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# Production Rates for Crews Using Hand Tools on Firelines

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Reported rates at which hand crews construct firelines can vary widely because of differences in fuels, fire and measurement conditions, and fuel resistance-to-control classification schemes. Real-time fire dispatching and fire simulation planning models, however, require accurate estimates of hand crew productivity. Errors in estimating rate of fireline production affect estimates of fire size in simulation models predicting fire suppression effectiveness. Productivity rates, therefore, are crucial for such models and the high variability makes choices difficult. Studies of crews using hand tools to build firelines were compared. Wide variations in construction rates were found. The results suggest the need for future productivity studies to standardize procedures and to develop resistance-to-control classifications that can be identified with field measurements. Approaches showing the most promise are those that measure probability distributions of productivity.

*Retrieval Terms*: hand crews, initial attack simulation, fireline, resistance-to-control, fuels

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Table 1—*Production rates of handcrews in building firelines, by fuel type, and crew experience*

| Region | Rate of line construction (RLC)[1] | Samples | Classes[2] | Class range | Samples in each class | Class mean | Observations in each sample[3] | Fireline type[4] | Crew experience[5] |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Low resistance-to-control fuels | | | | | |
| Northern (1) | 0.15 to 3.3 | 10 | 2 | 0.15 to 1.50 | 6 | 0.77 | Many | C | IE |
| | | | | 1.96 to 3.30 | 4 | 2.44 | N.D. | C | E |
| Rocky Mountain (2) | .62 to 2.70 | 7 | 2 | .63 to .72 | 2 | .66 | Many | C | IE |
| | | | | 1.00 to 2.70 | 5 | 1.63 | Many | CH | E |
| Southwestern (3) | 3.00 to 7.00 | 2 | 1 | 3.00 to 7.00 | 2 | 5.00 | N.D. | C/CH | IE |
| Intermountain (4) | 1.14 to 6.00 | 2 | 1 | 1.14 to 6.00 | 2 | 3.57 | N.D. | CH | IE |
| Pacific Southwest (5) | .40 to 4.97 | 3 | 2 | .40 | 1 | .40 | Many | C | E |
| | | | | 3.75 to 4.97 | 2 | 4.36 | N.D. | C | E/IE |
| Pacific Northwest (6) | 4.35 | 1 | 1 | 4.35 | 1 | 4.35 | N.D. | C | IE |
| Southern (8) | 3.01 | 1 | 1 | 3.01 | 1 | 3.01 | N.D. | CH | IE |
| Eastern (9) | 2.50 to 5.30 | 2 | 1 | 2.50 to 5.30 | 2 | 3.90 | Few/N.D. | CH | E/IE |
| Alaska (10) | 4.00 | 1 | 1 | 4.00 | 1 | 4.00 | N.D. | C | E |
| | | | | Medium resistance-to-control fuels | | | | | |
| 1 | 0.15 to 2.00 | 11 | 2 | 0.15 to 0.80 | 6 | 0.51 | Many | C | IE |
| | | | | 1.00 to 2.00 | 5 | 1.40 | N.D. | C | E |
| 2 | .20 to 2.00 | 5 | 2 | .20 to 0.35 | 4 | .28 | Many | CH | E |
| | | | | 2.00 | 1 | 2.00 | N.D. | C | E |
| 3 | 4.00 | 1 | 1 | 4.00 | 1 | 4.00 | N.D. | CH | IE |
| 4 | .20 to 3.00 | 2 | 1 | .20 to 3.00 | 2 | 1.60 | N.D. | CH | IE |
| 5 | .28 to 3.18 | 6 | 2 | .28 to 0.83 | 5 | .52 | Many | C | IE |
| | | | | 3.18 | 1 | 3.18 | N.D. | C | IE |
| 6 | .32 to 3.15 | 4 | 2 | .32 to 0.55 | 3 | .44 | Many | C | IE |
| | | | | 3.15 | 1 | 3.15 | N.D. | C | IE |
| 8 | 1.51 to 3.00 | 2 | 1 | 1.51 to 3.00 | 2 | 2.26 | N.D. | CH | IE |
| 9 | 2.10 to 2.70 | 2 | 1 | 2.10 to 2.70 | 2 | 2.40 | N.D./few | CH | IE |
| 10 | 1.30 | 1 | 1 | 1.30 | 1 | 1.30 | N.D. | C | IE |
| | | | | High resistance-to-control fuels | | | | | |
| 1 | 0.05 to 0.80 | 11 | 2 | 0.05 to .39 | 7 | 0.25 | Many | C | IE |
| | | | | .45 to .80 | 4 | .59 | N.D. | C | E |
| 2 | .15 to 2.70 | 9 | 2 | .15 to .30 | 4 | .23 | Many | CH | E |
| | | | | 1.00 to 2.70 | 5 | 1.92 | Many | CH | E |
| 3 | .20 to 1.40 | 2 | 2 | .20 | 1 | .20 | N.D. | C | IE |
| | | | | 1.40 | 1 | 1.40 | N.D. | CH | IE |
| 4 | .14 to 1.20 | 2 | 1 | .14 to 1.20 | 2 | .67 | N.D. | CH | IE |
| 5 | .12 to 1.25 | 7 | 2 | .12 to .23 | 3 | .18 | Many | C | E |
| | | | | .51 to 1.26 | 4 | .86 | N.D. | C | IE |
| 6 | .23 to 1.20 | 2 | 2 | .23 | 1 | .23 | Many | C | IE |
| | | | | 1.20 | 1 | 1.20 | Few | C | IE |
| 8 | .76 to 1.50 | 2 | 1 | .76 to 1.50 | 2 | 1.13 | N.D. | CH | IE |
| 9 | 1.30 to 1.40 | 2 | 1 | 1.30 to 1.40 | 2 | 1.35 | Few/N.D. | CH | IE |
| 10 | .70 | 1 | 1 | .70 | 1 | .70 | N.D. | C | IE |
| | | | | Extreme resistance-to-control fuels | | | | | |
| 1 | 0.02 to 0.25 | 9 | 2 | 0.02 to 0.19 | 6 | 0.10 | Many | C | IE |
| | | | | .20 to .25 | 3 | .23 | N.D. | C | E |
| 2 | .05 to 1.30 | 8 | 2 | .05 to .20 | 4 | .13 | Many | CH | E |
| | | | | .60 to 1.30 | 4 | .95 | Many | CH | E |
| 4 | .08 | 1 | 1 | .08 | 1 | .08 | N.D. | C | IE |
| 5 | .20 to .55 | 5 | 2 | .20 to .35 | 3 | .26 | Many | C | E |
| | | | | .52 to .55 | 2 | .54 | N.D. | C | IE |
| 6 | .25 to .46 | 2 | 1 | .25 to .46 | 2 | .36 | N.D./many | C | IE |
| 8 | .75 | 1 | 1 | .75 | 1 | .75 | N.D. | CH | IE |
| 9 | .68 to 1.00 | 2 | 1 | .68 to 1.00 | 2 | .84 | Few/N.D. | CH | IE |
| 10 | .40 | 1 | 1 | .40 | 1 | .40 | N.D. | C | IE |

