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AN ANALYSIS OF THE ECONOMIC EFFICIENCY OF AN EXPERIMENT IN CONFLAGRATION CONTROL ON THE STANISLAUS NATIONAL FOREST, CALIFORNIA

by
Lester James Murphy

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy in the
University of Michigan
1965

Doctoral Committee:

Professor Kenneth P. Davis, Chairman
Professor Ayers Brinser
Professor John Carow
Professor G. Robinson Gregory
Professor William J. Schlatter

PREFACE

This study into the control of conflagrations was started by the United States Forest Service in 1961. The Stanislaus National Forest in California was chosen for the study because it was representative of the problems in fire control and land management for which a solution was to be attempted. The author was appointed project leader of the Duckwall Conflagration Control Project and organized and carried out the field portions of the study during the 1961-62 field seasons. In 1963 he became project leader of the research portion of the project.

The analysis described in this dissertation was done at the University of Michigan during the author's residency in 1961, 1962, and 1963. The data were collected during the field seasons in California and compiled in Ann Arbor, Michigan.

The entire investigation has as its one major objective the eventual elimination of disaster forest fires. If this study in some small part succeeds in helping satisfy this objective, then the efforts expended have been more than repaid.

I owe the United States Forest Service a great debt of gratitude for making this study possible. The Pacific Southwest Forest and Range Experiment Station and Dr. Keith Arnold were responsible for instigating and financing the study and for selecting me to participate in it. Sincere gratitude must also be extended to Schoen-Rene Foundation, the Horace H. Rackham School of Graduate Studies,

University of Michigan, and the Society of Sigma Xi-RESA for fellowships and research grants received during the period of study.

I wish to thank Dr. Richard McConnen of the United States Forest Service, Pacific Southwest Forest and Range Experiment Station, for encouraging me to undertake this form of investigation and for helping crystallize an analytical procedure. Professor David Milstein, now at Michigan State University, contributed considerably to my basic training in analytical methods and in formulating the problem. Professor G. Robinson Gregory of my doctoral committee was a great help in clarifying many concepts. Professor John Carow, also of my committee, made special efforts to visit the California project, and his help and suggestions were much appreciated.

To my program chairman, Professor Kenneth Davis, must go a special note of appreciation for his encouragement, his understanding help, and his constant support.

My two student assistants, Clif Dickason and Karl Kadish, deserve a large share of gratitude for their faithful service, their many suggestions, and their high quality of work. Mr. Dickason in particular remained loyal to the Duckwall Project even after moving to a new job in Washington, D.C. I am especially grateful to him.

And, finally, to my wife and our lineage go the greatest thanks of all. They have been uprooted, shuttled, and then uprooted again for many years. Without their loyalty and encouragement the completion of this study would never have been possible.

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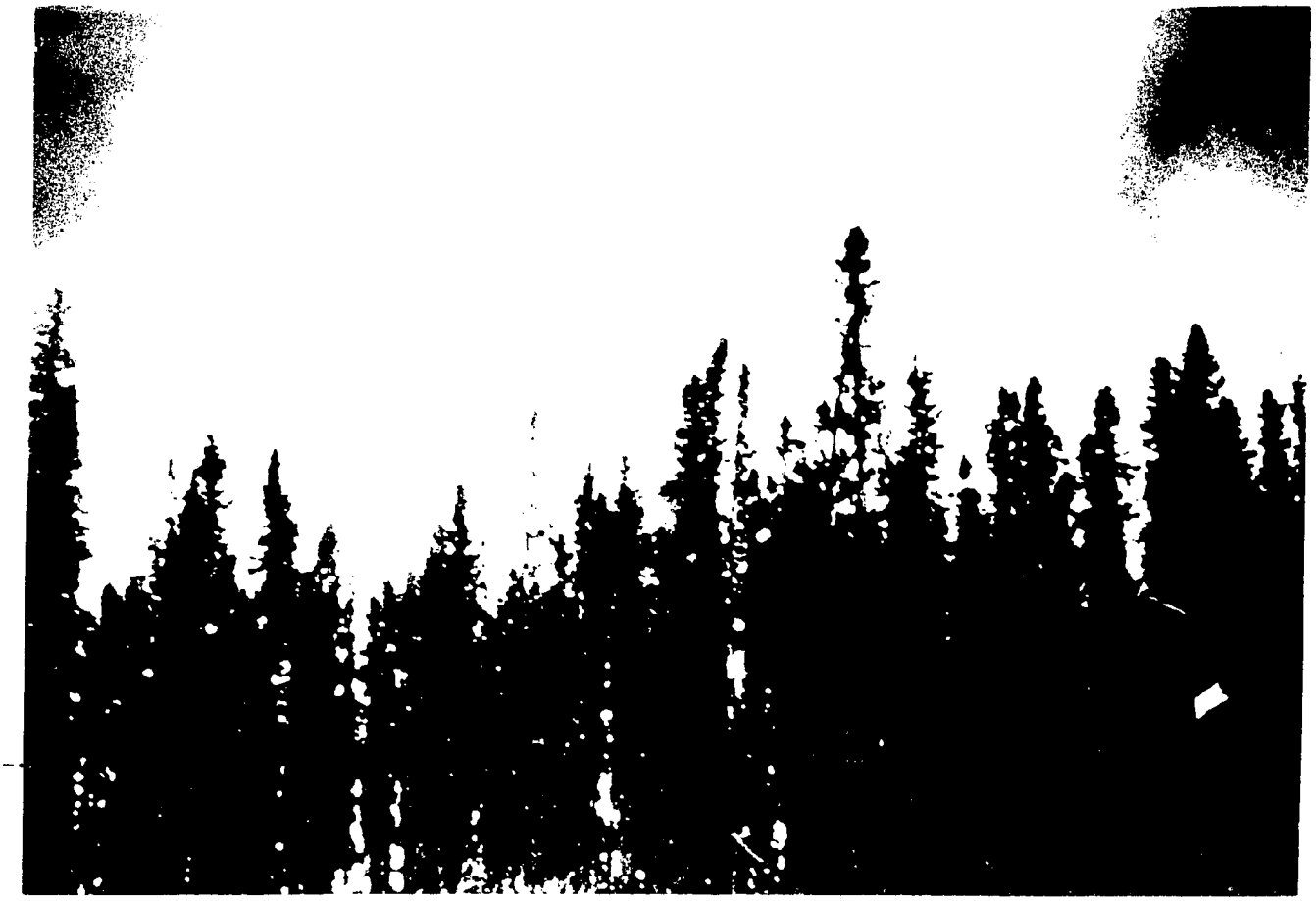

Fig. 1.--A Forest Fire.

CHAPTER I

INTRODUCTION

Five billion dollars--this is the total annual cost of hostile fire in the United States.[1] It includes the loss from actual physical damage and the costs of fire departments, fire-protection insurance operation, and research and development (Table 1). Forest fire costs make up approximately 5 per cent of this total.[2]

Table 2 indicates fires over 100 acres in size which occurred in California during the period 1954-1960. It is evident that the fire problem is concentrated in a few large fires. A small percentage of fires consistently accounts for a large percentage of the area burned.

Large fires, over 100 acres in size, are California's problem. On the average, 3 per cent of the fires are producing 90 per cent of the burned area. Conflagration is the term given to large disaster fires.[3] In California, because of high values a 100 acre

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[1] National Academy of Sciences, National Research Council, A Study of Fire Problems, Publication No. 949 (Washington, 1961), p. 1.

[2] Ibid.

[3] Webster's New World Dictionary (College Edition; New York: World Publishing Company, 1962), p. 113.

TABLE 1

ESTIMATED ANNUAL FIRE COSTS IN THE UNITED STATES IN BILLIONS OF DOLLARS[a]

Source of Cost	Cost	Pct. of Total
Direct physical damage	1.5	29.5
Suppression activities	1.65[b]	32.2
Prevention	0.7[b]	13.7
Loss of use	unknown	unknown
Injury	0.24	4.7
Insurance operation	1.0	19.5
Research and development	0.02	0.4
Total	5.11[b]	100.0

[a]National Academy of Sciences, National Research Council, A Study of Fire Problems, Publication No. 949 (Washington, 1961), p. 1.

[b]Estimated.

TABLE 2

FIRES IN CALIFORNIA OVER ONE HUNDRED ACRES IN SIZE, 1954-1960[a]

Year	Pct. of All Fires	Pct. of Total Area Burned
1954	6.0	92.3
1955	4.8	96.1
1956	2.7	92.1
1957	6.1	93.4
1958	4.3	89.8
1959	4.9	95.1
1960	2.5	88.1

[a]Paul Casamajor, Wildland Fire Problems (Operations Research Center, University of California, 1962), p. 7.

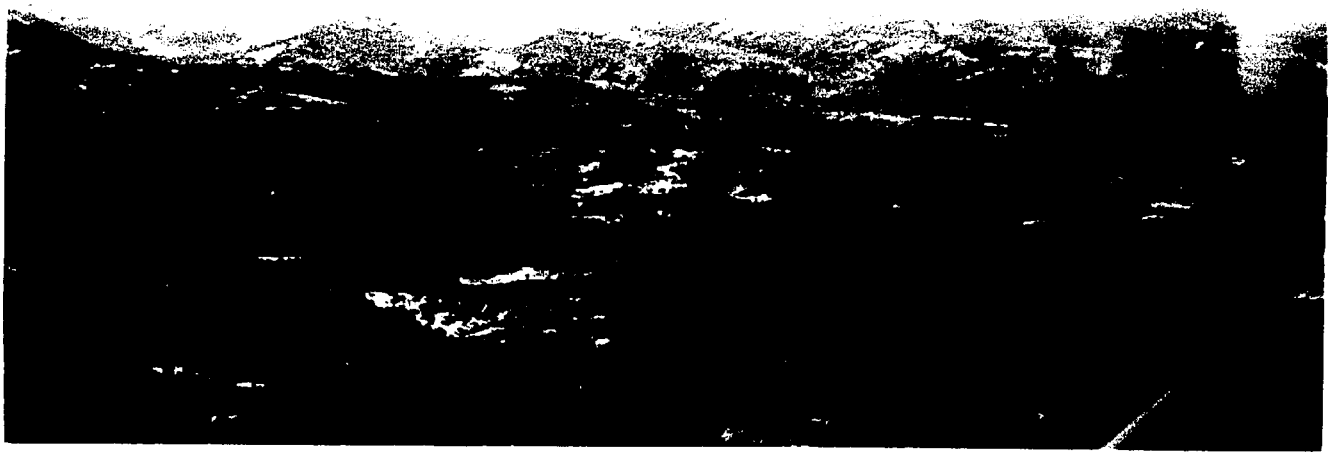

Fig. 2.--California's wildland is characterized by steep terrain, heavy fuels, and high values. On the average 3 per cent of all forest fires that start cause 90 per cent of the area burned.



Fig. 3.--A California conflagration.

fire can be a disaster fire. For purposes of this study, therefore, conflagrations will be regarded as those fires over 100 acres in size.

The conflagration problem has no easy solution. Of the presently available alternatives that could contribute to solution of the large fire problem--i.e., prevention of ignitions, overcoming effects of topography, weather modification, fuel modification, and more and better fire control--the last two seem to be the best.[1] This study is concerned with an experiment in conflagration control through fuelbreak systems[2] as carried out in California.

Objectives and Methodology of This Study

The objectives of this study are: (1) to determine if any fuelbreak system on a study area on the Stanislaus National Forest, California, is economically justified and technologically effective; (2) to determine, if justified, the economic scale and "mix" of fuelbreaks and a fire-suppression organization on the area; (3) to determine an economically supportable burned area objective; and (4) to determine pars or working objectives to meet total objectives.

Chapter II describes the Duckwall Conflagration Control Project, a 40,000 acre wildland unit located in the Stanislaus National

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[1] James L. Murphy, "Conflagration Barriers--A New Concept," Forest Fire Conditions Western North America, 1963 (Portland, Ore.: Western Forestry and Conservation Association), p. 11.

[2] A fuelbreak is a strategically located area on which fuels which burn with high intensity (brush) are changed to fuels that burn with low intensity (grass). Resistance to fire control is less, and safer access is provided firemen.

Forest, California. The Duckwall project is an experiment in conflagration control through fuelbreak systems combined with a fire-suppression organization. Basic assumptions and principles, including a viewpoint for analysis, anlytical objectives, and specific study assumptions, are outlined in Chapter III. Costs and methods of obtaining them are presented in Chapter IV. Dollar fire damage potentials are presented in Chapter V, and costs and dollar damage potentials are synthesized by a special application of the least-cost-plus-damage method, in Chapter VI. The analysis is modified for field conditions in Chapter VII and considers the realistic cases of shared costs, risks of not stopping fires at fuelbreaks, periods during which burning conditions exceed those at the optimum level of protection, and one level of fire protection for the entire Duckwall Unit. Discussion and implications of the study are in Chapter VIII. Summary and conclusions are presented in Chapter IX.

CHAPTER II

THE DUCKWALL CONFLAGRATION CONTROL PROJECT

The Duckwall Conflagration Control Project was begun in 1961 as an experiment in control of conflagrations. The project was based upon a planned system of conflagration barriers. Conflagration barriers consisted of fuelbreaks and natural barriers. Fuelbreaks are areas strategically located at key fire defense points such as ridges on which the fuel has been modified. Heavy fuel has been changed to light fuels. Changing heavy brush to perennial grass and cleaning up slash and ground debris and thinning understory trees in timber stands are examples (Figures 5 and 6). The continuity of hazardous fuels is broken. Resistance to fire line construction is thus reduced. Fire intensity is reduced also. Safer access and attack points are provided. If the natural tendency for unilateral forest management could be overcome by integrated efforts, timber management projects, as well as range, recreation, watershed, wildlife, roads and trails, and special use projects could all combine and share with fire control the fuelbreak construction and maintenance program. An efficient, hard-hitting fire-control organization would still be necessary to make fuelbreaks fully effective. This chapter describes the study area and the planning, preparation, and a summary of project results.

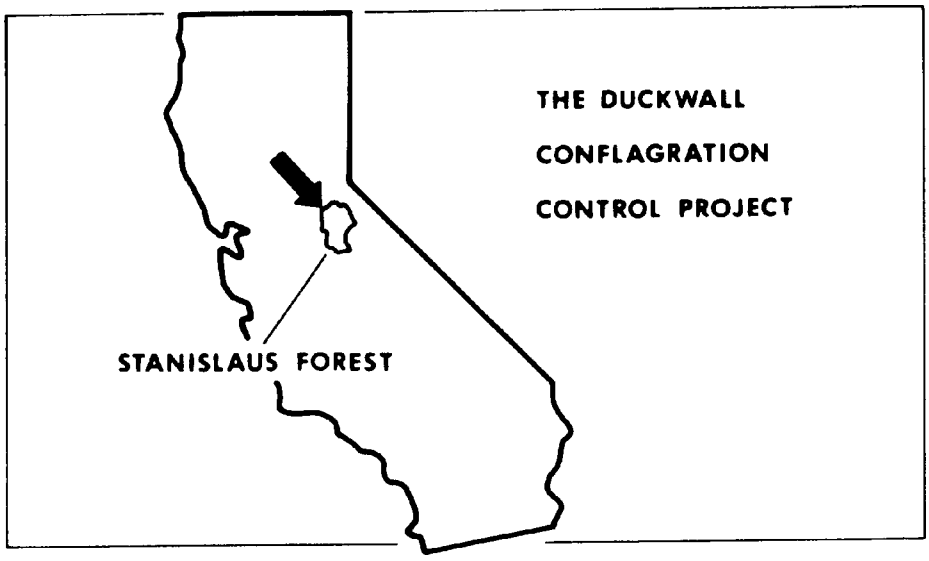

FIG. 4 LOCATION OF THE DUCKWALL PROJECT



Fig. 5.--A timbered fuelbreak from which brush and slash have been cleared, and on which trees have been thinned and pruned.



Fig. 6.--A section of fuelbreak in brush on the Duckwall Unit.

Description of Study Area

The United States Forest Service set up the 40,000 acre Duckwall Test Unit on the Stanislaus National Forest in the Sierra Nevada Mountains of California for the project. The test unit was picked by a management team from the California Forest Service Region, the Pacific Southwest Forest and Range Experiment Station, and the Stanislaus National Forest. It was chosen because the Stanislaus Forest had an active multiple-use program, high-hazard fuels, and a history of severe conflagrations. The Duckwall Unit has prominent ridges and steep canyons. Elevations range from approximately 900 feet at the river levels to 5,825 feet above sea level at the highest point. Cover types consist of annual grass and brush on the lower river slopes, some hardwood areas at the middle elevations, and timber, predominantly Ponderosa pine and sugar pine-fir, at the higher elevations. Precipitation amounts to 20-25 inches of rain annually, normally occurring from November to April. Summers are hot, dry, and windy. The Duckwall Unit is part of a much larger wildland area, the Mi-Wok Ranger District, over which conflagration control planning was to be done.

Planning for Conflagration Control

A team of Stanislaus forest fire specialists carried out pre-attack planning. They had been oriented in various other management plans for the unit. The crew gathered the following tools for planning and directing action:

1. Project area maps, 2 inch to the mile scale, topographic and planimetric.

2. Aerial photos--1:15,000 and 1:10,000 (for specific small area treatment).

3. Land status maps and records.

4. Transportation map and plan.

5. Value classification maps.

6. Cover type map.

7. Fire planning data, including fire occurrence and history, risk and hazard map, and weather records.

8. District multiple-use plan.

9. Management plans for all management functions, including timber, range, wildlife, recreation, watershed, forest roads and trails, and special uses.

A helicopter flight provided oblique aerial photo coverage of the unit and data for the location of the primary barrier system. The entire ranger district was broken into preattack blocks. These blocks generally circumscribed large drainages or other natural topographical units. The Duckwall Unit was designated as "A" block. The primary barrier system was designed and located on a preliminary block map. It consisted of main barriers along main divides, ridges, and canyons and secondary barriers along key "tie-in" ridges and canyons. The over-all criterion for fuelbreak location was that barriers were to be located at points where fire attack would have been made in the absence of the fuelbreak. Specific criteria are contained in the references Preattack Planning and Construction for Forest Fire Suppression[1] and Guidelines for

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[1]U.S., Dept. of Agriculture, Preattack Planning and Construction for Forest Fire Suppression (U.S. Dept. of Agriculture, Forest Service, 1959), p. 5.

Fuelbreaks in Southern California.[1] Emphasis was on breaking up the entire unit rather than locating a few widely spaced fuelbreaks of extreme width. Existing fire-control facilities were located also. A tentative fire barrier and facility (heliports, helispots, etc.) numbering system was assigned. Figure 7 illustrates the tentative barrier system, type of barrier, and location of fire-control facilities and numbering as planned during the survey.

A team of foresters were assigned the job of reviewing future programs in timber management, range and wildlife management, recreation, watershed, special uses, and forest road and trail programs. All projects scheduled on the Duckwall Unit were delineated on map overlays and the portions coinciding with the fuelbreak system were noted.

A field survey was made. The purpose of the field survey was to determine all proposed barrier locations and to collect information on the work needed and how it could fit into the total management program.

The field survey crew consisted of three men. One of the men was thoroughly familiar with the district multiple-use management plan, as well as all specific functional management plans. All crewmen were experienced firemen. A total of 150 miles of potential fire barriers was surveyed over the entire Duckwall Unit by the crew. Because ridges and canyons of the Sierra Nevada Wildland are so well defined, specific location of fuelbreaks on the ground was pretty much dictated by topography. Crews actually walked 35 miles of the total. They were able to drive another 18 miles. The remainder of the survey was done through a combination

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[1]Anonymous, Guidelines for Fuel-Breaks in Southern California, Fuel-Break Report 9 (Dept. of Natural Resources; Div. of Forestry; Los Angeles County Fire Dept.; U.S. Forest Service, 1963).

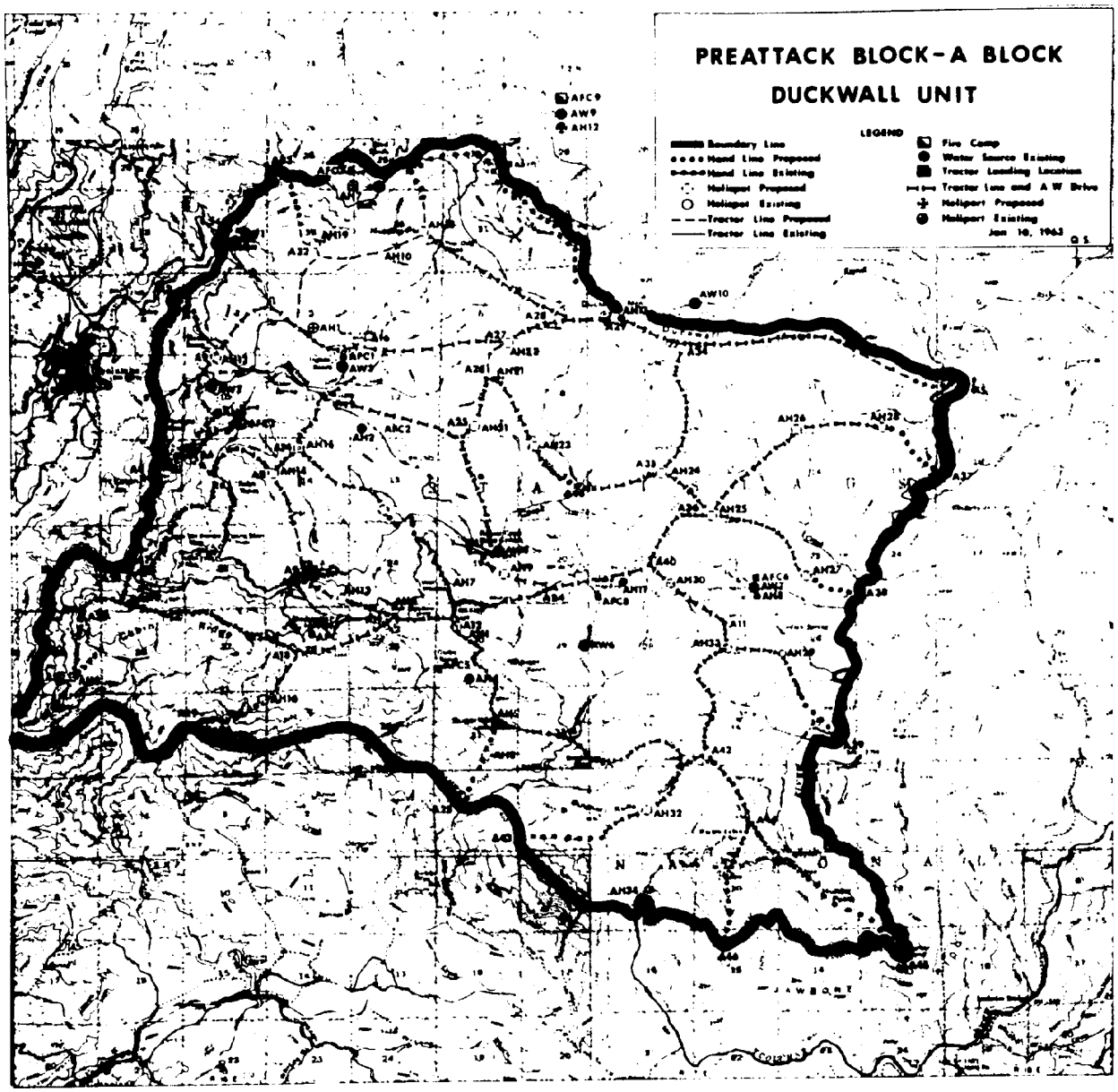

FIG. 7 PREATTACK BLOCK-A BLOCK DUCKWALL UNIT

of observations from nearby ridges, aerial reconnaissance, the use of aerial and oblique photos, and local knowledge of the area.

All field observations were recorded on conventional preattack planning forms[1] revised for conflagration control planning. Information for fire-control purposes, such as helispots and heliports, mechanized trails, et cetera, was recorded. Additional management information, such as range revegetation projects and reforestation projects needed, was gathered also. Steel preattack identification signs, keyed to preattack map numbers as shown in Figure 7, were placed at designated points on the ground by the crew.

At the end of each work day, all field forms were checked for completeness. When the forms were completed they were filed by block and line number for later reference.

At the end of the field survey, all data gathered during the field survey were written up. That part of the information gathered specifically for fire suppression was written according to the format suggested in the Region 5 Preplanning Instructions,[2] with revisions for conflagration-control planning. This information along with preattack maps was placed in the Preattack Handbook for fire-suppression use.[3] Management project work needed was placed on conventional project work plans.

The fire-control and management phases of the planning and field survey were combined to produce plans for the conflagration-control action program. Existing and proposed management projects

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[1] U.S., Dept. of Agriculture, Preattack Planning . . . , pp. 13-17.

[2] Ibid., pp. 35-63.

[3] Ibid., p. 35.

were laid out on overlays. They were matched with the block map of fire barriers as determined by the field survey crews. Barrier locations were adjusted according to fire history and values at stake. A plan of action for the first and future field seasons was written and placed in a notebook. The plan included: (1) management projects, such as timber sales, range revegetation projects, wildlife habitat improvement program, which were scheduled so that they could contribute to the fuelbreak construction program, yet still be consistent with good land management; (2) needs for fuelbreak construction by fire control to complete the system and the scheduling and financing of this work.

The final product of preattack planning was a planned-action program of conflagration control through integrated land management.

Preparation for Conflagration Control

After planning, including the field survey, was complete, crews and equipment began fuelbreak construction according to the action plan. Methods of construction of fuelbreaks differed according to the cover types and steepness of topography. The Duckwall Unit consisted mainly of timber type at the higher elevations and the brush type at the lower elevations. The topography ranged from moderate slopes, on which heavy equipment (tractors) could perform most of the work, to very steep slopes, such as canyons and draws, on which only hand crews could work. Width of fuelbreaks was generally dictated by topography. Usually, side slopes were cleared to the point where they became too steep for men or equipment to work safely or efficiently, producing fuelbreaks which averaged about 300 feet for tractor-constructed breaks and 80 feet

wide for hand-constructed breaks. Snags located within and near the fuelbreak system were removed.

Numerous helispots and nearly 15 acres of safety zones were constructed at strategic ridgetop locations as a part of fuelbreak construction. Hand crews restored and/or maintained trails to assure quick access by crews if fuelbreaks were to be manned during a fire. Foot trail work was a part of fuelbreak construction also.

Summary of Work Done

At the end of two field seasons (1964), the Duckwall experiment was approximately one-third completed. The 40,000 acre study unit was broken into blocks by the fuelbreak network. Some 22 miles of fuelbreaks, totaling about 1,300 acres, had been completed.

The remainder of this dissertation presents the costs of two years of fuelbreak work and an economic analysis of fuelbreaks and fire suppression on the Duckwall Unit. Discussed are the costs of fuelbreak construction and maintenance, the dollar fire damage potential of timber and brush in the Duckwall Unit, and an economic analysis of alternative combinations of fuelbreak systems and fire-suppression organizations.

CHAPTER III

PRINCIPLES AND GENERAL ASSUMPTIONS OF THE ANALYSIS

Levels of Economic Evaluation

Three levels of economic evaluation may be considered: the national level, the community level, and the local level.[1] The same common denominator of economic balance extends through each of these levels, but the basis of comparison differs. The analysis of the Duckwall Unit is located at the local level. This level can be looked upon as the level of the Duckwall Unit itself. At this level each of the monetary items can be most readily weighed, and the nonmonetary items can be given full consideration. The need for economic efficiency is as great at this level as at any other level and can be more readily obtained and applied.

Objectives and Criteria

As Arnold noted,[2] objectives have not been clear cut because of the lack of recognition of the level of viewpoint from which they

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[1] National Academy of Sciences, A Study of Fire Problems, p. 28.

[2] R. K. Arnold, "Economic and Social Determinants of an Adequate Level of Forest Fire Control" (unpublished Ph.D. dissertation, University of Michigan, 1950), p. 70.

must be formulated and interpreted. Davis[1] also stressed the importance of clear definition of objectives and the viewpoint from which they are presented. The author has noted considerable confusion existing among terms theoretically meaning "objectives," even after the level of viewpoint has been defined. Economic and fire-control literature contains such terms as (in addition to objectives) criteria, goals, tests, standards, gauge, purpose, tasks, pars, et cetera. For purpose of this study, the following distinctions (and it is hoped clarifications) will be made.

An objective is defined as "something toward which effort is directed--an end or aim of action."[2] As McKean[3] has pointed out, enumeration of objectives or goals seldom comprises guides to specific action.

The objective of this study of conflagration control on the Duckwall Unit is to determine the level of conflagration control consisting of fuelbreaks and fire suppression necessary to hold costs and damage to a level commensurate with values protected and to do this job safely.

Criteria are defined by McKean[4] as "tests of preferredness" which distinguish preferred combinations of consequences from less desirable ones. Criteria allow one to choose among alternatives.

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[1]Kenneth P. Davis, Forest Fire: Control and Use (New York: McGraw Hill Book Company, 1959), p. 483.

[2]Webster's New World Dictionary, p. 1012.

[3]Roland McKean, Efficiency in Government through System Analysis (New York: John Wiley and Sons, 1958), p. 202.

[4]Ibid.

Criteria must be viewed and checked at all levels to avoid inconsistencies with higher-level criteria or objectives.

The criterion of this study--the one that is a "test of preferredness" among alternatives to reach the objective--is the "least-cost-plus-damage economic test." Because this analytical method considers costs and benefits (values saved) it is definitely consistent with the over-all objective.

Pars are "predetermined performance standards designed to measure adequacy of . . . efforts."[1]

In this study pars will be determined by the least-cost-plus-damage analysis and will consist of acreage objectives, size of fire at discovery, and elapsed-time standards.

Policies or "governing principles, plans or courses of action"[2] will be recommended to carry out alternatives shown to be preferable according to the study criteria and objectives.

General Assumptions

Conflagrations.--This study is based upon all fires over 100 acres in size that have occurred on the Duckwall Unit during the fifty-year period 1910-1959. It will be recalled that fires of this size are assumed to be conflagrations for purposes of this study. Specific acreage objectives for conflagration control will be calculated as part of this study.

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[1] U.S., Forest Service, Forest Service Manual 5102 (Washington: U.S. Forest Service, 1964), sec. 5101.2.

[2] Seventh New Collegiate Dictionary (Springfield, Mass.: G. and C. Merriam Company, 1961), p. 1131.

Area of analysis.--The analysis is of conflagration control work done on the 40,000 acre Duckwall Unit. Ownership of land and improvements and administration of the Duckwall Unit are assumed to be by the United States government, Forest Service. In Chapter VI the unit is assumed to be a specific administrative unit. Then this assumption is relaxed in Chapter VII to show the effect of shared costs of fire suppression.

Fuels, weather, and topography.--The state of California is divided into 144 fire-danger rating areas as basic units for the California Wildland Fire Danger Rating System. Each area is a broadly homogeneous combination of fuels, weather, and topography.[1] The Duckwall Unit falls into two fire-danger rating areas--area 348, brush, which covers the southern portion of the unit; and area 370, timber, which covers the northern part of the unit (Figure 8). The Duckwall Unit's economic analysis first will be carried out separately for each fire-danger rating area (Chapter VI). Then in Chapter VII one level of protection for both fire-danger rating areas will be found. The analysis will be carried out also for three separate burning indexes within each fire-danger rating area. Figures 9 and 10 show cumulative probability curves. Burning indexes, which express worsening burning conditions as one progresses toward 100, are on the vertical axis, and the percentage probability of a lower burning index is on the horizontal axis. Figure 9 is for brush areas and Figure 10 is for timber areas on the Duckwall Unit. Planning levels on California national forests are currently at the

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[1] Arthur Pirsko, "Selecting Fire Control Planning Levels by Burning Index Frequencies," Fire Control Notes, XXII, No. 4 (October, 1961).

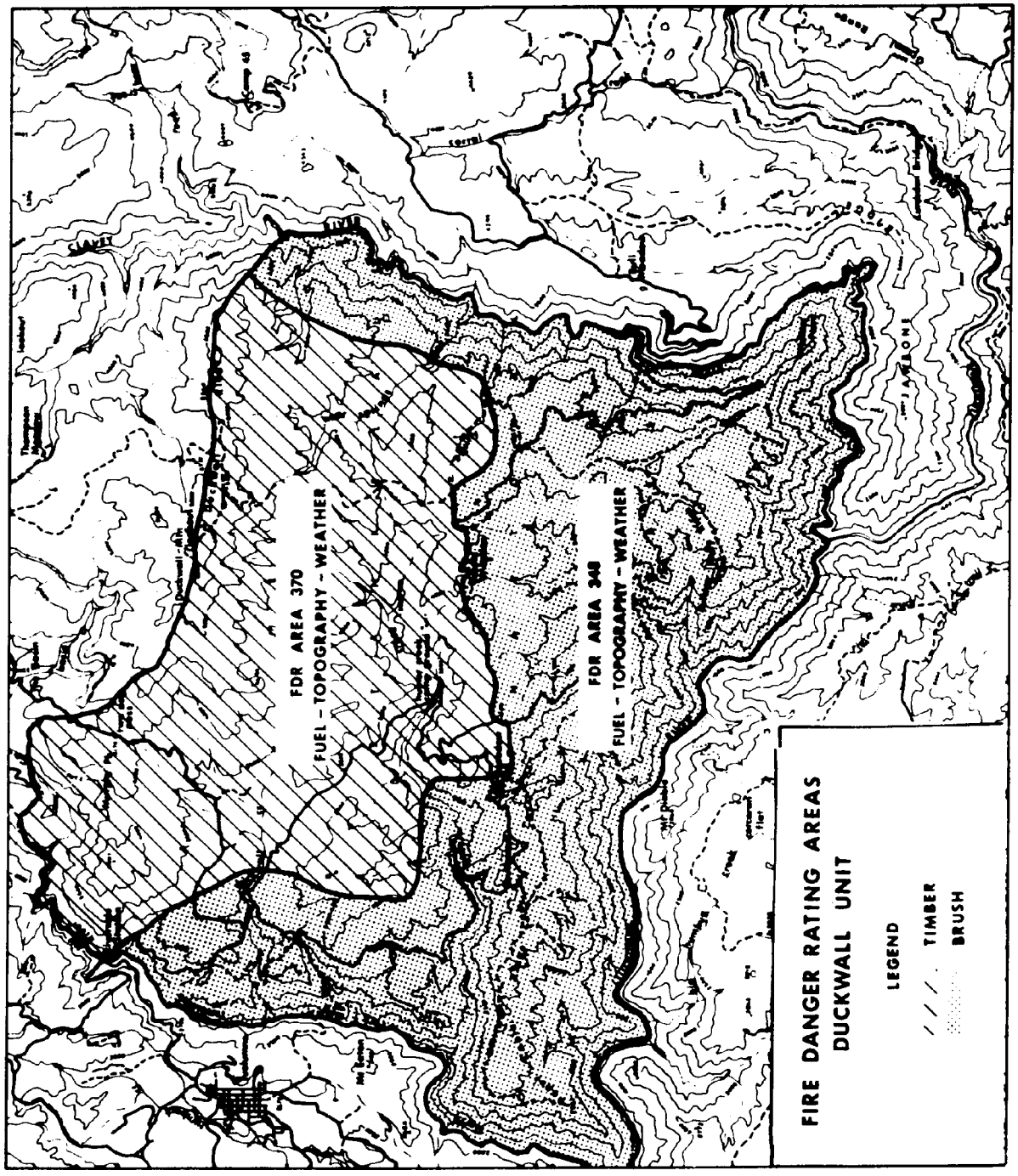
FDR AREA 370
FUEL - TOPOGRAPHY - WEATHER
FDR AREA 348
FUEL - TOPOGRAPHY - WEATHER
FIRE DANGER RATING AREAS
DUCKWALL UNIT
LEGEND
TIMBER
BRUSH

FIG. 8

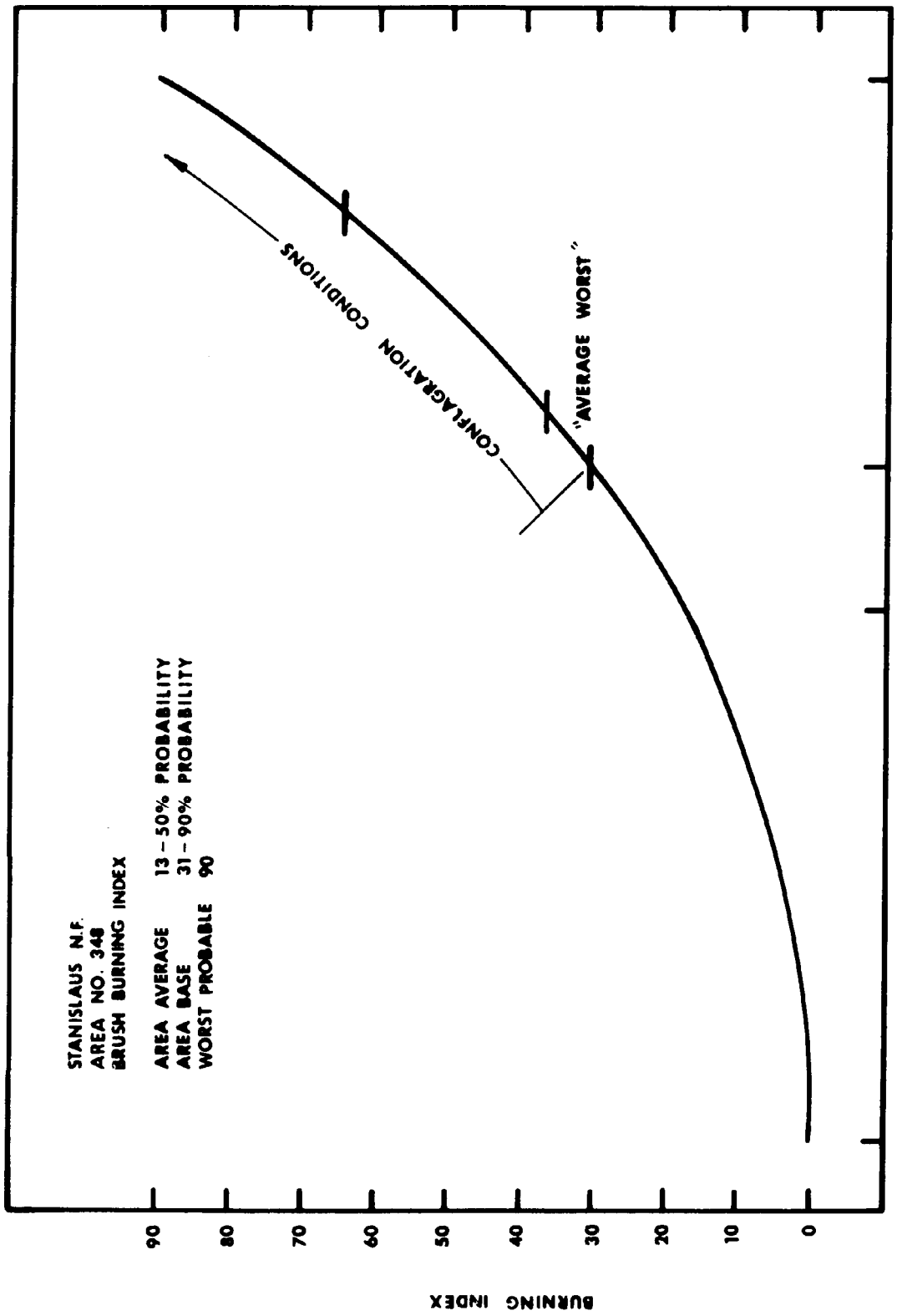

FIG. 9 PERCENTAGE PROBABILITY OF LOWER BURNING INDEX

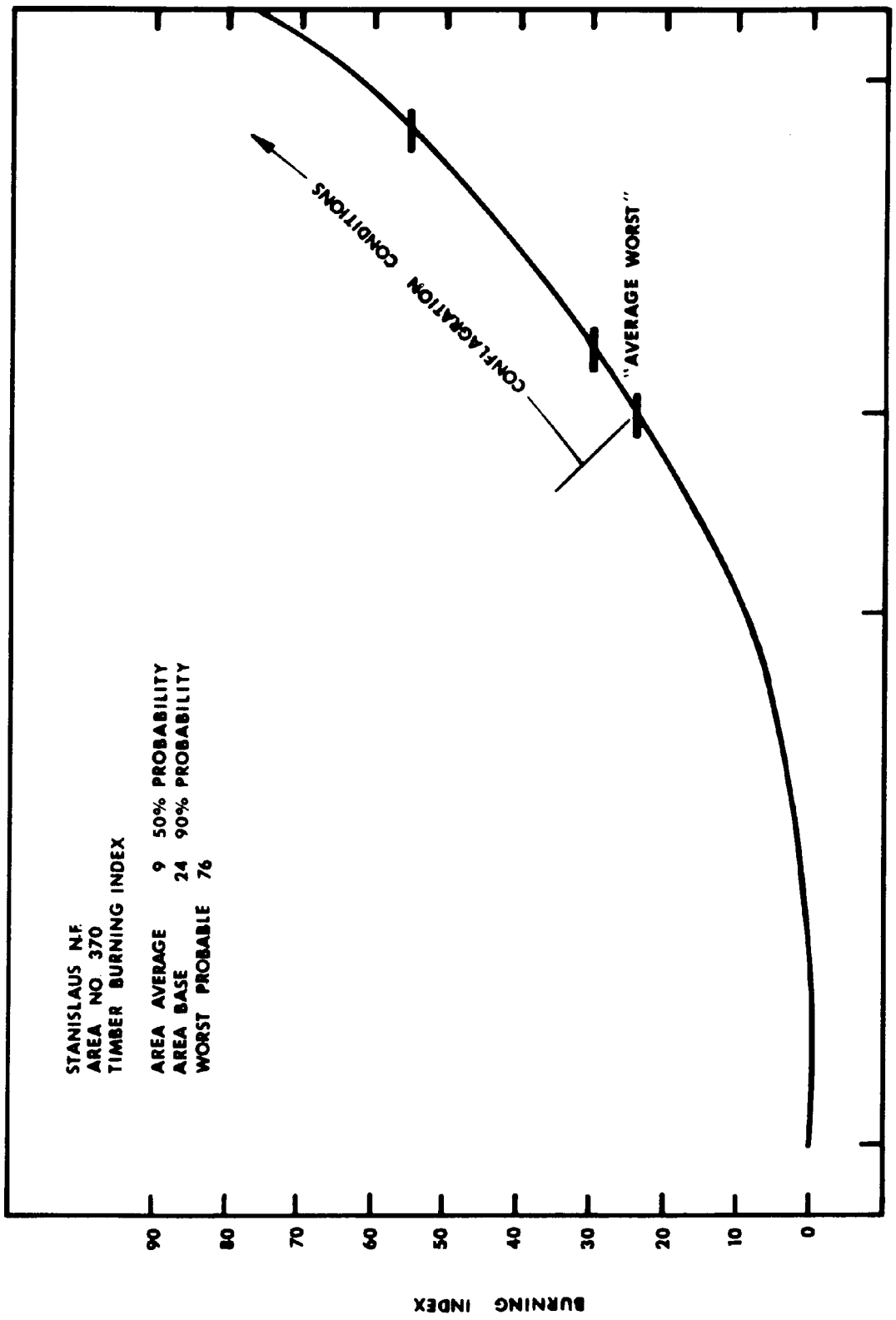

FIG. 10 PERCENTAGE PROBABILITY OF LOWER BURNING INDEX

90 per cent burning index frequency. California considers this level as "average worst" conditions. This analysis will be carried out at the "average worst" level for each fire-danger rating area and also for two higher burning index levels in each fire-danger rating area which are assumed to be "worsening" conflagration conditions, to see at which burning index the optimum level of protection falls. In area 348, brush (Figure 9), these burning index levels are 31, 37, and 65. In area 370, timber (Figure 10), the levels of analysis are burning indexes 24, 30, and 55. After the optimum levels have been found, adjustments for those periods when the fire danger exceeds the optimum levels will be made.

