aster's Thesis

Business Management in Forest Fire-protection

Floyd L. Otter   January 1935

BUSINESS MANAGEMENT IN FOREST FIRE-PROTECTION

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A REPORT

SUBMITTED TO PROFESSOR S. W. ALLEN

OF THE

SCHOOL OF FORESTRY AND CONSERVATION

UNIVERSITY OF MICHIGAN

AND AT THE SAME TIME

A SURVEY

FOR THE USE OF FORESTRY STUDENTS

BY

FLOYD L. OTTER

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Professor Shirley W. Allen
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Dear Professor Allen:

The survey of the subject of fire-protection planning which I promised to send you is enclosed herewith. It covers more territory than was originally intended because of a desire to give the reader, who will usually be a forestry student, a birdseye view of the whole subject instead of a detailed analysis of any one phase.

It is assumed that the reader will be familiar with the ordinary terms and the ordinary equipment and methods used in fire-protection. The English term, "fire-protection" is used as it seems to me to be, all angles considered, a simpler and more descriptive term than fire control, fire prevention and control, or forest protection: fire. Forest fire engineering might be a more descriptive and attractive term. Fire prevention is assigned its narrowest meaning, the restraining of fire-starting agencies. All phases having to do with fuels and fire weather are placed under the heading of preparedness, which is defined as in the Region Seven Handbook.

The subjects of forest fire insurance and appraisal and valuation of fire damages were left out because it was thought that they constituted a division of the field of forest fire finance distinct from planning. Three sections listed in the table of contents were omitted because of limited time and the belief that they are not essential to the understanding of the subject.

The material for the sections on attack requirements and placement planning was largely obtained orally from L.G. Hornby, C. B. Sutliff, and R. A. Bottcher of the U. S. Forest Service. If those sections contain discrepancies or errors of fact, it is due to differences between regions, to having few written sources of reference, or to recent changes. Other sources of reference are given credit in the list of references. The philosophy underlying the setting up of burned-area objectives I believe to be largely my own, and as such is practically the only original material included. In the six main steps in planning I have added the first and the prevention step to the four that Show and Kotok set up in 1931. The arrangement of material under the subheadings is my own. If the survey should seem to be "the elaboration of the obvious", Chief Justice Holmes said once that "We need education in the obvious more than investigation of the obscure". I have tried throughout to discuss only what seem to be basic principles and to avoid details of methods, except when details are needed as illustrations.

Respectfully submitted,

Floyd L. Otter

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Floyd L. Otter

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BUSINESS MANAGEMENT IN FOREST FIRE-PROTECTION

The protection branch of a forestry enterprise demands for its management the utmost in executive skill and business sense. This is not only because it is charged with the safeguarding of immensely valuable and highly combustible resources, but also because in the work of safeguarding these resources, there is an unusual possibility for waste of money and effort if there is a lack of foresight in planning or of good organization of the fire work. Care must be taken that fire does not eat into the forest capital--the forest itself--to the extent that the earning power of the forest is seriously impaired, and at the same time, that fire-protection costs do not become so great as to use up all of the profits of the forest business that may be earned. Fire-protection is a means and not an end. It must be made efficient and aggressive and it must be kept in check. It makes no difference whether the forest enterprise be public or private, or whether it is carried on primarily for wood production or for park or other purposes, good management is essential if both fire damage and fire protection costs are to be kept within a limit that will allow the forest to serve the purposes for which it is maintained.

Management may be defined as the skillful correlation of work to be done, and of men and methods with which to do it in such a way as to accomplish certain stated objectives. The correlation of fire-protection work, fire-protection men, and fire-protection methods in such a way as to accomplish the protection objective set up for a given forest is a management job calling for the highest skill and judgement.

The workman who makes a better mousetrap than any other workman, the world beats a path to his door; the foreman who gets out more logs than any other foreman may someday be made walking boss; the manager of a forest who protects it from fire and does the job with foresight, economy, and judgement, although his principal reward may be in being given more territory to protect, has been exercising good management; he is a "good man." A good manager in the fire-protection field is no less sought after than the good mousetrap craftsman is in his or the good logging camp foreman or the million-dollar business executive are in their fields.

How does the good manager go about it to get results in fire-protection? If the man in charge of the fire work knows the details of the fire game in his region, and if the owners of the forest, be they the public or private persons, appreciate fully the need for fire-protection, the foundation is laid for a well managed protection unit. Then what remains to be done before the actual work of fire prevention, pre-suppression, and suppression begins? It is planning the work, setting down on paper how work, men, and methods are to be correlated so as to accomplish some definite, stated objective.

It is the purpose of this paper to outline, at least, what is now considered to be good management practice in planning fire-protection work, remembering at all times that the application of management through conscious and comprehensive planning is something comparatively new in fire-protection and consequently that which is the last word today may be replaced tomorrow with something entirely different. The tools with which we must work--fire occurrence and damage figures, predictions of timber yields and values, maps and cost data--

are now admittedly inadequate. When better tools are available, new and better ways of building our fire-protection structure will be developed.

It is assumed that the reader has previously been convinced by logic or experience, of such things as

the desirability of protection,
the possibility of suppression,
the prudence of preparedness,
the economy of prevention,
the fallibility of human nature,
the indispensibility of organization,
the significance of time,
the wisdom of planning ahead.

And the greatest of these is the wisdom of planning ahead. Upon a full appreciation of these points rests the attitude which gets things done in fire-protection. They should always be kept in mind.

At the present time these six steps are commonly considered to be essential in fire-planning:

1. Recognition of the relation of fire protection methods, improvements, and men to the other forest activities, for the particular protection unit under consideration.

2. Determination and statement of a specific objective which can be used as a basis for planning fire-protection work.

3. A thorough examination of the causes of fires to see where effort can be put forth in the prevention of fires that will yield returns by saving effort and money in preparedness and suppression, while keeping fire losses within the objective.

4. For the fires which will probably occur in spite of prevention efforts, determination of the speed necessary in attacking them in order to hold fire losses within the stated objective (2, above). Strength of attack must also be decided upon. These decisions must be made for both:
(a) initial attack or first line defense, and
(b) crew attack or second line defense.

5. Determination of the amount and placement of man power and fire-protection improvements required to attain the needed speed and strength of attack. This step involves the gathering of all necessary basic fire information and from it building up a comprehensive fire-preparedness plan.

6. Working out suppression methods and equipment that will improve the performance of men on the fireline.

Planning the fire protection work is, of course, only one part of the job. Execution of the plans after the fire season starts is the test of both the plan and the executive. But the ability to plan, to coordinate, to correlate is primarily what the manager is hired for, and for that reason and also because the details of execution are discussed quite thoroughly elsewhere or are best learned on the trail and fireline, good planning is here considered to be the essential part of good management in fire-protection. It is assumed that a fire-protection plan built by fire-protection men for their own protection unit will be put into practice without difficulty.

This discussion which follows is divided into six sections corresponding to these six essential steps in fire-planning.

The Place of Fire-protection in the Work of the Forest and Other Considerations Fundamental to Fire Planning.

The first step in taking charge of a fire-protection unit involves orientation. The head of the fire-protection branch finds out what sort of conditions he is up against. He learns where he stands in relation to his boss and associates--how fire-protection is related to the whole of the forest organization and to its several divisions; he learns how he can know what to expect as to the number, type, and location of fires and the probable results of any proposed protection effort; he determines the geographical limits and divisions of his work.

A principle of management states (12), "All plans, tasks and programs must be so applied to each person concerned with their attainment, that he will have a definite and full knowledge of the purpose of his portion of the task or program, and the relationship of that portion to the whole, and the limits within which his responsibility and authority extend."

The Place of Fire-protection in Forest Management

All businesses and other enterprises operate under more or less uncertainty--more or less fear of loss through fire, flood, lightning, hail, theft, depression, obsolescence of their product or their methods, shipwreck, loss of key men, strikes, "war, riot, insurrection, and acts of God." Among ordinary businesses most unforeseeable contingencies can be insured against--there are on the market policies for marine insurance, fire, hail, rain and lightning insurance, and the lives of key men in the organization can be insured. Insurance for the average business takes a great deal of the risk out of the enterprise but it cannot by any means take care of all causes or cover fully all possible losses.

Forestry is no exception to the general rule in that it is threatened by several unforeseeable dangers although the special dangers to which forestry is subject have often been exaggerated, and the many ways in which forest investments are relatively very safe have been generally overlooked.

It is true, however, that, unlike other businesses, forestry as yet in the United States cannot insure against some of its most important causes of damage namely fire, insects, and disease in timber stands. Neither can protection be left to outside agencies such as fire departments in cities. The result is that in forest enterprises the protection branch, instead of consisting merely of a night watchman, a fire alarm system, and some water buckets marked "Fire" as is the case with many factories, is a very important branch of the organization.

There are three essential branches to a complete forestry organization. The responsibility of one branch is to operate the forest producing plant (the forest itself--soil and the growing forest products) so as to produce a continuous supply of the wood and other forest products needed. Another branch must protect this producing plant ~~from fire~~ so that it and its mature products may not suffer so much damage that the orderly progress of removal and replacement of forest products will be disrupted. A third branch utilizes the mature products by converting them into lumber or by using them in other ways so as to get the greatest possible return from these products either in money returns or in other benefits. The forest protection man need not feel that his work is any the less important because he is producing neither trees nor lumber. His work is essential to both and therefore no less in importance.

The Interrelation of Fire-protection Methods With Other Forest Activities.

There are two important ways in which fire-protection is dependent upon or interrelated with other work of the forest. The protection man will recognize very early the fact that the methods of each of the three branches of utilization (particularly logging, grazing, and recreation), forest production, and protection often greatly influence the success of the efforts of the other two branches. Logging slash, for example, if left unburned or carelessly burned may seriously interfere with both protection and timber reproduction. Thinning young stands often makes protection easier. Grazing is often an aid to protection and may either aid or hinder forest production. Roads necessary for protection may, in many instances, be made of service in logging if both uses are taken into account in locating them. It is the responsibility of forest management, that is, of all the branches of the forest enterprise centered in one head, to weigh the relative merits and disadvantages of each proposed logging or grazing method, of each reproduction and stand improvement method, and of each protection scheme, and to integrate the work of the three branches so that the objectives of forest management will be accomplished economically and without friction.

The other important relation of fire-protection to the general work of the forest is the one of selecting an objective upon which fire-protection plans may be based. This also is a responsibility of forest management because a fire-protection objective cannot be decided upon by taking into consideration only fire-protection factors. It is a problem in economics and technical forestry. This problem is discussed in a later section.

Fires and Fire Damage are Predictable.

The argument for conscious and detailed planning of fire-protection work is based upon two premises. Fire-planning is a waste of time if they do not hold true. The first premise or assumption is that fires are predictable, that is, that their occurrence in the future can be foretold with enough accuracy that effective preparations may be made to suppress them. Are forest fires like earthquakes in that we can do nothing about them until after they occur, or are they more like bedbugs in that they can be prevented by the wise and exterminated in their early stages if they do occur?

This first premise is discussed more at length in the following paragraphs. The other needs only to be mentioned. It is that there is a definite relation between forest fire damage and protection costs. Do we have fewer and smaller fires and less damage if fire-protection is practiced than if fires are uncontrolled or do fires become more prevalent and larger in size if "annoyed" by protection efforts? To dispute premise No. 2 it would be necessary to out-talk city fire departments and explain away most of the records of forest fire costs and damage. Fault may be found with our methods of fire-protection as a good many people do, including the clan of "light-burners" who come to town periodically, but it would be difficult to disprove our second major premise, that with greater and greater fire-protection effort, we tend to get less and less fire damage. A corollary is that with greater and greater preparedness effort, we tend to need less and less suppression money. Figure 1 illustrates these principles.

