., firehosing), (2) the par-

ticular plane or planes decontaminated (e.g., sidewalks and driveways), (3) the fraction of fallout material removed, and (4) the team-hours of effort to be expended.

Dose reductions for persons spending specified amounts of time at (perhaps) several detector locations are also computed. The sites and facilities selected for analysis from San Jose and Detroit are listed below:

San Jose, California

1. California Packing Corporation Plant No. 51
2. California Pharmaceutical Laboratory
3. Pacific Telephone and Telegraph Company
4. Dole Corporation Warehouse
5. San Jose Mercury-News
6. Western Greyhound Bus Lines Depot
7. San Jose City Lines
8. City Corporation Yard
9. Fire Station No. 8
10. Radio Station KRRX
11. Outdoor Areas in a Residential Area
12. Outdoor Locations in the Central Business District
13. San Jose City Hall
14. Valley Fair Shopping Center
15. San Jose Hospital
16. Sewage Treatment Plant

Detroit, Michigan

1. Mercy Hospital
2. E. J. Korvette Department Store
3. Mistersky Power Plant
4. Springwells Pumping Station

5. Cobo Convention Hall
6. City-County Building
7. Detroit City Airport
8. Detroit OCD Building
9. Saint Mary's High School and Elementary School
10. Isaac Crary Elementary School
11. Cadillac Motor Car Division, General Motors Corporation
12. Pure Oil Gasoline Station

The results of these studies, as well as all of the assumptions used, are described in Volumes III and IV of this report.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The primary conclusion of this study is that the recovery of substantial city areas and multi-building complexes can be accelerated by practical decontamination procedures. Another general conclusion is that for most indoor detector locations, the roof directly above the detector must be decontaminated as part of any strategy of decontamination which appreciably reduces the intensity at that detector location. Similarly, for outdoor detectors, the plane directly beneath the detector must be decontaminated for appreciable intensity reduction. From a cost and effectiveness point of view, mechanized procedures such as flushers or mechanical street sweepers are by far the best methods for decontaminating paved (outdoor) surfaces. Firehosing (where possible) is the best method for decontaminating the roofs. The dose and dose-rate reductions were relatively insensitive to the effectiveness of the decontamination methods as long as at least ninety percent of the fallout material was removed.

Another important conclusion of this study is that a substantial command and control structure will be necessary to conduct effective municipal decontamination. Whether or not a separate decontamination command and control system is necessary

is not determined in this study--nor will it be determined without a far more extensive research effort which looks at the decontamination system as it relates to other postattack operating systems (particularly those related to direct weapons effects).

B. Recommendations

On the basis of the above conclusions, it is recommended that decontamination be viewed and analyzed in the context of coordinated municipal recovery from both the residual effects of fallout and direct weapons effects. Particular attention should be placed on the control and disposition of the actual fallout material removed from the contributing planes of contamination.

Chapter 2
Development of Analytical, Computer, and Systems Models in
Support of Decontamination Analysis

I. INTRODUCTION

As stated in Chapter 1, when this work began the contribution of fallout from the many planes found in large complexes comprised of several buildings could not be analyzed quickly or efficiently. A number of models were subsequently developed for approximating gamma ray intensity at a specified detector location in the presence of complex contaminated plane configurations. Each of these is discussed in Section II below.

Paralleling the development of the analytical models and the analog computer model, two digital computer programs written in FORTRAN for the CDC 3600 were completed and debugged to perform most of the computation required to analyze decontamination operations as applied to several sites and facilities selected from San Jose and Detroit. Both of these programs are described in Section III below.

The nature and scope of the command and control system elements required to effect practical municipal decontamination are also determined. The preattack and postattack data requirements are identified and related to the system as a whole. The influence of direct weapons effects on the decontamination system are examined. This work is described in Section IV below.

II. THE ANALOG COMPUTER MODEL AND OTHER ANALYTICAL MODELS
TO COMPUTE APPROXIMATELY GAMMA RAY INTENSITY AT A DETECTOR

A. The Analog Computer Model

1. Introduction

A number of operating digital computer programs currently exist which can calculate the protection factor at a detector as a function of the shielding characteristics of the environment. With modifications, these programs can be used to estimate the value of decontaminating one or more of the surfaces which

contribute to the intensity at a detector location. All of these programs, however, require large amounts of information and set-up time (collecting data, preparing punched cards, etc.) so that models utilizing simpler approximations and equations appeared to be a desirable alternative. Analog models, typically smaller in scope, faster running, and more easily changed than digital models are a natural consideration.

Investigation of the utility of analog models led to the development of an exploratory model - a simplified analog simulation of decontamination in a post-attack environment. Each contribution to radiation intensity at a detector is assumed to come from a point source (perhaps the centroid of the area of the contaminated plane). Either decontamination can be described as an instantaneous operation or an appropriate time factor can be used. All of the important parameters associated with decontamination efficiency can be varied manually. These include the percent of fallout which can be removed from a given surface, the effort in man-hours applied to the surface, and the constant which is associated with the type of surface and the method of decontamination. It is also possible to vary the order of a sequence of decontamination operations. Both dose-rate and total dose can be measured and displayed as a function of time, thus showing the effect of decontamination.

Test runs indicate the general validity of the model; however, to be useful it must include more detail and will require more equipment. Specifically, the decay approximations and the limit on the number of contaminated planes were a compromise between the accuracy desired and the means available.

It is felt that this work should be continued and directed toward an analog-type model of less restricted size. Such an effort might be very useful in the training of personnel responsible for the planning of decontamination applied to large municipal areas.

A complete description of the model, including all of the equations used, is contained in Volume II.

A Description of the Limited Decontamination Simulation

a. Introduction

The limited decontamination analog model was developed as a means of exploring the possibilities and determining the limitations of the application of analog computers to the analysis of decontamination. As such, this model does not provide any particular answers to decontamination problems and only roughly simulates any real situation. Very gross treatment was necessary in order to contain the main features of a single decontamination operation on a small-sized computer.

b. The Hardware Used

The limited analog model described was fitted to a basic installation of the model 3400 Desk Top Donner Analog Computer. The basic model 3400 computer contains ten amplifiers, usable as summers or integrators. The Research Triangle Institute installation also includes a Donner Model 3430 Problem Board and a Donner Model 3073 Potentiometer Strip. The problem board is used to interconnect components for the solution of particular problems and the potentiometers are used to adjust constant and parametric coefficients in the equations which describe particular problems. The output from the analog model is graphed using an Offner Dynograph Amplifier - Recorder Model 542. A more detailed description of the components used in this model is contained in Volume II.

c. The Limited Decontamination Model

In the limited decontamination analog, all contaminated planes which contribute to the intensity at a detector location are assumed to be point sources of radiation intensity. That is, all of the intensity contribution from any contaminated plane is hypothesized to come from a single point, the centroid of the area of the particular contaminated plane.

The contributions, C_i , to radiation intensity from ground level sources of contamination are computed using Equation 1.^{1/}

$$C_i = \frac{A_i}{r_i^2} S_i \quad (1)$$

where A_i = the area in square feet of the i^{th} contaminated plane,

r_i = the distance in feet from the centroid of the i^{th} contaminated plane to the detector location, and

S_i = the shielding factor associated with the i^{th} contaminated plane.

Here C_i is the contribution to total intensity (received at the detector location) which comes from the i^{th} plane. The shielding factor S_i is a dimensionless number which attenuates the contribution according to the shielding existing between the detector and the i^{th} plane. (Note that $0 \leq S_i \leq 1$.)

The contribution to total intensity received at the detector which comes from the roof of the building in which the detector is centrally located is found by Equation 2.^{2/}

$$C_r = \pi \ln \left(1 + \frac{r^2}{h^2} \right) S_r \quad (2)$$

where r = the radius of a circular roof, with an area equal to the area of the actual roof over the detector,

h = the height of the roof above the detector, and

S_r = the shielding factor associated with the roof.

Equation 2 can also be used to determine the contribution to the intensity at an unshielded detector (located outside) from the plane above which the detector is located. Here $S_r = 1$ and h equals a height corresponding to the ground roughness factor.^{3/}

^{1/} See Reference 5 for a derivation of Equation 1.

^{2/} See page 743 of Reference 6 for a derivation of Equation 2.

^{3/} An explanation of how the ground roughness factor affects the "effective" height of the detector is found in Reference 7: Office of Civil Defense, Shelter Design and Analysis, TR-20, Vol. I, Rev. Ed., Nov. 1962, pp. 6-6, 6-7.

In the simplified model, both C_i and C_r are treated as single constant inputs. Any variations in these individual parameters can be simulated by appropriately changing the capacitors which represent these aggregate variables before running the model.

Decontamination is governed (for each individual plane) by Equation 3,^{1/}

$$F_i = F_i^* + (1 - F_i^*) e^{-K_i E_i} \quad (3)$$

where F_i = the fraction of fallout remaining on the i^{th} contaminated plane after it has been decontaminated.

F_i^* = the limiting fraction of fallout remaining on the i^{th} contaminated plane after infinite decontamination.

K_i = a constant associated with a given method and the physical nature of the i^{th} contaminated plane.

E_i = the effort (usually measured in man-hours) which is applied to the i^{th} contaminated plane.

Here, both $(1 - F_i^*)$ and $K_i E_i$ are treated as single variable inputs. Both of these variables can be varied by changing settings of the potentiometer which is assigned to the particular variable parameter. This can be done while the model is being run.

The following page contains the equation used in the limited model of decontamination.

While the model is being run, the individual contributions are summed and the radiation intensity at the detector is output as a function of time. The total dose which an individual would receive at the detector location is also output as a function of time. This is simply given by Equation 4:

^{1/} Derived in: Miller, G. F., etc. (Reference 8)

System Equations for the Simplified Model

1. Intensity contribution from the i^{th} ground level contaminated plane:

$$C_i = \frac{A_i}{r_i^2} S_i \quad \text{where}$$

A_i = The areas in square feet of i^{th} contaminated plane.

r_i = Distance in feet from centroid of fallout on i^{th} contaminated plane to the detector location.

S_i = Shielding factor associated with the i^{th} contaminated plane.

2. Intensity contribution from roof:

$$C_r = \pi \ln \left(1 + \frac{r^2}{h^2} \right) S_r \quad \text{where}$$

r = The radius of an equivalent circular roof.

h = Height of roof (above detector).

S_r = Shielding factor associated with roof.

3. Decontamination efficiency:

$$F_i = F_i^* + (1 - F_i^*) e^{-K_i E_i} \quad \text{where}$$

F_i = fraction of fallout remaining after decontaminating i^{th} plane.

F_i^* = fraction of fallout which cannot be removed.

K_i = constant associated with i^{th} surface and the method used to decontaminate it.

E_i = The amount of effort applied to decontaminate the i^{th} contaminated plane. (Usually measured in man-hours of effort).

For the simplified model the following parts of the above equations were set to single constant parameters;

$$1. \quad K_1^i = \frac{A_i}{r_i^2} S_i \qquad 2. \quad K_2^r = \pi \ln \left(1 + \frac{r^2}{h^2} \right) S_r$$

The following parts of the above equation were set to single variable parameters:

$$1. \quad V_1^i = 1 - F_i^* \qquad 2. \quad V_2^i = K_i E_i$$

$$\text{Total Dose} = \begin{cases} 0 & \text{for } t < t_1 \\ \int_{t_1}^t H(x) x^{-1.2} dx & \text{for } t_1 \leq t \leq t_2 \\ \int_{t_1}^{t_2} H(x) x^{-1.2} dx & \text{for } t > t_2 \end{cases} \quad (4)$$

$H(t)$ denotes the value (represented by a voltage on the analog computer) associated with the sum of the intensity contributions from the individual planes as a function of time. For a system with a number of instantaneous decontamination operations, $H(t)$ will be a monotonically decreasing step function. The dose is measured during the time interval from t_1 to t_2 .

d. Sample Runs with Prototype Model

Several test runs were made to demonstrate the model.

Several of these runs are included in Volume II to illustrate the mechanics of the model and the nature and format of the answers obtainable. The situation simulated in all of these runs was the decontamination of a single contaminated plane. For simplicity, no fallout build-up function was used. The $t^{-1.2}$ decay curve was approximated as the sum of two exponential decay curves (i.e., $t^{-1.2} \approx e^{-K_1 t} + e^{-K_2 t}$). A fuller discussion of this approximation is also contained in Volume II.

e. Conclusions and Recommendations

The basic conclusion of this study is that the analog computer provides a potentially feasible and useful tool for simulating and analyzing decontamination operations.

The development and implementation of this first analog model of decontamination has pinpointed the areas of difficulty and the direction in which further work appears most promising. The most difficult problem encountered was accurately approximating the $t^{-1.2}$ decay

rate. This problem is considered in detail in Appendix A; since a high-accuracy analytic function generator would be very costly (about \$1000), some form of approximation involving the sum of exponential functions of the form $K_1 e^{-K_2 t}$ is a practical compromise solution.

Future Work

Any future work must be undertaken in the light of the major difficulty found in using the limited analog model--the large amount of equipment required for an adequate simulation. Nonetheless, it is recommended that two major directions be explored.

- (1) The development of a larger, more detailed simulation, but with simplified aggregation of variables where possible, and
- (2) The development of a ready analysis and training tool.

B. The Circular Model and the Square Grid Model

1. Introduction

The purpose of this section is to show the initial results of recent studies directed toward the development of simplified procedures for determining the gamma ray intensity at a detector, due to nuclear-weapon induced fallout. The consensus of those involved in this research effort was that if such an approach proved feasible it would result in a considerable reduction in both labor and computer costs for those cases where approximate results are considered adequate. In addition, the development of such an analytical tool would be of considerable value in simplifying the analysis of decontamination effectiveness in municipal areas. This research was the first step in the development of alternative approaches to field analysis of fallout decontamination effectiveness.

2. The Models

In order to assure a reasonable degree of accuracy in the analytical model presented in the following discussions, such pertinent factors as gamma ray attenuation, build-up, backscatter, and skyshine are incorporated. The model has been based upon the familiar results contained in NBS Monograph 42 (Reference 3).

The general notational scheme presented in Volume II of this report, selected elementary geometric consideration, and the information contained in Reference 3 provide the bases for the "circular model" and the "square-grid model". These models are utilized to furnish values of the so-called "reduction factor", D/D_0 , due to various planes of contamination at different heights, with or without the inclusion of barrier shielding. The planes of contamination are divided into angular sectors with the detector located in each instance at the origin of a polar coordinate system.

