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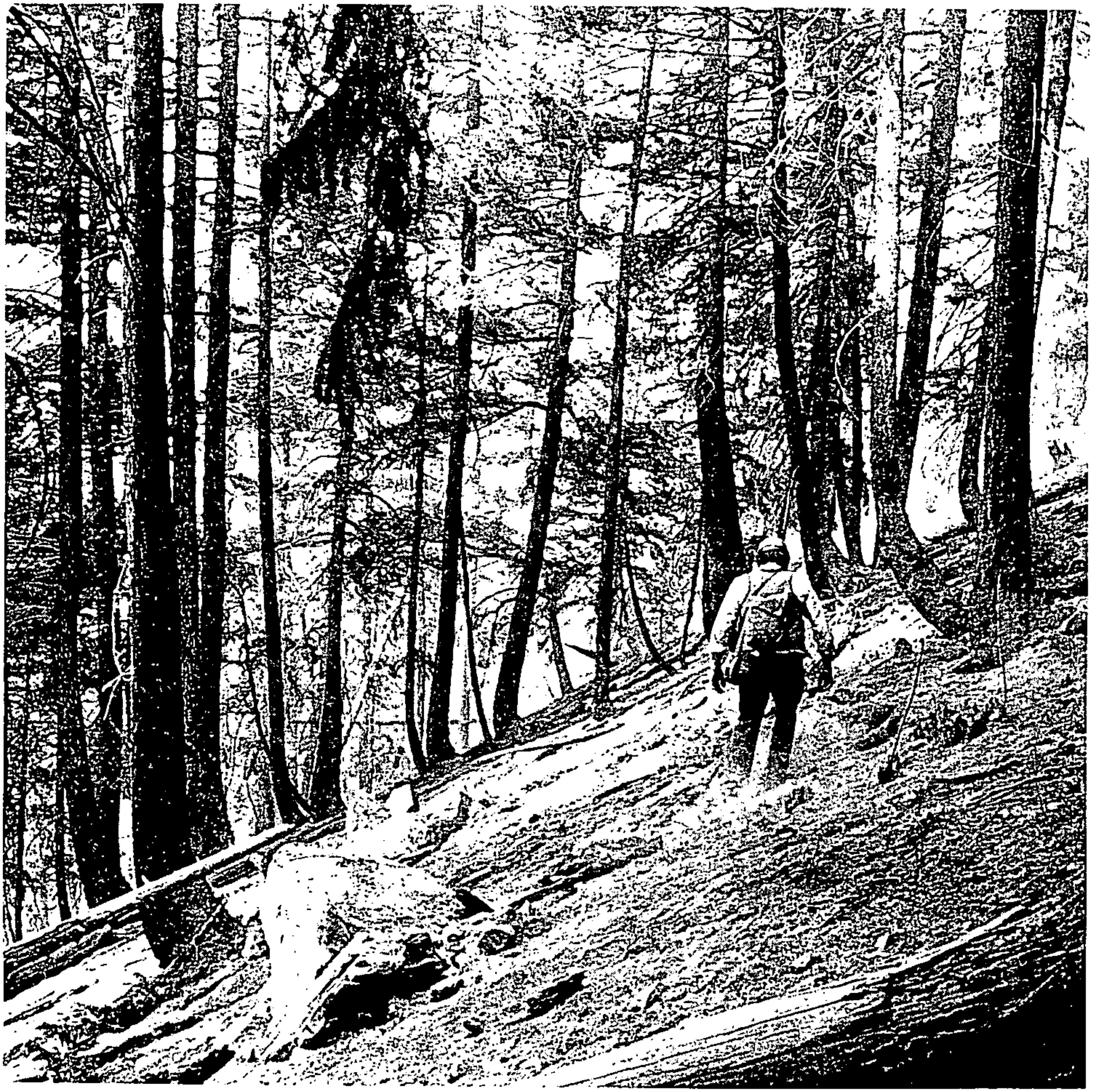

FIRE MANAGEMENT NOTES

An international quarterly periodical devoted to forest fire management

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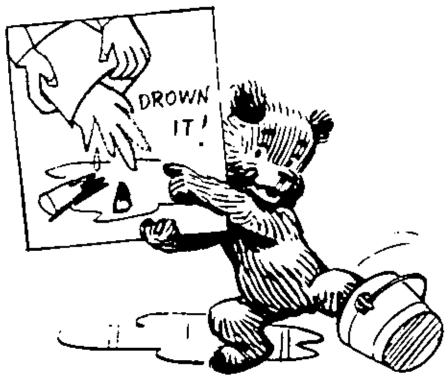
The Cover

Our lead story explains how the Troy Ranger District of the USDA-Forest Services Kootenai National Forest in Montana is utilizing unplanned ignitions to meet prescribed fire objectives. The cover photo shows employees checking the fire area to insure prescribed conditions are being met.



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Fire Management; a New Image

Dan W. Bailey

"Sometimes, under specific and controlled conditions, fire can be beneficial rather than destructive." This is the message the USDA Forest Service is giving residents in the northwestern corner of Montana. It is the result of a new fire management plan implemented by the Northern Region's Troy Ranger District, Kootenai National Forest. In April 1978, the Regional Forester approved the Troy fire management plan, paving the way for its implementation during the 1979 fire season, and making the Troy District the first ranger district within the USDA Forest Service's National Forest System to be under an approved integrated fire management plan involving more than wilderness areas.

A Need for Change

The Troy plan reflects a change in Forest Service policy, requiring a transition from a fire *control* emphasis to one of fire *management* (Nelson 1979). The concept of managing fire is to make the fire suppression objective, either suppression or control at a reasonable cost, compatible with meeting land management objectives.

Early in 1978, the Troy Ranger District, with the help of interdisciplinary specialists, began working a fire management plan that would integrate the 1978 revised National Fire Management Policy with the District's land and resource management objectives. In doing so, a pioneering effort toward understanding the fire management process and making it work was begun.

Fire Planning

National Forest management policies now require that fire be included in forest planning as a component of the ecosystem. Fire planning is to be viewed as an increment of land management planning. This has led to changes in attitude toward fire management. Fire is recognized as a basic environmental factor, and total wildfire suppression may not be compatible with meeting land management objectives. The Troy fire management plan, then, is an effort to plan for the best mix of fire suppression and fire use under definite guidelines.

The Basic Plan

A fire management plan should be based on prescriptions that consider biological, physical, historical, climatic, and economic factors. It must reflect sound land management objectives, be ecologically and economically realistic, and be professionally prescribed and carried out. (Lotan 1977)

The Troy fire management plan integrates the revised National Fire Management Policy, discussed earlier, with the District's land and resource management objectives. The fire management objectives of the plan are:

- to include wildfire considerations in meeting land and resource management objectives defined in the land use planning process;
- to return the natural role of fire to certain areas in the environment and use fire effectively as a management tool;
- to provide an effective wildland fire protection organization when needed;
- to develop a cost effective fire management program by reducing supression costs; and
- to identify wildfire potential and fire ecology by areas, and to interpret the effects of fire on the current forest ecosystem.

Based on the guidelines provided by land use plans, all areas of the Troy District have been assigned to one of five categories of fire management areas:

Protected Areas—State and private lands within the District.

Observation Areas—Lands managed for primitive recreation, wildlife habitat, viewing, and natural vegetative diversity.

Special Areas—Lands set aside for recreational and educational uses, and managed as directed by land use plans.

Operational Areas—Forested lands managed primarily for timber and big game.

Wilderness Areas—Designated wilderness area.

In each of these five planned areas, when an unplanned ignition

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occurs and where the use of prescribed fire has been approved previously and the criteria are met, the fire will be treated as a prescribed fire. As long as the fire is maintained within the prescribed fire criteria, land management objectives are being met. As soon as prescribed fire criteria fail to be met, wildfire suppression will take place until the fire is out.