Fire ignition, spread, and behavior.--All assumptions about the start, spread, and behavior of fires on the Duckwall Unit were based upon an analysis of all Class D and E fires, 100 acres and over, that have occurred during the fifty-year period 1910-1959. Thirty-three Class D and E fires have occurred over this period (Exhibit 2 and Table 27, Appendix). The average annual burn on the Duckwall Unit has been 2,202 acres. Of this, an average of 1,225 acres in timber and 976 acres in brush have burned annually (Table 28, Appendix). At no time during the fifty-year period did two conflagrations start at the same time (Table 29, Appendix). Therefore, it will be assumed for purposes of this analysis that no two conflagrations will start and burn at the same time in either brush or timber.[1]

Fire season.--An annual fire season of 150 days is assumed. This assumption is based on the fire season of May 15 to October

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[1]Fire-danger rating areas 348 and 370 will hereafter be referred to as brush and timber areas.

15, as defined by the Stanislaus National Forest, and the fact that all but two conflagrations during the past fifty years have occurred during this period (see Exhibit 4, Appendix).

Source of funds.--It will first be assumed, in Chapter VI, that fire control pays all costs of fuelbreaks on the Duckwall Unit. This assumption will be relaxed in Chapter VII to show the effects of shared costs of fuelbreak construction and maintenance on the optimum solutions.

Measurement Standards

The benefits and costs of the Duckwall project occur in diverse forms, at different times, and have effect over varying periods of time. It is necessary to bring these effects to a common basis of measurement to permit sound comparison of benefits with costs. The basis used for doing this is the monetary unit and interest. A relatively high level of resource employment is assumed for the analysis.

Prices and price levels.--Market prices are used as the starting point for the analysis. It is the most practicable measure of the relative desirability of goods and services for meeting various needs and demands.[1]

Price levels for calculating costs of investment are prices assumed to occur during the period of construction. Costs of

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[1]Federal Inter-Agency River Basin Committee, Subcommittee on Benefits and Costs, Proposed Practices for Economic Analysis of River Basin Projects (Washington, 1958), p. 7.

operation and maintenance are assumed to be average prices estimated to prevail over the life of the project. Dollar damage potentials are based upon present price levels, and the rationale for this decision is explained in Chapter VI.

Interest and discount rates.--The values attached to benefits and costs at their time of accrual can be made comparable only after conversion to an equivalent basis for time and degree of risk. Adjustment to a uniform time basis will be through the use of interest rates. An interest rate of 3.5 per cent, which is taken as the expected average long-term government bond rate, is used in this study. The analysis will first be carried out under the assumption of certainty (Chapter VI). Crews will be assumed to meet all travel times "for sure," for example, and fires will be assumed to be held on all fuelbreaks.

Then in Chapter VII the assumption of certainty will be relaxed. Allowances for risk will be partially made by use of a "decision game," which will adjust optimum solutions for the risk of not stopping fires at fuelbreaks.

Period of analysis.--The period of analysis for this study is fifty years. Fifty years is chosen because of the more than unusual uncertainty involved in predicting the future beyond that point and because changing technology may produce substitute measures for fuelbreak systems after that time.

CHAPTER IV

COSTS

Fuelbreaks

No one knew what fuelbreaks might cost. An important part of the Duckwall experimental project was the collection of costs of fuelbreak construction. Fund accounting as done by the United States Forest Service on a national forest level does not give a true picture of project or job costs as carried out by an individual ranger district. Many jobs as parts of several projects were going on at the same time each season on the Duckwall Unit.[1] Therefore, a cost-accounting system was set up for the Duckwall Conflagration Control Project. The ultimate objective of cost accounting was to obtain valid work or direct[2] and total[3] costs of fuelbreak construction for planning and for the analytical job that was to follow. The costs and amount of fuelbreak work contributed by management functions (range management, etc.) was recorded also. Costs were collected in timber (fire-danger

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[1]Camps at which crews stayed, and from which crews operated, were in place and operating; this was taken as given for purposes of this study.

[2]Could be identified with an "acre of work done."

[3]Includes overhead or "indirect costs" which could not be identified with an acre of work done.

rating area 370) and in brush (fire-danger rating area 348). Within each of these areas, costs for constructing fuelbreaks by hand crews (steep country) and fuelbreaks by heavy equipment such as tractors (relatively level country) were desired. To obtain these costs, records were kept during 1962 and 1963 for all projects in timber or brush and for tractor lines or handlines. These projects were: (1) preattack planning, (2) Murphy Ridge clearing, (3) Hunter Creek timber sale fuelbreak, (4) Hunter Creek handline, (5) Sugarloaf Ridge clearing, (6) Sugarloaf handline, (7) Grass seeding project, (8) burning project. Within each of these projects, different jobs were done for which costs were obtained. Examples of jobs are: planning, preparation, supervision, clearing, snag piling, snag felling, brushing, thinning, and pruning.

Costs, broken down in this manner, were necessary to estimate valid construction and maintenance costs for planning and analysis. For the analysis, the field cost records were compiled by project and job. Acres of fuelbreak in each type according to tractor line or handline were calculated, and the total costs of fuelbreak work could then be obtained. A construction and maintenance schedule was prepared for the fifty-year planning period. The annual cost of fuelbreak investment and maintenance over the fifty-year period was thus determined. Each of these steps is described in detail in the sections that follow.

Recording and compilation of costs.--The cost forms shown in Exhibits 6 and 7 (in the Appendix) were designed to collect costs per acre for work done by the Forest Service and for work done for the Forest Service (contract work). The forms were purposely overstratified, because experience has demonstrated that collecting complete cost information from crews in the field is difficult, and too little rather than too much information is generally the outcome. The forms were

given to the foremen of each job and were filled out daily. They were summarized bimonthly. Indirect (overhead) costs were added by the project clerk when the forms were turned in.[1]

At the end of the second year, the cost forms were compiled and stratified. Summaries of work costs and total costs, which include indirect costs, are presented in Tables 30 and 31 (Appendix). Indirect costs were prorated on the basis of acres of fuelbreaks completed. The sources of these costs were projects and jobs from which actual costs were collected. Several items should be mentioned about the cost information collected and which is on file that make them adaptable to analysis and useful to others who are planning fuelbreak work. Because the costs were collected as a result of a cost-accounting system designed especially for the Duckwall project, all project costs were obtained, and the costs could be matched with work done at the time it was done. Costs were accounted for by dates, by area on which expended (preattack planning numbers--e.g., A-4 to AH-8; see Figure 7), and by cover types (which showed reason for differences in costs on the same area for the same job). Sources of costs, grades and rates per hour for men, and rates for equipment were itemized because costs might be high on a job where a few highly paid men and expensive pieces of equipment were used. Unusual cost items, such as on-the-job repairs, were factored out and recorded to show their relationship to total costs.

Levels of fuelbreak systems.--A given fuelbreak system was called a level. Systems represented given densities of fuelbreaks.

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[1]Indirect costs included RDMA (Ranger District Managerial Account), facilitating services such as secretaries and clerical help, food and housing, times crews and equipment could not work because of equipment breakdowns, bad weather, etc., insurance, and medical and retirement benefits.

Four levels of fuelbreak systems were planned (see Exhibits 8 to 11, in the Appendix). Level 2 corresponds to the designed system presently being constructed on the experimental project. The fuelbreak locations for the other three levels were selected on the basis of information gathered during the preattack field survey. The miles and acres of fuelbreak planned by area (timber or brush) or tractor line or handline were determined for each level and are shown in Table 51 in the Appendix. The total fuelbreak system was adjusted for rivers and other natural fire barriers which were already present and which would not have to be constructed.

Total and annual costs of fuelbreaks.--Acres of fuelbreaks, stratified by timber and brush, tractor lines and handlines, were multiplied by the appropriate costs per acre to obtain total construction costs per acre and are presented in Tables 34 through 41 in the Appendix.

To determine the annual costs of fuelbreaks for the fifty-year analysis period, a construction and maintenance schedule was prepared for each level. It is shown in Tables 42 through 45 in the Appendix.

It is assumed that construction of the fuelbreak system will be carried out equally over the five-year period 1962-1967. Regrowth of brush (in brush areas only) will have to be sprayed once each year for a period of three years to finally kill it. Maintenance, on a limited scale, is assumed to be necessary from 1964 to 1971. In 1971 full annual maintenance of initial construction work begins and continues over the fifty-year period. The maintenance needed each year after 1971 is assumed the same as 1971. The details of the construction and maintenance schedule are shown in the Appendix, Exhibit 12. The source of maintenance costs is presented in Tables 46 and 47 in the Appendix.

The annual costs of fuelbreaks are presented in Table 3, and were determined by finding the present value of construction and maintenance costs, expended at different years, and then determining the annual cost by use of a sinking-fund formula.[1] The cost to society for tying up capital for the fifty-year period is thus included.

Consequential Costs and Benefits from Fuelbreaks

Fuelbreaks could have consequential costs. If realizable timber volume became less because of special cutting patterns needed for fuelbreak effectiveness then there would be a consequential cost associated with fuelbreaks. On the other hand, construction of fuelbreaks may add benefits that offset costs. Careful thinning and pruning of the stand may in fact increase realizable volume. Brush and other undesirable species are removed in fuelbreak construction, making way for more desirable species such as perennial grass and trees. For purposes of this study all possible consequential costs are assumed to be offset by increased benefits from fuelbreak construction and maintenance.

Fire-Suppression Costs

In this section methods used for determining the size and costs of the fire-suppression organization are described. A method for determining the number of fireline workers, based upon known rates of line construction, needed to fight fires in timber and brush at the selected burning indexes is shown first. This basic organization must be adjusted for ground and air equipment to obtain strength of attack

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[1]Kenneth P. Davis, American Forest Management (New York: McGraw-Hill Book Company, 1954), p. 316.

TABLE 3

ANNUAL FUELBREAK COST SUMMARY
FOR THE DUCKWALL UNIT

Level	Area	Annual Cost[a]
I	Timber	$19,114
	Brush	7,042
II	Timber	55,956
	Brush	10,008
III	Timber	63,601
	Brush	14,639
IV	Timber	84,246
	Brush	18,282

[a]Calculated from investment schedule by:

$$Vo = \frac{Vn}{(1+p)^n}$$

and

$$a = Vo \frac{p(1+p)^n}{(1+p)^n - 1}$$

where: Vo = value of fuelbreak investment or maintenance discounted to its present value (1964).
Vn = value of investment or maintenance at year "n."
p = 3.5 per cent interest.
n = fifty years, or year investment or maintenance made.
a = annual cost of construction and maintenance.

needed. Then the supplementary and facilitating organization, which together with the fireline organization makes up the total fire-suppression organization, must be found. A method for these two steps will be described. The source of costs per unit of the fire-suppression organization will be presented. From these elements (fireline organization, total fire organization, and unit costs of the fire organization), the total annual costs of the fire-suppression organization can the be found.

Strength of attack.--Fire-control planning should be tied to the burning index, which gives some idea of the expected fire behavior as influenced by fuels, weather, and topography. Pirsko[1] correlated rates of fire spread with burning indexes and rates of fireline construction by fire crews as determined by fire reports, weather records, and field tests. He developed charts from which the job load related to fire size at discovery and burning index can be found. An example of this chart for a 10 acre objective is shown in Figure 11. By estimating burning index, proceeding vertically to the fire size at discovery, and then proceeding horizontally to the vertical scales, one may find: (1) elapsed time from discovery to a given fire size; (2) estimated number of men to control perimeter, or head, of the fire.

The number of men is based upon rates of fireline construction in a given fuel type, such as brush or timber. The correlations have been made for all primary cover types in California. In order to obtain the correct number of men needed in a given fuel type for a given acreage objective the gross elapsed time from discover of fire to the time it reaches the given acreage must be reduced to allow for report, getaway, and travel times. The adjusted

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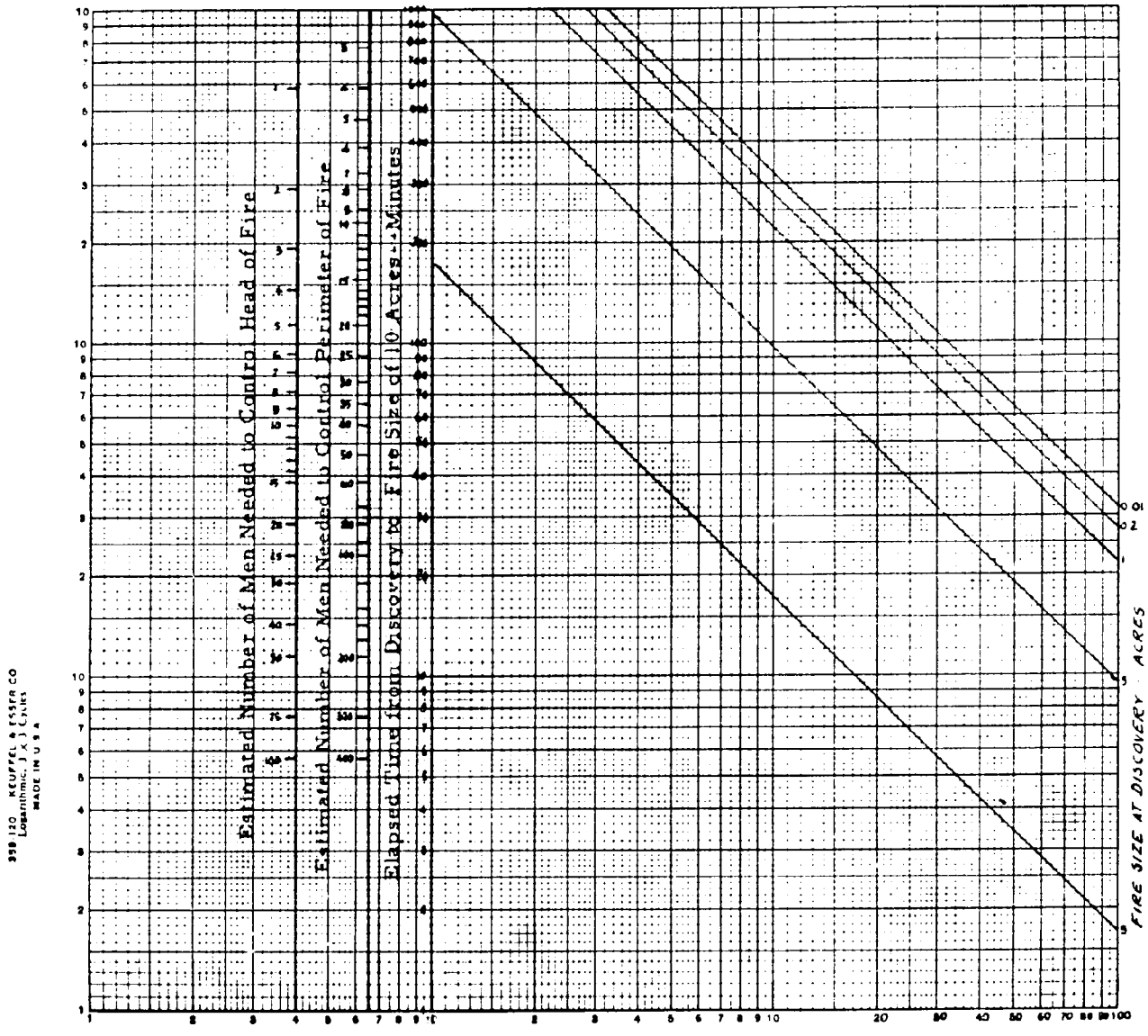
[1]Arthur Pirsko, "Why Tie Fire Control Planning to the Burning Index?" Fire Control Notes, XXII, No. 1 (January, 1961).

Fire Control Planning
PSW-FFR
1.4 ch./man hour
line construction rate

EST IMATED MANPOWER REQUIREMENTS FOR FIRE CONTROL BY BURNING INDEX AND FIRE SIZE AT DISCOVERY

To Use, Deduct Report, Get Away, and Travel Time from Initial Gross Time to Obtain Net Working Time and Crew Size.



Brush Mixed With Sage, or
Timber-medium Reproduction and Brush

FIG. 11

time then determines the correct number of men needed on the scale of number of men.

To use Pirsko's charts for this study, the average block size, in terms of number of acres at each fuelbreak level, was calculated first. By use of overlays (Exhibit 1, Appendix), past fire spread and size on the average was then determined. It was assumed that a fire would only burn a portion of a fire block in Level I at burning indexes 24 and 30 in timber, and 31 and 37 in brush. It was further assumed that a conflagration would burn an entire block at burning index 55 in timber, 65 in brush, and at all other levels and at all other burning indexes. Because of the intensity, rate of spread, and erratic behavior of conflagrations, it would be foolhardy both from a practical and safety standpoint to attempt control at any location other than main ridges or canyons. The assumption of a fire burning an entire fire block is then a practical one, it is believed. This then gives the size of fire for which manpower requirements are obtained by Pirsko's method. Size of fire at discovery was assumed to be 0.2 acre, and elapsed times assumed were: report[1] = two minutes; getaway = two minutes: travel time to first attack = fifteen minutes.

Total fire-suppression organization.--The prevention and detection organizations were assumed for purposes of the study to be adequate, efficient, and constant. It is acknowledged that prevention and detection are important, but the emphasis here is on fuelbreaks and fire suppression. It is also true that most of the

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[1]Report and getaway time are regional standards. Travel time is based upon first attack by aircraft.

prevention organization would already be included in the fire organization presented.

The manpower requirements as obtained from Pirsko's study are the basic fireline organization. Needed air and ground equipment and supervisory and facilitating personnel must be added to make up the total fire-suppression organization.

Fire suppression using fuelbreak systems has to be specialized. Under the assumption of conflagration conditions followed in this study, fire responses has to be quick and hard-hitting. This means reconnaissance aircraft are necessary for the determination of quick positive location and condition of fires once they are reported. Retardant-dropping aircraft are necessary to hold fire within fuelbreaks until ground crews can arrive to construct firelines and backfire from fuelbreaks. Helicopters are necessary to transport crews to the fire within the fifteen-minute travel time assumed for this study. Therefore, in this study the following aircraft were added to the basic fireline organization:

10 to 19 man basic fireline organization

- 1 light reconnaissance aircraft
- 1 small helicopter
- 1 air tanker (TBM type)

20 to 49 man fireline organization

- 2 light reconnaissance aircraft
- 1 small helicopter
- 2 air tankers (TBM type)

50 to 99 man fireline organization

- 2 light reconnaisance aircraft
- 1 small helicopter
- 3 air tankers (TBM type)

100 to 299 man fireline organization

2 light reconnaissance aircraft
2 small helicopters
4 air tankers (TBM type)

300 to 1,000 man fireline organization

2 light reconnaissance aircraft
3 small helicopters
5 air tankers (TBM type)

To obtain the size of the total fire organization, instructions contained in the United States Forest Service Handbook, "Principles of Organization for Forest Fire Suppression,"[1] were followed. The handbook was followed because it gives detailed instructions for finding the organization, equipment, and facilities for all sizes of fire-suppression organizations based upon the number of fireline workers. The organization necessary to support a 63 line worker crew is illustrated in Figure 12. In Figure 12, two tractor units of two tractors each and crew are substituted for 42 line workers. A backfiring organization is indicated also.

An example of specialized suborganizations or "teams" such as the backfiring team is shown in Figure 13. These organizations are based upon experience, and it is this experience that forms the basis for the art and science of fire control. There is no other reference for estimating sizes and structure of fire-suppression organizations. It is for this reason that these sources are used in this study.

Unit and total annual costs.--Once the physical fire-control requirements of men and equipment are determined, the annual costs

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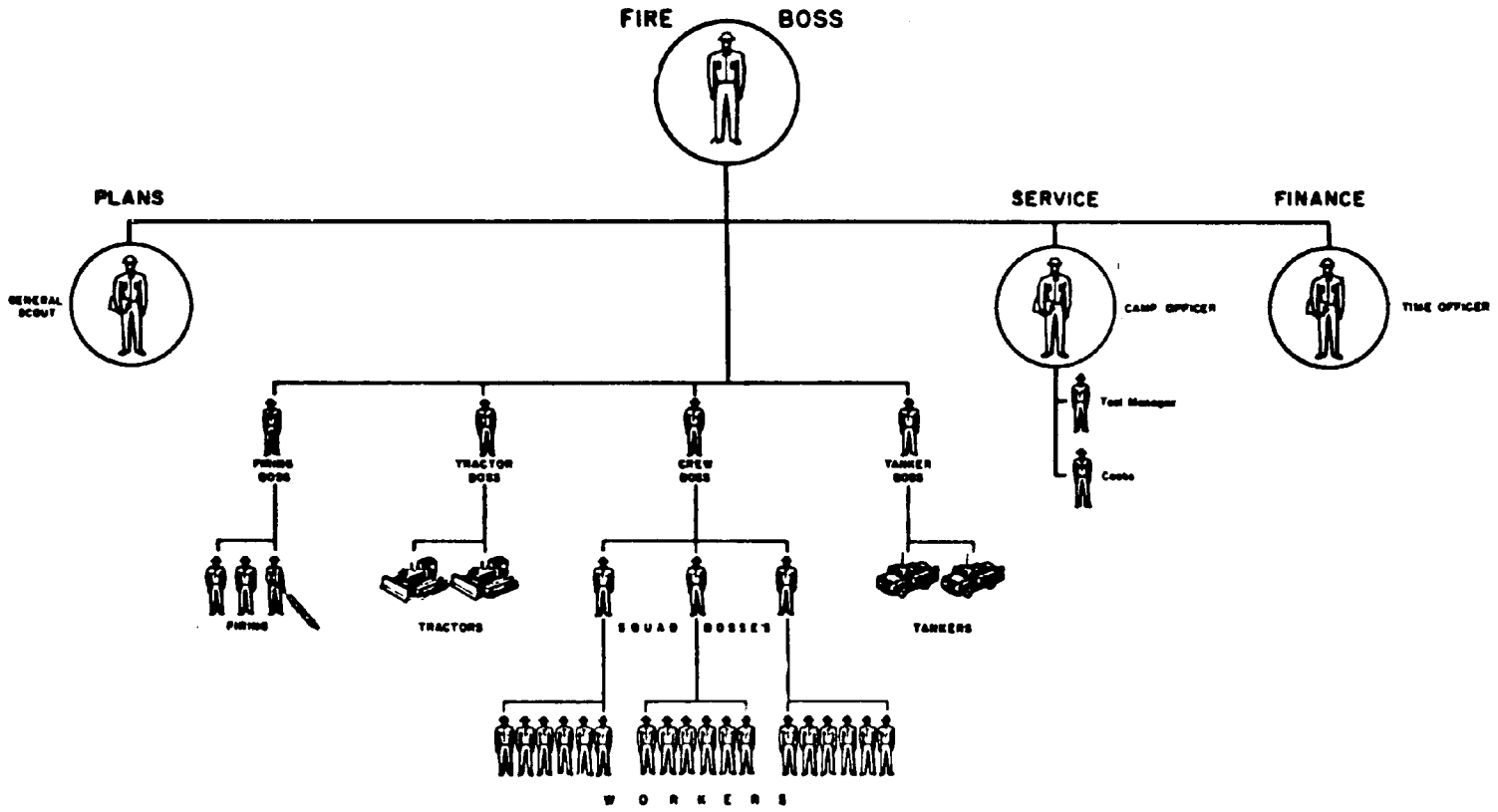
[1]U.S., Forest Service, Forest Service Handbook (Washington: U.S. Forest Service, November, 1958), sec. 5132.32.

Chart 4

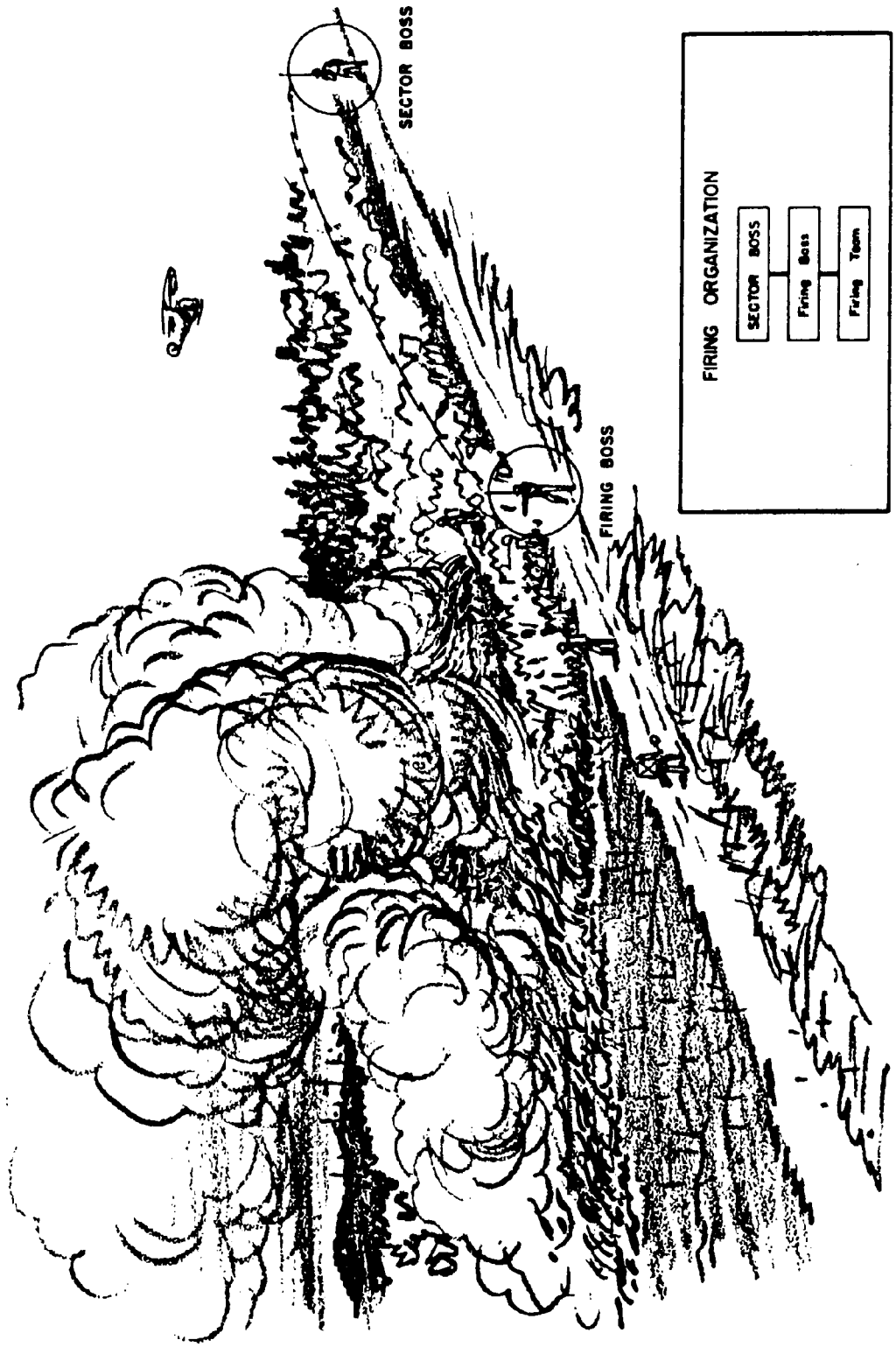
ORGANIZATION FOR MULTIPLE-CREW FIRE

(6 line workers per shift)



(From U.S. Forest Service Fire Control Handbook)

FIG. 12



(From U.S. Forest Service Fire Control Handbook)

FIG. 13

of the fire-control organization necessary to man any level of fuelbreak system during the fire season can be found. Unit costs are available on the United States Forest Service, California Region's 10:00 A.M. Fire Report (Table 49, Appendix), which is used to determine costs of Class D and E fires. Since the rates for men include subsistence and camp expenses, cost of fixed investments, tools, maintenance of equipment, and facilitating services, they are taken as valid estimates of the costs of a fire-control organization. Operating camps and airports[1] are already available, and they are taken as given for the study.

In performing calculations, air tanker cost was computed at a 100 hour seasonal guaranteed minimum, the usual practice in California. Other aircraft costs, including helicopters, are calculated at a 200 hour seasonal guarantee.

Actual suppression costs, which are costs that are incurred only when a fire occurs, are based upon an average of 0.32 conflagration per year, which is supported by averages from Duckwall Unit fire history. Time to control a given fire in a given fuel type at a given burning index is taken from data as illustrated in the Manpower Requirements Charts, Figure 11, which give time for a fire to reach a given acreage size. Demobilization is based upon 50 per cent crew and equipment release at control and the remainder in 10 per cent increments per day for six days.

The annual costs of the fire-presuppression organization and suppression costs necessary to man the completed fuelbreak systems are presented in Tables 4 and 5.

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[1]Riverside Guard Station, Camp Clavey, Columbia Air Attack Base.

TABLE 4

ANNUAL PRESUPPRESSION, SUPPRESSION, AND MOP-UP COSTS FOR DUCKWALL UNIT TIMBER

Level	BI	Costs of Pre-suppression	Costs of Suppression and Mop-up	Total Annual Costs
I	24	$1,426,300	$3,386	$1,429,686
	30	2,612,100	4,816	2,616,916
	55	7,614,400	6,298	7,619,698
II	24	1,406,800	3,401	1,410,201
	30	1,562,400	3,444	1,565,844
	55	3,099,300	2,160	3,101,460
III	24	1,167,400	2,669	1,170,069
	30	1,077,900	2,525	1,080,425
	55	1,734,800	1,181	1,735,981
IV	24	581,200	1,809	583,009
	30	803,200	1,746	804,946
	55	1,562,400	1,048	1,563,448

TABLE 5

ANNUAL PRESUPPRESSION, SUPPRESSION, AND MOP-UP COSTS FOR DUCKWALL UNIT BRUSH

Level	BI	Costs of Pre-suppression	Costs of Suppres-sion and Mop-up	Total Annual Costs
I	31	$3,930,600	$46,947	$3,977,547
	37	3,738,900	4,551	3,743,451
	65	4,922,100	2,224	4,924,324
II	31	3,107,700	41,803	3,149,503
	37	1,543,800	1,166	1,544,966
	65	3,166,850	2,317	3,169,167
III	31	3,123,500	38,318	3,161,818
	37	1,544,400	1,078	1,545,478
	65	2,955,500	1,613	2,957,113
IV	31	803,200	13,513	816,713
	37	1,077,900	771	1,078,671
	65	2,955,500	1,555	2,957,055

CHAPTER V

ESTIMATING THE DOLLAR FIRE DAMAGE POTENTIAL ON THE DUCKWALL UNIT

The benefit from fire control is reduction of fire damage to resources. In order to value damage reduction, some estimate of the dollar damage potential of the land and its resources must be obtained. In this chapter an estimate of the dollar damage potential of the average acre of forestland in timber and in brush on the Duckwall Unit is made. These dollar damage potential figures are then used in the analysis in Chapter VII.

In determining the damage potential, the estimated value of the timber resource is first determined. The extent to which the timber resource is damaged by high-intensity fire is then estimated. Mortality plus growth loss and salvage is also considered. Other values--watershed, recreation, hunting, grazing, and improvements on the Duckwall Unit--will then be ranked according to their estimated damage potential, based upon a recent study of wildland value structure.[1] Each is then valued according to its weight with respect to the damage potential of timber, as suggested by Swager,

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[1] L. S. Davis and A. DeBano, "A Wildland Value Survey," California Agriculture, XVI, No. 10 (University of California, Division of Agricultural Sciences, October 10, 1962).

Fetterman, and Jenkins.[1] Benefits received because of fire are considered. The resulting dollar damage potential is then justified in the light of a market analysis of sales made during the past fourteen years on and adjacent to the Duckwall Unit.

Estimation of Damages to Timber

Timber and growing stock inventory.--The Tuolumne Working Circle Timber Management Plan[2] was the basis for timber inventories. Cruise data from the Hunter Creek timber sale, located on the Duckwall Conflagration Control Unit, was used for supplemental information. Inventories are shown in Table 53 in the Appendix. All timber 12 inches in diameter and over was classed as saw timber. Poles were taken to be trees from 4 through 11 inches. Seedlings and saplings were all growing stock under 4 inches in diameter. The inventory includes only the principal commercial species--Ponderosa pine, sugar pine, white fir, Douglas fir, and incense cedar--for which there is an accepted value. Other species for which there is not a consistent market value are not included in the inventory. Volume calculated is for the average site. Nontimbered areas such as meadows are excluded from all acreage figures.

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[1] W. L. Swager, L. G. Fetterman, and F. M. Jenkins, A Study of the Cooperative Forest Fire Control Problem (Columbus, Ohio: Batelle Memorial Institute, 1958), p. 10.

[2] Stanislaus National Forest, Timber Management Plan for the Tuolumne Working Circle (rev. ed.; San Francisco: U.S. Forest Service, California Region, 1960).

Unit prices and costs.--Saw timber rates were taken from the Hunter Creek timber sale and are Western Pine Association base indexes on 1954-1956 basis for pine, 1942-1949 basis for white fir and incense cedar, and 1957-1960 basis for Douglas fir, all adjusted to the second quarter of 1962[1] (see Table 54, Appendix). Pole timber rates are from the "Region 5 Supplement" to the Forest Service Handbook,[2] listing timber product unit prices. Rates for seedlings and saplings are planting costs per acre from the Sale Area Betterment Plan of the Hunter Creek Timber Sale Report and Appraisal.[3] This is accepted practice in valuing unmerchantable stands and is used by the United States Forest Service in fire planning. It is recommended by the Michigan fire-damage appraisal team.[4] Realization or selling prices of lumber rather than stumpage prices are used for saw timber. This study is concerned with the whole impact of the timber resource to the local economy. The town of Tuolumne, located adjacent to the Duckwall Unit, is almost wholly dependent upon this timber supply. Gross income from the timber resource represents the whole return to the economy.[5]

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[1]Stanislaus National Forest, Mi-Wok Ranger District, Hunter Creek Timber Sale Report and Appraisal (U.S. Forest Service, March, 1962), p. 14.

[2]U.S., Forest Service, Forest Service Handbook (Washington: U.S. Forest Service, 1962), sec. 2-2425-R-5-4.3(1) and (3).

[3]Stanislaus National Forest, Hunter Creek Timber Sale . . . .

[4]Michigan, Dept. of Conservation, "The Michigan Fire Damage Appraisal System" (unpublished study, 1961).

[5]Swager, Fetterman, and Jenkins, p. C-50.

Timber and growing stock value.--The estimated present value of the timber inventories on the Duckwall Unit were obtained by multiplying inventory amounts by unit values and are presented in Table 55 in the Appendix. The total value of timber and growing stock is estimated to be $21,562,993, or $999 per acre.

Estimation of the growth impact potential.--Fire can kill timber. This is termed mortality. Fire also denies the future economy of the country some amount of timber growth--the growth that would have taken place if the fire had not occurred. This is termed "growth loss." The sum of mortality plus growth loss is growth impact.

In terms of mortality, experience on the Stanislaus National Forest demonstrates that during a conflagration, such as the 30,000 acre Wright's Creek burn in 1950, all foliage is consumed on all trees. This alone is enough to substantiate 100 per cent mortality, according to Wagener.[1] As further evidence of mortality, cambium injury, particularly to the higher portions of stems and boles where bark is thinner, would be severe. Also, Wagener states that insect infestation follows fire in the central Sierra Nevada Mountains, and all fire-damaged trees still alive are attacked. Therefore, it is assumed for purposes of this study that mortality following high-intensity fires is 100 per cent.

Salvage experience on the Wright's Creek fire of 1950 and the Flora fire of 1960, both either on or adjacent to the Duckwall Unit, demonstrated that selling of a large amount of fire-killed

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[1]Willis Wagener, Guidelines for Estimating the Survival of Fire Damaged Trees in California, Misc. Paper 60 (PSW Station, September, 1961), p. 4.

timber is difficult. Local mill capacities may not be able to absorb it; offering the timber at minimum rates will not always attract bids from distant mill owners. Much of the timber on these two fires could not be sold; actual salvage percentages were low. Salvage percentages for saw timber and growing stock following high-intensity fire are estimated to be from 20 (incense cedar) to 40 per cent (Ponderosa pine) for merchantable species and sizes, and zero for other than saw timber. Additional percentages assumed are shown in Table 56 in the Appendix.

The total mortality potential from high-intensity fires on the Duckwall Unit, after saw timber is adjusted for salvage, is estimated to be $13,723,019, or $635.91 per acre. Table 57 in the Appendix presents the mortality potential figures.

Growth loss as a part of growth impact must be estimated next. One element of growth loss is sustained which represents the growth in the period prior to the fire. Another element of growth loss is sustained which represents the growth that would have been obtained between the time of the fire and the time of adequate reseeding. These two loss elements are measured at time R, the time at which normal cutting would have taken place. One way of calculating growth loss[1] is by:

$$G = \frac{A+S}{R} VX$$

where: G = growth loss in board feet,
A = the average age of timber at the time of the fire,
S = average time for restocking for new stand,
R = age at the time of normal cut,
V = the normally expected volume per acre at age R,
X = the number of acres involved.

