

# FIELD GUIDE TO THE CANADIAN FOREST FIRE BEHAVIOR PREDICTION (FBP) SYSTEM

S.W. Taylor  
R.G. Pike  
and  
M.E. Alexander



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# **Field Guide to the Canadian Forest Fire Behavior Prediction (FBP) System**

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## Abstract

The Canadian Forest Fire Behavior Prediction (FBP) System is a systematic method for assessing wildland fire behavior potential. The guide provides a simplified version of the system, presented in tabular format. It was prepared to assist field staff in making first approximations of FBP System outputs when computer-based applications are not available. Quantitative estimates of head fire spread rate, fire intensity, type of fire, and elliptical fire area, perimeter, and perimeter growth rate are provided for sixteen discrete fuel types within five broad groupings (coniferous, deciduous, and mixedwood forests, logging slash, and grass), covering most of the major forest fuel types found in Canada. The FBP System is intended to supplement the experience and judgement of fire managers.

## Résumé

La Méthode canadienne de prévision du comportement des incendies de forêt est une méthode systématique d'évaluation prospective du comportement des feux de forêt. Ce guide fournit une version simplifiée de la méthode, sous forme de tableaux. Il a pour objet d'aider le personnel de terrain à établir les premières approximations tirées de la méthode lorsqu'on ne dispose pas de version informatisée. Les estimations quantitatives du taux de propagation de la tête de l'incendie, de l'intensité du feu, du type d'incendie, de la superficie elliptique du feu, du périmètre et du taux d'accroissement du périmètre sont données pour seize types de combustibles différents correspondant à cinq grandes catégories (conifères, essences caduques, peuplements mixtes, déchets de coupe, herbes) couvrant la plupart des principaux types de combustibles forestiers trouvés au Canada. La méthode canadienne de prévision du comportement des incendies de forêt vise à compléter l'expérience et le jugement des gestionnaires d'incendies.

# Acknowledgments

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This guide was first published as Canada-B.C. FRDA Handbook 012. Some changes were made to this version to clarify the worksheet procedures; however, the general procedures and values in the tables are unchanged. Funding for the original version of this publication was provided by the Canada-British Columbia Partnership Agreement on Forest Resources Development. We acknowledge their support.

## **Disclaimer**

Her Majesty the Queen in right of Canada and the authors do not warrant or guarantee the accuracy or completeness of the information, statements and opinions expressed in this publication, and do not assume any liability with respect to any damage or loss incurred as a result of the use made of the information, statements or opinions contained in this publication.

## **Caution**

Fire behavior predictions are intended to assist in decision making, and are not a substitute for experience, sound judgment, or observation of actual fire behavior. This document is not intended to be a guide to safe working conditions; almost any fire can be hazardous in some circumstances. Fire behavior can change rapidly due to changes in fuel conditions, slope, and exposure to wind. No system can ever fully account for all of the variables that affect fire behavior; operational personnel must be aware of the limitations of the system and be able to recognize unique or unusual situations.

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# Introduction

The Canadian Forest Fire Behavior Prediction (FBP) System is a systematic method for assessing wildland fire behavior potential. It is a series of mathematical equations relating fire characteristics to wind, fuel moisture, and topographic conditions for 16 benchmark fuel (vegetation) types. Complete and precise fire behavior predictions are best made using computer-based representations of the system. However, this guide was prepared to allow first approximations of FBP System outputs when computer-based applications are not available. It is intended mainly to be used as a field reference and should be used in place of the forest fire growth calculator (McAlpine 1986), which is based on the interim version of the FBP System (Alexander et al. 1984). Certain simplifications were made so that important fire behavior characteristics could be presented in tabular form, and these are noted in the appropriate section.

The core of the FBP System Field Guide is the rate of spread (ROS) and fire intensity class tables. They allow determination of a fire's ROS, intensity level, and general type (i.e., surface, intermittent crown, or continuous crown fire) in one simple accessible procedure. These tables can also be helpful in visualizing the fire potential in a particular fuel type across a broad spectrum of burning conditions.

A complete technical description of the FBP System is given in Forestry Canada Fire Danger Group (1992). Further guidance on its application is given in Hirsch (1996). Fire suppression interpretations based on head fire intensity class are also available for several fuel types (Alexander and De Groot 1988; Alexander and Lanoville 1989; Cole and Alexander 1995).

## General assumptions

Users must be careful not to apply the system beyond its useful range. In the FBP System, predictions are limited to a fire spreading during one burning period from a single point source ignition or line of fire, assuming that:

- fuels conditions are similar to one of the 16 benchmark fuel types.
- the fuel moisture codes used are representative of the site conditions.
- fuels are uniform and continuous, topography is simple and homogenous, and wind is constant and unidirectional.
- the fire is wind or wind/slope driven, and spread is not affected by a convection column. Wind is represented by the 10-m open wind.
- the fire is unaffected by suppression activities (free burning).
- a fire starting from a point source will have an elliptical shape under the above conditions.
- the effect of firebrands on spread is accounted for.



## Accuracy of the guide

This guide will give a good estimate of the Fire Intensity Class and Type of Fire in most cases. In most fuel types users should be able to estimate fire size characteristics within  $\pm 20\%$  of computed values for rate of spread  $> 3$  m/min. The fire size estimates are less accurate for the 0–20 Buildup Index class and for  $ROS \leq 3$  m/min because of interpolation and rounding errors; however, the predictions are still of practical value.

## Fire behavior prediction worksheet procedures

A procedure to determine several key fire characteristics using this guide is outlined below. Repeat the procedure (separate prediction point) for each different fuel type or slope/aspect class that is likely to be encountered during the prediction time interval. The abbreviations used are listed in Appendix 1 and many of the terms are defined in Appendix 2. Some examples, correction and conversion factors are given in Appendixes 3–6. The fire behavior prediction worksheet presented in Appendix 7 can be used to record the input data, intermediate computations and the resulting fire characteristics; a blank worksheet suitable for copying and a sample of a completed worksheet can be found in Appendix 7. All calculations made on one sheet should be for the same time interval. Use a new worksheet for each successive or new time interval. In some cases interpolation may be required to obtain precise values.

### Line no(s).

- 1–3 Enter the **fire number** and/or **name**; **date** and **time**; **prediction date** and **interval**; and the ignition type for each prediction point: point ignition (PI) or line source (LS).
- 4 Select the most appropriate **fuel type** (Table 1) and enter the fuel type **identifier** that best represents the fuels at the prediction point. In choosing a fuel type, the physical properties of the fuel complex such as surface fuel conditions, stand density, and crown base height should be considered in addition to the tree species composition. Photographic examples of each fuel type are given in Appendix 3.
- 5 Record any relevant fuel type **modifiers**: for C-6 enter **Crown Base Height (CBH)**; for M-1 and M-2 enter the Percent Conifer (PC) / Percent Hardwood (PH) composition (e.g., 75:25); and for M-3 and M-4 enter Percent Dead Fir (PDF).

- 6–7 Enter the **standard daily Fine Fuel Moisture Code (FFMC)** for the prediction date. Enter the **hourly FFMC** (which is calculated from hourly weather observations) for the prediction date/time, if available. Alternatively, determine the **diurnal FFMC** for the prediction time from the standard daily FFMC (Appendix 5, Table A.1 or A.2).
- 8–10 Enter **ground slope (%)** and **aspect** (cardinal direction) for the area ahead of the prediction point, disregarding minor variations. For slash and grass fuel types, also record the slope and aspect of the weather observation point in brackets (use L for level: e.g., Ground slope 50 [15]; Aspect S [E]). These values can be used to determine a topographically **adjusted FFMC** on clear days during the months of March, April, August, September, or October between 1200 and 2000 Local Standard Time (LST) (Table A.3, Appendix 5).
- 11 Determine the **slope equivalent wind speed** corresponding to the ground slope for the selected fuel type (Table 2).
- 12–13 Enter the on-site **10-m open wind speed** as measured, estimated, or forecast for the prediction point. Appendix 4 (Beaufort scale) may be used as a guide if instruments are not available. Enter wind speed as a positive value if the wind is blowing upslope (e.g., 23 km/h) or a negative value if it is blowing downslope (e.g., -3 km/h). Determine the **effective wind speed** (i.e., 10-m open wind plus slope equivalent wind). Note that if the wind is blowing downslope the result can be positive or negative. If the winds are blowing across the slope, the effective wind speed will also be cross-slope; however, the strength and direction of the effective cross-slope wind are determined using trigonometry, which is beyond the scope of this guide.
- 14 Find the **Initial Spread Index (ISI)** relevant to the head fire and backfire from the FFMC and effective wind speed (Table 3).
- 15 Enter the **Buildup Index (BUI)** for the prediction date from the closest representative fire weather station, or the **degree of curing (%)** for the O-1 fuel types.
- 16–20 For each fuel type, find the **equilibrium rate of spread (ROS)**, **fire intensity class**, **type of fire**, and **crown fraction burned (CFB) level**, and type of fire for both the head fire and the backfire (if relevant) from

the head fire and backfire ISI and the BUI or degree of curing (Tables 4.1 – 4.26). If the BUI is not known use the class denoted by the box. The background shading in the tables indicates fire intensity class. The type of fire is indicated as follows:

black figures indicate surface fire with < 10% CFB

black figures with \* indicate intermittent crown fire with 10–89% CFB

white figures indicate continuous crown fire with > 90% CFB

Record the type of fire as S (surface fire), IC (intermittent crown fire), or CC (continuous crown fire). The 50% CFB level is indicated by a horizontal line within the intermittent crown fire class. For surface fire (S) enter CFB as < 10%, for continuous crown fire (CC) enter > 90% CFB, and for intermittent crown fire select the closest CFB level, i.e., 10, 50, or 90%. Note: if the effective wind speed is negative the fire is predicted to spread downslope.

21–24 Enter the **elapsed time** corresponding to the prediction time interval.

Determine the **head fire spread distance**, **backfire spread distance**, and **total spread distance** (head fire + backfire spread distances) from Table 5.1 or 5.2. Distances are given for three spread functions:

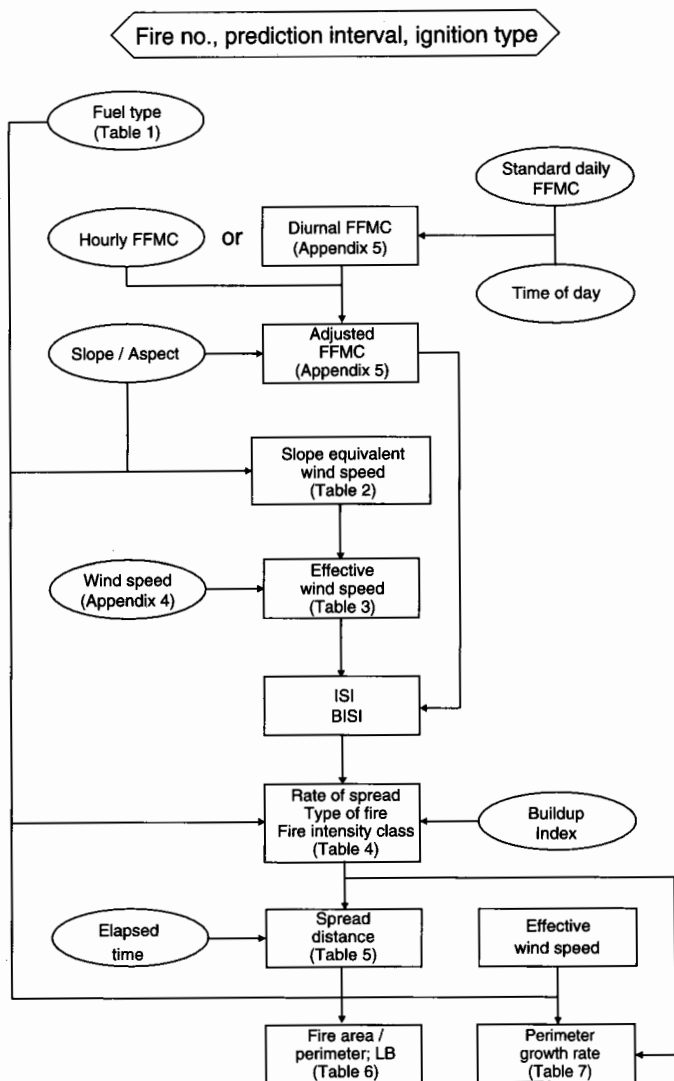
- equilibrium ROS: all fuel types
- accelerating ROS: open fuels and surface fires in closed fuel types ( $\leq 10\%$  CFB)
- accelerating ROS: crown fires in closed fuel types (50 and  $\geq 90\%$  CFB)

Use the equilibrium ROS function for fires spreading from an active fire perimeter or other line ignition (LS). Use the acceleration function for fires spreading from a point ignition type (PI). Determine the backfire spread distance only if there are no barriers to backfire spread.

25–27 For fires starting from a point source, determine the **elliptical fire area**, **elliptical fire perimeter** and the **length-to-breadth ratio** (LB) from the total spread distance and effective wind speed during the prediction interval (Table 6.1 or 6.2).

28 The **perimeter growth rate** can be determined from the head fire ROS and effective wind speed in Table 7.1 or 7.2. Values are given for both timber/slash and grass fuel types. An elliptically shaped fire's maximum width or breadth can be calculated by dividing the total spread distance by the LB ratio (Table 6.1 or 6.2).

# Flow chart of procedures used in the guide



**Table 1**  
**FBP System**  
**Fuel types**

<b>Group</b>	<b>Identifier</b>	<b>Description</b>
<b>Coniferous</b>	C-1	Spruce-lichen woodland
	C-2	Boreal spruce
	C-3	Mature jack or lodgepole pine
	C-4	Immature jack or lodgepole pine
	C-5	Red and white pine
	C-6*	Conifer plantation
	C-7	Ponderosa pine/Douglas-fir
<b>Deciduous</b>	D-1	Leafless aspen
<b>Mixedwood</b>	M-1*	Boreal mixedwood—leafless
	M-2*	Boreal mixedwood—green
	M-3*	Dead balsam fir mixedwood—leafless
	M-4*	Dead balsam fir mixedwood—green
<b>Slash</b>	S-1	Jack or lodgepole pine slash
	S-2	White spruce/balsam slash
	S-3	Coastal cedar/hemlock/Douglas-fir slash
<b>Open</b>	O-1a*	Matted grass
	O-1b*	Standing grass

\* Note the following fuel type modifiers must be specified:

C-6	Crown base height (CBH).
M-1/M-2	Percent conifer (PC) and percent hardwood (PH) composition.
M-3/M-4	Percent dead fir (PDF).
O-1a/O-1b	Degree of curing.