The circular model initially develops the detector response for the single contaminated annulus case. The detector response is then developed with increasingly more complex annular geometries and barrier shielding considerations are included. This model is described in detail in Volume II.

The next step in the research was to develop a practical procedure for estimating fallout gamma ray intensity at a detector as a function of the geometry of the contributing planes of contamination and related shielding, where this geometry is approximated by square grids. The need for such a procedure arises from requirements for analyses of large municipal areas with many contaminated planes and multiple scattered detector locations. Conceptually, the "circular-model" procedure is

simple to use, but accuracy suffers when the contaminated planes and barriers do not have approximately polar symmetry about the detector location. A square-grid model can more accurately approximate real situations since most planes of contamination (and most buildings) are rectangular. Further, the square-grid model can be readily applied to an arbitrary detector location with the use of scaled map overlays.

A problem encountered during the development of the square-grid model was the increased difficulty in computing the solid angles subtended at the detector by the square areas. Adjunct to this problem is the subsequent determination of the radiation at a detector using Spencer's L-functions. A simple sector-type weighting (as used in the circular model) is not possible with the square-grid model.

The overall approach to the square-grid model for studying the effects of decontamination of fallout radiation is based on the following criteria:

- a. The techniques must enable local civil defense personnel in the field to calculate the effects of large-scale decontamination of municipal areas;
- b. The approximate techniques and procedures must not require computers; i.e., graphical and tabular forms should be adequate.

As with the circular model, the square-grid model is used to estimate the reduction factor D/D_0 for the various planes of fallout contamination--each at differing heights. The planes of contamination are divided into square-grid areas and the detector may be located at any arbitrary position, at height z . The size of the square-grid sections for the first prototype model was chosen as 50 feet, an area which is large enough that subsequent computations are not unwieldy but which is also sufficiently small to yield an acceptable approximation of major contaminated planes in almost any area. Each plane of contamination is approximated in this model by

50 foot square-grids.

Since several planes of contamination at varying heights will contribute to the fallout gamma radiation at a detector, the analysis will depend to a large extent on the variable z , the detector height.

In this model the z dependence of the detector response is treated separately from the other functional dependences. This is accomplished by separately considering the detector response from planes of contamination which are located at each vertical distance from the detector. The responses due to planes of contamination at other heights are then superimposed to obtain the total detector response or reduction factor D/D_0 at a given point.

3. Conclusions

It is concluded that when detailed maps of a standard scale are available from an area (such as Sanborn maps), a square-grid overlay technique (such as that provided by the Square-Grid Model) can offer a feasible, if not practical, tool for the analysis of decontamination effectiveness. The models described in this section were the by-products of the research which led to the development of the "point-source model" and the "equivalent planes method" discussed in the following section.

C. The Point-Source Model and the Equivalent Planes Method

1. Introduction

This section presents a method for analyzing the dose contributions from areas of fallout radiation where each contaminated plane is treated as a weighted point source of radiation intensity. Only the area, the location of the center, and the eccentricity of the rectangle which approximates the contaminated plane and the intervening shielding is necessary to compute a dose-rate contribution. Limits are developed for the eccentricity

of an area, centered over the detector, which can be represented by a square of the same area with an error of less than ten percent in dose-rate contribution. Limits are also developed for the area of off-center contaminated planes such that the product of the area times the dose-rate contribution per unit area from the center is within ten percent of the contribution from the area as approximated by Spencer's method.

A step-by-step procedure based on this model was developed and is presented in Volume II of this report. (A small booklet whose format is that of a programmed procedure is enclosed in an envelope at the back of Volume II.) This procedure, called the "equivalent planes method", makes available a tool for evaluating in the field the effectiveness of decontaminating specified planes of contamination.

2. The Underlying Model

In this model the detector and source point are presented in Cartesian coordinates. Since the detector is isotropic, the geometry reduces to two distances. These are $|h-z|$, the vertical separation of the detector from the source plane, and r , the horizontal separation of the detector axis from the point representing a given contaminated area. Here h is the height of the source planes, and z is the height of the detector above a reference plane.

The shape of the contaminated areas to be represented by a point is of concern. It is shown that for the area centered vertically below (or above) the detector, a circle or square of the same area subtends essentially the same solid angle and thus yields the same relative dose. Off-center areas are all assumed to be squares. Off-center areas which are not square should be approximated as closely as possible with squares, unless the maximum dimension meets a prescribed criterion.

It has been shown that the orientation of a square area within a source plane does not appreciably affect the solid angle subtended at a detector. Thus, to a good approximation the relative contribution by a contaminated area to a detector is a function only of the vertical height $|h-z|$ separating source and detector, the horizontal distance r from the center of the area to the detector axis, the size of the area, and the intervening shielding.

The relative dose-rate, or reduction factor, at the detector from a given area is developed in Volume II of this report. This relative dose-rate for area i is given by the ratio D_i/D_o where D_i is the dose-rate contributed to the detector by plane i and D_o is the total dose-rate three feet above an infinite, uniform plane of contamination. The reduction factor RF is then given by Equation 5.

$$RF = \sum_{\text{all planes}} D_i/D_o \quad (5)$$

The relative contribution from all areas beyond those analyzed individually may be obtained by subtracting the "centered area" relative contribution from the infinite plane contribution $L(|h-z|)$.

A major consideration in the development of this model was the establishment of the maximum area of a square which could be accurately represented by a point source at the center of the square. A criterion was devised and maximum areas were calculated as a function of horizontal separation for several vertical separation distances ($|h-z| = 3', 10', 20', 50', \text{ and } 100'$). The criterion establishes that for a square area less than or equal to the maximum area, the relative contribution calculated on an area basis from Spencer's curves within 10% of the contribution calculated from equation 6. (See Reference 3.)

$$C(A_i, |h_i-z|, r_i) = C_1(|h_i-z|, r_i) A_i \quad (6)$$

3. The Equivalent Planes Method

The equivalent planes method is based on the point-source model described above. The keys to the method are two limiting criteria. The first gives limits on the length-to-width ratio (eccentricity) of an area centered above or below the detector such that the dose contribution is within ten percent of the approximating dose from a centered square of the same area. The other criterion gives limits on the area of an off-center square such that the dose contribution is within ten percent of the approximation given by the product of the area times the dose contribution per unit area from the center of the square.

Shielding factors are presented for above-ground detectors which are separated from source areas by relatively light shields. These data should be most applicable to decontamination studies. The dose contributions calculated are suitable for inclusion in formulas for decontamination analysis. A small booklet containing all of the graphs and directions required to use the method is contained in an envelope at the back of Volume II of this report.

4. Conclusions and Recommendations

It is concluded that the point-source model and the accompanying equivalent planes method can be a useful method of analyzing fallout radiation contributions for decontamination studies. Inasmuch as the criteria of the equivalent planes method are based on unshielded areas, it is recommended that these criteria be investigated for shielded areas. Also, a thorough error analysis of the equivalent planes method should be performed.

III. TWO FORTRAN MODELS USED TO CONDUCT DECONTAMINATION ANALYSES

A. Introduction

Although the models described above in Section II were developed under this contract, they were not used to evaluate decontamination in the urban area studies because a convenient method was developed and became available as a result of research conducted under a separate contract at RTI.

Therefore, proven techniques were employed in the use of two computer programs written in FORTRAN for large-scale computers such as the CDC 3600.

The first of these programs used was developed and debugged under another contract at RTI and is described in Reference 4. This program computes the plane-by-plane contribution to intensity at a specified detector location. This program is described briefly in Section III-B below.

The second of these programs determines, for a given level of decontamination, the reductions in dose-rate and in total dose at specified detector locations. This program is described in Section III-C below.

B. Computer Program for Analysis of Building Protection Factors

A building protection factor (PF) computational procedure written in FORTRAN 64 for use on large-scale computers such as the CDC 3600 is described next.^{1/} This procedure is based on the methods of the Engineering Manual, FM 100-1, Design and Review of Structures for Protection from Fallout Gamma Radiation (Reference 9). This procedure considers contributions from the roof, setbacks, and limited planes of contamination (including areaways). The effects of apertures, interior partitions, floors, plane, heights, mutual shielding, and building geometry are included.

This program determines the PF in the center of the "building part", at eight other predetermined detector locations, and at one additional arbitrary detector location. The desired location of the additional detector must be indicated on a Data Collection Form. Knowledge of the PF's at these points enables the computer to determine the approximate area of the building part having a given protection factor.

^{1/} The computer program described in this section was developed under OCD Contract No. OCD-PS-64-65. The documentation of the program from which the following paragraphs were extracted was accomplished under OCD Contract No. OCD-PS-65-47.

C. A FORTRAN Program for Decontamination Analysis

1. Introduction

This section describes a computer program written in FORTRAN to compute the effectiveness parameters used to analyze municipal decontamination. The program was written under this contract by RTI in FORTRAN 64 to be used on large-scale computers such as the CDC 3600. The program has been debugged and tested and has been used under OCD Subtask 3233B.

For a given level of decontamination, the program is capable of determining both the reductions in dose-rate at specified detector locations and the reductions in total dose for persons spending prescribed amounts of times at specified detector locations. Other parameters used in the analysis of municipal decontamination, such as the PF's at the detector locations and the equivalent PF's^{1/} associated with the activities (without decontamination), are also computed.

2. The Computer Program

The CDC 3600 FORTRAN program computes the values of the following: the protection factor (PF) at each location, the equivalent protection factor (EPF) for each activity pattern, the fraction (CF) of the total intensity prior to decontamination at a given detector due to a particular contaminated plane, the intensity reduction factor (RN) for each decontamination strategy at each detector location, and the activity dose reduction factor for each combination of activity and decontamination strategy at all detector locations.

Calculations are made from the following input data: Contributions to intensity at each detector location from each plane of contamination, the fraction of time that an individual spends at each detector location performing

^{1/} The basic equation defining the equivalent protection factor is:

$$EPF = \frac{1}{f_1/P_1 + f_2/P_2 + \dots + f_n/P_n}$$

where f_1 is the fraction of time spent with protection P_1 .

each particular activity, the mass reduction factor for each decontamination strategy, and the key to associate the appropriate value of F with each composite decontamination strategy for each plane.

3. Conclusions

The program is fast and easy to use. A total of 30 minutes of computing time on the CDC 3600 was required for the twenty-eight sites and facilities selected from San Jose and Detroit for analysis. This includes all reruns because of keypunch errors and other input errors but does not include debugging time. The inputs required ten man-weeks to prepare (most of this time was spent interpreting and translating the output from the PF computer program described in Section III-B, above) and the outputs required virtually no time to be interpreted. A typist could type summary tables directly from the printed outputs if necessary.

IV. THE NATURE AND SCOPE OF COMMAND AND CONTROL SYSTEM ELEMENTS REQUIRED FOR CONDUCTING EFFECTIVE DECONTAMINATION IN URBAN AREAS

A. Introduction

The purpose of this part of the study was to determine the nature and scope of the command and control system elements which are required to effect practical decontamination. Emphasis is placed on decontamination within municipalities. Such a study was necessary in order to answer a number of questions basic to decontamination analysis. The five questions on which this study focused were:

- (1) What are the preattack and postattack data required to effect decontamination operations?
- (2) What are the essential components of the information system needed to effect decontamination operations?
- (3) How should trained personnel and decontamination equipment be prepositioned, organized, and controlled?

(4) How can a decontamination command and control system in an urban area be evaluated?

(5) How can a decontamination command and control system in an urban area be most effectively modeled to provide a ready vehicle for system analysis?

Of course, all of these questions were asked for various levels of decontamination capabilities, requirements, and attack environments. As implied by the questions above, a subsidiary purpose of this study was to develop a procedure for analyzing a decontamination system in a municipality.

It is shown that a command and control system for decontamination operations must provide both for decisions on whether or not to undertake a mission and for manpower and decontamination resource commitment and allocation decisions. These decision functions require an elaborate information subsystem consisting of organized data files containing prestored (preattack) data and postattack assessments (including system feedback).

The detailed characteristics of the individual components in each of the essential subsystems of a decontamination command and control system are studied and reported in detail in Volume II of this report. The interrelationships among the individual subsystem components also are identified and displayed.

In order to determine the command and control system elements required to accomplish practical decontamination missions in a municipality, the environment and the system goals were reviewed and analyzed. Basic system evaluation criteria are also discussed and the essential decontamination system evaluation criteria are identified.

Recommendations and guides leading to the design of a basic command and control system for municipal decontamination are indicated.

B. A Command and Control System for Municipal Decontamination

1. General

It is the purpose of this section to identify the basic system elements required by municipal decontamination and to imbed these elements into the

general command and control system framework of the previous section. In order to accomplish this, the following steps are taken in this section:

- (1) The environment within which municipal decontamination is expected to operate is analyzed.
- (2) The goals of municipal decontamination are identified.
- (3) The performance of the decontamination system is prescribed.
- (4) The elements of a decontamination system are identified and related to one another.
- (5) The elements identified in (4) above are related to the general command and control system framework.

2. Environmental Aspects of Municipal Decontamination

Municipal decontamination by itself is only a part of the broader system of postattack radiological defense. The time during which a radiological defense system operates can be logically divided into three time phases: the emergency phase, the operational recovery phase, and the final recovery phase. The underlying reason for dividing radiological defense into three time phases is the change due to fallout decay.

The objective of radiological countermeasures during the emergency phase is survival, for it is during this period that the fallout arrives, radiation attains its maximum intensity, and the largest part of the exposure dose is usually received. It has been shown that the optimal or primary radiological countermeasure during this period is enshelterment. The central requirement of the system during this period is to provide a sufficient number of adequate shelters so located as to minimize casualties. The potential effectiveness of the system during this period is determined by the degree of protection afforded, space availability and accessibility, and warning time.

The operational recovery phase follows the emergency phase and encompasses the operations prerequisite to:

- (1) Sustaining life in a hostile environment; and

- (2) The recovery of essential postattack activities and/or facilities.

The final recovery phase begins when radiation intensity decays in most places to an insignificant level and primary considerations can be focused on functional restoration of the target area as nearly as possible to its pre-attack condition.

Municipal decontamination will be activated primarily during the operational recovery phase. The following environmental conditions will then prevail:

- (1) Fallout deposition, generally, will be complete.
- (2) Fallout radiation will still be a hazard in some areas. Most of the civilian population will be sheltered during much of the time that decontamination is being performed.
- (3) There may be damage in the area from direct weapons effects (blast, thermal, EMP, etc.).
- (4) The entire Civil Defense System will be very active, i.e., communications lines, logistics support, etc. will be very busy.