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[1]Swager, Fetterman, and Jenkins, pp. C-36, C-37.

The equation expresses growth loss in board feet as a proportion of the normally expected volume at rotation age, with an allowance for restocking the new stand. The equation gives an approximation of growth loss only, but since no better method of estimation could be found it is used in the study.[1]

Because the saw timber stand is an old-growth virgin stand, it will be assumed for reasons of a "defensible minimum" that saw timber growth loss is negligible. The dollar growth loss potential for poles and seedlings and saplings on the Duckwall Unit is $8,729,016, or $404.49 per acre (Table 59, Appendix). It must be stressed again that both the data and the equation give an approximation of growth loss. Growth loss from site deterioration and ecological changes, which are effects from forest fire, is not considered.

In order to develop a present value of the increased supply of wood in future years through reduced growth impact by fire-control efforts, some method of discounting is needed. At the same time, some estimate of the future unit values of wood must be considered. The Batelle study suggests a method for doing so.[2] In the past fifty years (to 1960) the unit value of most lumber has increased in terms of constant dollars from threefold to over sixfold, averaging about 3.5 per cent.[3] This long-term trend is unlikely to be reversed in light of the

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[1]This equation, though used by the Forest Service and in the Batelle study, must be used with caution. Extreme values can give questionable results. Suppose A = 100, S = 10, R = 100, V = 10,000, X = 1, then G = 11,000. Since this study does not include growth loss from the old growth stand, considers young age classes only (15-40 years) on a 140-year rotation, and short restocking periods (2-5 years), the formula is accepted as giving usable estimates of growth loss.

[2]Ibid.

[3]Ibid., p. C-43.

projected tight supply of large, high-quality wood in the future.[1] Assuming that over the long pull stumpage prices will tend to follow the same patterns, the increase over the fifty years amounts to an interest rate of nearly 3.5 per cent compounded annually.[2]

A discounted value of future increased wood supplies would have to be based on the cost of long-term money, which is also in the same range, about 3.5 per cent. Any portion of growth impact realizable in any future year--for example, 1980--should be increased in value 3.5 per cent per year and also discounted by the same 3.5 per cent to obtain present value. This is equivalent to using today's

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[1] U.S., Department of Agriculture, Forestry in the United States--A Real Success Story (Washington: U.S. Dept. of Agriculture, Forest Service, March, 1965), pp. 3-4.

[2] The assumption that stumpage values will continue to increase about 3.5 per cent per year must be based upon a future tight supply. According to Forestry in the United States--A Real Success Story, demands for timber products are projected to increase about 80 per cent by the year 2000. Demand for saw timber and lumber is estimated to rise 43 per cent. Demand for plywood is projected to increase 2.7 times by 2000. These are timber products which come from the Duckwall Unit. By the year 2000 projected saw timber supplies fall short of projected cut by about 16 per cent. For the lumber and plywood industries the timber supply is not encouraging because of trends in smaller timber sizes and lower quality. For these industries the adequacy of raw material supplies does not depend on total inventory of fiber, but rather on the supply of wood of desirable quality, and sufficient size and volume to permit low-cost processing and production of salable products. National forests must contribute a substantial part of demanded future cut. This is particularly true because of the uncertainty of achieving increased growth on farm and other private holdings. If substitution of wood from Canada or Alaska or substitution of other materials can make up the difference, then the assumption of a future tight supply of lumber is not valid. A positive and factual answer to this question is impossible.

price. For this reason, the volume of growth impact has been valued at the unit rates given in Table 54 in the Appendix.

The sum of estimated mortality plus growth loss values, calculated above, gives the total estimated timber growth impact potential. The total growth impact potential from high-intensity fires spread over the entire Duckwall Unit is estimated at $22,452,035, or $1,040.41 per acre. The figures are presented in Table 60 in the Appendix. Again, this is a defensible minimum. There are additional economic costs resulting from fires; for example, the costs for relocating a sawmill--and for a community such as Tuolumne County with ten mills employing 2,000 skilled men out of a total population of 12,585 this impact could be substantial, but complexities of even a local economy becloud these and other secondary consequences of fire.

This damage potential figure is judged in the right order of magnitude when one compares it to the United States Forest Service fire-planning value classes.[1] Timber class 6 represents potential timber loss of $2,000 per acre and above. This is the highest value class. The damage potential figure $1,040.41 places the Duckwall Unit in value class 5, which is the class in which it was placed during the Stanislaus National Forest fire-planning project.

Estimation of Damage to Values Other than Timber

The timber resource is not the only value subject to damage by fire on the Duckwall Unit. Watershed, recreation and wildlife, and grazing are principal values. There are five active mines and three ranches which have improvements and production subject to damage from

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[1] U.S., Forest Service, Handbook, sec. 5109.11.

fires. Davis[1] depicts the structure of wildland values and the potential damage in the central Sierra Nevada Forests, and assigns a relative valuation to them.

The Batelle Memorial Institute assigned a field study team to the problem of resource values.[2] California was one of the states sampled. The study team judged the potential damages to watersheds, recreation, and hunting as a range of percentage of damages to timber. The study group stated that, although the percentage represented the right order of magnitude of the damage value, they would vary with local application.[3]

Using these methods, adjusting them for the resource rank according to damage potential (Table 6) and basing estimates upon local conditions, the estimated damage potential from high-intensity fire to values other than timber on the Duckwall Conflagration Control Unit are presented and justified as follows.

Watershed.--The Duckwall Unit is bordered on three sides by major rivers. The north fork and main forks of the Tuolumne River border the west and south side, respectively. The Clavey River borders the east side. Hunter Creek originates within the Duckwall Unit and flows into the north fork of the Tuolumne River at the west edge of the unit. All finally flow together to form the main Tuolumne, which proceeds through the town to Tuolumne, as well as many other towns, on its way to the Don Pedro Dam, a key unit in California's water economy. It is estimated that damage potential to watersheds on the Duckwall Unit

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[1]Davis and DeBano, California Agriculture, XVI, No. 10.

[2]Swager, Fetterman, and Jenkins, p. 10.

[3]Ibid.

TABLE 6

RANK OF RESOURCES ACCORDING TO DAMAGE POTENTIAL[a]

Resource	Relative Rank	
	Timber Area	Brush Area
Timber	1	none
Watershed	2	1
Recreation and hunting	3	2
Grazing	4	3

[a]Based on Davis and DeBano, California Agriculture, XVI, No. 10, 3.

is 20 per cent of that for timber in the timber type, and, because it borders on much of the river area, 30 per cent in the brush type.

Recreation and hunting.--The trends toward more leisure time, more money available for personal use, better transportation (including all-wheel-drive vehicles and motorcycles), together with highway and road construction and improvement, indicate greater use of wildland recreational areas. In 1962, 2,055,000 people visited the Stanislaus National Forest, according to the Tuolumne County Chamber of Commerce.[1] Over a million of these people stayed for at least a day, while the other million enjoyed the forest while traveling through on one of the three major highways traversing it. A study by the California Department of Water Resources[2] showed that the population of the Tuolumne Water District No. 2, which covers most of Tuolumne County, will increase from 13,300, its present population, to 93,400 in the year 2020. Present heavy local use of the Duckwall Conflagration Control Unit recreational facilities, which include four campgrounds and excellent hunting and fishing, will thus increase. Recreation is now the second most important industry, behind logging and lumbering, in Tuolumne County.[3]

The Stanislaus National Forest is 2-1/2 hours by excellent highways from San Francisco. An excellent all-year climate on the Stanislaus Forest assures good hunting and fishing, camping and picknicking

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[1]Letter from Mr. John J. Muzio, secretary of Tuolumne County Chamber of Commerce, March 28, 1963. Based upon traffic counts made at all national forest entrances.

[2]California, State Division of Water Resources, Tuolumne Water District No. 2 Study (Sacramento, Calif., 1961), p. 4.

[3]Tuolumne County, Facts about Tuolumne County (pamphlet, published by the County of Tuolumne, 1962), p. 2.

in the summer, and skiing in the winter. Much of the private forestland is now being utilized for summer and permanent home subdivisions. Recreational use of the Stanislaus Forest has increased eightfold since World War II.[1]

On the basis of the Batelle Institute study team's judgment, and recreational trends on the Duckwall Unit, it is estimated that the damage potential of recreation, including wildlife, hunting, and aesthetic values, which are intimately related to the damage to recreational use of forest and watershed lands, should be weighted 10 per cent that of timber in the timber type and 15 per cent in the brush type. The brush includes valuable winter deer range and the important fishing resource of the Clavey and Tuolumne rivers.

Grazing.--On the Duckwall Unit are three grazing allotments and one all-year pasture permit. Nearly 1,000 head of cattle graze the area each year. Forage is particularly good along the Tuolumne River front. It is estimated that the damage potential of the grazing resource is 5 per cent that of timber in the timber areas and 10 per cent in brush.

Mining and ranching.--There are five active mines on the Duckwall project, all located within the brush type. There are also three ranches, two of which are located in the brush type and two in timber. The fire damage potential to mines and ranches was taken as the loss of improvements[2] plus one year's production while rebuilding.

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[1]Stanislaus National Forest, Recreation Plans (U.S. Forest Service, Stanislaus National Forest, 1962), p. 3.

[2]Value of improvements and production taken from Phillip Parson and C. O. McCorkle, Jr., A Statistical Picture of California's Agriculture, Circular 459 (revised California Experiment Station Extension Service, University of California, May, 1963), pp. 23-25.

Total Dollar Damage Potential

When adjustments for watershed, recreation, grazing, mining, and ranching were made, the total dollar damage potential from high-intensity forest fires was estimated to be $26,656,966 or $1,235.26 per acre in timber, and $5,622,130 or $305.22 per acre in brush, as shown in Table 7.

Benefits from Fire that Offset Costs

Most benefits from fire cannot be measured except qualitatively. Under the guiding rule of a "defensible minimum" followed in this study, it is argued that offsetting benefits will not exceed unknown or unincluded costs and losses. The dollar damage potential figures presented in the preceding section, therefore, will be used as they stand.

Analysis of Open Market Sales of Forestland on and Adjacent to the Duckwall Unit, 1950-1963

The market analysis method of appraisal[1] was used to determine the market selling price per acre for private land on and adjacent to the Duckwall Unit to check the order of magnitude of values and the damage potential calculated for the Duckwall Unit.

All land sales on and adjacent to national forest land have been recorded by the lands adjustment officer on the Stanislaus

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[1]California, State Division of Water Resources, Tuolumne Water District No. 2 Study, p. 42.

TABLE 7

TOTAL DOLLAR FIRE DAMAGE POTENTIAL
FOR THE DUCKWALL UNIT

Resource or Activity	Timber Type (21,580 acres)		Brush Type (18,420 acres)	
	Total	Per Acre	Total	Per Acre
Timber	$22,452,035	$1,040.41	--	--
Watershed	2,329,345	107.94	$2,982,382	$161.91
Recreation and hunting	1,164,672	53.97	1,491,099	80.95
Grazing	582,228	26.98	994,127	53.97
Mining	51,425	2.38	--	--
Ranches	77,261	3.58	154,522	8.39
Total	$26,656,966	$1,235.26	$5,622,130	$305.22

National Forest. The sale information is used in land exchange negotiations. This was the source of data for the analysis. The year 1950 was chosen as the beginning year for the study because very few sales were made before that year. The area chosen for analysis was the Duckwall study unit and each adjacent township that contained national forest land. Information recorded for each sale was the year of the sale, principal cover type (brush or timber), total price, total acres and price per acre, and the factors that affected the price, such as power, telephone, roads, recreation values, timber, et cetera. Forty-six land sales were studied --thirty in timber and sixteen in brush. The information from these sales is recorded in Table 60 in the Appendix.

In summary, the number of sales per year and the frequency of years during which sales have been made are increasing (Figure 14). The average sale value per acre in timber country rose from $28.00 per acre to $802.00 per acre (1962)[1] (Figure 15). In brush country, average value increased from $3.00 per acre to $1,200.00 per acre. The high sale value per year rose from $28.00 to $4,500.00 per acre in timber, and from $3.00 to $1,200.00 per acre in brush (Figures 16 and 17).

The reasons for increases in frequency and value of sales can be conjectured as follows: The Stanislaus Forest is close to large population centers, the San Francisco Bay area and the Sacramento and San Joaquin valleys. The pressures of urban living have made people want to spend some time in more relaxed

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[1] No attempt is made to adjust price levels, as most sales and the most expensive sales have been made in the past several years.

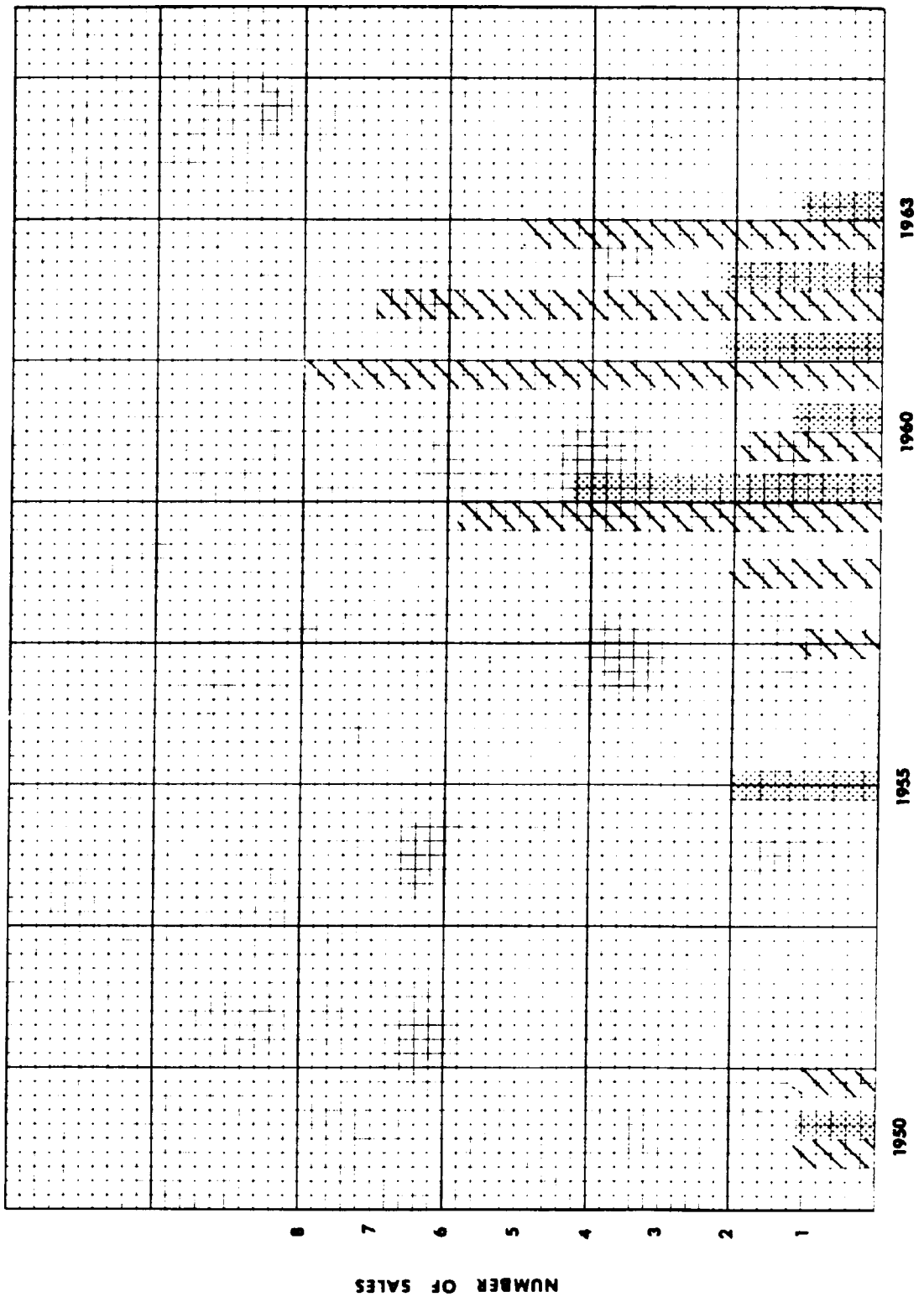

FIG. 14 NUMBER OF FORESTLAND SALES PER YEAR — DUCKWALL CONFLAGRATION CONTROL UNIT AND ADJACENT FORESTLAND

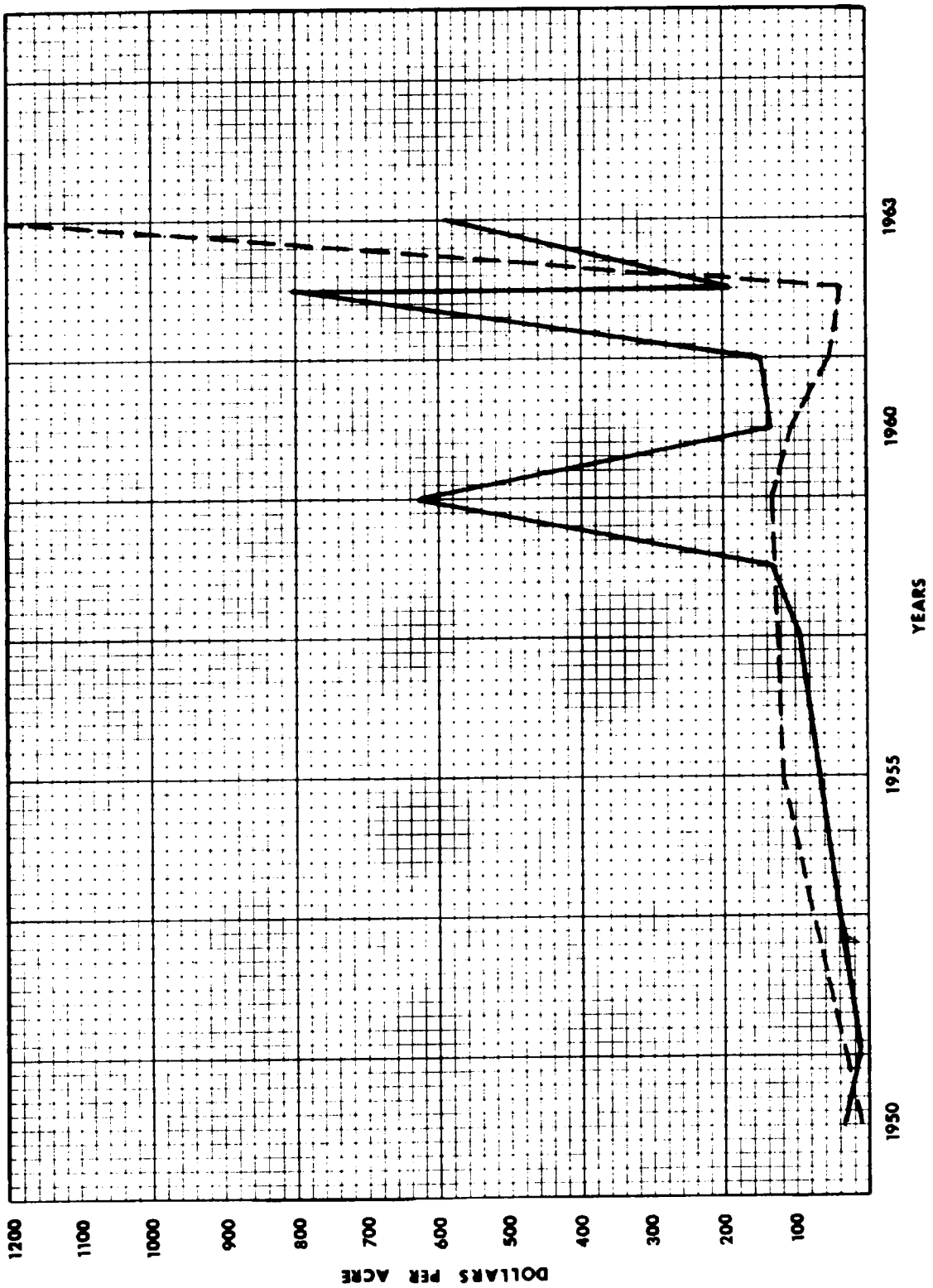

FIG. 15 AVERAGE SALE VALUE PER ACRE — DUCKWALL CONFLAGRATION CONTROL UNIT AND ADJACENT FOREST LAND

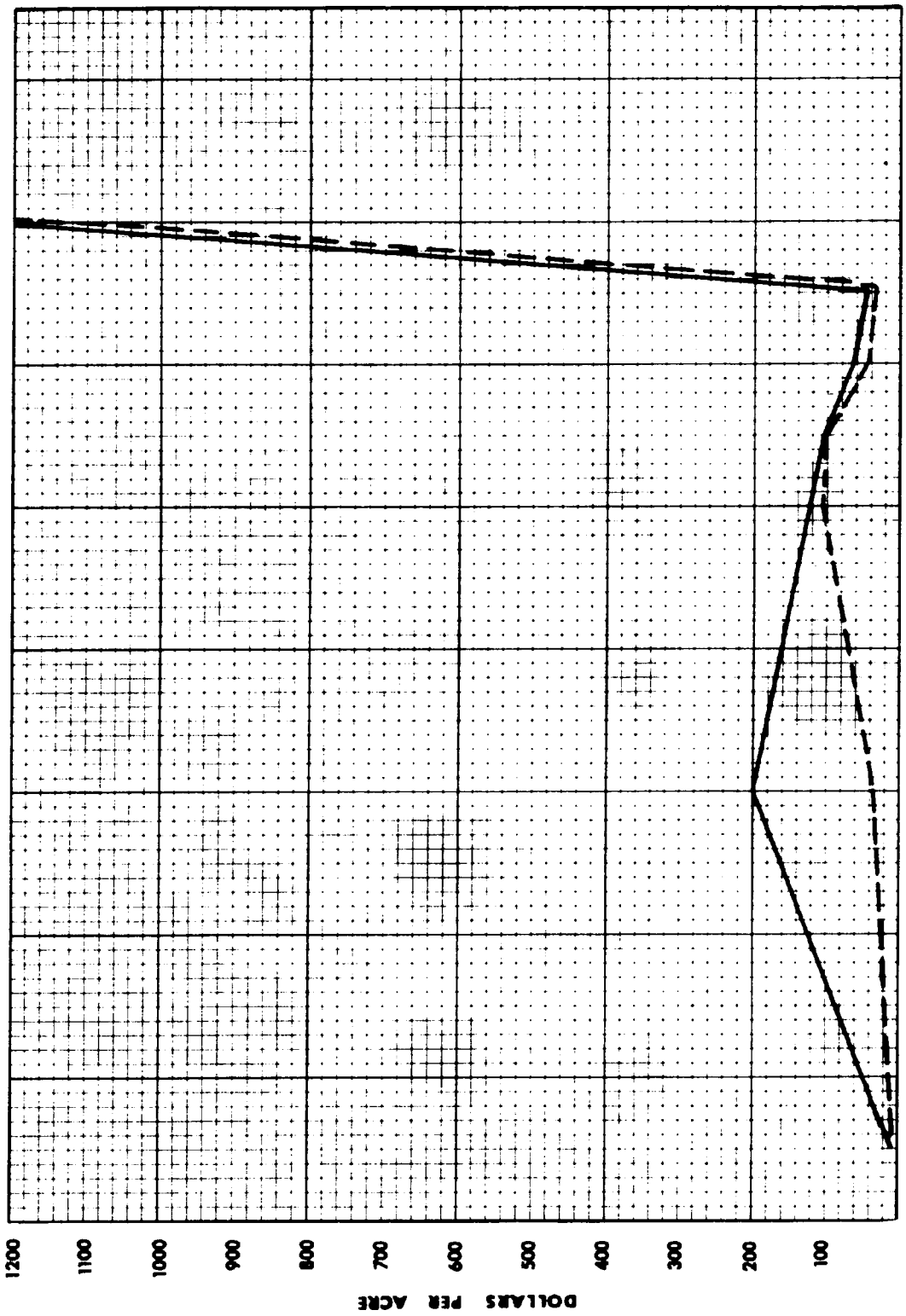

FIG. 16 HIGH AND LOW MARKET VALUE PER ACRE FOR BRUSH TYPE LAND—DUCKWALL CONFLAGRATION CONTROL UNIT AND ADJACENT FOREST LAND

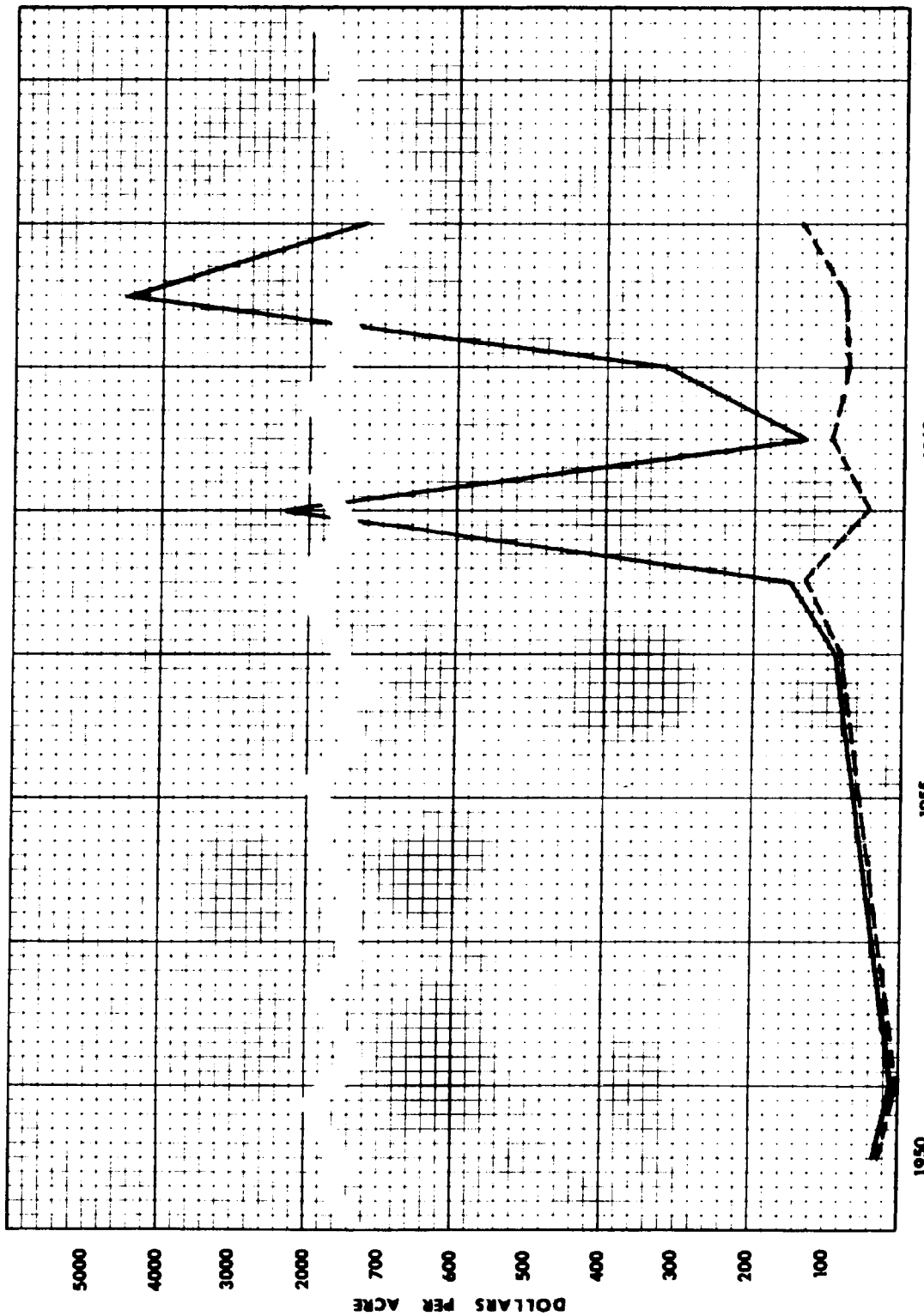

FIG. 17 HIGH AND LOW MARKET VALUE PER ACRE FOR TIMBER TYPE LAND — DUCKWALL CONFLAGRATION CONTROL UNIT AND ADJACENT LAND

rural or wilderness types of living. More leisure time, higher incomes, more and better highways, and better means of transportation have allowed people to do so. Forestland that fifteen years ago had value principally for timber, grazing, or mining suddenly had recreational value, and this value greatly overshadowed all others. Most timber had been cut or burned. There was only so much private land available, and competition for acres of land for recreational summer home sites became more intense with each passing year. Land values went up. It has already been brought out that population and demand for land in Tuolumne County, principally for recreation, will increase in the foreseeable future.

The increasing values per acre for forestland use for privately owned land represent primarily increasing pressure for recreation--principally summer homes in the forest. These values have increased from less than fifty to several thousand dollars per acre from 1950 to 1963. On national forest land, the value to society is made up of recreational values to be sure, but also timber, grazing, wildlife, and watershed values. Therefore, it is argued that dollar damage potentials of $305.00 in forestlands where brush is the principal cover type to $1,235.00 per acre (based on present and future impairments) in timber are within an acceptable order of magnitude, are justified, and represent a defensible minimum.

CHAPTER VI

ANALYSIS OF ALTERNATIVE FUELBREAK AND FIRE-SUPPRESSION SYSTEMS USING THE LEAST-COST-PLUS-DAMAGE CRITERION

Researchers on the Duckwall Unit are investigating ways of controlling conf'⌝grations through fuelbreak systems combined with a fire-suppression organization. Some method of analysis is necessary to weigh benefits against costs to determine the economic feasibility of the program. The least-cost-plus-damage method of analysis has been advocated and used by many for determining economic levels of fire-control. Headley[1] first proposed it in 1916, and Sparhawk produced a theoretical picture of the method in 1923. Figure 18 is Sparhawk's conception of least cost plus damage. In his diagram, as prevention and presuppression costs increase, suppression costs and losses decrease. Sparhawk stated a very simple principle, which is again illustrated by Figure 18: "The sum of costs plus loss should be reduced to a minimum and the objective should not be to eliminate all loss regardless of cost."[2]

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[1]Arnold, p. 89; Davis, Forest Fire: Control and Use, p. 484.

[2]Arnold, p. 90.

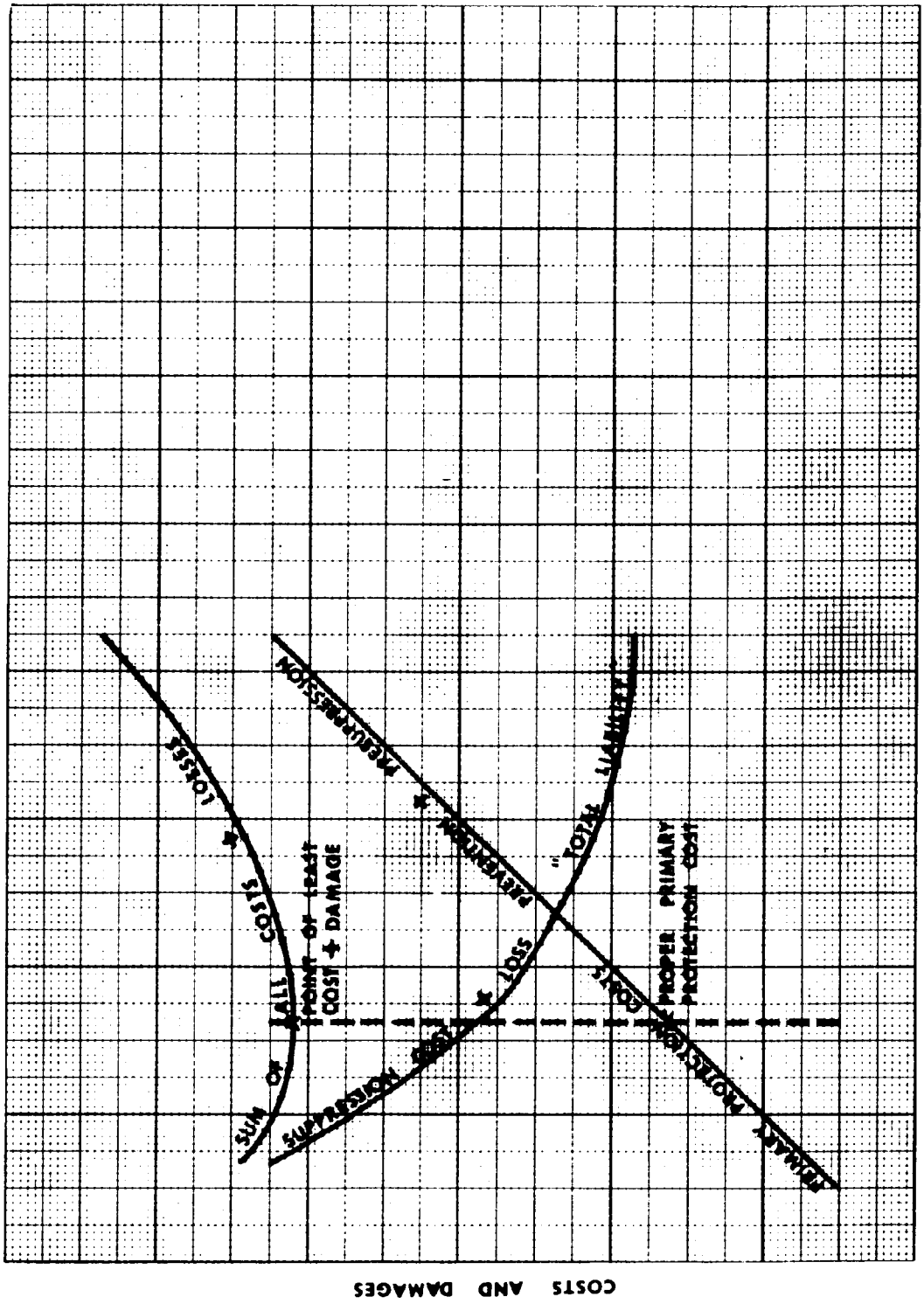

FIG.18 LEAST-COST-PLUS-DAMAGE DIAGRAM - SPARHAWK'S CONCEPTION

Flint,[1] in 1928, was the first to carry out a least-cost-plus-damage analysis. The method was also applied to areas of Virginia and South Carolina by staff members of the Southeastern Forest Experiment Station in 1945 and 1946,[2] and it was reviewed by Brown and Folweiler[3] in 1953. They stressed the need for loss valuation when applying the method. Arnold,[4] in 1949, stated that the least-cost-plus-damage method, which is also an objective, remains the single most useful determinant of an adequate level of protection effort. Blythe's chapter in Duerr and Vaux[5] endorsed the method as the best for evaluation of forest protection programs. A study team from the North Carolina Department of Conservation and Development and the Tennessee Valley Authority[6] used the least-cost-plus-damage concept to determine justifiable costs of protection at

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[1]Howard R. Flint, "Adequate Fire Control," Journal of Forestry, XXVI (1928), 626-38.

[2]R. B. Craig, B. Frank, G. L. Hayes, and G. M. Jemison, Fire Losses and Justifiable Protection Costs in Southern Piedmont of Virginia (Asheville, N.C.: U.S. Forest Service, Appalachian Forest Experiment Station, 1945).

[3]A. A. Brown and A. D. Folweiler, Fire in the Forests of the United States (St. Louis: John S. Swift Company, Inc., 1953), p. 173.

[4]Arnold, p. 177.

[5]William A. Duerr and Henry J. Vaux, Research in the Economics of Forestry (Charles Lathrop Pack Foundation, 1953), p. 252.

[6]Ralph A. Vogenberger, Earl F. Olsen, and G. H. Corpening, A Method for Determining Public Fire Control Expenditures for Private Lands (North Carolina Dept. of Conservation and Development, The Tennessee Valley Authority Division of Forest Relations, June, 1957).

the county level, and the Batelle Memorial Institute in 1958[1] used it to analyze the cooperative forest fire control problem. Davis[2] emphasizes the need for the least-cost-plus-damage procedure in determining cost and damages more accurately but states that the method is difficult to translate into an operating policy. Charters,[3] in 1960, determined optimum levels of expenditures for protection of pine plantations in England by the least-cost-plus-damage method, and in 1961 the Woods Hole study[4] concluded the method would place fire control on a sound economic basis. Because the least-cost-plus-damage method and objective has been widely used and endorsed, and because the method will place fire control on a sound economic basis, it will be used for this study.

A brief explanation of least cost plus damage is in order here. As expenditures for fire-control purposes increase, substantial reductions in fire loss would be expected. Finally, some point is reached where even large additional amounts expended on fire control would result in very little reduction in fire loss. The point of least cost plus damage is that point where an increase in fire-control cost is just matched by a decrease in fire loss. In

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[1]Swager, Fetterman, and Jenkins, A Study of the Cooperative Forest Fire Control Problem.

[2]Davis, Forest Fire: Control and Use, p. 486.

[3]Haldane Charters, Fires in State Forests in the Years 1929-1956, Forest Record No. 45 (London: Great Britain Forestry Commission, 1960).

[4]National Academy of Sciences, A Study of Fire Problems, p. 27.

economic language it is the point at which marginal cost equals marginal benefits (value of acres saved).

In this chapter the annual costs of fuelbreaks and the fire-suppression organization will be synthesized with value of fire damage averted to obtain: (1) economic justification of the costs of fuelbreaks and fire suppression for conflagration control; (2) the economic level or scale of protection from conflagrations based upon costs of fuelbreaks, fire suppression, and the value of fire damage averted; (3) the economic "mix" of fuelbreaks and the fire-suppression organization at the economic level of protection; (4) the acreage-burned objective on the Duckwall Unit based on the economic level of protection.

In order to do this, marginal rates of substitution curves, expressing different combinations of fuelbreaks and fire suppression necessary to keep fires to a certain acreage, will be presented first. Each of these curves will have a least-cost point. A path of least-cost points will result. Then damage will be introduced and the justification considered. The fuelbreak density, at which least cost plus damage is lowest, will be determined. This is the optimum density. The economic mix of fuelbreaks and a fire-suppression organization, the optimum acreage objective, and the basic fireline organization needed to man the fuelbreak system will be the final product of this chapter.

Isoquants--Marginal Rate of Substitution, Fuelbreaks for Fire-Suppression Organization

Isoquants show different combinations of two resources with which the same amount of product can be produced. The two

resources are fuelbreaks and a fire-suppression organization. The product is reduction of burned area.

To a point, fuelbreaks substitute for a fire-suppression organization. When a fire starts a fire crew is dispatched to it, and once they arrive the crew begins to build fireline by removing fire fuel. Any fireline constructed before a fire means less work for the fire crew at the time a fire occurs, since now only a minimum effort is required to clear the line to mineral soil, and the fireline has mainly to be defended, or "held" as firemen call it. A smaller, cheaper fire-suppression effort should then be required.

A fuelbreak is a preconstructed fireline. Fuelbreaks are constructed at key fire-defense points such as ridges and because of this they will be used by fire crews. The more fuelbreak constructed over a given area, the less the break construction needed at the time of a fire. In constructing fuelbreaks, existing fuels are changed to relatively cool-burning fuels at key fire-defense locations. It is necessary only to clear a fireline from which to backfire or on which to make a stand. This fireline construction is in grass or other light ground fuel. Therefore, it is argued that, in economic analytical terms, there is a marginal rate of substitution of fuelbreaks for fire suppression. It is the amount of fuelbreaks which could be substituted for one unit of the fire-control organization without any gain or loss in acres burned or saved.

When a fuelbreak is constructed in timber, a light, live perennial ground cover called bear clover is maintained. This is the cover through which firelines must be built on timbered fuelbreaks. When fuelbreaks are constructed in brush, perennial grass is planted and line construction is through this grass. Thus every

mile of fuelbreak constructed before a fire must result in some reduced fire suppression at the time of a fire.

To plot marginal rates of substitution curves, the following steps were taken:

1. The point showing the annual cost of fire-suppression organization necessary to hold fires to a given acreage objective in the absence of fuelbreaks is found first. To do this, the number of line workers to control the perimeter of a fire of a given acreage objective is determined from Pirsko's charts. Because fuelbreaks are not present, the cover type in the timber type on the Duckwall Unit, for example, would be unmodified timber. The entire fire-suppression organization is then found, based on the line-worker organization. The annual cost of this organization is determined and plotted on the chart. For example, in Figure 19, for the 758 acre burned area objective, which is the average block size at Level III in timber, the annual cost is about 4.3 million dollars.