Table 2

# Slope equivalent wind speeds (km/h)

Fuel type identifier	Slope (%)					
	10	20	30	40	50	60
C-1	1	3	4	6	8	10
C-2	3	7	12	17	23	29
C-3	2	4	6	9	12	15
C-4	3	7	12	17	23	29
C-5	1	3	5	7	9	12
C-6	2	4	7	10	13	17
C-7	2	5	9	13	17	21
D-1	3	7	11	16	21	26
M-1	3	7	12	16	22	28
M-2	3	7	11	16	21	26
M-3 30 PDF	3	7	11	16	21	26
60 PDF	3	8	13	18	24	32
100 PDF	4	9	14	21	29	41
M4 30 PDF	2	5	8	11	14	18
60 PDF	2	6	9	13	18	23
100 PDF	3	8	13	18	25	32
S-1	4	8	14	20	27	35
S-2	3	7	11	16	21	26
S-3	2	4	6	9	12	16
O-1a	3	8	13	19	25	32
O-1b	3	7	11	15	21	26

Find the fuel type identifier, then move horizontally to the most appropriate slope column to read the **slope equivalent wind speed**. If the FPMC  $\geq 95$  and slope  $\geq 50\%$  add 5 to the table value.

Slope equivalent windspeed varies with FPMC. Those given above are for FPMC 90 and are accurate to  $\pm 2$  km/h of the true values for FPMC 80–96. The values for FPMC  $\geq 95$  and slope  $\geq 50\%$  may be underestimated by  $\geq 5$  km/h.

M-1 and M-2 values are for 50:50 conifer/hardwood. M-3 and M-4 modifiers are percent dead fir (PDF).

Table 3

# ISI Initial Spread Index

FFMC	Effective wind speed (km/h)										
	0	5	10	15	20	25	30	35	40	45	50
77	1	1	1	2	2	3	4	5	7	8	9
	1	1	1	0	0	0	0	0	0	0	0
78	1	1	2	2	3	3	4	5	7	8	9
	1	1	1	0	0	0	0	0	0	0	0
79	1	1	2	2	3	4	5	6	8	9	10
	1	1	1	0	0	0	0	0	0	0	0
80	1	1	2	2	3	4	5	7	9	10	11
	1	1	1	1	0	0	0	0	0	0	0
81	1	2	2	3	3	4	6	7	10	11	13
	1	1	1	1	0	0	0	0	0	0	0
82	1	2	2	3	4	5	6	8	11	13	14
	1	1	1	1	1	0	0	0	0	0	0
83	2	2	3	3	4	6	7	9	12	15	16
	2	1	1	1	1	0	0	0	0	0	0
84	2	2	3	4	5	6	8	11	14	17	18
	2	1	1	1	1	1	0	0	0	0	0
85	2	3	3	4	6	7	10	12	16	19	21
	2	2	1	1	1	1	0	0	0	0	0
86	2	3	4	5	7	9	11	14	18	22	24
	2	2	1	1	1	1	0	0	0	0	0
87	3	4	5	6	8	10	13	16	21	25	28
	3	2	2	1	1	1	1	0	0	0	0
88	3	4	5	7	9	11	15	19	24	29	32
	3	3	2	2	1	1	1	1	0	0	0
89	4	5	6	8	10	13	17	22	28	33	37
	4	3	2	2	1	1	1	1	0	0	0
90	4	6	7	9	12	15	19	25	32	39	43
	4	3	3	2	2	1	1	1	1	0	0
91	5	6	8	11	14	17	22	29	37	45	50
	5	4	3	2	2	1	1	1	1	1	0
92	6	7	9	12	16	20	26	33	43	51	57
	6	4	3	3	2	2	1	1	1	1	0
93	7	8	11	14	18	23	30	38	49	59	66
	7	5	4	3	2	2	1	1	1	1	1
94	8	10	12	16	21	27	34	44	57	68	76
	8	6	5	4	3	2	2	1	1	1	1
95	9	11	14	18	24	31	39	51	65	78	87
	9	7	5	4	3	2	2	1	1	1	1
96	10	13	16	21	27	35	45	58	74	89	99
	10	8	6	5	4	3	2	2	1	1	1
97	11	15	19	24	31	40	51	66	85	102	114
	11	9	7	5	4	3	3	2	2	1	1
98	13	17	21	28	36	46	59	76	97	117	130
	13	10	8	6	5	4	3	2	2	1	1

Use red figures for the head fire and use black figures for the back fire.

**Table 4.1**  
Equilibrium rate of spread (m/min)  
and fire intensity class

**C-1 spruce-lichen woodland**

Intensity class

1	< 10 kW/m
2	10 - 500
3	500 - 2 000
4	2 000 - 4 000
5	4 000 - 10 000
6	> 10 000

ISI	BUI							
	0-20	21-30	31-40	41-60	61-80	81-120	121-160	161-200
1	0	0	0	0	0	0	0	0
2	0	0	0	0	1	0	0	0
3	0	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
5	0.2	0.2	0.3	0.3	2	0.3	0.3	0.3
6	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.6
7	0.6	0.8	0.9	0.9	1	1	1	1
8	1	1	1	1	2	2	2	2
9	1	2*	2*	2*	3	2*	2*	2*
10	2*	3*	3*	3*	3*	3*	3*	3*
11	3*	4*	4*	4*	4	4*	5*	5*
12	4*	5*	5*	5*	6*	6*	6*	6*
13	5*	6*	7*	7*	7*	7*	7*	7*
14	6*	8*	8*	9*	9*	9*	9*	9*
15	7*	9*	10*	10*	5	11*	11*	11*
16	8*	11*	12	12	13	13	13	13
17	9*	13	14	14	15	15	15	15
18	11*	15	16	16	17	17	17	18
19	12	17	18	19	19	20	20	20
20	14	19	20	21	21	22	22	22
21-25	18	25	27	28	29	29	30	30
26-30	26	35	38	39	40	41	42	42
31-35	33	45	48	50	51	52	53	54
36-40	39	53	56	59	6	60	62	63
41-45	44	59	63	66	68	69	70	71
46-50	50	64	68	71	73	75	76	77
51-55	51	68	72	75	78	79	81	81
56-60	52	71	75	78	81	83	84	85
61-65	54	73	77	81	83	85	86	87
66-70	55	75	79	83	85	87	88	89

Constants: foliar moisture content = 97%; CBH = 2 m; surface fuel consumption for FPMC 90. □ = average BUI. Type of fire: **surface**, **intermittent crown\***, **continuous crown**. \_ = CFB 50%.



Table 4.2

Equilibrium rate of spread (m/min)  
and fire intensity class

**C-2 boreal spruce**

Intensity class

1	< 10 kW/m
2	10 - 500
3	500 - 2 000
4	2 000 - 4 000
5	4 000 - 10 000
6	> 10 000

ISI	BUI							
	0-20	21-30	31-40	41-60	61-80	81-120	121-160	161-200
1	0.1	0.3	0.4	0.5	2	0.5	0.6	0.6
2	0.3	0.9	1	1	3	1	2*	2*
3	0.6	2	2	2*	3*	3*	3*	3*
4	0.9	3	3*	4*	4	4*	4*	5*
5	1	3*	4*	5*	5*	6*	6*	6*
6	2	4*	5*	6*	5	7*	8*	8*
7	2	5*	7*	8*	9*	9*	10*	10*
8	2	7*	8*	9*	10*	11	12	12
9	3	8*	9*	11*	12	13	14	14
10	3	9*	11*	12	14	15	16	16
11	4	10*	12	14	16	17	18	18
12	4	11*	14	16	17	19	20	20
13	4	12	15	17	19	21	22	22
14	5	13	16	19	21	23	24	25
15	5	15	18	21	6	23	25	26
16	6*	16	19	22	25	27	28	29
17	6*	17	21	24	27	29	30	31
18	6*	18	22	26	28	31	32	33
19	7*	19	23	27	30	33	34	35
20	7*	20	25	29	32	34	36	37
21-25	8*	24	29	34	37	40	42	43
26-30	10*	29	35	41	46	49	52	53
31-35	12*	34	41	48	53	57	60	62
36-40	14*	39	47	54	60	65	68	70
41-45	15	43	52	60	66	72	75	78
46-50	16	46	56	65	72	78	82	84
51-55	17	49	60	70	77	83	87	90
56-60	18	52	64	74	82	88	92	95
61-65	19	55	67	77	85	92	97	100
66-70	20	57	69	80	89	96	101	104

Constants: foliar moisture content = 97% ; crown base height = 3 m. □ = average BUI.

Type of fire: surface, intermittent crown\*, continuous crown. \_ = CFB 50%.

Table 4.3

Equilibrium rate of spread (m/min)  
and fire intensity class

# C-3 mature jack or lodgepole pine

Intensity class

1	< 10 kW/m
2	10 - 500
3	500 - 2 000
4	2 000 - 4 000
5	4 000 - 10 000
6	> 10 000

ISI	BUI							
	0-20	21-30	31-40	41-60	61-80	81-120	121-160	161-200
1	0	0	0	0	1	0	0	0
2	0	< 0.1	0.1	0.1	0.1	0.1	0.1	0.1
3	0.1	0.2	0.2	0.2	2	0.2	0.2	0.2
4	0.1	0.3	0.4	0.4	0.5	0.5	0.5	0.5
5	0.3	0.6	0.7	0.8	0.9	0.9	1	1
6	0.4	1	1	1	1	2	2	2
7	0.7	2	2	2	3	2	2	2
8	1	2	2	3	3	3	3	3*
9	1	3	3	4	4	4	4*	5*
10	2	4	4	5	5	6*	6*	6*
11	2	5	5	6	7*	7*	7*	7*
12	2	6	7	7	8*	8*	9*	9*
13	3	7	8	9	10*	10*	11*	11*
14	3	8	9	10*	11*	12*	12*	13*
15	4	9	11	12*	13*	14*	14	15
16	4	10	12	14*	15*	16	16	17
17	5	12	14	16*	17	18	19	19
18	6	13	15	17*	19	20	21	21
19	6	15	17*	19	21	22	23	24
20	7	16	19*	21	23	25	26	26
21-25	9	21	24*	27	30	31	33	34
26-30	12	28*	33	38	41	43	45	46
31-35	16	36*	42	47	51	55	57	58
36-40	18	43	50	56	61	65	68	69
41-45	21	49	57	64	70	74	77	79
46-50	23	54	63	71	77	82	86	88
51-55	25	58	69	77	84	89	93	95
56-60	27	62	73	82	89	95	99	101
61-65	28	65	77	86	94	100	104	106
66-70	29	68	80	90	97	103	108	110

Constants: foliar moisture content = 97%; crown base height = 8 m. □ = average BUI.

Type of fire: surface, intermittent crown\*, continuous crown. \_ = CFB 50%.

Table 4.4

Equilibrium rate of spread (m/min)  
and fire intensity class**C-4** immature jack or lodgepole pine

Intensity class

1	< 10 kW/m
2	10 - 500
3	500 - 2 000
4	2 000 - 4 000
5	4 000 - 10 000
6	> 10 000

BUI

ISI	0-20	21-30	31-40	41-60	61-80	81-120	121-160	161-200
1	0.2 (1)	0.4	0.5	0.5	0.6	0.6	0.6	0.6
2	0.6	1	1	1	2	2	2*	2*
3	1	2 (2)	2	3	3*	3*	3*	3*
4	2	3	3	4*	4*	4*	4*	5*
5	2	4	5 (3)	5*	6*	6*	6*	6*
6	3	5	6*	7*	7*	8*	8*	8*
7	4	7	8*	8*	9*	9*	10*	10*
8	4	8	9*	10*	11*	11*	11	12
9	5	9	11*	12* (5)	12	13	13	14
10	6	11* (4)	12*	13	14	15	15	16
11	6	12*	14*	15	16	17	17	18
12	7	14*	15*	17	18	19	19	20
13	8	15*	17	19	20	21	21	22
14	9	16*	19	20	22	23	23	24
15	9	18*	20	22	24	25	26	26
16	10	19*	22	24	25	27	28	28
17	11	21	23	26	27	29	30	30
18	12	22	25	27 (6)	29	31	32	32
19	12	23	27	29	31	33	34	34
20	13	25	28	31	33	34	36	36
21-25	15	29	33	36	38	40	41	42
26-30	18	35	40	44	47	49	50	51
31-35	21	41	46	51	54	57	59	60
36-40	24	46	52	57	61	64	66	67
41-45	27	51	58	63	67	71	73	74
46-50	29	55	62	69	73	76	79	80
51-55	31	59	67	73	78	82	84	86
56-60	32	62	70	77	82	86	89	90
61-65	34	65	74	81	86	90	93	95
66-70	35	67	76	84	89	94	97	98

Constants: foliar moisture content = 97%; crown base height = 4 m. □ = average BUI.

Type of fire: **surface**, **intermittent crown\***, **continuous crown**. \_ = CFB 50%.

