NWCG FIRELINE HANDBOOK
APPENDIX B
FIRE BEHAVIOR

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PURPOSE

The purpose of this appendix is to provide some basic fire behavior information that will enable a person with a moderate level of fire behavior training (Introduction to Wildland Fire Behavior Calculations, S-390) to predict and calculate some basic elements of fire behavior and fire size.

Information in this appendix will provide the qualified user with the means to:

- Predict rate of spread (ROS) and flame length (FL) for each Fire Behavior Fuel Model based on the 1-hour timelag dead fuel moisture, live fuel moisture for Fuel Models 2, 4, 5, 7 and 10, midflame windspeed and percent slope.
- Estimate the area and perimeter of a fire, given inputs of spread distance (rate of spread x time) and midflame windspeed.
- Predict maximum spotting distance and probability of ignition.
- Provide worksheets for fire behavior prediction.

The Fire Behavior Worksheet is on page B-5. Other worksheets that help track fire behavior input and output date (Fine Dead Fuel Moisture/Probability of Ignition, Wind Adjustment, Slope, Map-Spread, Size, Spotting, and Map-Spot) are provided on pages B-6 through B-9. Pages B-10 through B-37 go over the six required input items on the Fire Behavior Worksheet and B-38 through B-55 cover the output items.

It is imperative that the user of information contained in this appendix know the assumptions, limitations, and appropriate uses of fire behavior prediction models and is able to recognize how environmental factors and processes affect fire behavior predictions and safety.

FIRE BEHAVIOR WORKSHEET

NAME OF FIRE __________FIRE PRED SPEC____________
DATE___________________ TIME____________________

PROJ PERIOD DATE______PROJ TIME FROM _____TO____

INPUT

0	PP	PROJECTION POINT	___ ___ ___
1	MODEL#	FUEL MODEL NUMB (1-13)	___ ___ ___
2	1H-FDFM	FINE DEAD FUEL MOIST, %	___ ___ ___
3	LFM	LIVE FUEL MOISTURE, %	___ ___ ___
4	MFWS	MIDFLAME WINDSPD, mi/h	___ ___ ___
5	SLP	SLOPE, %	___ ___ ___
6	EWS	EFFECTIVE WNDSPD, mi/h	___ ___ ___

OUTPUT

1	ROS	RATE OF SPREAD, ch/h	___ ___ ___
2	HA	HEAT PER UNIT AREA, Btu/sq ft	___ ___ ___
3	FLI	FIRELINE INTENSITY, Btu/ft/s	___ ___ ___
4	FL	FLAME LENGTH, ft	___ ___ ___
5	SD	SPREAD DISTANCE, ch MAP SPREAD DIST, in	___ ___ ___
6	PER	PERIMETER, ch	___ ___ ___
7	AC	AREA, ac	___ ___ ___
8	SPOT	MAX SPOTTING DIST, mi MAP DIST SPOT, in	___ ___ ___ ___ ___ ___
9	PIG	PROB OF IGNITION, %	___ ___ ___

FINE DEAD FUEL MOISTURE/PROBABILITY OF IGNITION WORKSHEET

INPUT

0	PP	PROJECTION POINT	____	____	____
1	D	DAY TIME CALCULATION	D	D	D
2	DB	DRY BULB TEMP. °F	____	____	____
3	WB	WET BULB TEMP. °F	____	____	____
4	DP	DEW POINT, °F	____	____	____
5	RH	RELATIVE HUMIDITY, %	____	____	____
6	RFM	REFERENCE FUEL MOIST, % (TABLE 2)	____	____	____
7	MO	MONTH	____	____	____
8	SH	UNSHADED (U) SHADED (S)	U/S	U/S	U/S
9	T	TIME	____	____	____
10	CH	ELEVATION CHANGE	B/L/A	B/L/A	B/L/A

B = 1000' to 2000' below site
L = ±1000' of site location
A = 1000' to 2000' above site

11	ASP	ASPECT, (N, E, S, W)	____	____	____
12	SLP	SLOPE %	____	____	____
13	FMC	FUEL MOIST CORRECT, % (TABLE 3, 4, OR 5)	____	____	____

OUTPUT

1	1H-FDFM	FINE DEAD FUEL MOIST, % (line 6 + line 13)	____	____	____
2	PIG	PROB OF IGNITION, % (TABLE 12)	____	____	____

WIND ADJUSTMENT WORKSHEET

INPUT

0	PP	PROJECTION POINT	____	____	____
1	20' W	20-FT WINDSPEED, mi/h	____	____	____
2	MODEL #	FUEL MODEL # (1-13)	____	____	____
3	SHLTR	WIND SHELTERING	____	____	____