The good fire protection manager, then, according to our first premise must recognize that, although forest fires are unforeseeable as to the exact conditions which surround their start and spread, they are foreseeable and predictable in the sense that fires in buildings, damage from hail and lightning, automobile collisions, and deaths are predictable. Lightning may never strike twice in the same place but if it has struck on the average of 231 buildings in Iowa each year for the last twenty years, insurance companies will gamble that it will strike about 231 buildings in Iowa next year. If there has been as many as ten simultaneous fires in a large city and their causes cannot be removed, the fire department clearly must provide men and facilities to handle at least ten fires at one time in the future. Forest fire-protection, too, must be ready to handle any load of fires which experience teaches may occur.

From the experience tables of mortality of life insurance companies you can predict not only how many 40-year old men will die next year, but you can be fairly certain what percentage will die of pneumonia, and of how many will die in Oklahoma. Similarily from the fire records of a forest it may be predicted with fair accuracy how many fires will occur next year, how many of them will be caused by lightning and how many by careless smokers, how many of them will be on the Skookumchuck drainage, and what their probable sizes will be when reached. If insurance companies will gamble their resources on tables of past experience, fire protection can base its plans on past records of fires. Past records interpreted in the light of experienced judgement and of changes which may have taken place in the forest or among fire-starting agencies are the only reliable sources of information on the amount and character of "fire business" that a forest may expect.

Fire-protection Units

Fire-protection units may or may not coincide with working circles or other units for timber production or logging, but their limits must be decided upon and must remain relatively fixed if fire planning and fire-protection are to be efficient. Fire-protection units must be large, the more difficult the suppression problem in the region is, the larger must be the ultimate unit, in order that the unit as a whole will be able to muster men and resources enough to handle the largest fire that may occur(6). In the South the territory of one fire warden may be sufficient to form a unit because he and what local help he can pick up may be able to cope with the worst fire situation. In such a region as Northern Idaho, some sort of fire plan must be made to cover a whole region so that its combined suppression forces may be brought to bear on one fire or one division of the region if needed. The large unit may be subdivided administratively in any way considered advantageous and also for purposes of detailed fire planning, subdivision must often be made.

The unit for the detailed first-line-defense fire plan should be small enough to have similar fire-protection characteristics. In the Northern Rocky Mountains such fire planning units vary from a whole national forest to as small as 100,000 acres. It is difficult to set up separate detection and smokechasing systems for smaller areas. The units selected should be as uniform as possible as to

1. Value, considering timber type, site quality, and accessibility.

2. Fuel danger, percentage of burned area and cut-over area being most important.(26).

Even if the white pine belt of the St Maries Palouse and Clearwater Rivers was not under a different type of ownership than the back country of the St. Joe and Clearwater National Forests it would be logical to make a separate fire plan for the two types of country because of their differences in value and percentage of cut-over land. At the same time the plans for the two units might be logically put into execution by a single organization directed by one man.

In addition to the necessary delineation of planning units, the administrative boundaries for fire-protection must be decided upon and made known to all concerned. The good manager will find out the exact area for which he is responsible and the amount and type of cooperation expected of him and what cooperation he can expect from other fire-protection units.

The fundamental considerations of the place of fire-protection in forestry, of its interrelation with other activities, of the predictableness of forest fires and fire damage, and of the delineation of fire-protection units having been touched upon, the most important and most perplexing step preparatory to fire-planning will now be discussed. This is the determination of a definite objective.

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Determination of An Objective

The fire-protection manager must recognize at the outset that complete exclusion of fire from forests is usually both physically impossible and economically unjustifiable. An intensity of protection must be found under which neither the fire damage sustained nor the fire-protection costs, nor both together will be too heavy a burden for the forest business to carry. How can this intensity of protection be determined for a given unit? The manager must know where he is going before he can figure out a way to get there. If complete exclusion of fire were desired he would have to plan an airtight and expensive system. If the forest can stand to burn one hundredth of its area annually an entirely different system is called for.

"For every business activity there must be a definite and clear knowledge of the objective toward which that activity moves, the successive steps necessary to reach that objective, and a time schedule in which the various steps are assigned definite times for accomplishment."

The determination of objectives, as mentioned before, is a task for the general management, since it must correlate all activities. In fire-protection objectives have been set up usually by general administrators of forest lands who were also experts in fire-protection. The principles used and the results of their labors are outlined in the following paragraphs:

P plus S plus D

As has been explained, practically all businesses set aside a certain amount for protection against unforeseen contingencies. For protection against fire in the ordinary business this fund provides not only for the premiums of insurance policies but often for such items as water-buckets, sprinkler systems, night-watchmen, alarm systems, fire-escapes and fire-proof safes. Now business management requires proof of returns from every expenditure. The business reason for incurring a good many fire-protection expenditures is that by making their property safer from fire, the owners can get the fire insurance company to reduce their premiums more than enough to offset the added protection costs. Forests are not commonly insured against fire, but good management dictates, nevertheless, that every fire-protection expenditure return its cost or more to the forest business through decreased fire losses. This principle is sometimes called the minimum cost principle. Stated in another way, the principle is that the intensiveness of prevention and preparedness shall be such that the sum of prevention and preparedness costs, suppression costs, and fire losses (P + S + D) shall be a minimum. The working of this principle may be illustrated by Figure 1. The first two sections are taken from the fire records of the Shasta National Forest. Plan I and Plan II are hypothetical plans, the former illustrating that by good management the total of P + S + D may be still further reduced, and the latter showing that somewhere there is a point at which additional expenditures for prevention and preparedness do not pay even though losses are still further reduced.

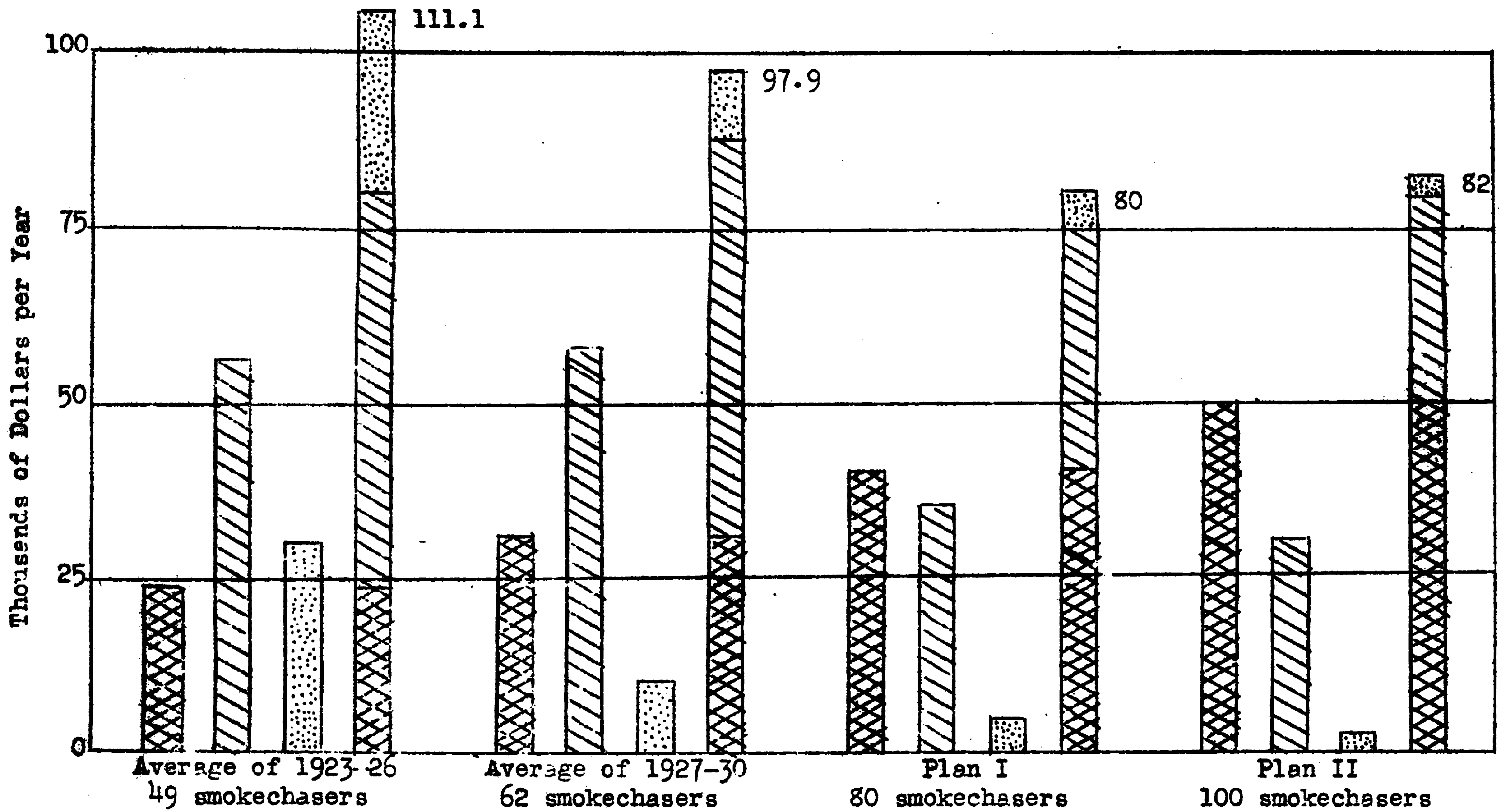

Fig. 1. Effect on Total Costs plus Damage of Increasing Prevention and Preparedness Effort
Shasta National Forest 1923-1930

P, Prevention and Preparedness Costs

S, Suppression Costs

D, Fire Losses

P & S & D, Total

Table 1, with an example from the Clearwater National Forest, Idaho, goes a little further by showing what might be expected if fire-protection were carried from the one extreme of no protection at all to the other of making prevention and preparedness so efficient that there would be no burned area at all. Line 3 is taken mainly from fire records, and lines 4,5, and 6 from plans actually made, the figures being those of the Forest Service. The other figures are purely hypothetical, the intention being to illustrate what could be expected to happen on an average forest under the conditions given.

←Weaknesses of Minimum Cost Principle

The minimum cost principle--when all types of fire damage are taken into account, is the logical basis for fire-protection plans, but in few if any cases is it usable without considerable modification. The reason that it is not usable is that the true valuation of fire damage cannot be accurately determined. The loss sustained by a private owner of merchantable timber in the event of a fire on his lands can be determined with an accuracy approaching that with which fire losses to buildings, standing farm crops, and ships at sea are now determined by insurance componies, but the damage to merchantable timber is only one of the many losses sustained by the owner and by the public when fires burn on forest lands. The other losses, indirect or intangible, are too well known to require detailed discussion here, but they are important enough to have caused many workers to discard the minimum cost principle entirely. It can be shown that it could lead to widely differing plans and different fire-protection costs depending upon who estimated fire damage and upon what bases. In Figure 1, for example, using the damage figures as shown which are based mainly on timber losses, Plan I appears to be the most efficient. If the damage were multiplied by three, as some foresters would recommend in order to include damage to watersheds and site quality and the increased difficulty of future protection and reproduction, plan II would appear to be the efficient one.

The Allowable Annual Burn

Because the exact or even approximate evaluation of fire damage is at the present time impossible of determination, fire-protectionists have looked around for a more usable even if a more arbitrary, substitute for the damage factor in the equation P + S + D. This substitute was found in the so-called allowable annual burn. Instead of juggling three cost figures (P, S, and D) until a plan was found that would reduce the total to as near zero as possible, it was decided to eliminate the D factor from the problem by assigning to each forest type an allowable annual burn figure expressed as a percentage of the total area of that type. The number of variables in the equation is thus reduced to two and the minimum cost principle can be restated to read: The intensiveness of prevention and preparedness shall be

TABLE I. **EXAMPLE OF THE RELATION BETWEEN FIRE-PROTECTION COSTS AND FIRE LOSSES**

	Prev. and Presup. Costs (P)	Suppr. Costs (S)	Fire Losses (D)	Total of P+S +D	Area burned annually: Acres	Area burned annually: % Total Area
	(thousands of dollars)					
1. No protection from fire	0	0	300	300	20,000	2.2
2. Suppression only	00	200	150	1350	10,000	1.1
3. Lookout system and prevention work. Approx. 40 lookout stations.	81[1]	90	77	248[1]	4,700[3]	0.52[3]
4. Increase to 70 stations	115[2]	54	48	217[2]	2,900	0.34
5. Increase to 112 stations	123[2]	30	45	198[2]	2,750	0.30
6. Addition of one more road	127[2]	26	43	196[2]	2,600	0.27
7. 20% increase in preparedness costs	152	10	36	198	2,200	0.25
8. Another 20% increase	180	5	30	215	1,800	0.21
9. Another 20% increase	218	2	25	245	1,500	0.18
10. Preparedness that would reduce burned area to practically nothing	500	0	0	500	0	0.