Implementation

When a wildfire is reported on the Troy District under conditions that indicate a prescribed fire, the District Fire Management Committee meets to decide upon a course of action. The committee consists of the District fire management officer, silviculturist, and resource representative. After evaluating the fire situation, the existing and forecasted weather, the fuel conditions, the prescription for the area, and the management objectives, risks, and benefits, the committee recommends to the District Ranger the action to be taken. The District Ranger then either approves, disapproves, or modifies the recommendations. If the Ranger decides that the prescribed fire criteria have been met, project management takes such action as necessary to insure criteria continues to be met. Any changes in conditions or fire behavior may call for reevaluation by the committee. The prescriptions outlined in the fire plan are used as guidelines, not rigid formulas, to help the committee make informed, indepth decisions quickly.

Making it Public

Throughout the process of writing and implementing the fire plan, special efforts have been made to inform local residents of the changes in fire management policy. Informational brochures, presentations to local groups, public review of the plan, and numerous news releases have kept the public informed at each step in the development and implementation process.

The Troy fire management plan affects all personnel on the District, whether they work in fire, timber, recreation, or some other function. For instance, a 10-year browse burning program has been developed by the District in conjunction with the plan.

One offshoot of community involvement in the fire planning process has been the development of a local county fire prevention cooperative. Hoping to implement a positive approach toward fire prevention, the co-op has sponsored poster and essay contests, radio spots, brochures, and a special newspaper edition. Future plans include workshops and increasing community involvement. The local group includes members from government agencies, logging and mining interests, and landowners.

The Plan in Action

During the 1979 season, the decision to confine three fires instead of complete suppression was made on the Troy Ranger District. Two of these fires were in the Cabinet Mountains wilderness. One fire went out within a few days and the other, started by lightning near the end of July, burned less than 10 acres and went out. The third, in the Timber-Rattle Mountains Observational Area burned for approximately 2 months.

In the latter fire, lightning ignited a snag near Smith Mountain along the Idaho-Montana border, starting a fire that the Troy District Management Fire Committee recommended only be confined to meet specific prescribed fire objectives. The decision was made by the District Ranger. The fire spread slowly to about 500 acres across steep slopes ranging from 3,000 to 6,300 feet in elevation. It burned undergrowth and accumulated fuels in an area reserved for primitive recreation, wildlife habitat, and vegetative diversity.

Summary

The Troy fire management plan is the first of many future fire management plans that will cover most National Forest lands. It recognizes and uses fire as a natural ecological agent. It also gears fire suppression expenditures to land and resource values. What is being learned on the Troy District will benefit others in their understanding of and planning for management fires in the future.

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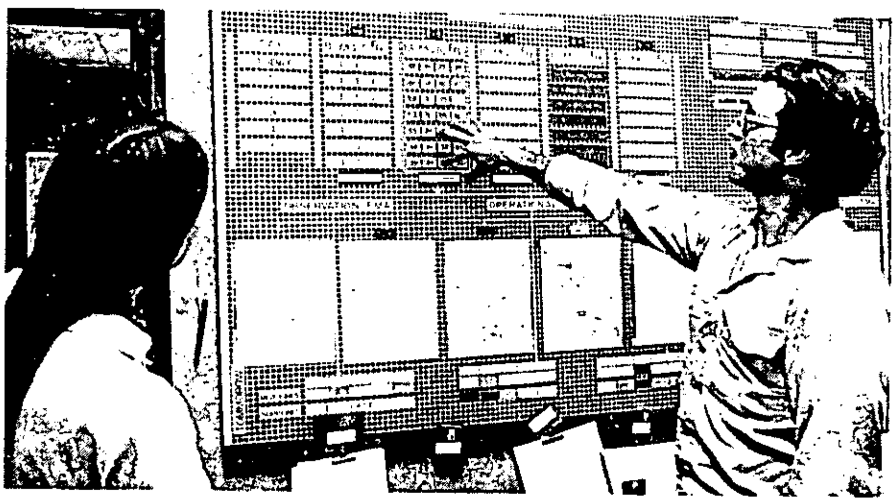
Figure 3.—Troy Fire Management Plan status board.



Using Fire Reports to Estimate Fire Spread for FOCUS Simulation Modeling

Delvin R. Bunton

FOCUS[1] is a large, computerized simulation model that enables a fire planner to determine the effects of various suppression manning plans on a protection unit in terms of number of fires, acreage burned, etcetera. FOCUS simulates the spread and suppression action on historical fire occurrences based on a large number of input data items including the forward rate of spread of each free-burning wildland fire in the data set. This article describes a simple method to assist fire planners in estimating the forward rate of spread of fires for use in FOCUS from data available on individual fire reports.

Historical Perspective

Fire planning in the past has used fire perimeter as an aid in estimating the suppression requirements on a given fire. Hornby (1936) described the relationship of fire perimeter to the perimeter of a circle, and Pirsko (1961) developed a nomogram to calculate the perimeter increase of a free-burning wildfire. Pirsko's research also indicated that the fire spread data on the fire reports in the 1960's were not very reliable. Both Hornby's and Pirsko's methods are still useful for estimating fire perimeter but not for determining forward rate of spread. Bratten (1978) described the fire growth model used in FOCUS as a "growing ellipse," with the length-to-width ratio (also called fire shape) and forward rate of spread used as defining parameters for a particular elliptical fire. Albini (1976) described fire shape using a "double ellipse," which more closely approximates the perimeter of a wind-driven fire, but is also more complex to use. This article will use the growth model described by Bratten so that the results mesh with FOCUS.

Forward Rate of Spread

Forward rate of spread estimates based on fire report data usually cover the free-burning period between the time of discovery and the first action. A free-burning fire is influenced by weather, fuels, and topography, but once suppression begins, the spread is usually altered or stopped. As a fire grows in size, the probability increases that the fuel type, topography, or other factors will change, which affects the forward and lateral spread rates. This spread estimation method assumes that the fire is burning in an essentially homogeneous fuel bed, that there are no major topographic changes (such as a knife ridge) in the fire area, and that the weather factors remain relatively constant over the estimation period.

Estimating Process

A number of fire managers on several National Forests in the Pacific Northwest Region have used this method to estimate spread rates for FOCUS input on over 2,000 fires. We found that the validity of the spread rates increased with the experience of the fire manager making the estimates. Judgment is needed because some of the data must be inferred from the fire reports, such as the initial size and shape of the fire. Local experience on similar fires is invaluable for estimating the fire potential given the scanty information available on fire behavior from the fire report. To estimate the forward rate of spread of a fire, follow the steps below:

1. Estimate the size of the fire at the time of discovery (See table 1 or figure 1 for aid in estimating fire size). Several factors from the fire report that can help in making this estimate are: the cause of the fire, the length of time between discovery and attack, the fuel type, the kind and amount of suppression forces on the fire, and the length of time required to control the fire.

2. Estimate the fire shape (denoted by the symbol R) at the time of discovery. Figure 2 shows the differences between ellipses of the same area with different R values. The shape ratio R is defined as the ratio of the major (long) axis of an ellipse to its minor (short) axis. An ellipse with $R=2$ is a 2:1 ellipse, that is, the ellipse is twice as long as it is wide. An ellipse with $R=1$ is a circle. The R values given in the graphs and in Table 1 are:

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[1]FOCUS—Fire Operational Characteristics Using Simulation. For a basic discussion of FOCUS, see: Storey, Theodore G., 1972. A computer simulation model for fire control planning. Fire Technology 8(2):91-103.

1) Expected only for very small, slowly spreading fires.
2&3) Normal fire shape on flat to moderate ground.
4&5) Normal fire shape on steep slope or with moderate winds.
6) Very windy or very steep terrain.

3. Find the fire length in feet in table 1 or figure 1 for the size and shape at the time of discovery.

4. Estimate the fire size at the time of attack as in step 1.

5. Estimate the fire shape at the time of attack (if different from the shape at the time of discovery).

6. Find the fire length in feet in table 1 or figure 1 for the size and shape at the time of attack.

7. Find the distance in feet that the fire spread between the time of discovery and the time of attack. This can be expressed algebraically as:

$$S_f = L_A - L_D \qquad (1)$$

where S_f=forward spread in feet from discovery to attack;
L_A=fire length at time of attack; and
L_D=fire length at time of discovery.