1=Unsheltered
2=Partially Sheltered
3=Fully Sheltered, Open
4=Fully Sheltered, Closed

4	WAF	WIND ADJUST FACTOR (TABLE 7)	____	____	____

OUTPUT

1	MFWS	MIDFLAME WNDSPD, mi/h (line 1 x line 4)	____	____	____

SLOPE WORKSHEET

INPUT

0	PP	PROJECTION POINT	____	____	____
1	CON INT	CONTOUR INTERVAL	____	____	____
2	SLC	MAP SCALE	____	____	____
3	CF	CONVERSION FACTOR, ft/in	____	____	____
4	# INTVLS	# CONTOUR INTERVALS	____	____	____
5	RISE	RISE IN ELEVATION	____	____	____
6	MD	MAP DISTANCE, in (Between Points)	____	____	____
7	HZGD	HORIZ GROUND DIST, ft	____	____	____

OUTPUT

1	SLP %	SLOPE, %	____	____	____

COMPLETING THE FIRE BEHAVIOR WORKSHEET

INPUT 0: Projection Point (PP)

Assign a number or letter to designate the projection point location and enter as Input 0 on the Fire Behavior Worksheet on page B-5.

INPUT 1: Fuel Model (Model #)

- Using the guidelines below, proceed through the fuel model key and descriptions which follow and select a fuel model and enter as Input 1 on the Fire Behavior Worksheet on page B-5.
- Determine the primary carrier of fire.
- Determine which stratum of the surface fuels is most likely to carry the spreading fire (grass, needle litter, leaves, logging slash, etc.).
- Determine the appropriate fuel group/general vegetation type; i.e., Grass (Models 1-3), Shrub (Models 4-7), Timber Litter (Models 8-10), or Logging Slash (Models 11-13).
- Using the fuel model key, determine the appropriate fuel model.
- Go to the fuel model description and determine if it fits.
- If yes, use it and enter into Input 1 on the Fire Behavior Worksheet.
- If no, find another that more closely fits your situation.
- The fuel models used here are those used by Albini (1976)[1] to develop the nomograms published in his paper Estimating Wildfire Behavior and Effects. There are 13 models which are called the Fire Behavior Fuel Models.

[1] Albini Frank A.; Estimating Wildfire Behavior and Effects. Gen. Tech. Report INT-30; 1976.

They are tuned to the fine fuels that carry the fire and thus describe the conditions at the head of the fire or the flaming front. These models are designed to give predictions for fire spread at a steady rate. It is important to recognize that rate of spread (ROS) and flame length (FL) predictions are estimates and the actual ROS and FL may vary considerably from the predicted.

- Assessment of fire behavior is simpler if a single fuel model is used to describe the fuels in the area. In fact, as experience is gained by observation of fires and estimating their behavior, it is possible to pick the fuel model not only by its description of physical vegetation, but also by its known fire behavior characteristics.

  Examples: The fire may be in timbered area, but the timber is relatively open and dead grass, not needle litter, is the stratum carrying the fire. In this case, Fuel Model 2, which is not listed as a timber model, should be considered, or

  In the same area if the grass is sparse and there is no wind or slope, the needle litter would be the stratum carrying the fire and Fuel Model 9 would be the better choice.

- Determine the general depth and compactness of the fuel. This information will be needed when using the fuel model key. There are very important considerations when matching fuels, particularly in the grass and timber types.
- Determine which fuel models are present and what their influence on fire behavior is expected to be.

  Example: Green fuel may be present, but will it play a significant role in fire behavior? Large fuels may be present, but are they sound, or decaying and breaking up? Do they have limbs and twigs attached or are they bare cylinders? Look for the fine fuels and choose a model that represents their depth, compactness, and to some extent, the amount of live fuel and its contribution to fire. Do not be restricted by the model name or the original intended application.

FIRE BEHAVIOR FUEL MODEL KEY[1]

I. **PRIMARY CARRIER OF THE FIRE IS GRASS.** Expected rate of spread is moderate to high, with low to moderate fireline intensity (flame length).

A. Grass is fine structured, generally below knee level, and cured or primarily dead. Grass is essentially continuous. SEE THE DESCRIPTION OF MODEL 1.

B. Grass is coarse structured, above knee level (averaging about 3 ft.) and is difficult to walk through. SEE THE DESCRIPTION OF MODEL 3.