2. A point representing the annual costs of the completed fuelbreak system with average blocks the size of the acreage objective, and the fire-suppression organization needed to man the fuelbreaks, are found next. For manpower requirement determination, the cover type is bear clover because fuelbreaks are present. In Figure 19, for the 758 acreage objective, this point is at a combination of $65,000 annual costs of fuelbreaks and $1,000,000 annual cost of the fire-suppression organization.

3. Points along the marginal-rate-of-substitution curve are then plotted. The curve representing the 758 acreage objective is not linear, because physical and money units are not proportional. This is because there are varying proportions of tractor line and handline, each with different costs. In plotting the curve, points

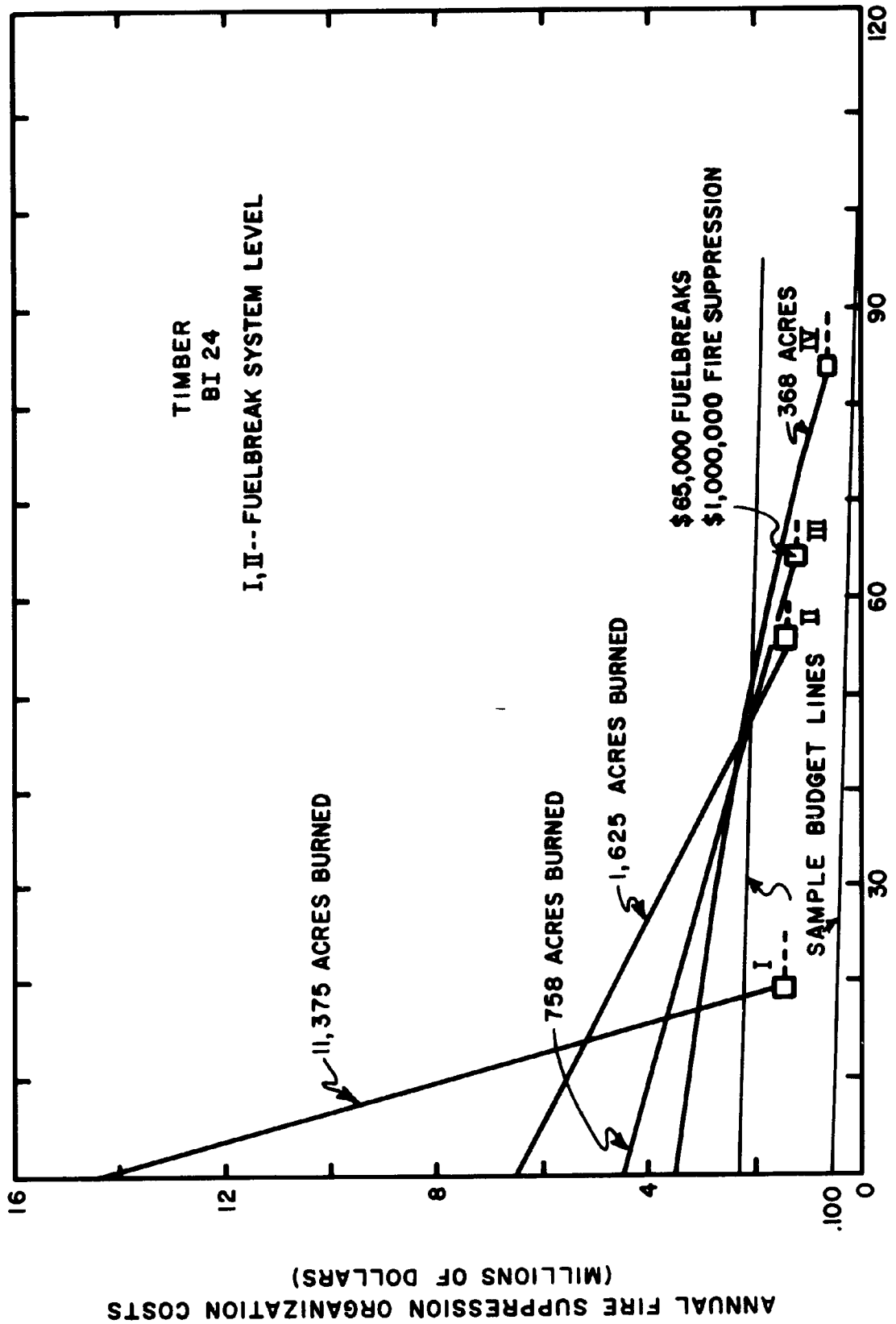

FIG. 19 MARGINAL RATE OF SUBSTITUTION CURVES AND LEAST-COST CORNERS

are taken along the fuelbreak axis where costs of fuelbreaks are known. These occur at each fuelbreak system level--I, II, III, and IV (Figure 19) --assumed for the study. The number of men is determined for each of these points on the basis of the proportion of fuelbreak system completed. The costs of the organization are then found as previously described, and the point is plotted.

Figures 19 and 20 illustrate marginal rates of substitution curves for timber at BI 24, and for brush at BI 37. Similar marginal rates of substitution relationships were calculated for each burning index level in both brush and timber. In summary, each curve represents a burned-acreage objective. Any point on the curve represents the combination of fire suppression and fuelbreaks necessary to obtain that acreage objective. Annual costs of fire suppression are on the vertical axis, and annual costs of fuelbreaks are on the horizontal axis. The 758 acre burned-acreage-objective curve in Figure 19 begins at the 4.3 million dollar point on the fire-suppression axis. This is the calculated annual cost of holding all fires to 758 acres with a fire-suppression organization alone (no fuelbreaks).

As fuelbreaks are substituted for fire suppression, the marginal-rate-of-substitution curve falls to the right until it reaches the point where the acreage objective is equal to the density of fuelbreaks which result in this average size block. This point is at an annual cost of about $65,000 in fuelbreaks and $1,000,000 in fire suppression. The curve then levels out because the average block is completely surrounded by fuelbreaks and manned adequately according to Pirsko's data. A corner results at this point. These corners are denoted I, II, III, and IV on Figures 19 and 20 and are represented by a □ for emphasis. They correspond to the four levels of fuelbreak systems assumed for this study. Representative isocost lines or budget lines are drawn on

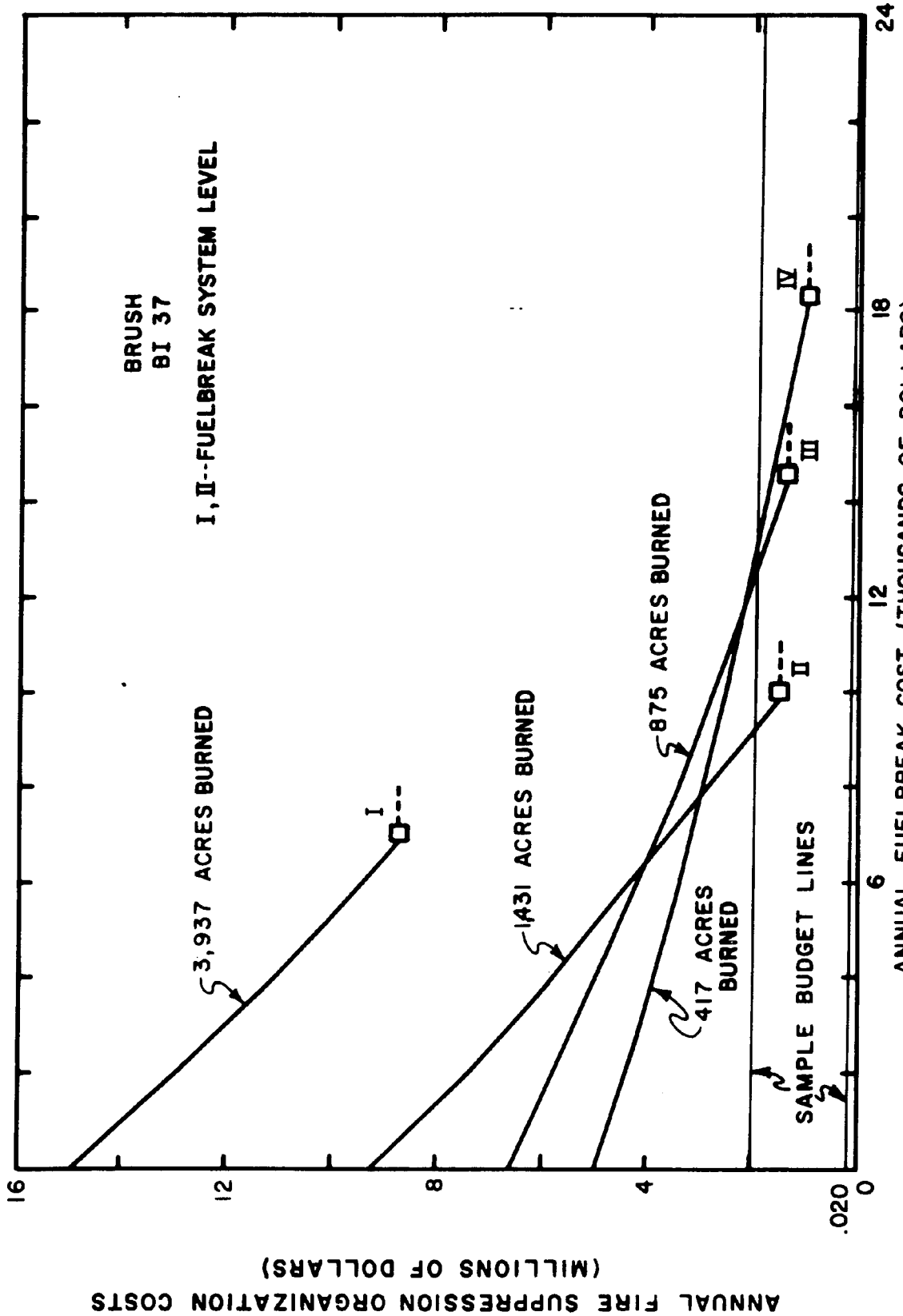

FIG. 20 MARGINAL RATE OF SUBSTITUTION CURVES AND LEAST-COST CORNERS

Figures 19 and 20 also. They are lines of equal cost.[1] There is an infinite number of them that could be drawn. The point on an isoquant that is tangent to a budget line is the least-cost point on that curve. It is obvious from the shape of the curves of Figures 19 and 20 that budget lines could not be tangent to marginal-rate-of-substitution curves at any other point than at the corners. The corners then are the least-cost points. This same relationship was true for all isoquants representing burned-acreage objectives at all burning indexes in timber and in brush.

Two important points of Figures 19 and 20 should be noted: (1) Fire suppression costs a lot of money! (2) Ten thousand dollars invested in fuelbreaks could save over a million dollars in fire-suppression-organization costs.

Path of Least-Cost Corners

When designing the study it was thought that the optimum density of fuelbreaks would be found between Level I and Level IV. But the least-cost corners on all charts, of which Figures 19 and 20 are two, when calculated and plotted for all burning indexes and cover types, progressed downward and to the right as one moved from one acreage objective to the next lowest. This downward path is still evident in moving from Level III to Level IV, which was the densest assumed fuelbreak system. In going from Level III to Level IV, several hundred thousand dollars of fire-suppression-organization costs are still saved by a few thousand dollars of fuelbreak construction. Clearly, there is

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[1] In Figure 20 the isocost lines appear almost horizontal; this is because of the differences in money units represented on the horizontal and vertical axes. The vertical axis is in millions of dollars, while the horizontal axis is in thousands of dollars.

an acreage objective smaller than that of Level IV at which, when moving to a smaller acreage objective and a lower budget (a lower least cost), a higher net expenditure (net from the savings on smaller fire-suppression organizations versus the additional cost of a denser fuelbreak network) would result. This higher net expenditure would then finally be just balanced by the value of fire damage averted[1] to produce the economic mix, scale, and acreage objective. Figure 21 illustrates a hypothetical path of the least-cost corners. In order to find which of the corners on Figure 20 for brush represent the economic-acreage-objective scale and mix, it will be necessary to determine, in effect, which point gives the greatest profit. To do this the procedure theoretically becomes one of finding the value of acres saved, and subtracting the budget line cost of each corner from it until the corner is found that gives the greatest profit; e.g., value of acres saved net of costs. In practice this method could be laborious and time-consuming, however.

Obtaining the Least-Cost Solution

The analytical job of determining economic optimums can be made easier, without sacrificing accuracy, if mathematical expressions of the relationships between fuelbreaks and the fire-suppression organization can be derived. Conceptually, the problem becomes one of finding equations to express the paths taken by the fire-suppression and fuelbreak costs as shown in Figure 22. Most of the additional fuelbreak work which would be done to produce fuelbreak systems denser than Level IV would be hand work in both

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[1] Assuming that the value of the acres saved from fire is high enough to justify the costs of fuelbreaks and fire suppression.

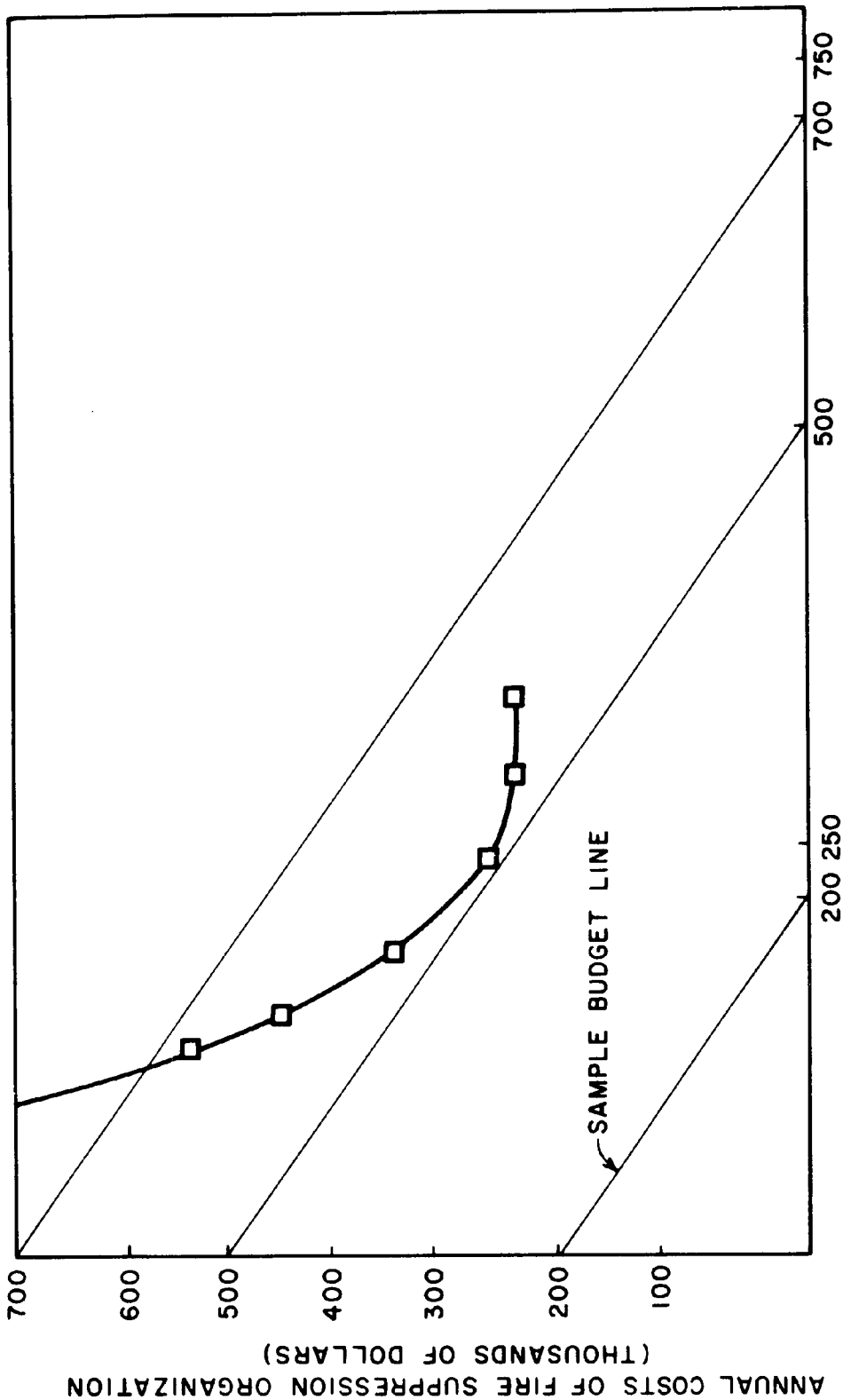

FIG. 21 HYPOTHETICAL PATH OF LEAST-COST CORNERS

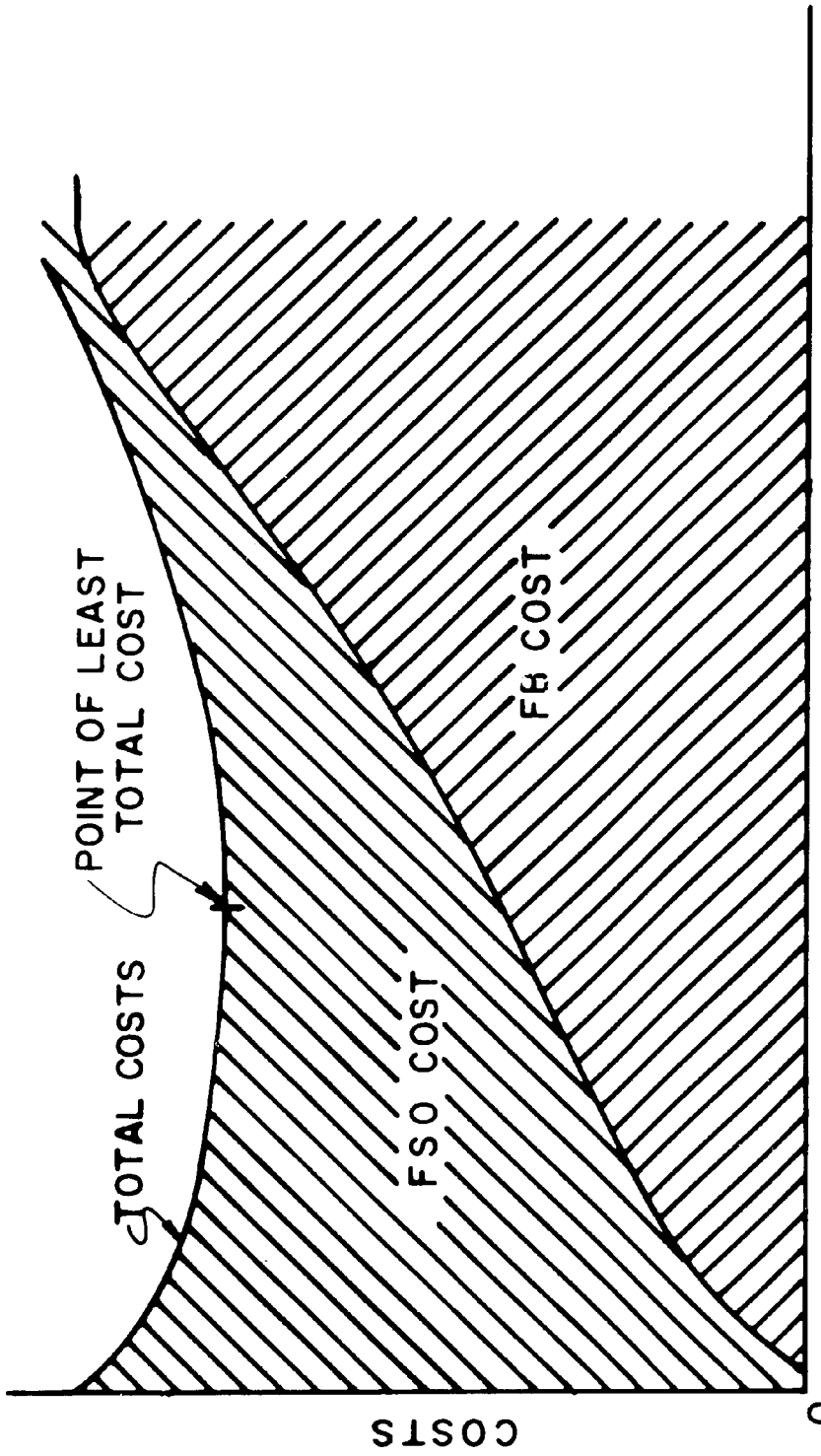

FIG. 22 CURVE PATHS OF FUELBREAK & FIRE SUPPRESSION COSTS

timber and brush, principally because of steepness of topography. Level IV is used as a base from which increased fuelbreak-system densities and small fire-suppression organization can be analyzed.

To be consistent with previous calculations, an equation for the fuelbreak curves must express the estimated average anual costs of interest charges. The equation used in this study is:[1]

$$C = [c + c_1(x-1)]i + m(x-1) \qquad (1)$$

where: C = total annual cost of construction and maintenance for any multiple x of Level IV density.

c = total cost of construction of Level IV fuelbreaks.

c_1 = cost of an equivalent number of miles of handline, Level IV.

i = the factor 0.04263371, which at fifty years with interest at 3.5 per cent is taken from compound interest tables and expresses an annuity whose present value is one.

m = cost of maintenance of Level IV fuelbreaks.

x = multiple of Level IV fuelbreak-system density (e.g., twice as dense).

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[1]I am indebted to Mr. Clif Dickason, graduate student at the University of Michigan, for help in deriving the equations.

The fire-suppression-cost curve must express the total annual cost of the fire-suppression organization needed to construct fireline through fuelbreaks which surround blocks of timber or brush as the fuelbreak system gets denser and the blocks become smaller.

The equation used for this study is:

$$C = \frac{ac}{x} \qquad (2)$$

where: C = total annual cost of the fire-suppression organization.

a = number of line workers needed per season at Level IV.

c = annual cost per man.

x = multiple of Level IV fuelbreak density.

The least total cost of fuelbreaks and fire suppression is found at the point where the slopes of the two curves are equal and opposite (Figure 23). At this point an increase in fuelbreak cost is just matched by a decrease in fire-suppression costs. To find the least total cost, the slopes of the two equations were equated and $\underline{x}$, the multiple of Level IV fuelbreak system density, was solved for. It ($\underline{x}$) was then substituted back in equations (1) and (2) above to solve for the total annual costs of fuelbreaks and fire suppression at the new fuelbreak-system density. The density multiple $\underline{x}$ was also used to solve for the optimum acreage objective and basic fireline organization in calculations which follow in a later section. The least-cost figures and the mix of fuelbreaks and fire-suppression organization are presented in Table 8.

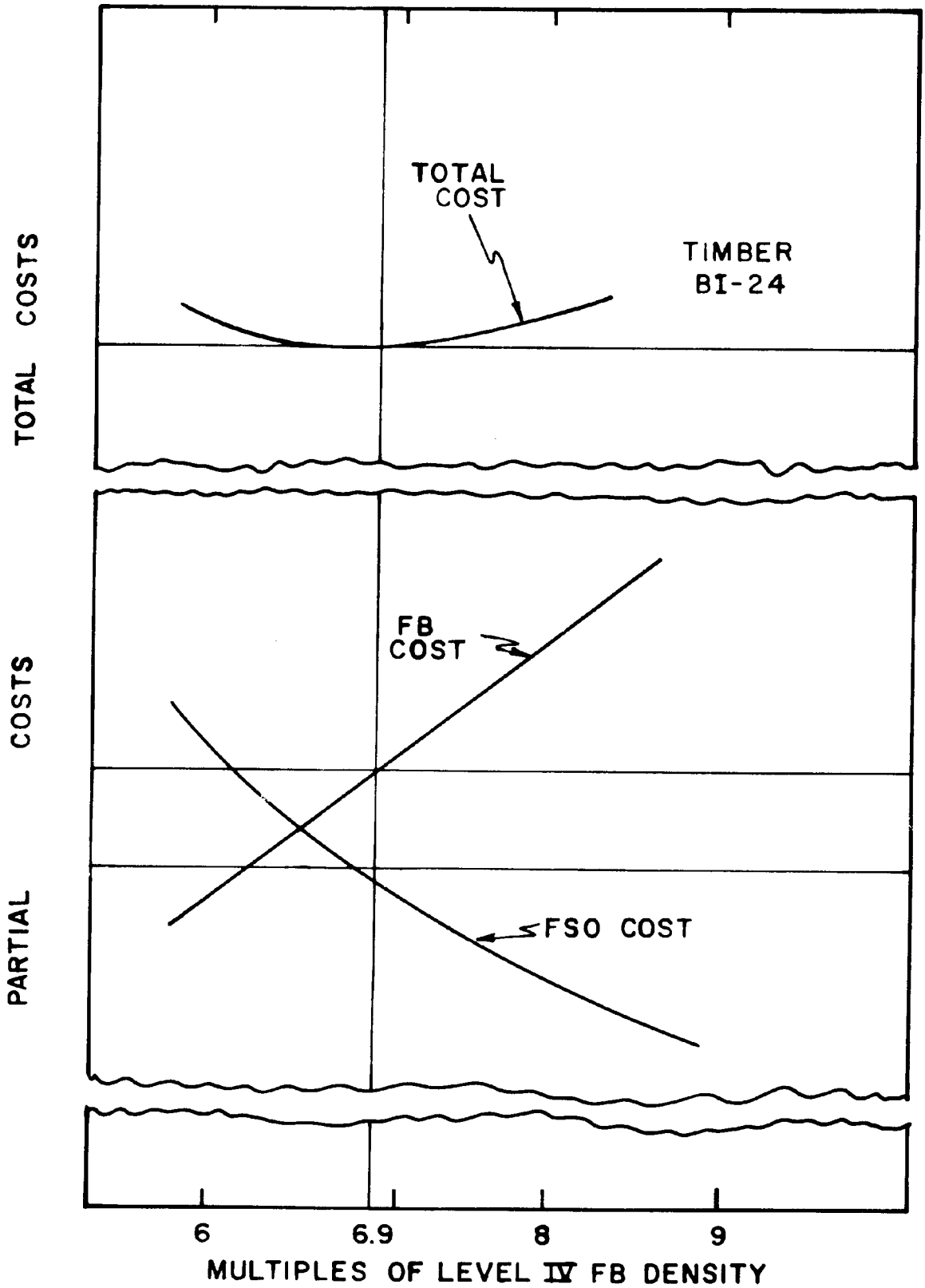

FIG. 23 SAMPLE FUELBREAK, FIRE SUPPRESSION, AND TOTAL COST CURVES

TABLE 8

ANNUAL LEAST TOTAL COST AND DOLLAR MIX OF FUELBREAK AND FIRE SUPPRESSION ON THE DUCKWALL UNIT

Burning Index	Least Total Cost	Fuel-breaks	Fire Sup-pression
		Timber Type	
24	$ 766,446	$413,946	$352,500
30	849,200	447,200	402,000
55	1,326,700	686,700	640,000
		Brush Type	
31	$508,906	$266,400	$242,500
37	567,906	284,406	283,000
65	896,500	452,500	444,000

Checking the Least-Cost Points

In order to be sure that the least-total-cost levels and mix of fuelbreaks and fire suppression produced by the curve formulas are indeed the lowest cost levels, a segment of the isoquant, or marginal-rate-of-substitution curve was plotted in the vicinity of the least-cost point. Figures 24 and 25 show the curve segments for timber BI 24 and brush BI 31. In all cases the shape of the curves indicated that a lower budget line could not be reached. The curves were concave to the origin on the left of the corner. Once the fuelbreak network is completely manned by the fire-suppression organization, which occurs at the corner of each curve, the extension of the curve to the right of the corner is nearly horizontal. The tangency has to be at the corner. The equations then give the lowest-cost combination of fuelbreaks and a fire-suppression organization. But the least costs and optimum mixes thus far determined are in terms of costs only. They key question remains: Is conflagration control by fuelbreaks and a fire-suppression organization worth the cost?

Least-Cost-Plus-Damage Solution

The economic feasibility of conflagration control depends upon the value of acres saved from fire by fuelbreaks and the fire-suppression organization.

Conceptually, the curve paths are shown in Figure 26. The fire-damage curve is superimposed on the total-cost curve of Figure 22. The fire-damage curve falls rapidly at first as the fuelbreak network becomes denser. Then the curve levels off as a higher

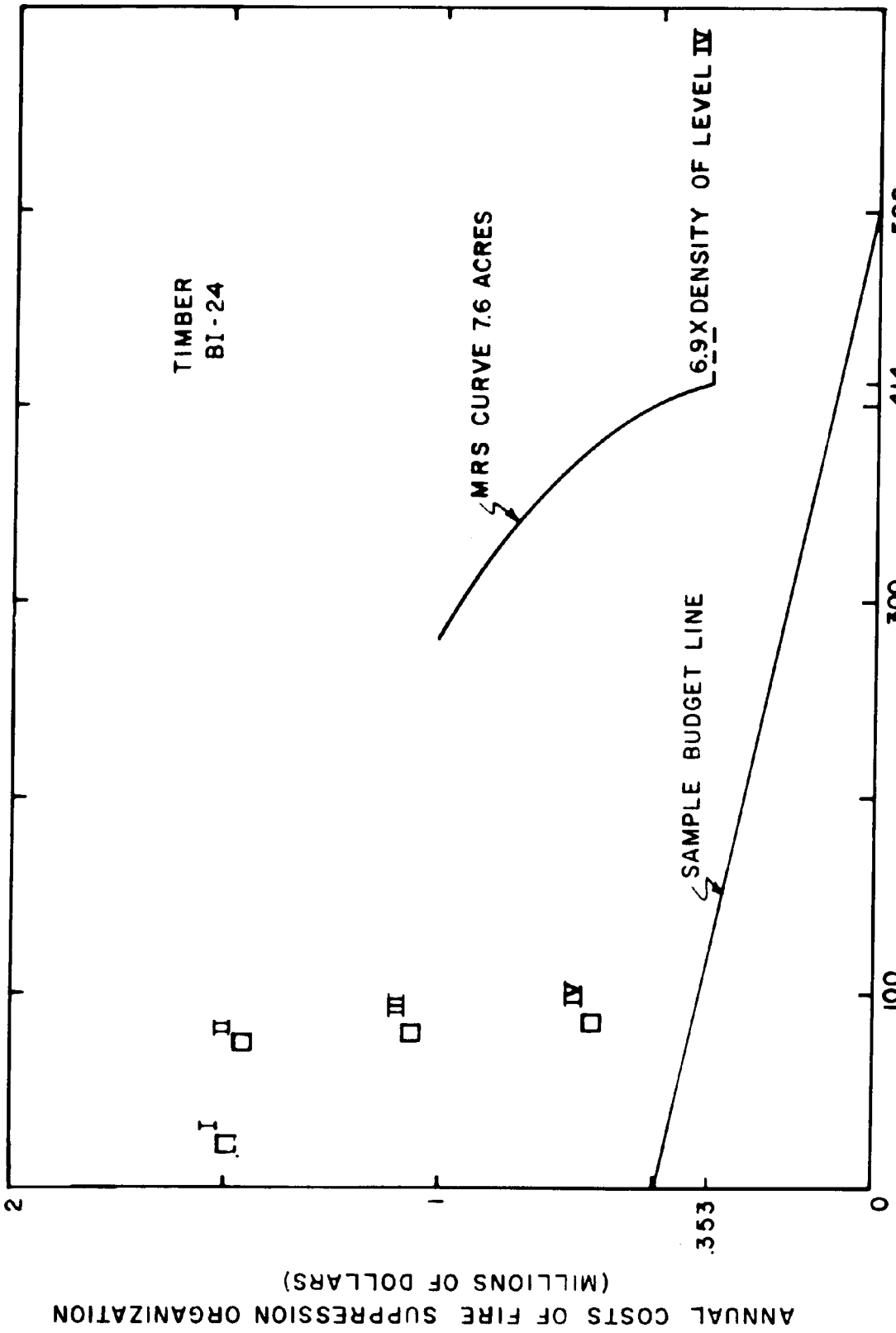

FIG. 24 MARGINAL RATE OF SUBSTITUTION CURVE SEGMENT AT OPTIMUM ACREAGE

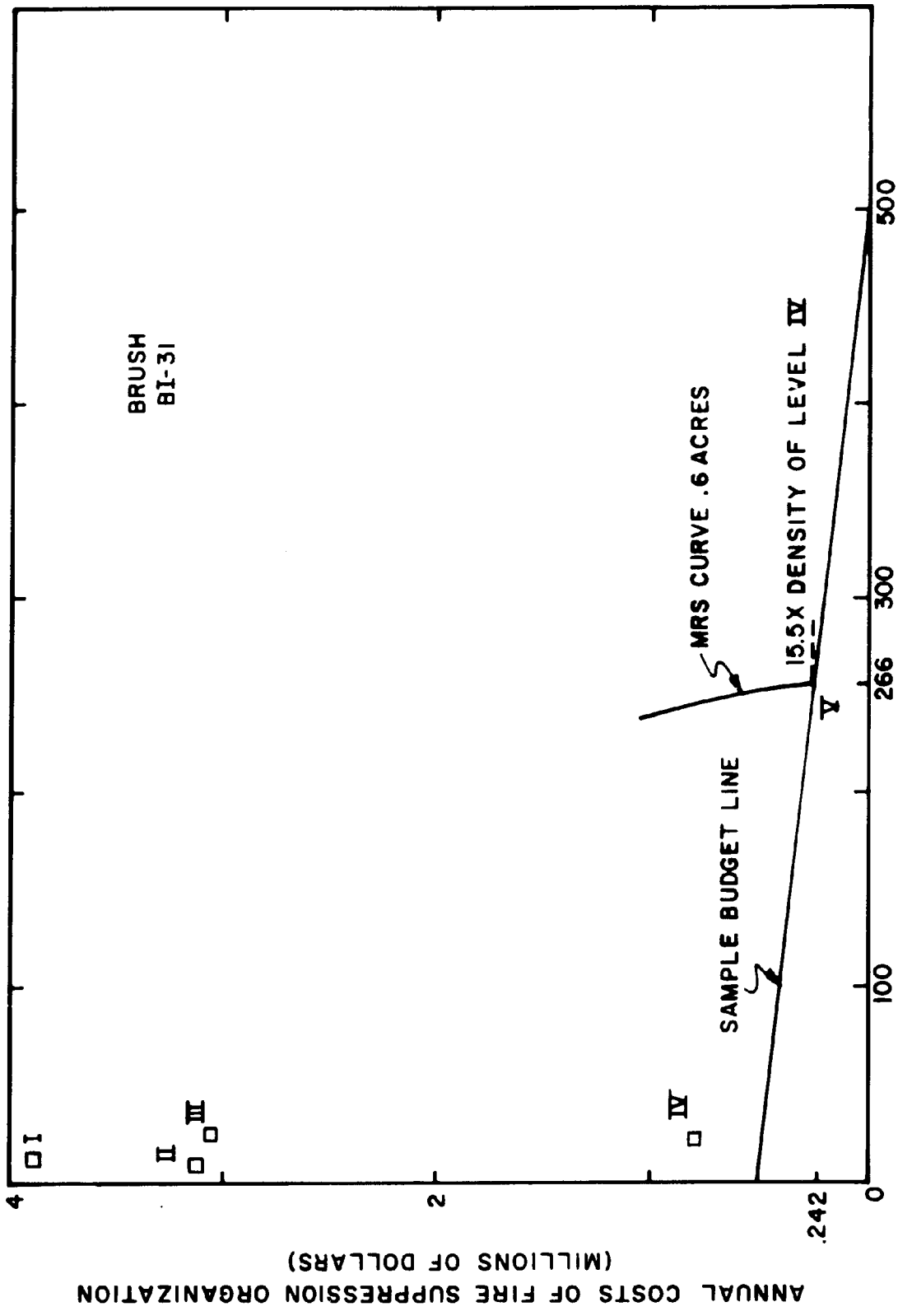

FIG. 25 MARGINAL RATE OF SUBSTITUTION CURVE SEGMENT AT OPTIMUM ACREAGE

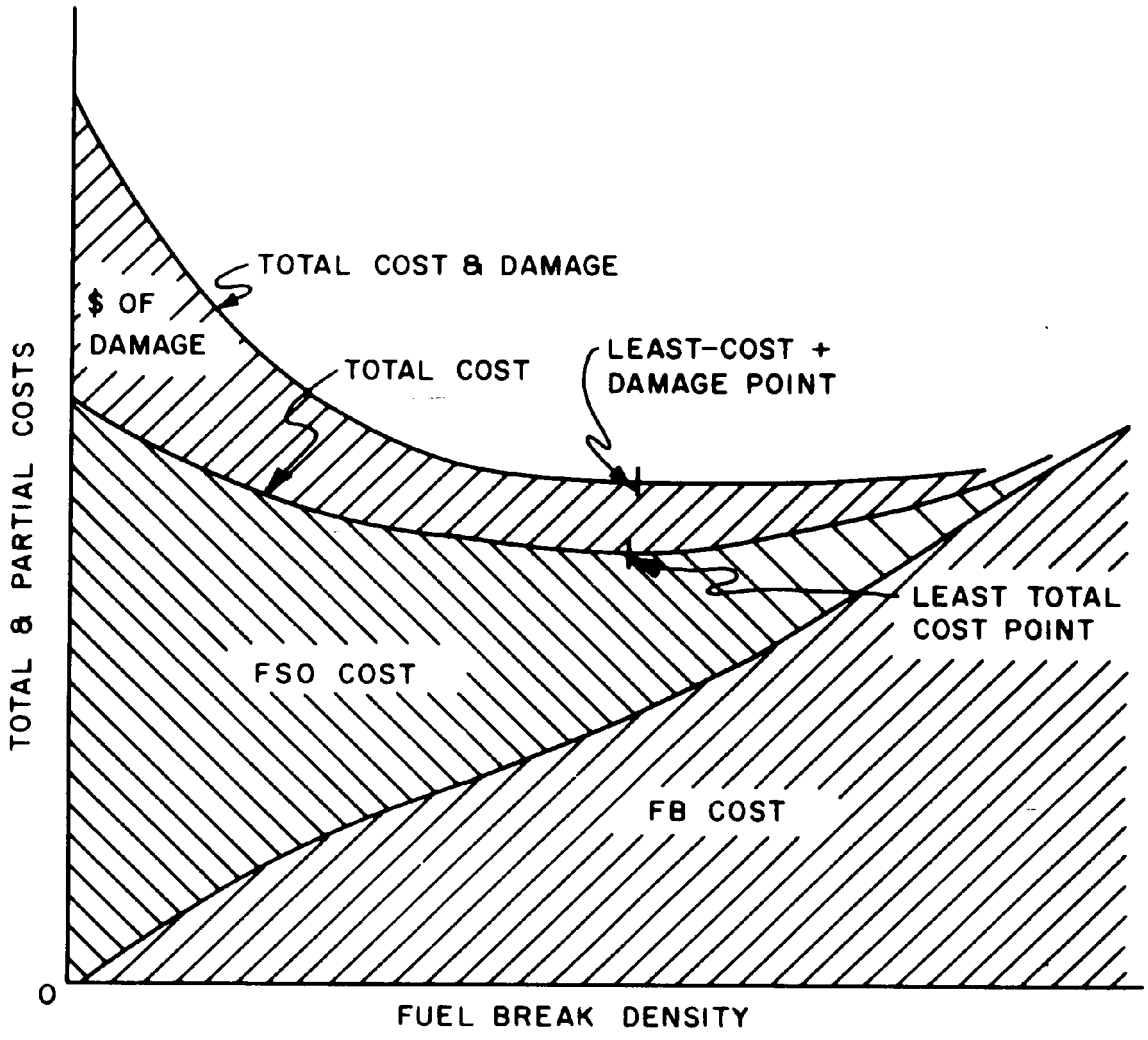

FIG. 26 ILLUSTRATION OF LEAST-COST-PLUS-DAMAGE

density of fuelbreaks is reached and blocks become small. The "economic balance" or the point of least cost plus damage is reached when the slopes of the total-cost and damage curves are equal and opposite.

Duckwall fire history shows that sixteen conflagrations (Class D and E fires) start every fifty years, or 0.32 fire per year. It will be assumed that this occurrence rate will continue. Fire damage then may be calculated as follows:

$$D = pb(0.32) \tag{3}$$

where: D = annual fire damage.

p = damage potential per acre.

b = size of average block in fuelbreak system.

A fire-damage curve was plotted but the slope could not be incorporated into an over-all equation that would give the least-cost-plus-damage solution.

