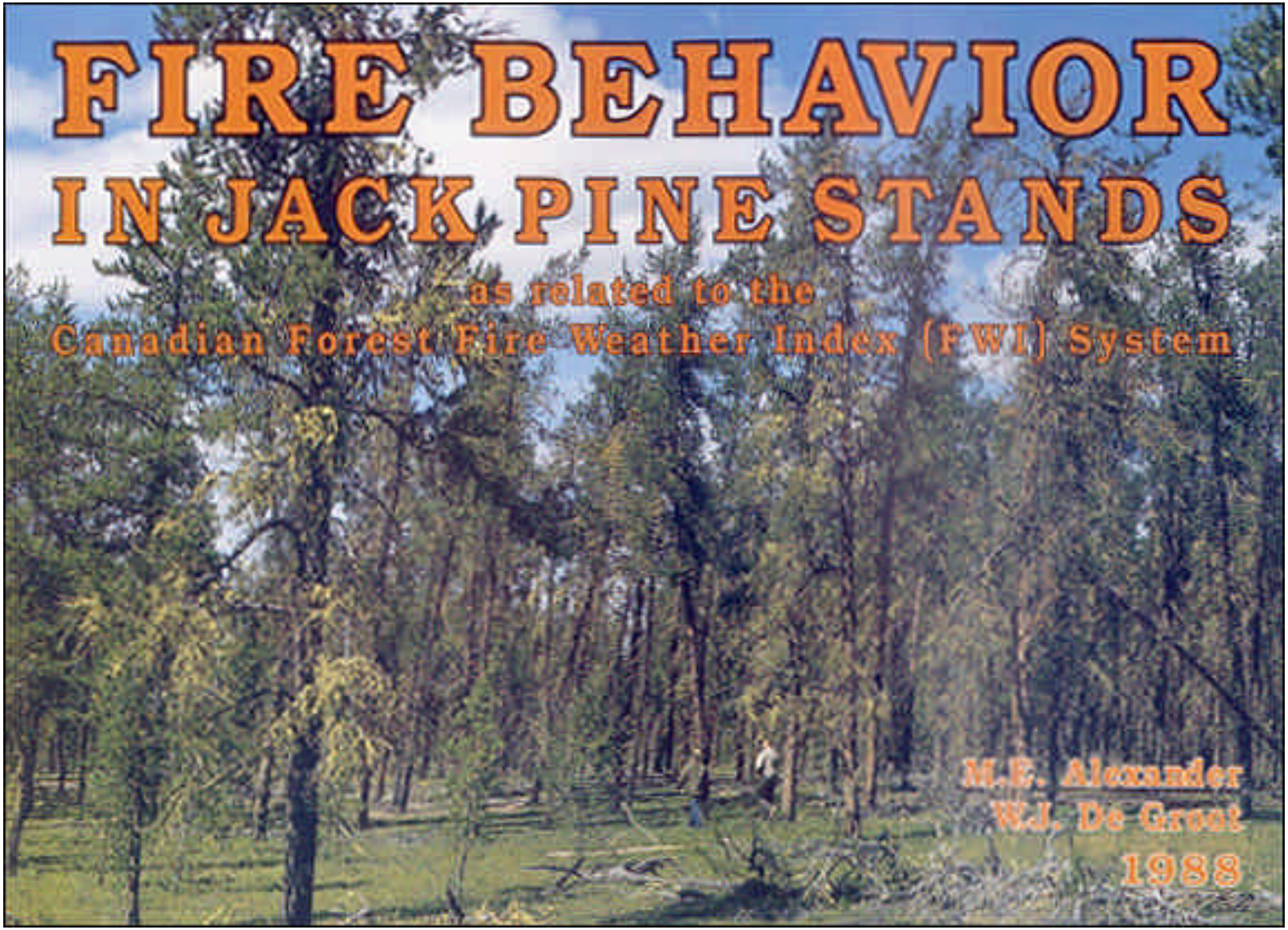

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During the 1974 fire season the Alberta Forest Service, Canadian Forestry Service, and three other federal agencies successfully completed a short-term program of experimental burning in the jack pine forests of northeastern Alberta. A detailed account of the Darwin Lake Project, as it is commonly called, has been published by Quintillio et al. (1977). Two popular articles dealing with the project were also produced (Burbidge and Janz 1974; Fahnestock 1975). Nine plots or units, ranging in size from 1-3 ha, were delineated for burning. Seven experimental fires were eventually conducted and documented over a wide range of weather conditions during a two-week period. The results of the study confirmed the strong relationship that exists between the various aspects of fire behavior and the components of the Canadian Forest Fire Weather Index (FWI) System.

The FWI System consists of six components that account for the effects of fuel moisture and wind on fire behavior (Van Wagner 1987). The three fuel moisture codes are numerical ratings of the moisture content of fine surface litter, loosely compacted duff of moderate depth, and deep compact organic matter represented by the Fine Fuel Moisture Code (FFMC), Duff Moisture Code (DMC), and Drought Code (DC). The three fire behavior indexes, namely, the Initial Spread Index (ISI), Buildup Index (BUI), and Fire Weather Index (FWI) component itself, are intended to represent the rate of fire spread, fuel available for combustion, and frontal fire intensity; their values rise as the fire danger increases.

Several of the 35-mm color slides taken of the Darwin Lake fires have already been used in numerous training courses and other presentations as an instructional aid and interpretive guide to the FWI System. This poster presents a representative photo of each experimental fire and information on the attendant environmental conditions and associated fire behavior characteristics (Plates 1 to 7) in order of increasing FWI. Calculation of the FWI System components is based on the computer program (Van Wagner and Pickett 1985) for the most recent version of the system (Canadian Forestry Service 1984), The descriptions of fire behavior are adapted from Appendix III of the original publication by Quintillio et al. (1977).