**Table 4.5**  
Equilibrium rate of spread (m/min)  
and fire intensity class

**C-5 red and white pine**

Intensity class	
1	< 10 kW/m
2	10 - 500
3	500 - 2 000
4	2 000 - 4 000
5	4 000 - 10 000
6	> 10 000

ISI	BUI							
	0-20	21-30	31-40	41-60	61-80	81-120	121-160	161-200
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
4	< 0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
5	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.3
6	0.2	0.3	0.4	0.4	0.4	0.4	0.5	0.5
7	0.3	0.5	0.6	0.7	0.7	0.7	0.8	0.8
8	0.5	0.8	0.9	1	1	1	1	1
9	0.6	1	1	1	1	2	2	2
10	0.8	2	2	2	2	2	2	2
11	1	2	2	2	3	3	3	3
12	1	2	3	3	3	3	3	4
13	2	3	3	4	4	4	4	4
14	2	4	4	4	5	5	5	5
15	2	4	5	5	6	6	6	6
16	3	5	5	6	6	7	7	7
17	3	5	6	7	7	8	8	8
18	3	6	7	8	8	9	9	9
19	4	7	8	9	9	10	10	10
20	4	8	9	9	10	10	11	11*
21-25	5	10	11	12	13	13	14*	14*
26-30	7	13	14	16	17	18*	18*	19*
31-35	8	15	18	19	20	21*	22	23
36-40	9	18	20	22	23	24*	25	26
41-45	10	19	22	24	25*	27	28	28
46-50	11	20	23	25	27*	28	29	30
51-55	11	21	24	27	28*	30	31	31
56-60	11	22	25	27	29*	31	32	32
61-65	12	22	25	28	30*	31	32	33
66-70	12	23	26	28	30*	32	33	33

Constants: foliar moisture content = 97%; crown base height = 18 m. □ = average BUI.

Type of fire: **surface**, **intermittent crown\***, **continuous crown**. \_ = CFB 50%.

Table 4.6

Equilibrium rate of spread (m/min)  
and fire intensity class**C-6 conifer plantation**  
7-m crown base height

Intensity class

1	< 10 kW/m
2	10 - 500
3	500 - 2 000
4	2 000 - 4 000
5	4 000 - 10 000
6	> 10 000

BUI

ISI	0-20	21-30	31-40	41-60	61-80	81-120	121-160	161-200
1	0	0	1	0	0	0	0	0
2	< 0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
3	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3
4	0.2	0.5	0.5	0.6	0.6	0.7	0.7	0.7
5	0.4	0.8	1	1	1	1	1	1
6	0.7	1	1	2	2	2	2	2
7	1	2	2	2	2	3	3	4
8	1	2	3	3	3	3	6*	7*
9	2	3	4	4	4	7*	10*	11*
10	2	4	4	5	5	11*	14*	15*
11	2	5	5	6	8	15*	18*	19*
12	3	5	6	7	13*	19*	21*	22*
13	3	6	7	8	17*	22*	24*	24*
14	4	7	8	9	21*	25*	26*	27*
15	4	8	9	10	24*	28*	29*	29*
16	5	9	10	16*	27*	30*	31*	31
17	5	10	11	20*	30*	32*	33	33
18	5	10	12	24*	32*	34	34	34
19	6	11	13	28*	34*	35	36	36
20	6	12	13	30*	35*	37	37	37
21-25	7	14	16	37*	40	40	40	41
26-30	9	17	22*	43	45	45	45	45
31-35	10	19	34*	47	48	48	48	48
36-40	10	20	41*	50	51	51	51	51
41-45	11	21	45*	52	53	53	53	53
46-50	11	22	48*	54	54	54	54	54
51-55	12	22	50*	55	56	56	56	56
56-60	12	23	51*	56	57	57	57	57
61-65	12	23	52*	57	57	57	57	57
66-70	12	23	53*	58	58	58	58	58

Constants: foliar moisture content = 97%; crown base height = 7 m. □ = average BUI.

Type of fire: surface, intermittent crown\*, continuous crown. \_ = CFB 50%.

**Table 4.7**  
Equilibrium rate of spread (m/min)  
and fire intensity class

**C-6 conifer plantation**  
2-m crown base height

Intensity class

1	< 10 kW/m
2	10 - 500
3	500 - 2 000
4	2 000 - 4 000
5	4 000 - 10 000
6	> 10 000

ISI	BUI							
	0-20	21-30	31-40	41-60	61-80	81-120	121-160	161-200
1	0	0	0	0	0	0	0	0
2	<0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
3	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3
4	0.2	0.5	0.5	0.6	0.6	0.9	1	1
5	0.4	0.8	0.9	1	2	3*	3*	3*
6	0.7	1	1	2	4*	5*	6*	6*
7	1	2	2	5*	7*	8*	9*	9*
8	1	2	3	8*	10*	11*	12*	12*
9	2	3	6*	11*	13*	14*	15*	15*
10	2	4	10*	15*	17*	17*	18*	18*
11	2	5	14*	18*	20*	20*	21*	21*
12	3	6	17*	21*	22*	23*	23*	24*
13	3	11*	21*	24*	25*	25*	26*	26*
14	4	15*	23*	26*	27*	28*	28*	28*
15	4	19*	26*	28*	29*	30	30	30
16	5	22*	28*	30*	31	31	32	32
17	5	25*	31*	32	33	33	33	33
18	5	27*	32*	34	34	35	35	35
19	6	30*	34*	35	36	36	36	36
20	6	32*	36	37	37	37	37	37
21-25	7	37*	40	40	40	41	41	41
26-30	9	43	44	45	45	45	45	45
31-35	10	47	48	48	48	48	48	48
36-40	10	50	51	51	51	51	51	51
41-45	11	52	53	53	53	53	53	53
46-50	11	54	54	54	54	54	54	54
51-55	12	55	56	56	56	56	56	56
56-60	12	56	56	57	57	57	57	57
61-65	12	57	57	57	57	57	57	57
66-70	12	57	58	58	58	58	58	58

Constants: foliar moisture content = 97%; crown base height = 2 m. □ = average BUI.

Type of fire: **surface**, **intermittent crown\***, **continuous crown**. \_ = CFB 50%.



Table 4.8

Equilibrium rate of spread (m/min)  
and fire intensity class

**C-7 ponderosa pine/Douglas-fir**

Intensity class

1	< 10 kW/m
2	10 - 500
3	500 - 2 000
4	2 000 - 4 000
5	4 000 - 10 000
6	> 10 000

BUI

ISI	0-20	21-30	31-40	41-60	61-80	81-120	121-160	161-200
1	0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2
3	0.2	0.3	0.3	0.3	0.3	0.3	0.4	0.4
4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.6
5	0.4	0.7	0.8	0.8	0.9	1	1	1
6	0.6	1	1	1	1	1	1	1
7	0.8	1	1	2	2	2	2	2
8	1	2	2	2	2	2	2	2
9	1	2	2	2	2	3	3	3
10	2	2	3	3	3	3	3	3
11	2	3	3	3	4	4	4	4
12	2	3	4	4	4	4	4	4
13	2	4	4	4	5	5	5	5
14	3	4	5	5	5	5	6	6
15	3	5	5	6	6	6	6*	6*
16	3	5	6	6	6*	7*	7*	7*
17	4	6	6	7*	7*	7*	8*	8*
18	4	6	7	7*	8*	8*	8*	8*
19	4	7	7*	8*	8*	9*	9*	9*
20	5	7	8*	9*	9*	9*	10*	10*
21-25	6	9*	10*	11*	11*	11*	12*	12*
26-30	7	12*	13*	14*	14*	15*	15*	15*
31-35	9*	14*	16*	17	17	18	18	19
36-40	10*	17*	18	19	20	21	22	22
41-45	12*	19	21	22	23	24	24	25
46-50	13*	21	23	24	26	26	27	27
51-55	14*	23	25	27	28	29	29	30
56-60	15*	24	27	28	30	31	32	32
61-65	16*	26	28	30	32	33	33	34
66-70	17*	27	30	32	33	34	35	36

Constants: foliar moisture content = 97%; CBH = 10 m; surface fuel consumption for FPMC 90.

□ = average BUI. Type of fire: surface, intermittent crown\*, continuous crown. \_ = CFB

50%.

**Table 4.9**  
**Equilibrium rate of spread (m/min)**  
**and fire intensity class**

# D-1 leafless aspen

Intensity class	
1	< 10 kW/m
2	10 - 500
3	500 - 2 000
4	2 000 - 4 000
5	4 000 - 10 000
6	> 10 000

ISI	BUI							
	0-20	21-30	31-40	41-60	61-80	81-120	121-160	161-200
1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
2	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.5
4	0.4	0.6	0.6	0.7	1	1	1	1
5	0.6	0.8	0.9	1	1	1	1	1
6	0.8	1	1	1	1	1	1	1
7	1	1	1	2	2	2	2	2
8	1	2	2	2	2	2	2	2
9	1	2	2	2	2	2	2	2
10	2	2	2	3	3	3	3	3
11	2	3	3	3	3	3	3	3
12	2	3	3	3	3	3	4	4
13	2	3	4	4	4	4	4	4
14	3	4	4	4	4	4	4	4
15	3	4	4	4	5	5	5	5
16	3	4	5	5	5	5	5	5
17	4	5	5	5	5	6	6	6
18	4	5	5	6	6	6	6	6
19	4	6	6	6	6	6	7	7
20	4	6	6	7	7	7	7	7
21-25	5	7	7	8	8	8	8	8
26-30	6	9	9	10	10	10	10	11
31-35	8	11	11	12	12	12	13	13
36-40	9	12	13	14	14	14	14	15
41-45	10	14	15	15	16	16	16	16
46-50	11	15	16	17	17	18	18	18
51-55	12	17	18	18	19	19	20	20
56-60	13	18	19	20	20	21	21	21
61-65	14	19	20	21	22	22	22	23
66-70	15	20	21	22	23	23	24	24

Note: crown fires are not expected in deciduous fuel types. □ = average BUI.

Type of fire: **surface**.



Table 4.10

Equilibrium rate of spread (m/min)  
and fire intensity class

# M-1 boreal mixedwood—leafless

75% conifer / 25% hardwood

Intensity class

1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

ISI	BUI							
	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
1	0.2	0.3	0.4	0.4	0.4	0.4	0.5	0.5
2	0.5	0.9	1	1	1	1	1	1
3	0.8	2	2	2	2	2	2	2
4	1	2	3	3	3	3*	3*	4*
5	2	3	4	4	4*	5*	5*	5*
6	2	4	5	5*	6*	6*	6*	6*
7	3	5	6*	7*	7*	7*	8*	8*
8	3	6	7*	8*	8*	9*	9*	9*
9	4	7	8*	9*	10*	10*	11*	11*
10	4	9*	10*	11*	11*	12*	12*	13
11	5	10*	11*	12*	13*	13	14	14
12	6	11*	12*	14*	14	15	16	16
13	6	12*	14*	15	16	17	17	18
14	7	13*	15*	16	17	18	19	19
15	7	14*	16	18	19	20	21	21
16	8	15*	18	19	20	21	22	23
17	9	17*	19	21	22	23	24	24
18	9	18	20	22	24	25	25	26
19	10	19	21	24	25	26	27	28
20	10	20	23	25	27	28	29	29
21–25	12	23	26	29	31	32	34	34
26–30	15	29	32	36	38	40	41	42
31–35	18*	34	38	42	44	47	48	49
36–40	20*	38	43	47	50	53	54	55
41–45	22*	42	48	52	56	58	60	61
46–50	24*	46	52	57	60	63	65	67
51–55	26	49	55	61	65	68	70	71
56–60	27	52	59	64	69	72	74	75
61–65	28	54	62	68	72	75	78	79
66–70	30	57	64	70	75	79	81	82

Constants: foliar moisture content = 97%; crown base height = 6 m. □ = average BUI.

Type of fire: surface, intermittent crown\*, continuous crown. \_ = CFB 50%.

Table 4.11

Equilibrium rate of spread (m/min)  
and fire intensity class

# M-1 boreal mixedwood—leafless

50% conifer / 50% hardwood

Intensity class	
1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

ISI	BUI							
	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
1	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3
2	0.3	0.7	0.7	0.8	0.9	0.9	0.9	0.9
3	0.6	1	1	1	2	2	2	2
4	1	2	2	2	2	2	3	3
5	1	2	3	3	3	3	4*	4*
6	2	3	4	4	4	4*	5*	5*
7	2	4	4	5	5*	5*	6*	6*
8	2	5	5	6*	6*	7*	7*	7*
9	3	6	6	7*	7*	8*	8*	8*
10	3	6	7*	8*	8*	9*	9*	9*
11	4	7	8*	9*	10*	10*	10*	11*
12	4	8	9*	10*	11*	11*	12*	12*
13	5	9	10*	11*	12*	12*	13*	13
14	5	10*	11*	12*	13*	14	14	14
15	6	11*	12*	13*	14	15	15	16
16	6	12*	13*	14*	15	16	17	17
17	6	12*	14*	15	16	17	18	18
18	7	13*	15*	17	18	18	19	19
19	7	14*	16*	18	19	20	20	21
20	8	15*	17	19	20	21	22	22
21–25	9	18*	20	22	23	24	25	26
26–30	11	22	24	27	29	30	31	31
31–35	13	25	29	32	34	35	36	37
36–40	15	29	33	36	38	40	41	42
41–45	17	32	36	40	42	44	46	47
46–50	18	35	39	43	46	48	50	51
51–55	19*	37	42	46	49	52	53	54
56–60	21*	40	45	49	52	55	57	58
61–65	22*	42	47	52	55	58	59	60
66–70	23*	43	49	54	57	60	62	63

Constants: foliar moisture content = 97%; crown base height = 6 m. □ = average BUI.

Type of fire: surface, intermittent crown\*, continuous crown. \_ = CFB 50%.