The Economic-Balance Point

Because a least-cost-plus-damage equation could not be formulated, a trial-and-error method was finally used in which total costs were added to damages in the vicinity of the least-total-cost points, shown in Figure 23, to determine the least-cost-plus-damage point. It was found that the least-cost-plus-damage point in all cases was within a hundredth of a unit[1] from the least-total-cost points. This is because the slope of the fire-damage curve in this least-total-cost range is so slight that it

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[1]The unit is a multiple of Level IV fuelbreak density.

scarcely affects the position of the least-cost-plus-damage point.[1] Thus, it will be assumed that the least-cost point and the least-cost-plus-damage point are the same.

Gain or Loss from Conflagration Control

The last and most important question--does conflagration control pay?--now can be answered. The analysis of fire history on the Duckwall Unit showed that in the fifty-year analysis period there were 976 and 1,225 acres, respectively, burned during an average year in timber and brush on the Duckwall Unit (Table 28, Appendix). The dollar fire damage potential for timber and brush are known. The average expected acres of loss per year multiplied by the dollar damage potential value gives the expected value of acres lost each year on the average. Some annual loss will still occur because it is assumed that an entire block will burn when 0.32 of a potential conflagration starts. The actual loss (the block size) subtracted from the expected loss (the acreage lost during the average year) gives the value saved annually. The difference between annual value saved and the total annual costs of fuelbreaks and the fire-suppression organization give the gain or loss from conflagration control (see Tables 9 and 10).

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[1] An implication here is that, at denser fuelbreak systems which characterize the optimums of this study, flexibility in planning is afforded. This is because there is a relatively wide range of fuelbreak densities which give almost the same least-cost-plus-damage level. (I am indebted to Professor G. Robinson Gregory for this observation.)

TABLE 9

GAIN OR LOSS WITH CONFLAGRATION CONTROL AT THE OPTIMUM LEVEL FOR TIMBER TYPE ON THE DUCKWALL UNIT

Item	BI 24	BI 30	BI 55
Expected annual loss without conflagration control	$1,205,360	$1,205,360	$1,205,360
Actual loss per year with conflagration control	3,010	2,565	1,105
Value saved annually . . .	$1,202,350	$1,202,795	$1,204,255
Total annual costs of fuelbreaks and fire suppression	766,446	849,200	1,326,700
Annual gain with conflagration control . . .	$ 435,904	$ 353,595	--
Annual loss with conflagration control . . .	--	--	$ 122,445

TABLE 10

GAIN OR LOSS WITH CONFLAGRATION CONTROL AT THE OPTIMUM LEVEL FOR BRUSH TYPE ON THE DUCKWALL UNIT

Item	BI 31	BI 37	BI 65
Expected annual loss without conflagration control	$373,895	$373,895	$373,895
Actual loss per year with conflagration control	166	136	59
Value saved annually	$373,729	$373,769	$373,886
Total annual costs of fuel-breaks and fire suppression	509,900	567,906	896,500
Annual gain with conflagration control	--	--	--
Annual loss with conflagration control	$135,171	$194,137	$522,614

It will be recalled that $\underline{x}$, the multiple of Level IV fuelbreak-system density, has already been calculated. This is the fuelbreak-system density called for at the optimum least-cost point. The acreage objective and the basic fireline organization at the optimum protection level were calculated using $\underline{x}$. The equation used to calculate the acreage objectives in Table 11 is:

$$A = \frac{b}{x^2} \tag{4}$$

where: A = acreage objective which is average block size.
b = block size at Level IV density.
x = multiple of Level IV density.

The equation is based on the relationship that when fuelbreak mileage is doubled the average block size (acreage objective) decreases to one-fourth its previous size; when tripled, to one-ninth its previous size.

The number of line workers in Table 11 was obtained by the formula:

$$W = \frac{a}{x} \tag{5}$$

where: W = number of line workers at new level.
a = number of line workers at Level IV.
x = multiple of Level IV density.

According to Tables 9 and 10, conflagration control in brush does not pay. Conflagration control geared to BI 24 or 30 in timber does pay. Conflagration control in timber at BI 24 produces the most gain. At BI 24 the optimum acreage objective (block size) is 8 acres (Table 11). The economic scale of conflagration control is $766,446 annually. The factor mix at this scale is $413,946 in

TABLE 11

OPTIMUM ACREAGE OBJECTIVES AND FIRE-SUPPRESSION ORGANIZATION ON THE DUCKWALL UNIT

Burning Index	Acreage Objectives (No. of Acres)	Fire-Suppression Organization (No. of Line Workers)
	Timber Type	
24	8	7
30	7	8
55	3	13
	Brush Type	
31	2	5
37	1	6
65	0.6	9

fuelbreaks and $325,500 in fire suppression (Table 8). The size of the basic fireline organization necessary to man the economically feasible fuelbreak system is about seven line workers. The complete fire-suppression organization, geared to conflagration control that must be built around this manpower base, will cost about $352,500. This level of protection is based upon the assumption of certainty, that the Duckwall Unit is a distinct administrative unit, and that fire control pays all the costs. In the next chapter these assumptions will be relaxed to see how the optimum levels of this chapter change.

CHAPTER VII

APPLICATION OF THE LEAST-COST-PLUS-DAMAGE CRITERION TO FIELD CONDITIONS

In this chapter the following assumptions of Chapter VI are relaxed:

1. Duckwall Unit as a distinct administrative unit. Costs of the fire-suppression organization are spread over the Stanislaus Forest.

2. Fire control assumes the total burden of costs of fuelbreak construction and maintenance on the Duckwall Unit. Part of the costs of fuelbreaks are assumed to be shared by management functions.

3. Certainty, or that all fuelbreaks will hold all fires. The effect on the optimum solutions of Chapter VI of a decision game in which experienced firemen estimate how many times in a hundred fuelbreaks will hold fires will be explored.

4. Planning is done for timber and brush separately. One level of fire suppression for the entire Duckwall Unit will be calculated.

The additional level of fire-suppression organization needed during the few days each season when the fire danger exceeds the economic level of protection will also be discussed.

Shared Costs of Fuelbreaks

The basic financing principle on the Duckwall Unit was that each function--e.g., timber, range management, et cetera--would carry out the prescribed fuelbreak work where the primary purpose of this work was to be in the direct interests of timber management, range management, and other functions. That part of fuelbreak work which was primarily for the purpose of fire control was financed from fire-control money. The cost-accounting system was designed to collect not only expenditures, but sources of funds also. During 1961 and 1962, of the total moneys spent on fuelbreak construction and maintenance, 39 per cent were borne by forest-management functions other than fire control, and 61 per cent of the costs were borne by fire control.[1] This proportion is assumed to remain constant. The fuelbreak equation presented in the last chapter is adjusted to reflect these changes. To do this, adjustment of the coefficients of the fuelbreak formula were made to reflect this assumption that 39 per cent of the fuelbreak construction and maintenance costs were in the direct interest of management functions.

$$C = [0.61c + 0.61c_1(x-1)]\ i + 0.61m(x-1) \qquad (6)$$

where: C = total annual cost of construction and maintenance for any multiple x of Level IV fuelbreak density when 39 per cent of the costs are paid by management functions.

c = total cost of construction of Level IV fuelbreak.

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[1] Murphy, in Forest Fire Conditions Western North America, 1963, p. 10.

c_1 = cost of an equivalent number of miles of handlines, Level IV.

i = the factor 0.04263371, which at fifty years with interest at 3.5 per cent is taken from compound interest tables and expresses an annuity whose present value is one.

m = cost of maintenance of Level IV fuelbreaks.

x = multiple of Level IV fuelbreak density.

The slopes of the modified fuelbreak equation above and the fire-suppression equation (Chapter VI) are again equated. Tables 12, 13, and 14 show the changes in the optimum solutions that result. Conflagration control still does not pay in brush on the Duckwall Unit. Conflagration control now pays at all three burning index levels in timber, however. It still shows the most gain at BI 24 in timber. Total costs of conflagration control and of fuelbreaks and fire suppression are considerably less now. The acreage objective is smaller, and it takes a smaller stand-by fire-suppression organization to construct fireline on the fuelbreak system when a fire starts.

Shared Costs of Air Operations

Air operations on the Stanislaus National Forest are planned and financed on a national forest level. Fixed-wing and rotary-wing aircraft serve the entire forest. Under the assumption of manning for conflagration conditions and a 15 minute attack time, aircraft based at the airport adjacent to the Duckwall Unit--the Columbia, California, airport--could conservatively serve approximately

TABLE 12

OPTIMUM LEAST TOTAL COSTS, DOLLAR MIX OF FUELBREAKS AND FIRE-SUPPRESSION ORGANIZATION, ACREAGE OBJECTIVES, AND BASIC FIRELINE ORGANIZATION, ADJUSTED FOR SHARED COSTS OF FUELBREAKS, ON THE DUCKWALL UNIT

Burning Index	Annual Costs			Acreage Objective[a]	Basic Fire-Suppression Organization[b]
	Fuelbreaks	Fire Suppression	Total		
		Timber Type			
24	$314,400	$284,500	$ 598,900	5	6
30	348,000	318,700	667,700	4	7
55	535,400	503,000	1,038,400	2	10
		Brush Type			
31	$195,185	$190,000	$385,185	1	4
37	222,485	221,300	443,785	0.8	5
65	348,185	340,000	688,185	0.3	7

[a]Block size in acres.

[b]Number of line workers.

TABLE 13

GAIN OR LOSS WITH CONFLAGRATION CONTROL REFLECTING SHARED COSTS OF FUELBREAKS FOR TIMBER TYPE ON THE DUCKWALL UNIT

Item	BI 24	BI 30	BI 55
Expected annual loss without conflagration control	$1,205,360	$1,205,360	$1,205,360
Actual annual loss with conflagration control	1,968	1,899	691
Value saved annually . . .	$1,203,392	$1,203,461	$1,204,679
Total annual costs of fuelbreaks and fire-suppression organization	598,900	666,700	1,038,400
Annual gain with conflagration control . . .	$ 604,492	$ 536,761	$ 166,279
Annual loss with conflagration control . . .	--	--	--

TABLE 14

GAIN OR LOSS WITH CONFLAGRATION CONTROL REFLECTING SHARED COSTS OF FUELBREAKS FOR BRUSH TYPE ON THE DUCKWALL UNIT

Item	BI 31	BI 37	BI 65
Expected annual loss without conflagration control	$373,894	$373,894	$373,894
Actual annual loss with conflagration control	108	83	35
Value saved annually	$373,786	$373,811	$373,859
Total annual costs of fuelbreaks and fire-suppression organization	385,185	443,785	688,185
Annual gain with conflagration control	--	--	--
Annual loss with conflagration control	$ 11,399	$ 69,974	$314,326

77,000 acres.[1] The Duckwall Unit is only 40,000 acres of that total. It will be assumed, therefore, that risk, hazard, and value are constant over the entire area[2] and that the costs of air operations are shared on a per-acre basis. The Duckwall Unit's share of costs of air operations, then, is 52 per cent, and 26 per cent will be charged to timber areas and 26 per cent to brush areas.

The fire-suppression organization formula as presented in Chapter VI can be adjusted to reflect these shared costs of air operations:

$$C = \frac{ac}{x} \qquad (7)$$

where: C = total annual cost of the fire-suppression organization.

a = number of line workers at Level IV.

c = rate per line worker, adjusted for new cost of air operations.

x = multiple of Level IV fuelbreak density.

After the slopes of the adjusted fire-suppression organization and the fuelbreak equations are equated, the optimum levels change again (Table 15). Conflagration control now pays in timber and at BI 31 in brush (Tables 16 and 17). It still does not pay at BI 37 and BI 65 levels in brush. Conflagration control still pays the most at BI 24 in timber. In brush it pays the most at BI 31. Total costs and costs of both fuelbreaks and fire suppression have

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[1] An average aircraft cruising speed of 100 mph is assumed. Air coverage taken from air operations plan, Stanislaus National Forest, Sonora, California, and from Dispatcher's Air Operations Map.

[2] Risk, hazard, and value are, of course, not usually constant over larger areas, and other allocations are feasible.

TABLE 15

OPTIMUM LEAST TOTAL COSTS, DOLLAR MIX OF FUELBREAKS AND FIRE-SUPPRESSION ORGANIZATION, ACREAGE OBJECTIVES, AND SIZE OF FIRE-SUPPRESSION ORGANIZATION, ADJUSTED FOR SHARED COSTS OF AIR ATTACK, ON THE DUCKWALL UNIT

Burning Index	Annual Costs			Acreage Objective[a]	Basic Fire-Suppression Organization[b]
	Fuelbreaks	Fire Suppression	Total		
		Timber Type			
24	$269,400	$245,000	$514,400	7	7
30	272,940	268,100	541,040	6	8
55	461,400	432,500	893,900	2	12
		Brush Type			
31	$168,685	$162,000	$330,785	1	4
37	192,985	188,500	381,485	1	5
65	298,185	293,500	591,685	0.5	8

[a]Block size in acres.

[b]Number of line workers.

TABLE 16

GAIN OR LOSS WITH CONFLAGRATION CONTROL, REFLECTING SHARED COSTS OF AIR ATTACK, FOR TIMBER TYPE ON THE DUCKWALL UNIT

Item	BI 24	BI 30	BI 55
Expected annual loss without conflagration control	$1,205,360	$1,205,360	$1,205,360
Actual annual loss with conflagration control .	2,620	2,160	902
Value saved annually . . .	$1,202,740	$1,203,200	$1,204,458
Total annual costs of fuelbreaks and fire-suppression organization	514,400	541,040	893,900
Annual gain with conflagration control . . .	$ 688,340	$ 662,160	$ 310,558
Annual loss with conflagration control . . .	--	--	--

TABLE 17

GAIN OR LOSS WITH CONFLAGRATION CONTROL, REFLECTING SHARED COSTS OF AIR ATTACK, FOR BRUSH TYPE ON THE DUCKWALL UNIT

Item	BI 31	BI 37	BI 65
Expected annual loss without conflagration control	$373,894	$373,894	$373,894
Actual annual loss with conflagration control	137	107	49
Value saved annually	$ 757	$ 787	$ 845
Total annual costs of fuelbreaks and fire-suppression organization	330,785	381,485	591,685
Annual gain with conflagration control	$ 42,972	--	--
Annual loss with conflagration control	--	7,698	217,840

been reduced. At an annual cost of $269,400, for example, a fuelbreak system with an average block size of about 7 acres could be constructed and maintained in timber (Table 15). A basic seven line worker fire-suppression organization backed up by air tanker support would be needed to man the fuelbreak system at an annual cost of $245,000. This combination of fuelbreaks and fire suppression would be geared to handle fires starting and burning at BI 24, the economic level of conflagration control.

Risk of Not Stopping Fires at Fuelbreaks

The analysis, thus far, has anticipated definite and specific results. For example, fires will be discovered at or before they reach 0.2 acre in size. A report, crew getaway, and travel time of 2, 2, and 15 minutes, respectively, have been regarded as "sure" to happen. The most frequently asked question by visitors to the Duckwall Experimental Unit is, "Can a fire crew hold a high-intensity fire on those fuelbreaks?" The answer to this question is predicated upon all the things happening for sure, which were assumed in this study thus far. The moment of truth comes when the fire approaches a fuelbreak. Fuelbreaks, as they exist on the Duckwall Unit, are new and have yet to be fully and fairly tested. Experimental fires have not been used to test fuelbreaks. One of the few alternatives left for gaining some idea of the chances of a given fire-suppression organization holding a fire within fuelbreak blocks was to ask seasoned fire-control men who were regarded as

"experts." The judgment and experience of these men was used to estimate probabilities of conflagration-control success.[1] This method is known among operations-research experts as a decision game. A group of five Stanislaus National Forest firemen[2] were used for the decision game. Each was taken independently of the rest of the group to the timber and brush areas of the Duckwall Unit. Ten sample areas were chosen systematically, five in timber and five in brush. The conditions of Table 14--e.g., burning indexes and the size of the fire-suppression organization at the near optimum conditions of Tables 9, 10, and 11--were presented to them. Initial and follow-up attack was assumed to be from existing airports and stations. Assumptions about elapsed time and size at detection used in this study were also explained. Fires were assumed to start at the bottoms of drainages. Wind direction assumed was that of most past conflagrations--west to east.

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[1]All of these men were taken as experts, all with the same ability to judge conflagration-control success. It is true that conceivably one of the men could be right all of the time and the others wrong each time they differed with him. One way of checking credibility of expert opinion would be to use a fire which actually encountered a fuelbreak, extract weather, topographical, and fire-behavior characteristics from this encounter, including the fire-suppression organization, and then use this fire-fuelbreak encounter as a "check" situation. In this manner experts' opinions could be matched against actual outcome. Unfortunately, there had been no fire-fuelbreak encounters on the Duckwall Unit to use as a check situation. It is argued, therefore, that even considering the inherent fallacies of the methods used in this study there is presently no other practical way of estimating conflagration-control success.

[2]The firemen were all qualified fire bosses and all had had experience on conflagrations which had occurred on or adjacent to the Duckwall Unit: the Walton Spur fire, the Wright's Creek fire, and the Flora fire. This experience helped them estimate fire behavior characteristics, particularly with reference to spotting.

The men's knowledge of local conditions and their fire experience then allowed each of them to give an independent estimate of the probability of control of the fire. The estimates were averaged, and the averages are presented in Table 18. The values in this table represent the average number of times in a hundred the fire-control men estimated the fire could be held within the block. These values are systematically obtained judgments of experienced firemen, and until fuelbreak systems are actually tested by fire they are the best estimates available.

The fire-control men concluded that all fires will not be held within blocks of origin by the fire-suppression crews (Table 18). The values saved annually, therefore, can be reduced by the probability-of-success estimates (Tables 19 and 20) to give a more realistic picture of how much conflagration control really pays (see Tables 21 and 22). They show that, although the gain from conflagration control has been reduced at the higher burning indexes, it still pays at all burning indexes in timber and at BI 31 in brush.

Periods when Fire Danger Exceeds the Protection Level

The optimum level of conflagration control by fuelbreaks and a fire-suppression organization has been calculated to be at burning index 24 in timber and 31 in brush on the Duckwall Unit. According to the curves in Figures 9 and 10, there will be 10 per cent of the days in each fire season when the burning index exceeds these levels. The question then becomes: "Does a fire-control planner simply ignore the crisis periods, or does he systematically plan to increase fire-control efforts on the high burning index days?" Burning index

TABLE 18

PROBABILITY OF SUCCESS ON FUELBREAKS AND FIRE-SUPPRESSION CREWS IN CONTROLLING CONFLAGRATIONS ON THE DUCKWALL UNIT

Economic Level of Conflagration Control	Probability of Success[a]
Timber Type	
BI 24 level	100
BI 30 level	97
BI 55 level	89
Brush Type	
BI 31 level	98
BI 37 level	97
BI 65 level	91

[a]Number of times in a hundred fire would be held within the block.

TABLE 19

ANNUAL VALUE SAVED, ADJUSTED FOR PROBABILITY OF SUCCESS OF CONFLAGRATION CONTROL, FOR TIMBER TYPE ON THE DUCKWALL UNIT

Economic Level of Conflagration Control	Annual Value Saved[a]
BI 24 level	$1,202,740
BI 30 level	1,166,634
BI 55 level	1,070,486

[a]Using the figures from Tables 16 and 18: BI 24 = $1,202,740 × 1.00; BI 30 = $1,203,200 × 0.97; BI 55 = $1,204,458 × 0.89.

TABLE 20

ANNUAL VALUE SAVED, ADJUSTED FOR PROBABILITY OF SUCCESS OF CONFLAGRATION CONTROL, FOR BRUSH TYPE ON THE DUCKWALL UNIT

Economic Level of Conflagration Control	Annual Value Saved[a]
BI 31 level	$366,253
BI 37 level	--
BI 65 level	--

[a]Using the figures from Tables 17 and 18: BI 31 = $373,757 × 0.98; BI 37 and BI 65 levels were not economically feasible.

TABLE 21

GAIN OR LOSS, REFLECTING PROBABILITIES OF SUCCESS OF CONFLAGRATION CONTROL, FOR TIMBER TYPE ON THE DUCKWALL UNIT

Item	BI 24	BI 30	BI 55
Adjusted values saved annually[a]	$1,202,740	$1,166,634	$1,070,486
Total annual costs of fuelbreaks and fire-suppression organization	514,400	541,040	893,900
Annual gain with conflagration control . . .	$ 688,340	$ 625,594	$ 176,586
Annual loss with conflagration control . . .	--	--	--

[a]From Table 19.

TABLE 22

GAIN OR LOSS, REFLECTING PROBABILITIES OF SUCCESS OF CONFLAGRATION CONTROL, FOR BRUSH TYPE ON THE DUCKWALL UNIT

Item	BI 31	BI 37	BI 65
Adjusted values saved annually[a]	$366,253	Not economically feasible	Not economically feasible
Total annual costs of fuelbreaks and fire-suppression organization	330,785	--	--
Annual gain with conflagration control	$ 35,468	--	--
Annual loss with conflagration control	--	--	--

[a]From Table 20.

frequency curves, examples of which are shown in Figures 9 and 10, are now available for the 144 fire-danger rating areas in California. They give the fire-control planner an idea of the number of good, bad, or worst fire days he might expect in a given fire season. According to Figure 9, for example, the burning index will average 34 for 5 per cent of the days and 51 for 5 per cent of the days in fire-danger rating area 348, the brush area on the Duckwall Unit. In the timber area, fire-danger rating area 370, the burning index will average 27 on 5 per cent of the days and 40 on 5 per cent of them. These are the periods for which special planning must be done.

The manpower requirement charts were used to find the number of line workers needed to control firest at 7 and 4 acres, respectively, as shown in Table 15, at the higher burning indexes. The number of line workers already determined for the optimum level were subtracted from these figures, giving the additional numbers of line workers necessary to man the fuelbreak system for the 10 per cent of the days during which the burning index is above 24 in timber and 31 in brush. The total fire-suppression organization and its cost was determined as previously described.

Then 0.05 times this cost gives the cost for 5 per cent of the season when the burning index is 27 in timber and 34 in brush. The calculations can then be repeated for BI 40 in timber and BI 51 in brush. The new costs are presented in Table 22 for the critically high burning indexes in brush and timber. One way of looking at crisis-period manning is that according to Table 23 there is ample gain from conflagration control to cover these crisis-period costs. This additional cost of the crisis-period fire-control organization, when added back in the equations, did not change the optimum acreage objective from that shown in Table 15. A smart

TABLE 23

GAIN OR LOSS WITH CONFLAGRATION CONTROL, ADJUSTED FOR PERIODS OF HIGH FIRE DANGER, ON THE DUCKWALL UNIT

Item	Timber BI 24	Brush BI 31
Annual gain with conflagration control at protection level	$688,340	$35,468
Additional costs of fire suppression to man to:		
5 per cent of season; BI 27, 34 . .	4,790	3,040
5 per cent of season; BI 40, 51 . .	14,690	8,200
Gain less additional fire-suppression-organization costs: remaining gain	$668,860	$24,228

fire planner would use this money to decrease travel time, and increase strength and flexibility of attack to keep fires within their block of origin in the fuelbreak system.

One Level of Fire-Suppression Organization for the Entire Duckwall Unit

The two fire-danger rating areas (timber and brush) on the Duckwall Unit represent different fuels, weather, topography, and fuelbreak and fire-suppression costs, as well as fire-damage potentials. Thus the analysis in Chapter VII was done separately for each area. Separate fuelbreak densities and fire-control organizations resulted. For large administrative units, maintenance of this separation may be practical. For smaller administrative units different densities of fuelbreaks are practical, but maintenance of two fire-suppression organizations is not. The decision of whether to maintain separate fire-control organizational intensities must be based upon the travel times of the fire crews. The fire-suppression organization thus far determined for timber areas, as shown in Table 15--a basic seven line worker organization--is more than enough to protect brush areas which require a basic four line worker organization. On the Duckwall Unit an analysis of travel times indicated that one fire-control organization could make initial attack on any fire within the Duckwall Unit within the travel time assumed for this study, 15 minutes. It has also been assumed that only one conflagration will start and burn on the Duckwall Unit at one time. Duckwall Unit fire history gives strength to this assumption. The costs of fire suppression on the Duckwall Unit, then, can be realistically spread over the entire unit, both timber and brush. One way of

doing this is to weight the financial burden of fire suppression according to the value of average annual acres burned in timber and brush. This weighting method combines risk, hazard, and value. When this is done, timber area accounts for 76 per cent of the average annual damage on the Duckwall Unit,[1] and the brush areas account for 24 per cent.[2] Air-operations costs have already been divided between timber and brush areas. When the costs of the ground organization are divided between timber and brush according to the weighted values and the slopes of the fuelbreak and fire-suppression organization formulas are equated, the optimums once again change. The total costs are reduced (Table 24). The acreage objective is now about 8 acres in timber and 3 acres in brush. A basic nine line worker organization, at an annual cost of $339,300, is required to protect the entire Duckwall Unit. It will cost about $24,000 to finance additional crews and equipment during the 10 per cent of the days when the burning index exceeds BI 24 in timber and BI 31 in brush (Table 26).

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[1]Average burn of 976 acres per year multiplied by $1,235.26 per acre damage potential.

[2]Average burn of 1,225 acres per year multiplied by $305.22 per acre damage potential.

TABLE 24

LEAST TOTAL COSTS, MIX OF FUELBREAKS AND FIRE SUPPRESSION, ACREAGE OBJECTIVES, AND FIRE-SUPPRESSION ORGANIZATION, ADJUSTED FOR ONE LEVEL OF FIRE SUPPRESSION, ON THE DUCKWALL UNIT

Item	Annual Cost	Acres	No. of Line Workers
Annual cost of fuelbreaks:			
Timber, BI 24	$250,400		
Brush, BI 31	122,385		
Total	$372,785		
Annual cost of fire-suppression organization:			
Timber, BI 24	$222,500		
Brush, BI 31	116,800		
Total	$339,300		
Total annual cost of fuelbreaks and fire-suppression organization:			
Timber, BI 24	$472,900		
Brush, BI 31	239,185		
Total	$712,085		
Acreage objective (block size):			
Timber, BI 24		8	
Brush		3	
Size of fire-suppression organization			9

TABLE 25

GAIN OR LOSS WITH CONFLAGRATION CONTROL, ADJUSTED FOR ONE LEVEL OF FIRE-SUPPRESSION ORGANIZATION, ON THE DUCKWALL UNIT

Item	Timber BI 24	Brush BI 31
Expected annual loss	$1,202,740	$366,253
Actual annual loss	3,020	254
Value saved annually	$1,199,720	$365,460
Total annual costs of fuelbreaks and fire-suppression organization	472,900	126,275
Annual gain with conflagration control	$ 726,820	$126,275
Annual loss with conflagration control	--	--

TABLE 26

GAIN OR LOSS WITH CONFLAGRATION CONTROL, ADJUSTED FOR PERIODS OF HIGH FIRE DAMAGE, WITH FIRE-SUPPRESSION ORGANIZATION AT ONE LEVEL TO MAN FUELBREAKS ON ENTIRE DUCKWALL UNIT

Item	Timber		Brush	
	BI	Amount	BI	Amount
Annual gain with conflagration control at protection level . .	24	$726,820	31	$126,275
Additional costs of fire suppression to man to:				
5 per cent of season	27	$ 4,000	34	$ 1,975
5 per cent of season	40	12,765	51	5,320
Total ($24,060)		$16,765		$ 7,295
Gain, less additional fire-suppression-organization costs: remaining gain	24	$710,055	31	$118,980

CHAPTER VIII

IMPLICATIONS OF THE ANALYSIS

Implications of the analysis, its analytical model, and results are discussed in the section that follows.

Marginal Concept

The least-cost-plus-damage method of analysis compares rates of change of total costs. For example, in Figure 23 the intersection of the fuelbreak and the fire-suppression curves has no significance. It is the fuelbreak density, where the slopes of the two curves are equal and opposite, that determines the optimum least-cost point. At that minimum sum, the rate of increase in fuelbreaks per unit change in fuelbreak density is equal to the rate of decrease of fire-suppression cost per unit change in fuelbreak density. The important thing here is that the full extent of the curves does not have to be known. Total costs do not have to be known. If the cost increase in fuelbreak construction is known and some idea of the resulting decrease in fire-suppression costs is also known, a good indication of the need for change and its direction can be obtained. If an increase in fuelbreak results in approximately the same decrease in fire-suppression-organization costs, then no change in fuelbreak density is indicated.

Establishment of Pars

One of the most important uses of the methods employed in this study is to establish pars with economic foundations. Least cost plus damage as a criterion for measuring satisfaction of objective can be interpreted in terms of the pars which it establishes. The annual-burned-area objective at the economic level of conflagration control is about 8 acres in timber and 3 acres in brush. This economic balance is achieved when a fire is discovered before it reaches 0.2 of an acre, when the report time is 2 minutes, getaway time is 2 minutes, and travel time is 15 minutes.

Clarification of Relationships

The marginal rates of substitution curves show the "trade off" between fuelbreaks and the suppression organization. A few thousand dollars in fuelbreaks substitute for several hundred thousand dollars in fire suppression. The importance of fuelbreaks can be illustrated in no better manner. In the study when costs of fuelbreaks were reduced because other management functions did part of the work, total costs and cost and size of the fire-suppression organization were reduced as well as area burned. When costs of the fire-suppression organization were also reduced because of shared costs of air attack, total costs, costs of fuelbreaks, and costs of the fire-suppression organization were reduced. The

number of acres lost, however, was greater and the suppression organization became larger. The effects of detection efficiency, report times, getaway times, and travel times on the economic balance can also be determined. For example, if detection efficiency falls off and fires become larger before they are detected, a larger fire-suppression organization will be required. Higher suppression costs probably will result, and more fuelbreaks will be needed. Increased report, getaway, and travel times would have the same effect.

Sound Economic Bases

By use of the methods described in this study, an optimum scale and mix can be found and a decision may be made as to whether to protect areas of doubtful value, provided the costs of fuelbreak construction and the suppression organization can be obtained and the value per acre and its damage potential can be estimated. When a conflagration-control project is thought to be needed, it can be analyzed and a scale can be determined based upon sound economics.

Cost-Equals-Loss Point

At the least-cost-plus-damage point an increase in costs results in an equal decrease in loss. The Batelle Institute assumed that a reasonable approximation of the least-cost-plus-damage

point was at the intersection of two lines where cost equals loss.[1] Tables 13, 14, 16, 19, 20, 21, and 22 show that in this study at the optimum point loss is nowhere near total costs. Cost equals loss as a criterion can be a dangerous generalization.[2]

A Goal of Financing

The optimum level of financing that resulted from the analysis is at the highest level, to be sure. It is naive to think that it is immediately obtainable and should happen tomorrow. The present annual cost of the Stanislaus National Forest fire-control organization, for example, is $387,663.[3] This organization annually protects over a million acres of forestland. The Duckwall Unit is only 40,000 acres of this total. The annual cost of fuelbreak construction and maintenance presently allowed the entire Stanislaus Forest is only $40,000. The cruel fact still remains, however, that over time conflagrations cause as much as 95 per cent of the burned area from forest fires. Therefore, a good hard look should be taken at:

1. Increased financing for fuelbreaks. A much denser fuelbreak system than now exists is indicated.

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[1] Swager, Fetterman, and Jenkins, p. B-4.

[2] In fact, as Figure 23 illustrates, when a nonlinear curve sloping downward to the right, as is typical of curves depicting loss, is added to a linear curve sloping upward to the right, as is typical of fire-control-cost curves, the least-total-cost point is to the right of the intersection of the cost and loss curves.

[3] Stanislaus National Forest, Recommended 1961-1965 Program for Fire Control (U.S. Forest Service, California Region, 1961), p. 6.

2. Adjusting and financing fire-control organization for fire offense and defense using fuelbreak systems. The fire-suppression organization determined for this study was at a much higher level and more specialized than the present organization on the Stanislaus Forest.

3. Looking for ways of reducing the cost factors that result in the high costs of fuelbreaks and fire control.

Integrated Land Management

When fuelbreak construction and maintenance was planned and carried out so that management functions accounted for 39 per cent of the costs, total costs of conflagration control were reduced almost $200,000 per year and the costs of fuelbreaks and fire suppression were reduced about $100,000 annually.

The very obvious implication here is that fire control is a service to all management functions. In order to let it be a service, management cannot be unilateral. Fire-control considerations must be threaded through all management planning and action programs on the fire forests of California. Only in this way can the most effective and economically efficient management of wildlands be achieved.

CHAPTER IX

SUMMARY AND CONCLUSIONS

This study has investigated conflagrations as a separate part of the forest-fire problem. It has been stressed that conflagrations are the critical forest-fire problem in California. Alternatives for solution to the conflagration problem have been considered, and fuelbreaks combined with a specialized fire-control organization were taken to be the most encouraging. An experiment on conflagration control involving fuelbreak systems was started on the Stanislaus National Forest in California and was described. A specially designed cost-accounting system was used to obtain the cost of construction and maintaining fuelbreaks. This study presented these costs--both work and total costs. These costs were synthesized with value of fire damage averted by conflagration control in an analysis of the economic efficiency of combining fuelbreaks and fire suppression. The marginal rate of substitution of fuelbreaks for fire suppression was found and integrated with the classic least-cost-plus-damage method of analysis to determine that:

1. Conflagration control through fuelbreaks combined with a complementary fire-suppression organization is economically justified on the Duckwall Unit. Furthermore, it is consistent with higher-level objectives in that it "holds fire losses (costs and damage) to

a level commensurate with values protected."[1] Even after adjusting for the risk of not holding fires on fuelbreaks, conflagration control still pays off.

2. Conflagration control will cost a lot of money. At the economic level it will cost in the order of $372,785 annually for fuelbreaks and $339,300 for fire suppression to protect timber and brush areas combined on the Duckwall Unit--assuming that 39 per cent of fuelbreak construction and maintenance is shared by management functions, and aircraft costs are shared on a forest basis. The point to be stressed here is that it appears that present values and the extent to which those values may be damaged by fire, of Duckwall Unit forestland, justify these costs. These costs represent the highest level of protection. They should be viewed as goals toward which financing should be aimed.

3. The combination of fuelbreaks and fire suppression at the economic level will have a reasonable chance of controlling fires at about 8 acres in timber and 3 acres in brush. These acreage objectives are based upon burning indexes of 24 in timber and 31 in brush. To reach these objectives, fires must be discovered before they are 0.2 of an acre in size, and report, getaway, and travel times are 2, 2, and 15 minutes, respectively. Present California objectives are to plan to "average worst" fire danger and hold all fires to 10 acres in size. "Average worst" on the Duckwall Unit is BI 24 in timber and BI 31 in brush. The economically justified levels of protection from conflagrations turn out to be at these burning indexes on the Duckwall Unit. With the help of fuelbreaks, California's average worst and 10 acre objective may be reached.

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[1] U.S., Forest Service, Forest Service Manual, sec. 5101.

As the intensity of use of wildlands increases, the forest-fire problem may be literally eliminated as forests change from wildlands with a high fuel hazard to parklike forests with a low fuel hazard. If this happens it will be at some distant time in the future, however. In the meantime, 3 per cent of the fires--the conflagrations--are causing up to 90 per cent of the damage. We cannot wait for the conflagration problem to be eliminated by intensive forest use. The job of reducing fuel hazard and more efficiently suppressing fires must begin now. This paper has presented and justified one promising solution to the conflagration problem.

APPENDIX

TABLE 27

CLASS D AND E FIRES, 1910-1959, ON THE DUCKWALL UNIT

Map No.	Year	Dates (from) (to)	Area in Acres	Name	Sup. No.[a]	Remarks (direction of spread)
1	1960	6/13 6/14	280	Crook	7	
2	1957	9/6 9/8	705	Mustang Gulch	30	
3	1950	9/3 9/9	24,956	Wrights Creek	44	S to N
4	1950	9/3 9/9	1,203	Bear Springs	49	W to E
5	1950	10-15 10/18	980	Hayward	66	S to W
6	1949	8/22 8/28	6,359	Walton Spur	65	W to E
7	1944	7/30 7/31	497	Spring Gulch	42	W to E
8	1944	9/21 9/22	200	Big Creek	63	N to S
9	1936	7/16 7/16	600	Duckwall Creek	17	S to N
10	1936	10/16 10/16	370	Paper Cabin	73	S to N
11	1934	8/17 8/18	700	Tuolumne	54	N to S
12	1934	8/22 8/24	1,670	Tuolumne Reservoir	58	W to E

[a]NE = none entered.

TABLE 27 (Continued)

Map No.	Year	Dates (from) (to)	Area in Acres	Name	Sup. No.	Remarks (direction of spread)
13	1933	8/20 8/20	115	Golden Stairs	NE	W to E
14	1931	4/16 4/21	601	Murphy	12	N to S
15	1929	6/20 7/1	190	Humbug	NE	N to S
16	1929	8/27 8/28	1,375	John Myers	NE	No map (Sec. 18 T1S R17E)
17	1919	9/1 9/13	1,110	Provo	NE	N to W
18	1929	8/19 8/26	37,690	Cave Diggings	NE	W to E
19	1928	7/15 7/17	2,815	Providence	NE	W to S & E
20	1927	7/6 7/7	250	Pickering Lumber Co. No. 1	NE	N to S
21	1926	7/17 7/19	1,000	Camp 9	NE	W to E
22	1925	12/13 12-17	346	Mt. Provo	NE	S to N
23	1925	9/5 9/6	1,020	Ingalls	NE	S to N
24	1924	7/6 7/9	4,000	Kassabaum	NE	S to N & W to E
25	1924	6/19 6/19	300	Eaton Point	NE	S to N

TABLE 27 (Continued)

Map No.	Year	Dates (from) (to)	Area in Acres	Name	Sup. No.	Remarks (direction of spread)
26	1923	8/2 8/3	200	Cave Diggings	NE	W to E
27	1921	6/5 6/6	250	Cave Diggings	NE	No map, E to N & S to N
28	1920	8/12 8/23	14,340	Hunter Bend	49	S to N
29	1919	10/13 10/15	240	Ingalls	29	No map, NW to SE
30	1917	9/30 10/6	3,500	Cave Diggings	48	
31	1916	7/5 7/5	100	Mustang Bridge	NE	No map, N to S
32	1914	8/8 8/9	220	New Albany Mine	NE	N to S
33	1910	8/20 8/25	1,900	Districts Fires No. 7	NE	No map

TABLE 28

FIRE SIZE IN ACRES OF CLASS D AND E FIRES BY COVER TYPE, 1910-1959, ON THE DUCKWALL UNIT[a]

Item	Cover Type	
	Timber	Brush
1	100	190
2	115	200
3	240	200
4	300	220
5	346	250
6	497	250
7	601	280
8	610	370
9	605	700
10	1,000	980
11	1,020	375
12	1,110	900
13	1,203	2,815
14	1,670	3,500
15	14,340	4,000
16	24,956	6,359
17		37,690
Total	48,813	61,279

[a]Averages: timber, 976 acres per year; brush, 1,225 acres per year; timber and brush combined, 2,202 acres per year.

TABLE 29

DAYS ON WHICH CLASS D AND E FIRES STARTED AND BURNED, 1910-1919, ON THE DUCKWALL UNIT[a]

Month	Timber, Area 370		Brush, Area 348	
	Dates Fires Started	Dates Fires Burned	Dates Fires Started	Dates Fires Burned
April	16	16-21	5	5, 6
June	19	19	5	5, 6
			13	13, 14
			30	30, 1
July	5	5	6	6-9
	16	16	15	15, 16
	17	17-19		
	30	30, 31		
August	20	20	2	2, 3
	22	22-24	8	8, 9
			12	12-23
			17	17, 18
			19	19-26
			20	20-25
			22	22-28
			27	27, 28
September . . .	3	3-9	21	21, 22
	5	5, 6	30	Oct. 1-6
	6	6-8		
	11	11-13		
October	13	13-17	15	15-18

[a]Summary: Fires burned on 78 days in brush and timber during the period 1910-1959. On 5 days fires were burning on same dates in brush and in timber. At no time were fires burning on same day in either brush or timber.

TABLE 30

WORK COST AND PRODUCTION SUMMARY FOR THE DUCKWALL UNIT[a]

Job	No. of Acres	Cost per Acre
Preattack Planning Project		
Preparation	3,820	$ 0.21
Field survey	3,820	0.91
Postsurvey activities	3,820	0.07
Tractor work by area contract		
Tractor work by hourly contract		
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Contract costs of snag felling		
Hand seeding		
Tractor and drill seeding		
Burning		
Mop-up and patrol		
Marking trees to be thinned		
Cutting access trails		
Felling trees		
Brushing		
Thinning		
Pruning		
Piling brush		
Machine chipping		
Swamper burning		
Total	3,820	$ 1.18

[a]Fire fueltypes: (1) grass; (3) mature timber, little chopping; (5) open manzanita, patchy brush; (6) timber, medium reproduction and brush; (13) heavy mixed brush; (15) second growth, medium poles, closed woodland, little chopping.