1. Actual figures from fire reports for Clearwater N. F. Average 1924-1931
2. Figures computed or forecast by fire-planners for Clearwater N. F.
3. Average for 1921 to 1931 excluding 1929. The objective in terms of allowable annual burned area which has been set up for the Clearwater National Forest is 2876 acres.

such as is necessary to attain the objective of allowable annual burn set up for the protection unit, the preparedness to be so organized that the sum of preparedness costs and suppression costs (P + S) shall be a minimum. The balancing of preparedness costs against suppression costs is a comparatively simple problem, to be solved by common sense and good judgement. Under the modified statement of the principle, the most intangible of the factors is eliminated and plans can be based on the preparedness necessary to keep annual burned area to a definite percentage of the total area for each timber type. If it should be agreed, for example, that protection needs of the Shasta National Forest would be satisfied if the area burned over annually were kept to 0.3% of the total of 900,000 acres, or 2700 acres, then it is possible to look up burned area records for past years and the forecasts of the burned area results of plans proposed for the future and readily ascertain which of the past or proposed schemes attained or promise to attain the allowable annual burn of 2700 acres.

The following table shows the actual burned areas and their percentages of the total area on the Shasta National Forest for the two four-year periods shown in Figure 1 and also figures for the two assumed plans:

	Burned Area Acres	Ratio average annual burned area to total area percent
1923-1926	40750	4.5
1927-1930	14175	1.6
Plan I	6300	.7
Plan II	2250	.25

It is thus a very simple matter to tell whether the objective has been attained in the past or can be attained by any proposed plan, providing the results of each plan are estimated correctly. Plan II is seen to be the only one of the four which meets the objective of allowable annual burn. Before going further, the method used in arriving at the allowable annual burn figures referred to in the previous paragraphs should be explained. This can best be done by an extract from the Copeland Report. (26, p1397-9)

> "The major purposes of management of forest land will be the chief guide in the formulation of the objective in fire control or the limit to which the area annually burned must be held. There are four universal criteria that can be applied as a gage in determining what the objective should be. These are as follows:

1. How much damage will a given fire cause to present and potential timber growth and other forest values?

2. How much damage will a given fire cause to the productivity of the land (the site)?

3. With what degree of difficulty will a forest be reestablished after fire?

4. Will future protection be increased in difficulty after a fire runs over the forest?

Indexes of effective fire control for various forest types
Table 3.

Type	Annual allowable burn	Type	Annual allowable burn
	Percent		Percent
White pine	0.1	Slash pine	0.7
Spruce	.1	Sand pine	1
Douglas fir	.2-.3	Longleaf pine	3
Larch-fir	.25	Northern hardwood	.2
Larch-fir-white pine	.15	Appalachian hardwood	.5
True fir	.2-.3	Bottomland hardwood	.2
Ponderosa pine	.3	Oklahoma hardwood	1
Mixed conifers(Calif.)	.3	Aspen	.7
Lodgepole pine	1	Noncommercial forests	2
Jack pine	.5	Brush and nontimbered	2.5
Norway pine	.3	Watersheds	.4-2.5
Shortleaf pine	1	Recreational values	0-0.5
Loblolly pine	1		

"These criteria, which reflect the major purposes in all forest management are interrelated and have been used in this inquiry as a device to measure the degree of damage that a given forest type is likely to suffer as a result of fire. In applying them we frequently find, for example, that a mere surface fire may cause the complete destruction of a spruce or white-pine forest. A fire of moderate intensity in the ponderosa pine type will seriously injure the site, wipe out young reproduction, and take some toll of mature timber. In the hardwood forests of the Central States, a ground fire will usually diminish the growth capacity of the forest and stimulate decay from damaging wood-destroying fungi, seriously depreciating the quality of timber. In the longleaf-pine type, fires do far less damage than in the other types mentioned. A fire in the brush-field watersheds of California seriously threatens storage resevoirs, special spreading grounds, and dependent agricultural land for 3 to 5 years, until a new brush cover returns. In a like manner, the damage done by fire to forage and watershed values, recreation values, and wild life varies between regions and even within a region. These varying factors have been taken into account in the determination of the objective in fire control.

"Realizing that complete fire exclusion is not a practicable measure and in many instances is too costly, an objective in fire control has been set up for each forest type based on the percentage of the area that may burn over annually without impairing radically the forest values as determined by the predominant purposes of management. This objective of fire control is expressed as the area of allowable burn, and has been determined for each of the major forest types (table 3). It becomes obvious that the absolute acreage burned over in different forest types is not the sole criterion either of the damage sustained or of how nearly the objective has been met. This annual allowable percentage index has been calculated by considering how the four factors influencing damage from fires operate in the different forest types of the United States. Controlled fires used for definite silvicultural or protective purposes are not included in computing the allowable burn."

Careful Selection of Annual Burn-Objective is Essential.

The objectives of fire-protection expressed as allowable annual burn percentages should, of course, be carefully arrived at and not accepted for any given forest unless found to be applicable to its particular conditions. If the allowable annual burn percentage is too high and fire-protection is consequently not intensive enough it causes a loss to the forest business. For example, consider a white pine forest of 200,000 acres, under sustained yield management, rotation and cutting cycle of 100 years, disregarding for the time all fire losses except those to the timber itself. If no fire losses need be expected, 2000 acres could be cut over annually representing, let us say, with a stumpage worth $6 per M and an average stand of 20 M per acre

2,000 x 20 x 6 = $240,000 per year income from stumpage.

If we take 0.1% as the percentage which must be sacrificed to fire each year to keep fire-protection costs within reason, and if we assume that this burned area is evenly distributed among the age classes, and assume further that half the burned area contains salvageable timber worth, on account of fire damage, checking, extra logging costs, and under-maturity, only 20% of its ordinary value per acre, then this annual sacrifice to fire amounts to

200,000 x .001 = 200 acres.

Multiplying by the average age of the timber destroyed and dividing by the rotation age, we have

$$\frac{200 \times 50}{100} = 100 \text{ acres a year}$$

which must be taken off the books as timberland which might have been logged each year. This reduces the annual return by

(100-20)% of (100 x 20 x 6), or

.80 x 12,000 = $9600.00

Since management costs such as taxes and carrying charges are constant, this sum represents a loss which is not compensated for in any way.

If an allowable burn of 0.2% instead of 0.1% were set up for this forest it would cost the forest business another $9600.00 or a total of $19200 which represents 8% of the total returns which would be possible if fire were not a problem. This is in addition, of course, to all the indirect and intangible losses that would be caused by the fires which would be permitted by such a decrease in the intensity of fire-protection.

If, on the other hand, the intensity of protection were increased, for example, to attain an allowable burn objective of 0.05% the forest business would gain by half of $9600 or $4800, but the cost of fire-protection would be greatly increased. If attainment of the 0.1% objective would cost 5¢ per acre, which is near an average figure for the northwest, or $10,000 per year, the attainment of the 0.05% objective would probably cost at least 12¢ per acre or $24,000 because costs tend to be more than directly proportional to results. This would be an increased cost of $14,000 to save $4800 to the business, a move clearly not justifiable unless there were values other than timber production involved. We might also assume that an intensity of protection necessary to hold losses to 0.2% would cost 2¢ per ~~year~~ acre or $4000 for the 200,000 acres. If we grant, then, that the men who set the allowable annual burn of 0.1% for a white pine type correctly evaluated all the fire factors, we may summarize in the following table the financial results if too high or too low an objective had been set:

Allowable Annual Burn	Annual Cost of Protection (P + S)	Cost of losses to the business (D)	P + S + D
0.2%	$ 4,000.00	$19,200	$23,200
0.1%	10,000.00	9,600	19,600
0.05%	24,000.00	4,800	28,800

The objective upon which fire-protection plans are to be based must satisfy two requirements. It must be justifiable from the standpoint of business management, and it must be in such a form as to be usable. The allowable annual burn as such an objective has been shown to satisfy the first of these requirements if it is selected by men of competent judgement who take all of the types of fire damage into account. Whether it is usable and how it may be used will be brought out in the section on attack requirements. Before taking up attack the administrative problems in preventing the start of forest fires will be briefly discussed.

Examination of the Causes of Fires

Every forest fire has its cause. With few exceptions the causes of all of our fires are known. No method of attaining the allowable-annual-burn objective, then, would appear simpler than to find out, for any given forest, what agencies start fires and then to proceed to make it impossible for these agencies to start fires in the future. This is exactly the line of attack that is used in well-thought-out fire prevention work.

Fire prevention, however, is not as simple as that. In the first place not all fires are preventable; in the second place, even if all fires were man-caused and therefore theoretically preventable, it would not be humanly possible to so control the carelessness and cussedness of human beings that no fire would be started; and finally, if it were humanly possible to prevent all preventable fires, such fire prevention effort would cost money and therefore as a business proposition would have to be controlled and directed according to business principles.

The principle involved is parallel to the minimum cost principle explained in the foregoing section. Here, however, instead of determining what is the most economical amount to spend for P (prevention and preparedness), the problem is one of determining the proper proportion of P to devote to prevention.

No formulae are needed for the solution of this problem. Horse sense will tell the manager that if the burned-area objective could be attained by spending all of the protection money and effort in prevention work he could save himself a lot of planning and sweat in developing detection, communication, and transportation systems and in fire-fighting. The same kind of intelligence will lead him, before he makes any such decision, to study carefully the fire records of past years to find out (1) what the probable future causes of fires will be, (2) which causes are the most important from the standpoint of probable damage, and (3) the geographical location of each cause, i.e. the risk zones in his district. In addition he would (4) examine carefully into the relative preventability of each of the various fire causes. Finally, he would (5) prepare a plan "providing specific lines of action to ward off, overcome, or minimize each risk within each zone" (32).

These are the first steps in preparation for fire-planning to meet a previously stated objective, and since the whole question of the choice of the type of fire-protection system and its entire makeup is involved no effort can be spared to get all the facts necessary.

> "There should be no business move of whatsoever nature without thorough and timely preparation, such preparation to be as exhaustive as permitted by the importance of the move." The first step is to determine the causes for conditions as they are.

Determination of Causes and Their Relative Importance.

Past records of fires on most forests of the United States are adequate to tell what the most important causes have been in the past and the acreage burned from each cause. These must ordinarily be modified in the light of present day conditions. As an example, on most forests the danger from smokers' fires is increasing. Again, the danger of lumbering fires may pass with the completion of lumbering operations and the danger from settlers' clearing fires increase. Railroad fires are decreasing with the perfecting of spark-arresters and the increased use of electricity and oil for fuel. Smokers' fires from airplanes may now be expected. A large fire like the Selway fire of 1934 may convert green timber into snag areas where lightning fires start easily or may clean off old single burns so as to make them relatively fireproof. Past fire records, nevertheless, are very good indicators of both probable causes and probable damage to be expected if fire-protection methods were not to be changed.

A point to be kept in mind is that numbers of fires alone is not a fair basis of comparison. The acreage burned and damage resulting from each cause should be compared for the forest for which the fire plan is being made. Man-caused fires in general are much more destructive than those caused by lightning, because they are started without the warning of approaching thunder clouds, they often occur in the most hazardous places such as at the base of a long steep slope, and in the worst fire weather. Table 4, computed from the 1934 statistics of the U. S. Forest Service shows some interesting comparisons of acreage burned by the several causes of fires, and shows the type of analysis that may be made for an individual forest from its records. The average size of fire computed as an arithmetic average exaggerates the prevailing sizes of fire because of a few very large fires in each class, but it serves to compare the seriousness of the fire causes. Damage figures in dollars, if based on reasonably accurate estimates, would give a still better comparison, but they are not available for these large areas. Tables 1 and 2 in the appendix give additional figures on causes of fires and damage.