Table 4.12

Equilibrium rate of spread (m/min)  
and fire intensity class

**M-1 boreal mixedwood—leafless**  
25% conifer / 75% hardwood

Intensity class

1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

BUI

ISI	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
1	0.1 <sup>1</sup>	0.1	0.2	0.2	0.2	0.2	0.2	0.2
2	0.2	0.4	0.5	0.5	0.5	0.6	0.6	0.6
3	0.4	0.8 <sup>2</sup>	0.9	0.9	1	1	1	1
4	0.6	1	1	1	2	2	2	2
5	0.8	2	2	2	2	2	2	2
6	1	2	2	3	3	3	3	3
7	1	3	3	3 <sup>3</sup>	3	4	4	4
8	2	3	3	4	4	4	4*	4*
9	2	4	4	4	5	5*	5*	5*
10	2	4	5	5	6	6*	6*	6*
11	2	5	5	6	6*	7*	7*	7*
12	3	5	6	7 <sup>4</sup>	7*	7*	8*	8*
13	3	6	7	7*	8*	8*	8*	9*
14	3	6	7	8*	9*	9*	9*	9*
15	4	7	8	9*	9*	10*	10*	10*
16	4	8	9	9*	10*	11*	11*	11*
17	4	8	9*	10*	11*	11*	12*	12*
18	5	9	10*	11*	12*	5 <sup>5</sup>	12*	13*
19	5	9	11*	12*	12*	13*	13*	14
20	5	10	11*	12*	13*	14*	14	15
21–25	6	12*	13*	15*	16	16	17	17
26–30	8	15*	16*	18	19	20	21	21
31–35	9	17*	19	21	23	24	25	25
36–40	10	20*	22	24	26	27 <sup>6</sup>	28	28
41–45	11	22	25	27	29	30	31	32
46–50	12	24	27	30	31	33	34	35
51–55	13	26	29	32	34	35	37	37
56–60	14	27	31	34	36	38	39	40
61–65	15	29	32	36	38	40	41	42
66–70	16	30	34	37	40	42	43	44

Constants: foliar moisture content = 97%; crown base height = 6 m. □ = average BUI.

Type of fire: **surface**, **intermittent crown\***, **continuous crown**. \_ = CFB 50%.

Table 4.13

Equilibrium rate of spread (m/min)  
and fire intensity class

**M-2 boreal mixedwood—green**  
75% conifer / 25% hardwood

Intensity class

1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

ISI	BUI							
	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
1	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.5
2	0.5	0.9	1	1	1	1	1	1
3	0.8	2	2	2	2	2	2	2
4	1	2	3	3	3	3*	3*	3*
5	2	3	4	4	4*	4*	5*	5*
6	2	4	5	5*	5*	6*	6*	6*
7	3	5	6	6*	7*	7*	7*	7*
8	3	6	7*	8*	8*	8*	9*	9*
9	4	7	8*	9*	9*	10*	10*	10*
10	4	8*	9*	10*	11*	11*	12*	12*
11	5	9*	10*	12*	12*	13	13	14
12	5	10*	12*	13*	14	14	15	15
13	6	11*	13*	14*	15	16	16	17
14	7	13*	14*	16	17	17	18	18
15	7	14*	15*	17	18	19	20	20
16	8	15*	17	18	20	20	21	21
17	8	16*	18	20	21	22	23	23
18	9	17*	19	21	22	23	24	25
19	9	18	20	22	24	25	26	26
20	10	19	22	24	25	26	27	28
21–25	12	22	25	28	29	31	32	32
26–30	14	27	31	34	36	38	39	40
31–35	17*	32	36	40	42	44	46	46
36–40	19*	36	41	45	48	50	52	52
41–45	21*	40	45	49	53	55	57	58
46–50	23*	43	49	54	57	60	62	63
51–55	24*	46	52	57	61	64	66	67
56–60	25	49	55	61	65	68	70	71
61–65	27	51	58	64	68	71	73	75
66–70	28	53	60	66	70	74	76	78

Constants: foliar moisture content = 97%; crown base height = 6 m. □ = average BUI.

Type of fire: **surface**, **intermittent crown\***, **continuous crown**. — = CFB 50%.

Table 4.14

Equilibrium rate of spread (m/min)  
and fire intensity class

**M-2 boreal mixedwood—green**  
50% conifer / 50% hardwood

Intensity class

1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

BUI

ISI	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
1	0.1	0.2	0.2	0.3	0.3	0.3	0.3	0.3
2	0.3	0.6	0.7	0.7	0.8	1	1	1
3	0.6	1	1	1	1	1	2	2
4	0.8	2	2	2	2	2	2	2
5	1	2	2	3	3	3	3	3
6	1	3	3	4	4	4*	4*	4*
7	2	3	4	4	5*	5*	5*	5*
8	2	4	5	5	6*	6*	6*	6*
9	3	5	6	6*	6*	7*	7*	7*
10	3	6	6	7*	7*	8*	8*	8*
11	3	6	7*	8*	8*	9*	9*	9*
12	4	7	8*	9*	9*	10*	10*	10*
13	4	8	9*	10*	10*	11*	11*	11*
14	4	9	10*	11*	11*	12*	12*	12*
15	5	9*	11*	12*	12*	13*	13	14
16	5	10*	11*	13*	13*	14	14	15
17	6	11*	12*	13*	14	15	16	16
18	6	12*	13*	14*	15	16	17	17
19	6	12*	14*	15	16	17	18	18
20	7	13*	15*	16	17	18	19	19
21–25	8	15*	17	19	20	21	22	22
26–30	10	19*	21	23	25	26	27	27
31–35	11	22	25	27	29	30	31	32
36–40	13	25	28	31	33	34	35	36
41–45	14	27	31	34	36	38	39	40
46–50	15	30	34	37	39	41	42	43
51–55	17	32	36	39	42	44	45	46
56–60	18	34	38	42	44	47	48	49
61–65	18	35	40	44	47	49	50	51
66–70	19*	37	41	46	48	51	52	53

Constants: foliar moisture content = 97%; crown base height = 6 m. □ = average BUI.

Type of fire: **surface**, **intermittent crown\***, **continuous crown**, \_ = CFB 50%.

Table 4.15

Equilibrium rate of spread (m/min)  
and fire intensity class

# M-2 boreal mixedwood—green

25% conifer / 75% hardwood

Intensity class	
1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

ISI	BUI							
	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
1	0.1 <b>1</b>	0.1	0.1	0.1	0.1	0.2	0.2	0.2
2	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.5
3	0.3	0.6	0.6	0.7	0.7	0.8	0.8	0.8
4	0.4	0.8	<b>2</b>	1	1	1	1	1
5	0.6	1	1	1	2	2	2	2
6	0.8	2	2	2	2	2	2	2
7	1	2	2	2	2	3	3	3
8	1	2	3	3	3	3	3	3
9	1	3	3	3	3	4	4	4
10	2	3	3	<b>3</b>	4	4	4	4*
11	2	3	4	4	4	5	5*	5*
12	2	4	4	5	5	5*	5*	6*
13	2	4	5	5	6	6*	6*	6*
14	2	5	5	6	6*	6*	7*	7*
15	3	5	6	6	7*	7*	7*	7*
16	3	5	6	7	<b>4</b>	8*	8*	8*
17	3	6	7	7*	8*	8*	8*	8*
18	3	6	7	8*	8*	9*	9*	9*
19	3	7	7	8*	9*	9*	9*	10*
20	4	7	8	9*	9*	10*	10*	10*
21–25	4	8	9*	10*	11*	11*	12*	12*
26–30	5	10	11*	13*	13*	14*	14	15
31–35	6	12*	13*	15*	<b>5</b>	16	17	17
36–40	7	13*	15*	17	18	19	19	19
41–45	8	15*	17*	18	20	21	21	22
46–50	8	16*	18*	20	21	22	<b>6</b>	23
51–55	9	17*	20	21	23	24	25	25
56–60	10	18*	21	23	24	25	26	27
61–65	10	19*	22	24	25	27	27	28
66–70	10	20*	23	25	26	28	29	29

Constants: foliar moisture content = 97%; crown base height = 6 m. □ = average BUI.

Type of fire: **surface**, **intermittent crown\***, **continuous crown**, — = CFB 50%.



**Table 4.16**  
**Equilibrium rate of spread (m/min)**  
**and fire intensity class**

**M-3 dead balsam fir mixedwood—**  
**leafless, 30% dead fir**

Intensity class	
1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

ISI	BUI							
	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
1	<0.1 <b>1</b>	0.1	0.1	0.1	0.1	0.2	0.2	0.2
2	0.2	0.3 <b>2</b>	0.4	0.4	0.4	0.5	0.5	0.5
3	0.3	0.6	0.7	0.8	0.8	0.9	0.9	0.9
4	0.5	1	1	1	1	1	1	1
5	0.7	1	2	2	2	2	2	2
6	0.9	2	2	2	2	2	3*	3*
7	1	2	3	3	3	3*	3*	3*
8	1	3	3	3	4*	4*	4*	4*
9	2	3	4	4	4*	4*	5*	5*
10	2	4	4	5*	5*	5*	5*	5*
11	2	4	5	5*	6*	6*	6*	6*
12	3	5	5*	6*	6*	7*	7*	7*
13	3	5	6*	7*	7*	7*	8*	8*
14	3	6	7*	7*	8*	8*	8*	9*
15	3	6	7*	8*	9*	9*	9*	9*
16	4	7*	8*	9*	9*	10*	10*	10*
17	4	8*	9*	9*	10*	11*	11*	11*
18	4	8*	9*	10*	11*	11*	12*	12
19	5	9*	10*	11*	12*	12*	13	13
20	5	9*	11*	12*	12*	13	13 <b>6</b>	14
21–25	6	11*	13*	14	15	15	16	16
26–30	7	14*	16	17	18	19	20	20
31–35	9	17	19	21	22	23	24	24
36–40	10	19	22	24	25	27	28	28
41–45	12	22	24	27	29	30	31	31
46–50	13	24	27	30	31	33	34	35
51–55	14	26	29	32	34	36	37	38
56–60	15*	28	31	34	36	38	39	40
61–65	16*	29	33	36	39	40	42	43
66–70	16*	31	35	38	41	43	44	45

Constants: foliar moisture content = 97%; crown base height = 6 m. □ = average BUI.

Type of fire: **surface**, **intermittent crown\***, **continuous crown**. \_ = CFB 50%.

Table 4.17

Equilibrium rate of spread (m/min)  
and fire intensity class

**M-3** dead balsam fir mixedwood—  
leafless, 60% dead fir

Intensity class

1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

ISI	BUI							
	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
1	0.4	0.7	0.8	0.8	0.9	1	1	1
2	1	2	2	2	2	3	3*	3*
3	2	3	4	4*	4*	5*	5*	5*
4	3	5	6*	6*	7*	7*	7*	7*
5	4	7*	8*	8*	9*	9*	10*	10*
6	4	9*	10*	11*	11*	12*	12	13
7	5	11*	12*	13*	14	15	15	15
8	7	12*	14*	16	17	17	18	18
9	8	14*	16	18	19	20	21	21
10	9	16	19	20	22	23	24	24
11	10	18	21	23	24	25	26	27
12	11	20	23	25	27	28	29	30
13	12	22	25	28	29	31	32	32
14	13	24	27	30	32	33	35	35
15	14	26	29	32	34	36	37	38
16	15*	28	32	35	37	39	40	41
17	15*	30	34	37	39	41	42	43
18	16*	31	35	39	41	43	45	46
19	17*	33	37	41	44	46	47	48
20	18*	35	39	43	46	48	50	51
21–25	21*	39	45	49	52	55	56	57
26–30	24	46	52	57	61	64	66	67
31–35	27	52	59	64	69	72	74	76
36–40	30	57	64	70	75	78	81	82
41–45	32	60	68	75	80	84	86	88
46–50	33	64	72	79	84	88	91	93
51–55	34	66	75	82	87	92	95	96
56–60	36	68	77	85	90	95	98	99
61–65	36	70	79	87	92	97	100	102
66–70	37	71	81	88	94	99	102	104

Constants: foliar moisture content = 97%; crown base height = 6 m. □ = average BUI.

Type of fire: surface, intermittent crown\*, continuous crown, \_ = CFB 50%.



Table 4.18

Equilibrium rate of spread (m/min)  
and fire intensity class

**M-3** dead balsam fir mixedwood—  
leafless, 100% dead fir

## Intensity class

1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

BUI

ISI	0– 20	21– 30	31– 40	41– 60	61– 80	81– 120	121– 160	161– 200
1	0.9 (2)	2 (3)	2	2	2	2	2*	2*
2	2	4	5 (4)	5*	6*	6*	6*	6*
3	4	7*	8*	9* (5)	10*	10*	11*	11*
4	6	11*	12*	13*	14	15	15	15
5	7	14*	16	17	18	19	20	20
6	9	17	20	21	23	24	25	25
7	11	21	23	26	27	29	29	30
8	12	24	27	30	32	33	34	35
9	14*	27	31	34	36	38	39	40
10	16*	30	34	38	40	42	43	44
11	17*	33	38	42	44 (6)	46	48	49
12	19*	36	41	45	48	50	52	53
13	21*	39	44	49	52	54	56	57
14	22*	42	48	52	56	58	60	61
15	23	45	51	56	59	62	64	65
16	25	47	54	59	63	66	68	69
17	26	50	56	62	66	69	71	73
18	27	52	59	65	69	72	75	76
19	28	54	62	68	72	75	78	79
20	30	57	64	70	75	78	81	82
21–25	33	63	71	78	83	87	89	91
26–30	37	71	80	88	93	98	101	103
31–35	40	77	87	95	102	107	110	112
36–40	43	82	92	101	108	113	117	119
41–45	45	85	97	106	113	118	122	124
46–50	46	88	100	109	117	122	126	128
51–55	47	90	102	112	119	125	129	131
56–60	48	92	104	114	121	127	131	134
61–65	49	93	105	116	123	129	133	135
66–70	49	94	106	117	124	130	134	137

Constants: crown base height = 6 m. □ = average BUI.

Type of fire: surface, intermittent crown\*, continuous crown. \_ = CFB 50%.