The FWI, which combines the ISI and BUI components, is a relative measure of the frontal intensity of a spreading fire. Frontal fire intensity is ”the rate of heat energy release per unit time per unit length of fire front” and is synonymous with Byram’s (1959) fireline intensity (Merrill and Alexander 1987). Flame size is its main visual manifestation. Numerically, it is equal to the product of the net heat of combustion (18400 kJ/kg has been used here), quantity of fuel consumed in the active flaming front, and rate of fire spread (Byram 1959; Alexander 1982). The recommended SI unit is kilowatt per metre (kW/m). The mathematical relation between the FWI and frontal fire intensity of the experimental fires carried out at Darwin Lake is shown in Graph 1.

A better understanding of the crowning phenomenon in natural forest stands emerged from the Darwin Lake Project. The transition from a surface fire to a crown fire is obviously of great significance to fire managers, since crowning forest fires generally represent a level of fire behavior that precludes direct fire suppression action. The effect of crowning on frontal fire intensity is very pronounced above an FWI of about 25 (Graph 1) because of the increased spread rate resulting from greater exposure to the prevailing wind field and the added crown fuel involvement. The importance of the initial surface fire intensity and presence of ladder fuels on crown fire development (Van Wagner 1977) was especially noticeable in the Unit 4B fire (Plate 8). Below an FWI of around 14-15, fires spread slowly and erratically, consumed little fuel, and showed little inclination to torch or crown.

Frontal fire intensity is a major determinant of certain fire effects (Weber et al. 1987) and the difficulty of controlling a wildfire. Graph 2 and Table 1 have been prepared as an example of a decision aid for determining the kind(s) of suppression resources that would be most effective in fire containment. The five frontal fire intensity classes and related information presented in Table 1 were determined in part from a review of the literature (e.g., Byram 1959; Van Wagner 1977; Andrews and Rothermel 1982). Graph 2 was constructed on the basis of the relationship shown in Graph 1 and the relevant equations in Van Wagner (1987). Because the chart and guide are based to a large extent on the results of the Darwin Lake Project, they are thus most applicable to similar jack pine stands on level terrain in the northern sections of the boreal forest region of western Canada.