Table 4—Numbers of fires and areas burned by forest fires by causes, 1926-1930.

	Protected Area										Unprotected Area Totals	Grand Totals
	Lightning	Railroads	Campers	Smokers	Debris Burn	Incendiary	Lumbering	Misc.	Unknown	Total		
Total United States												
Ave. No. of Fires per Year	4261	4043	3525	9403	5602	7638	1752	4108	4335	44672	111511	156183
Ave. Burned per Yr. Thousand Acres	275	181	281	711	552	1305	222	443	459	4429	37071	41500
Ave. Size of Fire Acres	64.5	44.8	79.8	75.	98.6	171.1	126.7	107.9	106.1	99.3	332.0	265.7
Rocky Mountain States												
Ave. No. of Fires per Year	2334	180	279	486	116	85	51	101	47	3697	140	3837
Ave. Burned per Yr. Thousand Acres	116	5	9	35	9	36	16	12	18	256	47	303
Ave. Size of Fire Acres	49.7	27.7	30.3	72.1	77.5	423.0	313.8	118.7	383.0	693.8	335.4	79.1
Idaho												
Ave. No. of Fires per Year	1081	40	105	163	60	58	30	28	34	1599	31	1630
Ave. Burned per Yr. Thousand Acres	88	2	0.9	16	6	15	4	3	5	141	35	176
Ave. Size of Fire Acres	81.4	50.0	8.5	98.2	100.0	258.8	133.3	107.1	147.0	87.9	1129	107.6

Risk Zones.

The next study to be made of fire causes concerns their geographical location. Obviously, prevention work will be more efficient if it is concentrated upon the areas upon which man-caused fires have occurred in the past. Lightning-storm clouds never read "Prevent Forest Fire" signs. Neither does a sign stating that "Green Timber Means Jobs for Loggers" appeal to the sheepherder who burns the woods to make the green grass grow.

So the thing to do is to take a map and show the location on it of all past fires separated according to cause. Draw a line around the areas where smoker and camper fires have occurred. Encircle similarly the fishermen risk zone, and mark off the corner of the forest where the "woodsburners" operate. These zones will probably overlap, but they show the areas in which different types of prevention work may be effective. Patrolmen and strict law enforcement for the camper and smoker zones; signs, checking stations, and work with the rod and gun clubs for the fishing creeks; and perhaps a little railfence philosophy with the leaders of the woods-burners will turn out to be the best possible way to spend that limited time and money which is allotted to prevention and preparedness.

Relative Preventability of Fires.

All man-caused fires are preventable in theory. In practice, however, it is rarely advisable to set out with the idea of reducing the number of man-caused fires to zero. As is indicated in Table 1, such a procedure would cost too much. Fires in cities have never yet been eliminated and the fact that forest fires still occur in France, a country with over a century of intensive fire protection experience and a well regimented citizenry indicates that complete forest fire prevention is not to be expected (8).

Some classes of fires are more easily prevented by attacking their causes than others. The first division to be made is between lightning-caused and man-caused fires. If in any particular area lightning fires are so numerous and destructive as to overshadow the man-caused fires, a situation exists under which the preparedness system and organization must be based upon the characteristics of lightning fires, and fire prevention work can save little or none of the preparedness expense. This condition obtains in many of our back-country national forests of the West. If, on the other hand, man-causes are important (and they are important out of proportion to their numbers), they must be studied carefully as to the relative difficulty (cost) of eliminating or reducing their numbers before ever attempting a plan for transportation and placement of lookouts and suppression men. The attack requirements set up for California by Show and Kotok (21) were based upon man-caused fires, because it was assumed that any speed fast enough to "get" man-caused fires would stop lightning fires also.

Man-caused fires vary a great deal among themselves as to the effort required to prevent them, although of course there are no figures available on the relative costs of preventing fires of different origins. Campers' fires, for example, always occur along roads which can be patrolled and the camper warned. Hunters and fishermen are not so easily checked on. Incendiaries may or may not be easily persuaded, depending upon the motives for their illegal activities.

One forest had a particularly bad railroad fire problem. Fires started by sparks from locomotives started fires which ran up the steep slopes to high country before a crew could be gotten to them. Added speeder patrolmen failed to get results. Finally a direct approach was made to the president of the railroad and the fires were immediately stopped by suitable spark-arresters. A little fire-prevention work well-directed got good results.

Another thing that we know to be true, even in the absence of any figures to support it, is that the law of diminishing returns applies to fire prevention effort as it does to the general protection problem. That is to say, that with each added unit of effort applied, the tendency is to get less and less results per unit of effort. The first good radio talk and warning may reduce the number of smokers' fires by twenty-five. Doubling the amount of radio time may reduce the number by fifteen, and so on. In this way the point is soon reached, at which the addition of more and more good radio talks will have no effect whatever on the number of lighted cigarettes thrown into the brush.

Prevention Plans.

Fire prevention work requires intelligent planning if it is to be effective. Such work at present has a tendency to be cluttered up with educational and law enforcement methods, which are not based on adequate analyses of fire causes nor aimed at definite risks in definite areas. Fire signs, for example, are useless if they are too small to be read or are not seen by the right people, or do not produce the mental reaction desired when they are seen. Prevention work such as signs, radio programs, and public school education in fire prevention must be done under the handicap of not being able to see immediately the results of each piece of work, but notwithstanding this fact, every prevention method should be carefully weighed in comparison with other possible methods.

After analyzing the causes of fires, their relative seriousness, and their geographical distribution, a thorough survey of methods should be made. Billingsby, in a "Fire Inventory" of Arkansas (4), listed under three headings all of the methods in fire prevention that had been used or could be suggested as possible methods. The three headings, called by him "means of abatement" of fire danger, were: (1) physical, (2) legal, and (3) persuasive. He then analyzed each fire cause separately and tabulated on a large chart the methods under each means of abatement which could be used in Arkansas forests to reduce the danger from each fire cause. For his incendiary risk, for example, he found that the possible means of abatement were: "(1) physical: Keep patrolmen and other forest workers in forests during fire seasons. This helps to frighten would-be fire setters. (2) legal: Enforce more rigidly existing laws and strive for convictions. Make fire setters liable for full value of stand as appraised by the Forester. (3) persuasive: Contact adult member of every family living near forest lands yearly. Pledge as many as possible to help prevent forest fires. Make public fire-conscious. Introduce forestry courses in public schools."

His next step was to compare the methods in use then with these possible methods. The weak places in the fire prevention work showed up immediately on the chart. This would be especially illuminating if compared with the analysis of damage from each cause so as to indicate whether the most destructive fire causes were adequately covered by prevention measures.

To sum up, in planning ahead in prevention and in execution of plans, diligent study should be made of past records and of present tendencies in fire causes, Risk zones must be defined and the appropriate action lined up for each zone - and carried out. Constant vigilance and training of employees is required to detect new risks and to invent new methods of combatting new and old causes. In deciding among the priority of different lines of prevention work, effort should be concentrated where the results will be greatest, leaving to preparedness the task of looking after lightning fires and those man-caused fires which may be expected to occur in spite of the best directed efforts in prevention.

Attack Requirements and Other Uses of Burned-Area Objectives

Knowing the annual burn which is considered allowable for the forest, and how much of the fire load can be prevented by removal of fire causes, the fire-protection manager can then work out the best organization of men and methods to keep fire losses within the objective. However, a step preliminary to actually planning the fire-preparedness organization and improvements is necessary. It is the setting up of specifications which may be called attack requirements (the so-called hour-control standards).

Besides the determination of attack requirements, there are two other types of uses to which burned area objectives may be put in fire planning and in other fire-protection activities involving money. They are: (1) allotment of fire protection funds among regions, forest types, or administrative divisions; and (2) comparison of the effectiveness of protection effort as between separate forests or divisions, and determination of the safety from fire of forest investments. Although the determination of hour-control or speed-of-attack requirements is the only one of the three which is essential to the remaining steps in fire planning, the other two will be briefly touched upon in order to more fully explain the nature and use of the allowable-annual-burn figures.

←— Fire Surveys. Before setting up definite specifications, however, the manager will want to know all there is known about his forest. The same "principle of preparation" that requires that the causes of fires and their geographic occurrence be analyzed and used as a basis for prevention work requires also that the fire history of the forest which is to be protected and the forest itself be "taken apart", as it were, to see how its various parts react to fire when it does occur. To get the necessary basic facts a survey is made of the forest to get data primarily on (1) relative commercial values of the forest types and (2) their relative fuel danger. Weather and other factors in fire danger are too variable to study by means of the physical survey.

Value. Enough data on values can usually be determined from the data on forest types collected in the regular timber surveys made for purposes other than fire-protection. The question of relative values of these types has already been considered in a broad way in setting up the allowable-annual-burn objectives. Local variations in values, however, should be shown on the fire maps. Other factors being equal, more valuable lands deserve more intensive protection. Certain white pine lands, for example, may be very valuable due to accessibility or site quality, and others may be of very inferior value on account of their location, altitude, or soil. Age of timber would undoubtedly be a large factor in value in plans for protection by private companies, but the government usually takes the long-time viewpoint that it is the producing power of the land and its accessibility that are important.

Fuel-danger. Behavior of forest fires depends in the last analysis mainly upon fuels. Accordingly, it is very desirable to have the forest area classified as to fuel-danger or fuel types. Some forests consider the forest type and age class map adequate basis for judging fuel danger. Others such as Region One of the U. S. Forest Service classify "fuel types" by means of separate fuel danger surveys in the field. The method, described in detail in an instruction manual (28), consists of classifying all forest areas, first, as to probable rate of spread of fires, or inflammability; and second, resistance to control, or difficulty of constructing held fire line. A high rate of spread combined with a high resistance to control such as might be found on an exposed southwest slope in a 20-year burn in the white pine or larch fir types (a so-called high-high, H-H, fuel type) would indicate an area where fires must be attacked both promptly and hard, and would consequently call for stringent attack requirements.

The costs of the field work of fuel-type mapping for the North Idaho Protective Association area of 2,170,000 acres done in 1934 was $1.96 per thousand acres including supervision. This is higher than the costs have been on the National Forests.

Weather danger. Fire plans, while they may be made flexible enough to be adjusted readily to changes in fire weather, must above all, provide the organization to cope with "worst" fire conditions. "Worst danger" is defined as the condition "characterized by short vision distance of detection, rapid spread of fires, frequent necessity for two or more men per fire (even with short travel time), occurrence of numerous fire-setting lightning storms, and the presence of many people likely to set fires." (29). Region One expects six months of "worst danger" conditions in every ten years, based primarily on the factor of weather.

Total Fire Danger Map. If the three factors in fire danger mentioned above which are stable (namely, commercial value, rate-of-spread, and resistance to control) are combined with the fire occurrence map made in connection with fire prevention planning so as to make one composite map of the firest, we have a picture of the geographical distribution of fire danger which may be expected on the forest. If "high-high" fuel danger is combined with high value in an area where non-preventable fires have been concentrated in the past, a reasonable regard for facts will lead to the setting up of attack requirements which, when converted into a fire-protection organization, will prevent any recurrence of "worst danger"" conditions from causing fires which might upset the allowable-annual-burn objective for the forest. In other words, fire-traps call for air-tight organization or sooner or later hell will break loose.

Fuel Danger is Subject to Progressive Changes. Due primarily to ecological forces, fuel types change both in probable rate of spread and in resistance to control. The activities of man and fires which occur are also responsible for important changes in fuel danger. A fuel type rated now as high in probable rate of spread because of fine slash left from logging, may be expected, as the slash decays and reproduction comes in to shade the ground, to become medium or even low in this factor. A highly inflammable grass and dying brush fuel type may in a few years become a much less inflammable fuel type if it is taken over by tree reproduction. At the same time, the resistance to control will increase.

These changes are all predictable for at least a few years ahead, and are taken into account in fuel type mapping.