Table 4.19

Equilibrium rate of spread (m/min)  
and fire intensity class

**M-4** dead balsam fir mixedwood—  
green, 30% dead fir

Intensity class

1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

ISI	BUI							
	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
1	0	1	0	0	0	0	0	0
2	<0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
3	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3
4	0.2	0.4	0.4	0.4	0.5	0.5	0.5	0.5
5	0.3	0.6	0.7	0.7	0.8	0.8	0.8	0.9
6	0.5	0.9	1	1	1	1	1	1
7	0.6	1	1	2	2	2	2	2
8	0.8	2	2	2	2	2	2	2*
9	1	2	2	3	3	3*	3*	3*
10	1	3	3	3	3*	3*	4*	4*
11	2	3	3	4	4*	4*	4*	4*
12	2	4	4	4*	5*	5*	5*	5*
13	2	4	5	5*	6*	6*	6*	6*
14	2	5	5*	6*	6*	7*	7*	7*
15	3	5	6*	7*	7*	7*	8*	8*
16	3	6	7*	8*	8*	8*	9*	9*
17	4	7*	8*	8*	9*	9*	10*	10*
18	4	7*	8*	9*	10*	10*	11*	11*
19	4	8*	9*	10*	11*	11*	12*	12*
20	5	9*	10*	11*	12*	12*	13	13
21–25	6	11*	12*	14*	14	15	16	16
26–30	7	14*	16	18	19	20	20	21
31–35	9	18	20	22	23	24	25	26
36–40	11	20	23	25	27	28	29	30
41–45	12	23	26	29	31	32	33	34
46–50	13	25	29	31	33	35	36	37
51–55	14*	27	31	34	36	38	39	40
56–60	15*	29	33	36	38	40	41	42
61–65	16*	30	34	38	40	42	43	44
66–70	16*	31	36	39	42	44	45	46

Constants: foliar moisture content = 97%; crown base height = 6 m. □ = average BUI.

Type of fire: surface, intermittent crown\*, continuous crown. \_ = CFB 50%.

Table 4.20

Equilibrium rate of spread (m/min)  
and fire intensity class

**M-4 dead balsam fir mixedwood—  
green, 60% dead fir**

Intensity class	
1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

ISI	BUI							
	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2
2	0.2	0.4	0.5	0.5	0.6	0.6	0.6	0.6
3	0.5	0.9	1	1	1	1	1	1
4	0.8	2	2	2	2	2	2	2
5	1	2	3	3	3	3*	3*	3*
6	2	3	4	4	4*	4*	5*	5*
7	2	4	5	5*	5*	6*	6*	6*
8	3	5	6*	6*	7*	7*	7*	7*
9	3	6	7*	8*	8*	9*	9*	9*
10	4	7*	8*	9*	10*	10*	11*	11*
11	4	9*	10*	11*	11*	12*	12	13
12	5	10*	11*	12*	13	14	14	14
13	6	11*	13*	14	15	15	16	16
14	6	12*	14*	15	16	17	18	18
15	7	14*	15	17	18	19	20	20
16	8	15*	17	19	20	21	21	22
17	9	16	18	20	22	23	23	24
18	9	18	20	22	23	24	25	26
19	10	19	21	24	25	26	27	28
20	11	20	23	25	27	28	29	29
21–25	13	24	27	30	32	33	34	35
26–30	16*	30	34	37	40	42	43	44
31–35	18*	35	40	44	47	49	51	52
36–40	21*	40	45	50	53	56	57	58
41–45	23*	44	50	55	58	61	63	64
46–50	25	48	54	59	63	66	68	69
51–55	26	51	57	63	67	70	72	74
56–60	28	53	60	66	70	73	76	77
61–65	29	55	62	68	73	76	79	80
66–70	30	57	64	70	75	79	81	83

Constants: foliar moisture content = 97%; crown base height = 6 m. □ = average BUI.

Type of fire: surface, intermittent crown\*, continuous crown. \_ = CFB 50%.

Table 4.21

Equilibrium rate of spread (m/min)  
and fire intensity class

**M-4 dead balsam fir mixedwood—  
green, 100% dead fir**

Intensity class

1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

ISI	BUI							
	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
1	0.4	0.7	0.8	0.8	0.9	0.9	1	1
2	1	2	2	2	2	3	3*	3*
3	2	3	4	4	4*	5*	5*	5*
4	3	5	5*	6*	6*	7*	7*	7*
5	3	7	7*	8*	9*	9*	9*	10*
6	4	8*	9*	10*	11*	12*	12*	12
7	5	10*	12*	13*	13	14	15	15
8	6	12*	14*	15	16	17	17	18
9	7	14*	16	17	18	19	20	20
10	8	16*	18	20	21	22	23	23
11	9	18	20	22	23	25	25	26
12	10	20	22	24	26	27	28	29
13	11	22	24	27	28	30	31	31
14	12	23	26	29	31	32	33	34
15	13	25	28	31	33	35	36	37
16	14*	27	31	33	36	37	39	39
17	15*	29	32	36	38	40	41	42
18	16*	30	34	38	40	42	44	44
19	17*	32	36	40	42	45	46	47
20	18*	34	38	42	45	47	48	49
21–25	20*	38	43	48	51	53	55	56
26–30	24*	45	51	56	60	63	65	65
31–35	27	51	58	64	68	71	74	75
36–40	29	56	64	70	75	78	81	82
41–45	32	61	68	75	80	84	87	88
46–50	34	64	73	80	85	89	92	94
51–55	35	67	76	83	89	93	96	98
56–60	36	70	79	86	92	96	100	101
61–65	37	72	81	89	95	100	102	104
66–70	38	73	83	91	97	105	105	106

Constants: crown base height = 6 m. □ = average BUI.

Type of fire: surface, intermittent crown\*, continuous crown. \_ = CFB 50%.

Table 4.22

Equilibrium rate of spread (m/min)  
and fire intensity class

# S-1 jack or lodgepole pine slash

Intensity class

1	< 10 kW/m
2	10 - 500
3	500 - 2 000
4	2 000 - 4 000
5	4 000 - 10 000
6	> 10 000

BUI

ISI	0-20	21-30	31-40	41-60	61-80	81-120	121-160	161-200
1	0.3 (2)	0.6 (3)	0.7	0.8	0.9	1	1	1
2	0.7	2	2 (4)	2	2	2	2	2
3	1	3	3	3 (5)	4	4	4	4
4	2	4	4	5	5	6	6	6
5	2	5	6	6	7	7	8	8
6	3	6	7	8	8	9	9	10
7	3	7	8	9	10	11	11	11
8	4	8	10	11	12	13	13	13
9	4	9	11	13	14	14	15	15
10	5	11	12	14	15	16	17	17
11	5	12	14	16	17	18	19	19
12	6	13	15	17 (6)	19	20	21	21
13	6	14	17	19	20	22	23	23
14	7	15	18	20	22	23	24	25
15	7	16	19	22	24	25	26	27
16	8	18	21	23	25	27	28	29
17	8	19	22	25	27	29	30	30
18	9	20	23	26	28	30	31	32
19	9	21	24	28	30	32	33	34
20	9	22	26	29	31	33	35	36
21-25	11	25	29	33	36	38	40	41
26-30	13	30	35	39	42	45	47	48
31-35	15	34	40	45	48	51	54	55
36-40	16	37	44	50	54	57	59	61
41-45	18	41	48	54	58	62	65	66
46-50	19	44	51	58	62	66	69	71
51-55	20	46	54	61	66	70	73	75
56-60	21	48	57	64	69	73	77	78
61-65	22	50	59	66	72	76	80	81
66-70	22	52	61	68	74	79	82	84

Type of fire: **surface**. ☐ = average BUI.

Table 4.23

Equilibrium rate of spread (m/min)  
and fire intensity class

# S-2 white spruce/balsam slash

Intensity class

1	< 10 kW/m
2	10 - 500
3	500 - 2 000
4	2 000 - 4 000
5	4 000 - 10 000
6	> 10 000

ISI	BUI							
	0-20	21-30	31-40	41-60	61-80	81-120	121-160	161-200
1	0.1 (2)	0.1	0.2	0.2	0.2	0.2	0.2	0.2
2	0.2	0.4 (3)	0.5	0.6	0.6	0.6	0.7	0.7
3	0.4	0.8	1 (4)	1	1	1	1	1
4	0.6	1	1	2	2 (5)	2	2	2
5	0.8	2	2	2	3	3	3	3
6	1	2	3	3	3	4	4	4
7	1	3	3	4	4	5	5	5
8	2	4	4	5	5	5	6	6
9	2	4	5	6	6	6	7	7
10	2	5	6	6	7	7	8	8
11	2	6	7	7 (6)	8	8	9	9
12	3	6	7	8	9	10	10	10
13	3	7	8	9	10	11	11	11
14	3	8	9	10	11	12	12	12
15	4	8	10	11	12	13	13	13
16	4	9	10	12	13	14	14	14
17	4	10	11	13	14	15	15	16
18	4	10	12	13	15	16	16	17
19	5	11	13	14	16	16	17	18
20	5	11	13	15	16	17	18	19
21-25	6	13	15	17	19	20	21	21
26-30	7	16	19	21	23	24	25	26
31-35	8	18	21	24	26	28	29	29
36-40	9	20	23	26	29	30	32	32
41-45	9	22	25	29	31	33	34	35
46-50	10	23	27	30	33	35	36	37
51-55	10	24	28	32	34	37	38	39
56-60	11	25	29	33	36	38	39	40
61-65	11	26	30	34	37	39	41	42
66-70	11	26	31	35	38	40	42	42

Type of fire: **surface**. □ = average BUI.



Table 4.24

Equilibrium rate of spread (m/min)  
and fire intensity class

**S-3** coastal cedar/hemlock/  
Douglas-fir slash

Intensity class

1	< 10 kW/m
2	10 - 500
3	500 - 2 000
4	2 000 - 4 000
5	4 000 - 10 000
6	> 10 000

ISI	BUI							
	0- 20	21- 30	31- 40	41- 60	61- 80	81- 120	121- 160	161- 200
1	0	0	0	0	0	0	0	<0.1
2	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2
3	0.2	0.4	0.5	0.5	0.6	0.6	0.6	0.6
4	0.4	0.9	1	1	1	1	1	1
5	0.7	2	2	2	2	2	2	3
6	1	2	3	3	4	4	4	4
7	2	4	4	5	5	5	6	6
8	2	5	6	6	7	7	8	8
9	3	6	7	8	9	10	10	10
10	3	8	9	10	11	12	13	13
11	4	10	11	13	14	15	15	16
12	5	11	13	15	16	17	18	18
13	6	13	15	17	19	20	21	21
14	6	15	18	20	21	23	24	24
15	7	17	20	22	24	26	27	27
16	8	19	22	25	27	28	29	30
17	9	20	24	27	29	31	32	33
18	10	22	26	29	32	34	35	36
19	10	24	28	31	34	36	38	38
20	11	25	30	33	36	39	40	41
21-25	13	30	35	39	43	45	47	48
26-30	15	36	42	47	51	54	57	58
31-35	17	40	47	53	58	61	64	65
36-40	19	43	51	57	62	66	69	70
41-45	20	45	53	60	65	69	72	74
46-50	20	47	55	62	67	71	74	76
51-55	21	48	56	63	69	73	76	78
56-60	21	48	57	64	69	74	77	79
61-65	21	49	57	65	70	75	78	79
66-70	21	49	58	65	71	75	78	80

Type of fire: **surface.** ☐ = average BUI.

**Table 4.25**  
**Equilibrium rate of spread (m/min)**  
**and fire intensity class**  
**O-1a matted grass**

Intensity class	
1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

ISI	Degree of curing (%)					
	0–50	51–60	61–70	71–80	81–90	91–100
1	0	0.2	0.4	0.7	1	1
2	0	0.4	1	2	3	3
3	0	0.7	2	3	5	6
4	0	1	3	5	7	9
5	0	1	4	6	9	11
6	0	2	5	8	11	14
7	0	2	6	10	14	18
8	0	3	7	12	16	21
9	0	3	8	13	19	24
10	0	3	9	15	21	27
11	0	4	10	17	24	30
12	0	4	11	19	26	34
13	0	4	13	21	29	37
14	0	5	14	22	31	40
15	0	5	15	24	34	43
16	0	6	16	26	36	46
17	0	6	17	28	39	50
18	0	6	18	30	41	53
19	0	7	19	31	43	56
20	0	7	20	33	46	59
21–25	0	8	23	38	53	67
26–30	0	10	27	45	63	81
31–35	0	11	32	52	72	93
36–40	0	12	35	58	81	103
41–45	0	14	38	63	88	113
46–50	0	15	41	68	94	121
51–55	0	15	44	72	100	128
56–60	0	16	46	75	105	134
61–65	0	17	48	78	109	140
66–70	0	17	49	81	113	144

Constants: surface fuel load = 3 t/ha.  
 Type of fire: **surface**.



**Table 4.26**  
**Equilibrium rate of spread (m/min)**  
**and fire intensity class**

# **O-1b standing grass**

## Intensity class

1	< 10 kW/m
2	10 – 500
3	500 – 2 000
4	2 000 – 4 000
5	4 000 – 10 000
6	> 10 000

## Degree of curing (%)

ISI	0-50	51-60	61-70	71-80	81-90	91-100
1	0	0.1	0.3	0.4	0.6	0.7
2	0	0.3	0.8	1	2	2
3	0	0.6	2	3	4	5
4	0	0.8	2	4	6	7
5	0	1	3	6	8	10
6	0	2	5	8	10	13
7	0	2	6	10	13	17
8	0	3	7	12	16	21
9	0	3	8	14	19	25
10	0	3	10	16	22	29
11	0	4	11	18	26	33
12	0	4	13	21	29	37
13	0	5	14	23	32	41
14	0	5	15	25	35	45
15	0	6	17	28	39	50
16	0	7	18	30	42	54
17	0	7	20	33	45	58
18	0	8	21	35	49	62
19	0	8	23	37	52	67
20	0	9	24	40	55	71
21-25	0	10	28	47	65	83
26-30	0	12	35	57	80	102
31-35	0	14	41	67	93	120
36-40	0	16	46	76	105	135
41-45	0	18	51	83	116	148
46-50	0	19	55	90	125	160
51-55	0	21	58	95	133	170
56-60	0	22	61	100	140	179
61-65	0	23	64	105	146	187
66-70	0	23	66	108	150	193

Constants: surface fuel load = 3 t/ha.  
Type of fire: **surface**.