This last item may appear irrelevant. It is, however, perhaps the most important condition affecting the environment of municipal decontamination systems. It is an environmental factor over which the decision-maker has some control. It should be pointed out that the decision-maker has little or no control over most of the factors which comprise the environment. This factor is significant because it is expected that the decontamination C & C system will be a subsystem of a much larger postattack C & C system. To analyze only a small part of a large system with many interactions is an unacceptable over simplification. Unfortunately, this comprehensive analysis requires data which will not be available until several more of the EOSD tasks have been completed and published. It is recommended that the implications of the total command and control system load be kept in mind while reading

the following sections.

The environment is an important factor limiting the range of decisions which can be made in the postattack period. Because of the wide variation of damage, yielding a wide variety of physical environments (in which municipal decontamination might operate), the decision subsystem of any proposed decontamination system must be extremely flexible and capable of making very complex decisions. Further, it should be capable of making decisions based on varying amounts of reliable (and unreliable) information. This will subsequently be discussed in some detail.

3. Goals of Municipal Decontamination

The primary goals of decontamination within a municipality (in a very broad sense) are:

- (1) Continued survival within the municipality,
- (2) Accelerated municipal recovery, and
- (3) Assistance in the recovery of a region (not necessarily containing the municipality where the decontamination system is operating).

Since the three goals listed above are also primary goals of the overall radiological defense system, any decontamination system must be closely coordinated with other radiological defense systems. This implies the existence of an overall radiological defense command and control system. Although it is not the purpose of this report to elaborate on the larger system, it should be recognized that much of the command information input to the decontamination command and control system will be output from such a higher-echelon decision subsystem.

4. Municipal Decontamination System Performance Criteria

In light of the existence of a higher-echelon command and control system, the question might be asked: "Why a command and control system for decontamina-

tion?" There are two basic reasons for proposing a separate command and control system for decontamination operations in a municipality:

- (1) The specific decisions involved with effecting decontamination operations in a municipality are in themselves complex enough to warrant a "decontamination-level" decision subsystem.
- (2) The information requirements for effecting useful decontamination decisions are in themselves very involved and require a separate "decontamination-level" information subsystem. This is not to say that a decontamination information subsystem would not borrow components from, or overlap with, parts of other radiological defense information subsystems, e.g., RADEF.

Later in this report, the information input and decision structure requirements for effecting decontamination will be identified and will substantiate the above reasoning for a separate decontamination command and control system.

The basic criteria upon which to judge a decontamination command and control system are:

- (1) To what extent does the system increase the effectiveness of decontamination in achieving the goals and requirements prescribed by higher-echelon decision subsystems?
- (2) How effectively does the system reduce the actual decontamination costs (in manpower, crew doses, expenditures of fuel, water, etc.) for specified levels of performance?
- (3) How effectively does the system reduce the actual decontamination costs (research funds required, training of personnel, procurement of equipment, etc.) for specified levels of performance?

This last criterion is separated from the second, in that it can be

treated as a static goal of the system (i.e., one which is evaluated by off-line simulation and/or analysis of on-line system performance). The first two are dynamic goals (i.e., those evaluated by on-line performance and which can be controlled on-line).

5. Elements of a Decontamination Decision System

The purpose of this section is to identify the functional decontamination decision elements as well as to determine the data base and information flow required by these elements. These data and information flows may be internal to the decontamination system (between subsystems) or external to the system (to and from higher-echelon or parallel systems). The higher-echelon command and control system with regard to decontamination is the Postattack Civil Defense Emergency Operating System. Parallel systems would include systems to control such functions as rescue, law and order, engineering, welfare, fire-fighting, medical, etc. Certain other subsystems of the Emergency Operating System would provide sensor information inputs for the decontamination system. These include RADEF, damage assessment, NUDETS, etc.

The subsystems of the decontamination system must provide the basis for commanding and controlling all of the activities and decisions which comprise decontamination. Thus, a first step towards identifying the elements of a decontamination command and control system is to list all of the important activities and decisions which are required to perform effective decontamination. In order to determine whether or not to decontaminate a given facility or activity and thence to schedule the operation, the following steps must be taken:

- (1) Determine that the facility or activity is essential to sustaining life or accelerating recovery. This may involve no more than being told by the higher-echelon decision subsystem that a given facility or activity is essential.

- (2) Determine that the given facility or activity is presently denied by fallout or will be when it will be required for use.
- (3) Determine that decontamination can reduce the fallout denial time of this facility or activity to or below the minimum desired.
- (4) Determine that equipment and supplies (water, etc.) are available to decontaminate this facility or activity.
- (5) Determine that sufficient manpower (taking dose histories into account) is available to decontaminate this facility or activity.
- (6) Determine that the facility or activity can be decontaminated to a specified level of effectiveness without over-exposing the decontamination crews.
- (7) Determine that direct weapons effects or congestion will not impede the decontamination equipment in reaching the facility or activity.
- (8) Decide to decontaminate the given facility or activity.
- (9) Commit resources and schedule the decontamination of the given facility or activity.
- (10) Initiate and conduct the decontamination operation.
- (11) Monitor and control the decontamination operation.
- (12) Determine whether additional resources are required and available to complete the decontamination of the facility or activity.
- (13) Commit additional resources to decontaminate the facility or activity if needed.
- (14) Determine that the decontamination operation is completed.

Each of these activities triggers a response within the system. Thus, none of these activities can be omitted in the analysis without reflecting a gap in the required data base and organizational structure. Each activity demands a supporting data base, some resources, and an organizational (command and control) structure. This organizational structure should provide for both information channels and decision structures.

C. The Influence of Direct Weapons Effects on the Decontamination System

Previous analyses of decontamination, under Subtask 3233B, have assumed an environment complicated only by the presence of radioactive fallout. It is recognized, however, that removal of fallout contamination can be complicated by other environmental factors such as weather and the direct effects of weapons.

Direct weapons effects (blast, thermal pulse, and initial radiation) may occur. The initial nuclear radiation from present-day weapons is of consequence only within the zone of extremely heavy blast damage, and was not considered in this preliminary analysis. Since decontamination will be conducted primarily during the operational recovery phase, decontamination would not be performed until primary and secondary fires resulting from nearby weapons were under control and the communications blackout caused by the ionizing radiation had passed.

The influence on the decontamination system of the following direct weapons effects was considered:

- (1) blast damage (to facilities, shelters, and resources)
- (2) fire damage
- (3) debris accumulation
- (4) personnel casualties.

The purpose of this analysis of direct weapons effects is to determine the different ways in which system elements might be affected and the interrelationships among the affected elements. The most critical of these elements and relationships will require quantitative analysis in the future.

D. Conclusions and Recommendations

Some command and control structure will be necessary to conduct effective municipal decontamination. Whether or not a separate decontamination command and control system is necessary is not determined in this report--nor will it be determined without a far more extensive research effort. The decisions and activities for conducting decontamination do, however, require an elaborate information

subsystem consisting of organized data files containing prestored data (NFSS data, decontamination planning guides, etc.) and postattack assessments (including system feedback). A good argument for a decontamination information subsystem could be presented on the basis of the complex network of information flow.

Direct weapons effects clearly will influence the performance of any decontamination system. This aspect of decontamination analysis should be investigated more extensively before a municipal decontamination system is designed.

It is recommended that decontamination be considered in the development and design of any Postattack Emergency Operating System to be operational at the municipal or community level. It is further recommended that the system requirements for conducting decontamination be analyzed more thoroughly and that the necessary system functions and minimal organizational structure for conducting effective municipal decontamination be more precisely identified.

Chapter 3

Analyses of Real Cities

I. INTRODUCTION

This section of the report presents the results of an analysis of the cost and effectiveness of decontaminating selected sites and facilities in San Jose, California, and Detroit, Michigan. The general purpose of such an analysis is to determine the extent to which decontamination might accelerate a postattack recovery along with the associated costs. Specifically, this analysis attempts to:

- (1) determine the reduction in dose-rate at several detector locations for various strategies of decontamination;
- (2) determine the reduction in dose for persons performing operations in the activity area;
- (3) estimate costs in time and manpower for practical decontamination operations;
- (4) determine the feasibility of creating decontaminated "islands" or staging areas; and
- (5) determine the feasibility of recovering large city areas including vital facilities and their connecting links.

The two basic assumptions underlying the calculation of all of the decontamination effectiveness data are as follows:

- (1) the intensity at a specified detector location is linearly and independently related to the intensity contributions from the various contaminated planes. That is, if I_j is the intensity at detector location j , then one may write:

$$I_j = C_1 + C_2 + \dots + C_n \quad (7)$$

where the C_i 's are the individual contributions from the n contaminated planes which contribute to the intensity at detector location j ; and

- (2) the intensity due to the i^{th} contaminated plane is directly proportional to the amount of fallout material on the i^{th} contaminated plane.

Therefore, the intensity at location j after only the k^{th} area is decontaminated, I_j^k , is given by Equation (8).

$$I_j^k = I_j - CF_{k,j} \cdot F_k \quad (8)$$

where I_j is the intensity at location j prior to decontamination of plane k ; F_k is the fraction of fallout removed from the k^{th} contaminated plane; and $CF_{k,j}$ is the fraction of the total intensity prior to decontamination at detector j due to contaminated plane k . In other words,

$$CF_{k,j} = \frac{\text{pre-decontamination intensity at detector } j \text{ from } k^{\text{th}} \text{ area}}{\text{total pre-decontamination intensity at detector } j}. \quad (9)$$

Other parameters and symbols used are:

RN_j = the intensity reduction factor. This is the fraction of pre-decontamination dose-rate remaining at detector location j after decontamination has been accomplished.

RN_A = the activity dose reduction factor. This is the fraction of dose without decontamination accumulated by a person performing activity A after decontamination has been accomplished.

The values needed to determine the objectives set forth above were determined by use of the two computer programs described in Section III of Chapter 2. The C_i values were obtained through the use of the program described in Section III-B of Chapter 2. This is a FORTRAN program, based on fallout radiation shielding computational techniques, which are, in turn, based on the Engineering Manual. The remaining values were determined through the use of the program described in Section III-C of Chapter 2. This program, also written in FORTRAN, is a debugged and tested program for computing the effectiveness parameters used to analyze urban decontamination. The C_i values were inputs to the latter program. The costs in man hours to perform decontamination were computed using values derived by USNRDL, and reported in References 5 and 8.

Because the data on Detroit and San Jose were limited in many cases to Sanborn maps and photographs, it was necessary to assume certain pertinent information such as roof and floor psf percent of apertures, etc. in some of the case studies. However, it is believed that the assumptions made are realistic, and do not bias the conclusions of the analysis to any appreciable degree.

II. SOME EXAMPLE RESULTS FROM EIGHT OF THE FACILITIES

A. Introduction

In order to illustrate the analyses contained in Volumes III and IV of this report, as well as to point up some of the more important results which can be derived from the studies, some example results from eight of the facilities are presented here. Only one level of effort of roof decontamination and one level of effort of ground decontamination are included for each of these example analyses. Only 26 indoor detectors from all eight of the facilities are used in this example section. The facilities discussed here are:

Example 1: San Jose Hospital, San Jose, California.

Example 2: City-County Building, Detroit, Michigan.

Example 3: San Jose Mercury-News, San Jose, California.

Example 4: Dole Corporation Warehouse, San Jose, California.

Example 5: Pure Oil Gasoline and Service Station, Detroit, Michigan.

Example 6: Isaac Crary Elementary School, Detroit, Michigan.

Example 7: E. J. Korvette Department Store, Detroit, Michigan.

Example 8: Fire Station No. 8, San Jose, California.

The only effectiveness measure shown in these examples is the factor by which the radiation intensity at each detector is reduced. Costs are measured only in terms of team hours of effort. The complete analyses for each of these and all of the other facilities (contained in Volume III and Volume IV of this report) include dose reductions for selected activities and many more (as many as fifteen in a

number of cases) decontamination strategies. Many of the decontamination strategies in the complete analyses include both roof and ground decontamination.

The basic conclusion drawn from these analyses is that removing 90% of the fallout from the roof can reduce the intensity at most indoor detectors by at least a factor of three.^{1/} For most of the indoor detector locations considered in these analyses, removal of 90% or more of the fallout from paved ground level surfaces reduces the intensity by less than a factor of two. These results are also demonstrated by the examples which follow.

^{1/} These conclusions are based on somewhat idealized conditions. For example, fallout is assumed to be carried far enough away from the detector so as not to contribute at all to the radiation intensity; other idealizations, particularly those related to weathering of fallout, which may cause protection estimates to be in error, were largely ignored. Also, it should be noted that these conclusions were drawn in the light of uncertainties with regard to the accuracy of the Engineering Manual technique. It is recommended that research be undertaken to determine the extent to which errors are introduced and, if necessary, examine alternative problems, such as Monte Carlo techniques to possibly reduce these errors.

B. Examples of Real Cities

EXAMPLE 1: SAN JOSE HOSPITAL, SAN JOSE, CALIFORNIA

1. Location of Detectors

Figure 1 is a sketch of San Jose Hospital. In order to analyze the results of different decontamination strategies, four detector locations were selected. Their PF's and description are as follows:

<u>Detector Location</u>	<u>PF</u>	<u>Description</u>
1	40	Operating Room (Ground Floor)
2	23	Admitting Office (First Floor)
3	42	Nurses' Station (Second Floor)
4	11	Nursery (Third Floor)

The locations of these detectors within the facility are shown in Figure 2. All detectors are assumed to be three feet above the floor.

2. Results of Decontamination

Firehosing the roof of the hospital at a level which would leave only 7% of the original fallout material reduces the radiation at detector 1 by a factor of 1.79, at detector 2 by a factor of 10, at detector 3 by a factor of 1.96, and at detector 4 by a factor of 5.56. This level of effort requires a team of 7 men to work 1.5 hours.

Sweeping the surrounding streets with mechanical sweepers and firehosing the roofs of other buildings at levels which would leave only 6% and 7%, respectively, of the original fallout material reduces the radiation at detector 1 by a factor of 1.54, at detector 2 by a factor of 1.04, at detector 3 by a factor of 1.64, and at detector 4 by a factor of 1.06. Sweeping the streets requires one man to work 5.6 hours, and firehosing the other roofs requires a team of 7 men to work 5.2 hours.

Neither of the decontamination strategies takes into account travel or set-up time.