The changes which logging makes in fuel type may, from logging plans, also be foretold. Extensive fires which occur in spite of protection efforts call for revisions of fuel type maps and of the placement of men which was based on these maps. The Selway fire of 1934 necessitated a revision of fuel type maps and of preparedness organization on approximately 200,000 acres.

Planned Reduction of Hazard: A line of attack closely allied to fire prevention is that of reducing the probable rate of spread or the resistance to control or both. The best approach to this problem is undoubtedly by fuel types, just as the best approach to the problem of reducing the numbers of fires is by risk zones. The most common form of hazard reduction which enters into fire planning is the firebreak. Permanent firebreaks are constructed and maintained around every forty acres in some forests in the Lake States. The fire plan for California calls for construction of a wide firebreak and motorway known as the "Ponderosa Way" between the brush and timber zones around the Great Valley of California. Other plans in the West call for the falling of snags on strips a quarter mile wide through fuel types of especially high resistance to control. Cleanup of hazards along railroads and roads is necessary in many regions. Grazing may be used to reduce probable rate of spread.

Prevention of Hazards: Reduction of hazard through proper slash disposal and snag falling after logging and stand improvement work is one logical way of preventing the accumulation of areas of high fuel danger. The means employed to accomplish this work on private lands make it a field of work practically inseparable from prevention. The "means of abatement" of hazards will come under the heads, persuasive and legal.

Silvicultural work such as thinnings has been shown in the Black Hills to have resulted in decreased resistance to control as well as decreased rate of spread, even then the slash was not burned (24). Selective logging instead of clearcutting should prevent the leaving of areas of high fuel danger since even the partial abode, as shown by experiments at Priest River, Idaho, (29,23) reduces the inflammability of the finer fuels very materially.

The reduction of burned area itself is a means of preventing accumulation of hazardous areas, since single burns usually result in open snag-covered areas of high fuel danger.

These are but a few of methods employed in reducing and preventing hazards or fuel danger. Any conceivable method is worthy of consideration in the fire plan. Study should be made of the forest as to both its present fuel types and its trends in plant succession and of the future logging and silvicultural plans to see, fuel type by fuel type, what measures are applicable and necessary. Before going further with the planning of the placement of men and improvements the forest should be made as fireproof as its nature and purpose and the wise use of funds permit.

The point is now reached at which both the probable numbers of fires and their probable rates of spread and resistances to control should be known to a degree of accuracy upon which planning can be based. Specifications or standards known as hour-control standards or attack requirements are next to be worked out.

Determination of Attack Requirements.

If there are going to be fires which it is impossible or impracticable to prevent, the only way to keep the fire situation in hand is to attack these fires at the proper time with a sufficient force to control them. It is a first rule of fire-protection that all fires must be hit promptly and hard. But just how promptly and how hard? The attempt to solve this question so as to "get" the fires and at the same time to make ends meet financially, has led to the setting up of specifications considered both necessary and attainable. The question, "How hard?" is answered by working out the requirements for strength of attack; "How promptly?" by requirements for speed of attack.

The purpose of these attack requirements must be made entirely clear. They are not set up to serve as a guide for the number of men to send to any individual fire when it occurs, or to tell the smokechaser how fast he should walk or drive to any fire. They are set up purely as a guide for planning, as requirements in acre-feet might be given to engineers assigned to planning storage reservoirs for an irrigation project. An irrigation system may be planned and built on the basis of the storage space necessary to irrigate a given area under conditions of average rainfall, run-off, and evaporation, but the use of the water after the system is built will depend not upon average conditions, but upon conditions as they are each season. Similarly, attack requirements are set up to guide the planning of the system of improvements and the location of men. Distribution of fire-protection men and improvements in planning depends entirely upon how fast and how hard the average fire in "bad" fire years must be hit in order to keep burned-area within the objective. But after the system determined by planning to be adequate is in place on the forest, the use of the system in the routine of discovering and putting out fires depends upon the fire load and fire danger at the time and not upon the averages used in planning it.

In suppressing fires, of course, there always have been and always will be those which "get away" from the smokechaser who first tries to stop them, and they may get away again and again until their suppression is a major project for a large force of men. To meet this situation there are provided, as in trench warfare, several lines of defense. If the first-line troops cannot stop the enemy, there is a second line to throw into the breach, and perhaps a third and a fourth. The first line defense in fire suppression is the single smokechaser or the smokechaser crew. They can be started immediately and moved rapidly. Strength of attack will be low and speed will be comparatively high. Larger crews, on the other hand, take longer to assemble, must usually be transported farther, and always move more slowly than the same men would singly. The strength of the second line defense is much greater, but speed of attack is necessarily slower. It is obvious, then, that separate standards of attack must be set up for first line defense, for second line defense, and possibly for third line, if the suppression problems of the forest are very severe.

First Line Defense: The first line defense is the one which merits by far the most careful attention in planning. It is only when it fails that the others are needed. Strength of attack and speed of attack must be balanced carefully if the most economical use of man power and improvement funds is to be made.

Strength of Attack: Strength of attack may be arrived at the more simply of the two. Usually in the West fires can be reached when they are small enough for one man to control; and one man, therefore, is the strength usually chosen as the planning requirement for initial attack. In some types, for example, snag areas of the Douglas fire country, as many as five men are considered to be necessary for even the smallest fire, and five men is, therefore, the strength requirement for first line defense. Again, a forest may have weak detection or long distances to travel to fires, and a larger strength of initial attack would be more economical than to shorten speed of attack by strengthening detection and locating smokechasers closer to the points where fires occur. This type is common on forests where fires occur so infrequently that few or no full-time lookouts or smokechasers are employed. It may be said that such forests have no first line defense. Their protection system is a second-line-defense system. The general type of protection organization must be decided upon before setting up any attack requirements.

Speed of Attack: Speed-of-attack requirements are usually arrived at after more study and deliberation. Speed of attack or hour control is usually defined as by Show and Kotok (21), "The time elapsing between the start of a fire and the arrival of the suppression force." This would include the elapsed-time divisions of:

a. Discovery time - interval from ignition to discovery.
b. Report time - from discovery to report of location to headquarters.
c. Get-away time - from report to start of first suppression man.
d. Travel and search time - from start of suppression man to time of beginning work on the fire. Usually called simply travel time.

One more time division is significant in attack:

e. Fire-fighting time - from beginning of work on fire to the time spread is permanently checked.

These divisions and some additional ones are shown in Figure 2.

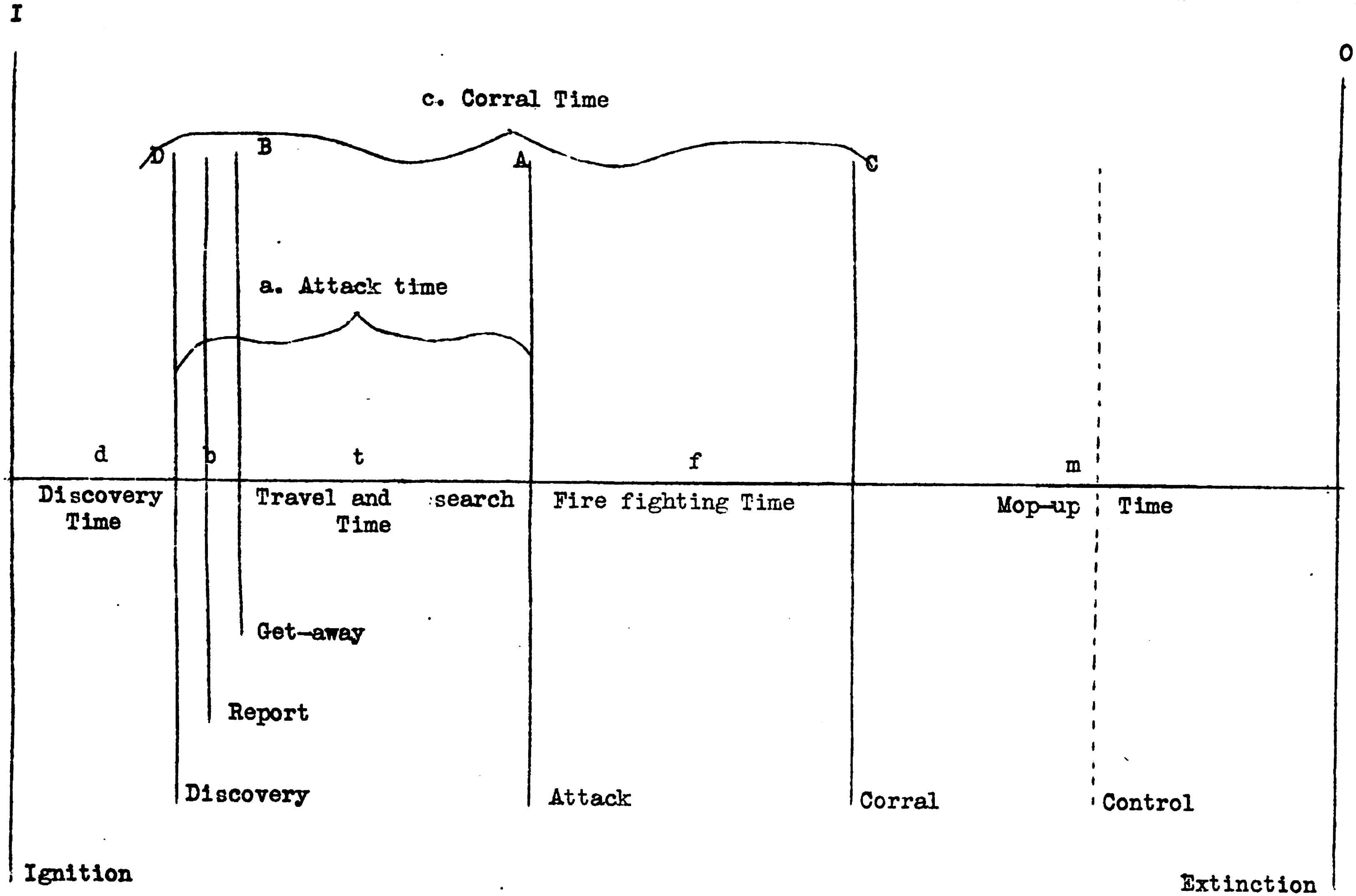

Figure 2. Elapsed Time Divisions

Total speed-of-attack requirements after they have been determined are usually split into several divisions corresponding more or less to these elapsed time divisions. Show and Kotok, for example, after deciding upon forty-five minutes as the requirement for the ponderosa pine type, allotted fifteen minutes for discovery, report, and getaway, and thirty minutes for travel. The detection and communication systems in this fuel type then, must be so located and the organization efficient enough that fires will be discovered, reported, and men on the way inside of fifteen minutes after ignition. Similarly, the whole system of roads, trails, and airplane landing fields, and the placement of all suppression men must be so arranged and maintained that men can get from their stations to any fire by thirty minutes' travel. The whole purpose of the speed-of-attack requirements is to serve as a specification to which the several units of the fire-protection system can be built. Forty-five minutes is a very short speed-of-attack requirement. They may be as long as six hours or even longer depending primarily upon the rate at which fires spread in the fuel type under consideration.

Coverage: The specifications embodied in speed-of-attack requirements cannot, of course, be held to rigidly in planning. In addition to the time requirements "coverage" specifications are usually set up. Coverage is the percentage of the area of a given forest or forest type upon which the speed-of-attack requirement or other specification is or is to be attained. In Region Six, for example (31), a transportation and placement system by which 80% of the area is reachable within the travel time requirement set up is considered to be the most economical attack coverage. The rapidly increased cost of the protection per square mile of protected area when the coverage is increased is shown in Table 5, (31), for a protection unit, "planned with 15 miles-per-hour light-car roads costing $50 per square mile for carrying charges, protective positions averaging $400 each (per year); cross-country travel 2 miles per hour.

Tabel 4. Annual cost of preparedness per square mile at varying travel times and coverages.