[1]Rate of fireline construction (RLC) was measured in lineal chains of fireline per person per hour.

[2]The classes refer to the number of distinct line construction rate changes classified by different studies under the same overall resistance-to-control class.

[3]RLC study results were based on few-many observations, where few = 1-9; many = 10-100. Often, however, the observations in each sample were not designated (N.D.).

[4]Fireline was either constructed (C) or constructed and held (CH).

[5]IE = Inexperienced fireline crews; E = experienced crews that may include smokejumpers.

Increasing costs of fire suppression have intensified the need to reevaluate all fire management practices to ensure that they are economically effective. One suppression activity, that of surrounding and containing a fire by building a fireline, has been studied in terms of rate of construction.

Estimates of fireline construction rates are used for real-time fire dispatching and in fire simulation planning models. The accuracy required for construction rate estimates depends on the purposes for which they are used. But because of differences in fuels, fire and management conditions, and fuel resistance-to-control classes, construction rate accuracy is difficult to obtain. And, because errors in construction rate estimates greatly affect estimates of fire size for simulation models of fire suppression effectiveness, accurate construction rates are crucial.

Fireline construction rates, however, have been found to vary by as much as 500 percent (Hanson and Abell 1941; Matthews 1940; Pirsko 1966; Stevenson 1951; U.S. Dep. Agric., Forest Serv. 1957, 1961, 1962, 1963, 1965a, 1965b, 1966a, 1966b, 1972a, 1972b, 1973, 1974). Such variability confounds even basic assessments and comparisons of suppression resource capabilities (Murphy and Quintilio 1978, Ramberg 1974, Storey 1969). The problem is accentuated when alternative suppression strategies are intensively analyzed by mathematical models (Davis and Irwin 1976; McMasters 1963, 1966; Parks and Jewell 1962; Quintilio and Anderson 1976; Simard and others 1978; Swersey 1963). Consequently, management decisions and justifications for fire suppression budgets are severely hindered at a time of increasing concern that costs of some suppression efforts may outweigh resultant benefits. Before current information on fireline construction rates from different studies can be reliably integrated into any mathematical analysis, additional information is needed as to what factors affect the high variability of construction rates.

This paper reports a comparison analysis of data on construction rates of crews using hand tools on firelines, and addresses the need for accurate production rates with a simple model for sensitivity analysis.