Table 5.1

# Spread distance (m)

equilibrium ROS: all fuel types  
 accelerating ROS: open fuels and  
 surface fires in closed fuel types

Equi-  
librium

Elapsed time

ROS	15 min		30 min		45 min		1 h		2 h		3 h	
0.2	3	2	6	4	9	7	12	10	24	22	36	34
0.4	6	3	12	9	18	15	24	21	48	45	72	69
0.6	9	5	18	13	27	22	36	31	72	87	108	103
0.8	12	6	24	17	36	29	48	41	96	89	144	137
1	15	8	30	22	45	36	60	51	120	111	180	171
2	30	16	60	43	90	73	120	103	240	223	360	343
3	45	24	90	65	135	109	180	154	360	334	540	514
4	60	31	120	86	180	145	240	205	480	445	720	685
5	75	39	150	108	225	182	300	257	600	557	900	857
6	90	47	180	129	270	218	360	308	720	668	1080	1028
7	105	55	210	151	315	254	420	359	840	779	1260	1199
8	120	63	240	173	360	291	480	411	960	890	1440	1370
9	135	71	270	194	405	327	540	462	1080	1002	1620	1542
10	150	79	300	216	450	364	600	513	1200	1113	1800	1713
12	180	94	360	259	540	436	720	616	1440	1336	2160	2056
14	210	110	420	302	630	509	840	718	1680	1558	2520	2398
16	240	126	480	345	720	582	960	821	1920	1781	2880	2741
18	270	141	540	388	810	654	1080	924	2160	2003	3240	3083
20	300	157	600	432	900	727	1200	1026	2400	2226	3600	3426
25	375	196	750	540	1125	909	1500	1283	3000	2783	4500	4283
30	450	236	900	647	1350	1091	1800	1539	3600	3339	5400	5139
35	525	275	1050	755	1575	1272	2100	1796	4200	3896	6300	5996
40	600	314	1200	863	1800	1454	2400	2053	4800	4452	7200	6852
45	675	353	1350	971	2025	1636	2700	2309	5400	5009	8100	7709
50	750	393	1500	1079	2250	1818	3000	2566	6000	5565	9000	8565
55	825	432	1650	1187	2475	1999	3300	2822	6600	6122	9900	9422
60	900	471	1800	1295	2700	2181	3600	3079	7200	6678	10800	10278
65	975	510	1950	1403	2925	2363	3900	3335	7800	7235	11700	11135
70	1050	550	2100	1511	3150	2545	4200	3592	8400	7791	12600	11991
75	1125	589	2250	1619	3375	2727	4500	3848	9000	8348	13500	12848
80	1200	628	2400	1726	3600	2908	4800	4105	9600	8904	14400	13704
85	1275	668	2550	1834	3825	3090	5100	4362	10200	9461	15300	14561
90	1350	707	2700	1942	4050	3272	5400	4618	10800	10017	16200	15417
95	1425	746	2850	1942	4275	3454	5700	4875	11400	10574	17100	16417
100	1500	785	3000	2168	4500	3635	6000	5131	12000	11130	18000	17130

Red figures are distances for equilibrium ROS in all fuel types.

Black figures are distances for accelerating ROS in open fuel types and surface fires ( $\leq 10\%$  CFB) in closed fuel types. Open fuel types are C-1, D-1, O-1, S-1, S-2, S-3 (C-2, C-7). C-2 and C-7 are considered open types when the crown closure is less than 50%.

Table 5.2

# Spread distance(m)

accelerating ROS:  
crown fires in closed fuel types

Equilibrium ROS	Elapsed time											
	15 min		30 min		45 min		1 h		2 h		3 h	
0.2	1	1	3	4	6	7	8	10	21	22	32	34
0.4	2	3	8	8	11	14	17	20	41	44	65	68
0.6	3	4	9	12	17	21	25	30	61	66	97	102
0.8	4	6	12	17	23	28	34	40	81	88	129	136
1	5	7	15	21	28	35	42	50	102	110	162	170
2	9	15	30	42	56	71	84	101	203	221	323	341
3	14	22	46	62	84	106	127	151	305	331	485	511
4	19	30	61	83	113	142	169	202	406	442	646	682
5	24	37	76	104	141	177	211	252	508	552	808	852
6	28	44	91	125	169	213	253	303	609	662	969	1022
7	33	52	106	146	197	248	296	353	711	773	1131	1193
8	38	59	121	167	225	284	338	403	812	883	1292	1363
9	43	67	137	187	253	319	380	454	914	994	1454	1534
10	47	74	152	208	281	355	422	504	1016	1104	1615	1704
12	57	89	182	250	338	426	507	605	1219	1325	1938	2045
14	66	104	212	292	394	497	591	706	1422	1546	2261	2386
16	78	119	243	333	450	568	676	807	1625	1766	2584	2726
18	85	133	273	375	507	639	780	908	1828	1987	2907	3067
20	95	148	303	417	563	710	845	1008	2031	2208	3231	3408
25	118	185	379	521	704	887	1068	1261	2539	2760	4038	4260
30	142	222	455	625	884	1065	1267	1513	3047	3312	4846	5112
35	165	260	531	729	985	1242	1479	1765	3554	3864	5653	5964
40	189	297	607	833	1126	1420	1690	2017	4062	4416	6461	6816
45	213	334	683	937	1266	1597	1901	2269	4570	4968	7269	7668
50	236	371	758	1041	1407	1775	2112	2521	5078	5520	8076	8520
55	260	408	834	1145	1548	1952	2323	2773	5585	6072	8884	9372
60	284	445	910	1250	1689	2130	2535	3025	6093	6624	9692	10224
65	307	482	986	1354	1829	2307	2746	3277	6601	7176	10499	11076
70	331	519	1062	1458	1970	2484	2957	3530	7109	7728	11307	11928
75	355	556	1138	1562	2111	2662	3168	3782	7617	8280	12115	12780
80	378	593	1213	1668	2251	2839	3380	4034	8124	8832	12922	13632
85	402	630	1288	1770	2392	3017	3591	4286	8632	9384	13730	14484
90	426	667	1365	1874	2533	3194	3802	4538	9140	9936	14537	15336
95	449	704	1441	1978	2674	3372	4013	4790	9648	10488	15345	16188
100	473	741	1517	2083	2814	3549	4224	5042	10155	11040	16153	17040

Black figures are distances for intermittent crown fires with 50% CFB.

Red figures are distances for continuous crown fires with 90% CFB.

Table 6.1

# Fire area(ha)

## Perimeter(m) timber and slash fuel types

Spread

Effective wind speed (km/h)

distance	0	5	10	15	20	25	30	35	40	45	50
25	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	79	74	66	61	57	55	54	53	52	52	52
50	0.2	0.2	0.1	0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	157	148	133	121	114	110	108	106	105	104	103
100	1	1	1	0.4	0.3	0.2	0.2	0.2	0.2	0.1	0.1
	314	297	266	243	229	220	215	212	209	208	206
150	2	2	1	1	1	1	0.5	0.4	0.4	0.3	0.3
	471	445	399	364	343	330	323	317	314	312	310
200	3	3	2	2	1	1	1	1	1	1	1
	628	594	532	486	457	441	430	423	419	415	413
250	5	4	3	2	2	2	1	1	1	1	1
	785	742	665	607	572	551	538	529	523	519	516
300	7	6	5	4	3	2	2	2	1	1	1
	942	891	798	728	686	661	645	635	628	623	619
400	13	11	9	6	5	4	3	3	2	2	2
	1257	1188	1064	971	915	881	860	847	837	831	826
500	20	17	13	10	8	6	5	4	4	4	3
	1571	1485	1330	1214	1144	1102	1075	1058	1047	1038	1032
600	28	25	19	14	11	9	7	6	6	5	5
	1885	1782	1596	1457	1372	1322	1290	1270	1256	1246	1239
800	50	45	34	25	20	16	13	11	10	9	8
	2513	2376	2128	1943	1830	1762	1720	1693	1675	1661	1652
1000	79	70	53	40	31	25	20	18	16	14	13
	3142	2970	2660	2428	2287	2203	2151	2116	2093	2077	2065
1200	113	101	77	57	44	35	29	25	22	20	19
	3770	3564	3192	2914	2745	2644	2581	2540	2512	2492	2478
1500	177	157	120	89	69	55	46	40	35	32	29
	4712	4455	3989	3642	3431	3305	3226	3175	3140	3115	3097
2000	314	279	213	159	122	98	82	71	62	56	52
	6283	5940	5319	4857	4575	4406	4301	4233	4187	4154	4130
2500	491	436	333	248	191	153	128	110	98	88	81
	7854	7425	6649	6071	5718	5508	5376	5291	5233	5192	5162
3000	707	628	479	357	275	221	184	159	140	127	117
	9425	8910	7979	7285	6862	6609	6452	6349	6280	6231	6195
4000	1257	1117	852	635	489	393	328	282	250	226	207
	12566	11880	10638	9713	9149	8812	8602	8466	8373	8307	8260
5000	1963	1746	1331	992	764	613	512	441	390	352	324
	15708	14849	13298	12141	11437	11015	10753	10582	10466	10384	10324
LB	1.0	1.1	1.5	2.0	2.6	3.3	3.8	4.4	5.0	5.6	6.1

Red figures are area. Black figures are perimeter length.

Note: in some cases interpolation may be required to obtain a precise value.

Table 6.2

Fire area (ha)

Perimeter (m) grass fuel types

Spread distance

Effective wind speed (km/h)

	0	5	10	15	20	25	30	35	40	45	50
25	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	79	58	55	54	53	52	52	52	52	51	51
50	0.2	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
	157	117	110	107	106	105	104	104	103	103	103
100	1	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1
	314	234	220	215	212	210	208	207	206	206	205.2
150	2	1	1	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.3
	471	350	330	322	318	315	313	311	310	309	308
200	3	1	1	1	1	1	1	1	1	0.5	0.5
	628	467	441	430	424	420	417	415	413	411	410
250	5	2	2	1	1	1	1	1	1	1	1
	785	584	551	537	530	525	521	518	516	514	513
300	7	3	2	2	2	1	1	1	1	1	1
	942	701	661	645	635	629	625	622	619	617	615
400	13	5	4	3	3	3	2	2	2	2	2
	1257	935	881	859	847	839	833	829	826	823	821
500	20	8	6	5	4	4	4	3	3	3	3
	1571	1168	1101	1074	1059	1049	1042	1036	1032	1029	1026
600	28	12	9	7	6	6	5	5	5	4	4
	1885	1402	1322	1289	1271	1259	1250	1244	1239	1234	1231
800	50	22	16	13	11	10	9	9	8	8	7
	2513	1869	1762	1719	1694	1678	1667	1658	1651	1646	1641
1000	79	34	25	20	18	16	15	14	13	12	12
	3142	2336	2203	2149	2118	2098	2084	2073	2064	2057	2052
1200	113	49	35	29	26	23	21	20	19	18	17
	3770	2804	2643	2578	2542	2518	2500	2487	2477	2469	2462
1500	177	76	55	46	40	36	33	31	29	27	26
	4712	3505	3304	3223	3177	3147	3126	3109	3096	3086	3077
2000	314	135	98	81	71	64	59	55	52	49	46
	6283	4673	4406	4297	4236	4196	4167	4146	4129	4115	4103
2500	491	211	153	127	111	100	92	86	81	76	73
	7854	5841	5507	5372	5295	5245	5209	5182	5161	5143	5129
3000	707	305	221	183	160	144	133	123	116	110	105
	9425	7009	6609	6446	6354	6294	6251	6219	6193	6172	6155
4000	1257	541	392	325	285	257	236	219	206	195	186
	12566	9346	8812	8595	8472	8392	8335	8291	8257	8229	8206
5000	1963	846	613	508	445	401	368	343	322	305	291
	15708	11682	11015	10743	10590	10490	10419	10364	10322	10287	10258
LB	1.0	2.3	3.2	3.5	4.4	4.9	5.3	5.7	6.1	6.4	6.8

Red figures are area. Black figures are perimeter length.

Note: in some cases interpolation may be required to obtain a precise value.



**Table 7.1**  
**Perimeter growth rate (m/min)**  
**PGR timber and slash fuel types**

Equilibrium ROS	Effective wind speed (km/h)										
	0	5	10	15	20	25	30	35	40	45	50
0.2	1	1	1	<1	<1	<1	<1	<1	<1	<1	<1
0.4	1	1	1	1	1	1	1	1	1	1	1
0.6	2	2	2	1	1	1	1	1	1	1	1
0.8	3	2	2	2	2	2	2	2	2	2	2
1	3	3	3	2	2	2	2	2	2	2	2
2	6	6	5	5	5	4	4	4	4	4	4
3	9	9	8	7	7	7	6	6	6	6	6
4	13	12	11	10	9	9	9	8	8	8	8
5	16	15	13	12	11	11	11	11	10	10	10
6	19	18	16	15	14	13	13	13	13	12	12
7	22	21	19	17	16	15	15	15	15	15	14
8	25	24	21	19	18	18	17	17	17	17	17
9	28	27	24	22	21	20	19	19	19	19	19
10	31	30	27	24	23	22	22	21	21	21	21
12	38	36	32	29	27	26	26	25	25	25	25
13	41	39	35	32	30	29	28	28	27	27	27
14	44	42	37	34	32	31	30	30	29	29	29
15	47	45	40	36	34	33	32	32	31	31	31
16	50	48	43	39	37	35	34	34	33	33	33
17	53	50	45	41	39	37	37	36	36	35	35
18	57	53	48	44	41	40	39	38	38	37	37
20	63	59	53	49	46	44	43	42	42	42	41
25	79	74	66	61	57	55	54	53	52	52	52
30	94	89	80	73	69	66	65	63	63	62	62
35	110	104	93	85	80	77	75	74	73	73	72
40	126	119	106	97	91	88	86	85	84	83	83
45	141	134	120	109	103	99	97	95	94	93	43
50	157	148	133	121	114	110	108	106	105	104	103
55	173	163	146	134	126	121	118	116	115	114	114
60	188	178	160	146	137	132	129	127	126	125	124
65	204	193	173	158	149	143	140	138	136	135	134
70	220	208	186	170	160	154	151	148	147	145	145
75	236	223	199	182	172	165	161	159	157	156	155
80	251	238	213	194	183	176	172	169	167	166	165
85	267	252	239	219	206	198	194	190	188	187	186
90	283	267	239	219	206	198	194	190	188	187	186
95	298	282	253	231	217	209	204	201	199	197	196
100	314	297	266	243	229	220	215	212	209	208	206

Note: in some cases interpolation may be required to obtain a precise value.