C. Grass is usually under an open timber or brush overstory. Litter from the overstory is involved, but grass carries the fire. Expected spread rate is slower than Fuel Model 1 and intensity is less than Fuel Model 3. SEE THE DESCRIPTION OF MODEL 2.

[1] Richard C. Rothermel; How to Predict the Spread and Intensity of Forest and Range Fires. Gen. Tech Report INT-143; June 1983 (NFES 1574).

FIRE BEHAVIOR FUEL MODEL DESCRIPTIONS[2]

- Grass Group

Fuel Model 1 (1 foot deep) Fire spread is governed by the fine herbaceous fuels that have cured or are nearly cured. Fires are surface fires that move rapidly through cured grass and associated material. Very little shrub or timber is present, generally less than one-third of the area.

Grasslands and savanna are represented along with stubble, grass-tundra, and grass-shrub combinations that meet the above area constraint. Annual and perennial grasses are included in this fuel model.

Fuel Model 2 (1 foot deep) Fire spread is primarily through the fine herbaceous fuels, either curing or dead. These are surface fires where the herbaceous material, besides litter and dead-down stemwood from the open shrub or timer overstory, contribute to the fire intensity. Open shrub lands and pine stands or scrub oak stands that cover 1/3 to 2/3 of the area may generally fit this model but may include clumps of fuels that generate higher intensities and may produce firebrands. Some pinyon-juniper may be in this model.

Fuel Model 3 (2.5 feet deep) Fires in this fuel are the most intense of the grass group and display high rates of spread under the influence of wind. The fire may be driven into the upper heights of the grass stand by the wind and cross over standing water. Stands are tall, averaging about 3 feet, but considerable variation may occur. Approximately one-third or more of the stand is considered dead or cured and maintains the fire.

[2] Anderson, Hal E.; Aids to Determining Fuel Models for Estimating Fire Behavior. Gen. Tech Report INT-122, 1982.

INPUT 2: Fine Dead Fuel Moisture (1-H FDFM), %

Fine Dead Fuel Moisture Content is an important input to fire behavior predictions. Fuel moisture measurements are difficult to make in the field; however, estimates can be made from measured or predicted values of dry bulb temperature and relative humidity.

Due to solar radiation differences that exist between aspect, time of year, shading, and the adiabatic difference between position on the slope, it is necessary to calculate an estimate of fuel moisture. This is necessary as the National Fire Danger Rating System (NFDRS) tables used here were developed for "worst case" conditions (summer, 1400, SW aspect, open conditions). These predictions are for fine, dead forest fuels. Heavier fuels can be estimated by other means as needed.

Temperature and humidity are predicted for a specific site (projection point) in relation to a site (site location) where dry bulb temperatures and relative humidity are measured. Since temperature and relative humidity change with elevation, it is necessary to estimate these changes between the projection point and the site location. There are tables to correct for elevation changes of 0 to 2000 feet above or below the site location, but a new site location is needed if the elevation difference between the site location and the projection point exceeds 2000 feet.

Time corrections **cannot** be made. Temperature and relative humidity must be obtained for the time in question.

The tables may be used to adjust the moisture of fuels in valley bottoms from conditions measured on the slopes above, but do not use weather data taken beneath a valley inversion and attempt to interpolate fuel moistures at drier sites upslope. The corrections are too large and uncertain, and you may get meaningless results.

To use the Fine Dead Fuel Moisture/Probability of Ignition Worksheet on page B-6, complete the following input/output items. **Enter the fine dead fuel moisture as Output 1 on the Fine Dead Fuel Moisture/Probability of Ignition Worksheet and as Input 2 on the Fire Behavior Worksheet on page B-5.**

INPUT

0 (Projection Point)—Record the number of the projection point for which a fire behavior prediction is to be made.

1 (Day Time Calculation)—Only day time calculations will be considered.

2 (Dry Bulb Temperature)—Dry bulb temperature is determined for the time period in question, either by measurement or forecast. The site location may or may not be at the projection point. Record temperature in degrees Fahrenheit.

3 (Wet Bulb Temperature)—Wet bulb temperature is determined for the time period in question, either by measurement or forecast. The site location may or may not be at the projection point. Record temperature in degrees Fahrenheit.

4 (Dew Point)—Record dew point for the time period in question.

5 (Relative Humidity)—Record relative humidity for the time period in question.

6 (Reference Fuel Moisture)—Go to Table 2 and determine the reference fuel moisture percent from the intersection of temperature and relative humidity (Inputs 2 and 5). Record as a percent.

7 (Month)—Record the appropriate month.