The Darwin Lake Project represents a major milestone in fire management and fire research in Alberta (Kiil et al. 1986). As Fahnestock (1975) noted, “Nobody left Darwin Lake with doubt in his mind that fire behavior correlates well with FWI when the weather elements are measured close to the fire.”

Plate 1

Experimental Fire: Unit 1 Date: July 23

Fire Weather Observations

Dry-bulb temperature	26.5°C
Relative humidity	48%
10-m open wind	6.3 km/h
Days since rain	2

FWI System Fire Behavior Indexes

Initial Spread Index (ISI)	3.7
Buildup Index (BUI)	64
Fire Weather Index (FWI)	12

FWI System Fuel Moisture Codes

Fine Fuel Moisture Code (FFMC)	88.7
Duff Moisture Code (DMC)	15
Drought Code (DC)	143

Fire Behavior Characteristics

Head fire rate of spread	0.6 m/min
Fuel consumption	1.0 kg/m^2
Frontal fire intensity	190 kW/m

Description of Fire Behavior:

Fire spread readily across litter and Caldonia when pushed by small gusts of wind. Flames exceeded a few centimeters in height only in the occasional small concentrations of woody fuels and in the lowest, lichen-covered, dead branches of a few young trees.

Type of Fire: creeping surface fire

Plate 2

Experimental Fire: Unit 3 Date: July 24

Fire Weather Observations

Dry-bulb temperature	24.5ºC
Relative humidity	45%
10-m open wind	14.8 km/h
Days since rain	3

FWI System Fire Behavior Indexes

Initial Spread Index (ISI)	7.8
Buildup Index (BUI)	28
Fire Weather Index (FWI)	13.7

FWI System Fuel Moisture Codes

Fine Fuel Moisture Code (FFMC)	89.0
Duff Moisture Code (DMC)	18
Drought Code (DC)	151

Fire Behavior Characteristics

Head fire rate of spread	1.0 m/min
Fuel consumption	2.0 kg/m^2
Frontal fire intensity	620 kW/m

Description of Fire Behavior:

Spread was slow. Flames were generally less than 0.6 m high, but brief flare-ups occurred in occasional patches of fine dead fuels, low shrubs, small pines. Some very short-range spotting occurred just ahead of the fire front. Fire frequently ran to the tops of the pines in the abundant tree lichens and bark flakes, but almost never involved other aerial fuels.

Type of Fire: low vigor surface fire

Plate 3

Experimental Fire: Unit 2 Date: August 2

Fire Weather Observations

Dry-bulb temperature	27.0ºC
Relative humidity	39%
10-m open wind	8.5 km/h
Days since rain	6

FWI System Fire Behavior Indexes

Initial Spread Index (ISI)	6.9
Buildup Index (BUI)	42
Fire Weather Index (FWI)	15.3

FWI System Fuel Moisture Codes

Fine Fuel Moisture Code (FFMC)	90.3
Duff Moisture Code (DMC)	28
Drought Code (DC)	214

Fire Behavior Characteristics

Head fire rate of spread	0.9 m/min
Fuel consumption	2.39 kg/m^2
Frontal fire intensity	670 kW/m

Description of Fire Behavior:

Fire spread was slow but rather steady. Flames were generally less than 0.6 m high. A few trees torched, and one spot fire occurred within the unit

Type of Fire: low vigor surface fire

Plate 4

Experimental Fire: Unit 4A Date: August 3

Fire Weather Observations

Dry-bulb temperature	29.0ºC
Relative humidity	40%
10-m open wind	8.5 km/h
Days since rain	7

FWI System Fire Behavior Indexes

Initial Spread Index (ISI)	7.2
Buildup Index (BUI)	46
Fire Weather Index (FWI)	16.8

FWI System Fuel Moisture Codes

Fine Fuel Moisture Code (FFMC)	90.6
Duff Moisture Code (DMC)	31
Drought Code (DC)	222

Fire Behavior Characteristics

Head fire rate of spread	2.0 m/min
Fuel consumption	1.54 kg/m^2
Frontal fire intensity	950 kW/m

Description of Fire Behavior:

Fire spread was steady. Fire frequently burned into the crowns, using thee lichens and bark flakes as ladder fuels. Occasionally enough heat was generated to torch out the green foliage. Short-range spotting occurred around hot spots.