8. Determine the elapsed time in minutes from discovery to attack. This can usually be read from the fire report.

9. Use the alinement chart (fig. 3) to determine the forward rate of spread by following the steps below:

a. Locate the forward spread in feet from step 7 on the left-hand vertical.

b. Locate the lapse time from step 8 on the right-hand vertical.

c. Connect the points found in a and b with a straight edge and read the forward rate of spread in chains per hour. The same result can be calculated algebraically as:

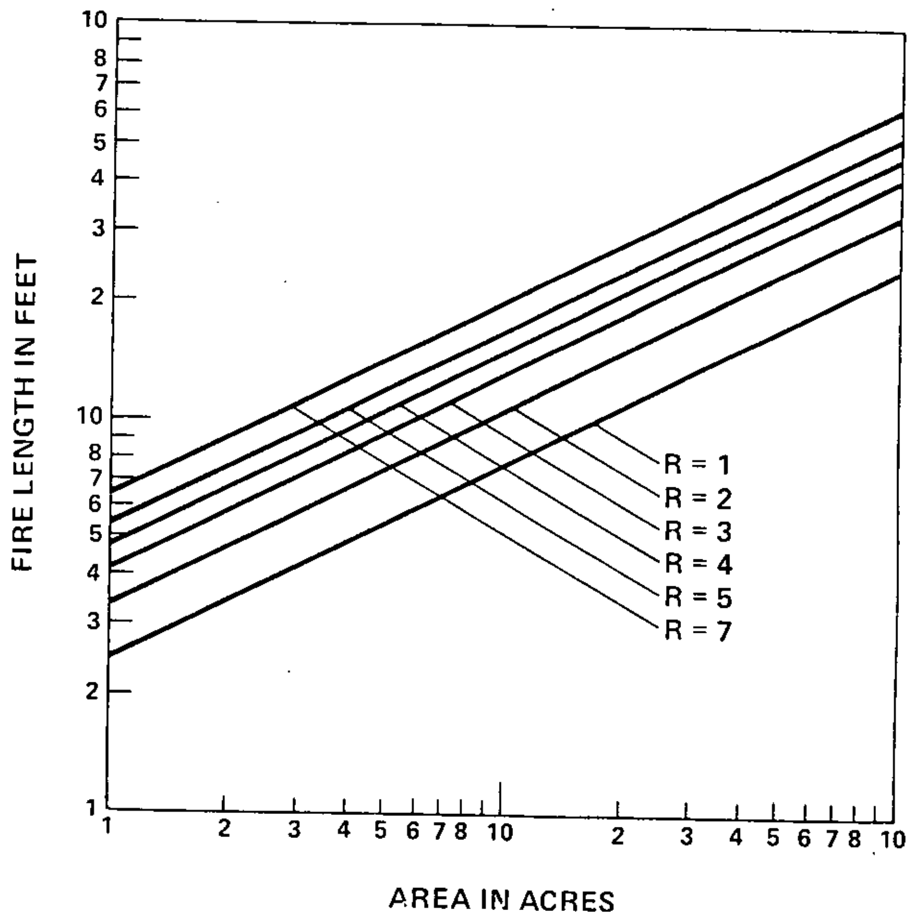
$$S_c = \frac{S_f}{T \times 1.1} \qquad (2)$$

where S_c=forward rate of spread per hour;
S_f=forward spread in feet during the period of the estimate;
T=the amount of time in minutes in the period of the estimate.

Check for Logical Results

A check for reasonableness to verify the computed rate of spread is to look at the number of people required to control the fire, how long it took to control the fire, the fuel type, how long the fire burned freely before the suppression forces arrived, and the final size. For example, a fire that took two people only 20 minutes to control probably had a very low spread rate and a short perimeter, while a fire that required 40 people working several hours either had a high spread rate or burned in heavy fuels. An additional check for small fires is to determine how large the fire would be if the spread rate held constant for half of the amount of time required to control the fire. For example, a fire burning at one chain per hour for 20 minutes would be 0.04 acres, while a fire burning at the same rate for 2 hours would be about 0.31 acres at the end of the period. The final check for reasonableness is "Does this estimate even sound valid?"

Figure 1.—Fire length in feet given fire size in acres and shape ratio. The ratio R is defined as the major axis length over the minor axis length.



The graph is arranged without explicit scales so that the user can determine the factors for fires not in the range of the table. The numbers below show the minimum and maximum for both axis. For example, if your fire area was between 1 and 100 acres, the length axis would range from 100–10,000 feet.

AREA	LENGTH
.0001-.01	1-100
.01-1.00	10-1000
1.00-100	100-10000

Table 1.—Length of Major Axis of Ellipse in Feet Given Area and Shape Ratio

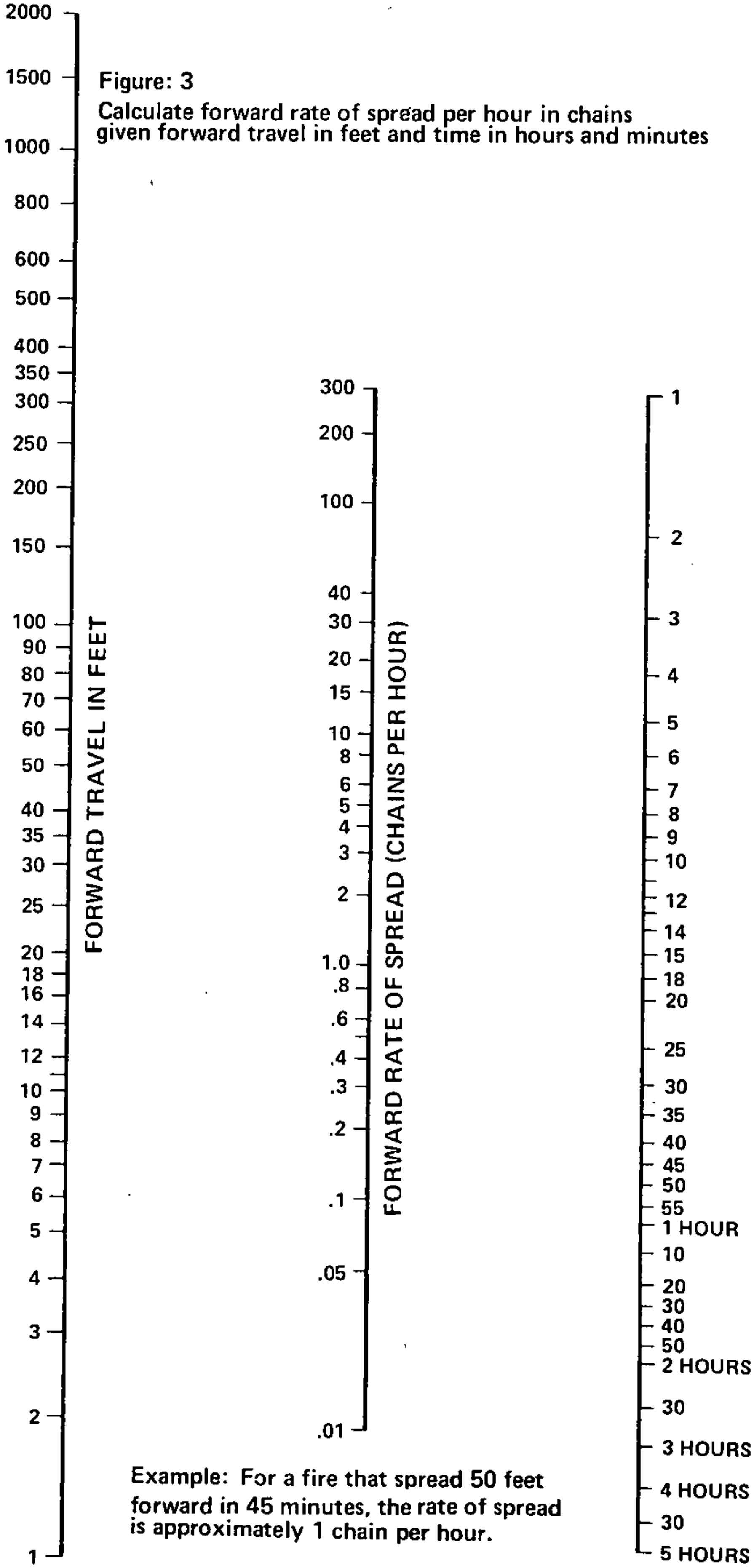
	ELLIPSE LONG AXIS					
Acres	1:1	2:1	3:1	4:1	5:1	7:1
0.0001	2.4	3.3	4.1	4.7	5.3	6.2
0.0005	5.3	7.4	9.1	10.5	11.8	13.9
0.001	7.4	10.5	12.9	14.9	16.7	19.7
0.005	16.7	23.6	28.8	33.3	37.2	44.1
0.010	23.6	33.3	40.8	47.1	52.7	62.3
0.015	28.8	40.8	50.0	57.7	64.5	76.3
0.020	33.3	47.1	57.7	66.6	74.5	88.1
0.025	37.2	52.7	64.5	74.5	83.3	98.5
0.030	40.8	57.7	70.7	81.6	91.2	107.9
0.035	44.1	62.3	76.3	88.1	98.5	116.6
0.040	47.1	66.6	81.6	94.2	105.3	124.6
0.050	52.7	74.5	91.2	105.3	117.8	139.3
0.060	57.7	81.6	99.9	115.4	129.0	152.6
0.070	62.3	88.1	107.9	124.6	139.3	164.9
0.080	66.6	94.2	115.4	132.2	148.9	176.2
0.090	70.7	99.9	122.4	141.3	158.0	186.9
0.100	74.5	105.3	129.0	149.0	166.5	197.0
0.120	81.6	115.4	141.3	163.2	182.4	215.8
0.140	88.1	124.6	152.6	176.2	197.0	233.1
0.150	91.2	129.0	158.0	182.4	204.0	241.3
0.160	94.2	133.2	163.2	188.4	210.6	249.2
0.180	99.9	141.3	173.1	199.8	223.4	264.4
0.200	105.3	148.9	182.4	210.6	235.5	278.7
0.220	110.5	156.2	191.3	220.9	247.0	292.3
0.240	115.4	163.2	199.8	230.7	258.0	305.2
0.250	117.8	166.5	204.0	235.5	263.3	311.5
0.260	120.1	169.8	208.0	240.2	268.5	317.7
0.280	124.6	176.2	215.8	249.2	278.7	329.7
0.300	129.0	182.4	223.4	258.0	288.4	341.3
0.350	139.3	197.0	241.3	278.7	311.5	368.6
0.400	148.9	210.6	258.0	297.9	333.1	394.1
0.450	158.0	223.4	273.6	316.0	353.3	418.0
0.500	166.5	235.5	288.4	333.1	372.4	440.6
0.550	174.7	247.0	302.5	349.3	390.5	462.1
0.600	182.4	258.0	316.0	364.8	407.9	482.6
0.650	189.9	268.5	328.9	379.7	424.6	502.3
0.700	197.0	278.7	341.3	394.1	440.6	521.3
0.750	204.0	288.4	353.3	407.9	456.1	539.6
0.800	210.6	297.9	364:8	421.3	471.0	557.3
0.850	217.1	307.1	376.1	434.2	485.5	574.5
0.900	223.4	316.0	387.0	446.8	499.6	591.1