8 (Unshaded or Shaded)—Circle "U" if fine dead fuels ahead of the projection point are unshaded (<50% shading) from solar radiation due to cloud cover and/or canopy cover. Circle "S" if fine dead fuels ahead of the projection point are shaded (>50% shading) from solar radiation due to cloud and/or canopy cover.

9 (Time)—Record the expected time when the projection point will be used to estimate fire behavior. The temperature/RH forecast or measurement must be the same time period as the projection time period.

10 (Elevation Change)—Record the elevation difference between the location of the projection point and the temperature/RH site location and circle:

"B" if the projection point is 1000 to 2000 feet below the site location.

"L" if the projection point is 0 to 1000 feet above or below the site location.

"A" if the projection point is 1000 to 2000 feet above the site location.

If the projection point is more than 2000 feet above or below the site location, get a new forecast or reading.

11 (Aspect)—Record the aspect of the projection point location (north, south, east, or west).

12 (Slope)—Record the slope in percent (%) at the project point. (See pages B-35 and B-36 for determining percent slope.)

13 (Fuel Moisture Correction)—From Input Values 7 through 12 and the appropriate Daytime Correction Tables (Tables 3, 4, or 5) determine fuel moisture correction. Record in percent.

OUTPUT

1 (Fine Dead Fuel Moisture)—Determine the fine dead fuel moisture by adding Input Item 6 and Input Item 13. Record as a percent.

TABLE 2: Reference Fuel Moisture, Day (0800-1959)

Dry Bulb Temp (°F)	Relative Humidity (Percent) 0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–99	100
10-29	1	2	2	3	4	5	5	6	7	8	8	8	9	9	10	11	12	12	13	13	14
30-49	1	2	2	3	4	5	5	6	7	7	7	8	9	9	10	10	11	12	13	13	13
50-69	1	2	2	3	4	5	5	6	6	7	7	8	8	9	9	10	11	12	12	12	13
70-89	1	1	2	2	3	4	5	5	6	7	7	8	8	8	9	10	10	11	12	12	13
90-109	1	1	2	2	3	4	4	5	6	7	7	8	8	8	9	10	10	11	12	12	13
109+	1	1	2	2	3	4	4	5	6	7	7	8	8	8	9	10	10	11	12	12	12

GO TO TABLE 3, 4, OR 5 FOR FUEL MOISTURE CONTENT CORRECTIONS.

NOTE: When using Tables 3, 4, and 5:
B = 1000-2000 feet below the site location.
L = 0-1000 feet above or below the site location.
A = 1000-2000 feet above the site location.

TABLE 3: Dead Fuel Moisture Content Corrections, Day (0800-1959)
May, June, July

UNSHADED – LESS THAN 50% SHADING OF SURFACE FUELS																			
Aspect	%Slope	0800>			1000>			1200>			1400>			1600>			1800>		
		B	L	A	B	L	A	B	L	A	B	L	A	B	L	A	B	L	A
N	0-30	2	3	4	1	1	1	0	0	1	0	0	1	1	1	1	2	3	4
	31+	3	4	4	1	2	2	1	1	2	1	1	2	1	2	2	3	4	4
E	0-30	2	2	3	1	1	1	0	0	1	0	0	1	1	1	2	3	4	4
	31+	1	2	2	0	0	1	0	0	1	1	1	2	2	3	4	4	5	6
S	0-30	2	3	3	1	1	1	0	0	1	0	0	1	1	1	1	2	3	3
	31+	2	3	3	1	1	2	0	1	1	0	1	1	1	1	2	2	3	3
W	0-30	2	3	4	1	1	2	0	0	1	0	0	1	0	1	1	2	3	3
	31+	4	5	6	2	3	4	1	1	2	0	0	1	0	0	1	1	2	2
SHADED – 50% OR MORE SHADING OF SURFACE FUELS																			
N	all	4	5	5	3	4	5	3	3	4	3	3	4	3	4	5	4	5	5
E	all	4	4	5	3	4	5	3	3	4	3	4	4	3	4	5	4	5	6
S	all	4	4	5	3	4	5	3	3	4	3	3	4	3	4	5	4	5	5
W	all	4	5	6	3	4	5	3	3	4	3	3	4	3	4	5	4	4	5

INPUT 3: Live Fuel Moisture (LFM), %

Live fuel moisture (foliage moisture) is required for Fire Behavior Models 2, 4, 5, 7 and 10. If data are unavailable for estimating live fuel moisture, the following rough estimates (Table 6) can be used. **Enter the live fuel moisture for Fire Models 2, 4, 5, 7 and 10 as Input 3 on the Fire behavior Worksheet on page B-5.**

TABLE 6: Live Fuel (Foliage) Moisture Content (Percent)

Moisture Content (%)	Stage of Vegetative Development
300	Fresh foliage, annuals developing early in the growing cycle.
200	Maturing foliage, still developing, with full turgor.
100	Mature foliage, new growth complete and comparable to older perennial foliage.
50	Entering dormancy, coloration starting, some leaves may have dropped from stem.
30	Completely cured, treat as dead fuel.