**Table 7.2**  
**Perimeter growth rate (m/min)**  
**PGR grass fuel types**

Equi- librium ROS	Effective wind speed (km/h)										
	0	5	10	15	20	25	30	35	40	45	50
0.2	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
0.4	1	1	1	1	1	1	1	1	1	1	1
0.6	2	1	1	1	1	1	1	1	1	1	1
0.8	3	2	2	2	2	2	2	2	2	2	2
1	3	2	2	2	2	2	2	2	2	2	2
2	6	5	4	4	4	4	4	4	4	4	4
3	9	7	7	6	6	6	6	6	6	6	6
4	13	9	9	9	8	8	8	8	8	8	8
5	16	12	11	11	11	10	10	10	10	10	10
6	19	14	13	13	13	13	13	12	12	12	12
7	22	16	15	15	15	15	15	15	14	14	14
8	25	19	18	17	17	17	17	17	17	16	16
9	28	21	20	19	19	19	19	19	19	19	18
10	31	23	22	21	21	21	21	21	21	21	21
12	38	28	26	26	25	25	25	25	25	25	25
13	41	30	29	28	28	27	27	27	27	27	27
14	44	33	31	30	30	29	29	29	29	29	29
15	47	35	33	32	32	31	31	31	31	31	31
16	50	37	35	34	34	34	33	33	33	33	33
17	53	40	37	37	36	36	35	35	35	35	35
18	57	42	40	39	38	38	38	37	37	37	37
20	63	47	44	43	42	42	42	41	41	41	41
25	79	58	55	54	53	52	52	52	52	51	51
30	94	70	66	64	64	63	63	62	62	62	62
35	110	82	77	75	74	73	73	73	72	72	72
40	126	93	88	86	85	84	83	83	83	82	82
45	141	105	99	97	95	94	94	93	93	93	92
50	157	117	110	107	106	105	104	104	103	103	103
55	173	129	121	118	116	115	115	114	114	113	113
60	188	140	132	129	127	126	125	124	124	123	123
65	204	152	143	140	138	136	135	135	134	134	133
70	220	164	154	150	148	147	146	145	145	144	144
75	236	175	165	161	159	157	156	155	155	154	154
80	251	187	176	172	169	168	167	166	165	165	164
85	267	199	187	183	180	178	177	176	175	175	174
90	283	210	198	193	191	189	188	187	186	185	185
95	298	222	209	204	201	199	198	197	196	195	195
100	314	234	220	215	212	210	208	207	206	206	205

Note: in some cases interpolation may be required to obtain a precise value.

## References

- Alexander, M.E.; De Groot, W.J. 1988. Fire behavior in jack pine stands as related to the Canadian Forest Fire Weather Index (FWI) System. Can. For. Serv., North. For. Cent., Edmonton, Alberta. Poster (with text).
- Alexander, M.E.; Lanoville, R.A. 1989. Predicting fire behavior in the black spruce-lichen woodland fuel type of western and northern Canada. For. Can., North. For. Cent., Edmonton, Alberta and Gov. N.W.T., Dep. Renewable Resour., Territ. For. Fire Cent., Fort Smith, N.W.T. Poster (with text).
- Alexander, M.E.; Lawson, B.D.; Stocks, B.J.; Van Wagner, C.E. 1984. User guide to the Canadian Forest Fire Behavior Prediction System: rate of spread relationships. Interim ed. Environ. Can., Can. For. Serv., Fire Danger Group, Ottawa, Ontario.
- Cole, F.V.; Alexander, M.E. 1995. Head fire intensity class graph for FBP System fuel type C-2 (Boreal Spruce). Alaska Dep. Nat. Resour., Div. For., Fairbanks, Alaska and Can. For. Serv., North. For. Cent., Edmonton, Alberta. Poster (with text).
- De Groot, W.J. 1993. Examples of fuel types in the Canadian Forest Fire Behavior Prediction (FBP) System. For. Can., Northwest Reg., North For. Cent., Edmonton, Alberta. Poster (with text).
- Forestry Canada Fire Danger Group. 1992. Development and structure of the Canadian Forest Fire Behavior Prediction System. For. Can., Sci. Sustainable Dev. Dir., Ottawa, Ontario. Inf. Rep. ST-X-3.
- Hirsch, K.G. 1996. Canadian Forest Fire Behavior Prediction (FBP) System: user's guide. Nat. Resour. Can., Can. For. Serv., Northwest Reg., North For. Cent., Edmonton, Alberta. Spec. Rep. 7.
- Lawson, B.D.; Armitage, O.B.; Hoskins, W.D. 1996. Diurnal variation in the Fine Fuel Moisture Code: tables and source code. Can. For. Serv., Pac. For. Cent., Victoria, British Columbia and B.C. Minist. For., Res. Branch, Victoria, British Columbia. Canada - British Columbia Partnership Agreement on Forest Resource Development: FRDA II. FRDA Rep. 245.
- List, R.J. 1951. Smithsonian meteorological tables. 6th rev. ed. Smithsonian Inst. Press, Washington, D.C.
- McAlpine, R.S. 1986. Forest fire growth calculator. Can. For. Serv., North. For. Cent., Edmonton, Alberta. For. Manage. Note 35.
- Merrill, D.F. and M.E. Alexander, eds. 1987. Glossary of forest fire management terms. 4th ed. Natl. Res. Coun. Can., Can. Comm. For. Fire Manage., Ottawa, Ontario. Publ. NRCC 26516.



# Appendix 1 Abbreviations

BUI	Buildup Index
CBH	Crown base height (m)
CFB	Crown fraction burned
FFMC	Fine Fuel Moisture Code
ISI	Initial Spread Index
LB	Length-to-breadth ratio
PC	Percent conifer
PDF	Percent dead fir
PH	Percent hardwood
PGR	Perimeter growth rate (m/min)
ROS	Rate of spread (m/min)

## Appendix 2 Glossary

**Buildup Index (BUI)** - A numerical rating of the total amount of fuel available for combustion that combines the Duff Moisture Code (DMC) and Drought Code (DC) components of the Canadian Forest Fire Weather Index System. In the FBP System, a buildup effect is applied to the primary ISI-based spread equations to represent the effect of increasing fuel consumption on rate of spread.

**Crown fraction burned (CFB)** - A measure of crown fuel consumption expressed as a percentage of the total preburn crown fuel load. The following descriptive classes are recognized in the FBP System:

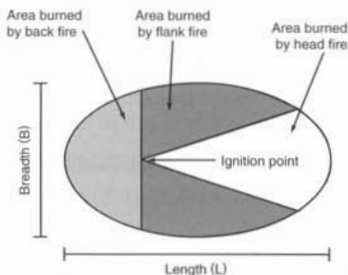
Crown fraction burned	Type of fire
< 10%	surface fire
10-89%	intermittent crown fire
> 90%	continuous crown fire

**Crown base height (CBH)** - The height, above ground, where the live crown of coniferous trees begins. This value is held constant in each FBP System fuel type except C-6.

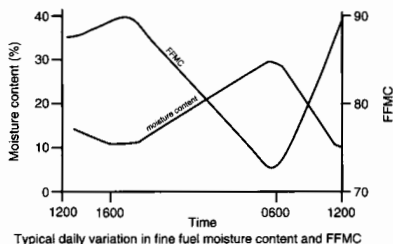
**Degree of Curing** - The proportion of cured and/or dead plant material in a grassland fuel complex.

**Effective wind speed** - The sum of the vectors of the observed wind speed and the slope equivalent wind speed.

**Elliptical fire growth model** - Theory: a free-burning point source fire is an ellipse when fuels are uniform and continuous, topography is homogeneous, wind speed is constant and unidirectional, and the fire is unaffected by suppression activities. The length of the ellipse is the sum of the head fire spread distance and the back fire spread distance. Fire shape or length-to-breadth ratio (LB) is determined by the wind speed. Fire area and perimeter length are calculated from the total spread distance and the LB ratio.



**Fine Fuel Moisture Code (FFMC)** - A numerical rating of the moisture content of litter and other cured fine fuels. This code indicates the relative ease of ignition and flammability of fine fuel. Fine fuel moisture content varies over a daily or diurnal cycle. The standard daily FFMC is calculated from noon weather observations, but represents fine fuel moisture at 1600 LST, when the fine fuel moisture content is at or near the daily minimum. The diurnal FFMC is an estimate of the FFMC at a particular hour, based on the typical daily variation in temperature and relative humidity in the absence of rain. The hourly FFMC is calculated from actual hourly weather observations.



**Fire intensity** - The rate of heat energy release per unit time per unit length of fire front. Frontal fire intensity is a major determinant of certain fire effects and difficulty of control. Numerically, it is equal to the product of the net heat of combustion, the quantity of fuel consumed in the flaming front and the linear rate of spread.

**Fire perimeter** - The entire outer edge or boundary of a fire. See elliptical fire growth model.

**Foliar moisture content** - The percent moisture content by weight of live conifer needles that are at least 1 year old.

**Initial Spread Index (ISI)** - A numerical rating of the expected rate of fire spread. It combines the effects of wind, slope, and FFMC on rate of spread but excludes the influence of the variable quantities of fuel.

**Length-to-breadth ratio (LB)** - See elliptical fire growth model.

**Rate of spread (ROS)** - The speed at which a fire extends its horizontal dimensions, expressed in terms of distance per unit of time. Generally thought of in terms of a fire's forward movement, or head fire rate of spread, but also applicable to back fire and flank fire ROS.

**Slope equivalent wind speed** - An approach used in the FBP System whereby the effect of slope on fire spread with zero wind is given a value in units of wind speed.

**Type of fire** - See crown fraction burned.

## Appendix 3 Photographic examples of FBP System fuel types<sup>1</sup>

The Canadian Forest Fire Behavior Prediction (FBP) System models rate of spread, fuel consumption, fire intensity, and fire growth for 16 national benchmark fuel types. A detailed description of the FBP System fuel types (stand structure, surface and ladder fuels) can be found in Forestry Canada Fire Danger Group (1992). The following photographs show the benchmark or most representative example of the stands used to develop the FBP System. The pole in the photographs is 180-cm tall. Additional photographs showing typical variations in stand structure and composition (indicating the range of condition to which each fuel type is applicable) are found in the poster by De Groot (1993)



**C-1 Spruce-Lichen Woodland** Open black spruce stands with lichen understory.

<sup>1</sup>Adapted from De Groot, W.J. 1993. Examples of fuel types in the Canadian Forest Fire Behavior Prediction (FBP) System. For. Can., Northwest Reg., North. For. Cent., Edmonton, Alberta. Poster (with text).



**C-2 Boreal Spruce** Upland and lowland black spruce, white and Engelmann spruce stands. Does not include spruce-sphagnum bogs. This photograph shows upland black spruce.



**C-3 Mature Jack or Lodgepole Pine** Fully stocked mature jack and lodgepole pine stands. This photograph shows a jack pine stand.



**C-4 Immature Jack or Lodgepole Pine Stands** Densely stocked immature jack and lodgepole pine stands. This photograph shows a jack pine stand.



**C-5 Red and White Pine** Mature red and white pine stands.





**C-6 Conifer Plantation** This fuel type is applicable to all conifer plantations with closed crown canopy and no understory shrub layer. This photograph shows a red pine plantation.



**C-7 Ponderosa Pine/Douglas-fir** Mixed stands of uneven-aged ponderosa pine and Douglas-fir.



**D-1 Leafless Aspen** Pure semimature trembling aspen stands in the leafless stage.



**M-1 Boreal Mixedwood—Leafless Mixed** stands of boreal species in the leafless stage. Photo shows a stand with 75% coniferous and 25% deciduous component.





**M-2 Boreal Mixedwood—Green Mixed** stands of boreal species in the green stage. Photo shows a stand with 75% coniferous and 25% deciduous component.



**M-3 Dead Balsam Fir/Mixedwood—Leafless Mixed** stands of dead balsam fir and boreal mixed wood species in the leafless stage. The stand in the above photo has 60% dead balsam fir and 40% live mixedwood species.



**M-4 Dead Balsam Fir/Mixedwood—Green Mixed** stands of dead balsam fir and boreal mixedwood species in the green stage. The stand in the above photo has 60% dead balsam fir and 40% live mixedwood species.



**S-1 Jack or Lodgepole Pine Slash** Jack or lodgepole pine slash, 1–2 seasons old.



**S-2 White Spruce/Balsam Slash** White or Engelmann spruce and balsam or subalpine fir slash, 1–2 seasons old.



**S-3 Coastal Cedar/Hemlock/Douglas-fir Slash** Western red cedar, western hemlock, and Douglas-fir slash, 1 season old. This fuel type is also applicable to interior wet belt cedar–hemlock slash.





**O-1 Grass Matted and standing grass.** This photograph shows well-cured standing grass with a 3 t/ha fuel load.

## Appendix 4 Beaufort scale<sup>1</sup> for estimating 10-m open wind speeds

Force or number	Wind speed (km/h)		Description	Observed wind effects
	Range	Mean		
0	< 1	0	Calm	Smoke rises vertically
1	1–5	3	Light air	Direction of drift shown by smoke drift but not by wind vanes
2	6–11	9	Light breeze	Wind felt on face; leaves rustle; vanes moved by wind
3	12–19	16	Gentle breeze	Leaves and twigs in constant motion; wind extends light flag
4	20–28	24	Moderate breeze	Raises dust and loose paper; small branches are moved
5	29–38	34	Fresh breeze	Small trees in leaf begin to sway; crested wavelets on inland waters
6	39–49	44	Strong breeze	Large branches in motion, whistling in telephone wires, umbrellas used with difficulty
7	50–61	55	Moderate gale	Whole trees in motion; resistance felt when walking against wind
8	62–74	68	Fresh gale	Breaks twigs off trees, generally impedes progress
9	75–88	82	Strong gale	Slight structural damage occurs
10	89–102	96	Whole gale	Seldom experienced inland; trees uprooted; considerable structural damage
11	103–117	110	Storm	Very rarely experienced; wide-spread damage
12 or above	118+	> 125	Hurricane	

<sup>1</sup> Adapted from List, R.J. 1951. Smithsonian meteorological tables. 6th rev. ed. Smithsonian Inst. Press, Washington, D.C.