Table 1. (Continued)

	ELLIPSE LONG AXIS					
Acres	1:1	2:1	3:1	4:1	5:1	7:1
0.950	229.5	324.6	397.6	459.1	513.3	607.3
1.00	235.5	333.1	407.9	471.0	526.6	623.1
1.10	247.0	349.3	427.8	494.0	552.3	653.5
1.20	258.0	364.8	446.8	516.0	576.9	682.6
1.30	268.5	379.7	465.1	537.0	600.4	710.4
1.40	278.7	394.1	482.6	557.3	623.1	737.2
1.50	288.4	407.9	499.6	576.9	645.0	763.1
1.60	297.9	421.3	516.0	595.8	666.1	788.1
1.70	307.1	434.2	531.8	614.1	686.6	812.4
1.80	316.0	446.8	547.3	631.9	706.5	836.0
1.90	324.6	459.1	562.3	649.2	725.9	858.9
2.00	333.1	471.0	576.9	666.1	744.7	881.2
2.50	372.4	526.6	645.0	744.7	832.6	985.2
3.00	407.9	576.9	706.5	815.8	912.1	1079.2
3.50	440.6	623.1	763.1	881.2	985.2	1165.7
4.00	471.0	666.1	815.8	942.0	1053.2	1246.2
4.50	499.6	706.5	865.3	999.2	1117.1	1321.8
5.00	526.6	744.7	912.1	1053.2	1177.5	1393.3
5.50	552.3	781.1	956.6	1104.6	1235.0	1461.3
6.00	576.9	815.8	999.2	1153.7	1289.9	1526.2
7.00	623.1	881.2	1079.2	1246.2	1393.3	1648.5
8.00	666.1	942.0	1153.7	1332.2	1489.5	1762.4
9.00	706.5	999.2	1223.7	1413.0	1579.8	1869.3
10.00	744.7	1053.2	1289.9	1489.5	1665.3	1970.4
11.00	781.1	1104.6	1352.9	1562.2	1746.5	2066.5
12.00	815.8	153.7	1413.0	1631.6	1824.2	2158.4
13.00	849.1	1200.8	1470.7	1698.2	1898.7	2246.6
14.00	881.2	1246.2	1526.2	1762.4	1970.4	2331.4
15.00	912.1	1289.9	1579.8	1824.2	2039.5	2413.2
16.00	942.0	1332.2	1631.6	1884.0	2106.4	2492.3
18.00	999.2	1413.0	1730.6	1998.3	2234.2	2643.5
20.00	1053.2	1489.5	1824.2	2106.4	2355.0	2786.5
22.00	1104.6	1562.2	1913.2	2209.2	2470.0	2922.5
24.00	1153.7	1631.6	1998.3	2307.5	2579.8	3052.5
25.00	1177.5	1665.3	2039.4	2355.0	2633.0	3115.4
26.00	1200.8	1698.2	2079.9	2401.7	2685.2	3177.1
28.00	1246.2	1762.4	2158.4	2492.3	2786.5	3297.1
30.00	1289.9	1824.2	2234.2	2579.8	2884.3	3412.8
35.00	1393.3	1970.4	2413.2	2786.5	3115.4	3686.2
40.00	1489.5	2106.4	2579.8	2978.9	3330.5	3940.7
45.00	1579.8	2234.2	2736.3	3159.6	3532.6	4179.8
50.00	1665.3	2355.0	2884.3	3330.5	3723.7	4405.9

Figure: 3

Calculate forward rate of spread per hour in chains given forward travel in feet and time in hours and minutes



Example: For a fire that spread 50 feet forward in 45 minutes, the rate of spread is approximately 1 chain per hour.

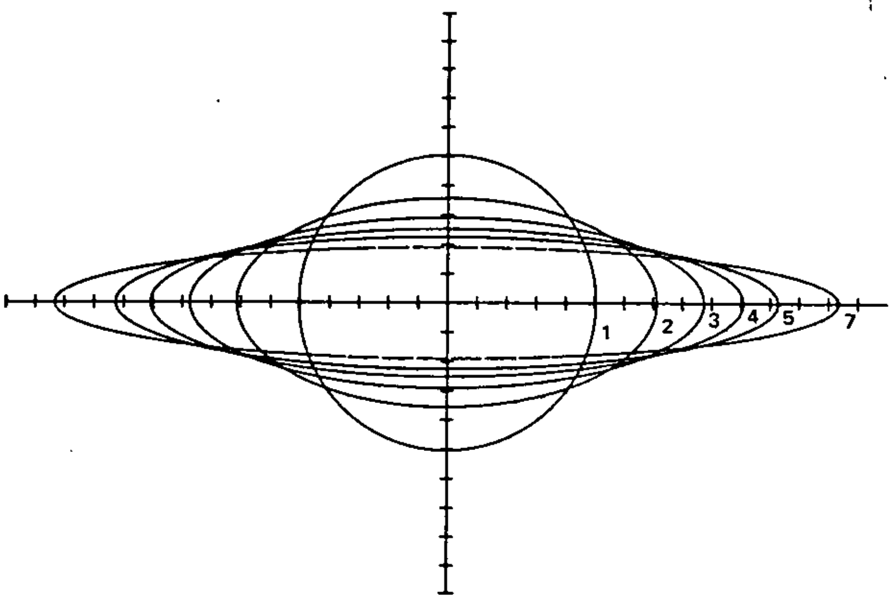


figure 2.—Ellipses with the same area showing differences due to change in shape ratio 4

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Prescribed Fire and Bark Beetle Attack in Ponderosa Pine Forests

William C. Fischer

Prescribed fire is fast becoming a routine understory treatment in ponderosa pine forests. Benefits of "underburning" include hazard reduction, site preparation, species and stocking control, and increased forage and browse production (Wright 1978, Martin and Dell 1978, Weaver 1974, Biswell and others 1973). Unanticipated bark beetle attack and subsequent tree kill has followed some prescribed fires in western Montana ponderosa pine stands (Ferry 1970, Henderson 1976). Personal communications with those conducting prescribed burns confirm similar occurrences in other parts of the ponderosa pine region.