INPUT 4: Midflame Windspeed (MFWS), mi/h

Midflame wind is the wind which acts directly on the flaming fire front at the level of one half the flame height. Fire generated convective winds must be ignored.

You may take wind readings directly with a handheld anemometer or other measuring device; however, the readings must be taken far enough upwind of the fire to ensure that the wind is not influenced by convective indrafts.

If you choose to use a weather forecast to estimate windspeeds, you must determine whether the forecast is for 20-foot windspeeds or midflame windspeeds.

When midflame winds are forecast, enter them directly in Input 4 of the Fire Behavior Worksheet.

If the 20-foot winds are forecast (which they usually are), the midflame windspeed must be calculated. Use the Wind Adjustment Worksheet on page B-7 and complete the following Input and Output Values.

Enter midflame windspeed as Output 1 on the Wind Adjustment Worksheet and as Input 4 on the Fire Behavior Worksheet on page B-5.

INPUT

0 (Projection Pint)—Record the number of the projection point for which a fire behavior prediction is to be made.

1 (20-foot Windspeed)—Enter the 20-foot windspeed provided in the Special Weather Forecast.

2 (Fuel Model Number)—Enter one of the 13 FBPS fuel models.

3 (Wind Sheltering)—Using Diagram 1 on page B-32, determine whether fuels are: 1) unsheltered, 2) partially sheltered, 3) fully sheltered (open) or 4) fully sheltered (closed).

4 (Wind Adjustment Factor)—Using Table 7 on page B-33, select the appropriate adjustment factor for the specific fuel and sheltering condition.

OUTPUT

1 (Midflame Windspeed)—Multiply Input 1 x Input 4 on the Wind Adjustment Worksheet for the midflame windspeed.

Remember, for basic point source predictions the wind should be blowing within ± 30 degrees of upslope.