Travel Time	Cost per Square Mile		
	80% coverage	90% coverage	100% coverage
4 hours	$ 7	$18	$ 9
2 hours	15	17	19
1 hour	32	34	39
½ hour	70	75	90

The most rapid rise in the curve occurs above 90%. Any extensive coverage over 90% should not be striven for unless fully justified. On the other hand, specifications must not be too low or the result is inadequate protection coverage. For detection plans the time requirement is usually dropped entirely and the specifications stated in terms of the percentage of the area which must be directly visible from lookouts under given conditions of atmosphere transparency and for the several fuel types.

Table 5 also shows the effect upon preparedness costs of decreasing the length of travel time specifications. Using 80% coverage, for example, the unit costs of preparedness increase at a greater ratio than the decrease in the speed requirement.

Methods: Three general methods of arriving at speed-of-attack requirements may be mentioned; by judgement without recourse to formal analyses and furmulae, the Show and Kotok method, and the method developed in Region One of the Forest Service.

If the fire-protection managers in charge of similar units can, by reference to fire records and the exercise of memory and judgement, agree upon speed-of-attack requirements for the different forest types under their jurisdictions, a detailed analysis of fire records, solely to set up attack requirements, may be unnecessary. They must know, of course, what speeds had proven successful in controlling fires in the past, and be able to estimate for those fires which got away through not being attacked soon enough, what speed would have been sufficient.

If they can thus arrive at satisfactory speed-of-attack planning requirements without the use of statistical methods, the danger inherent in the acceptance of conclusions based upon analysis of figures alone (and not all of the factors of fire-protection can be expressed in figures) is avoided. At least one national-forest region uses this method.

The method of Show and Kotok described in detail in their bulletin (21) is essentially this: They analyzed the records of 4,283 man-caused fires in California which occurred between 1923 and 1928, to answer the two questions: "What percentage of class C fires (those burning over 10 acres) will represent attainment of the burned-area objective"? and "What speed of attack is necessary to attain the allowable percentage of class C's"? To answer the first question, for example for the ponderosa pine type of California (which had been assigned a burned-are objective of 0.2% of 4,526,000 acres or 9,000 acres) they found that only in those years when the percentage of class C fires was kept under 15% was the objective reached. Fifteen per cent, therefore, was set as the allowable percentage of class C's. The second question was answered by comparing speed of attack with percentage of class C fires for the most difficult years. Of the fires reached within ½ hour only 4% reached class C size; ½ to 1-hour speed of attack resulted in 17% class C's; 1 to 2-hour, 21%, and so on. Three-fourths of an hour, then, was taken as the speed requirement for this type, in order to attain the burned-area objective in the future. This method has been criticised by some who do not see adequate statistical justification for the selection of 15% as the allowable percentage of class C's.

The third method of determining speed-of-attack requirements is based upon statistical data on several thousand fires. From these data the average size of fires when discovered, the average spread per hour, the average time taken by smokechasers to corral fires, etc., etc., for each forest type has been determined. Plans are based (1) on the assumption that smokechasers (one or two men) will get 85% of all fires. A fast second line defense is depended upon for the rest in "Bad" years.

(2) The second assumption is that firefighting time (f. in Fig. 2) will not average less than 2.25 hours, that t will be a 0.5 hour at the minimum, and that b will be 0.25 hour. The minimum probable corral time (c), then, is 3 hours. Since lightning fires (upon which this method is based) are usually discovered in the morning and the fires must be corralled by noon to be safe, only about 4.5 hours can be allotted to c as a maximum. The total speed-of-attack requirement (with different time limits than that of Show and Kotok), then, must lie between 3.0 and 4.5 hours. For the fuel types which have been classified into four rates of spread 3.0 hours is allowed for extreme rate of spread, 3.5 for high, 4.0 for medium, and 4.5 for low. The fuel type mapping as was explained previously classified the forests as to their "resistance to control," expressed in planning as the number a chains of fire line that can be built and held by one man in an hour.

(3) Knowing the total speed-of-attack requirement, the problem now is to determine the time available for travel and search. Assuming that fires will be of negligible size when discovered, when the smokechaser reaches a fire it will have a perimeter of p x a, where p = perimeter increase per hour (average) and a is attack time (Fig. 2). To corral a fire, however, it is assumed that only one-half its perimeter need be trenched and held. $\frac{pa}{2}$ would represent his task when he arrives, then, and if we assume also that he can prevent further spread, it represents the corralling job, f x w, where f is fire-fighting time (Fig. 2) and w is work in chains per man-hour of held-line.

$$\frac{pa}{2} = fw$$

$$f = c-a \text{ (Fig. 2)}$$

$$\text{Then, } .5\,pa = (c-a)\,w$$

$$.5\,pa = cw - aw$$

$$.5\,pa + aw = cw$$

$$a(.5p + w) = cw, \text{ and}$$

$$a = c\,\frac{w}{w + .5p}$$

$$\text{Now, } a = t - b \text{ (Fig. 2), and}$$

$$t = a - b. \text{ Then}$$

$$t = c\,\frac{w}{w + .5p} - b$$

which is a formula for determining travel time specifications.

Let c, corral time = 4.0 hours for medium rate-of-spread fuel type, w, rate of work - 1.8 chains per man hour of held line,

Table 6. Rates of spread of fires under different burning conditions for the various fuel types recognized.

U.S. Forest Service R-1.

Fuel Type	Chains Spread per Hr. of Burning (1st 4 Hrs.)	70% Burn. Cond. & Day Work		85% Burn. Cond. & Night Work		Allowable Smokechaser Travel Time
		Ch. Held Line per Hr. Work	Man-Hrs. Work per Hr. Burning	Ch. Held Line per Hr. Work	Man-Hrs. Work per Hr. Burning	
E-E	14.0	.5	28.0	.4	35.0	0.5
H-E**	11.0	.5	22.0	.4	27.5	0.5
M-E	8.5	.5	17.0	.4	21.2	0.5
E-H	14.0	1.5	9.3	1.0	14.0	0.5
H-H	11.0	1.5	7.3	1.0	11.0	1.0
M-H	8.5	1.5	5.7	1.0	8.5	1.0
E-M	14.0	3.0	4.7	2.0	7.0	1.0
H-M	11.0	3.0	3.7	2.0	5.5	1.0
Fuels Worse than Average above						
Fuels Less than Average below						
L-H	6.0	1.5	4.0	1.0	6.0	1.5
M-M	8.5	3.0	2.8	2.0	4.2	1.75
H-L	11.0	4.5	2.5	3.0	3.7	1.50
L-M	6.0	3.0	2.0	2.0	3.0	2.5
M-L***	8.5	4.5	1.9	3.0	2.8	2.25
L-L	6.0	4.5	1.3	3.0	2.0	3.00

*H-E = High rate of spread, extreme resistance to control.
**M-L = Medium rate of spread, low resistance to control.

These figures are for "Worst" Burning conditions. For "Average" burning conditions increase the travel time figures by 50%.

p, rate of perimeter increase = 8 chains per hour, and
b, report plus get-away time = 0.25 hour.

Then $$t = 4 \frac{1.8}{1.8 + (.5 \times 8)} - 0.25$$

$t = 0.99$ or approximately 1 hour, the travel time specification for the fuel danger type under consideration.

If the strength-of-attack specification were increased to two men, w would be doubled and we would have

$$t = 4 \frac{3.6}{3.6 - (.5 \times 8)} - 0.25,$$

$t = 1.25$ hour, travel time.

It is apparent, then, by algebra as well as by common sense, that if strength requirements are increased, speed requirements may be relaxed (increased) with savings in road and trail mileage needed or in number of protection positions or both. The combination of strength and speed that will result in the least total annual expense is the one to be selected. Table 6, from Forest Service planning instructions shows travel time requirements worked out for all fuel types in Region One.

These three methods of determining speed-of-attack requirements for first-line defense differ considerably both in the method of arriving at the time specifications and in the divisions of elapsed time considered. They agree, however, that travel time is the most important specification to determine. Transportation and placement planning, to be taken up in a later section, indicate the use in planning that is made of the travel time and strength specifications.

__Second-Line Defense:__ The second line of defense in the fire organization consists of crews which are assembled after the start of a fire and the equipment, supplies, transportation facilities and supervisory overhead necessary to make the crews effective on the fireline. They may be logging crews or improvement or other crews taken from other work on the forest. Or the fire crews may be composed of previously enrolled men who have agreed to fight fire when called. The last resort is the employment agencies and the "jungles" of the transients. Needless to say, fire crews vary in effectiveness, and the more provision that can be made for lining them up in advance, the better.

The setting up of attack requirements for second-line defense is very similar to that of first-line defense. Placement is usually determined by the location of cities and of logging camps or other semi-permanent centers. Mobility and quick attack must be gotten by fast transportation. In order to be considered as a second-line base, a town or camp must be able to provide a fully equipped crew large enough to handle the average fire within the tributary territory (31). This size of crew necessary may be anywhere from 5 to 50 or more men. Rural communities may sometimes be used as bases when arrangements can be made beforehand for assembling a large enough crew on short notice.

Attack requirements, by one method, are determined by the length of the period which ordinarily follows the first "run" that fires make. In Northern Idaho, if a fire gets away from the smokechaser or smokechaser crew, or if, as occasionally happens, it gets away before they reach it, it makes its run in the afternoon and evening. Ordinarily the suppression organization has from the time the lookouts report the "run" until about noon of the following day to corral it and map it up to a point of safety. If the average output in chains of held-line per hour of crews in the particular fuel type being planned for, and the maximum perimeter of fire to be worked are known, fire-fighting time requirements can be determined for the several fuel types.

If from 6:00 p.m. of one day to noon of the next is the time between realization of a "crew fire" to the time when it must be corralled, there are 18 hours for get-away, travel, and fire-fighting time (See Fig. 2). A certain amount of time must be reserved for crew assembly or get-away time. This depends on the type of labor and efficiency of supply. A much more variable amount must be reserved for fire-fighting, depending upon fuel type. The minimum would probably be six hours, from 6:00 a.m. to noon. High resistance to control or extreme weather conditions would necessitate night work in order to attain the objective of control by noon. What time is left, then, is available for travel, a short time for the worst fuel types, a longer time for the easier ones.

Up to this point the discussion has been entirely concerned with preparation for planning. The philosophy underlying the statement of burned-area objectives and the assembling of fire danger data has been described. We should now have as basic data for planning, maps of fire occurrence, commercial values, and fuel types, and a total fire danger map. More specifically we should have definite attack requirements expressed as "hour-control" or as travel time for each of the several forest or fuel types. These attack requirements are based on the fire danger maps and serve as the controlling specifications for the planning of improvements and the placement of detection and suppression men.

Planning Placement of Men and Improvements

Placement planning involves the location of men in the best positions for detection and first-line defense, and coordinated with this, the placement of the buildings, communication equipment, and transportation routes and facilities necessary for the most economical attainment of the attack requirements and the objective of allowable annual burn.

Detection Planning:

The detection system is usually the first one to be planned. Detection is the critical step in suppression, since report, get-away, travel, and fire-fighting must all wait for it. Detection planning is comparatively independent of the other plans. In some cases (21) the detection plan is based directly on the segment of "hour-control" or the attack requirement allotted to it. In others (29) the time element is dropped and seen-area coverage - the percentage of the area directly seen by at least one pair of eyes - is used as the basis for plans. In practice, instead of using percentage, standards of maximum "blind" spot sizes are set up for each fuel type. One hundred per cent coverage is obviously impossible in rugged country, but the more valuable and dangerous types should be practically all visible from some lookout. Smoke in the air is probably the most troublesome problem in detection, since it often almost obscures vision in the most dangerous fire weather.