# METHODS

## Data Collection

Our compilation of line production rate data relied on the bibliography of Storey (1969) *(table 1)* and a current literature survey for studies after 1969. Although some works may have been overlooked, it is unlikely that additional studies would reduce the uncertainties involved with use of existing rate-of-line construction (RLC) estimates.

## Fuel Resistance-to-control Classes

All production studies reviewed noted the general type of fuels in which firelines were constructed. Because certain fuels impede fireline construction more than others, fireline production rates vary among fuels. Grouping fuels into resistance-to-control classes (RTCC) has been the traditional means of classifying and comparing line construction rates. The RTCC broadly assesses the fuel size and structure so that the fireline construction job can be stratified by level of difficulty. Although the concept of resistance-to-control is the same in all Forest Service regions, standards for applying the classification system are needed.

A fuel's resistance-to-control rating—low, medium, high, or extreme—is determined by the rate at which fireline can be built in the fuel type. Specifically, RTCC is determined by dividing the relevant range of fireline production rates into four intervals and then classifying fuels by the interval into which they fall. Although this classification scheme is used by most Forest Service regions, it is inconsistently applied because of the lack of production rate range standardization between fireline production studies and throughout Forest Service regions. Much of the production range variability results from differences in fuels within each RTCC.

U.S. Department of Agriculture Forest Service Fireline Notebooks (U.S. Dep. Agric., Forest Serv. 1957, 1961, 1962, 1963, 1965a, 1965b, 1966a, 1966b, 1972a, 1972b, 1973, 1974) classify fuel type information by RTCC's for all Forest Service regions, except the Pacific Southwest and Pacific Northwest Regions. These two regions do not delineate RTCC's; they simply record fireline production information for each fuel type. Storey (1969) and Lindquist (1970) extrapolated on information from the Fireline Handbook by categorizing production rates given by fuel type into resistance-to-control classes.

To consistently interpret production rates for each RTCC, a description of fuel types within each RTCC must be known. Fuel type information rated by resistance-to-control class is listed in *table 3 (Appendix)* for all Forest Service regions, except the Pacific Northwest and Pacific Southwest. Productivity rates for specific fuel types in these Regions are summarized in *table 4 (Appendix)*.

An exception to the *ad hoc* determination of resistance-to-control is the procedure developed by Murphy and Quintilio

(1978). They quantitatively developed a fuel resistance-to-control classification by measuring the relative difficulty of clearing trees, clearing small trees and brush, building line through deadfall and slash, trenching, and building on slopes. Fuel can be given relative resistance-to-control rankings by measuring different associated stand variables.

### Data Standardization

Production information from all sources was compared. Standard analysis of variance techniques could not be applied to the data because of the relatively small information base and wide range of possible influential variables. Instead, a classification scheme was developed to isolate and reduce possible sources of variability. Conclusions were drawn on the basis of simplified comparisons of point estimates. The data were inadequate for any further forms of analysis.

The data were grouped according to Forest Service region and RTCC. This grouping eliminated much of the variability resulting from different RTCC fuel classification schemes among regions. When only one production rate was given, it was recorded in the medium RTCC, unless otherwise specified. If three fuel classes were delineated, the production information was tallied in the low, medium, and high RTCC's.

All production information was standardized into similar units of production and conditions of measurement. Most studies recorded fireline production rates in lineal chains of fireline constructed per hour per person. When production rates were not recorded in these units, the rates reported in the studies were converted back to a per person and per chain basis. If, for example, a production rate was recorded as 165 ft per hour per person, it was converted to 2.5 chains per hour per person. If a production rate was recorded as 5 chains per 10 hours per person, it was converted to 0.5 chains per hour per person. If a production rate was recorded as 3 chains per hour per 3-person crew, it was converted into 1 chain per hour per person. The conversions ignore the possibility that the work produced by many individuals together is different from the total work of each individual working separately. The rate in these situations is the average rate per person for an interacting crew.

Some studies recorded production for a long period of time (Lindquist 1970; U.S. Dep. Agric., Forest Serv. 1980) to account for diminishing productivity as the work shift progressed; that is, fatigue allowance. When fatigue factors were given, their influence was incorporated as the average production rate for the time period reported.

Some studies measured production as a forward rate of progress with a stated or assumed fireline width (Hanson and Abell 1941; Pirsko 1966; Steele 1961; U.S. Dep. Agric., Forest Serv. 1957, 1961, 1962, 1963, 1965a, 1965b, 1966a, 1966b, 1972a, 1972b, 1973, 1974). Other studies measured production in areal units of fireline constructed (Lindquist 1970). To make production rates comparable, author-specified conversions were used to convert fireline area measurements to lineal measurements. If no width was recorded in the study, the standard U.S. Department of Agriculture Forest Service fireline widths were used (Lindquist 1970).