DIAGRAM 1: 20-Foot Windspeed Adjusted to Midflame Windspeed Based on Overstory

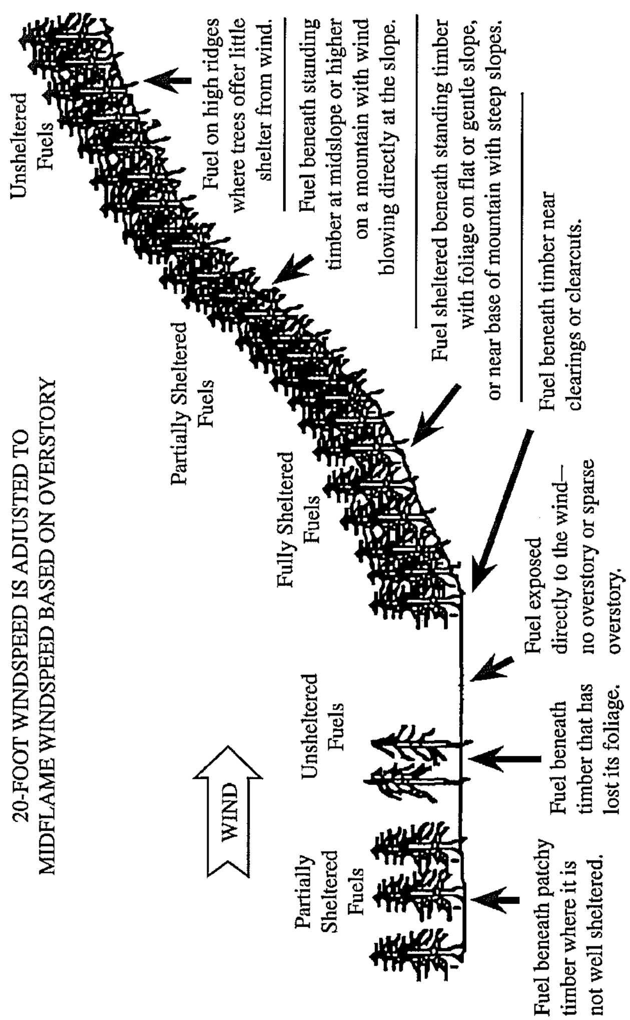

TABLE 7: Wind Adjustment Table

Fuel Exposure	Fuel Model	Adjustment Factor
UNSHELTERED FUELS: Fuel exposed directly to the wind. No or sparse overstory. Fuel beneath timber that has lost its foliage; fuel beneath timber near clearings or clearcuts; fuel on high ridges where trees offer little shelter form the wind.	4 13 1, 3, 5, 6, 11, 12 (2, 7)[1] (8, 9, 10)[2]	0.5 0.5 0.4 0.4 0.4 0.4
PARTIALLY SHELTERED FUELS: Fuel beneath patchy timber where it is not well sheltered; fuel beneath standing timber at midslope or higher on a mountain with wind blowing directly at the slope.	All Fuel Models	0.3
FULLY SHELTERED FUELS: Fuel sheltered beneath standing timber on flat or gentle slope or near base of mountain with steep slopes.	All Fuel Models	Open Stands 0.2 Dense Stands 0.1
[1]Fuels usually partially sheltered. [2]Fuels usually fully sheltered.		

FIRE BEHAVIOR OUTPUTS

Determine the Fire Behavior Output Items (1-9) listed below and enter them on the Fire Behavior Worksheet on page B-5.

OUTPUT 1: Rate of Spread (ROS), ch/h

Using the upper right quadrant (left vertical axis) of the nomogram and input items recorded on the Fire Behavior Worksheet, determine rate of spread. Tables 15 through 78 can also be used to approximate rate of spread.

OUTPUT 2: Heat per Unit Area (HA), Btu/sq ft

Using the upper right quadrant of the nomogram, determine heat per unit area from the lower axis.

OUTPUT 3: Fireline Intensity (FLI), Btu/ft/s

Using the upper right quadrant of the nomogram, determine fireline intensity along the curved lines.

OUTPUT 4: Flame Length (FL), ft

Using the upper right quadrant of the nomogram, determine the flame length along the curved lines. Flame length can also be approximated using Tables 15 through 78.

OUTPUT 5: Spread Distance (SD), ch

Rate of spread (Output 1) on the Fire Behavior Worksheet, multiplied by the hours in which a fire spreads at that rate, equals spread distance. Convert to map distance using the Map-Spread Worksheet as outlined on page 39.

OUTPUT 9: Probability of Ignition (PIG), %

Use Table 12 on page B-55 and the dry bulb temperature (Input 2), shading (Input 8) and the fine dead fuel moisture (Output 1) from the Fine Dead Fuel Moisture/Probability of Ignition Worksheet to determine probability of ignition.

Enter probability of ignition as Output 2 on the worksheet. Also record it as Output 9 on the Fire Behavior Worksheet on page B-5.

TABLE 12: Probability of Ignition Table

Shading (Percent)	Dry-Bulb Temp. (°F)	FINE DEAD FUEL MOISTURE (PERCENT)															
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Unshaded <50%	110+	100	100	80	70	60	60	50	40	40	30	30	20	20	20	20	10
	100-109	100	90	80	70	60	60	50	40	40	30	30	20	20	20	10	10
	90-99	100	90	80	70	60	50	40	40	30	30	30	20	20	20	10	10
	80-89	100	90	80	70	60	50	40	40	30	30	20	20	20	10	10	10
	70-79	100	90	70	60	60	50	45	40	30	30	20	20	20	10	10	10
	60-69	90	80	70	60	50	50	40	30	30	20	20	20	20	10	10	10
	50-59	90	80	70	60	50	40	40	30	30	20	20	20	10	10	10	10
	40-49	90	80	70	60	50	40	40	30	30	20	20	20	10	10	10	10
	30-39	80	70	60	50	50	40	30	30	20	20	20	10	10	10	10	10
Shaded >50%	110+	100	90	80	70	60	50	50	40	40	30	30	20	20	20	10	10
	100-109	100	90	80	70	60	50	50	40	30	30	30	20	20	20	10	10
	90-99	100	90	80	70	60	50	40	40	30	30	20	20	20	10	10	10
	80-89	100	80	70	60	60	50	40	40	30	30	20	20	20	10	10	10
	70-79	90	80	70	60	50	50	40	30	30	30	20	20	20	10	10	10
	60-69	90	80	70	60	50	40	40	30	30	20	20	20	10	10	10	10
	50-59	90	80	70	60	50	40	40	30	30	20	20	20	10	10	10	10
	40-49	90	80	60	50	50	40	30	30	30	20	20	20	10	10	10	10
	30-39	80	80	60	50	50	40	30	30	20	20	20	10	10	10	10	10