TABLE 30 (Continued)

Job	No. of Acres	Cost per Acre
Fuelbreak Clearing Project		
Preparation		
Field survey		
Postsurvey activities		
Tractor work by area contract	297	$ 41.13
Tractor work by hourly contract	301	48.00
Forest Service supervision of tractor clearing	438	0.68
Forest Service supervision of snag piling	351	0.06
Forest Service supervision of erosion control	543	0.07
Forest Service supervision of snag felling		
Contract costs of snag felling		
Hand seeding		
Tractor and drill seeding		
Burning		
Mop-up and patrol		
Marking trees to be thinned		
Cutting access trails		
Felling trees		
Brushing		
Thinning		
Pruning		
Piling brush		
Machine chipping		
Swamper burning		
Total	598	$ 45.39

TABLE 30 (Continued)

Job	No. of Snags	Cost per Acre
Snag Clearing Project		
Preparation		
Field survey		
Postsurvey activities		
Tractor work by area contract		
Tractor work by hourly contract		
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling	989	$ 0.09
Contract costs of snag felling	989	1.47
Hand seeding		
Tractor and drill seeding		
Burning		
Mop-up and patrol		
Marking trees to be thinned		
Cutting access trails		
Felling trees		
Brushing		
Thinning		
Pruning		
Piling brush		
Machine chipping		
Swamper burning		
Total	989	$ 1.56

TABLE 30 (Continued)

Job	No. of Acres	Cost per Acre
Grass Seeding Project		
Preparation		
Field survey		
Postsurvey activities		
Tractor work by area contract		
Tractor work by hourly contract		
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Contract costs of snag felling		
Hand seeding	36	$ 1.39
Tractor and drill seeding	256	18.07
Burning		
Mop-up and patrol		
Marking trees to be thinned		
Cutting access trails		
Felling trees		
Brushing		
Thinning		
Pruning		
Piling brush		
Machine chipping		
Swamper burning		
Total	292	$ 16.38

TABLE 30 (Continued)

Job	No. of Acres	Cost per Acre
Burning Project		
Preparation		
Field survey		
Postsurvey activities		
Tractor work by area contract		
Tractor work by hourly contract		
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Contract costs of snag felling		
Hand seeding		
Tractor and drill seeding		
Burning	973	$ 1.37
Mop-up and patrol	973	0.75
Marking trees to be thinned		
Cutting access trails		
Felling trees		
Brushing		
Thinning		
Pruning		
Piling brush		
Machine chipping		
Swamper burning		
Total	973	$ 2.13

TABLE 30 (Continued)

Job	No. of Acres	Cost per Acre
Hunter Creek Timber Sale, Fueltype 3		
Preparation		
Field survey		
Postsurvey activities		
Tractor work by area contract		
Tractor work by hourly contract	2.0	$ 17.19
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Contract costs of snag felling		
Hand seeding		
Tractor and drill seeding		
Burning		
Mop-up and patrol		
Marking trees to be thinned	2.0	4.38
Cutting access trails		
Felling trees		
Brushing	0.3	51.96
Thinning	2.0	38.61
Pruning	2.0	14.17
Piling brush	2.0	27.69
Machine chipping		
Swamper burning		
Total	2.0	$102.03

TABLE 30 (Continued)

Job	No. of Acres	Cost per Acre
Hunter Creek Timber Sale, Fueltype 15		
Preparation		
Field survey		
Postsurvey activities		
Tractor work by area contract		
Tractor work by hourly contract	3.0	$ 22.62
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Contract costs of snag felling		
Hand seeding		
Tractor and drill seeding		
Burning		
Mop-up and patrol		
Marking trees to be thinned	3.0	8.79
Cutting access trails		
Felling trees		
Brushing	6.6	65.48
Thinning	2.7	56.42
Pruning	1.7	30.79
Piling brush	5.3	17.47
Machine chipping		
Swamper burning		
Total	3.0	$135.69

TABLE 30 (Continued)

Job	No. of Acres	Cost per Acre
Hunter Creek Timber Sale, Fueltype 6		
Preparation		
Field survey		
Postsurvey activities		
Tractor work by area contract		
Tractor work by hourly contract	11.1	$ 18.97
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Contract costs of snag felling		
Hand seeding		
Tractor and drill seeding		
Burning		
Mop-up and patrol		
Marking trees to be thinned	11.1	1.54
Cutting access trails		
Felling trees		
Brushing	6.9	74.86
Thinning	4.3	68.94
Pruning	3.5	40.19
Piling brush	3.9	29.28
Machine chipping		
Swamper burning		
Total	11.1	$109.12

TABLE 30 (Continued)

Job	No. of Acres	Cost per Acre
Hunter Creek Timber Sale		
Preparation		
Field survey		
Postsurvey activities		
Tractor work by area contract		
Tractor work by hourly contract	16.1	$ 19.43
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Contract costs of snag felling		
Hand seeding		
Tractor and Drill seeding		
Burning		
Mop-up and patrol		
Marking trees to be thinned	16.1	3.24
Cutting access trails		
Felling trees		
Brushing	6.9	64.88
Thinning	9.0	58.44
Pruning	7.2	30.72
Piling brush	11.2	23.40
Machine chipping	12.1	39.13
Swamper burning	4.2	39.26
Total	16.1	$152.84

TABLE 30 (Continued)

Job	No. of Acres	Cost per Acre
Hunter Creek Handline, Total, Fueltype 6		
Preparation		
Field survey		
Postsurvey activities		
Tractor work by area contract		
Tractor work by hourly contract		
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Contract costs of snag felling		
Hand seeding		
Tractor and drill seeding		
Burning		
Mop-up and patrol		
Marking trees to be thinned		
Cutting access trails	0.40	$150.00
Felling trees	0.34	88.53
Brushing	1.93	141.55
Thinning		
Pruning	0.46	63.87
Piling brush	2.33	94.80
Machine chipping		
Swamper burning		
Total	2.33	$263.44

TABLE 30 (Continued)

Job	No. of Acres	Cost per Acre
Sugarloaf Clearing Project, Fueltype 6		
Preparation		
Field survey		
Postsurvey activities		
Tractor work by area contract		
Tractor work by hourly contract		
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Contract costs of snag felling		
Hand seeding		
Tractor and drill seeding		
Burning		
Mop-up and patrol		
Marking trees to be thinned		
Cutting access trails		
Felling trees	38.0	$ 2.65
Brushing	42.8	5.07
Thinning		
Pruning	42.8	4.52
Piling brush	42.8	6.51
Machine chipping		
Swamper burning		
Total	42.8	$ 18.43

TABLE 30 (Continued)

Job	No. of Acres	Cost per Acre
Sugarloaf Clearing Project, Fueltype 5		
Preparation		
Field survey		
Postsurvey activities		
Tractor work by area contract		
Tractor work by hourly contract		
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Contract costs of snag felling		
Hand seeding		
Tractor and drill seeding		
Burning		
Mop-up and patrol		
Marking trees to be thinned		
Cutting access trails		
Felling trees	15.0	$ 1.16
Brushing	19.2	3.13
Thinning		
Pruning	19.2	3.15
Piling brush	19.2	2.35
Machine chipping		
Swamper burning		
Total	19.2	$ 9.56

TABLE 30 (Continued)

Job	No. of Acres	Cost per Acre
Sugarloaf Clearing Project, Total		
Preparation		
Field survey		
Postsurvey activities		
Tractor work by area contract		
Tractor work by hourly contract		
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Contract cost of snag felling		
Hand seeding		
Tractor and drill seeding		
Burning		
Mop-up and patrol		
Marking trees to be thinned		
Cutting access trails		
Felling trees	53	$ 2.23
Brushing	63	4.40
Thinning		
Pruning	63	4.03
Piling brush	63	5.14
Machine chipping		
Swamper burning		
Total	63	$ 15.45

TABLE 30 (Continued)

Job	No. of Acres	Cost per Acre
Sugarloaf Handline Project, Fueltype 5		
Preparation		
Field survey		
Postsurvey activities		
Tractor work by area contract		
Tractor work by hourly contract		
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Contract cost of snag felling		
Hand seeding		
Tractor and drill seeding		
Burning		
Mop-up and patrol		
Marking trees to be thinned		
Cutting access trails		
Felling trees		
Brushing	1.56	$ 33.21
Thinning		
Pruning		
Piling brush	1.56	27.60
Machine chipping		
Swamper burning		
Total	1.56	$ 60.73

TABLE 30 (Continued)

Job	No. of Acres	Cost per Acre
Sugarloaf Handline Project, Fueltype 13		
Preparation		
Field survey		
Postsurvey activities		
Tractor work by area contract		
Tractor work by hourly contract		
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Contract costs of snag felling		
Hand seeding		
Tractor and Drill seeding		
Burning		
Mopup and Patrol		
Marking trees to be thinned		
Cutting access trails	0.18	$359.11
Felling trees		
Brushing	1.50	247.81
Thinning		
Pruning		
Piling brush	1.68	107.10
Machine chipping		
Swamper burning		
Total	1.68	$366.73

TABLE 30 (Continued)

Job	No. of Acres	Cost per Acre
Sugarloaf Handline Project, Fueltype 1		
Preparation		
Field survey		
Postsurvey activities		
Tractor work by area contract		
Tractor work by hourly contract		
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Contract costs of snag felling		
Hand seeding		
Tractor and drill seeding		
Burning		
Mop-up and patrol		
Marking trees to be thinned		
Cutting access trails		
Felling trees		
Brushing	0.41	$ 68.41
Thinning		
Pruning		
Piling brush	0.41	72.44
Machine chipping		
Swamper burning		
Total	0.41	$140.85

TABLE 30 (Continued)

Job	No. of Acres	Cost per Acre
Sugarloaf Handline Project, Total		
Preparation		
Field survey		
Postsurvey activities		
Tractor work by area contract		
Tractor work by hourly contract		
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Contract cost of snag felling		
Hand seeding		
Tractor and drill seeding		
Burning		
Mop-up and patrol		
Marking trees to be thinned		
Cutting access trails	0.18	$359.11
Felling trees		
Brushing	3.47	130.10
Thinning		
Pruning		
Piling brush	3.65	69.19
Machine chipping		
Swamper burning		
Total	3.65	$210.56

TABLE 31

TOTAL COST AND PRODUCTION SUMMARY
FOR THE DUCKWALL UNIT

Job	No. of Acres	Cost per Acre
Preattack Planning Project		
Planning	3,820	$ 0.15
Preparation	3,820	0.22
Field survey	3,820	1.02
Tractor clearing by area contract		
Tractor clearing by hourly contract		
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Snag counting by Forest Service		
Contract costs of snag felling		
Felling snags (Forest Service crews)		
Cutting access trails		
Brushing		
Marking trees to be thinned		
Thinning		
Pruning		
Piling brush		
Machine chipping		
Burning		
Mop-up and patrol		
Mixing seed		
Hand seeding		
Tractor and drill seeding		
Safety meetings		
Maintenance and on-the-job repairs		
Postfieldwork activities	3,820	0.07
Parts, supplies, and repairs	3,820	0.24
Meals		
Logging costs		
Indirect costs	3,820	0.60
Total cost per acre		$ 2.30

TABLE 31 (Continued)

Job	No. of Acres	Cost per Acre
Fuelbreak Clearing Project		
Planning		
Preparation		
Field survey		
Tractor clearing by area contract	297	$ 41.13
Tractor clearing by hourly contract	301	48.00
Forest Service supervision of tractor clearing	438	1.23
Forest Service supervision of snag piling	351	0.11
Forest Service supervision of erosion control	543	0.11
Forest Service supervision of snag felling		
Snag counting by Forest Service		
Contract costs of snag felling		
Felling snags (Forest Service crews)		
Cutting access trails		
Brushing		
Marking trees to be thinned		
Thinning		
Pruning		
Piling brush		
Machine chipping		
Burning		
Mop-up and patrol		
Mixing seed		
Hand seeding		
Tractor and drill seeding		
Safety meetings		
Maintenance and on-the-job repairs		
Postfieldwork activities		
Parts, supplies, and repairs		
Meals		
Logging costs		
Indirect costs	598	0.60
Total cost per acre		$ 2.05

TABLE 31 (Continued)

Job	No. of Snags	Cost per Acre
Snag Clearing Project		
Planning		
Preparation		
Field survey		
Tractor clearing by area contract		
Tractor clearing by hourly contract		
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling	989	$ 0.15
Snag counting by Forest Service	989	0.06
Contract costs of snag felling	989	1.47
Felling snags (Forest Service crews)	9	3.97
Cutting access trails		
Brushing		
Marking trees to be thinned		
Thinning		
Pruning		
Piling brush		
Machine chipping		
Burning		
Mop-up and patrol		
Mixing seed		
Hand seeding		
Tractor and drill seeding		
Safety meetings		
Maintenance and on-the-job repairs		
Postfieldwork activities		
Parts, supplies, and repairs		
Meals		
Logging costs		
Indirect costs	989	0.37
Total cost per acre		$ 2.05

TABLE 31 (Continued)

Job	No. of Acres	Cost per Acre
Sugarloaf Clearing Project		
Planning		
Preparation		
Field survey		
Tractor clearing by area contract		
Tractor clearing by hourly contract		
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Snag counting by Forest Service		
Contract costs of snag felling		
Felling snags (Forest Service crews)	53	$ 2.70
Cutting access trails		
Brushing	63	5.23
Marking trees to be thinned		
Thinning		
Pruning	63	4.92
Piling brush	63	6.38
Machine chipping		
Burning		
Mop-up and patrol		
Mixing seed		
Hand seeding		
Tractor and drill seeding		
Safety meetings		
Maintenance and on-the-job repairs	63	0.29
Postfieldwork activities		
Parts, supplies, and repairs	63	1.66
Meals	63	1.66
Logging costs		
Indirect costs	63	0.60
Total cost per acre		$ 23.02

TABLE 31 (Continued)

Job	No. of Acres	Cost per Acre
Sugarloaf Handline Project		
Planning		
Preparation		
Field survey		
Tractor clearing by area contract		
Tractor clearing by hourly contract		
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Snag counting by Forest Service		
Contract costs of snag felling		
Felling snags (Forest Service crews)		
Cutting access trails	0.18	$489.77
Brushing	3.47	176.64
Marking trees to be thinned		
Thinning		
Pruning		
Piling brush	3.65	96.76
Machine chipping		
Burning		
Mop-up and patrol		
Mixing seed		
Hand seeding		
Tractor and drill seeding		
Safety meetings		
Maintenance and on-the-job repairs	3.65	5.65
Postfieldwork activities		
Parts, supplies, and repairs	3.65	20.02
Meals	3.65	26.55
Logging costs		
Indirect costs	3.65	0.60
Total cost per acre		$351.62

TABLE 31 (Continued)

Job	No. of Acres	Cost per Acre
Hunter Creek Handline Project		
Planning		
Preparation		
Field survey		
Tractor clearing by area contract		
Tractor clearing by hourly contract		
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Snag counting by Forest Service		
Contract costs of snag felling		
Felling snags (Forest Service crews)	0.34	$105.09
Cutting access trails	0.40	195.70
Brushing	1.93	176.34
Marking trees to be thinned		
Thinning		
Pruning	0.46	86.61
Piling brush	2.33	122.71
Machine chipping		
Burning		
Mop-up and patrol		
Mixing seed		
Hand seeding		
Tractor and drill seeding		
Safety meetings		
Maintenance and on-the-job repairs	2.33	36.67
Postfieldwork activities		
Parts, supplies, and repairs	2.33	51.79
Meals	2.33	9.85
Logging costs		
Indirect costs	2.33	0.60
Total cost per acre		$433.79

TABLE 31 (Continued)

Job	No. of Acres	Cost per Acre
Hunter Creek Timber Sale		
Planning		
Preparation	12.1	$ 3.08
Field survey		
Tractor clearing by area contract		
Tractor clearing by hourly contract	16.1	23.76
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Snag counting by Forest Service		
Contract costs of snag felling		
Felling snags (Forest Service crew)		
Cutting access trails		
Brushing		
Marking trees to be thinned	16.1	4.01
Thinning	9.0	70.37
Pruning	7.2	37.41
Piling brush	11.2	28.97
Machine chipping	12.1	45.24
Burning	4.2	45.96
Mop-up and patrol		
Mixing seed		
Hand seeding		
Tractor and drill seeding		
Safety meetings	16.3	3.44
Maintenance and on-the-job repairs		
Postfieldwork activities	12.1	3.08
Parts, supplies, and repairs	16.1	8.83
Meals		
Logging costs	16.1	162.62
Indirect costs	16.1	0.60
Total cost per acre		$358.28

TABLE 31 (Continued)

Job	No. of Acres	Cost per Acre
Burning Project		
Planning	973	$ 0.08
Preparation	973	0.14
Field survey		
Tractor clearing by area contract		
Tractor clearing by hourly contract		
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Snag counting by Forest Service		
Contract costs of snag felling		
Felling snags (Forest Service crew)		
Cutting access trails		
Brushing		
Marking trees to be thinned		
Thinning		
Pruning		
Piling brush		
Machine chipping		
Burning	973	1.62
Mop-up and patrol	973	0.83
Mixing seed		
Hand seeding		
Tractor and drill seeding		
Safety meetings		
Maintenance and on-the-job repairs		
Postfieldwork activities	973	0.17
Parts, supplies, and repairs	973	0.32
Meals		
Logging costs		
Indirect costs	973	0.60
Total cost per acre		$ 3.44

TABLE 31 (Continued)

Job	No. of Acres	Cost per Acre
Seeding Project		
Planning		
Preparation	292	$ 1.46
Field survey		
Tractor clearing by area contract		
Tractor clearing by hourly contract		
Forest Service supervision of tractor clearing		
Forest Service supervision of snag piling		
Forest Service supervision of erosion control		
Forest Service supervision of snag felling		
Snag counting by Forest Service		
Contract costs of snag felling		
Felling snags (Forest Service crew)		
Cutting access trails		
Brushing		
Marking trees to be thinned		
Thinning		
Pruning		
Piling brush		
Machine chipping		
Burning		
Mop-up and patrol		
Mixing seed	292	0.31
Hand seeding	36	5.56
Tractor and drill seeding	256	19.07
Safety meetings		
Maintenance and on-the-job repairs		
Postfieldwork activities	292	0.45
Parts, supplies, and repairs	292	0.65
Meals		
Logging costs		
Indirect costs	292	0.60
Total cost per acre		$ 20.87

TABLE 32

SOURCES OF FUELBREAK CONSTRUCTION COSTS FOR TIMBER IN FIRE-DANGER RATING AREA 370

Job	Source
Handline:	
Planning	Preattack planning project
Construction	Hunter Creek handline project
Swamper burning	Hunter Creek timber sale project
Safety meetings	Hunter Creek timber sale project (adjusted for one meeting per week)
Tractor line:	
Planning	Preattack planning project
Construction	Hunter Creek timber sale project
Safety meetings	Hunter Creek timber sale project (adjusted for one meeting per week)

TABLE 33

SOURCES OF FUELBREAK CONSTRUCTION COSTS FOR BRUSH IN FIRE-DANGER RATING AREA 348

Job	Source
Handline:	
Planning	Preattack planning project
Construction	Sugarloaf handline project
Swamper burning	Hunter Creek timber sale project
Hand seeding	Seeding project (includes planning, mixing)
Safety meetings	Hunter Creek timber sales (adjusted for one meeting per week)
Tractor line:	
Planning	Preattack planning project
Fuelbreak clearing	Sugarloaf clearing project
Snag clearing	Snag clearing project
Burning	Burning project
Seeding	Seeding project
Safety meetings	Hunter Creek timber sales (adjusted for one meeting per week)

TABLE 34

PER ACRE AND TOTAL FUELBREAK CONSTRUCTION COSTS FOR LEVEL I, TIMBER, ON THE DUCKWALL UNIT

Job	No. of Acres	Cost per Acre	Total Cost
Handline:			
Planning preparation	80	$ 2.30	
Construction	80	433.79	
Swamper burning	80	45.96	
Safety meetings	80	2.10	
Total	80	$484.15	$ 38,732
Tractor line:			
Planning	588	$ 2.30	
Construction	588	358.28	
Safety meetings	588	2.10	
Total	588	$362.68	213,256
Total cost			$251,981

TABLE 35

PER ACRE AND TOTAL FUELBREAK CONSTRUCTION COSTS FOR LEVEL I, BRUSH, ON THE DUCKWALL UNIT

Job	No. of Acres	Cost per Acre	Total Cost
Handline:			
Planning, preparation	71	$ 2.30	
Construction	71	351.62	
Swamper burning	71	45.96	
Seeding (hand)	71	7.53	
Safety meetings	71	2.10	
Total	71	$409.51	$29,075
Tractor line:			
Planning, preparation	417	$ 2.30	
Fuelbreak clearing	417	46.46	
Snag clearing	417	2.05	
Handwork	417	23.02	
Burning	417	3.44	
Seeding	417	20.87	
Safety meetings	417	2.10	
Total	417	$101.55	42,346
Total cost			$71,421

TABLE 36

PER ACRE AND TOTAL FUELBREAK CONSTRUCTION COSTS FOR LEVEL II, TIMBER, ON THE DUCKWALL UNIT

Job	No. of Acres	Cost per Acre	Total Cost
Handline:			
Planning, preparation . . .	123	$ 2.30	
Construction	123	433.79	
Swamper burning	123	45.96	
Safety meetings	123	2.10	
Total	123	$484.15	$ 59,550
Tractor line:			
Planning, preparation . . .	1,925	$ 2.30	
Construction	1,925	358.28	
Safety meetings	1,925	2.10	
Total	1,925	$362.68	698,159
Total cost			$757,709

TABLE 37

PER ACRE AND TOTAL FUELBREAK CONSTRUCTION COSTS FOR LEVEL II, BRUSH, ON THE DUCKWALL UNIT

Job	No. of Acres	Cost per Acre	Total Cost
Handline:			
Planning, preparation	130	$ 2.30	
Construction	130	351.62	
Swamper burning	130	45.96	
Seeding (hand)	130	7.53	
Safety meetings	130	2.10	
Total	130	$409.51	$ 53,236
Tractor line:			
Planning, preparation	531	$ 2.30	
Fuelbreak clearing	531	46.46	
Snag clearing	531	2.05	
Handwork	531	23.02	
Burning	531	3.44	
Seeding	531	20.87	
Safety meetings	531	2.10	
Total	531	$101.55	53,923
Total cost			$107,159

TABLE 38

PER ACRE AND TOTAL FUELBREAK CONSTRUCTION COSTS FOR LEVEL III, TIMBER, ON THE DUCKWALL UNIT

Job	No. of Acres	Cost per Acre	Total Cost
Handline:			
Planning, preplanning . . .	149	$ 2.30	
Construction	149	433.79	
Swamper burning	149	45.96	
Safety meetings	149	2.10	
Total	149	$484.15	$ 72,138
Tractor line:			
Planning, preparation . . .	2,180	$ 2.30	
Construction	2,180	358.28	
Safety meetings	2,180	2.10	
Total	2,180	$362.68	790,642
Total cost			$862,780

TABLE 39

PER ACRE AND TOTAL FUELBREAK CONSTRUCTION COSTS FOR LEVEL III, BRUSH, ON THE DUCKWALL UNIT

Job	No. of Acres	Cost per Acre	Total Cost
Handline:			
Planning, preparation	178	$ 2.30	
Construction	178	351.62	
Swamper burning	178	48.96	
Seeding (hand)	178	7.53	
Safety meetings	178	2.10	
Total	178	$409.51	$ 72,893
Tractor line:			
Planning, preparation	819	$ 2.30	
Fuelbreak clearing	819	46.46	
Snag clearing	819	2.05	
Handwork	819	23.02	
Burning	819	3.44	
Seeding	819	20.87	
Safety meetings	819	2.10	
Total	819	$101.55	83,169
Total cost			$156,062

TABLE 40

PER ACRE AND TOTAL FUELBREAK CONSTRUCTION COSTS FOR LEVEL IV, TIMBER, ON THE DUCKWALL UNIT

Job	No. of Acres	Cost per Acre	Total Cost
Handline:			
Planning, preparation . .	448	$ 2.30	
Construction	448	433.79	
Swamper burning	448	45.96	
Safety meetings	448	2.10	
Total	448	$484.16	$ 216,904
Tractor line:			
Planning, preparation . .	2,513	$ 2.30	
Construction	2,513	358.28	
Safety meetings	2,513	2.10	
Total	2,513	$362.68	911,415
Total cost			$1,128,319

TABLE 41

PER ACRE AND TOTAL FUELBREAK CONSTRUCTION COSTS FOR LEVEL IV, BRUSH, ON THE DUCKWALL UNIT

Job	No. of Acres	Cost per Acre	Total Cost
Handline:			
Planning, preparation	265	$ 2.30	
Construction	265	351.62	
Swamper burning	265	45.96	
Seeding (hand)	265	7.53	
Safety meetings	265	2.10	
Total	265	$409.51	$108,520
Tractor line:			
Planning, preparation	893	$ 2.30	
Fuelbreak clearing	893	46.46	
Snag clearing	893	2.05	
Handwork	893	23.02	
Burning	893	3.44	
Seeding	893	20.87	
Safety meetings	893	2.10	
Total	893	$101.55	90,684
Total cost			$199,204

TABLE 42

CONSTRUCTION AND MAINTENANCE SCHEDULE FOR LEVEL I, MINIMUM INTENSITY, ON THE DUCKWALL UNIT

Job	No. of Acres	Cost per Acre	Total Cost
	1963		
Construction:			
Timber:			
Construction	133.6		$ 50,396
Brush:			
Construction	97.6		14,284
Spray regrowth			
F.S. supervision of spray job			
Total			$ 64,680
Maintenance:			
Timber:			
Planning and preparation			
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation			
Fuelbreak clearing			
Snag clearing			
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control			
Parts and supplies			
Safety meetings			
Meals			
Total			
Timber and brush:			
Indirect assessment			$ 4,132
Total yearly cost			$ 68,812

TABLE 42 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1964		
Construction:			
Timber:			
Construction	133.6		$ 50,396
Brush:			
Construction	97.6		14,284
Spray regrowth	97.6	$ 14.60	1,425
F.S. supervision of spray job	97.6	1.23	120
Total			$ 66,225
Maintenance:			
Timber:			
Planning and preparation	133.6	$ 0.25	$ 33
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	97.6	0.25	$ 24
Fuelbreak clearing			
Snag clearing	97.6	1.12	109
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	231.2	1.00	$ 231
Parts and supplies			
Safety meetings			
Meals			
Total			$ 397
Timber and brush:			
Indirect assessment			$ 4,132
Total yearly cost			$ 70,754

TABLE 42 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1965		
Construction:			
Timber:			
Construction	133.6		$ 50,396
Brush:			
Construction	97.6		14,284
Spray regrowth	195.2	$ 14.60	2,850
F.S. supervision of spray job	195.2	1.23	240
Total			$ 67,770
Maintenance:			
Timber:			
Planning and preparation	133.6		$ 33
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	97.6	$ 0.25	24
Fuelbreak clearing			
Snag clearing	97.6	1.12	109
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	462.4	0.53	245
Parts and supplies			
Safety meetings			
Meals			
Total			$ 411
Timber and brush:			
Indirect assessment			$ 4,132
Total yearly cost			$ 72,313

TABLE 42 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
1966			
Construction:			
Timber:			
Construction	133.6		$ 50,396
Brush:			
Construction	97.6		14,284
Spray regrowth	292.8	$ 14.60	4,275
F.S. supervision of spray job	292.8	1.23	360
Total			$ 69,315
Maintenance:			
Timber:			
Planning and preparation	133.6	$ 0.25	$ 33
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	97.6	0.25	24
Fuelbreak clearing			
Snag clearing	97.6	1.12	109
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	693.6	0.37	260
Parts and supplies			
Safety meetings			
Meals			
Total			$ 426
Timber and brush:			
Indirect assessment			$ 4,132
Total yearly cost			$ 73,873

TABLE 42 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1967		
Construction:			
Timber:			
Construction	133.6		$ 50,396
Brush:			
Construction	97.6		14,284
Spray regrowth	192.8	$ 14.60	4,275
F.S. supervision of spray job	292.8	1.23	360
Total			$ 69,315
Maintenance:			
Timber:			
Planning and preparation	133.6	$ 0.25	$ 33
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	97.6	0.25	24
Fuelbreak clearing			
Snag clearing	97.6	1.12	109
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	924.8	0.30	275
Parts and supplies			
Safety meetings			
Meals			
Total			$ 441
Timber and brush:			
Indirect assessment			$ 4,132
Total yearly cost			$ 73,888

TABLE 42 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
1968			
Construction:			
Timber:			
Construction			
Brush:			
Construction			
Spray regrowth	292.8	$ 14.60	$ 4,275
F.S. supervision of spray job	292.8	1.23	360
Total			$ 4,635
Maintenance:			
Timber:			
Planning and preparation	133.6	$ 0.25	$ 33
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	97.6	0.25	24
Fuelbreak clearing			
Snag clearing	97.6	1.12	109
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	1,156	0.25	289
Parts and supplies			
Safety meetings			
Meals			
Total			$ 455
Timber and brush:			
Indirect assessment			$ 60
Total yearly cost			$ 5,150

TABLE 42 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
1969			
Construction:			
Timber:			
Construction			
Brush:			
Construction			
Spray regrowth	195.2	$ 14.60	$ 2,850
F.S. supervision of spray job	195.2	1.23	240
Total			$ 3,090
Maintenance:			
Timber:			
Planning and preparation	133.6	$ 0.25	$ 33
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	97.6	0.25	24
Fuelbreak clearing			
Snag clearing	97.6	1.12	109
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	1,156	0.25	289
Parts and supplies			
Safety meetings			
Meals			
Total			$ 455
Timber and brush:			
Indirect assessment			$ 60
Total yearly cost			$ 3,605

TABLE 42 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
1970			
Construction:			
Timber:			
Construction			
Brush:			
Construction			
Spray regrowth	97.6	$ 14.60	$ 1,425
F.S. supervision of spray job	97.6	1.23	120
Total			$ 1,545
Maintenance:			
Timber:			
Planning and preparation	133.6	$ 0.25	$ 33
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	97.6	0.25	24
Fuelbreak clearing			
Snag clearing	97.6	1.12	109
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	1,156	0.25	289
Parts and supplies			
Safety meetings			
Meals			
Total			$ 455
Timber and brush:			
Indirect assessment			$ 60
Total yearly cost			$ 2,060

TABLE 42 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1971		
Construction:			
Timber:			
Construction			
Brush:			
Construction			
Spray regrowth			
F.S. supervision of spray job .			
Total			
Maintenance:			
Timber:			
Planning and preparation	133.6	$ 0.25	$ 33
Construction (handline)	16	101.20	1,619
Construction (tractor line) . . .	117.6	52.48	6,172
Brush:			
Planning and preparation	97.6	0.25	24
Fuelbreak clearing	4.0	46.46	186
Snag clearing	97.6	1.12	109
Construction (handline)	14.2	65.38	928
Handwork (tractor line)	83.4	14.00	1,168
Timber and brush:			
Erosion control	1,156	0.25	289
Parts and supplies	231.2	0.85	197
Safety meetings	231.2	0.85	197
Meals	231.2	2.57	594
Total			$ 11,476
Timber and brush:			
Indirect assessment			$ 105
Total yearly cost			$115,581

TABLE 43

CONSTRUCTION AND MAINTENANCE SCHEDULE FOR LEVEL II, MEDIUM INTENSITY, ON THE DUCKWALL UNIT

Job	No. of Acres	Cost per Acre	Total Cost
1963			
Construction:			
Timber:			
Construction	409.6		$151,542
Brush:			
Construction	132.2		21,432
Spray regrowth			
F.S. supervision of spray job			
Total			$172,974
Maintenance:			
Timber:			
Planning and preparation			
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation			
Fuelbreak clearing			
Snag clearing			
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control			
Parts and supplies			
Safety meetings			
Meals			
Total			
Timber and brush:			
Indirect assessment			$ 4,132
Total yearly cost			$177,106

TABLE 43 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1964		
Construction:			
Timber:			
Construction	409.6		$151,542
Brush:			
Construction	132.2		21,432
Spray regrowth	132.2	$ 14.60	1,930
F.S. supervision of spray job	132.2	1.23	163
Total			$175,067
Maintenance:			
Timber:			
Planning and preparation	409.6	$ 0.25	$ 102
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	132.2	0.25	33
Fuelbreak clearing			
Snag clearing	132.2	1.12	148
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	541.8	1.00	542
Parts and supplies			
Safety meetings			
Meals			
Total			$ 825
Timber and brush:			
Indirect assessment			$ 4,132
Total yearly cost			$180,024

TABLE 43 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1965		
Construction:			
Timber:			
Construction	409.6		$151,542
Brush:			
Construction	132.2		21,432
Spray regrowth	264.4	$ 14.60	3,860
F.S. supervision of spray job	264.4	1.23	325
Total			$177,159
Maintenance:			
Timber:			
Planning and preparation	409.6	$ 0.25	$ 102
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	132.2	0.25	33
Fuelbreak clearing			
Snag clearing	132.2	1.12	148
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	1,083.6	0.53	574
Parts and supplies			
Safety meetings			
Meals			
Total			$ 857
Timber and brush:			
Indirect assessment			$ 4,132
Total yearly cost			$182,148

TABLE 43 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
1966			
Construction:			
Timber:			
Construction			$151,542
Brush:			
Construction	132.2		21,432
Spray regrowth	396.6	$ 14.60	5,790
F.S. supervision of spray job	396.6	1.23	488
Total			$179,252
Maintenance:			
Timber:			
Planning and preparation	409.6	$ 0.25	$ 102
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	132.2	0.25	33
Fuelbreak clearing			
Snag clearing	132.2	1.12	148
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	1,625.4	0.37	601
Parts and supplies			
Safety meetings			
Meals			
Total			$ 884
Timber and brush:			
Indirect assessment			$ 4,132
Total yearly cost			$184,268

TABLE 43 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1967		
Construction:			
Timber:			
Construction			$151,542
Brush:			
Construction	132.2		21,432
Spray regrowth	396.6	$ 14.60	5,790
F.S. supervision of spray job	396.6	1.23	488
Total			$179,252
Maintenance:			
Timber:			
Planning and preparation	409.6	$ 0.25	$ 102
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	132.2	0.25	33
Fuelbreak clearing			
Snag clearing	132.2	1.12	148
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	2,167.2	0.30	650
Parts and supplies			
Safety meetings			
Meals			
Total			$ 933
Timber and brush:			
Indirect assessment			$ 4,132
Total yearly cost			$184,317

TABLE 43 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1968		
Construction:			
Timber:			
Construction			
Brush:			
Construction			
Spray regrowth	396.6	$ 14.60	$ 5,790
F.S. supervision of spray job .	396.6	1.23	488
Total			$ 6,278
Maintenance:			
Timber:			
Planning and preparation	409.6	$ 0.25	$ 102
Construction (handline)			
Construction (tractor line) . . .			
Brush:			
Planning and preparation	409.6	0.25	102
Fuelbreak clearing			
Snag clearing	132.2	1.12	148
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	2,709	0.25	677
Parts and supplies			
Safety meetings			
Meals			
Total			$ 960
Timber and brush:			
Indirect assessment			$ 120
Total yearly cost			$ 7,358

TABLE 43 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
1969			
Construction:			
Timber:			
Construction			
Brush:			
Construction			
Spray regrowth	264.4	$ 14.60	$ 3,860
F.S. supervision of spray job	264.4	1.23	325
Total			$ 4,185
Maintenance:			
Timber:			
Planning and preparation	409.6	$ 0.25	$ 102
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	132.2	0.25	33
Fuelbreak clearing			
Snag clearing	132.2	1.12	148
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	2,709	0.25	677
Parts and supplies			
Safety meetings			
Meals			
Total			$ 960
Timber and brush:			
Indirect assessment			$ 120
Total yearly cost			$ 5,265

TABLE 43 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1970		
Construction:			
Timber:			
Construction			
Brush:			
Construction			
Spray regrowth	132.2	$ 14.60	$ 1,930
F.S. supervision of spray job	132.2	1.23	163
Total			$ 2,093
Maintenance:			
Timber:			
Planning and preparation	409.6	$ 0.25	$ 102
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	132.2	0.25	33
Fuelbreak clearing			
Snag clearing	132.2	0.25	148
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	2,709	0.25	677
Parts and supplies			
Safety meetings			
Meals			
Total			$ 960
Timber and brush:			
Indirect assessment			$ 120
Total yearly cost			$ 3,173

TABLE 43 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1971		
Construction:			
Timber:			
Construction			
Brush:			
Construction			
Spray regrowth			
F.S. supervision of spray job			
Total			
Maintenance:			
Timber:			
Planning and preparation	409.6	$ 0.25	$ 102
Construction (handline)	24.6	101.20	2,490
Construction (tractor line)	385	52.48	20,205
Brush:			
Planning and preparation	132.2	0.25	33
Fuelbreak clearing	5.4	46.46	251
Snag clearing	132.2	1.12	148
Construction (handline)	26	65.38	1,700
Handwork (tractor line)	106.2	14.00	1,468
Timber and brush:			
Erosion control	2,709	0.25	677
Parts and supplies	541.8	0.85	461
Safety meetings	541.8	0.68	368
Meals	541.8	2.57	1,392
Total			$ 29,741
Timber and brush:			
Indirect assessment			$ 210
Total yearly cost			$ 29,951

TABLE 44

CONSTRUCTION AND MAINTENANCE SCHEDULE FOR LEVEL III, MODERATE INTENSITY, ON THE DUCKWALL UNIT

Job	No. of Acres	Cost per Acre	Total Cost
1963			
Construction:			
Timber:			
Construction	465.8		$172,556
Brush:			
Construction	199.4		31,212
Spray regrowth			
F.S. supervision of spray job			
Total			$203,768
Maintenance:			
Timber:			
Planning and preparation			
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation			
Fuelbreak clearing			
Snag clearing			
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control			
Parts and supplies			
Safety meetings			
Meals			
Total			
Timber and brush:			
Indirect assessment			$ 4,132
Total yearly cost			$207,900

TABLE 44 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
1964			
Construction:			
Timber:			
Construction	465.8		$172,556
Brush:			
Construction	199.4		31,212
Spray regrowth	199.4	$ 14.60	2,911
F.S. supervision of spray job	199.4	1.23	245
Total			$206,924
Maintenance:			
Timber:			
Planning and preparation	465.8	$ 0.25	$ 116
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	199.4	0.25	50
Fuelbreak clearing			
Snag clearing	199.4	1.12	223
Construction (handline)			
Handwork (tractorline)			
Timber and brush:			
Erosion control	665.2	1.00	665
Parts and supplies			
Safety meetings			
Meals			
Total			$ 1,054
Timber and brush:			
Indirect assessment			$ 4,132
Total yearly cost			$212,110

TABLE 44 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1965		
Construction:			
Timber:			
Construction	465.8		$172,556
Brush:			
Construction	199.4		31,212
Spray regrowth	398.8	$ 14.60	5,822
F.S. supervision of spray job	398.8	1.23	491
Total			$210,081
Maintenance:			
Timber:			
Planning and preparation	465.8	$ 0.25	$ 116
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	199.4	0.25	50
Fuelbreak clearing			
Snag clearing	199.4	1.12	223
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	1,330.4	0.53	705
Parts and supplies			
Safety meetings			
Meals			
Total			$ 1,094
Timber and brush:			
Indirect assessment			$ 4,132
Total yearly cost			$215,307

TABLE 44 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1966		
Construction:			
Timber:			
Construction	465.8		$172,556
Brush:			
Construction	199.4		31,212
Spray regrowth	598.2	$ 14.60	8,734
F.S. supervision of spray job	598.2	1.23	736
Total			$213,238
Maintenance:			
Timber:			
Planning and preparation	465.8	$ 0.25	$ 116
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	199.4	0.25	50
Fuelbreak clearing			
Snag clearing	199.4	1.12	223
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	1,995.6	0.37	738
Parts and supplies			
Safety meetings			
Meals			
Total			$ 1,127
Timber and brush:			
Indirect assessment			$ 4,132
Total yearly cost			$218,497