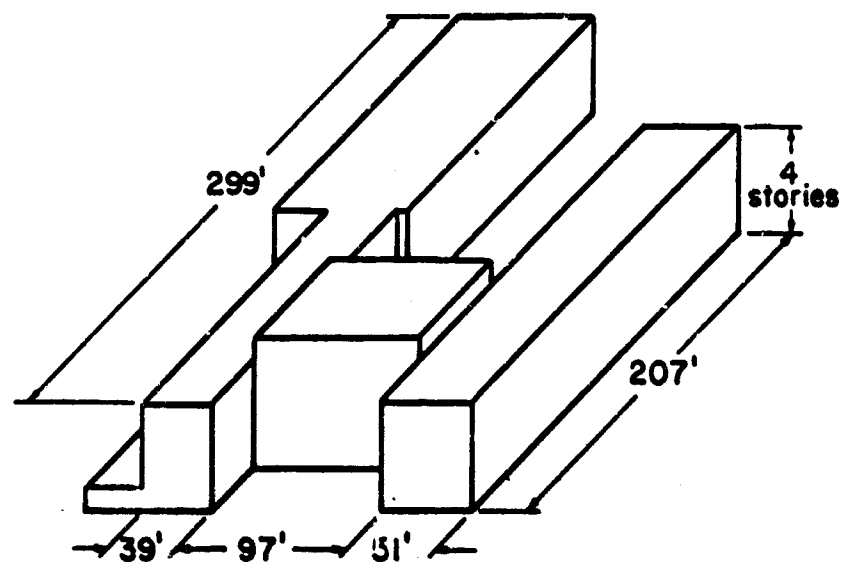
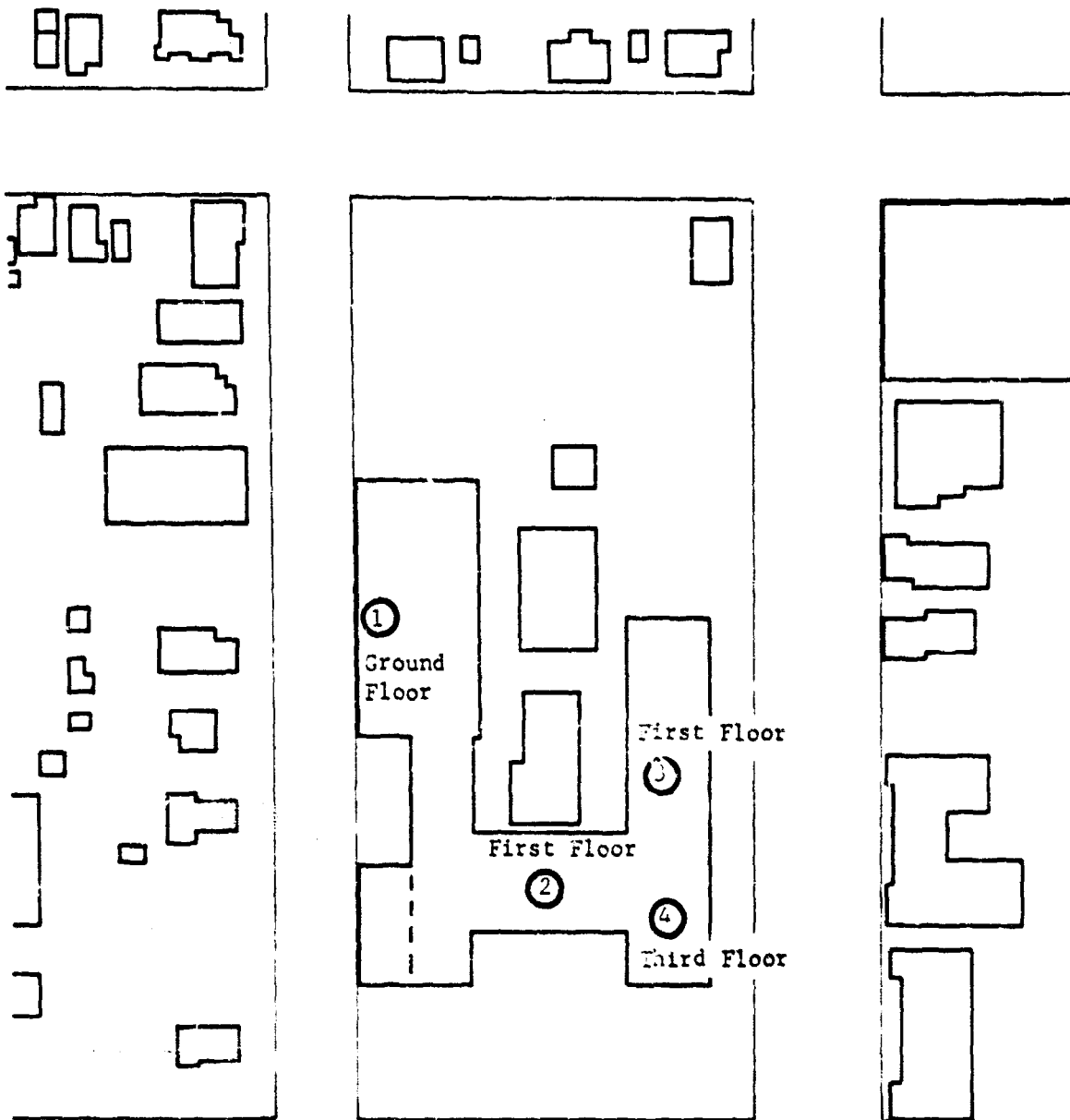


Figure 1

An Oblique View of San Jose Hospital Showing the Approximate
Dimensions of the building



① = 1th Detector Location

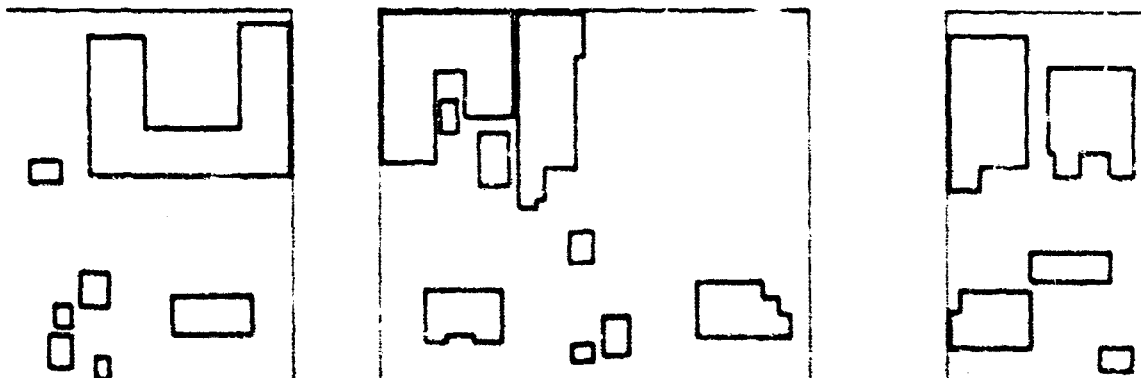


Figure 2

A Plan View of the Four-Story San Jose Hospital Showing the Detector Locations

EXAMPLE 2: CITY-COUNTY BUILDING, DETROIT, MICHIGAN

1. Location of Detectors

Figure 3 is a sketch of the City-County Building. In order to analyze the results of different decontamination strategies, six detector locations were selected. Their PF's and Descriptions are as follows:

<u>Detector Location</u>	<u>PF</u>	<u>Description</u>
1	11	Center Location in Corridor on First Floor in 20 Story Tower
2	769	Center Location in Corridor on Thirteenth Floor in 20 Story Tower
3	11	Center Location in Corridor on Twentieth Story in 20 Story Tower
4	111	Center Location in Main Lobby on First Floor in 14 Story Tower
5	101	Office on Twelfth Floor in 14 Story Tower
6	11	Center Location in Corridor on Fourteenth Floor in 14 Story Tower

The locations of these detectors within the facility are shown in Figure 4. All detectors are assumed to be three feet above the floor.

2. Results of Decontamination

Firehosing the roof of the building at a level which would leave only 7% of the original fallout material reduces the radiation at detector 2 by a factor of 3.23, at detector 3 by a factor of 100, at detector 5 by a factor of 3.45, and at detector 6 by a factor of 100. This decontamination strategy does not reduce the radiation at detectors 1 or 4. This level of effort requires a team of seven men to work 2.3 hours.

Firehosing the surrounding streets and paved parking lots and grading the ground at levels which would leave only 2% and 10%, respectively, of the original fallout material, reduces the radiation at detector 1 by a factor of 16.67, at detector 4 by a factor of 20, and at detector 5 by a factor of 1.35. This

decontamination strategy does not reduce the radiation at detectors 2, 3, or 6.

Firehosing the streets and parking lots requires a team of five men to work

10.1 hours, and grading the ground requires one man to work 56.8 hours.

Neither of the decontamination strategies takes into account travel or set-up time.

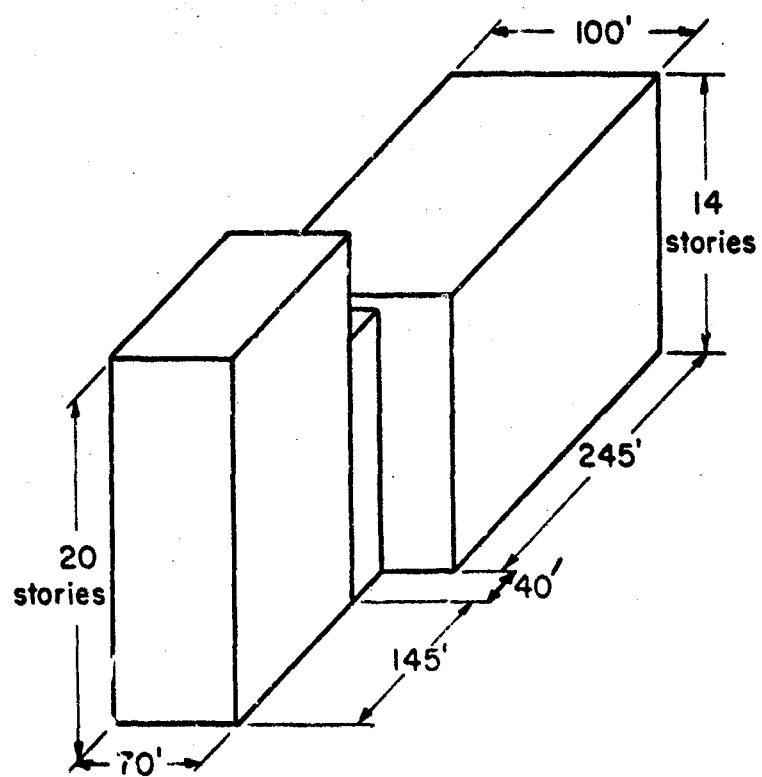


Figure 3

An Oblique View of the City-County Building Showing the
Approximate Dimensions of the Building

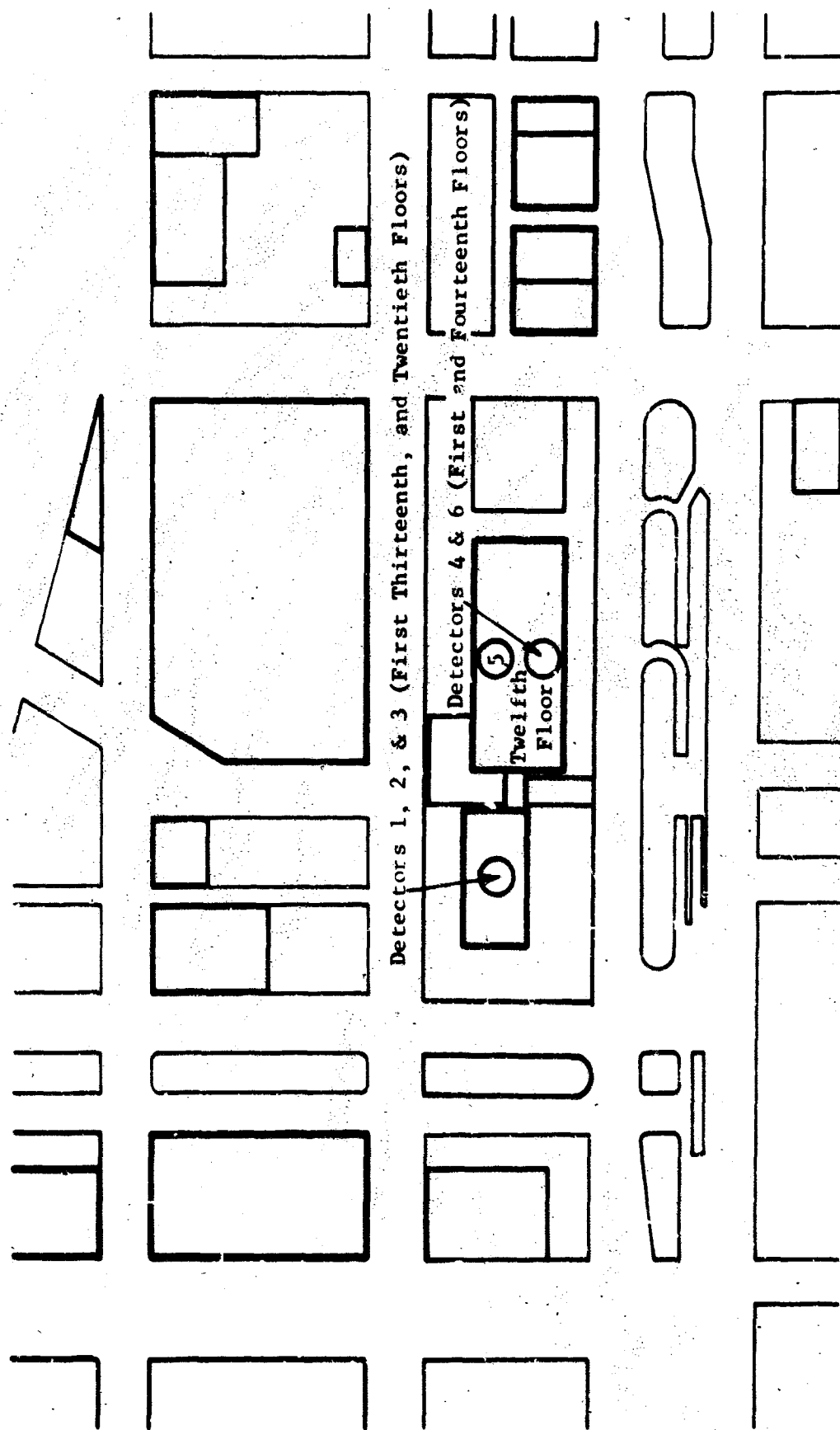


Figure 4

A Plan View of the High-Rise City-County Building Showing the Detector Locations

EXAMPLE 3: SAN JOSE MERCURY-NEWS, SAN JOSE, CALIFORNIA

1. Location of Detectors

Figure 5 is a sketch of the San Jose Mercury-News Building. In order to analyze the results of different decontamination strategies, three detector locations were selected. Their PF's and descriptions are as follows:

<u>Detector Location</u>	<u>PF</u>	<u>Description</u>
1	5.0	Loading Dock (First Floor)
2	4.0	Press Room (First Floor)
3	5.3	Type Setting Room (Second Floor)

The locations of these detectors within the facility are shown in Figure 6. All detectors are assumed to be three feet above the floor.