The widths used to convert lineal to area measures were 2.5 ft for light fuels, 3.5 ft for medium brush, 5.0 ft for heavy brush, and 6.0 ft for heaviest brush. The four categories listed were assumed to conform to low, medium, high, and extreme resistance-to-control classes.

For each region, the production data within each RTCC was ordinally ranked and inspected for trends by type of fireline, worker characteristics, and conditions of measurement. The resulting production rates were grouped according to study characteristics (*table 1*). Characteristics common to most studies were experience of the crew, number of observations used to estimate production, and quality of fireline production.

Crew experience was normally denoted by smokechasers and smokejumpers, high proficiency crew, medium proficiency crew, low proficiency crew, general crew, pickup firefighters, and trained or untrained woodsworkers. Characterizations classed as inexperienced were pickup firefighters, untrained woodsworkers, general crew, and low proficiency crew. Characterizations classed as experienced were smokechasers, smokejumpers, high proficiency crew, medium proficiency crew, and trained woodsworkers. Forest Service silviculture or inventory crews are sometimes called upon to assist in initial attack operations. Such crews are often classified as general handcrews. Although these crews have been instructed in firefighting techniques, their on-fire experience is infrequent. Because the term "general crew" has many interpretations, it was included in the inexperienced category.

## RESULTS

### Rates of Fireline Construction

The RLC estimates included in this report are based on many observations (10 to 100), few observations (1 to 9), or a nondesignated number of observations. Low production rates frequently resulted from studies that used large sample sizes; high production rates resulted from studies that used small or undesignated sample sizes.

Production rates should logically be greater for experienced as opposed to inexperienced hand crews. No consistent tendencies were found, however, when production rate was compared to level of crew experience.

The production rate results were not an obvious function of quality of fireline production. Some production rates only described constructed fireline (Biddison 1980; Buck 1938; Matthews 1940; Stevenson 1951; U.S. Dep. Agric., Forest Serv. 1966b); others described fireline constructed and held (Hanson and Abell 1941; U.S. Dep. Agric., Forest Serv. 1964, 1965a). No differences in rates of fireline constructed as against fireline constructed and held were apparent. A better indicator of fireline quality might be the width of fireline;

Table 2—*Effects of errors in estimates of line construction rates on final fire size predictions for a 20-man crew and a fire size of 1 acre at time of arrival*[1]

| Estimation error | Rate of spread (chains per hour) | | | | | |
|---|---|---|---|---|---|---|
| | 4 | | 8 | | 12 | |
| | Final size | Fire size error | Final size | Fire size error | Final size | Fire size error |
| | *Acres* | *Percent* | *Acres* | *Percent* | *Acres* | *Percent* |
| 50 percent underestimate | 2.4 | 60 | 16.5 | 588 | [2] | [2] |
| Correct | 1.5 | — | 2.4 | — | 4.9 | — |
| 50 percent overestimate | 1.3 | -13 | 1.7 | -29 | 2.4 | -51 |

[1]Assumptions: two chains per person per hour is the correct line construction rate; the fire is represented by a 2:1 ellipse; suppression forces arrive simultaneously; the attack is a direct, rear attack with 10 people on each flank; percent fire size error = $\frac{\text{incorrect-correct}}{\text{(correct)}} \times 100$ percent.

[2]Fire cannot be controlled.

however, this information was usually unavailable in the production studies reviewed here so that the source of potential variability could not be tested.

Other variables may influence production rates. These include fireline grade, elevation, terrain, weather, hours workers spend on the job, worker's pulse, worker's perceived effort, smoke density, and others. Differences have been found in productivity for length of time spent on the fireline (Lindquist 1970). Variability of rates was measured so that probability distributions of RLC as a function of time could be derived. The effects of differences in fire intensity and rate-of-spread and crew fitness on fireline productivity were analyzed (Ramberg 1974). Although results were inconclusive, the analysis suggested that unmeasured variables such as skill, training, and supervision may have significant effects on productivity.

## Fire Size and Line Construction Rates

Estimates of fireline construction rates are used for real-time fire dispatching and in fire simulation planning models. The accuracy required for production rate estimates depends on the purpose for which they are used and the effects of errors on fire size estimation.

Better estimates than those currently available may not be needed for real-time fire dispatching. Actual initial attack and suppression efforts are directed by regional experts who use professional judgments. These experts integrate the variables that affect productivity, and make management decisions accordingly.

But in planning models, where experienced fire bosses are not available for making localized (situation-specific) decisions, errors in productivity assumptions may be more crucial. Depending on the fire conditions simulated, errors in production values have the potential for radically biasing the simulated results.