TABLE 44 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1967		
Construction:			
Timber:			
Construction	465.8		$172,556
Brush:			
Construction	199.4		31,212
Spray regrowth	598.2	$ 14.60	8,734
F.S. supervision of spray job	598.2	1.23	736
Total			$213,238
Maintenance:			
Timber:			
Planning and preparation	465.8	$ 0.25	$ 116
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	199.4	0.25	50
Fuelbreak clearing			
Snag clearing	199.4	1.12	223
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	2,660.8	0.30	798
Parts and supplies			
Safety meetings			
Meals			
Total			$ 1,187
Timber and brush:			
Indirect assessment			$ 4,132
Total yearly cost			$218,557

TABLE 44 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
1968			
Construction:			
Timber:			
Construction			
Brush:			
Construction			
Spray regrowth	598.2	$ 14.60	$ 8,734
F.S. supervision of spray job	598.2	1.23	736
Total			$ 9,470
Maintenance:			
Timber:			
Planning and preparation	465.8	$ 0.25	$ 116
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	199.4	0.25	50
Fuelbreak clearing			
Snag clearing	199.4	1.12	223
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	3,326	0.25	832
Parts and supplies			
Safety meetings			
Meals			
Total			$ 1,221
Timber and brush:			
Indirect assessment			$ 130
Total yearly cost			$ 10,821

TABLE 44 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
1969			
Construction:			
Timber:			
Construction			
Brush:			
Construction			
Spray regrowth	398.8	$ 14.60	$ 5,822
F.S. supervision of spray job	398.8	1.23	491
Total			$ 6,313
Maintenance:			
Timber:			
Planning and preparation	465.8	$ 0.25	$ 116
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	199.4	0.25	50
Fuelbreak clearing			
Snag clearing	199.4	1.12	223
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	3,326	0.25	832
Parts and supplies			
Safety meetings			
Meals			
Total			$ 1,221
Timber and brush:			
Indirect assessment			$ 130
Total yearly cost			$ 7,664

TABLE 44 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1970		
Construction:			
Timber:			
Construction			
Brush:			
Construction			
Spray regrowth	199.4	$ 14.60	$ 2,911
F.S. supervision of spray job	199.4	1.23	245
Total			$ 3,156
Maintenance:			
Timber:			
Planning and preparation	465.8	$ 0.25	$ 116
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	199.4	0.25	50
Fuelbreak clearing			
Snag clearing	199.4	1.12	223
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	3,326	0.25	832
Parts and supplies			
Safety meetings			
Meals			
Total			$ 1,221
Timber and brush:			
Indirect assessment			$ 130
Total yearly cost			$ 4,507

TABLE 44 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1971		
Construction:			
Timber:			
Construction			
Brush:			
Construction			
Spray regrowth			
F.S. supervision of spray job			
Total			
Maintenance:			
Timber:			
Planning and preparation	465.8	$ 0.25	$ 116
Construction (handline)	29.8	101.20	3,016
Construction (tractor line)	436.0	52.48	22,881
Brush:			
Planning and preparation	199.4	0.25	50
Fuelbreak clearing	8.1	46.46	376
Snag clearing	199.4	1.12	223
Construction (handline)	35.6	65.38	2,328
Handwork (tractor line)	163.8	14.00	2,293
Timber and brush:			
Erosion control	3,326	0.25	832
Parts and supplies	665.2	0.85	565
Safety meetings	665.2	0.68	452
Meals	665.2	2.57	1,710
Total			$ 34,842
Timber and brush:			
Indirect assessment			$ 210
Total yearly cost			$ 35,052

TABLE 45

CONSTRUCTION AND MAINTENANCE SCHEDULE FOR LEVEL IV, MAXIMUM INTENSITY, ON THE DUCKWALL UNIT

Job	No. of Acres	Cost per Acre	Total Cost
1963			
Construction:			
Timber:			
Construction	592.2		$225,664
Brush:			
Construction	231.6		39,841
Spray regrowth			
F.S. supervision of spray job			
Total			$265,505
Maintenance:			
Timber:			
Planning and preparation			
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation			
Fuelbreak clearing			
Snag clearing			
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control			
Parts and supplies			
Safety meetings			
Meals			
Total			
Timber and brush:			
Indirect assessment			$ 4,132
Total yearly cost			$269,657

TABLE 45 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1964		
Construction:			
Timber:			
Construction	592.2		$225,664
Brush:			
Construction	231.6		39,841
Spray regrowth	231.6	$ 14.60	3,381
F.S. supervision of spray job	231.6	1.23	285
Total			$269,171
Maintenance:			
Timber:			
Planning and preparation	592.2	$ 0.25	$ 148
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	231.6	0.25	58
Fuelbreak clearing			
Snag clearing	231.6	1.12	259
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	823.8	1.00	824
Parts and supplies			
Safety meetings			
Meals			
Total			$ 1,289
Timber and brush:			
Indirect assessment			$ 4,132
Total yearly cost			$274,592

TABLE 45 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1965		
Construction:			
Timber:			
Construction	592.2		$225,664
Brush:			
Construction	231.6		39,841
Spray regrowth	463.2	$ 14.60	6,763
F.S. supervision of spray job	463.2	1.23	570
Total			$272,838
Maintenance:			
Timber:			
Planning and preparation	592.2	$ 0.25	$ 148
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	231.6	0.25	58
Fuelbreak clearing			
Snag clearing	231.6	1.12	259
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	1,647.6	0.53	923
Parts and supplies			
Safety meetings			
Meals			
Total			$ 1,388
Timber and brush:			
Indirect assessment			$ 4,132
Total yearly cost			$278,358

TABLE 45 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1966		
Construction:			
Timber:			
Construction	592.2		$225,664
Brush:			
Construction	231.6		39,841
Spray regrowth	694.8	$ 14.60	10,144
F.S. supervision of spray job	694.8	1.23	855
Total			$276,504
Maintenance:			
Timber:			
Planning and preparation	592.2	$ 0.25	$ 148
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	231.6	0.25	58
Fuelbreak clearing			
Snag clearing	231.6	1.12	259
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	2,471.4	0.37	914
Parts and supplies			
Safety meetings			
Meals			
Total			$ 1,379
Timber and brush:			
Indirect assessment			$ 4,132
Total yearly cost			$282,015

TABLE 45 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1967		
Construction:			
Timber:			
Construction	592.2		$225,664
Brush:			
Construction	231.6		39,841
Spray regrowth	698.4	$ 14.60	10,144
F.S. supervision of spray job	694.8	1.23	855
Total			$276,504
Maintenance:			
Timber:			
Planning and preparation	592.2	$ 0.25	$ 148
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	231.6	0.25	58
Fuelbreak clearing			
Snag clearing	231.6	1.12	259
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	3,295.2	0.30	988
Parts and supplies			
Safety meetings			
Meals			
Total			$ 1,453
Timber and brush:			
Indirect assessment			$ 4,132
Total yearly cost			$282,089

TABLE 45 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1968		
Construction:			
Timber:			
Construction			
Brush:			
Construction			
Spray regrowth	694.8	$ 14.60	$ 10,144
F.S. supervision of spray job	694.8	1.23	855
Total			$ 10,999
Maintenance:			
Timber:			
Planning and preparation	592.2	$ 0.25	$ 148
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	231.6	0.25	58
Fuelbreak clearing			
Snag clearing	231.6	1.12	259
Construction (handline)			
Handwork (Tractor line)			
Timber and brush:			
Erosion control	4,119	0.25	1,030
Parts and supplies			
Safety meetings			
Meals			
Total			$ 1,495
Timber and brush:			
Indirect assessment			$ 180
Total yearly cost			$ 12,674

TABLE 45 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1969		
Construction:			
Timber:			
Construction			
Brush:			
Construction			
Spray regrowth	463.2	$ 14.60	$ 6,763
F.S. supervision of spray job	463.2	1.23	570
Total			$ 7,333
Maintenance:			
Timber:			
Planning and preparation	592.2	$ 0.25	$ 148
Construction (handline)			
Construction (tractor line)			
Brush:			
Planning and preparation	231.6	0.25	58
Fuelbreak clearing			
Snag clearing	231.6	1.12	259
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	4,119	0.25	1,030
Parts and supplies			
Safety meetings			
Meals			
Total			$ 1,495
Timber and brush:			
Indirect assessment			$ 180
Total yearly cost			$ 9,008

TABLE 45 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1970		
Construction:			
Timber:			
Construction			
Brush:			
Construction			
Spray regrowth	231.6	$ 14.60	$ 3,381
F.S. supervision of spray job .	231.6	1.23	285
Total			$ 3,666
Maintenance:			
Timber:			
Planning and preparation	592.2	$ 0.25	$ 148
Construction (handline)			
Construction (tractor line) . . .			
Brush:			
Planning and preparation	231.6	0.25	58
Fuelbreak clearing			
Snag clearing	231.6	1.12	259
Construction (handline)			
Handwork (tractor line)			
Timber and brush:			
Erosion control	4,119	0.25	1,030
Parts and supplies			
Safety meetings			
Meals			
Total			$ 1,495
Timber and brush:			
Indirect assessment			$ 180
Total yearly cost			$ 5,341

TABLE 45 (Continued)

Job	No. of Acres	Cost per Acre	Total Cost
	1971		
Construction:			
Timber:			
Construction			
Brush:			
Construction			
Spray regrowth			
F.S. supervision of spray job .			
Total			
Maintenance:			
Timber:			
Planning and preparation	592.2	$ 0.25	$ 148
Construction (handline)	89.6	101.20	9,059
Construction (tractor line) . . .	502.6	52.48	26,376
Brush:			
Planning and preparation	231.6	0.25	58
Fuelbreak clearing	9.4	46.46	437
Snag clearing	231.6	1.12	259
Construction (handline)	53	65.38	3,465
Handwork (tractor line)	178.6	14.00	2,500
Timber and brush:			
Erosion control	4,119	0.25	1,030
Parts and supplies	823.8	0.85	700
Safety meetings	823.8	0.68	560
Meals	823.8	2.57	2,117
Total			$ 46,709
Timber and brush:			
Indirect assessment			$ 330
Total yearly cost			$ 47,039

TABLE 46

SOURCES OF FUELBREAK MAINTENANCE COSTS FOR TIMBER IN FIRE-DANGER RATING AREA 370

Job	Source
Handline:	
Marking trees to be thinned	Hunter Creek timber sale project
Thinning	Hunter Creek timber sale project
Brushing	Hunter Creek handline project
Pruning	Hunter Creek handline project
Piling	Hunter Creek handline project
Swamper burning	Hunter Creek timber sale project
Tractor line:	
Marking trees to be thinned	Hunter Creek timber sale project
Thinning	Hunter Creek timber sale project
Brushing	Hunter Creek timber sale project
Pruning	Hunter Creek timber sale project
Piling	Hunter Creek timber sale project
Swamper burning	Hunter Creek timber sale project
Mop-up and patrol	Burning project

TABLE 47

SOURCE OF FUELBREAK MAINTENANCE COSTS FOR BRUSH IN FIRE-DANGER RATING AREA 348

Job	Source
Handline:	
Brushing	Sugarloaf handline project
Piling	Sugarloaf handline project
Swamper burning	Hunter Creek timber sale project
Hand seeding	Seeding project, including planning, mixing, and postfield activities
Tractor line:	
Brushing	Sugarloaf clearing project
Piling	Sugarloaf clearing project
Pruning	Sugarloaf clearing project
Swamper burning	Hunter Creek timber sale project
Hand seeding	Seeding project, including planning, mixing, and postfield activities

TABLE 48

FIRE-SUPPRESSION MANPOWER REQUIREMENTS ON THE DUCKWALL UNIT

Level	Cover Type[a]	Burning Index					
		24	30	55	31	37	65
I	Timber .	676	880	2,095			
	B.Cl. . .	271	338	812			
	Brush .				1,380	1,820	4,400
	Grass .				240	320	760
II	Timber .	260	338	806			
	B.Cl. . .	104	130	312			
	Brush .				839	1,121	2,662
	Grass .				45	194	461
III	Timber .	174	226	504			
	B.Cl. . .	69.6	87	208			
	Brush .				648	856	2,062
	Grass .				113	151	357
IV	Timber .	124	161	384			
	B.Cl. . .	50	62	149			
	Brush .				442	583	1,405
	Grass .				77	102	243

[a]B.Cl. = bear clover.

TABLE 49

10 A.M. FIRE REPORT

REPORTING UNIT _____ NAME OF FIRE _____

DATE _____

This report shall be telephoned to Regional Office for ALL D&E FIRES AND CON-CONCENTRATION OF FIRES for conditions as of 0800 daily until fire is on patrol basis. Include outside threatening fires. The Ranger District or Forest Dispatcher will prepare a report on this form for all class A, B and C Fires. These reports will be attached to Form 131-R5 Semi-Monthly Fire Report to back up FF fire costs and filed in Forest Supervisor's Office.

1. Name of forest or agency responsible _____
2. Cause of fire _____
3. Acres burned: Total ___ -F.S. Prot. ___ Others Prot. _____
4. Location--origin or topographic location: Sec. _____
   T _____ R _____
5. Fire Fighting forces

	No. Units	F.S. Responsibility FF Cost Hour	Day	Total Cost	Other Agency
A. All fire personnel (except free help)		$ 4	60		
B. Free Coop. help		-	20		
C. Trailbuilders		26	525		
D. Tankers		25	200		
E. Power Saws		3	40		
F. Airplane hire on fire					
(1) Small planes		30	130		
(2) Large planes		150	600		
G. Helicopters					
(1) Small		90	900		
(2) Large		200	1600		
H. Air Tankers					
(1) Small		220	990		
(2) Medium		500	2250		

TABLE 49 (Continued)

(3) Large		900	4050		
(4) Mix Crew (each base)		65	800		
(5) Day cost based on avg. of 4.5 hours per day					
I. Transp. to and from fire--estimate --men					

J. Total cost today _____

K. Previous total adjusted _____

L. Total FF cost to date _____

6. Estimated Total FF cost of fire _____
7. Estimated final cost of fire, including mop-up _____
8. Timber burned: species, reprod. or mature _____

MBM _____

9. What does fire threaten: towns, valuable timber stands, etc. _____

_____

10. Damages: Timber $_____ Watershed $_____ Other $_____

11. Progress being made in control of fire _____

12. Special information, i.e., lives lost, serious injuries, loss of improvements, weather conditions, etc.

TABLE 50

10 A.M. FIRE REPORT: INSTRUCTIONS

The Forest Dispatcher is responsible for estimating daily FF cost of suppressing the fire. The estimated cost per day for fire fighters includes the following surcharges.

Subsistence $7.50; replacements, tools, etc. $2.75; cost of fixed investments $2.10; camp expenses $2.00; warehouse expense (include extra help and servicing camps) $2.00; tool reconditioning $1.50; laundry $0.50; truck and car hire $3.25; communication $0.50.

5A -Includes all paid fire fighters, project personnel, administration and protection personnel. Includes all on-line and non-line personnel organized and on hand to control the fire and paid directly or indirectly by the Forest Service from FF.

5B -Include all military manpower (except civilians who are paid for under agreement), free County and State aid when Forest Service furnishes food, equipment, etc.

5C -Include all dirt moving equipment, transports and lubers.

5D -Include all tank trucks used as pumping units on fire, mother tankers, water spreaders, and tractor trailers. Do not include if use of equipment is for transportation use only.

5E -Power saw rate does not include operator.

5F -Airplane hire on fire is confined to airplanes used for reconnaissance, dropping, hauling freight on short hops, etc. Small planes are those up to four place or similar size units.

5G -Small helicopters of size typical of Bell G-2. Large helicopters of size typical of S-55 and Alouette.

5H -Air tankers--small, typical size N3N; medium, size of TBM; large, 1,000 gallon capacity and over. Costs based on two

TABLE 50 (Continued)

trips per hour and 4.5 hours per day. Where actual use varies from this, make adjustment in reported costs.

5I -It will be necessary to estimate the cost of plane, rail, and bus transportation for primary transportation of men or equipment to and from the fire area. Zone dispatchers will furnish forest estimated costs incurred by them.

TABLE 51

FUELBREAK SYSTEM MILES AND ACRES
ON THE DUCKWALL UNIT

Level	Cover Type	Fuelbreak	
		Miles	Acres
I	Brush:		
	Handline	7.83	71
	Tractor	11.47	417
	Total	19.30	488
	Timber:		
	Handline	8.77	80
	Tractor	16.20	588
	Total	24.97	688
II	Brush:		
	Handline	14.32	130
	Tractor	14.58	531
	Total	28.90	661
	Timber:		
	Handline	13.25	123
	Tractor	52.93	1,925
	Total	66.18	2,048
III	Brush:		
	Handline	19.25	178
	Tractor	22.50	819
	Total	41.75	997
	Timber:		
	Handline	16.125	149
	Tractor	60.375	2,180
	Total	76.500	2,329
IV	Brush:		
	Handline	28.50	265
	Tractor	24.50	893
	Total	53.00	1,158
	Timber:		
	Handline	48.50	448
	Tractor	69.50	2,513
	Total	118.00	2,961

TABLE 52

TIMBER AND GROWING STOCK INVENTORY
ON THE DUCKWALL UNIT[a]

Type	Saw Timber (M net bd. ft.)		Poles (M cu. ft.)		Seedlings and Saplings (acres)
	Total	Per Acre	Total	Per Acre	
Ponderosa pine .	186,862	8.7	5,723	0.265	1,282
Sugar pine	24,370	1.1	733.74	0.034	130
White fir	331.6	0.015	36.7	0.002	
Douglas fir . . .	29,844	1.4	909.8	0.042	150
Incense cedar . .	829	0.038	73.4	0.004	
Total	242,236.6	11.2	7,476.6	0.346	1,562

[a]Source: Timber Management Plan, Stanislaus National Forest, Tuolumne Working Circle Supplement. Fixed plot and aerial survey methods used.

Hunter Creek timber sale cruise and appraisal information was used to supplement inventory data. The sale is located on the Duckwall Unit and was cruised in 1962.

TABLE 53

UNIT PRICES AND COSTS, TIMBER AND GROWING STOCK, ON THE DUCKWALL UNIT

Type	Saw Timber[a] (per M net bd. ft.)	Poles[b] (per M cu. ft.)	Seedlings and Saplings[c] (per acre)
Ponderosa pine	$ 83.67	$152.16	$97.86
Sugar pine	105.59	152.16	97.86
White fir	58.81	152.16	
Douglas fir	66.89	152.16	97.86
Incense cedar	58.81	152.16	

[a]Rates are Western Pine Association base indexes on 1954-56 basis for pine, 1942-49 basis for white fir and incense cedar, and 1942-49 basis for Douglas fir, adjusted for second quarter, 1962, as used on the Hunter Creek timber sale, Duckwall Unit.

[b]Rates are from R-5 Supplement to Forest Service Handbook; FHS 2-2425-R5-4.3 (1) d(3).

[c]Planting costs are from Sale Area Betterment Plan, Hunter Creek Timber Sale Appraisal, p. 14.

TABLE 54

TIMBER AND GROWING STOCK VALUE
ON THE DUCKWALL UNIT

Type	Total Value	Value per Acre[a]
Saw timber:		
Ponderosa pine	$15,634,744	$750
Sugar pine	2,573,228	119
White fir	19,501	0.90
Douglas fir	1,996,265	93
Incense cedar	48,753	2.20
Total	$20,272,491	$939.00
Poles:		
Ponderosa pine	$ 870,812	$ 40
Sugar pine	111,644	5.10
White fir	5,584	0.25
Douglas fir	138,435	6.30
Incense cedar	11,169	0.52
Total	$ 1,137,644	$ 52.70
Seedlings and saplings:		
Ponderosa pine	$ 125,457	$ 5.80
Sugar pine	12,722	0.59
White fir	(b)	(b)
Douglas fir	14,679	0.69
Incense cedar	(b)	(b)
Total	$ 152,958	$ 7.08
Total:		
Ponderosa pine	$16,631,013	$771
Sugar pine	2,697,495	125
White fir	25,085	1.16
Douglas fir	2,149,379	99.60
Incense cedar	59,922	2.78
Total	$21,562,943	$999.00

[a]Commercial forestland on the Duckwall Unit is 21,580 net acres (excluding meadow, recreation areas, etc.).

[b]White fir and incense cedar are not planted artificially. Although the species have value, their contribution to total value would be small.

TABLE 55

ESTIMATED SALVAGE PERCENTAGE OF TIMBER AND GROWING STOCK FOLLOWING HIGH-INTENSITY FIRES[a] ON THE DUCKWALL UNIT

Type	Saw Timber	Poles	Seedlings and Saplings
Ponderosa pine	40	0	0
Sugar pine	30	0	0
White fir	30	0	0
Douglas fir	40	0	0
Incense cedar	20	0	0

[a]Assumes "conflagration conditions," or burning indexes in excess of 30 in timber, California fire-danger rating area 370; and in excess of 37 in brush, California fire-danger rating area 348.

Percentages based upon salvage experiences on the Wrights Creek fire of 1950 and the Flora fire in 1960, both on or adjacent to the Duckwall Unit.

TABLE 56

ESTIMATED DOLLAR MORTALITY POTENTIAL FROM HIGH-INTENSITY FIRES[a] ON THE DUCKWALL UNIT

Type	Total Value	Value per Acre
Saw timber:		
Ponderosa pine	$ 9,380,846	$435.00
Sugar pine	1,801,259	83.30
White fir	13,651	0.63
Douglas fir	1,197,759	56.00
Incense cedar	39,002	1.76
Total	$12,432,517	$576.11
Poles:		
Ponderosa pine	$ 870,812	$ 40.00
Sugar pine	111,644	5.40
White fir	5,584	0.25
Douglas fir	138,435	6.30
Incense cedar	11,169	0.52
Total	$ 1,137,644	$ 52.70
Seedlings and saplings:		
Ponderosa pine	$ 125,457	$ 5.87
Sugar pine	12,722	0.59
White fir		
Douglas fir	14,679	0.68
Incense cedar		
Total	$ 152,858	$ 7.08
Total:		
Ponderosa pine	$10,377,115	$480.87
Sugar pine	1,925,625	89.23
White fir	19,235	0.89
Douglas fir	1,350,878	62.59
Incense cedar	50,171	2.32
Total	$13,723,019	$635.91

[a]Assumes "conflagration conditions," or burning indexes in excess of 30 in timber, California fire-danger rating area 370; and in excess of 37 in brush, California fire-danger rating area 348.

Includes total estimated mortality less salvage.

TABLE 57

ESTIMATED GROWTH LOSS FROM HIGH-INTENSITY FIRES[a] ON THE DUCKWALL UNIT

Type	Poles (avg. age, 40 yrs.; M bd. ft.)		Seedlings and Saplings (avg. age, 15 yrs.; M bd. ft.)	
	Total	Per Acre	Total	Per Acre
Ponderosa pine . .	56,333	2.6	22,423	1.1
Sugar pine	7,798	0.361	3,412	0.158
White fir	106.1	0.005	46.4	0.002
Douglas fir	9,550	0.443	4,178	0.194
Incense cedar . . .	285	0.013	116	0.005
Total	74,072	3.4	30,175	1.4

[a]Assumes conflagration conditions.

Basic Forest Service growth-loss equation: $G = \frac{A+S}{R} VX$

Where: G = growth loss in bd. ft.; A = average age of timber at time of fire; S = average time for restocking; R = age at the time of normal cut; V = the normally expected volume per acre at R age, in bd. ft.; X = the number of acres involved.

Basis: 140 year rotation; two year restocking period for pine; five year restocking period for other species; normal volume per acre assumed to be present inventory level; 21,580 net acres on unit classed as commercial forestland.

TABLE 58

ESTIMATED DOLLAR GROWTH LOSS POTENTIAL FROM HIGH-INTENSITY FIRES[a] ON THE DUCKWALL UNIT

Type	Total Value	Value per Acre
Poles:		
Ponderosa pine	$4,713,382	$218.00
Sugar pine	823,391	38.15
White fir	6,240	0.29
Douglas fir	638,799	29.60
Incense cedar	16,761	0.78
Total	$6,198,573	$278.00
Seedlings and saplings:		
Ponderosa pine	$1,881,153	$ 87.17
Sugar pine	360,273	16.69
White fir	2,729	0.10
Douglas fir	279,466	12.95
Incense cedar	6,822	0.32
Total	$2,530,443	$117.26
Total:		
Ponderosa pine	$6,594,535	$305.58
Sugar pine	1,183,664	54.85
White fir	8,969	0.41
Douglas fir	918,265	42.55
Incense cedar	23,583	1.09
Total	$8,729,016	$404.49

[a]Assumes conflagration conditions. See unit prices from Table 53.

TABLE 59

TOTAL ESTIMATED TIMBER GROWTH IMPACT POTENTIAL FROM HIGH-INTENSITY FIRES[a] ON THE DUCKWALL UNIT

Type	Item	Total Value	Value per Acre
Saw timber:			
Ponderosa pine . . .	Mortality	$ 9,380,846	$435.00
	Growth loss		
	Total	$ 9,380,846	$435.00
Sugar pine	Mortality	$ 1,801,259	$ 83.30
	Growth loss		
	Total	$ 1,801,259	$ 83.30
White fir	Mortality	$ 13,651	$ 0.63
	Growth loss		
	Total	$ 13,651	$ 0.63
Douglas fir	Mortality	$ 1,197,759	$ 56.00
	Growth loss		
	Total	$ 1,197,759	$ 56.00
Incense cedar	Mortality	$ 39,002	$ 1.76
	Growth loss		
	Total	$ 39,002	$ 1.76
All species	Mortality	$12,432,517	$576.11
	Growth loss		
	Total	$12,432,517	$576.11
Poles:			
Ponderosa pine . . .	Mortality	$ 870,812	$ 40.00
	Growth loss	4,713,382	218.00
	Total	$ 5,584,194	$258.00

[a]Assumes "conflagration conditions," burning indexes in excess of 30 in timber, California fire-danger rating area 370; and in excess of 37 in brush, California fire-danger rating area 348.

Table 59 (Continued)

Type	Item	Total Value	Value per Acre
Sugar pine	Mortality	$ 111,644	$ 5.10
	Growth loss	823,391	38.15
	Total	$ 935,035	$ 43.15
White fir	Mortality	$ 5,584	$ 0.25
	Growth loss	6,240	0.29
	Total	$ 11,824	$ 0.54
Douglas fir	Mortality	$ 138,435	$ 6.30
	Growth loss	638,799	29.60
	Total	$ 777,234	$ 35.90
Incense cedar	Mortality	$ 11,109	$ 0.52
	Growth loss	16,761	0.78
	Total	$ 27,930	$ 1.30
All species	Mortality	$ 1,137,646	$ 52.70
	Growth loss	6,198,573	287.00
	Total	$ 7,336,217	$339.70
Seedlings and saplings:			
Ponderosa pine . . .	Mortality	$ 125,457	$ 5.80
	Growth loss	1,881,153	87.17
	Total	$ 2,006,610	$ 92.97
Sugar pine	Mortality	$ 12,722	$ 0.59
	Growth loss	360,273	16.69
	Total	$ 372,995	$ 17.28
White fir	Mortality		
	Growth loss	$ 2,729	$ 0.10
	Total	$ 2,729	$ 0.10
Douglas fir	Mortality	$ 14,679	$ 3.68
	Growth loss	279,466	12.95
	Total	$ 294,145	$ 16.63

TABLE 59 (Continued)

Type	Item	Total Value	Value per Acre
Incense cedar	Mortality		
	Growth loss	$ 6,822	$ 0.32
	Total	$ 6,822	$ 0.32
All species	Mortality	$ 152,858	$ 7.08
	Growth loss	2,530,443	117.26
	Total	$ 2,683,301	$124.34
Totals:			
Ponderosa pine . . .	Mortality	$10,377,115	$480.87
	Growth loss	6,594,535	305.58
	Total	$16,971,650	$786.45
Sugar pine	Mortality	$ 1,925,625	$ 89.23
	Growth loss	1,185,664	54.85
	Total	$ 3,109,289	$144.08
White fir	Mortality	$ 19,235	$ 0.89
	Growth loss	8,969	0.41
	Total	$ 28,204	$ 1.30
Douglas fir	Mortality	$ 1,350,873	$ 62.59
	Growth loss	918,265	42.55
	Total	$ 2,269,138	$105.14
Incense cedar	Mortality	$ 50,171	$ 2.32
	Growth loss	23,533	1.09
	Total	$ 73,754	$ 3.41
All species	Mortality	$13,723,019	$635.91
	Growth loss	8,729,016	404.50
	Total	$22,452,035	$1,040.41

TABLE 60

OPEN-MARKET SALES MADE ON OR ADJACENT TO THE DUCKWALL UNIT

Map Ref.	Year and Type	Price	No. of Acres	Price per Acre
(40)	1950: Timber	$ 9,090	320	$ 28.41
(7)	1950: Brush	500	160	3.13
(48)	1951: Timber	1,500	144	10.42
(27)	1955: Brush	4,000	20	200.00
(9)	1955: Grass-brush	1,500	40	38.75
(17)	1957: Timber	7,000	75.6	92.59
(42)	1958: Timber	74,850	499	150.00
(43)	1958: Timber	5,000	39.9	125.00
(46)	1959: Timber	17,000	7.196	2,362.00
(44)	1959: Timber	2,500	2.5	1,000.00
(36)	1959: Timber	7,000	31.3	223.60
(26)	1959: Timber	60,000	598	100.33
(41)	1959: Timber	7,000	80	87.50
(8)	1959: Timber	2,000	40	50.00
(45)	1959: Mixed timber and brush	1,984	7.6	261.00
(37)	1959: Mixed timber and brush	5,000	39.9	125.30
(38)	1959: Mixed timber and brush	7,000	64.2	109.00
(35)	1959: Brush	4,000	154	25.97
(22)	1960: Timber	20,000	209	95.69
(25)	1960: Mixed timber and brush	20,000	110	181.81
(6)	1960: Brush	65,000	620	104.84
(28)	1961: Timber	5,000	15.76	317.25

TABLE 60 (Continued)

Map Ref.	Year and Type	Price	No. of Acres	Price per Acre
(23)	1961: Timber	$ 7,500	40	$ 187.50
(3)	1961: Timber	22,000	160	137.50
(16)	1961: Timber	10,500	80	131.25
(2)	1961: Timber	20,000	160	125.00
(39)	1961: Timber	32,000	320	100.00
(15)	1961: Timber	7,500	80	93.75
(14)	1961: Timber	12,000	160	75.00
(13)	1961: Brush	12,000	187	64.17
(12)	1961: Brush	8,000	187	42.78
(5)	1962: Timber	4,500	10	4,500.00
(21)	1962: Timber	8,900	40	222.50
(4)	1962: Timber	44,000	200	220.00
(31)	1962: Timber	40,000	185	216.21
(24)	1962: Timber	8,500	40	212.50
(34)	1962: Timber	3,500	20.6	169.90
(20)	1962: Timber	12,500	160	78.13
(11)	1962: Brush	4,000	88	45.45
(10)	1962: Brush	700	23.2	30.17
(33)	1963: Timber	14,500	20	725.00
(32)	1963: Timber	14,500	20	725.00
(29)	1963: Timber	14,500	20	725.00
(1)	1963: Timber	5,000	7.3	649.00
(19)	1963: Timber	5,500	40	137.50
(30)	1963: Brush	3,000	2.5	1,200.00

TABLE 60 (Continued)

Map Ref.	Timber	Recreation	Range Grazing
(40)		Subdivision	
(7)			
(48)	Cutover		
(27)			
(9)			
(17)			
(42)	Burned over	Subdivision	
(43)	Cutover		
(46)		Subdivision	
(44)		Subdivision	
(36)			
(26)			
(41)	Cutover	Subdivision	
(8)			
(45)			
(37)	39A	Subdivision	
(38)	32A cutover	Subdivision	
(35)	Few-steep brushy		
(22)	Cutover		Brushy
(25)			
(6)			Converted to grass
(28)			
(23)	Cutover		Brushy

TABLE 60 (Continued)

Map Ref.	Timber	Recreation	Range Grazing
(3)	Cutover with brush		
(16)	22A cutover		3A
(2)	Cutover with brush		
(39)	Burn		
(15)	75A		
(14)	Brush-cutover		
(13)	82A, 2nd 6		15A, 89A brush
(12)	82A, 2nd 6		15A, 89A brush
(5)	Cutover		
(21)	Cutover		Brush
(4)	Cutover		
(31)	Cutover		
(24)	Cutover		Brush
(34)	Cutover		Brush
(20)	Cutover		Brush
(11)			Burn, steep brush
(10)			
(33)			
(32)			
(29)			
(1)			
(19)	Cutover		Brush
(30)			

TABLE 60 (Continued)

Map Ref.	Watershed	Water	Improvement
(40)			Future subdivision
(7)	River breaks		
(48)			
(27)			Residence, garage-shed
(9)			Residence, misc. buildings
(17)			
(42)			Future subdivision
(43)			Cabin
(46)			Subdivision
(44)			Subdivision
(36)		Well needed	Future subdivision
(26)			
(41)			Future subdivision
(8)			
(45)			
(37)		Well needed	Future subdivision
(38)		Well needed	Future subdivision
(35)			
(22)			
(25)			Subdivision
(6)			House and barn
(28)	X		
(23)			

TABLE 60 (Continued)

Map Ref.	Watershed	Water	Improvement
(3)		X	
(16)		Stream and spring	
(2)			Old house
(39)		Spring	
(15)		Spring	5A cabin site
(14)			
(13)	X	None	
(12)	X	None	
(5)		X	
(21)		Spring	
(4)		X	
(31)		Well	Subdivision
(24)			
(34)			Subdivision
(20)		Spring	
(11)		X	
(10)		"Breaks" N. fork	
(33)		X	Subdivision
(32)		X	Subdivision
(29)		X	
(1)		Well	
(19)			
(30)		X	Subdivision

TABLE 60 (Continued)

Map Ref.	Roads	Mining	Power	Telephone
(40)	County			
(7)				
(48)				
(27)				
(9)				
(17)	Near hwy., fair access			
(42)	Old dirt existing			
(43)				
(46)				
(44)				
(36)	County		X	
(26)	Access to Hwy. 120		X	
(41)				
(8)				
(45)				
(37)	Dirt road			
(38)	County			
(35)	Fair county			
(22)	Fair		X	
(25)				
(6)				
(28)	Fair access to hwy.			
(23)	Fair			

TABLE 60 (Continued)

Map Ref.	Roads	Mining	Power	Telephone
(3)			X	
(16)	Dirt			
(2)				
(39)				
(15)	Poor			
(14)				
(13)	Dirt			
(12)	Dirt			
(5)	Highway 120		X	
(21)				
(4)			X	
(31)	County		X	X
(24)	Poor			
(34)	Fair			
(20)	Fair, FS			
(11)			X	
(10)		X		
(33)			X	X
(32)	Does not border hwy.		X	X
(29)	Not on highway		X	
(1)			X	
(19)	Fair, FS			
(30)	County		X	X