TABLE 13—Fire Severity Related to Fuel Moisture Chart

Relative Humidity	Fuel Moisture	Fuel Moisture	Relative ease of chance ignition and spotting, general burning conditions.
>60	>20	>15	Very little ignition; some spotting may occur with winds above 9 mi/h.
45-60	15-19	12-15	Low ignition hazard – campfires become dangerous; glowing brands cause ignition when relative humidity is <50 percent.
30-45	11-14	10-12	Medium ignition hazard – matches become dangerous; "easy" burning conditions.
26-40	8-10	8-9	High ignition hazard – matches are dangerous; occasional crowning, spotting caused by gusty winds; "moderate" burning conditions.
15-30	5-7	5-7	Quick ignition, rapid buildup, extensive crowning; any increase in wind causes increased spotting, crowning, loss of control; fire moves up bark of trees igniting aerial fuels; long distance spotting in pine stands; dangerous burning conditions.
<15	<5	<5	All sources of ignition dangerous; aggressive burning, spot fires occur often and spread rapidly, extreme fire behavior probable; critical burning conditions.

DIAGRAM 3—Fire Behavior Characteristics Chart (Light Fuel)

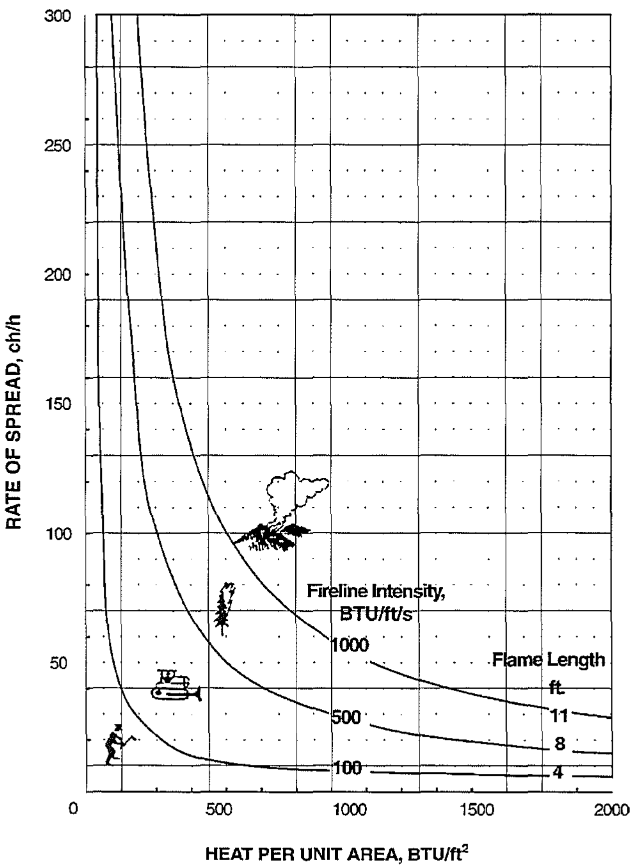

TABLE 14—Fire Suppression Interpretations[1]

CAUTION: These are not guides to personal safety. Fires can be dangerous at any level of intensity. Wilson (1977) has shown that most fatalities occur in light fuels on small fires or isolated sections of large fires.

Flame Length (ft)	Fireline Intensity (Btu/ft/s)	Interpretations
0-4	0-100	Fires can generally be attacked at the head or flanks by persons using hand tools. Handline should hold the fire.
4-8	100-500	Fires are too intense for direct attack on the head by persons using hand tools. Handline cannot be relied on to hold fire. Equipment such as dozers, engines, and retardant aircraft can be effective.
8-11	500-1,000	Fires may present serious control problems – torching out, crowning, and spotting Control efforts at the head of the fire will probably be ineffective.
11+	1,000+	Crowning, spotting, and major runs are common. Control efforts at the head of the fire are ineffective.

[1] Help in Making Fuel Management Decisions, 1975; Research Paper NC-112, USDA: Forest Service.

Tables 15 through 78—Rate of Spread and Flame Length Tables by Fuel Type and Percent Slope

NOTE: Tables 15 through 78 for ROS and FL (Output Items 1 and 4) on the Fire Behavior Worksheet reflect slope classes 0, 30, 45, 60 and 90 percent. You may use the slope class closest to the actual slope recorded (for Input Item 5) or interpolate between the slope class.