2. Results of Decontamination

Firehosing the roof of the building at a level which would leave only 12% of the original fallout material reduces the radiation at detector 1 by a factor of 2.17, at detector 2 by a factor of 1.75, and at detector 3 by a factor of 2.33. This level of effort requires a team of seven men to work 1.5 hours.

Street sweeping the surrounding streets and paved parking areas with a mechanical sweeper at a level which would leave only 6% of the original fallout reduces the radiation at detector location 1 by a factor of 1.56, at detector location 2 by a factor of 1.92, and at detector location 3 by a factor of 1.49. This level of effort requires one man to work a total of 11 hours.

Neither of the decontamination strategies takes into account travel or set-up time.

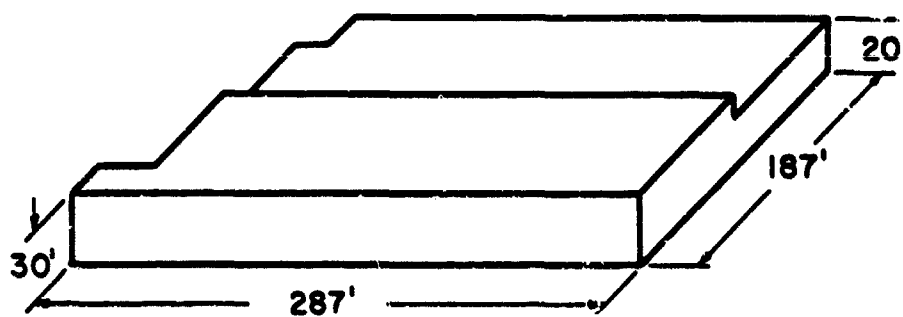


Figure 5

**An Oblique View of the San Jose Mercury-News Building Showing the
Approximate Dimensions of the Building**

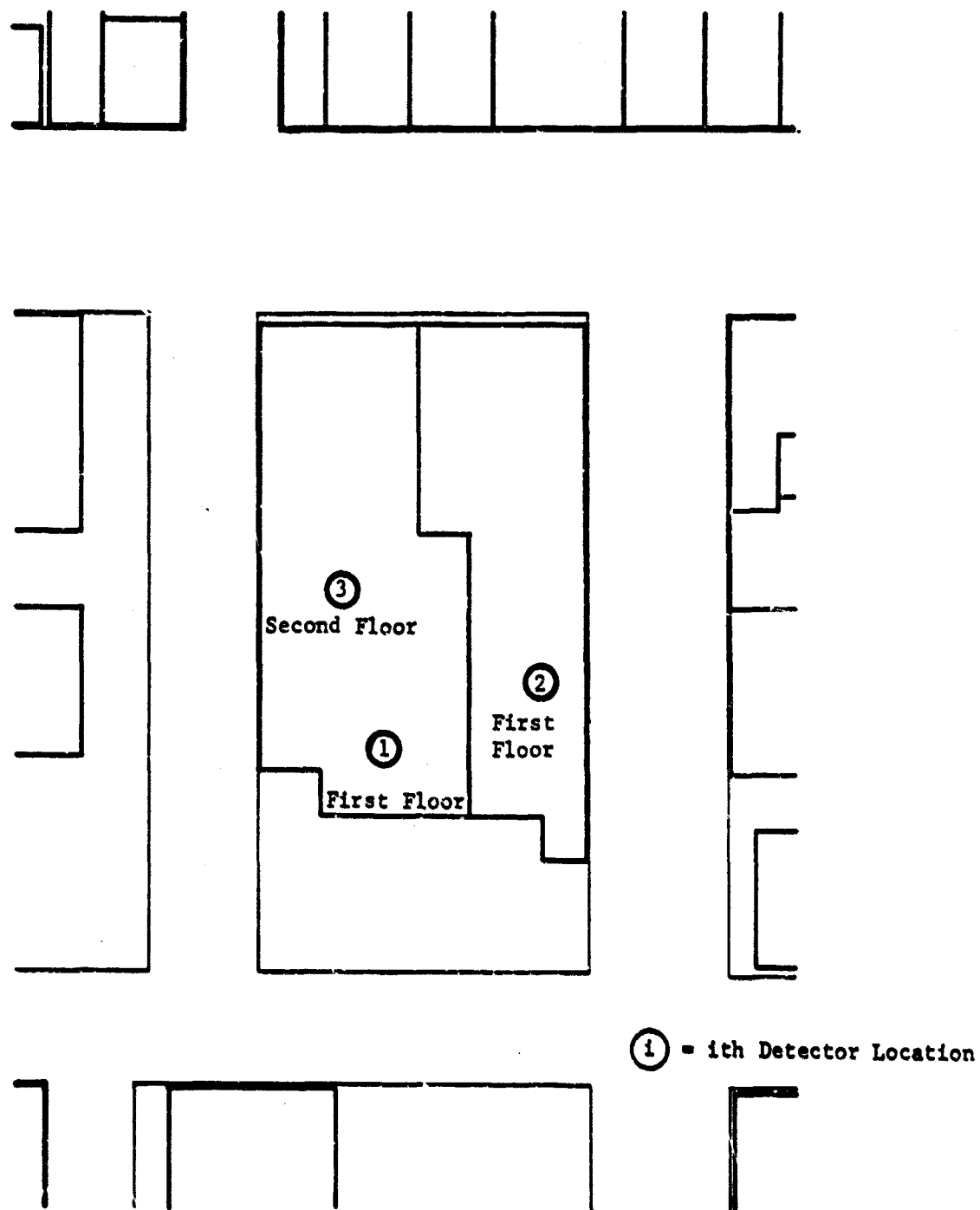


Figure 6

A Plan View of the Three-Story San Jose Mercury-News Building
Showing the Detector Locations

EXAMPLE 4: DOLE CORPORATION WAREHOUSE, SAN JOSE, CALIFORNIA

1. Location of Detectors

Figure 7 is a sketch of the Dole Corporation Warehouse. In order to analyze the results of different decontamination strategies, three detector locations were selected. Their PF's and descriptions are as follows:

<u>Detector Location</u>	<u>PF</u>	<u>Description</u>
1	3.3	Just inside the door at the Loading Dock
2	3.1	Area A in Warehouse
3	3.4	Area B in Warehouse

The locations of these detectors within the facility are shown in Figure 8. All detectors are assumed to be three feet above the floor.

2. Results of Decontamination

Firehosing the roof of the building at a level which would leave only 3% of the original fallout material reduces the radiation at detector 1 by a factor of 1.92, at detector 2 by a factor of 8.33, and at detector 3 by a factor of 5.00. This level of effort requires a team of seven men to work 8.6 hours.

Vacuumized sweeping of the surrounding streets and paved parking at a level which would leave 9% of the original fallout material reduces the radiation at detector 1 by a factor of 1.85, at detector 2 by a factor of 1.09, and at detector 3 by a factor of 1.20. This level of effort requires one man to work a total of 4.7 hours.

Neither of the decontamination strategies takes into account travel or set-up time.

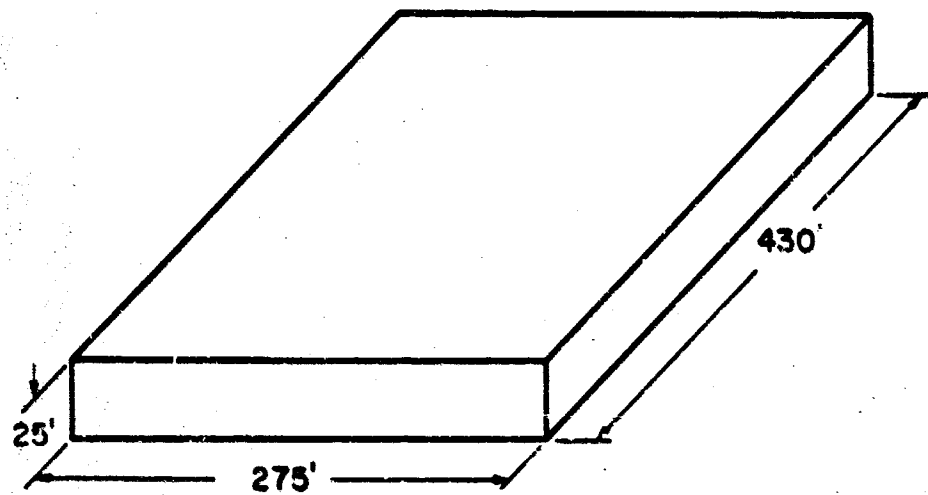


Figure 7

An Oblique View of the Dole Corporation Warehouse Showing the
Approximate Dimensions of the Building

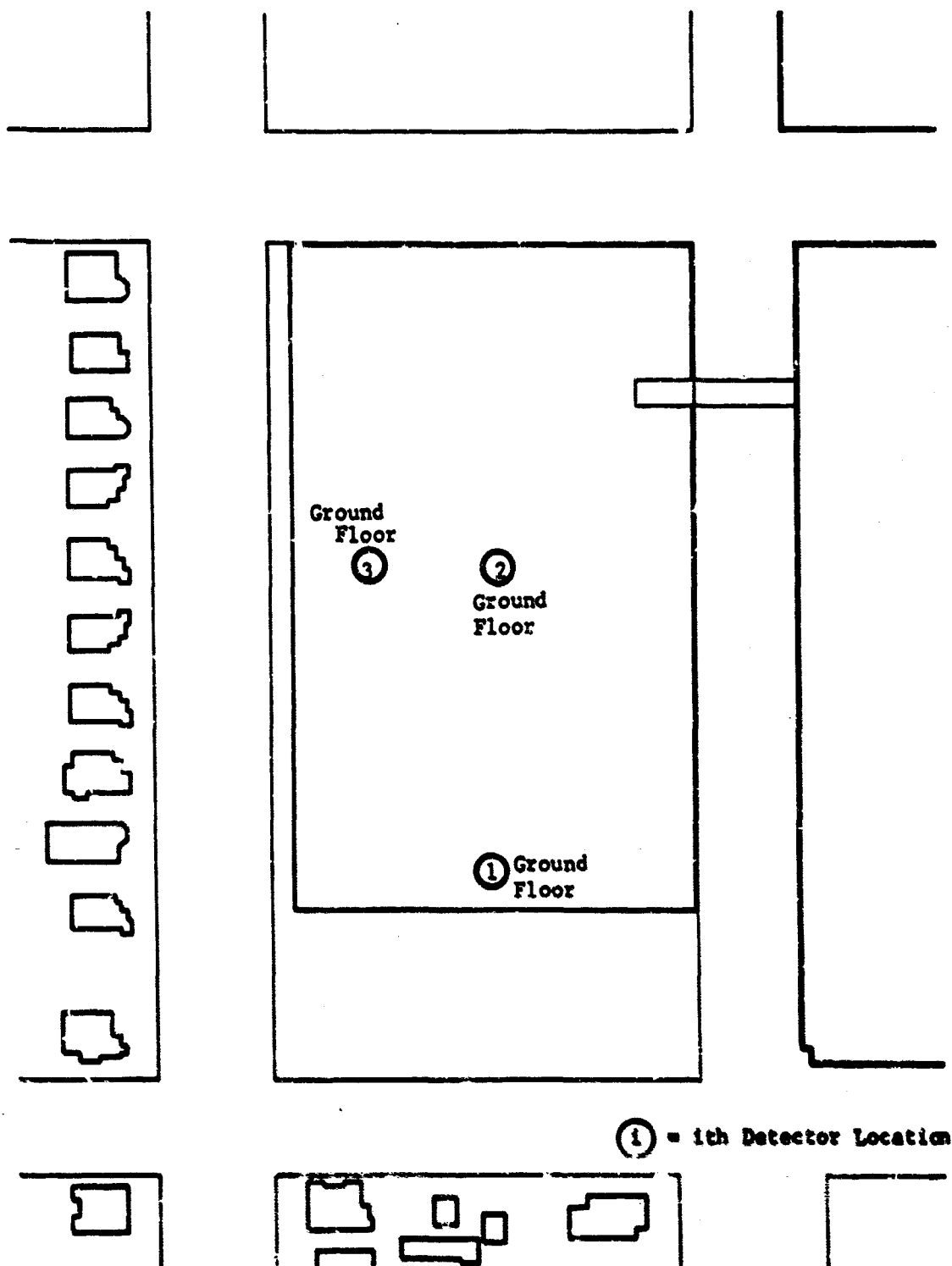


Figure 8

A Plan View of the One-Story Dole Corporation Warehouse
Showing the Detector Locations

EXAMPLE 5: PURE OIL GASOLINE AND SERVICE STATION, DETROIT, MICHIGAN

1. Location of Detectors

Figure 9 is a sketch of the Pure Oil Gasoline and Service Station. In order to analyze the results of different decontamination strategies, two detector locations were selected. Their PF's and descriptions are as follows:

<u>Detector Locations</u>	<u>PF</u>	<u>Description</u>
1	2.5	Indoor Service Area
2	1.8	Outdoor Service Area

The locations of these detectors are shown in Figure 10. All detectors are assumed to be three feet above the floor.

2. Results of Decontamination

Firehosing the roof of the station at a level which would leave only 1% of the original fallout material reduces the radiation at detector 1 by a factor of 2.13. There is no reduction at detector 2. This level of effort requires a team of seven men to work .2 hours.

Motorized flushing of the paved service area of the station and the nearby streets at a level which would leave only 2% of the original fallout reduces the radiation at detector location 1 by a factor of 1.72 and at detector location 2 by a factor of 33.33. This level of effort requires one man to work a total of .4 hours.

Neither of the decontamination strategies takes into account travel or set-up time.