The ranges of reported fireline construction rates for each RTCC per region are wide (*table 1*). The range of reported productivities in low resistance-to-control fuels for the Forest Service's Northern Region (Region 1) is 0.15 to 3.3 chains per person per hour (*table 1*). The upper boundary of the range is 22 times larger than the lower boundary. The effects of errors in productivity on fire size estimates must be known to assess the significance of range size.

An initial attack simulation is sensitive to errors in line construction rate estimates (*table 2, figs. 1, 2*). The examples were derived from a model (Bratten 1978) that relates ratios of final fire area to area at time of attack to different ratios of line construction rate to rate-of-spread. The effects of a 50 percent over- or underestimate of line construction capability for a 20-man crew with a fire spreading at three different rates have been delineated (*table 2*). A 50 percent overestimate in productivity results in a 13 percent underestimate of fire size for fires with rates of spread of 4 chains per hour and a 51 percent underestimate for fires spreading at 12 chains per hour. An underestimate in productivity results in a larger percentage error in final size prediction than an overestimate. For the conditions outlined (*table 2*) for a rate-of-spread of 8 chains per hour, a correct size at containment of 2.4 acres (0.97 ha) would be predicted as 16.5 acres (6.68 ha) with a 50 percent underestimate, and 1.7 acres (0.69 ha) with a 50 percent overestimate. The effects of errors in productivity estimation are asymmetrical.

Fire size predictions are related to production rate estimates. *Figure 1* gives the predicted ratio of final area to initial fire area as a function of the ratio of rate of line construction to rate-of-spread (ROS). Each curve is for a different percentage error in the ratio. The graph is interpreted as follows:

Point A: For a true RLC/ROS of 2.4, the ratio of final fire area to initial area is 2.5. This means a 1-acre (0.40-ha) fire initially attacked with a force size such that RLC/ROS = 2.4 would be 2.5 acres (1 ha) at containment.

Points B and C: For a true ratio of RLC/ROS of 2.4, a 50 percent underestimate of RLC results in a predicted ratio of final area to initial area of 22.7. A 50 percent overestimate of RLC results in a predicted area ratio of 1.8.

The shapes and positions of the curves further indicate the asymmetry of area error differences between equal percentage

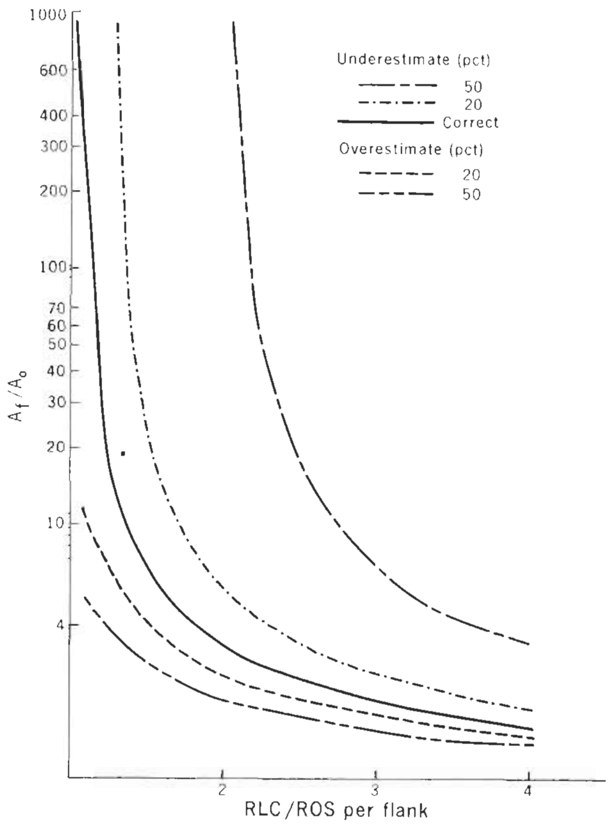


**Figure 1**—Sensitivity of final fire size to errors in the RLC/ROS ratio. Assumptions are (a) 2:1 fire ellipse, (b) simultaneous force arrival, and (c) direct, rear attack.

RLC overestimates and RLC underestimates. A 50 percent RLC underestimate results in more dramatic errors in the prediction of final fire size than does a 50 percent RLC overestimate. The difference is obvious for specific cases (*table 2*). Also, the error effect is large for RLC/ROS ratios near 1 and decreases as the ratio increases. A 50 percent RLC error is much smaller than the error magnitudes possible in the range of fireline construction rates historically reported (*table 1*).

Significant planning errors can be made by blind reliance on published rates. Different assessments of fire crew effectiveness are possible, depending on the rates chosen. A 20-person crew producing line at the rate of 1 chain per person per hour, for example, could not control a fire by direct rear attack if the fire was spreading at 10 chains per hour. If the productivity were 3 chains per person per hour, the same fire would only double in size between the time of initial attack and containment (*fig. 2*). Again, 1 to 3 chains per person per hour production rates are well within the range reported in the literature.