The literature indicates that current understanding of fire-bark beetle relationships is incomplete. The information that does exist, however, can help fire managers develop prescriptions that minimize the probability of unacceptable bark beetle-caused tree kill following fire use in ponderosa pine forests.

The bark beetles that are most often associated with tree damage following prescribed fire in ponderosa pine stands are the western pine beetle, *Dendroctonus brevicomis;* the red turpentine beetle, *D. valens;* and the pine engraver beetle, *Ips pini*. Locally, other bark beetles with attack characteristics similar to these three may be important.

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The Western Pine Beetle

Much of our current understanding of the relationships between fire and bark beetles is based on results of early studies of western pine beetle attack on ponderosa pine following fire in California, Oregon, Idaho, and Montana (Miller and Keen 1960). These studies found an increased susceptibility of overstory trees to bark beetle attack following fire.

Trees killed outright during a fire are not attractive to the western pine beetle. Neither are trees under 6 inches (15 cm) in diameter (Furniss and Carolin 1977). The beetle selects fire-scorched trees that have survived the fire with enough green phloem and live buds to permit new needle growth.

The degree of crown scorch or fire-related defoliation, appears to be the primary indicator of a scorched tree's susceptibility to western pine beetle attack. Cambium injury adds to the defoliated tree's susceptibility. The relationship between western pine beetle-caused mortality and fire-scorched ponderosa pine is as follows (Miller and Keen 1960):

Percent defoliation by fire	*Percent of trees killed*
less than 25	9–15
25–50	4–14
50–75	18–42
more than 75	19–87

As a general rule, the lower (percent of trees killed) values for each level of defoliation are associated with slight cambium injury. The larger values suggest moderate to heavy cambium injury. The seemingly erratic behavior of the 0 to 25 and 25 to 50 percent defoliation classes is not explained in the literature.

The Red Turpentine Beetle

The red turpentine beetle frequently attacks fire-scorched ponderosa pine. This beetle attacks the lower part of scorched pines and can hasten mortality of severely defoliated trees (Herman 1950). Where not numerous, however, the presence of this beetle by itself seems to have no apparent effect on the survival of scorched trees (Wagener 1961). Through repeated attacks it sometimes kills trees, but more often weakens them, thus setting the stage for fatal attack by other bark beetles such as the western pine beetle (Furniss and Carolin 1977).

The Pine Engraver Beetle

The pine engraver beetle is a common associate of the western pine beetle in ponderosa pine forests. Engravers like thin bark, so they are often found in the tops and limbs of trees killed by the western pine beetle. Often, attack by the pine engraver precedes, and sets the stage for, attack by the western pine beetle. The pine engraver beetle is also found in fire-damaged pole-sized trees, freshly cut logs, and pieces of fresh slash over 2 inches (5 cm) in diameter.

When suitable host material is plentiful, the engraver can develop in sufficient numbers to attack and kill healthy, young ponderosa pine, 2 to 8 inches (5 to 20 cm) in diameter and the tops of larger trees. Outbreaks seldom last for more than one season (Furniss and Carolin 1977).

Beetle Attraction

Fire-injured trees usually suffer a loss in vigor and a slow down in growth as a result of defoliation and cambium damage (Miller 1929). Such trees are especially susceptible to beetles because they are less likely to successfully repel an attack for two or more seasons following burning (Miller and Keen 1960).

There are at least two hypotheses to explain how a susceptible tree is located by a bark beetle (Wood 1972). One is that beetles respond to primary chemical attractants produced by the tree that may be symptomatic of the stress caused by scorching. The other hypothesis is that the first beetle randomly lands on the susceptible tree after alighting on many healthy trees. Once the first beetle(s) locates a suitable tree, it generates a complex mixture of chemicals (a pheromone), which attracts other beetles to the area (Birch 1978).

The area from which the attacking beetles are drawn is not well defined in the literature. Initial attack most likely comes from beetles in or near the fire area. Results of early studies indicate that western pine beetles can be drawn from at least 3 miles away (Miller and Patterson 1927).

Season of Fire is Important

The season in which a prescribed fire is conducted is an important factor influencing the occurrence, duration, and severity of beetle attack on fire-weakened ponderosa pine. The result of crown scorching is usually more severe during the active growth period early in the summer than later when growth has slowed, terminal buds have formed, and a food reserve is being accumulated (Wagener 1955, 1961). Likewise, crown scorching that occurs in early spring, before or immediately after bud burst, often results in minimum damage to the tree.

When fires are conducted in late spring or early summer, beetles may infest fire-weakened trees during the summer and fall of the same year. In such cases, maximum losses of scorched trees may not become evident until the following year.

Following late summer or fall fires, beetles will not usually become established in the burned area until the next year. Consequently, maximum losses may not be obvious until the second year after the fire. If a late season fire is followed by an insect flight, attack is often confined to those heavily scorched trees that would have died anyway (Miller and Patterson 1927; Wagener 1955, 1961; Miller and Keen 1960).

Fire Management Implications

The threat of bark beetle attack should serve as a constraint, but not a deterrent, to the use of fire in ponderosa pine stands. Fire managers should consider the probability of beetle attack and write fire prescriptions that minimize its occurrence (Fischer 1978).

More specifically, fire managers should:

- become familiar with signs of bark beetle activity so the presence of beetles can be detected during field reconnaissance of areas proposed for burning (Martin and Dell 1978). Remember, however, just because you don't see signs of beetles doesn't mean they are not present within their attack range.
- become familiar with the timing of beetle flights in the area to be burned. Whenever possible, schedule prescribed fires around these high risk periods. This is especially important if you plan to thin ponderosa pine stands with fire. Crown scorch is inherent in such a treatment.
- avoid scorching tree crowns (unless your objective is to thin the stand). Crown scorch can be predicted. Albini (1976) used equations developed by Van Wagner (1973) to graphically relate crown scorch to flame length for different windspeeds. He also provides aids for estimating flame length. Norum (1977) suggests a procedure for using Albini's charts to estimate crown scorch when writing a fire prescription. This procedure works for any tree species. Fire managers should use these aids when planning fire use in ponderosa pine stands.

If severe crown scorching does occur, the fire manager has a dilemma. Should he or she immediately remove the scorched trees, thereby avoiding the possibility of a beetle infestation? Or, should a wait-and-see approach be followed?

As indicated earlier, season of the year is important. Ponderosa pine are often only slightly affected by crown scorching that occurs in early spring or late fall. When ponderosa pine are

Figure 1.—Prescribed fire can be used to reduce fire hazard in young ponderosa pine stands. Excessive crown scorch can, however, result in unacceptable damage to crop trees by *Ips pini*.

scorched outside the active growing season, cambium injury becomes an important factor, especially with the thinner bark, pole-sized trees. Unfortunately, cambium damage is not easy to detect, although Hare (1960, 1965) has suggested several techniques. Unless local experience indicates otherwise, or if severe cambium injury is detected, the fire manager is well advised to go slow with the saw. Scorched trees should be watched closely, especially for signs of *Ips*, and if they become infested, should be removed to lessen the chance of adjacent standing green trees being infested.

One final point—as a general rule, ponderosa pine are more susceptible to bark beetle attack during periods of drought. Consequently, the degree of scorching that a tree can sustain and still survive beetle attack is less than it is under more normal moisture conditions.

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North Carolina Aerial Ignition Program

James F. Sain

In January 1978, the North Carolina Division of Forest Resources began an experimental Aerial Ignition Program to determine feasibility for hazard reduction burning, site preparation burning, and backfiring on wildfires.