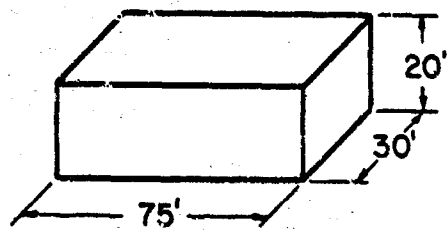


Figure 9

An Oblique View of the Pure Oil Gasoline and Service Station Showing the
Approximate Dimensions of the Building

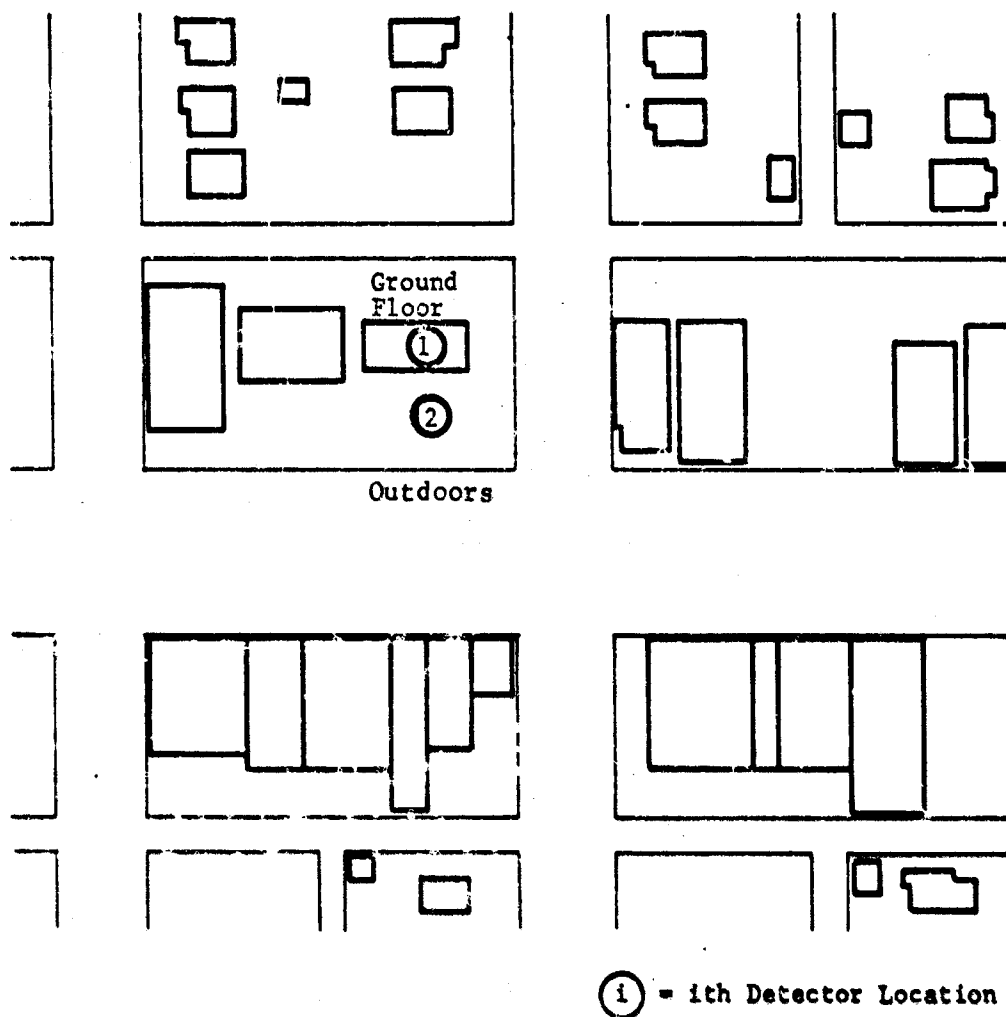


Figure 10

A Plan View of the Pure Oil Gasoline and Service Station Showing the Detector Locations

EXAMPLE 6: ISAAC CRARY ELEMENTARY SCHOOL, DETROIT, MICHIGAN

1. Location of Detectors

Figure 11 is a sketch of Isaac Crary Elementary School. In order to analyze the results of different decontamination strategies, three detector locations were selected. Their PF's and descriptions are as follows:

<u>Detector Location</u>	<u>PF</u>	<u>Description</u>
1	39	Center Corridor (First Floor)
2	18	Auditorium (First Floor)
3	23	Classroom (Second Floor)

The locations of these detectors within the facility are shown in Figure 12. All detectors are assumed to be three feet above the floor.

2. Results of Decontamination

Firehosing the roof of the school at a level which would leave only 7% of the original fallout material reduces the radiation at detector 1 by a factor of 1.23, at detector 2 by a factor of 1.16, and at detector 3 by a factor of 1.75. This level of effort requires a team of 7 men to work 1.6 hours.

Motorized flushing of the paved parking lots and grading the playground and lawns with a grader at levels which would leave only 2% and 10%, respectively, of the original fallout material reduces the radiation at detector 1 by a factor of 2.44, at detector 2 by a factor of 3.03, and at detector 3 by a factor of 1.85. Flushing the paved parking lots requires one man to work .2 hours, and grading the playground and lawn requires one man to work 43.2 hours.

Neither of the decontamination strategies takes into account travel or set-up time.

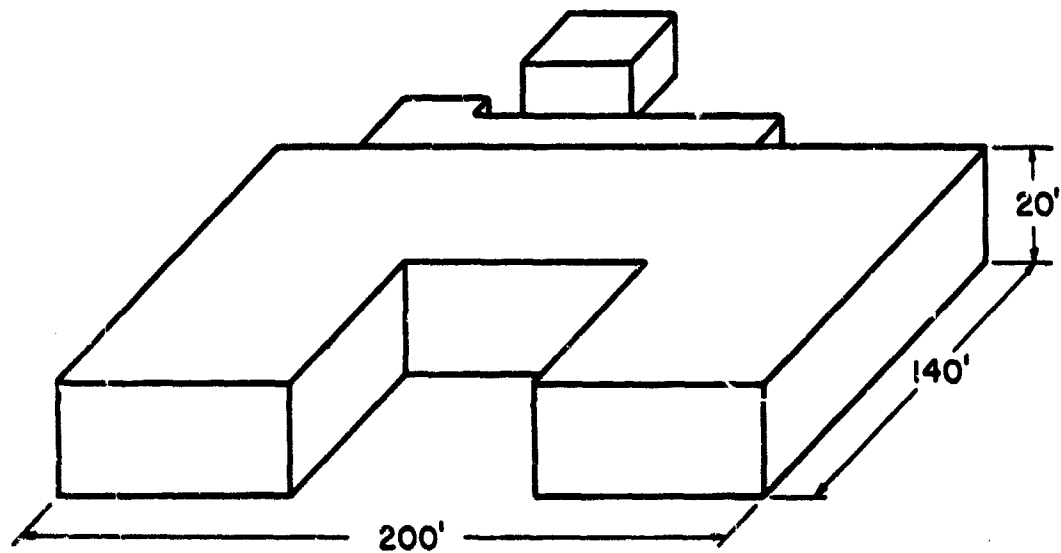


Figure 11

An Oblique View of Isaac Crary Elementary School Showing the
Approximate Dimensions of the Building

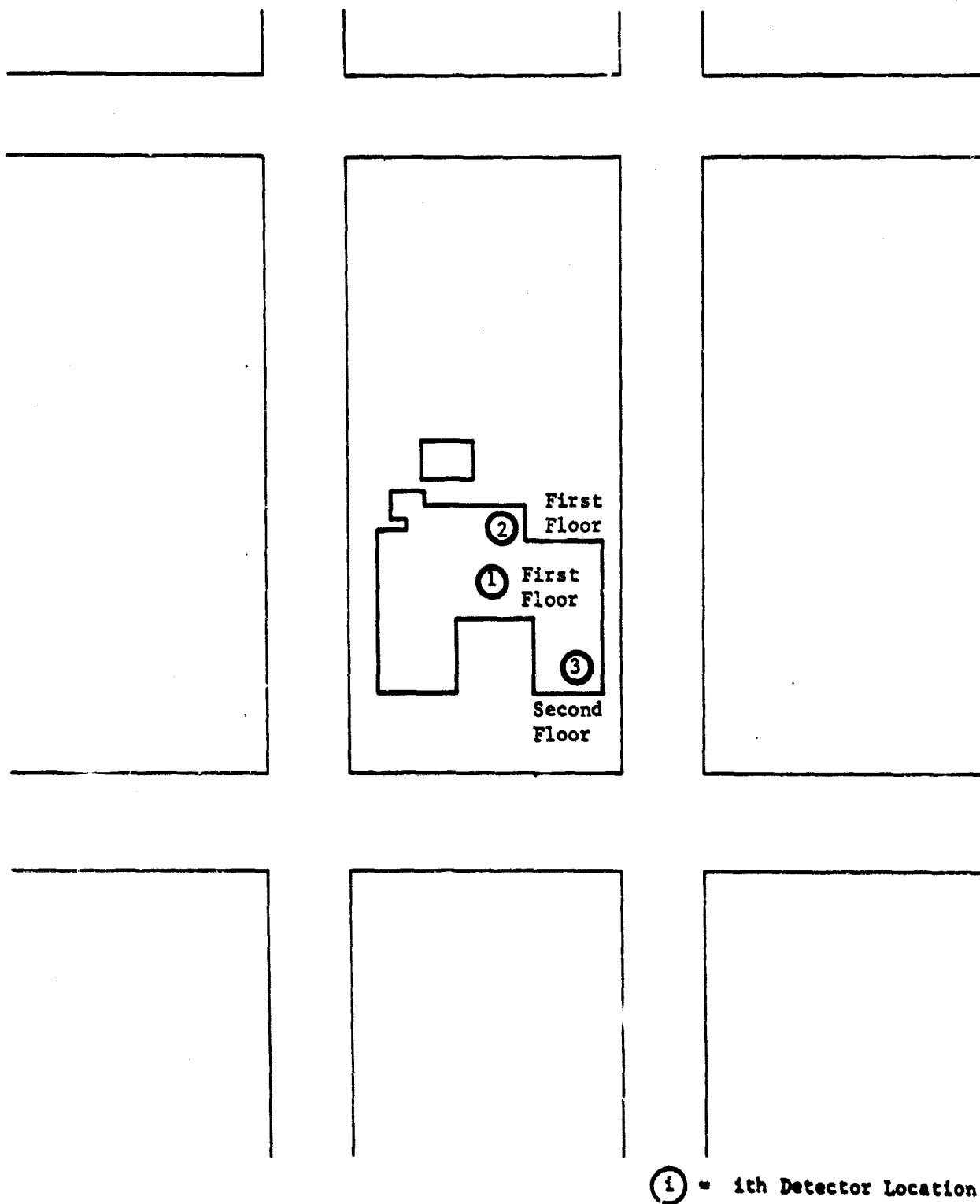


Figure 12

A Plan View of the Two-Story Isaac Crary Elementary School
Showing the Detector Locations

EXAMPLE 7: E. J. KORVETTE DEPARTMENT STORE, DETROIT, MICHIGAN

1. Location of Detectors

Figure 13 is a sketch of E. J. Korvette Department Store. In order to analyze the results of different decontamination strategies, three detector locations were selected. Their PF's and descriptions are as follows:

<u>Detector Location</u>	<u>PF</u>	<u>Description</u>
1	52	Center of First Floor
2	13	Off-Center Location on Second Floor
3	13	Office on Second Floor

The locations of these detectors within the facility are shown in Figure 14. All detectors are assumed to be three feet above the floor.

2. Results of Decontamination

Firehosing the roof of the department store at a level which would leave only 1% of the original fallout material reduces the radiation at detector 1 by a factor of 1.75, at detector 2 by a factor of 9.09, and at detector 3 by a factor of 10.00. This level of effort requires a team of 7 men to work 9.8 hours.

Streetsweeping the parking lot with a mechanical sweeper at a level which would leave only 4% of the original fallout material reduces the radiation at detector 1 by a factor of 1.96, at detector 2 by a factor of 1.10, and at detector 3 by a factor of 1.07. This level of effort requires one man to work 14.8 hours.

Neither of the decontamination strategies takes into account travel or set-up time.