The examples cited show that reliance on the published rates of line construction for either planning or modeling purposes can bring about unexpected results. In some situations, the final fire size is fairly insensitive to sizable errors in production rate, but in others, fire size sensitivity is high. The sensitivity is also asymmetrical with respect to overestimates and underestimates. An underestimated production rate results in a larger percentage error in final fire size prediction than an overestimated rate. Size prediction sensitivity also decreases when RLC/ROS ratios are large.

## SUMMARY AND CONCLUSIONS

Marked inconsistencies result from different fuels, fire and measurement conditions, and fuel resistance-to-control classification schemes. Substantial variability in production rates results from other variables that could not be identified by comparing results of previous studies. For example, crew supervision and team spirit may be major, yet difficult-to-measure, determinants. Recent and future production studies may attempt more detailed information coverage, but even with adequate accurate knowledge, some resulting variability in production rate may be a function of the type of production being measured.

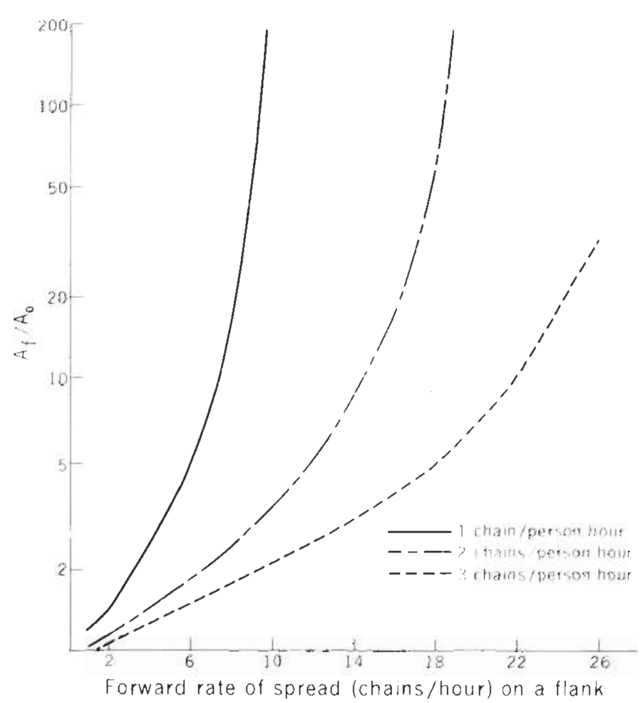


**Figure 2**—Effectiveness of a 20-man crew for different line construction rate assumptions. Assumptions are (a) 2:1 fire ellipse, (b) simultaneous force arrival, and (c) direct, rear attack.

Such inherent variability suggests that it is risky to rely on point estimates of production rates as a measure of estimating effectiveness of fire management activity. Production rate ranges, therefore, are provided for specific resistance-to-control classes. These ranges may be used in a variety of ways. They may be useful aids for helping fire managers assess the inherent risk in determining an adequate suppression force size. In certain instances, a fire manager may choose appropriate production rates by consistently selecting rates from the high or low ends of the given range, depending on fire site conditions and the manager's attitude toward risk.

The simplified sensitivity analysis shows the asymmetry of effects on fire size prediction resulting from errors in estimating production rates. A simulation model's percentage error of prediction is larger if crew production rates used are less than the real rate and smaller if production rates used are greater than the real rate. The effects of errors in productivity on real-time dispatching are equally severe. An assumption of high productivity results in too few forces being dispatched. Too few forces can have a dramatic impact on the final size of the fire. As the ratio of line construction rate to rate-of-spread increases, errors in production rates decline in importance for predicting final fire sizes.

Historically, studies on line production rates for hand crews show the difficulty of the research problem and the variability of the results. Point estimates and associated variances are needed for modern fire suppression modeling and planning decisions. Future studies need to assess probabilities of obtaining line production rates under different conditions. Any future studies of line production rate should be designed to measure variability so that probability distributions of rate of line construction can be derived. Probability distributions allow risk to be accounted for explicitly in fire analysis models. A methodology for obtaining the probability distributions required has been provided (Lindquist 1970). Productivity rates also need to be measured under actual fire rather than simulated conditions. Productivity under simulated conditions tends to be higher than productivity measured under actual conditions.

Another area of study needing attention is the development of resistance-to-control classes that can be determined by field analysis. Pioneering work on quantitatively determining resistance-to-control has already been done (Murphy and Quintilio 1978). Standardization of resistance-to-control measures and productivity probability distributions are required for future applications of line production rate measures.