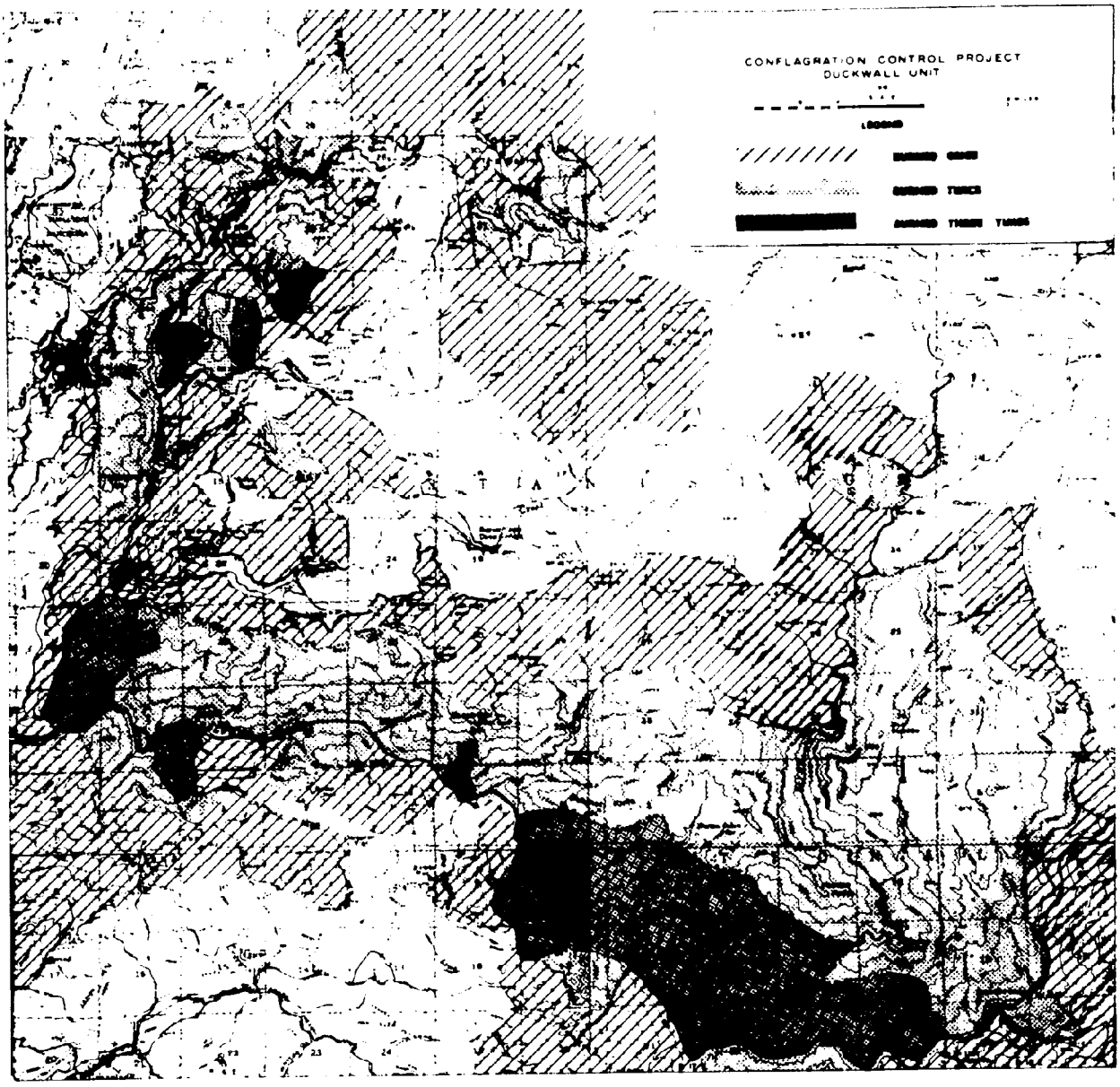

EXHIBIT 1

BURNED AREA 1910—1959, DUCKWALL AREA

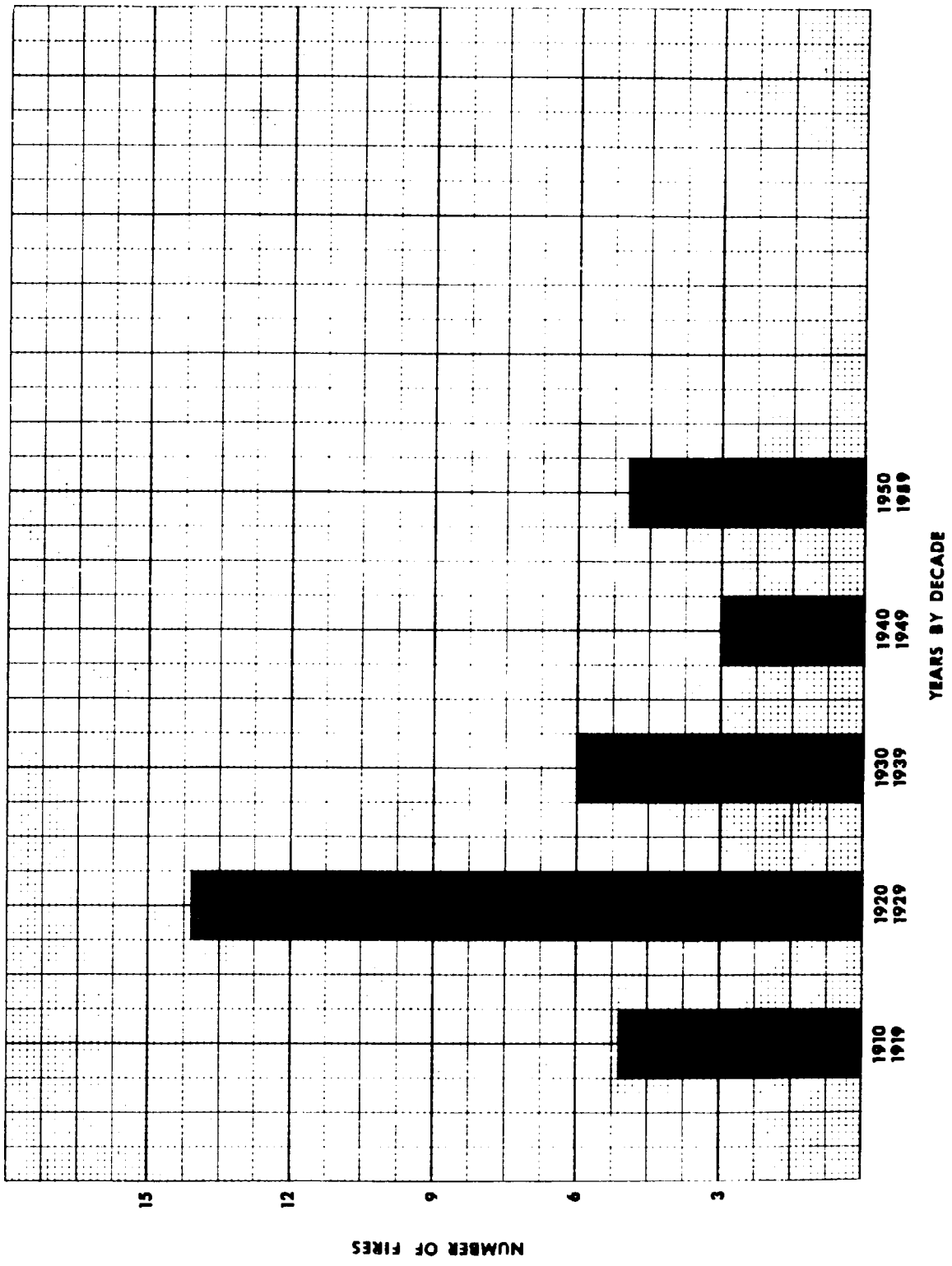

EXHIBIT 2 NUMBER OF D AND E FIRES BY DECADE—DUCKWALL UNIT AND ADJACENT FOREST LAND

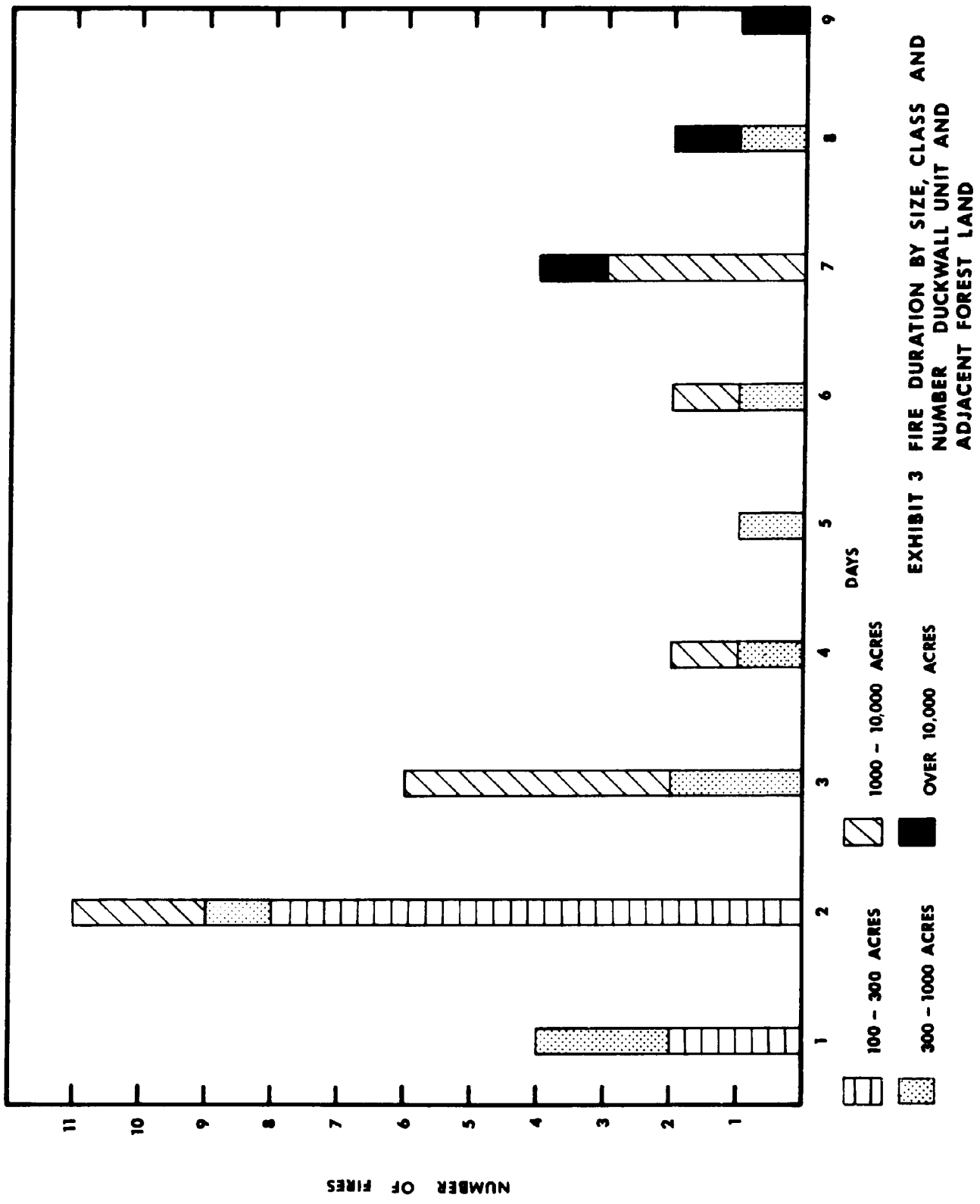

EXHIBIT 3 FIRE DURATION BY SIZE, CLASS AND NUMBER DUCKWALL UNIT AND ADJACENT FOREST LAND

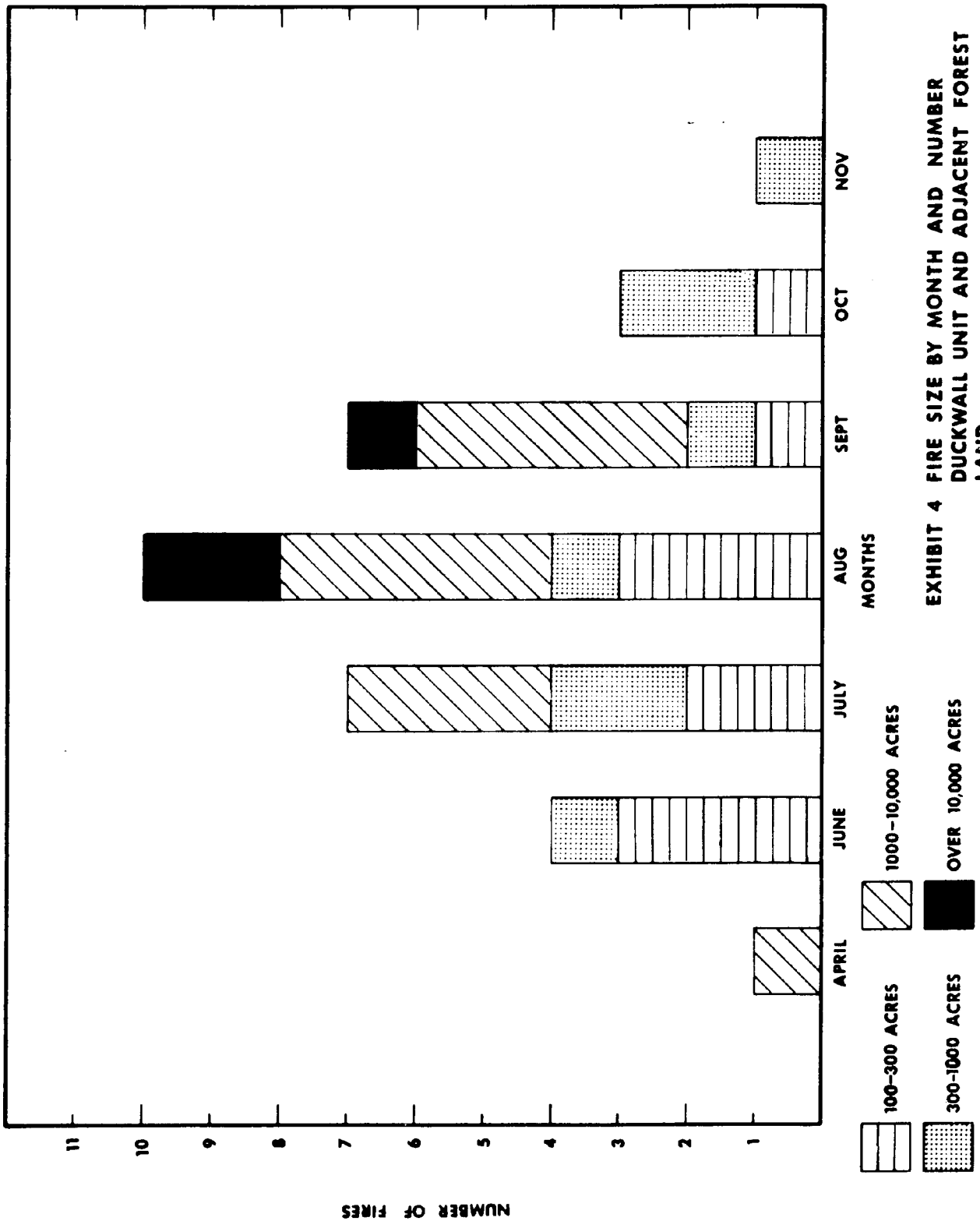

EXHIBIT 4 FIRE SIZE BY MONTH AND NUMBER
DUCKWALL UNIT AND ADJACENT FOREST
LAND

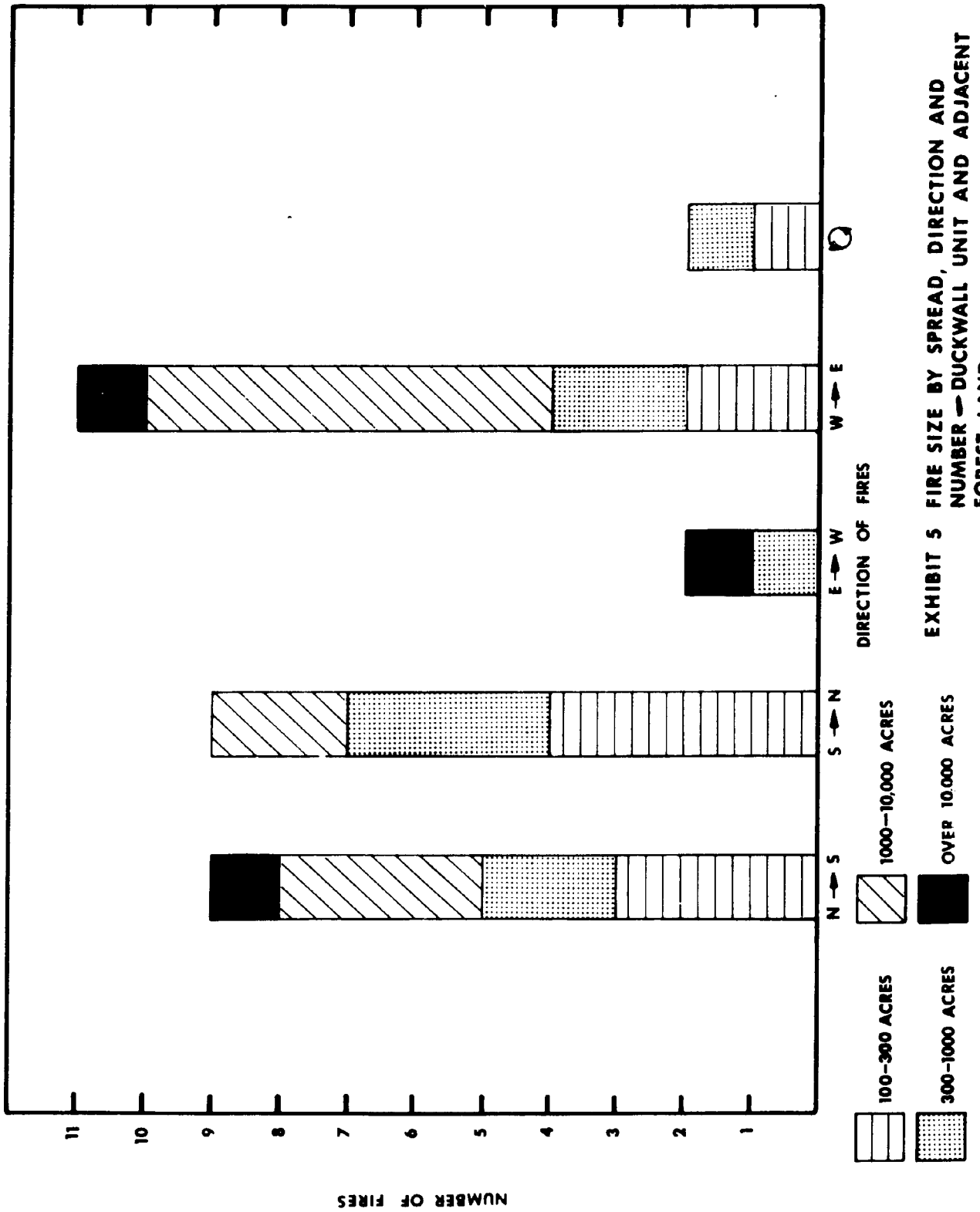

EXHIBIT 5 FIRE SIZE BY SPREAD, DIRECTION AND NUMBER — DUCKWALL UNIT AND ADJACENT FOREST LAND

Bruce A Engstrom Stokes
Kramer Baker
Kellog
Barajas
Martinelli
Hazellon

EXHIBIT 6

CONFLAGRATION CONTROL PROJECT
Foreman's Daily Cost and Accomplishment Record

FORM I: Work Done by Forest Service

Unit: Duncanwall Project: Hunter Cr. Sale Date: 12/9-62

MANDAYS

	Area	Job	No. Men	No. Hrs.	Rt/hr 1/	TOTAL	Charged to: (Specify) Function	Supplemental
Foreman: (Example)	A-40 to river	Fire line const.	1	8	$3.00	$24.00		Confl. Cont. 202-01-50
		Cook	1	8	2.27	18.16		
Crew:			7	56	1.94	108.64		

Special Equipment Operators: (Specify)

(Example)	Walton Ridge	Brush Clearing	1 FS Catskinner	8	$4.00	$32.00	033 plant	

RDMA 2/: (Specify title)

(Example)	Walton Ridge	Supv. Insp.	1- DFCO	8	$4.00	$32.00		Confl. Cont. 202-01-50

EQUIPMENT

Area	Job	No.	Type	No. Miles/hr.	Rt. 3/ (mi.)(hr.)	TOTAL	Charged to: (Specify) Function	Supplemental
(Example) Walton Ridge	Haul men, supplies	1	1/2T PU	60 miles	$.125	$6.25	P&M 031	
		1	1 Ton	20 miles	.16	3.20		
		1	¼ ton	20 miles	.11	2.20		
SAW		1	72	6.5 hours				
SAW		1	52	5.0 hours		5.40		

1/ Use extended rates to include FICA, FEGLI, Leave charge, etc.
2/ Include all planning, supervision, inspections, reporting, etc., directly related to Conflagration Control.
3/ Use standard hourly rate. Adjust for minimum charges, if necessary, on summary reports.

REMARKS: _____

EXHIBIT 6, Continued

SUPPLIES USED

Area	Job	Item Used	No. Units	Price per Unit	Total Charges
(Example)					
Walton Ridge	Planting	Fertilize	2,000 lbs.	$40.00	$40.00
		(Amm.Nitro)			

PER DIEM

Area	Job	No. Men	Rt./Day	Total Charges	Charged to: (Specify)	
					Function	Supplemental
(Example)						
Walton Ridge	Crew Supv.	1	$4.00	$4.00		Confl. Cont.
						202-01-50

MEALS

No. Meals	Rt./Meal	Total Charges	Charged to: (Specify)	
			Function	Supplemental
(Example) 30	$.75	$22.50	$15.00	Confl. Cont.
			031	$7.50

OTHER CHARGES

Item	No. Units	Rt./Unit	Total

WORK COMPLETED

Area	Job	Cover Type	No. Units Worked	Work benefits: 4/ (Specify) Function	Supplemental
(Example)					
A-21 to A-50	Slash disposal	Mixed conifer	3 acres	60%Sl.Disp.	40% Conf. Cont
	Brushing & Burning	Mixed conifer	1 acre		

4/ Is work done to satisfy normal project requirements or is it "extra" to satisfy Conflagration Control?

EXHIBIT 7

CONFLAGRATION CONTROL PROJECT

Daily Accomplishment Record

FORM 2: Contract Work Performed for Forest Service

Unit Duckwall Confla. Control Project Sugarloaf --- Murphy Ridge Date 9/4/through 7th.

WORK DONE BY CONTRACTOR

Area (Example) Murphy Ridge	Job Brush clearing, piling with cattle	Cover Type Oak-Manzanita	No. Units Completed 2 acres	Work Charged To: Function Range reveg. Cedar Gulch, 1 acre	Work Charged To: Supplemental 1 acre confl. control 202-01-50
A-8	Brush Clearing	Oak & Manzanita			302-101-01-50
A-8	Brush Clearing	Oak & Manzanita			302-101-01-50
A-8 to A-49	Snag Felling Brush Clearing		290 Snags		302-101-01-50
A-8	Brush Clearing	Oak & Manzanita			302-101-01-50

FOREST SERVICE CHARGES (for supervisory assistance, etc.)1/

MAN-DAYS

Area Murphy Ridge	Job Super-vision	No. 1	No. Hrs. 8	Rt./Hr 2/ 3.00	Total $24.00	Work Charged To: Function	Work Charged To: Supplemental Confl. Control 202-01-50
A-8	Supervision	1	8	$ 1.95	$ 15.60		302-101-01-50
A-8	Supervision	1	8	$ 1.95	$ 15.60		302-101-01-50
A-8 to A-49	Supervision	1	8	$ 1.95	$ 15.60		302-101-01-50
A-8	Supervision	1	8	$ 1.95	$ 15.60		302-101-01-50

Equipment

Job	No.	Type Pu	No.(Mi.)(Hrs.)	Rt./hr	Total	Work Charged To: Function	Work Charged To: Supplemental
Trans.	1	½ Pu	20	$.125	$2.50		
Trans	1	½ Pu	36 Mi.				302-101-01-50
Trans	1	½ Pu	24 Mi.				302-101-01-50
Trans	1	½ Pu	36 Mi.				302-101-01-50
Trans	1	½ Pu	26 Mi.				302-101-01-50

Other Forest Service Charges

Item	No. Units	Rt./Unit	Total

Remarks: It will be more help by getting an accurate count of the snags before the fallers are called in on the job. I think that raising the size and quality of the tractors has been a big improvement.

Snags - best to work - tags to be turned in -

L. Null
Officer Reporting

1/ Enter all charges directly related to the contract job. Do not include these charges on Form 1 "Work done by Forest Service."

2/ Use extended rates.

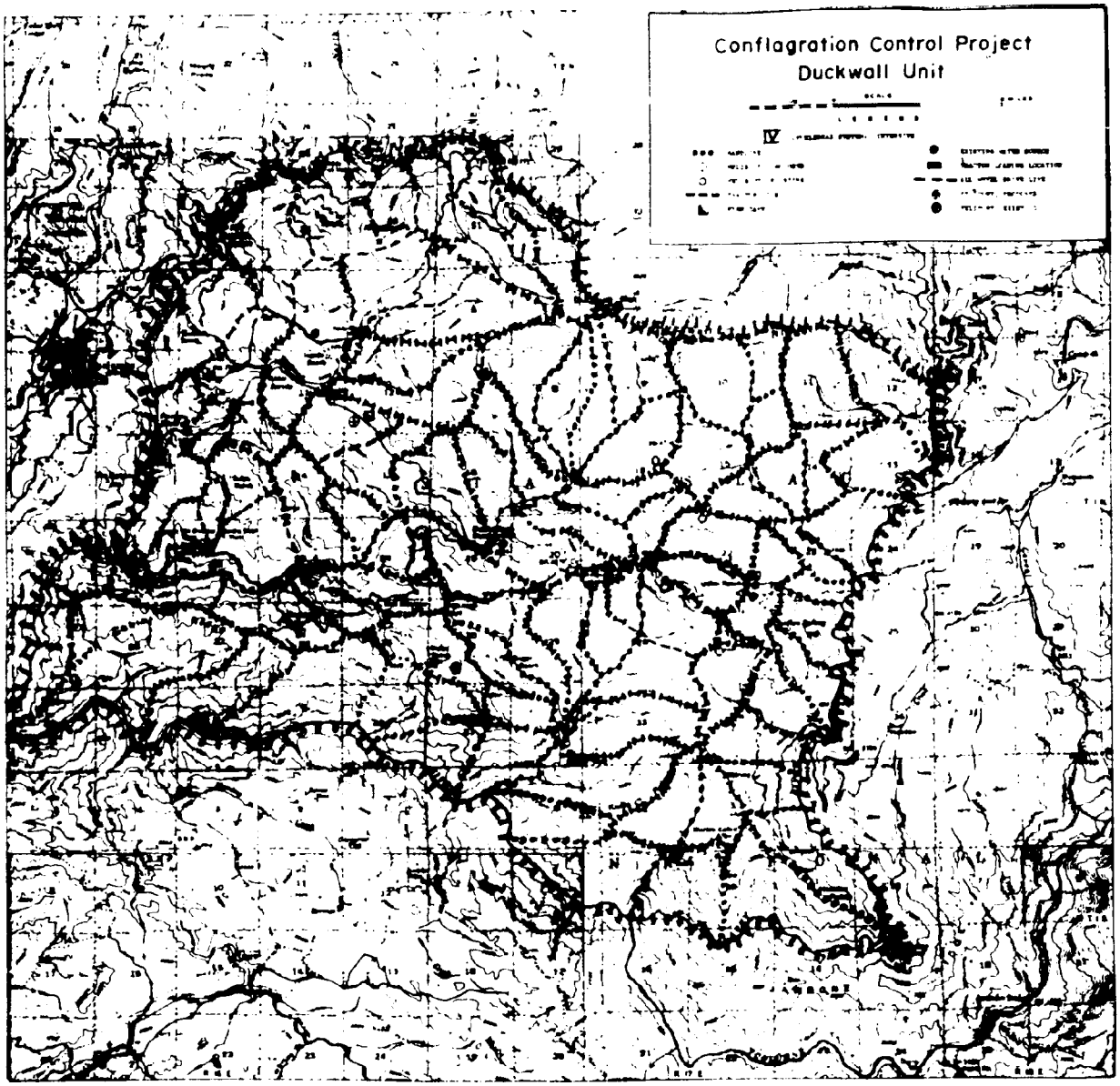

EXHIBIT 8
FUELBREAK SYSTEM, LEVEL IV, DUCKWALL UNIT

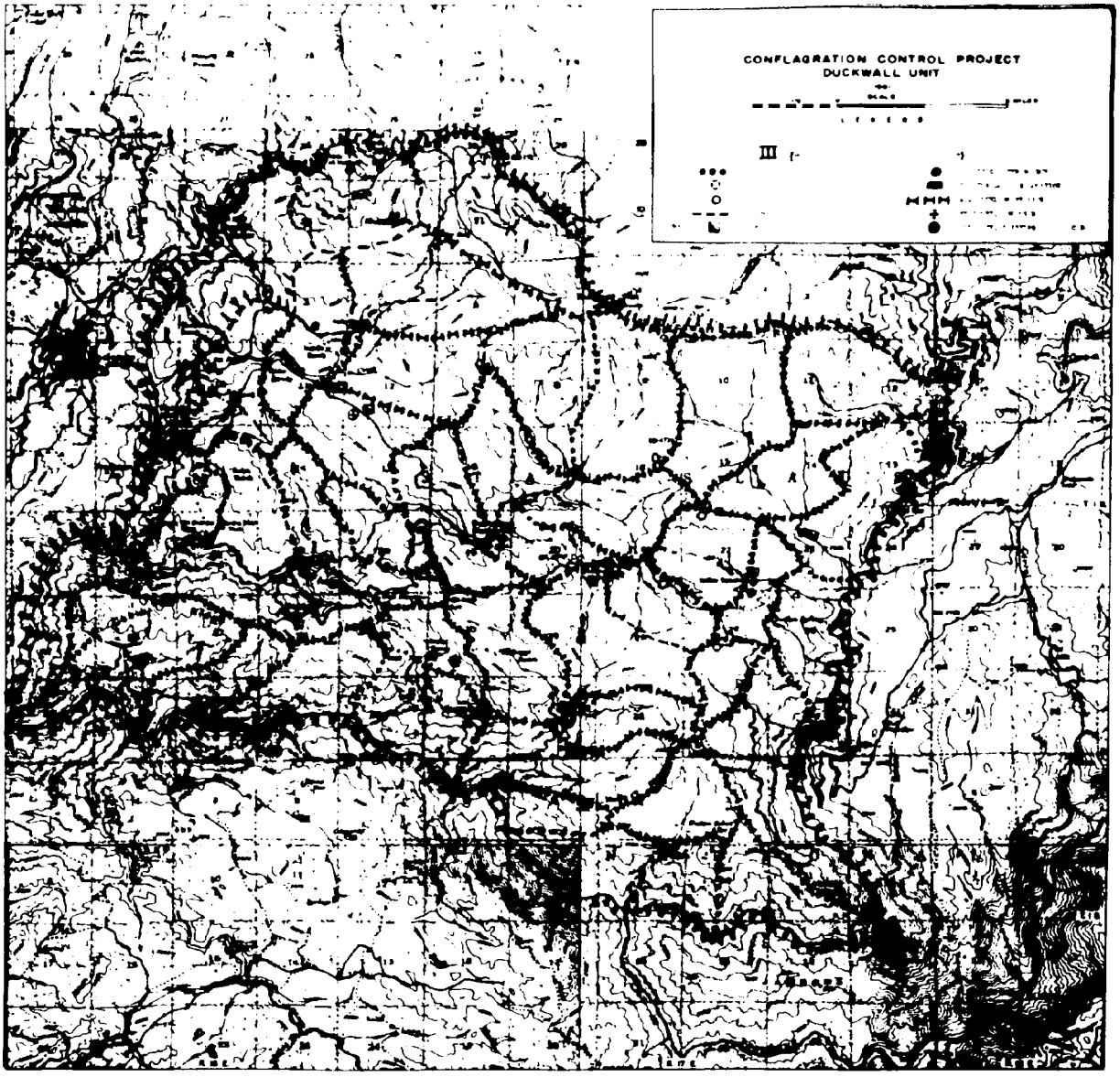

EXHIBIT 9
FUELBREAK SYSTEM, LEVEL III, DUCKWALL UNIT

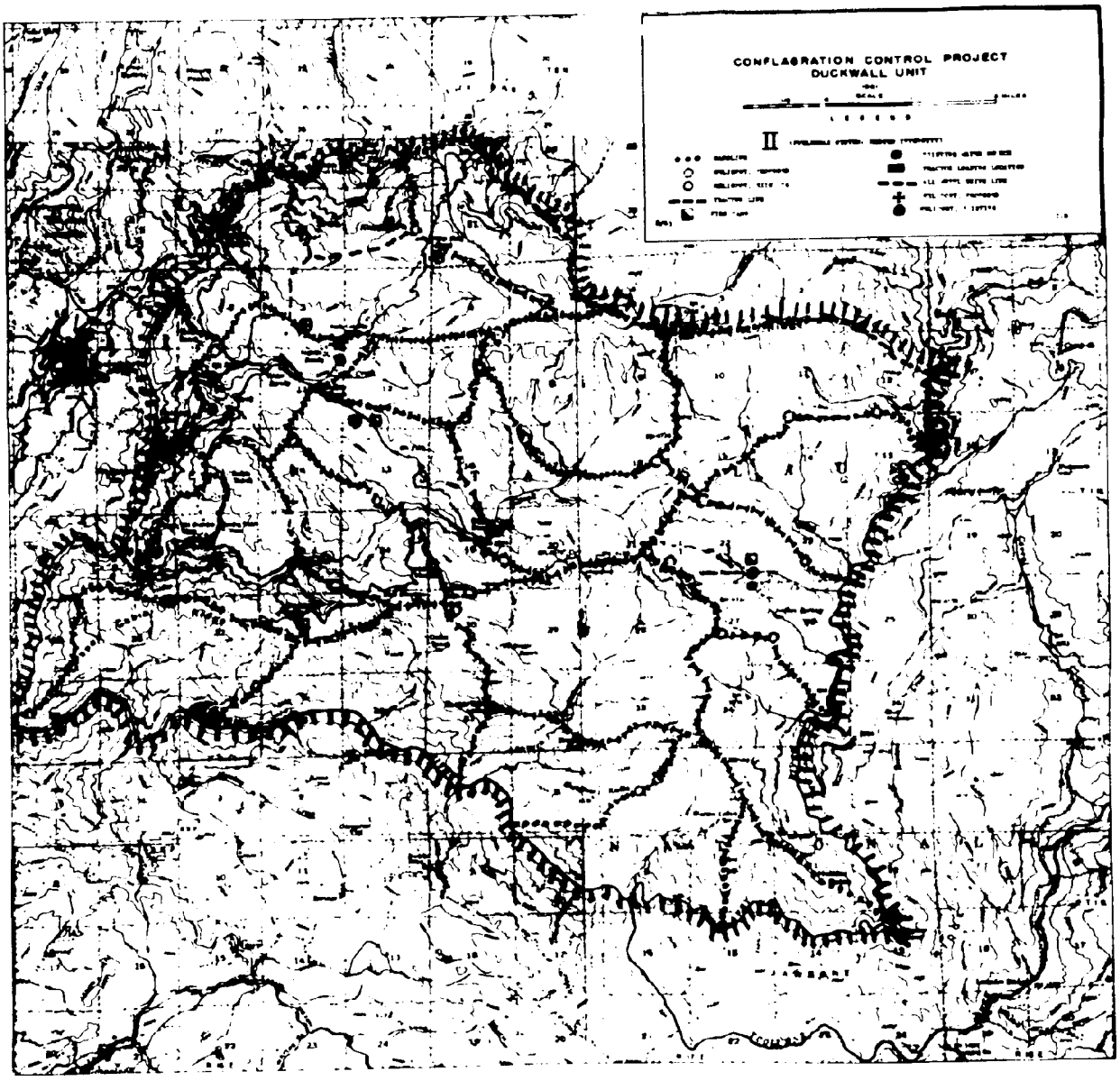

EXHIBIT 10
FUELBREAK SYSTEM, LEVEL II, DUCKWALL UNIT

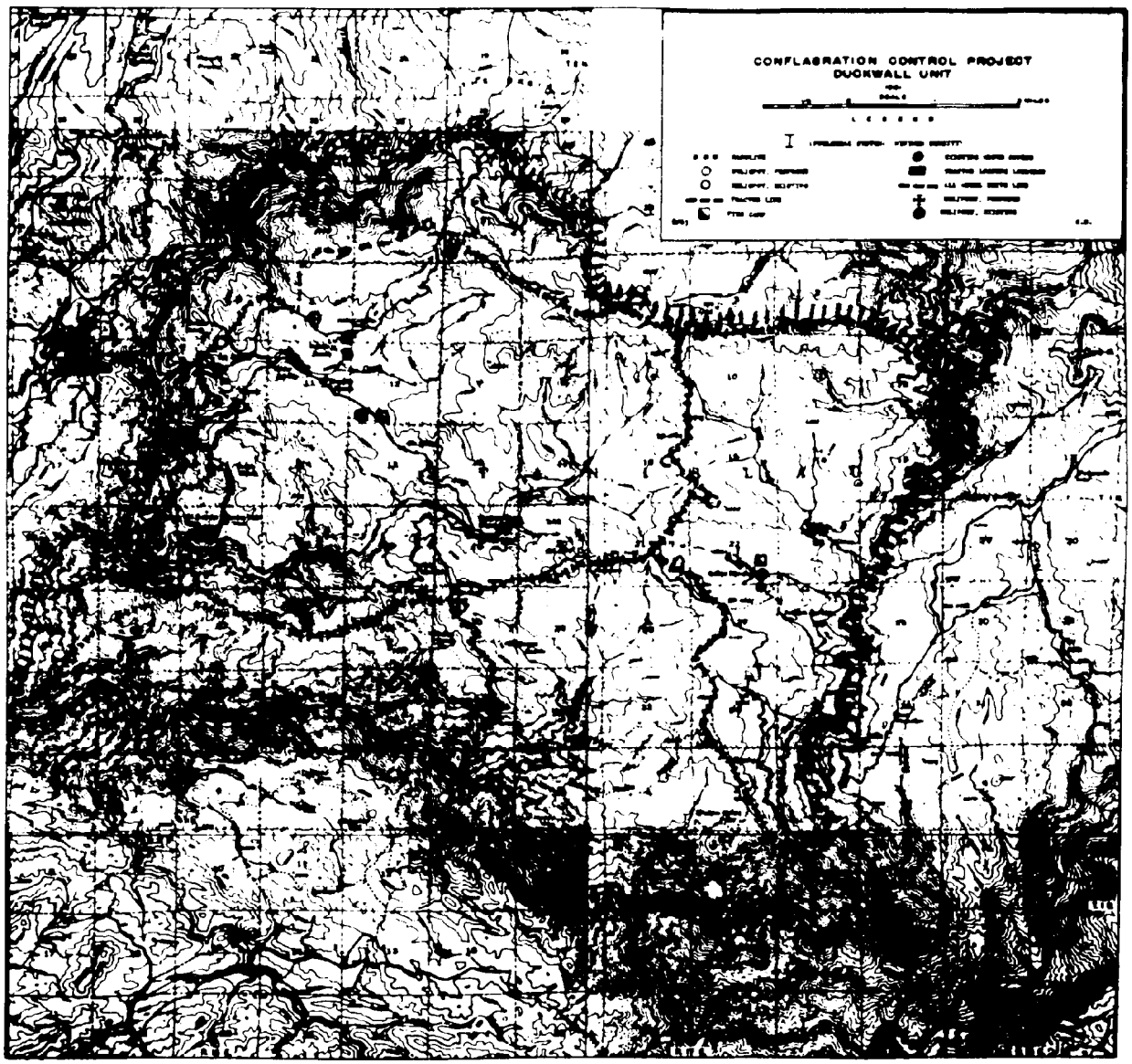

EXHIBIT 11
FUELBREAK SYSTEM, LEVEL I, DUCKWALL UNIT

EXHIBIT 12

CONSTRUCTION AND MAINTENANCE SCHEDULE ASSUMPTIONS

Construction schedule assumptions

A. Construction will be finished in five years (1963-1957). Total construction costs shall be divided amongst these years and subdivided according to timber (handline and tractor line) and brush (handline and tractor line).

B. Spray regrowth will be done only in brush. Each acre of brush will be done three times at $14.60 per acre which is estimated to be average cost over the three-year period. Supervision for this spraying will be $1.23 per acre.

Spraying shall be started in 1964 and will continue until the total acreage has been sprayed three times. This shall carry the spraying job until 1970. The amount of total acreage done each year will be as follows:

1964--20 per cent (total brush acreage)

1965--40 per cent	1968--60 per cent
1966--60 per cent	1969--40 per cent
1967--60 per cent	1970--20 per cent

Maintenance schedule assumptions

A. Planning and preparation will be done each year at the cost of $0.25 per acre. Total acreage shall be covered once every five years; thus 20 per cent of the total shall be done each

year. Planning and preparation will be done in both timber and brush beginning in 1964.

B. Fuelbreak clearing will be done in brush only. This will be done from 1971 to 2012. In this time one-third of the total brush acreage will be cleared. This acreage cleared is divided proportionately amongst forty-one years to get the yearly acreage cleared.

C. Snag clearing will be done from 1964 to 2012 in brush only. The total acreage will be covered once every five years.

D. Several extra costs that will be incurred between timber and brush are as follows:

1. Parts	$0.85 per acre
2. Safety meetings	0.68[1]
3. Meals	2.57
4. Erosion control	As listed[2]
5. Indirect costs	As listed

Maintenance of construction and handwork will begin in 1971 and will cover every acre once every five years. Thus, each year will be one-fifth of the total acreage. The area covered during the normal day would be five times as great as that in a normal day of

---

[1]The cost per acre for safety meetings is an average figure based on one meeting per week. On the assumption that manpower is directly related to hand acreage worked, the cost per acre remains a constant figure.

[2]Erosion control will cost $0.25 per acre when covering total acreage. One-fifth of this acreage will cost $1.00 per acre. Between one-fifth and the total acreage, the cost will vary proportionately between $1.00 and $0.25 per acre.

investment construction. Thus, the cost per acre would be 20 per cent of the investment cost per acre.

EXHIBIT 13

November 13, 1962

TO : Cooperators--Conflagration Control Project
FROM : James L. Murphy, Research Forester
SUBJECT : Forest Fire Research (Fuelbreak Evaluation)

Each of you has been asked to help us evaluate the success of fuelbreaks and a specialized fire-suppression organization in stopping conflagrations. You have been selected because of your forest-fire control judgment and experience. The objective of your assignment is:

> Estimate how many times in a hundred fuelbreaks and a fire-suppression organization will stop fires burning at very high to extreme burning indexes on the Duckwall Conflagration Control Unit.

The estimates will be made at five locations in timber and five locations in brush. You will be able to see the fuelbreak system, will have the fire-suppression organization available to you for reference, and will be given the weather conditions under which assumed fires start and burn. Each of you was on the Wright's Creek, the Flora, and the Walton Spur fires. Use your knowledge of fire behavior based on these fires to help you make your times-in-a-hundred estimates.

Thanks for your help,

James L. Murphy

Times-in-Hundred Estimate of Conflagration Control on the Duckwall Conflagration Control Project

ASSUMPTIONS

I. Fire control organization

Manpower

Lineworkers	10
Air attack organization	6
Helitack crew	4
Firing crew	4
Heavy equipment organization	3
Total	27

Ground equipment

Tractors	1
Pumper	1
Total	2

Air operations

Reconnaissance plane	1
Air tankers (TBM)	2
Helicopter	1
Retardant mix crew	1
Total	5

Bases: Aircraft--Columbia Airport

Ground crews and equipment--Riverside Guard Station

II. Size at detection--0.2 acre (starts in bottom of draw)

Report time	2 minutes
Getaway time	2 minutes
Travel time	15 minutes
Elapsed time	19 minutes

Time crew has to work before fire reaches block size:

Timber

BI 24	100 minutes
BI 30	70 minutes
BI 55	28 minutes

Brush

BI 31	70 minutes
BI 37	52 minutes
BI 55	28 minutes

III. Weather

For each estimate assume:

In timber

BI 24

Fuel stick moisture	10

Relative humidity 10

Wind speed . . . . . 10 mph

Wind direction . . . . . West

Build-up index (heavy fuels) 25.9

BI 30

Fuel stick moisture 6

Relative humidity 7

Wind speed . . . . . 15 mph

Wind direction . . . . . West

Build-up index 30.0

BI 55

Fuel stick moisture 1-3.5

Relative humidity 0-6

Wind speed . . . . . 22 mph

Wind direction . . . . . West

Build-up index 50.0

In brush

BI 31

Fuel stick moisture 8

Relative humidity 9

Wind speed . . . . . 11 mph

Wind direction . . . . . West

Build-up index	81
BI 37	
Fuel stick moisture	5
Relative humidity	6
Wind speed	13 mph
Wind direction	West
Build-up index	90
BI 65	
Fuel stick moisture	0-4.5
Relative humidity	0-4
Wind speed	20 mph
Wind direction	West
Build-up index	100

Duckwall Conflagration Control Project
Estimate Sheet

Take as long as you like. Move to any vantage point you desire. Make three estimates to yourself: the first--reconsider; a second--consider again; a third--then enter your final estimate below. The estimate is:

HOW MANY TIMES IN A HUNDRED WILL A FIRE BE HELD WITHIN THIS BLOCK BY FIRE CREWS

Timber	BI 24	BI 30	BI 55
Block 1			
Block 2			
Block 3			
Block 4			
Block 5			

Brush	BI 31	BI 37	BI 65
Block 1			
Block 2			
Block 3			
Block 4			
Block 5			

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