Type of Fire: moderately vigorous surface fire

Plate 5

Experimental Fire: Unit 7 Date: August 6

Fire Weather Observations

Dry-bulb temperature	23.0ºC
Relative humidity	48%
10-m open wind	8.5 km/h
Days since rain	10

FWI System Fire Behavior Indexes

Initial Spread Index (ISI)	7.5
Buildup Index (BUI)	60
Fire Weather Index (FWI)	19.9

FWI System Fuel Moisture Codes

Fine Fuel Moisture Code (FFMC)	90.9
Duff Moisture Code (DMC)	43
Drought Code (DC)	246

Fire Behavior Characteristics

Head fire rate of spread	2.0 m/min
Fuel consumption	2.02 kg/m^2
Frontal fire intensity	1230 kW/m

Description of Fire Behavior:

Spread was moderately fast where exposure to wind was greatest. Limited crowning occurred in one quarter of the unit, but elsewhere steady surface fire prevailed. Numerous small spot fires developed just outside the downwind side of the unit, nad the only long-range spot of the project was 140 m away.

Type of Fire: moderately vigorous surface fire

Plate 6

Experimental Fire: Unit 4B Date: July 4

Fire Weather Observations

Dry-bulb temperature	31.0ºC
Relative humidity	26%
10-m open wind	8.5km/h
Days since rain	8

FWI System Fire Behavior Indexes

Initial Spread Index (ISI)	10.9
Buildup Index (BUI)	52
Fire Weather Index (FWI)	24.1

FWI System Fuel Moisture Codes

Fine Fuel Moisture Code (FFMC)	93.6
Duff Moisture Code (DMC)	36
Drought Code (DC)	231

Fire Behavior Characteristics

Head fire rate of spread	3.4 m/min
Fuel consumption	1.86 kg/m^2
Frontal fire intensity	1900 kW/m

Description of Fire Behavior:

Increased fire intensity was apparent from taller flames and faster spread immediately upon ignition. Torching of crowns was common. Every case of torching resulted in abundant spot fires, which considerably increased the spread rate over that attained through continuous spread in surface fuel.

Type of Fire: very intense surface fire

Plate 7

Experimental Fire: Unit 6 Date: August 5

Fire Weather Observations

Dry-bulb temperature	30.5°C
Relative humidity	33%
10-m open wind	16.9 km/h
Days since rain	9

FWI System Fuel Moisture Codes

Fine Fuel Moisture Code (FFMC)	93.7
Duff Moisture Code (DMC)	41
Drought Code (DC)	239

FWI System Fire Behavior Indexes

Initial Spread Index (ISI)	16.9
Buildup Index (BUI)	57
Fire Weather Index (FWI)	34.0

Fire Behavior Characteristics

Head fire rate of spread	6.1 m/min
Fuel consumption	3.92 kg/m^2
Frontal fire intensity	7460 kW/m

Description of Fire Behavior:

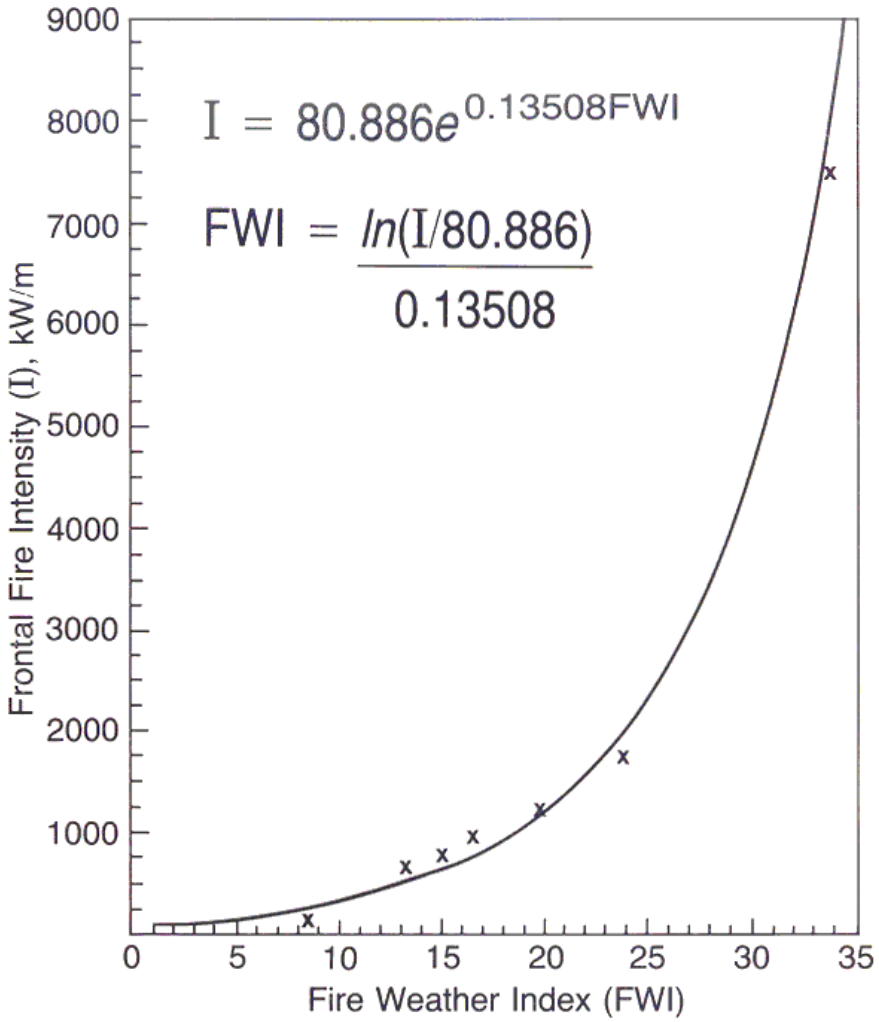
A crown fire developed almost immediately. flames were about 30 m high, 10 m higher than the trees. Spotting and high fire intensity resulted in a small, quickly controlled escape.

Type of Fire:

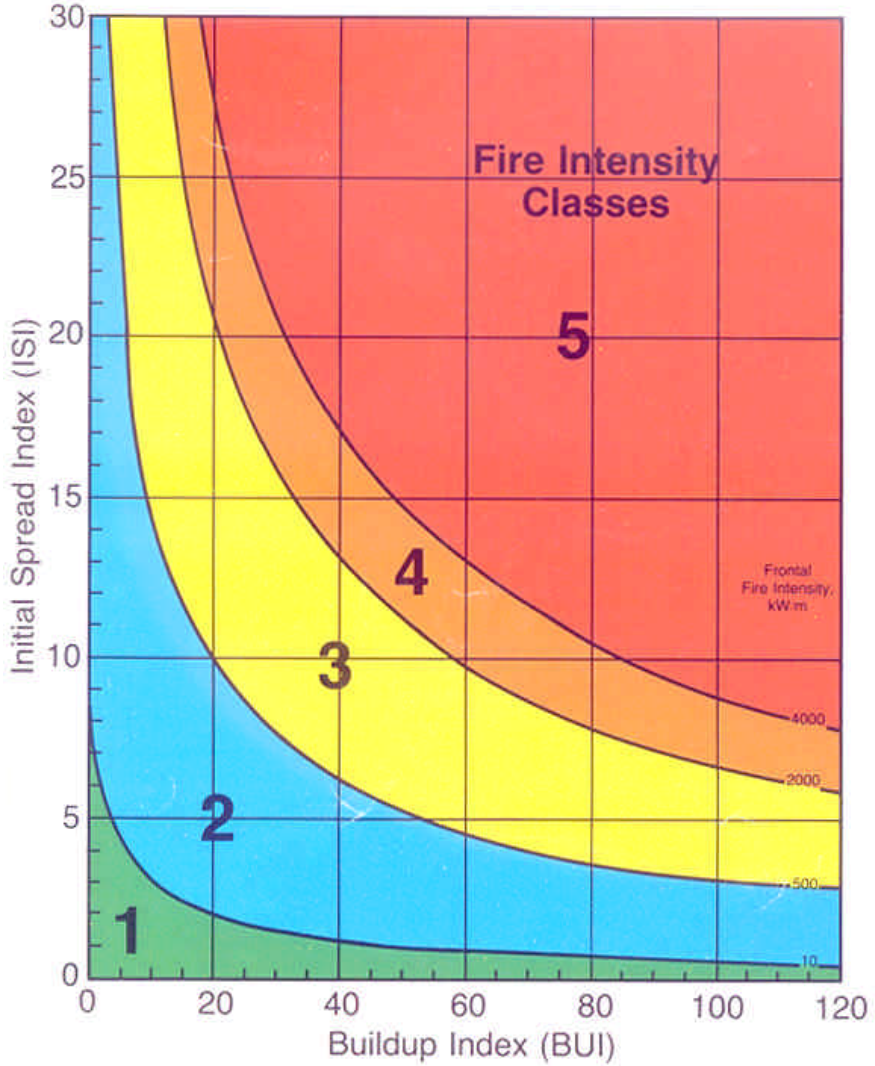
developing active crown fire

Graph 1

Frontal fire intensity as a function of the Fire Weather Index for the Darwin Lake Project experimental fires.



Graph 2



Fire Intensity Classes (refer to Table 1 for the fire control management applications).

Table 1

Fire behavior characteristics and fire suppression interpretations association with the Fire Intensity Classes in Graph 2

Fire intensity class	Frontal fire intensity (kW/h)	Surface Head Fire[1]		Type of fire and fire suppression difficulties	Fire Weather Index (FWI)[2]
		Flame length (m)	Flame height (m)		
1	<10	<0.2	<0.1	Firebrands that cause an ignition to occur are self-extinguishing (i.e., fire fails to spread). Going fires remain of the smouldering ground or subsurface variety, provided there is a forest floor layer of significant dept and a general level of dryness[3]. Extensive mop-up is generally required.	0-3
2	10-500	0.2-1.4	0.1-1.0	Creeping or gentle surface fire. Direct manual attack at fire's head or flanks by firefighters with hand tools and water is possible. Constructed fireguard should hold.	4-13
3	500-2000	1.4-2.6	1.0-1.9	Low vigor to moderately or highly vigorous surface fire. Hand-constructed fireguards likely to be challenged. Heavy equipment (bulldozers, pumpers, retardant aircraft, skimmers, helicopter with bucket) generally successful in controlling fire.	14-23
4	2000-4000	2.6-3.5	1.9-2.5	Very vigorous or extremely intense surface fire (torching common). Control efforts at fire's head may fail.	24-28
5	>4000	>3.5	>2.5	Intermittent crown fire[4] to active crown fire development (at >1000 kW/m)[5]. Very difficult to control Suppression action must be restricted to fire's flanks. Indirect attack with aerial ignition (i.e., helitorch and/or A.I.D. dispenser) may be effective.	>29

1 Flame length based on relationship with fire intensity according to Byram (1959). Flame height based on flame length and a 45° flame angle (Alexander 1982).

2 Based on the second equation given in Graph 1, except the upper and lower FWI values for Fire Intensity Classes 1 and 2 were determined from Van Wagner (1987) since none of the Darwin Lake fires were conducted at the very low end of the frontal fire intensity scale.

3 Drought Code (DC) > 300 and /or Buildup Index (BUI) >40.

4 Synonymous with passive crown fire as described by Van Wagner (1977) (Merrill and Alexander 1987).

5 Violent physical behavior probable at frontal fire intensities greater than 30000kW/m (i.e., blow-up or conflagration type fire run); suppression actions should not be attempted until burning conditions ameliorate.

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