## APPENDIX

Table 3—*Fuels rated by resistance-to-control class, by Region within Forest Service*

| Region | Low | Medium | High | Extreme |
|---|---|---|---|---|
| Northern (Region 1)[1] | Generally open with primarily grass cover. | Timber stands with minor amounts of dead branchwood, may contain some brush. | Timber stands with medium amounts of dead branchwood, tree stems, or rock. May contain heavy underbrush. | Timber stands with extensive dead tree stems, branchwood, brush, and rock. |
| Rocky Mountain (Region 2)[2] | Open, park-like stands of:<br>1. Ponderosa pine<br>2. Spruce<br>3. Douglas-fir<br>4. Hardwoods<br>Pinyon juniper<br>Linden-bristlecone<br>Patchy oak<br>Grass<br>Patchy subalpine spruce and fir<br>Patchy sagebrush | Light reproduction<br>Uneven-aged stands<br>Slash | Slash<br>Heavy reproduction<br>Mature stands<br>Mixed aspen<br>Dense oak<br>Dense sagebrush | Slash (heavy) |
| Southwestern (Region 3)[3] | Woodland<br>Grassland | Ponderosa pine<br>Brush<br>Spruce fir<br>Aspen | Slash<br>Chaparral | |

[1]Source: Region 1 Supplement 1 to the Fireline Handbook (U.S. Dep. Agric., Forest Serv. 1974).

[2]The fuels listed are summarized from the fuels description in the Region 2 Supplement 1 to the Fireline Handbook (U.S. Dep. Agric., Forest Serv. 1972a). Twenty-one fuel classes with a total of 60 subclasses are listed in the supplement.

[3]Source: Region 3 Supplement to the Fire Fighting Overhead Notebook (U.S. Dep. Agric., Forest Serv. 1965a).

Table 3—*Fuels rated by resistance-to-control class, by Region within Forest Service* (continued)

| Region | Low | Medium | High | Extreme |
|---|---|---|---|---|
| Intermountain (Region 4)[4] | Lodgepole pine<br>1. Light windfall, clear trees<br>2. Sapling stand | Lodgepole pine<br>1. Moderate windfalls with grass carpet<br>2. Open, pole stand<br>3. Scattered other species, some grass | Lodgepole pine<br>1. Mature with windthrow and bug kill | |
| | Subalpine<br>1. Protected NE slopes<br>2. Fully exposed ridgetops | Spruce<br>1. Snags, scattered brush, trees | Subalpine<br>1. Dense<br>2. Limbs thick to the ground | |
| | Spruce<br>1. Clean trees, no snags or windfall | Ponderosa pine<br>1. Dense, intermixed reproduction | Slash<br>Old growth, Douglas-fir and white fir | |
| | Open, grassy stands of ponderosa pine, Douglas-fir, and subalpine fir<br>Ceanothus brush<br>Sagebrush<br>Cheatgrass | Fir<br>Mixed age, older trees<br>Mixed brush<br>Ceanothus brush | | |
| Northeastern (Region 7)[5] | Grass, ferns, and weeds<br>Unburnable | Northern and Appalachian hardwood, 3 inches d.b.h. | Northern conifers, 4 inches d.b.h.[7] | Conifer slash |
| | | Southern pine 6 inches d.b.h.[6] | Northern conifers, cutover duff and no slash | |
| | | Southern pine reproduction | Hardwood and hemlock<br>Hardwood, cutover, no duff or slash<br>Hardwood reproduction<br>Hardwood and Southern pine slash[7]<br>Laurel and rhododendron[7] | |
| Southern (Region 8)[8] | | *Plains area except Florida* | | |
| | Pine (except sand pine)<br>Grass | Sand pine<br>Bottomland hardwood | Pine and hardwood<br>Scrub oak | Organic soil<br>Pocosin |
| | | *Florida* | | |
| | Grass | Longleaf pine–scrub oak<br>Sand pine<br>Pine–hardwood | Loblolly pine–slash pine<br>Palmetto flatwoods | Pond pine–titi<br>Grass–tupelo |
| | | *Mountain area* | | |
| | | Upland hardwood<br>Conifers and hardwoods<br>Pine (all except white pine)<br>Pine–hardwood (all except white pine) | Brush (rhododendron, laurel)<br>Scrub hardwood | |
| | | *Intermountain area* | | |
| | Grass | Pine (all)<br>Pine–hardwood | Scrub hardwoods<br>Pine–youpon | |

[4]The fuels listed are summarized from the fuels description in Region 4 Supplement 1 to the Fireline Handbook (U.S. Dep. Agric., Forest Serv. 1972b). The Handbook lists 17 classes with a total of 48 subclasses.

[5]Sources: Banks and Frayer (1966) and Jemison and Keetch (1942). Region 7 no longer exists. Parts of it have been incorporated into Regions 8 and 9.