# Appendix 5 FFMC adjustments<sup>1</sup>

Tables A.1 and A.2 can be used to estimate the FFMC for each hour from noon of the current day to noon of the subsequent day for latitudes 48–60° N, in the absence of rain. Table A.3 can be used for topographic adjustments.

**Table A.1 Diurnal FFMC adjustments: 1200–0559 LST**

Local standard time					Standard FFMC	Local standard time																		
1200	1300	1400	1500	1600		1700	1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0559					
41	43	46	48	50		51	52	53	53	52	51	50	49	48	47	46	45	44	43					
48	52	55	57	60		61	62	62	62	61	59	58	56	55	54	52	51	50	49					
57	61	65	68	70		70	71	70	69	68	66	65	63	62	60	59	58	56	55					
59	63	67	70	72		72	72	72	71	69	68	66	65	63	62	61	59	58	57					
62	66	70	72	74		74	74	73	72	71	69	68	66	65	63	62	61	59	58					
63	67	71	73	75		75	75	74	73	72	70	69	67	66	64	63	61	60	59					
64	68	72	74	76		76	76	75	74	72	71	69	68	66	65	64	62	61	60					
66	69	73	75	77		77	77	76	75	73	72	70	69	67	66	64	63	62	60					
67	71	75	76	78		78	78	77	76	74	72	71	69	68	67	65	64	63	61					
69	72	76	78	79		79	78	77	76	75	73	72	70	69	67	66	65	63	62					
71	74	77	79	80		80	79	78	77	76	74	73	71	70	68	67	66	64	63					
74	76	79	80	81		81	80	79	78	77	75	73	72	71	69	68	66	65	64					
76	78	80	81	82		82	81	80	79	77	76	74	73	71	70	69	67	66	65					
78	80	81	82	83		83	82	81	80	78	77	75	74	72	71	70	68	67	66					
80	81	82	83	84		84	83	82	81	79	78	76	75	73	72	70	69	68	67					
82	82	83	84	85		85	84	83	82	80	79	77	76	74	73	71	70	69	68					
83	84	85	85	86		86	85	84	83	81	79	78	77	75	74	72	71	70	68					
84	85	86	86	87		87	86	85	83	82	80	79	78	76	75	73	72	71	70					
85	86	87	87	88		88	87	86	84	83	81	80	79	77	76	74	73	72	71					
86	87	88	89	89		89	88	87	85	84	82	81	80	78	77	75	74	73	72					
88	88	89	90	90		90	89	88	86	85	83	82	81	79	78	77	75	74	73					
89	89	90	91	91		91	90	89	87	86	84	83	82	80	79	78	76	75	74					
90	90	91	92	92		92	91	90	88	87	85	84	83	81	80	79	77	76	75					
91	91	92	93	93		93	92	91	89	88	86	85	84	82	81	80	79	77	76					
92	93	93	94	94		94	93	92	90	89	88	86	85	84	82	81	80	79	77					
93	94	94	95	95		95	94	93	91	90	89	87	86	85	83	82	81	80	79					
94	95	95	96	96		96	95	94	92	91	90	88	87	86	85	84	82	81	80					
95	96	96	97	97		97	96	95	93	92	91	90	88	87	86	85	84	83	81					
96	97	97	98	98		98	97	96	94	93	92	91	90	88	87	86	85	84	83					
97	98	98	99	99		99	98	97	95	94	93	92	91	90	88	87	86	85	84					
98	99	99	100	100		100	99	98	96	95	94	93	92	91	90	89	88	86	85					
1300	1400	1500	1600	1700		1800	1900	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0659					

Local daylight time

Local daylight time

To estimate the FFMC during the afternoon or overnight, find the daily standard FFMC then move horizontally to the column that corresponds to the prediction time.

<sup>1</sup> Adapted from Lawson, B.D.; Armitage, O.B.; Hoskins, W.D. 1996. Diurnal variation in the Fire Fuel Moisture Code: tables and source code. Can. For. Serv., Pac. For. Cent., Victoria, British Columbia and B.C. Minist. For., Res. Branch, Victoria, British Columbia. Canada-British Columbia Partnership Agreement on Forest Resource Development: FRDA II. FRDA Rep. 245.

2 Table A.2 Diurnal FFMC adjustments: 0600–1159 LST

Standard daily FFMC

Time LST	RH	50	60	70	72	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	
0600	< 68	54	57	62	63	64	65	66	66	67	68	69	69	70	71	72	73	74	75	76	78	79	80	81	83	84	86	87	89	90	92	93	
	68-87	48	53	58	60	61	62	63	63	64	65	66	66	67	68	69	70	71	72	73	74	75	76	77	78	80	81	82	84	85	87	88	
	> 87	43	49	55	57	58	59	60	60	61	62	63	64	65	66	67	67	68	69	71	72	73	74	75	76	77	79	80	81	83	84	85	
0700	< 58	56	60	64	65	67	67	68	69	69	70	71	72	72	73	74	75	76	77	78	79	80	81	83	84	85	87	88	90	91	93	94	
	58-77	49	54	60	61	63	63	64	65	66	67	67	68	69	70	71	72	73	74	75	76	77	78	79	81	82	83	84	86	87	88	90	
	> 77	44	49	56	57	59	60	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	77	78	79	81	82	83	85	86	88	
0800	< 48	59	63	67	68	69	70	70	71	72	72	73	74	75	75	76	77	78	79	80	81	82	83	84	85	86	88	89	90	92	93	95	
	48-67	50	55	61	63	64	65	66	67	68	68	69	70	71	72	73	74	75	76	77	78	79	81	82	83	84	85	87	88	89	90	91	
	> 67	45	50	57	58	60	61	61	62	63	64	65	66	67	68	69	70	71	72	73	74	76	77	78	79	81	82	84	85	87	88	90	
0900	< 43	64	67	71	72	73	74	74	75	75	76	77	77	78	79	80	80	81	82	83	84	85	86	87	88	89	90	91	93	94	95	96	
	43-62	56	60	66	67	69	69	70	71	72	72	73	74	75	76	77	77	78	79	80	81	82	83	85	86	87	88	89	91	92	93	94	
	> 62	51	56	62	63	64	65	66	66	67	68	69	70	70	71	72	73	74	75	76	77	78	79	80	82	83	84	85	87	88	90	91	
1000	< 38	70	72	76	77	77	78	78	79	79	80	81	81	82	82	83	84	85	85	86	87	88	89	90	91	92	93	94	95	96	97	98	
	38-57	62	66	71	72	73	74	75	75	76	77	77	78	79	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	96	97	
	> 57	57	61	67	68	69	70	70	71	72	72	73	74	74	75	76	77	77	78	79	80	81	82	83	84	85	86	87	88	89	91	92	
1100	< 35	76	78	80	81	82	82	83	84	84	85	85	86	86	87	87	88	89	89	90	90	91	91	92	92	93	93	94	95	96	97	98	
	35-54	69	0	72	76	77	78	79	80	80	81	82	82	83	83	84	85	86	87	87	88	88	89	89	90	91	91	92	93	94	96	97	
	> 54.5	64	68	72	73	74	75	76	76	77	77	78	78	79	80	80	81	81	82	82	83	84	84	85	85	86	86	87	88	89	91	92	
1159	< 33	82	83	85	86	87	87	87	88	88	88	89	89	89	90	90	90	91	91	91	91	92	92	92	92	93	93	93	94	95	96	97	98
	33-52	77	79	82	83	84	84	84	85	85	86	86	86	87	87	88	88	88	89	89	89	90	90	90	91	91	91	92	93	94	96	97	
	> 52	72	75	78	79	80	80	81	81	81	82	82	82	83	83	83	83	84	84	84	85	85	85	86	86	86	86	87	88	89	90	92	

To estimate the FFMC in the morning, find the previous day's standard FFMC, then move down to the time and relative humidity for the prediction time. If the RH is unknown use the highest value.

**Table A.3 FFMC slope - aspect adjustments**

Level	Ground slope and aspect															
	1-15 %				16-30 %				31-45 %				46-60 %			
	N	E	S	W	N	E	S	W	N	E	S	W	N	E	S	W
80	78	79	82	80	77	78	82	80	74	77	83	81	72	76	84	81
82	80	81	84	82	79	80	84	82	76	79	85	83	74	78	85	83
84	83	83	85	84	81	82	86	84	79	81	87	84	76	80	88	84
86	85	85	87	86	83	84	88	86	81	83	89	86	78	82	90	86
87	86	86	88	87	84	85	89	87	82	84	90	87	80	83	90	87
88	87	87	89	88	85	87	90	88	83	86	91	88	82	85	91	88
89	88	88	90	89	87	88	91	89	85	87	91	89	83	86	92	89
90	89	89	91	90	88	89	92	90	86	88	92	90	84	87	93	90
91	90	90	92	91	89	90	92	91	87	89	93	91	86	88	93	91
92	91	91	93	92	90	91	93	92	88	90	94	92	87	89	94	92
93	92	92	94	93	91	92	94	93	89	91	95	93	88	90	95	93
94	93	93	95	94	92	93	95	94	91	92	96	94	90	92	96	94

Determine the slope and aspect of the weather observation point, find FFMC, then move horizontally to the column that best describes the prediction point and read adjusted FFMC (from Alexander et al. 1984). These adjustments should be used with caution as they have not been rigorously tested.

They should only be applied in slash and open fuel types on clear days in March, April, August, September, or October between 1200 and 2000 LST.



## Appendix 6 Selected unit conversion factors

If the SI units are	Multiply by	To obtain	Inverse factor
hectares (ha)	2.4711	acres (ac)	0.40469
kilometres per hour (km/h)	0.62137	miles per hour (mi/h)	1.6093
kilowatts per metre (kW/m)	0.28909	Btu per second per foot (Btu/sec/ft)	3.4592
metres (m)	0.049709	chains (ch)	20.117
metres (m)	3.2808	feet (ft)	0.3048
metres per minute (m/min)	3.2808	feet per minute (ft/min)	0.3048
metres per minute (m/min)	2.9826	chains per hour (ch/h)	0.33528
metres per minute (m/min)	60.0	metres per hour (m/h)	0.016667
metres per minute (m/min)	0.06	kilometres per hour (km/h)	16.667
tonnes per hectare (t/ha)	0.44609	tons per acre (T/ac)	2.2417

Note: all factors are given to five significant digits. If fewer, the value is exact. To convert Imperial or old metric unit values to the International System of Units (SI) multiply by the inverse factor given in the right-hand column. Btu = British thermal unit.

## Appendix 7 Fire Behavior Prediction worksheet example

1	Fire no./Name	SAMPLE	Date	29.04.95	Time	1600 LST
2	Prediction date & time	30.04.95	From	1200 LST	To	1300 LST
3	Prediction point & Ignition type	1 PI	2 PI	3 LS	4 LS	5 PI
Fuel type						
4	Fuel type identifier	C-4	M-1	D-1	S-2	O-1a
5	Modifiers (CBH; PC:PH; PDF)		75:25			
Fine Fuel Moisture Code						
6	Standard daily FFMC	93	94	88	94	94
7	Diurnal or hourly FFMC	91	92	85	92	92
8	Ground slope (%)	0	15	10	50(15)	20(L)
9	Aspect	–	N	E	S(E)	W(L)
10	Adjusted FFMC	91	92	85	95	92
Wind and Initial Spread Index						
11	Slope equiv. wind speed (km/h)	–	5	3	26	8
12	10 m wind speed (km/h)	23	15	-3	5	-15
13	Effective wind speed (km/h)	23	20	0	31	-7
14	ISI – head/back	16/2	16/2	2/2	41/2	8/4
Rate of Spread and Intensity						
15	BUI or Degree of Curing (%)	100	25	60	100	95
16	Equil. ROS (m/min) – head	27	15	0.2	33	21
17	– back	2	0.9	0.2	0.6	9
18	Fire intensity class – head/back	6/3	5/2	2/2	6/4	3/3
19	Type of fire – head/back	CC/S	IC/S	S/S	S/S	S/S
20	CFB level (%) – head/back	90/10	90/10	–	–	–
Fire size						
21	Elapsed time (min)	60	60	60	60	60
22	Head fire spread distance (m)	1362	757	12	1980	1077
23	Backfire spread distance (m)	103	46	12	36	462
24	Total spread distance (m)	1465	803	24	2016	1539
25	Elliptical fire area (ha)	62	20	–	–	72
26	Elliptical fire perimeter (m)	3350	1830	–	–	3514
27	LB ratio	3.0	2.6	–	–	3.6
28	Perimeter growth rate (m/min)	61	41	–	–	48

## FIRE BEHAVIOR PREDICTION WORKSHEET

1	Fire no./Name	Date	Time			
2	Prediction date & time	From	To			
3	Prediction point & Ignition type	1	2	3	4	5
Fuel type						
4	Fuel type identifier					
5	Modifiers (CBH; PC:PH; PDF)					
Fine Fuel Moisture Code						
6	Standard daily FFMC					
7	Diurnal or hourly FFMC					
8	Ground slope (%)					
9	Aspect					
10	Adjusted FFMC					
Wind and Initial Spread Index						
11	Slope equiv. wind speed (km/h)					
12	10 m wind speed (km/h)					
13	Effective wind speed (km/h)					
14	ISI – head/back					
Rate of Spread and Intensity						
15	BUI or Degree of Curing (%)					
16	Equil. ROS (m/min) – head					
17	– back					
18	Fire intensity class – head/back					
19	Type of fire – head/back					
20	CFB level (%) – head/back					
Fire size						
21	Elapsed time (min)					
22	Head fire spread distance (m)					
23	Backfire spread distance (m)					
24	Total spread distance (m)					
25	Elliptical fire area (ha)					
26	Elliptical fire perimeter (m)					
27	LB ratio					
28	Perimeter growth rate (m/min)					