During the first 15 months of use, 10,452 acres of hazard reduction burning and 4,824 acres of site preparation burning were completed, most of it on a contract basis for private nonindustrial landowners.

The Aerial Ignition System

The aerial ignition system used in this program was developed by the Canadian Forestry Service and is commercially available from Premo Plastics Eng. Ltd., Victoria, B.C. Aerial Ignition Devices (AID) consist of 3.5 grams of potassium permanganate contained by two permanently sealed hemispheres of high impact polystyrene. Each AID is sphere-shaped and 1.25 inches in diameter. As the AID is dropped through a specialized dispenser, it is injected by a hollow stainless steel needle with 1 milliliter of 50 percent water and ethylene glycol solution. The AID is then dropped out of the dispenser, and the subsequent chemical reaction produces ignition in about 25 to 30 seconds.

The key to successful aerial ignition burning is ignition spacing. Spacing is determined by four feed chutes, capable of being controlled individually, and by air speed. Each chute is capable of dropping one AID per second. The desired spacing can be accomplished by varying the number of chutes and the air speed of the helicopter.

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Firing Techniques for Prescribed Burning

The firing technique used in hazard reduction burns consisted of setting spot fires in a uniform pattern over the entire tract. The most satisfactory spacing for most eastern North Carolina fuel types has proven to be flight lines flown every 60 to 70 feet with ignitions set 60 to 70 feet apart. However, spacing that varied from 30 by 40 feet to 70 by 130 feet was used satisfactorily, depending on the fuel type. The best results were obtained on days when temperature was less than 50°F, humidity was 30 to 45 percent, and windspeed was 5 to 15 miles per hour.

Areas having heavy fuel accumulation were fired at a rate of approximately 15 acres per minute. As an example, an approximately 1,000-acre tract, composed of 30- to 40-year-old loblolly pine natural stands and 20-year-old loblolly plantations with 4 to 5 tons per acre of available fuel, was fired by helicopter in 64 minutes. Both Forest Resources personnel and the landowners were extremely satisfied with the resulting fuel reduction and the limited needle scorch. The same tract had been burned 5 years prior, with 10 to 12 people able to burn only 100 to 150 acres per day.

Firing techniques on site preparation burns varied from simple "ringing" the tract on drum-chopped areas having a heavy, continuous fuel bed to firing strips (60 to 150 feet wide) in cutover tracts where the fuel bed was light and scattered. When stripping was used, ignition spacing within the flight line normally averaged 60 to 70 feet. The best results were obtained on recently cutover tracts and drum-chopped areas where less AIDs and less firing time were needed.

Figure 1.—Huey Model UHIB Helicopter with aerial ignition dispenser attached

Use on Wildfire

Aerial ignition was used to backfire seven wildfires during the 1979 spring fire season. Six of these fires were coded project fire potential with the seventh coded high potential and burning in pine plantation. The usual firing technique employed was to fire from a break and burn out as much area as possible in front of the approaching wildfire. This was accomplished by firing strips approximately 60 feet apart with ignitions every 40 to 50 feet in the flight line. The firing was

Figure 2.—Aerial Ignition Dispenser

continued until the indraft effect of the head of the wildfire began drawing the ignitions away from the base line (first strip).

Because of the dense, heavy fuel loads (up to 37 tons per acre) associated with high pocosin fuel types (fuel model 0), backfiring with aerial ignition must begin earlier in this fuel type than in other eastern North Carolina fuels (McNab et al 1979). To compensate for the long distance spotting associated with high pocosin fires, it appears that backfiring must begin when the wildfire is at least ½ mile away.

Use of aerial ignition proved to be very effective in stopping the running head fires and in reducing the amount of long distance spotting across control lines. The Division is giving this facet of the Aerial Ignition Program close attention during the 1980 spring fire season to develop definite parameters for fire control use.

Cost-Analysis

Cost records were kept on the Aerial Ignition Program to allow a cost-analysis after a full year of aerial ignition burns. Data was kept on operating expense of the helicopter, AIDs used, and cost of ground equipment and personnel on each burn. Initial investment consisted of approximately $3,000 to put a surplus Huey-model UH1B helicopter into operations, $3,3000 to purchase the aerial ignition dispenser, and approximately $2,000 to purchase 20,000 AIDs. After this initial investment, the actual cost of operating the Huey for 250 hours averaged $63.27 per hour. Including the cost of the pilot and a two-person crew, the figure is approximately $85.00 per hour.

The total cost to efficiently do hazard reduction burning on a 1,000 acre tract (including helicopter and crew, all ground personnel, and all equipment) averaged $1.50 to $1.60 per acre. With a contract helicopter, the same tract would have likely cost closer to $4.50 to $6 per acre.

An efficiently organized 100 acre site preparation burn (again including helicopter and crew, all ground personnel, and all equipment) cost an average of $2.90 to $3 per acre. If this tract were burned with a contract helicopter, the total cost would have been in the $8.00 to $12.00 per acre range.

Summary

After approximately 1 year of aerial ignition burning, firing techniques have been developed that will work in most of the prescribed burning situations in eastern North Carolina. Acreages that would have taken weeks for ground personnel to burn can now be burned in 1 day. With efficient use of the helicopter, ground personnel, and equipment, aerial ignition can increase prescribed burning capabilities and be cost efficient at the same time. Promise has been shown in the use of aerial ignition on wildfires and more study is being done during the 1980 spring fire season to further develop and refine the capabilities of this system.

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Remote Automatic Weather Stations (RAWS)

John R. Warren

Remote Automatic Weather Stations (RAWS) have been developed and are operating in numerous States across the country in a variety of areas. Stations of this type will satisfy requirements for weather data from remote locations. They can operate unattended for periods of 6 months or longer. They are battery operated and recharged by solar panels. The weather data are transmitted via the Geostationary Operational Environmental Satellite (GOES) to the east coast where they are stored and readily available to the user via dial-up or dedicated phone lines.

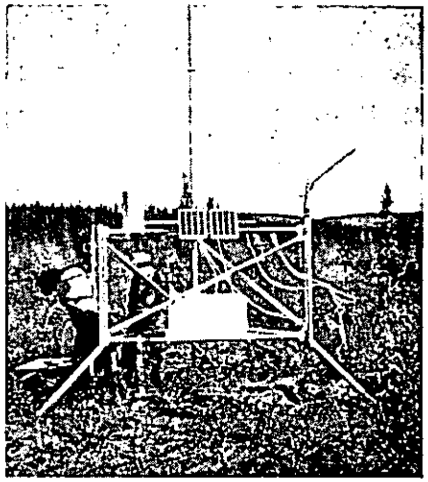

Figure 1.—Installing RAWS unit

Figure 2.—RAWS unit installed and operational

Background

Agencies involved in wildland fire management have long needed weather data from remote locations where people are not available to make observations. USDA Forest Service and USDI Bureau of Land Management (BLM) engineers have worked cooperatively since 1976 to develop this capability.

Numerous manufacturers, equipment, and techniques were reviewed individually and jointly. In 1977, two stations were procured from La Barge Electronics Division, Tulsa, Oklahoma, and operated by BLM.

Those 2 stations were forerunners of the 10 stations now operating and undergoing field evaluation. In early 1978, a RAWS Steering Committee consisting of meteorologists, engineers, and foresters met. At the meeting, plans were made to procure, operate, and evaluate the 10 stations. Subsequently, the BLM and Forest Service electronic engineers met with La Barge engineers to define the modifications needed for the previous two stations. The 10 stations were ordered (5 Forest Service, 5 BLM), delivered, and installed as planned. The first station was delivered and installed in Honolulu on June 5, 1978, and the remaining stations were installed later that month. The Alaska stations are operating alone in remote locations. The other five are adjacent or near to existing weather stations for data comparison. Data are being routinely acquired each hour and transmitted every 3 hours via the GOES to the National Environmental Satellite Service (NESS) computer for storage and quick access via low-speed (110-baud) or high-speed (1200 baud) terminals. Work is underway to automatically transfer the data into the AFFIRMS network for the convenience of National Fire Danger Rating System (NFDRS) or other AFFIRMS users.