[6]Classified as low by Jemison and Keetch (1942).

[7]Classified as medium by Jemison and Keetch (1942).

[8]Source: Region 8 Fireline Notebook (U.S. Dep. Agric., Forest Serv. n.d.).

Table 3—*Fuels rated by resistance-to-control class, by Region within Forest Service* (continued)

| Region | Low | Medium | High | Extreme |
|---|---|---|---|---|
| Eastern (Region 9)[9] | Short grass, weeds, and marshgrass | Wet brush, muskeg | Swamp conifers | Slash |
| | | Lowland hardwoods | Slash | |
| | | Upland hardwoods | | |
| | | Oak | 1. Swamp conifers | 1. Hardwoods and swamp conifers |
| | | Aspen | 2. White cedar | 2. Upland conifers, oak, and white cedar |
| | | Scrub oak | 3. Oak | |
| | | Upland conifers | 4. Hardwoods | |
| | | Understory upland conifers | 5. Upland conifer and white cedar | |
| | | | 6. Aspen | |
| | | Understory upland conifers | | |
| | | Slash | Understory-upland conifers | |
| | | 1. Upland conifers | | |
| | | 2. Oak and hardwoods | Oak | |
| | | 3. Aspen | Upland conifer plantations | |
| | | Drybrush and muskeg | | |
| | | Broom sedge | | |

[9]Source: Region 9 Fire Overhead Notebook (U.S. Dep. Agric., Forest Serv. 1957). Duplicates in table result from size differences within a fuel type

Table 4—*Rates of construction of fireline for Forest Service Pacific Southwest and Pacific Northwest Regions, by fuel type and source of estimates (chains per hour per person)*[1]

| Fuel type[2,3] | Fireline handbook: Basic rate | Fireline handbook: After 8 h | Scowcroft and others (1966) | Stevenson (1951) | Buck (1938) | U.S. Dep. Agric., Forest Serv. (1938) | Lindquist (1970)[4]: 1 h | Lindquist (1970)[4]: 8 h |
|---|---|---|---|---|---|---|---|---|
| 1 | 4.0 | 2.1 | | | | 2.9 | 1.2 | 0.6 |
| 2 | 3.6 | 1.8 | 1.0 | | | 1.8 | | |
| 3 | 4.7 | 2.5 | | | | 2.4 | .8 | |
| 4 | 3.7 | 2.1 | | | | 2.2 | | |
| 5 | 2.7 | 1.4 | | | | 1.5 | .8 | .5 |
| 6 | 1.4 | .7 | .5 | | 1.1 | 1.5 | .8 | .5 |
| 7 | 2.7 | 1.4 | .8 | | | 1.4 | .8 | .5 |
| 8 | 1.4 | .7 | .7 | | | 1.1 | .8 | .5 |
| 9 | 1.2 | .6 | | | | 1.0 | .8 | .5 |
| 10 | 1.1 | .6 | | | 1.1 | 1.0 | | |
| 11 | .7 | .4 | .7 | 0.3 | | .6 | | |
| 12 | .7 | .4 | | .5 | | .5 | | |
| 13 | .4 | .2 | .3 | .22 | | | .5 | .2 |
| 14 | .3 | .2 | | | | .7 | .3 | .2 |
| 15 | .5 | .3 | | | | | | |
| 16 | 1.2 | .6 | | | | | | |
| 17 | 6.2 | 3.1 | | | | | | |
| 18 | .7 | .4 | | | | | | |

[1]Regions 5 and 6 use the same fireline construction rates for each numbered fuel type. Region 5 information is from Region 5 Fireline Handbook (U.S. Dep. Agric., Forest Serv. 1973); Region 6 information is from Region 6 Fireline Notebook (U.S. Dep. Agric., Forest Serv. 1965b).

[2]Fuel types 4, 7, 8, 11, 12, and 17 are excluded from the Region 6 source; fuel type 18 is excluded from the Region 5 source.

[3]*Fuel descriptions:*

1. Grass
2. Grass and scattered sage
3. Mature timber—little chopping
4. Bear clover
5. Open manzanita—patchy brush
6. Timber—medium reproduction and brush
7. Light-to-medium chamise (southern California)
8. Brush mixtures with sage
9. Medium brush—in cutover or timber burn
10. Mixed Douglas-fir—white fir, with brush and reproduction
11. Medium brush and oak (southern California)
12. Heavy pure manzanita, chamise, or buckbrush
13. Heavy mixed brush
14. Heaviest mixed brush
15. Second growth—medium poles
16. Slash in cutovers
17. Woodland—little chopping
18. Mature timber (westside forests)

[4]The fuel groupings into regional fuel classes are the authors', based on descriptions given in the publications.

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