Size of Fire the Critical Factor: The detection coverage needed depends upon the size which fires may safely be allowed to reach before they are seen and reported. Within any given fuel type this size depends upon fire-weather conditions and varies within wide limits throughout the fire season. When fuels are moist, the air still, and the days short and cool (conditions obtaining often in "Indian Summer") relatively large fires may be controlled by the same number of men that would have difficulty in holding a fire one-tenth the size in August. For this reason, and also because the fires spread more slowly under low-hazard weather conditions, fires may be allowed to become much larger before being seen by lookouts. Fires which have burned a longer time and have reached a larger area may be assumed to be putting out more smoke and hence will be visible even in "blind" areas. It is the difference in size to which fires may be allowed to burn before discovery that determines the detection coverage which must be given. A fuel type which require a seen area coverage of 90% in "worst" fire danger periods may require only 30% coverage in minimum danger periods when three degrees of fire danger are being planned for as in U. S. Forest Service Region One (29).

Similarly, and for the same reason, different fuel types under the same conditions of weather danger and risk require different degrees of detection coverage. This is partly taken care of by the different travel time requirements allotted to the fuel types, but additional allowance is made by planning a detection system with higher coverages (larger allowable blind spot sizes) for the worst fuel types.

Visibility, or degree of atmospheric obscurity must also be considered in planning. In periods of low fire danger, visibility from lookouts is usually good, which is an additional reason for saving protection money by stationing fewer lookouts in such periods. In periods of worst fire danger, visibility on account of smoke and haze is usually lower and may even be practically zero. But since these are the periods during which quick detection is most imperative, detection must not fail. Lookouts spaced closely enough that eight miles is the maximum distance that they are expected to discover fires is one way of getting the needed coverage. Supplementing stationary lookouts with foot, horse, rail, auto, water, and air patrol is another. Various mechanical aids such as colored goggles and field glasses, designed to"cut through" smoke and haze have been tried, but none have yet been successful in materially increasing the distance at which "smokes" can be discovered.

Example of Benefits of Planning: The advantages, both financial and technical, of planned lookout systems over systems built up by use only of the judgement of rangers, wardens, and forest supervisors, have been abundantly demonstrated. One demonstration of the effect of using this common sense approach to the detection problem is shown by a report from the Shasta Experimental Fire Forest. Sacramento Canyon on this forest has probably the heaviest concentration of fires in the United States, over 95% man-caused. In detection planning, this area where "worst danger" periods were common (on account of high danger of occurrence plus general high hazards), was marked out as a high-risk area. It was proposed to secure as nearly 100% seen-area coverage as possible in this high-risk zone. A new lookout system was devised for the area by means of seen-area studies. The old and new systems were then compared as to coverage and particularly as to their coverage of the points of origin of the 1004 fires which had occurred in the area from 1921 to 1930. Some comparisons are shown in the following table:

	Old lookout System	New Lookout System
Number of lookout stations	3	7
Coverage of high-risk zone	13%	87%
Coverage of low-risk zone	53%	54%
Total coverage	43%	68%
Coverage of points of origin of 1921-1930 fires. (i.e. percentage in seen-area)	29%	90%

None of the three original lookout stations were kept in the new system. The old lookouts had been covering the areas of low risk very well. The new system did not increase the coverage on them, but brought the coverage on the areas where the fires were starting up to 90% from a previous 29%. By adding four men to the detection force, properly located, an immense burden could be removed from the suppression end of the work by discovering the fires while they were still small.

Steps in Detection Planning: Detection and communication systems in use in North America range from the negro tennant and gong system used in parts of the South to daily airplane patrol with radio (17) and to complete systems of stationary lookouts. The last-named type is rapidly superceding the others. If a system of stationary lookouts is to be planned the steps in planning procedure are rather definite. One method is described in detail in two manuals of the U. S. Forest Service (28, 29). The steps in this method involve the following:

1. Selection of ~~of~~ possible locations for lookouts and of nearby patrol points to which lookout men could go to see additional areas. This is done by forest officers familiar with the country supplemented by selections by seen-area mappers. At least twice as many points should be

selected as will ever ultimately be used.

2. Mapping of the areas directly seen from each selected point as differentiated from those not seen (blind areas). There are several methods of seen-area mapping:

a. By sketching from observation in the field. This method is described and compared with other methods by Shank (19). A two-man party made the survey of one ranger district (1,602 sq. mi.) at a cost of 33.9 cents per square mile, making sketches of seen area from each of the seven lookout points. Shank concluded that it is a satisfactory method for use where a topographic map is not obtainable. It was only 62% as costly as a survey by the relief model method (e). Both of these methods have the disadvantage that the degree of "unseen-ness" cannot be determined. For example, it is oftentimes desired to place areas which are less than 200 feet below the line of sight (indirectly seen areas) in a class separate from the areas more than 200 feet below the line of sight. This can be done accurately only by the profile method (d).

b. By traverse on the ground, noting at intervals whether or not certain lookout points are visible. This method is costly and has disadvantages in timbered country, but might be used in connection with timber surveys.

c. By photography. Photography "has possibilities which have not been fully developed, but it calls for considerable technical skill both in carrying out and in application after completion of the work " (27). Osborne (16) reports some progress in this direction, and Region Six has since developed a fire dispatching system based on permanent panorama photographs from each occupied lookout.

d. By profile method. "There results a series of cross sections of the earth's surface radiating from the lookout point at suitable arc intervals to define the seen and unseen areas". An accurate topographic map is essential. The construction of the seen-area map may be done in the office by plotting on cross-section paper or by use of a slide-rule (22) or may (and preferably) be done in the field. The method most widely used is a combination of method a. and this method, depending on the quality of the base map. Mapping is done from the proposed lookout points in the field. The costs of this method for the North Idaho Association area mapped in 1934 were $29.03 per point, including supervision, 447 points being mapped. This amounts to between $3 and $4 per square mile.

e. By the relief model method by which a relief model of the area in miniature is made from a good topographic map. A small light is suspended in a dark room on the point representing each proposed lookout point. Unseen areas will be in shadow and may be transferred to maps (19).

3. The third step is selecting the points to be used as lookout stations. The combination of points selected should result in the required coverage with the least number of points, and furthermore, the unseen areas should be in the least dangerous fuel types. Limits of allowable blind spot sizes have been set up in Region One which range from 50 acres

in cutover white pine and cedar-hemlock types on south and west slopes to 1000 acres in lodgepole pine green timber or clean double burn on south and west slopes (29). The mechanics of the method of selection used is essentially: transfer each seen-area map to a separate sheet of transparent material (xylonite is used); stack the sheets one on the other over a glass-top table with strong light underneath. The unseen areas will show as spots of light. By taking out maps of stations that add little or nothing to the total seen area and cutting and trying the others a combination of lookouts is obtained which satisfies the seen-area standards with the least number of stations. At the same time the value of the lookouts as smokechaser stations is considered. Three combinations of stations are planned for each protection unit corresponding to the three degrees of fire danger: minimum, average, and worst. They are called skeleton, regular, and overload systems respectively.

Analysis by this method has meant in some cases the abandonment as inefficient of previously used lookout points and in practically all cases it has shown the need of many more lookout points. The stations that have been shown to be least efficient are usually those on high peaks far from the country of high hazard. The trend in Idaho is definitely toward splitting two- and three-man stations up into two or three <u>one-man</u> stations and locating the new lookouts on the lower hills where they will be close to their protective areas. This aids both in quick detection and in shorter travel distances in putting out fires.

4. According to the Forest Service Fire Code Region Seven (32), detection plans should make "Provision for detection comprehending the entire protective area, accurate, sustained, and prompt." Provision for a system "comprehending the entire protective area" has just been outlined. Accuracy in location of fires is obtained by using the right type of men and equipment. For sustained observation a permanent lookout house is almost essential. Region One has set up standards of continuous observation ranging from 15 minutes every 1½ hours for the high-hazard types to 60 minutes every 24 hours for the lowest hazard types. The latter is the type in which patrol from lookouts or by means of autos, boats, or airplanes is sufficient. Some regions specify observation every fifteen minutes throughout the day on all areas upon which a hazard exists (30).

Promptness in discovery of fires is a result of adherence to these standards in planning and of efficiency of lookout men. Promptness in report is a result of the communication system. Telephone lines should connect all occupied points at least expense, and should be planned so that lines will not be overloaded. Radio may replace the telephone for temporary camps (11). Report time should be the shortest of the elapsed-time divisions.

<u>Planning Placement and Improvements for Attack</u>:

A large percentage of detection men in any region act also as smokechasers. Necessarily, therefore, the planning for placement of suppression men must be closely correlated with detection planning. The two plans may be built up simultaneously. Placement and improvement planning is based directly upon the attack or travel time requirements set up previously.

The theory underlying this phase of fire planning is best summed up by Norcross and Grefe (15). "Briefly stated, the objective of transportation planning is the design of a transportation system, together with the placement plan for protection personnel, which at the least annual cost per unit of area will permit a fire anywhere within the protection unit being reached within the allowable travel-time. In other words, the purpose is to plan the most economical system of transportation facilities and firemen which will enable fire fighters to reach any fire within a certain travel-time, this time being determined by the value of resources, the degree of inflammability and consequent rapidity of action deemed necessary to hold losses below a specified limit.

"A man located in the forest can reach any point in an adjacent area of certain size within a specified time. The size of the area that he can reach depends upon his location, the transportation facilities available to him and topographic and ground conditions. With no roads or trails available, the area that a man can reach within the allowable travel-time is roughly a circle with a radius equalling the speed of cross-country travel in miles per hour multiplied by the allowable hours of travel-time. If, however, the man were located at the end of a road or trail he would be able to reach one-half of the cross-country circle plus a triangle equal in altitude to the speed of the route in miles per hour multiplied by the hours of travel-time and with a base equal to the diameter of the circle. If the same man were placed at a mid point along a road or trail he would be able to cover two triangular areas base to base, and from an intersection of two roads, two trails or a road and trail, a combination of four partially overlapping traingular areas.

"With a man located along a road or trail, and with the speed of cross-country travel constant, the 'reachable area' varies in proportion to the speed on the road or trail. Obviously a fire-man located at the junction of two or more roads can cover far more area within a given time than if placed at the road terminus. As the rate of cross-country speed approaches that on trails, the value of trails as means of increasing coverage decreases. Topography, drainage, ground cover and other conditions affect the speed of cross-country travel considerably.

"To comply completely with the specifications, 100 per cent of the area should be reached within the prescribed travel-time, but planning on this basis will result in a large overlapping in coverage from various protective positions and certain relatively small areas can be brought within the allowable travel-time only at excessive cost. In planning the protection system, therefore, it is a matter of great importance that careful consideration be given to the percentage of coverage and a correct determination made of the allowable variation from 100 per cent. Where such a determination has not been made, the latest instructions for the transportation planning provide (1) that not less than 80 per cent of the total area shall be within the prescribed travel-time, (2) that the area of any unreached block shall not exceed a stated percentage of the entire area and (3) that practically all points in such a block shall be within a travel-time fifty per cent greater than that specified for the surrounding territory.

"The necessary coverage can usually be secured with several different lay-outs of transportation facilities and men. It is relatively easy and requires little time to work out a system that will make the entire area accessible within the allowed travel-time. The objective, however, is the system which at the least annual cost will satisfy the travel-time requirements.

"The difficulty in planning arises in finding the best possible combination of men, roads and trails. The men in charge of the planning must repeatedly answer several questions. Should men only be provided or should there be a combination of men and trails; men and roads; men, trails and roads? How many men are needed and where should they be located? What should be the speed standard for the roads and trails? Obtaining a satisfactory solution would be well-nigh hopeless if aids to the determination had not been provided. For various combinations of speed of roads, trails and cross-country travel, allowable travel-times, annual costs for firemen, roads and trails, tables and graphs have been prepared which show the cost per square mile and the most efficient distance between firemen."

Since the mechanics of working out the plan is a specialized operation very similar to detection planning, the details will be omitted here. It is obvious that the new smokechaser positions and the new roads will be located to as to benefit those areas found to be beyond the reach of suppression forces within the specified travel times. The steps used in Region One may be outlined briefly:

1. A field study to get mileage and speeds of present roads and trails and speed of cross country travel.

2. Location of possible additional roads and landing fields on a map and the speed-standard to which the roads can be built. Other uses of roads, such as for logging and for recreation should be considered when locating them and when figuring the percentage of the cost chargeable to fire.