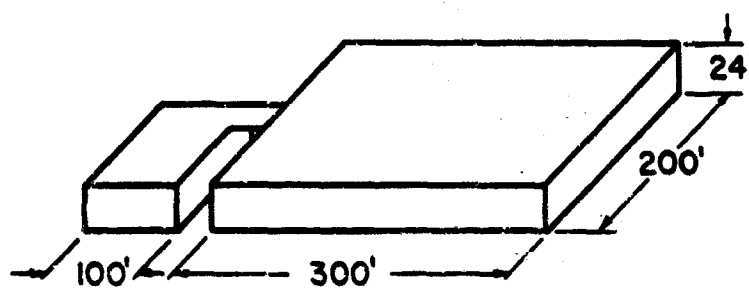


Figure 13

**An Oblique View of E. J. Korvette Department Store Showing the
Approximate Dimensions of the Building**

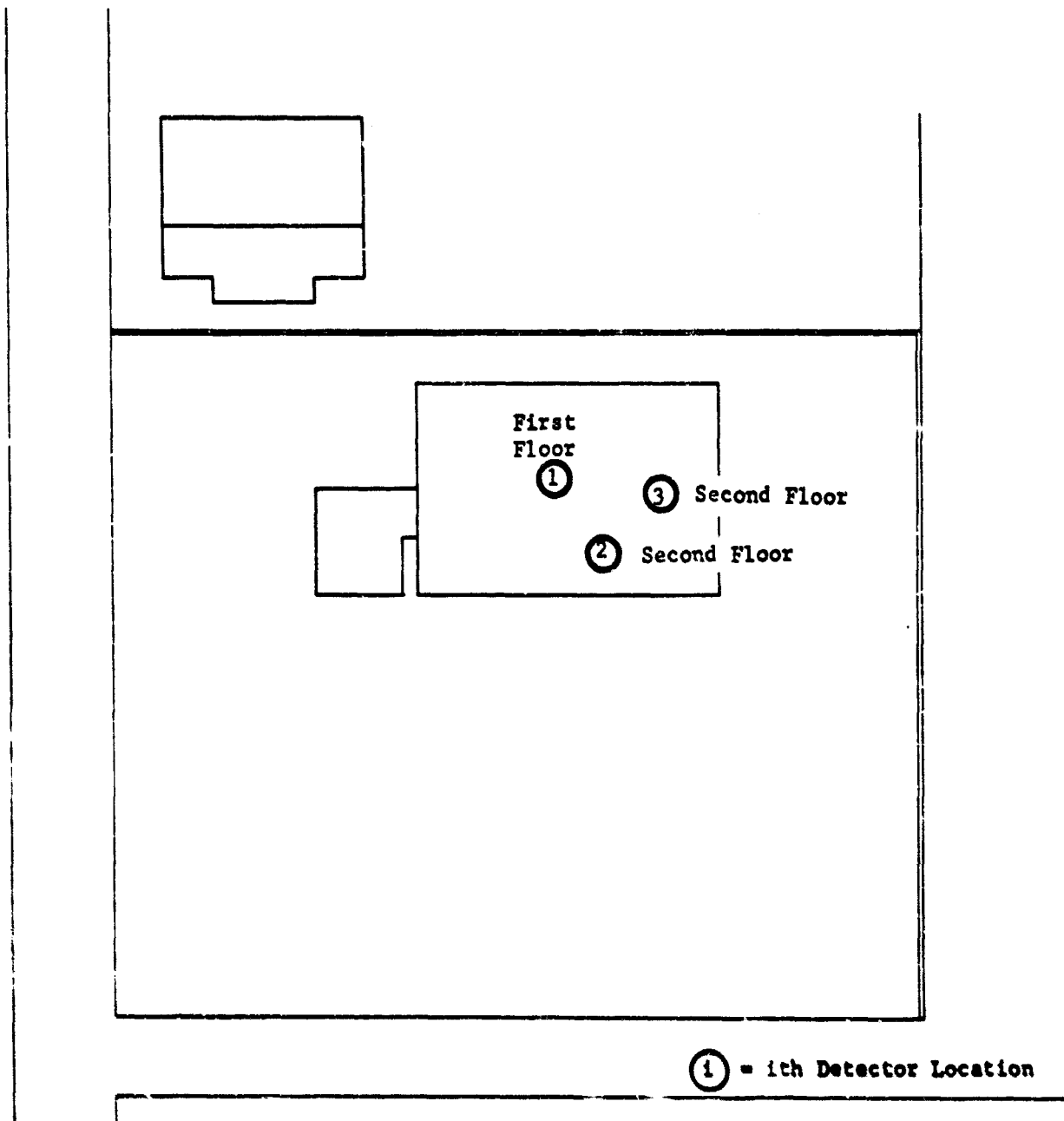


Figure 14

A Plan View of the Two-Story E. J. Korvette Department Store
Showing Detector Locations

EXAMPLE 8: FIRE STATION NO. 8 - SAN JOSE, CALIFORNIA

1. Location of Detectors

Figure 15 is a sketch of Fire Station No. 8. In order to analyze the results of different decontamination strategies, two detector locations were selected. Their PF's and descriptions are as follows:

<u>Detector Location</u>	<u>PF</u>	<u>Description</u>
1	5.5	Equipment Storage Area
2	9.2	Alarm Switchboard

The locations of these detectors within the facility are shown in Figure 16. All detectors are assumed to be three feet above the floor.

2. Results of Decontamination

Firehosing the roof of the building at a level which would leave only 3% of the original fallout material, reduces the radiation at detector 1 by a factor of 1.28 and at detector 2 by a factor of 1.61. This level of effort requires a team of seven men to work .2 hours.

Firehosing the surrounding streets and grading the ground with a grader at levels which would leave only 3% and 10%, respectively, of the original fallout material, reduces the radiation at detector 1 by a factor of 3.85 and at detector 2 by a factor of 2.33. Firehosing the streets requires a team of seven men to work 11.5 hours, and grading the ground requires one man to work 79.2 hours.

Neither of the decontamination strategies takes into account travel or set-up time.

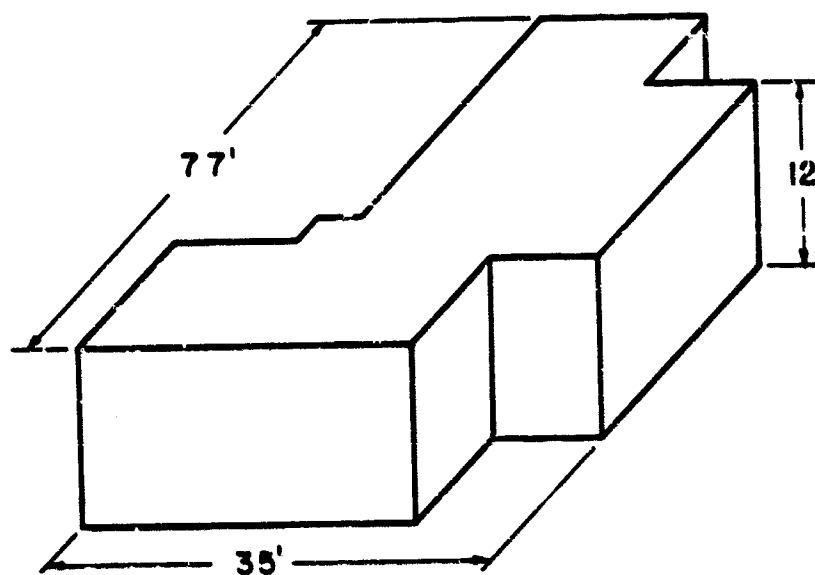


Figure 15

An Oblique View of Fire Station No. 8 Showing the
Approximate Dimensions of the Building

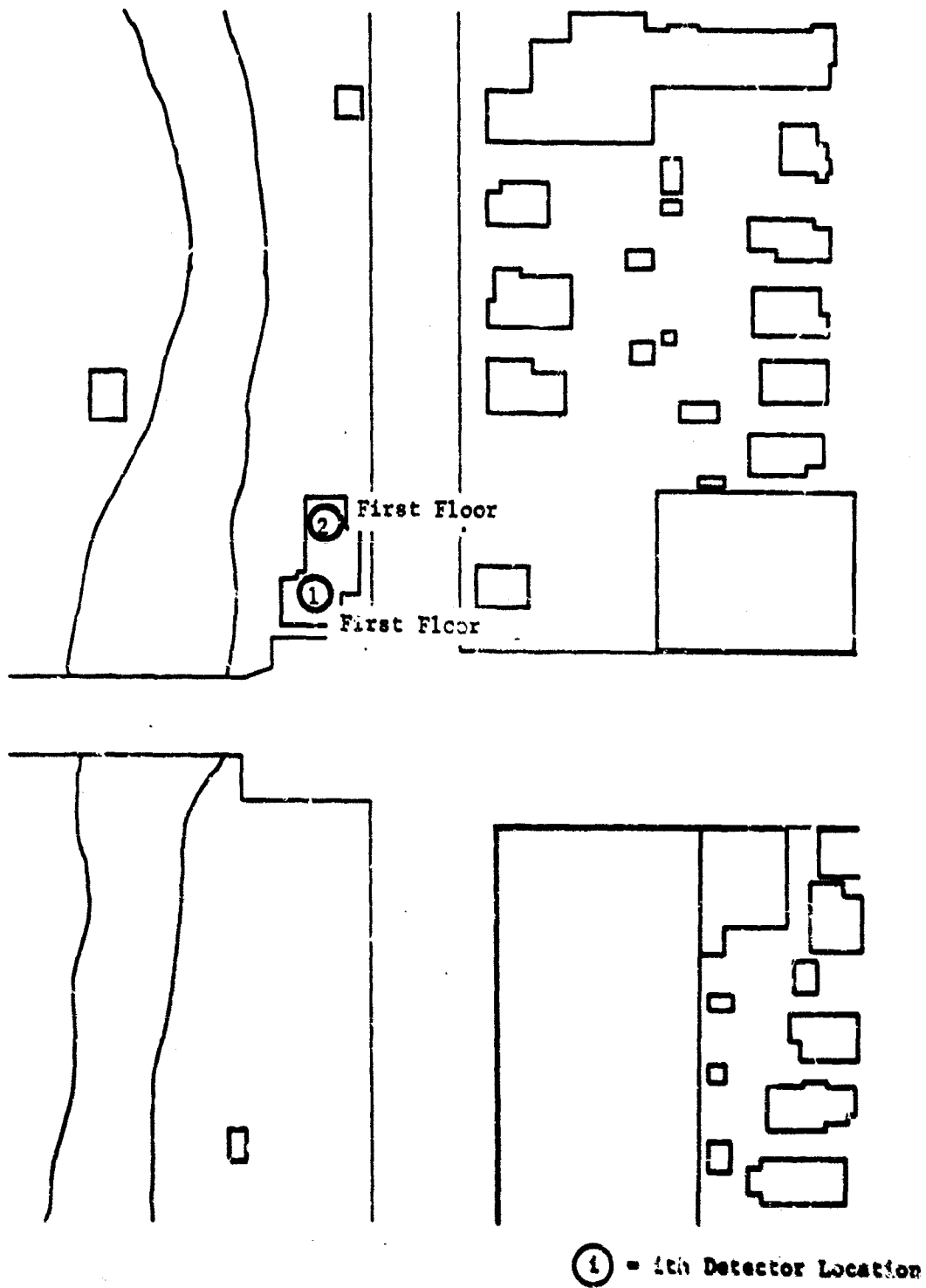


Figure 16

A Plan View of the One-Story Fire Station No. 8
Showing the Detector Locations

III. RADIOLOGICAL RECOVERY OF STAGING AREAS

A. Introduction

One of the objectives of this study was to determine the effectiveness and decontamination costs associated with creating decontaminated "islands" or marshalling areas. It is recognized that in many situations it would be very difficult to recover essential facilities directly out of personnel shelters. Furthermore, most of the personnel required to operate an essential facility may have to wait in shelters while a relatively small number of decontamination personnel recover the facility. Since the decontamination might not be completed until three or four weeks after the attack, shelter facilities may be inadequate. Therefore, a desirable alternative might be to move all personnel to a suitable decontaminated "island" or staging area as soon as movement of personnel is possible.

These staging areas (large enough that have an acceptably low radiation field) should be large enough to permit the facility personnel to assemble, organize, and possibly live under reasonable conditions for a period lasting up to a month or more. These areas may be inside or outside of the contaminated area. This study concentrated on creating such areas inside the contaminated area. Inasmuch as decontamination was the operation under analysis, consideration was not given to creating staging areas on off-shore ships or other such novel places. Indeed, for many of the facilities in Detroit, which were located very close to the Detroit River, such staging areas might be very practical.

Both an indoor and an outdoor staging area are considered here. The indoor area selected is Cobo Exhibition Hall in Detroit, and the outdoor location selected for presentation here is the E. J. Korvette Department Store parking lot (also in Detroit). Other possible locations from among the facilities studied are the legislative amphitheater in the City-County Building (Detroit), the Valley Fair Shopping Center (San Jose), and the Dole Corporation Warehouse (San Jose).

B. Cobo Convention Hall--a Potential Indoor Staging Area

1. General

Cobo Convention Hall is a three-level, rectangular structure with a circular annex, the convention arena, connected to its southeast corner. The hall and arena cover 17 acres of the Civic Center in downtown Detroit and provide 2,220,490 square feet of usable floor space. Figure 17 is an aerial view of the hall showing both the rectangular convention building and the circular arena annex.

The hall is located on the slope of the north bank of the Detroit River and has two ground level floors. The main or middle level contains the entrance from Washington Boulevard, the main exhibit area, the ballroom and other major meeting rooms, and the main truck access. Located on the river, or lower level, are entrances from Civic Center Drive and Larned Street, another exhibit area, the coffee shop, the service and storage area, a truck access, and two underground parking garages. The upper level contains meeting rooms, dressing rooms, the cafeteria, and the administrative offices. The rooftop is a 1200-car parking deck.

The electric power system in the building can provide 22,500 kva (10,000 kva in each of the exhibit halls). The gas line system can provide 200,000 btu from regular outlets and 1,000,000 btu through auxiliary piping in strategic locations. The water system maintains a constant 70 psi pressure at all one-inch outlets. The buildings are completely equipped with television lines, a telephone system with 3,000 external connections to the Bell system, and are completely air-conditioned.

The complex seems a natural candidate for an indoor staging area. Table I lists several detector locations and their original PF's (computed using the FORTRAN protection factor computation program described in Chapter 2).

Structural characteristics of the building are given in Volume IV of this report.

Table I

INDOOR DETECTOR LOCATIONS AND ORIGINAL PF'S AT COBO CONVENTION HALL

Detector Location	Description	Original PF
1	Center Location in Center Hall on Main Floor	208
2	Off-center Location in South Hall on River Level	52
3	Cafeteria in Upper Level	278
4	Center Location in Garage on River Level	769
5	Northmost Office in Administrative Office Section of Upper Level	303
6	Lighting Control Room, Rectangular Hall	1111
7	Power Plant on River Level	909
8	Storage Area on River Level	1667

2. Decontamination Analysis

Three decontamination strategies are considered here:

Strategy 1: Firehosing the parking deck over the rectangular hall (removing 98% of the fallout material).

Strategy 2: Firehosing the streets around the convention hall (removing 98% of the fallout material).

Strategy 3: A combination of strategy 1 and strategy 2.

Table II shows the fraction of dose-rate remaining at each of the eight detector locations after decontamination using each of the above three strategies. This table shows that decontamination can increase the protection at some detector locations by as much as a factor of ten. It also shows that substantial areas are virtually unaffected by decontamination. These areas, primarily on the river level, have very high PF's before decontamination so that the building could be used as a staging area for great numbers of people without decontamination. Of course, the number of good shelter spaces can be appreciably increased by decontaminating on and around the facility. Strategy 1 would require a team

TABLE II

FRACTION OF DOSE-RATE REMAINING AT THE INDOOR DETECTOR LOCATIONS AT COBO CONVENTION HALL
AFTER SPECIFIED DECONTAMINATION OPERATIONS ARE PERFORMED

Decontamination Strategy	Detector Location							
	1 Center Location in Center Hall on Main Floor	2 Off-center Location in South Hall on River Level	3 Cafeteria in Upper Level	4 Center Location in Garage on River Level	5 Northmost Office in Administrative Office Section of Upper Level	6 Lighting Control Room Rectangular Hall	7 Power Plant on River Level	8 Storage Area on River Level
1	.92	1.00	.40	1.00	.32	.56	1.00	1.00
2	.16	.71	.95	1.00	.82	.67	1.00	1.00
3	.08	.71	.35	1.00	.14	.24	1.00	1.00

Strategy 1 - Firehose parking deck (roof).