Meteorological Outputs

The stations will measure, store, and transmit wind speed, wind direction, air temperature, fuel temperature, precipitation, relative humidity, and barometric pressure. Battery voltage is also monitored as a station-keeping function. The wind speed and wind direction outputs are conditioned by a 10-minute time-weighted average circuit to provide a better indication of conditions than an instantaneous sample.

John Warren is an electronics Engineer for the USDA Forest Service stationed at the Boise Interagency Fire Center in Boise, Idaho.

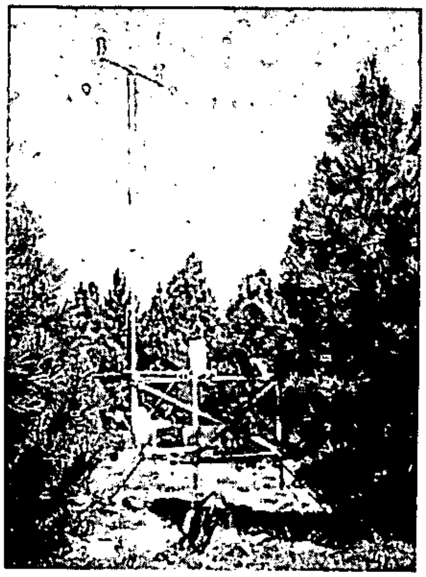

Figure 3.—Convertible Data Collection Platform

Station Description—Physical

The station consists of a group of meteorological sensors mounted on a tower structure with the electronic units and batteries inside a metal, lockable enclosure. The transmitting antenna and solar panels are also mounted on the basic structure. The wind sensors are located at the top of a hinged pole at a height of approximately 20 feet. The pole can be easily raised or lowered to facilitate initial installation, orientation, replacement, and so forth. The entire station can be installed in about 2½ hours by two experienced technicians under average conditions. There are no outside power or telephone line connections. During setup, the wind direction sensor must be pointed properly, the transmitting antenna and solar panels must be oriented, and the tower must be made level. All of these can be easily accomplished. Wiring and cabling are mostly protected from the environment, since all the electronics, cabling, etcetera, are approximately 3 feet above ground level (except the intentional lower location of the fuel moisture sensor). Leveling adjustments are provided on all three legs of the triangular base to permit setup under a variety of terrain slopes and conditions.

Station Description—Electrical

The station acquires and stores data from its various sensors every hour and transmits the data every 3 hours. (The acquisition and transmission times are completely selectable, in 15-minute increments at the time of station activation or later.) The data are processed by a signal conditioner and presented in the proper format (analog or digital) to the convertible data collection platform (CDCP). The analog data are converted to digital and stored in the CDCP memory for subsequent or immediate transmission. The stations are self-timed and automatically transmit at their assigned time following activation.

The CDCP contains a microprocessor into which all control parameters are entered via a test set during initial setup. Subsequently, the microprocessor takes over full control of the stations, querying the sensors, storing the data, encoding and formatting the data, supplying power to sensors and circuits when appropriate, and activating the transmitter to send the data to Wallops Island, via the GOES. The microprocessor operates on a precise time schedule, initially synchronized with a WWV reference. The transmission frequency, modulation, format, coding, parity, etcetera, are in accordance with National Environmental Satellite Service (NESS) standards to insure correct reception and processing by the GOES and the NESS Data Collection System/Data Processing System (DCS/DPS). The station operates on batteries that are recharged by solar panels. Each sensor uses an individual printed circuit board for flexibility in adding/deleting/changing sensor types and for ease in trouble shooting.

Data Retrieval

The data from any station are stored in the DCS/DPS computer and are available to users using dedicated lines or dial-up lines. The dial-up lines may use either a low speed (110 baud) or high speed (1200 baud) terminal. The Forest Service is currently devising a method for automatic transfer of the remote station data from the DCS/DPS into the AFFIRMS, which is in use by many Forest Service and other users.

Conclusion

The RAWS provides a very adequate means for automatically acquiring data from remote unattended sites. The heart of the station, the CDCP, has been in use successfully in large numbers over the past years in a variety of data acquisition systems. The 10 RAWS completed their field evaluation as planned, and appear to be quite satisfactory for operational use.

An Instrument for Rapid, Accurate, Determination of Fuel Moisture Content

Stephen S. Sackett

Moisture contents of dead and living fuels are key variables in fire behavior. Accurate, real-time fuel moisture data are required for prescribed burning and wildfire behavior predictions. The convection oven method has become the standard for direct fuel moisture content determination. Efforts to quantify fuel moisture through indirect methods have not been sufficiently site specific. Previous attempts to make direct measurements less time consuming have also been inadequate in one way or another.

Instrument Developed

A recently developed instrument (COMPU-TRAC™, manufactured by Motorola Processing, Inc.), designed to be used by a variety of industries and disciplines, may significantly shorten the time needed to determine dead and live fuel moisture for those people trying to predict prescribed or wildfire behavior and effects. It can be used both in the laboratory and in the field.

This moisture analyzer is actually a miniature oven. The sample is dried on a pan connected directly to a rugged weight sensor. It has solid-state electronics throughout and a built-in computer system that eliminates calibrating, weighing, balancing, and making mathematical calculations. It completely eliminates operator skill and judgment factors. Moisture content readings are obtained in 5 to 20 minutes. Because the instrument is completely automatic, the operator is left free to complete other tasks while the instrument processes the material—a distinct advantage over other methods.

Small Size

The moisture analyzer weighs 26 pounds and is completely portable (possibly air dropable). Its physical dimensions are 19 inches wide by 8 inches high, and 10 inches deep. The analyzer can be run on generated 120 volt-60 Hz power, and is accurate even at wide variations of electrical input from as low as 90 volts to as high as 150 volts. The instrument draws 6 amps when the heating element is on—an equivalent of 710 watts—and 1 amp when not heating. LED indicator lights display three-digit readings of moisture content. An array of other indicator lights provides a continuous status check of the instrument.

Sample Process

Since the samples must be small, it is important that they be adequate and representative of the fuels being considered. Samples should be collected specifically from the area where wildfire behavior is being predicted or prescribed fire decisions are being made. A variety of leakproof sample containers are available. Autoclavable plastic bottles are perhaps the best, but glass jars with airtight lids or seamless metal tins also may be used.

The number of samples must be large enough to provide adequate information for estimating the average fuel moisture if a lot of variability is present. The samples should be stratified to eliminate combining fuels with known differences in moisture content, such as samples from sunny or shaded sites. If samples are combined for a single estimate of an area, each should be

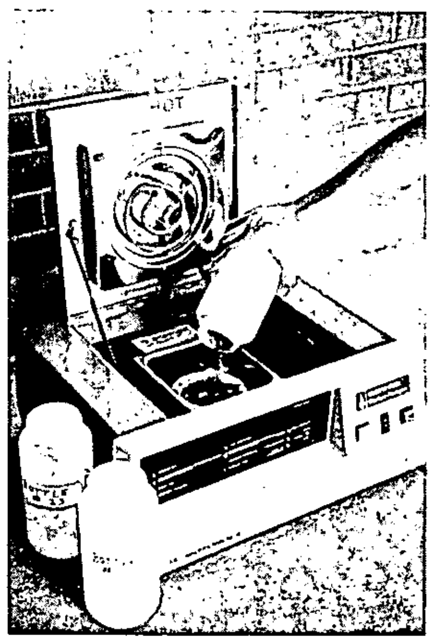

Figure 1.—Samples are "sprinkled" on a pan inside the moisture analyzer

Stephen Sackett is a Research Forester (Fire) with the Rocky Mountain Forest and Range Experiment Station, Research Work Unit in Tempe, in cooperation with Arizona State University. The Station's headquarters is at Fort Collins, in cooperation with Colorado State University.

weighted according to the portion of total area it occupies within each stratum. Samples should not be exposed to conditions that will cause the moisture to start evaporating from the material and collecting as condensation inside the container. This situation can be eliminated by not allowing the sample to be exposed to radiant (sunlight) heating which allows the fuel sample to be hotter than its surroundings. Quickly getting the sample back for processing also helps.