TABLE 15: FUEL MODEL 1—0% SLOPE

Fuel Moisture (1-Hour)	Midflame Wind, mi/h						
	0.	2.	4.	6.	8.	10.	12.
	Rate of Spread/Chains per Hour						
3.0	5	22	77	172	307	•446	•446
6.0	4	18	61	135	242	•270	•270
9.0	3	13	45	101	•136	•136	•136
12.0+	0	0	0	0	0	0	0
	Flame Length/Feet						
3.0	1.3	2.5	4.5	6.4	8.4	•10.0	•10.0
6.0	1.1	2.1	3.8	5.4	7.1	•7.5	•7.5
9.0	0.9	1.7	3.0	4.3	•5.0	•5.0	•5.0
12.0+	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	•MEANS YOU HIT THE WIND LIMIT.						

TABLE 20: FUEL MODEL 2—0% SLOPE

Fuel Moisture % (1-Hour)	Midflame Wind, mi/h						
	0.	2.	4.	6.	8.	10.	12.
	Rate of Spread/Chains per Hour						
3.0 120-90	3	11	28-31	56-62	92-102	138-152	191-211
6.0 120-90	2	9	23-25	45-50	75-83	112-124	156-172
9.0 120-90	2	8	20-22	40-44	66-73	99-109	137-151
12.0 120-90	2	6	16	30-33	49-54	73-81	102-112
15.0 120-90	•0	•0	•3	•3	•3	•3	•3
18.0+ 120-90	0	0	0	0	0	0	0
	Flame Length/Feet						
3.0 120-90	2.1	3.8	6.2	8.4	10.7	12.8	14.9
6.0 120-90	1.8	3.2	5.3	7.2	9.1	11.0	12.8
9.0 120-90	1.7	3.0	4.8	6.6	8.4	10.0	11.6
12.0 120-90	1.3	2.3	3.7	5.2	6.5	7.8	9.1
15.0 120-90	•0.2	•0.3	•0.4	•0.5	•0.5	•0.5	•0.5
18.0+ 120-90	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	•MEANS YOU HIT THE WIND LIMIT.						

TABLE 21: FUEL MODEL 2—30% SLOPE

Fuel Moisture % (1-Hour)	Midflame Wind, mi/h						
	0.	2.	4.	6.	8.	10.	12.
	Rate of Spread/Chains per Hour						
3.0 120-90	9	15-17	34-37	61-68	98-109	144-159	197-218
6.0 120-90	8	14	27-30	50-55	80-88	117-129	161-177
9.0 120-90	7	12	24-27	44-49	70-78	103-113	141-156
12.0 120-90	5	9	18-20	33-36	52-57	76-84	105-115
15.0 120-90	•1	•1	•2	•2	•2	•2	•2
18.0+ 120-90	0	0	0	0	0	0	0
	Flame Length/Feet						
3.0 120-90	3.5	4.7	6.7	8.8	10.9	13.0	15.1
6.0 120-90	3.0	4.0	5.8	7.5	9.4	11.2	12.9
9.0 120-90	2.8	3.7	5.3	6.9	8.6	10.2	11.8
12.0 120-90	2.2	2.9	4.1	5.4	6.7	8.0	9.3
15.0 120-90	•0.3	•0.3	•0.5	•0.5	•0.5	•0.5	•0.5
18.0+ 120-90	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	•MEANS YOU HIT THE WIND LIMIT.						

TABLE 25: FUEL MODEL 3—0% SLOPE

Fuel Moisture (1-Hour)	Midflame Wind, mi/h						
	0.	2.	4.	6.	8.	10.	12.
	Rate of Spread/Chains per Hour						
3.0	6	52	121	201	290	387	490
6.0	5	39	89	148	214	286	361
9.0	4	32	73	122	176	234	296
12.0	3	28	64	107	154	206	260
15.0	3	25	57	95	137	182	213
18.0	2	20	47	79	114	151	191
21.0	2	14	32	53	77	103	130
	Flame Length/Feet						
3.0	3.8	10.1	14.8	18.7	22.2	25.3	28.2
6.0	3.0	8.0	11.8	14.9	17.7	20.2	22.5
9.0	2.6	7.0	10.3	13.0	15.4	17.6	19.6
12.0	2.4	6.5	9.5	12.1	14.3	16.3	18.2
15.0	2.2	6.0	8.9	11.2	13.3	15.2	16.9
18.0	2.0	5.3	7.7	9.8	11.6	13.2	14.7
21.0	1.4	3.8	5.6	7.1	8.4	9.6	10.7

DIAGRAM 2—Approximate Fire Shapes for Various Effective Windspeeds