Strategy 2 - Firehose streets around Hall.

Strategy 3 - Combine Strategy 1 and Strategy 2.

of five men to work for about two and a half hours. The combined strategy (strategy 3) would require a team of five men to work for about eight and a half hours.

C. E. J. Korvette Department Store Parking Lot--A Potential Outdoor Staging Area

The parking lot at the E. J. Korvette Department Store included in this analysis is a very large paved surface and could serve as a staging area for large decontamination equipment and personnel if the radiation field is low enough there.

The protection factor in the center of the parking lot (before decontamination) is 1.36. If the parking lot is firehosed using a five man team for about seven and a half hours (removing 98% of the fallout material), the intensity would be decreased by about a factor of twelve.

D. Conclusions

The two analyses described above indicate that decontamination could create "islands" or staging areas. Large indoor areas such as Cobo Hall might have very high PF locations indoors prior to decontamination, but decontamination might still increase the number of high PF areas appreciably. Inasmuch as the PF's outdoors are very low, reductions in intensity by factors from ten to twenty might not be enough to create a marshalling area out of large paved areas. If the paved area was outside of the high radiation fallout field, however, it might be possible to reduce the intensity to the extent required for its use as a staging area. In neither of the above cases was the cost on team-hours of effort very high. Decontamination analyses of similar facilities included in Volumes III and IV of this report reinforce the conclusions drawn from only two facilities.

IV. RADIOLOGICAL RECOVERY OF A LARGE MUNICIPAL AREA

A. Introduction

One of the basic objectives of this study is to determine the feasibility of recovering "extensive city areas in a realistic postattack environment." In this

study, the area for which decontamination is applied is assumed to have sustained little or no damage from blast or fire. It is believed that this is not uncommon and this assumption simplifies the analysis considerably. It will be seen in Section V of this chapter that direct effects could markedly affect decontamination analyses. For this study, the feasibility of recovering all of the vital facilities in Detroit together with their connecting links is examined. Staging areas of the type described in Section III of this chapter are also recovered.

B. Decontamination Analysis

The facilities considered vital to the radiological recovery of Detroit, their interconnecting links, and the necessary staging areas are listed in Table III together with the man-hours of decontamination effort required to recover the individual facilities or areas. These estimates were in most cases extrapolations from the cost estimates computed for facilities among those analyzed in Volumes III and IV of this report. The total number of man-hours required to decontaminate the vital elements of Detroit is estimated to be about 17 hundred man-hours not including travel or set-up time. Approximately 1000 man-hours of time is estimated for travel and set-up time. Thus it is estimated that less than 3,000 man-hours of time would be required to recover the interconnected system described by Table III.

Table III

DECONTAMINATION COSTS ASSOCIATED WITH RECOVERING VITAL ELEMENTS IN DETROIT, MICHIGAN

Facility or Area	Required Man- hours of Decontamination Effort	Decontamination Method
1. Mistersky Power Plant (Public Power Plant Described in Volume III)	102	Firehose
2. Two Edison Electric Company Power Plants (Private Electric Company Plants assumed to be of the same size and characteristics as Mistersky Power Plant)	204	Firehose

Table III (Continued)

Facility or Area	Required Man- hours of Decontamination Effort	Decontamination Method
3. Waterworks Park (The Large Water Intake and Filtration Plant on the Detroit River, assumed to be about twice the size of Springwells Station which is described in Volume IV)	460	Firehose
4. Two Water Pumping Stations (assumed to be of the same size and characteristics as Springwells Station)	460	Firehose
5. Cobo Convention Hall (Described in Volume IV)	45	Firehose
6. Twelve Large Parking Lots (assumed to be the same size as the E. J. Korvette Department Store Parking Lot described in Volume IV)	180	Street-Sweeper
7. Four Small Hospitals (assumed to be the same size as Mercy Hospital described in Volume IV)	56	Firehose
8. Two Large Hospitals (assumed to be the same size as the San Jose Hospital described in Volume III)	60	Firehose
9. Michigan Bell Telephone Building (assumed to be of the same size and characteristics as the Pacific Telephone and Telegraph Building described in Volume III)	42	Firehose
10. Fifteen Fire Stations (assumed to be of the same size and characteristics as Fire Station No. 8 in San Jose which is described in Volume III)	30	Firehose
11. Thirty Miles of Interconnecting Roads (assumed to be 100 feet wide; thirty miles is a rough estimate of the number of miles of roads required for a completely interconnected system linking the facilities listed in this table)	60*	Flusher
Total Man-Hours of Effort Required Not Including Set-Up or Travel Time	1699	

*This number was computed using an application rate of two miles per hour and a team of two persons.

C. Conclusions

The major conclusion of this section is that the radiological recovery of the vital elements in large municipal area where there are virtually no direct weapons effects is quite feasible if trained personnel and equipment are available. The availability of sufficient water is also a requirement for this decontamination strategy to be feasible. For the decontamination methods listed in Table IV, about 10 million gallons of water would be required. The average amount of water used daily during 1962 in Detroit was 483 million gallons. The rated capacity of the treatment plants in Detroit are as follows:

Waterworks Parks Station	320 million gallons per day
Springwells Station	452 million gallons per day
Northeast Station	192 million gallons per day

Additional water is available in city storage reservoirs. (This information was abstracted from Reference 13). Therefore, it is concluded that water would probably be available to conduct such a decontamination effort.

V. DIRECT EFFECTS CONSIDERATIONS

A. Introduction

In all of the above studies in this chapter, it is assumed that the area for which decontamination is planned has sustained little or no damage from blast and fire. This, of course, may not be the case in a real postattack situation. It is the purpose of this section to at least point out some of the aspects of the above studies which might be influenced by direct weapons effects. Section B, below, considers the influence on the detector contributions of direct effects damage (and thus the potential influence of direct effects on the effectiveness of decontamination). Section C, below, considers the influence of direct weapons effects on the cost and effectiveness of decontamination. Inasmuch as little research has been done on this subject, quantitative results are impossible at this time.

B. Influence of Direct Effects Damage on Radiation Contribution to Detectors

The results of blast and thermal damage can greatly affect the contributions received by an indoor detector. The protection afforded by a shelter can be increased or decreased whether or not the shelter structure itself is damaged.

Surrounding buildings, which would normally shield some of the ground contribution received at the detector could be leveled by the blast wave or fire. The otherwise small planes of ground level contamination could be greatly increased allowing a larger ground contribution to the detector.

In the case of upper-story detectors, the results may be just the opposite. By destroying the surrounding buildings, the planes of contamination would be lowered and therefore contribute less to the detectors.

The influence of direct effects on the building shielding the detector are also potentially significant. Windows could break at about one psi overpressure with doors and light paneling requiring only a little more, making possible fallout ingress. Studies have shown that in extreme cases ingress can decrease the equivalent PF in upper stories and basements as much as 50 percent to 55 percent (see Reference 12). The extent to which direct effects damage influences an inside detector depends on the shielding characteristics of the building housing the detector as well as on the surrounding buildings.

C. Influence of Direct Effects on the Cost and Effectiveness of Decontamination

The blast and thermal effects of a nuclear weapon can affect the cost and effectiveness of a decontamination operation by adversely affecting the following:

- (1) the condition of the facility to be decontaminated (including surrounding planes).
- (2) equipment and supply inventories.
- (3) condition of transportation routes.

Damage to a facility can affect decontamination effectiveness by changing shielding, as discussed above in paragraph B. Damage can also reduce effectiveness

(and increase cost) by requiring the use of a less damaged structure to shelter the recovery and decontamination personnel. Another example of increased effort involves damaged roofs which might require sweeping rather than flushing with water, a method which is much more costly in manpower and generally less effective. Debris on surrounding planes will require more effort or more costly, less effective means, e.g., bulldozer in lieu of street sweeper.

If equipment and supply inventories are damaged or depleted as the result of direct weapons effects, the use of a given amount of a resource will increase. For example, if bulldozers are required to clear transportation routes, move rubble to effect rescue, or to fight fires, the time required to use a bulldozer (and its fuel) for decontamination will increase.

Finally, the conditions of transportation routes can affect the cost of decontamination by affecting the dose received by a decontamination crew in moving from shelter to the place of operation or in moving equipment to the place of operation. The restriction of the movement of equipment could also require the use of more costly and less effective alternative means of accomplishing decontamination.

D. Conclusions and Recommendations

Damage to the facility to be decontaminated may be one of the major ways in which direct weapons effects might affect a decontamination operation. It is recommended that bases for the computation of "damaged PF's" be derived immediately since these have broad implications beyond decontamination. It is also recommended that the corresponding alternative means of decontamination be analyzed for cost and effectiveness under conditions of direct weapons damage to the facility and to the required resources.

Chapter 4

Conclusions and Recommendations

I. INTRODUCTION

In a moderate to severe postattack fallout environment it is necessary to insure that individual radiation doses remain below an acceptable safety level. In accomplishing this objective, fallout shelters are the most important element. They pave the way for recovery by protecting the population in the early fallout environment. When shelter emergence becomes possible, however, more direct actions toward recovery are not only warranted, but, in fact, are essential. Areas and facilities other than shelters must be made habitable in the same sense that shelters are habitable--they must be made safe from radiation exposure.

It is in such broad recovery problems, beginning with shelter emergence, that decontamination was shown in earlier studies (see References 1 and 2) to be as vital to recovery as shelters are to survival. The spontaneous recovery of such areas and facilities that occurs as a natural consequence of radioactive decay will proceed, in many cases, too slowly to provide the necessary hospitals, communications, transportation, food, water, and sanitation facilities; public utilities, etc. Decontamination makes practicable the quick recovery of such areas and facilities by limiting individual radiation dose levels to an acceptable range. In terms of reduced dose and dose-rate, decontamination operations were analyzed to yield the following conclusions and recommendations.

II. CONCLUSIONS

The major conclusions derived from the analyses performed are:

- (1) The recovery of substantial city areas and multi-building complexes can be accelerated appreciably by practical decontamination procedures. (Denial times can be reduced by a factor of ten or more.)

- (2) For most indoor detectors, the roof directly above the detector must be decontaminated for appreciable intensity reduction.
- (3) It is feasible to decontaminate all of the vital elements of a large municipal area, including all of the necessary roads, when there are no direct weapons effects.
- (4) It is possible to create decontaminated "islands" or staging areas with reasonable decontamination effort.
- (5) A substantial command and control system would be required to effect practical municipal decontamination.

III. RECOMMENDATIONS FOR FUTURE WORK

Finally, on the basis of these conclusions, it is felt that studies should be extended to embrace the following:

- (1) Decontamination should be analyzed in the context of coordinated municipal recovery from both the residual effects of fallout and direct weapons effects.
- (2) Particular emphasis should be placed on the development of procedures for computing plane by plane contributions to detectors inside of buildings damaged by blast or fire.
- (3) The systems analysis of decontamination should be extended toward the design of an optimal decontamination system for coordinated municipal recovery.

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Enclosure (1)

Contract Specifications

Work Title: Radiological Recovery Requirements, Structures, and
Operations Research

OCD No. 3233B

T. O. 64-200(51)

Background: Under OCD Subtask 3233B, Contract No. OCD-PS-64-56, decontamination operations were analyzed to determine their potential contribution to accelerating recovery in an early postattack environment and to develop appropriate planning guides for effecting decontamination. This study concentrated on developing the appropriate theoretical basis and on testing it by analyzing the possible decontamination of several NFSS structures and the contiguous ground surfaces. From these studies, it was concluded that decontamination could effectively speed the postattack recovery but recommended that additional research be accomplished to determine the realistic costs (crew dose, training, equipment, etc.) involved when specialized structures or multi-building complexes were involved. To determine realistic cost and effectiveness information relating to the application of decontamination and the extent of its utility when applied to the recovery of extensive city areas in a realistic post-attack environment, this follow-on study is initiated.

Approach: Using the operational planning guides for decontamination developed under OCD Project 3233B and related materials, decontamination of extensive city areas will be studied. City areas of various sizes, ranging from large to very small will be examined in regards to decontaminating vital sections and connecting links. Such areas will be selected from business (downtown), industrial, and suburban locations within real cities.

Certain specific facilities also will be studied to examine vital operations which may be outside a city, e.g., a manufacturing plant. Both high and low building densities are included in the above studies.

The effect of decontamination also will be determined for a number of critical facilities such as power plants, water pumping stations, etc. An attempt will be made to determine whether it is feasible to create marshalling areas or "islands" through decontamination. In determining this, a shopping center will be studied as well as a number of large indoor areas (theaters, gymnasiums, halls, etc.).

Scope of Work. For a broad spectrum of fallout conditions likely to be encountered in an early postattack nuclear environment, the contractor shall analyze a number of localities specified using available planning guides to determine:

- (1) The extent to which decontamination can aid the recovery of cities under various fallout environments.
- (2) The cost and effectiveness of decontamination in recovering city areas.
- (3) The preattack and postattack data required for decontaminating city areas with various levels of effort and/or capability.
- (4) The nature and scope of command and control system elements required for conducting effective decontamination in practical situations.
- (5) Those areas where existing experimental and/or theoretical data are insufficient for planning operations or assessing capabilities.

Enclosure (2)

Contract Specifications - Modification No. 1

For the purpose of the OCD Five-City Study, determine the value and costs of decontaminating specific real city areas selected from the study for a variety of precise attacks as prescribed, and together with work from on-going work under this contract,

- (1) evaluate alternative decontamination strategies for specific situations taking into account all of the aspects of the precisely specified post-attack environments including the residual effects of blast, fire, etc.;
- (2) test developed decontamination hypotheses in an appropriate series of specific cases; and
- (3) determine the costs in manpower, equipment, and supplies required to achieve specific levels of recovery under the prescribed attacks.

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13. ABSTRACT Volume I is a comprehensive summary of the research conducted under OCD Subtask 3233B. This research is reported in detail in Volumes II, III, and IV of this report. This study examines the application of decontamination strategies to extensive urban areas. Urban areas of various sizes (from a few acres to an interconnected system involving hundreds of acres) are examined with regard to decontaminating vital sections and their connecting links. The task of creating decontaminated "islands" or marshalling areas is determined to be feasible. The nature and scope of command and control system elements required for conducting effective decontamination in practical situations is determined together with the preattack and postattack data required by such a system. Several models were developed during the course of the project and are discussed.			

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KEY WORDS

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Dose Rate
Cleaning
Structures
Protection Factor
Civil Defense System

LINK A

LINK B

LINK C

ROLE

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ROLE

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