3. Decision as to what types of trucks, airplanes, or other transportation equipment will be used, what construction equipment and methods, and what maintenance equipment, methods, and organization will be used to result in the least annual cost.

4. From detection planning procedure determine and transfer to transparent sheets the areas which lookouts and other possible smokechasers can reach within the specified travel-time limits. Select from among these and add others if necessary to get the combination which will be most efficient. This selection is done by the cutting and trying method with silhouettes over a light.

5. Carry out a similar analysis for second-line defense. Roads and airplane landing fields will be located mainly as aids to second-line defense. Smokechasers depend on existing roads and on foot and horse travel.

It is necessary as a part of this planning procedure to determine what is the "peak load" of fires that is ever likely to occur and to plan either by regular organization or an "overload plan" what will be done in such a situation. "Peak loads" of fires for some national forests in Idaho may be as high as 100 or more fires in one day on a single ranger district.

__Use of Plans in Routine Fire Work:__

The first use of the large amount of data that is collected and analyzed for fire planning is, of course, the development of a fire-protection system exactly suited to the economic and physical needs of the forest. But after these needs are determined and the detection and smokechasing stations and roads and landing fields are in place and in use, the usefulness of the planning data is not over. Fire plans usually provide for "worst danger" conditions, and may in addition provide for various other danger conditions. But the recognition of worst danger or of no danger at all is up to the fire executive. Aids and instruments to measure fluctuations in fire weather and other dangers should be a a part of his regular operating equipment, but the point to be emphasized here is that fire organization under a detailed fire plan should be just as flexible as under any less controlled system and should in addition be more closely correlated with actual dangers. Headley (11) states that, "although considerable experience and skill is required it is actually possible to get flexibility and control in expenditures for forest protection which will possess a high degree of correlation with the often extreme and usually more or less unpredictable fluctuations in forest fire danger." It is nearly as important to save unnecessary expenses by reducing the force on days and in seasons when fire danger is low as it is to increase the coverage when fire danger is high.

The silhouettes used in Region One for planning detection and smokechasing positions are meant to be kept in the supervisor's office so that any combination that is in the field at one time is readily visualized by referring to the corresponding silhouettes on the table. By switching on the light he can see just which areas are seen and which not seen from lookouts, and which areas are reachable within the travel time limits. If lightning storms occur in one end of the forest, men may be moved to put that area under "worst danger period" organization and the combinations of silhouettes will show the coverage on all poritions of the forest. In this way flexibility in both __time__ and __location__ not only may be secured, but may be immediately visualized by the supervisor.

The fire danger meter developed by Region One furnishes a means of evaluating the various factors of fire danger so that seven degrees of fire danger may be recognized. This device also helps the fire executive to correlate his fire plan with the several degrees of fire danger, from a skeleton organization for the first dangerous condition to calling the overload plan into operation if the sixth or seventh degree of fire danger is imminent.

Vertical airplane photographs which are very useful in fire planning are fully as valuable in routine fire work. A ranger may turn to his file of photographs, select the ones showing the area where a fire is reported, and by use of the stereoscope determine the exact topography, relation to roads and water, and often the timber types as well. The panorama photographs from lookouts to which reference has been made previously are used in Region Six for this same purpose.

It should be emphasized, too, that fire plans are never exactly applicable to present conditions unless they are kept up-to-date by annual revision. Since the fire history of a forest property is the basis for fire planning, fire statistics should be carefully kept from year to year and carefully reviewed to see what changes are taking place in fire danger. The progressive changes that take place in fuel types have already been discussed. Every serious fire, particularly should be reviewed to determine where the organization fell down in prevention, preparedness, or suppression.

Personnel Problems in Planning:

The human element enters into fire planning as into all other human activities. Allowance must be made both for the ever-present possibility of human errors and for the equally ever-present possibility for the improvement of human behavior. Any analysis of fire records brings to light many instances of mistakes. Practically every large fire is the result of one or more mistakes in judgement by those responsible for its suppression. We can never wholly eliminate them. On the other hand, through application of scientific principles of labor management and personnel organization and through persistant and thorough training of men, great advances may be made in the efficiency of fire-protection. This is probably more true of suppression than of any other fire activity. The advances which the Forest Service and fire associations have made in the last fifteen years in better controlled action is apparent from examination of the records of individual fires.

Justification of the Cost of Putting the Fire Plan into Operation.

Development of a fire plan is one thing; getting the money to put it into operation is another. Determination of how much the forest property can theoretically afford for fire-protection is involved in setting up the burned-area objective; but how much the owners of the forest (persons or governments) will put up for protection is really the determining factor at any one time. Of course, if the burned-area objective is correctly determined (which can't be known with what we can usually learn about a forest), and if the proposed fire plan is really the cheapest means of attaining that objective (which is what the good plan by all means should be) good financial management should furnish the necessary money. But certain practical limitations usually rule that fire plans shall be put into full operation by degrees. The changes which will result in better protection at the same cost should, of course, be made first.

In practice a maximum justifiable cost in cents per year per square mile is usually set up and fire plans must be reworked until their projected cost of operation per year (including interest on investment in all improvements, and depreciation on them) does not exceed that amount.(31).

In presenting a proposed plan its superiority over the present system and over other proposed plans must, of course, be shown. This may be done by comparing the cost of each plan with the coverage attained by it. The cost has been determined in Region One by adding prevention costs, annual preparedness costs such as wages and supplies, maintenance of roads and trails and protection improvements, two per cent retirement on road and trail investment, four to ten per cent depreciation on protection improvements; and one half the cost of maps, surveys and fire research. Coverage is taken as an average of the percentages covered by detection, smokechasers, and second-line defense. There is a point usually found to be between 75 and 80 per cent of average coverage at which the annual total of P + S + D is a minimum.

The best proof of the efficiency of any plan (as of any pudding) is found, no doubt, in trying it out. Fire plans proposed are necessarily conservative on account of scarcity of fire-protection money and are more likely to err on the side of proposing too little protection than of too much. Prevention and preparedness will always be cheaper than suppression, up to a point not reached as yet.

Fig. 3. The Factors of Fire Danger and Their Relation to Steps in Fire Planning.

<u>Factors of Fire Danger</u> (State the problem) →	<u>Steps in Preparation</u> (Analyze the problem) →	<u>Steps in Planning</u> (Plan the details) →	<u>Executive Action</u> (Get the work done)
Destructible Resources or Values. → Timber. Reproduction. Forage. Soil & water. Recreation. Other property and life.	Determination of: → Policies. Units. Justifiable Loss. Justifiable cost. Allowable annual burn.	Justification and comparison of plans.	Keep plans up-to-date.
Causes, Risks, or Danger of Occurrence. Man-causes Lightning.	Determination of: → Causes. Risk zones. Preventability.	Prevention Plan. →	Execution: By the right methods. At the right times. With the right people. In the right places.
Hazards. Fuel danger. Weather danger. Topography. Accessibility.	Determination of: Fuel types. Weather factors. Seen-Areas. Attack requirements. Transportation facilities and possibilities. Personnel policy. Adequate suppression equipment, tactics, organization.	Preparedness Plans for:	Execution by:
		Reduction of fuel dangers. →	Slash disposal, firebreaks; control of species, shade, grazing.
		Flexibility for weather, visibility, and overloads. →	Fireweather, visibility, and risk measurement, and interpretation in terms of organization.
		Detection and communication. Smokechaser placement. Second-line defense readiness. →	Equipping, supervising, testing, maintaining, to insure prompt discovery and attack.
		Improvements for: First-line defense. Second-line defense. →	Final location, construction, maintenance.
		Organization, training, and inspection of men. →	The right men in the right places, training, check-up.
	For Each Fire → Determination of: Perimeter. Location with respect to fuel types, topography, and transportation. Present and future weather danger Strategic points of attack.	A Suppression Plan for Each Fire: → Objective: control before next p.m. Where to build line to check fire. How to build and mop-up line to corral fire. What to do along line to put fire out.	Execution by: Adequate strength of attack. The right equipment. The right tactics; where, how, mop-up. Adequate scouting, re-planning, supervision, check-up.

SUMMARY

Figure 3, suggested by Gisborne's "Scheme of Forest Fire Control" (3), shows the relationships of the various factors and phases of the fire problem that have been discussed.

After going through the steps which are involved in building up a plan along business lines for the protection of a forest from fire we should have the following, all of which should be useful in fire work:

1. A statement of policies.

2. An objective stated as a percentage of the area which may burn and protection still be considered adequate.

3. Fire occurrence maps and a prevention plan based largely upon them.

4. A total fire danger map made up from:

   a. Fire occurrence maps.
   b. Commercial value map.
   c. Fuel-type maps showing both probable rates of spread and resistances to control.

5. A set of seen-area maps with plans for detection systems based on them and the fire danger maps.

6. A set of travel-time-coverage maps for both first- and second-line defense, and plans for placement of smokechasers and location of transportation routes based on travel-time maps and on the fire-danger maps.

7. Provision for all necessary flexibility in organization to correlate organization with weather danger, visibility, and peak loads.

8. A plan for organization, training, and inspection of the fire forces.

9. A plan for organization of second-line defense (man-power, leadership, transportation equipment, supplies, and equipment).

In short, we will have the basic data and a complete plan of action that will cover all phases of the fire problem adequately, economically, and each according to its relative importance, and one which is flexible enough to fit itself to the seasonal and annual fluctuations in fire danger. Skillful execution of the provisions of the fire plan should result in attainment of the objective upon which the plan was based, the keeping of annual burned area within the allowable limit so that the purpose for which the forest is managed may be fulfilled.

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APPENDIX

Table 1. Numbers of fires and area burned by forest fires, Pacific States.

	Protected Area										Unprotected Area Totals	Grand Totals
	Lightning	Railroads	Campers	Smokers	Debris Burn.	Incendiary	Lumbering	Misc.	Unknown	Total		
All forest area, 1936–1930												
Ave. No. of Fires per Yr.	1612	339	670	1620	502	907	337	774	103	6864	34	6898
Ave. Burned per Yr. Thousand Acres	136	20	55	229	60	390	68	105	18	1081	71	1152
Ave. Size of Fire Acres	84.7	59.0	82.1	141.9	119.4	429.0	201.	135.9	17.4	157.3	2088.	167.2
Federally-owned area, 1933												
Ave. No. of Fires per Yr.	480	8	185	347	52	112	9	95	13	1301	—	—
Ave. Burned per Yr. Thousand Acres	7	0.1	0.3	46	2	19	0.9	0.6	—	75.9	—	—
Ave. Size of Fire Acres	14.6	12.5	1.6	132.5	38.5	169.5	100.0	6.3	—	58.3	—	—
Area owned by State and Private agencies, 1933												
Ave. No. of Fires per Yr.	229	109	332	1270	510	896	116	420	—	3882	11	3893
Ave. Burned per Yr. Thousand Acres	8	1	12	50	23	129	266	24	—	513	13	526
Ave. Size of Fires Acres	34.9	9.2	36.1	39.3	45.2	144.0	229.2	57.2	—	132.1	1183.	135.

Table 2. Damage by forest fires.

	United States 1926-1930	Idaho 1926-1930	Pacific States 1926-1930	Pacific States Federally owned 1933	Pacific States State & Private 1933
Protected Area					
Timber	4,700,664	681,604	1,082,964	33,110	11,198,780
Reproduction	3,533,074	291,340	427,070	17,120	611,690
Forage	400,676	430	205,930	650	21,060
Other	2,210,636	47,416	1,103,876	10,590	913,230
Total Protection	10,845,050	1,020,790	2,819,840	61,470	12,744,760
Forest Value	461,213	20,928	252,050	68,390	116,550
Grand Total	11,306,263	1,041,718	3,071,890	129,860	12,861,310
Ave. per Acre	2.53	7.23	2.53	1.60	25.03
Unprotected Area					
Total Damage	51,525,160	15,792	100,402	—	9,030
Ave. per Acre	1.39	.45	1.40	—	.68
Grand Total					
Total Damage	62,831,423	1,057,510	3,172,292	—	12,870,340
Ave. per Acre	1.96	3.84	1.96	—	12.85