Operating Procedures

The moisture analyzer is simple to operate. Samples are "sprinkled" on a pan inside the analyzer (fig. 1) until a light and beeper indicate the proper amount has been added. After the door is closed, the weighing and drying process takes place. All calculations are made automatically within the microprocessor. Approximately 5 to 20 minutes later, the moisture content is illuminated on the instrument panel. A light and beeper also "tell" the operator the process is complete. Because the sample pan is only 4.25 inches in diameter, it is sometimes necessary to cut the sample into smaller pieces. For instance, we cut ponderosa pine needles into ½- to ¾-inch segments, making sure to include both fascicle and tip ends. The sample pan can be emptied and cleaned easily. The instrument is best suited to small-dimension (fine) fuels.

Rapid determination of fuel moisture can greatly enhance the accuracy of predictions and decisions based on the effects of fuel moisture. Tests comparing the moisture analyzer data from a mechanical convection oven yielded a coefficient of determination (r^2) of 0.98.

Summary

Moisture content of forest fuels is a key variable in fire behavior. Indirect and direct methods of determining fuel moisture are often inadequate. An instrument was recently tested, COMPU-TRAC™, that accurately measures fuel moisture directly in a short time. The moisture analyzer completely eliminates operator skill and judgment by using a rugged load sensor and electronic microprocessor to automatically process fuel moisture samples.

Slash Burning Equipment

Tim Tyree

About 10 years ago the Sweet Home Ranger District on the Willamette National Forest in western Oregon began piling unutilized logging residue on and near landings. One objective of doing this was to increase the utilization of wood fiber unsuitable for milling, in other forms such as chips or firewood. Often it would take 2 or 3 years for these decks or piles to be utilized. In the meantime, the small material in the units would be broadcast burned, and occasionally the unutilized piles would be burned, starting from radiant heat and/or embers. An economical method of saving these decks during broadcast burning operations was needed.

Since water is quite plentiful on the Ranger District, the decision was made to investigate the use of large field irrigation equipment that is available from various commercial sources.

We visited Moore-Rain Equipment Company in Corvallis, Oregon, and consulted with their irrigation experts. As a result of their advice a P-150-T "Big Gun" water cannon was purchased.

The P-150-T has both full circle and part circle capability. It has an array of taper bore nozzles from 0.7 to 1.3 inches, which gives a circle or part circle area coverage of 330 feet to 460 feet in diameter at 120 pounds of pressure.

Tim Tyree is a Fire Management Officer on the Sweet Home Ranger District on the Willamette National Forest in Oregon.

Opportunities for Use

Numerous opportunities were available to experiment with the P-150-T during the spring and summer of 1978. We found it very effective for saving unutilized piles or decks. In addition, it was found to be extremely valuable for various other jobs such as wetting down areas outside of units before and during burning operations. After burning, it is useful in mop-up operations. When water is available, it is estimated that 1 person using a P-150-T can mop up as much area as a 10-person crew.

More recently, two smaller, somewhat lighter versions (P-100-T's) were purchased, which were easier to move and provided nearly as much performance. They were used on the Swift Fire, on the Williamette National Forest, for mopping up a felled and bucked unit in the fire area that was considered to be too hazardous for crew operation. The P-100-T's required only two people to operate and were considered to be very effective.

One was also used on a 1-acre spot fire in a heavy clearcut slash area; the fire was controlled by two people within 30 minutes. The water source for this instance was a 5,000-gallon tanker that was available on the slash burning operation.

Power Unit

In initial use of the "Big Guns," two Mark III pumps on parallel lines to each gun were used. This is a satisfactory approach to operating the smaller nozzles, but for larger and more efficient operations, large hose and pumps are needed.

We are now using a trailer mounted Hale pump, powered by a six cylinder gas engine, which pumps about 600 gallons per minute at 120 pounds of pressure. This will operate three guns with medium nozzles or two of the smaller guns with the largest nozzles. Three thousand feet of 3-inch CJRL is used with the Hale pump to deliver water from as much as ½ mile away.

Bases Needed

The bases for the guns are manufactured by Moore-Rain. They are made of aluminum irrigation pipe and are extremely light weight. The entire

Figure 1.—P-150-T (Big Gun) Water Cannon

base fills with water as the hoses are charged and provides adequate weight for holding the guns firmly in place. Both the 100 and the 150 use the same base.

Costs

The cost of a P-150-T with base is about $500, the P-100-T is about $350. The Hale pump and 3-inch hose are from Wilco Fire Equipment. Cost of the pump was $6,800, with hose costing $3 per foot.

Summary

Where water is plentiful, the P-150-T water cannon and the smaller P-100-T's are cost effective tools in saving piles of unutilized material during broadcast burn operations. In addition, this equipment is effective in maintaining control lines on broadcast burn units and mop-up operations in both prescribed and wildfire situations.

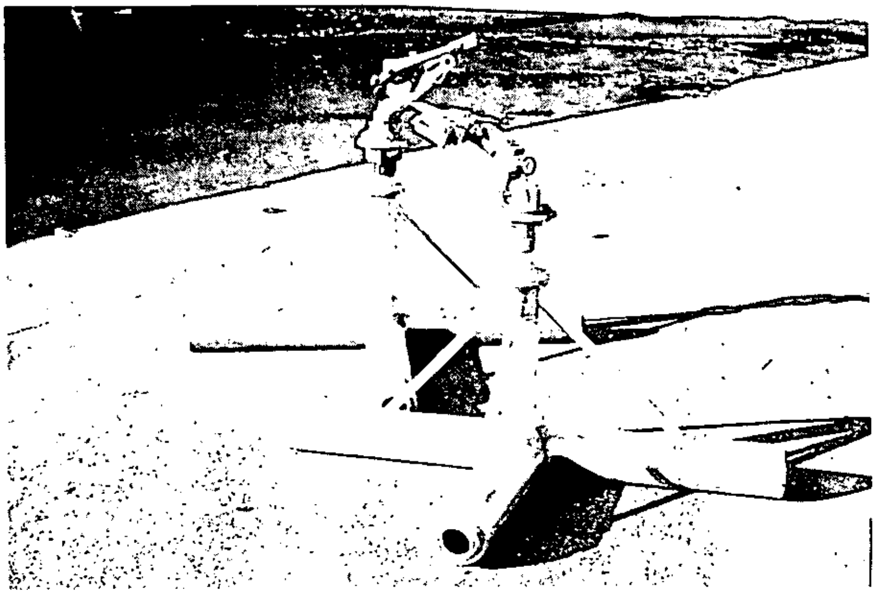

Figure 2.—P-150-T mounted on aluminum base

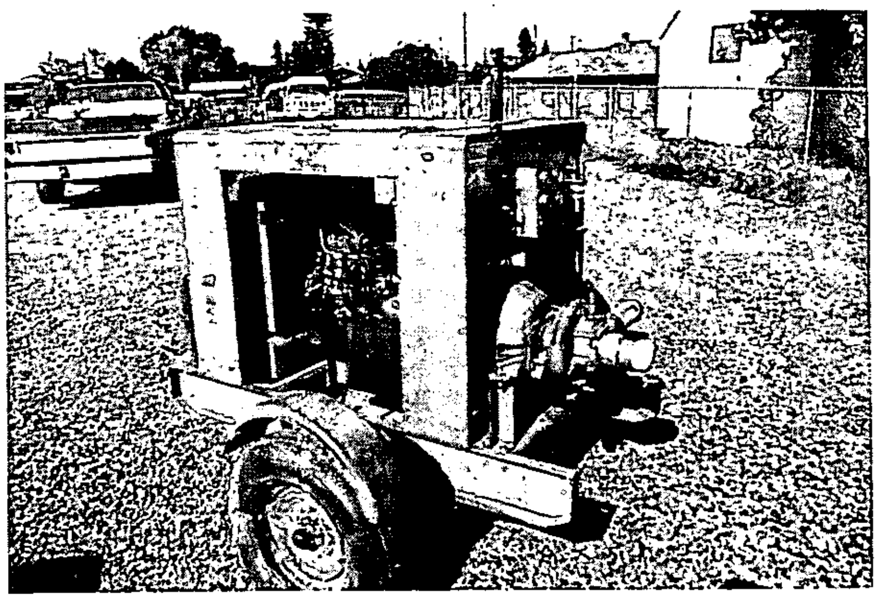

Figure 3.—6 cylinder gas engine and Hale pump

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