



An Overview of Systems for Rating Fire Danger & Predicting Fire Behavior Used in Canada



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Lesson 30

S-590 Advanced Fire Behavior Interpretation Course

National Advanced Fire & Resource Institute

Tucson, Arizona

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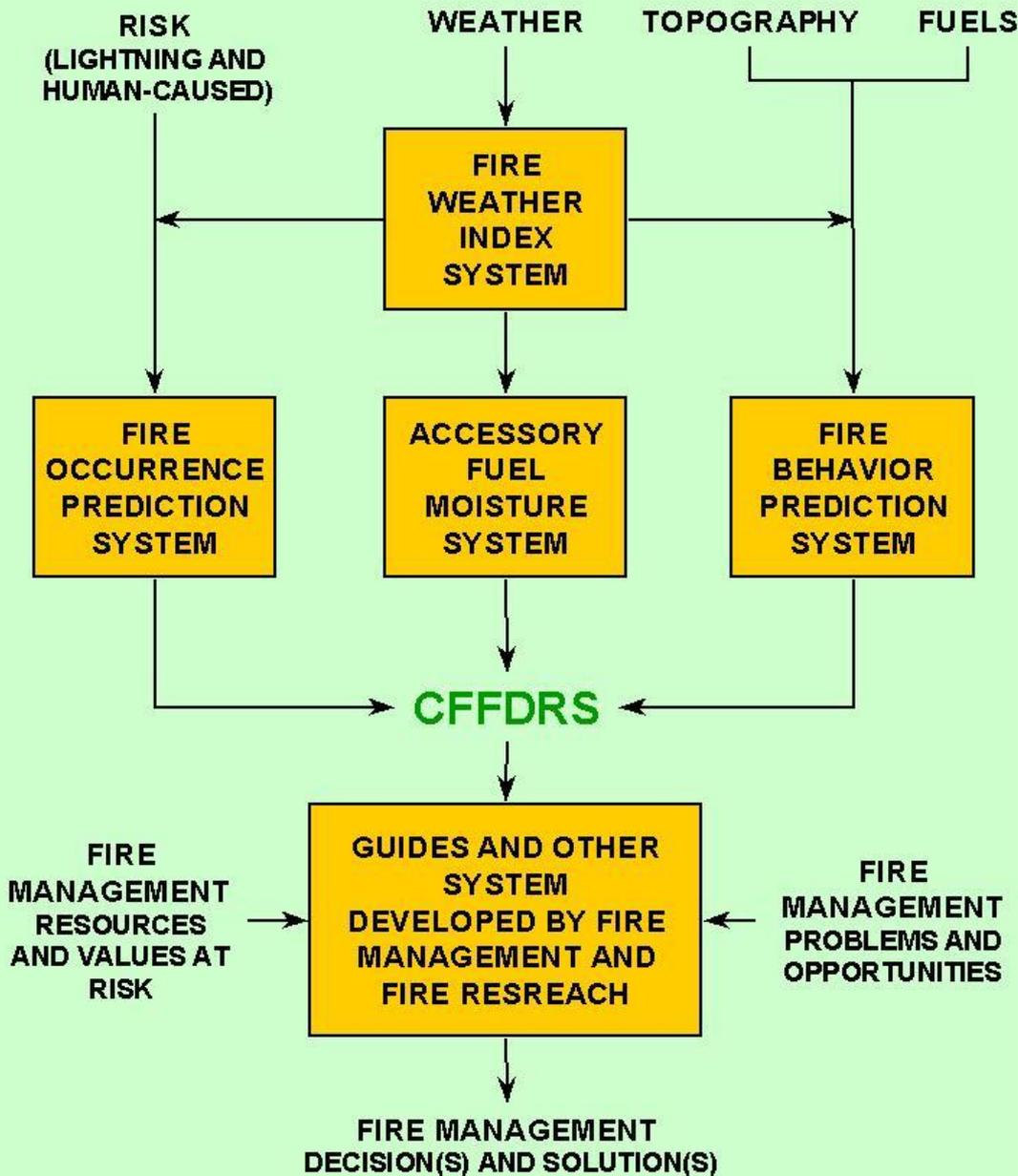


National Advanced Fire & Resource Institute

Lesson Objectives

- **Gather a cursory understanding of the philosophy and structure of the Canadian Forest Fire Danger Rating System (CFFDRS).**
- **Identify the fundamental differences in modeling approaches and basic similarities in the operational application of the fire behavior prediction systems used in the U.S. & Canada.**
- **Identify training courses provided to fire behavior analysts in Canada.**

CANADIAN FOREST FIRE DANGER RATING SYSTEM (CFFDRS)



Simplified CFFDRS structure diagram illustrating the linkage to fire management actions



Fire Weather Index Module or Subsystem

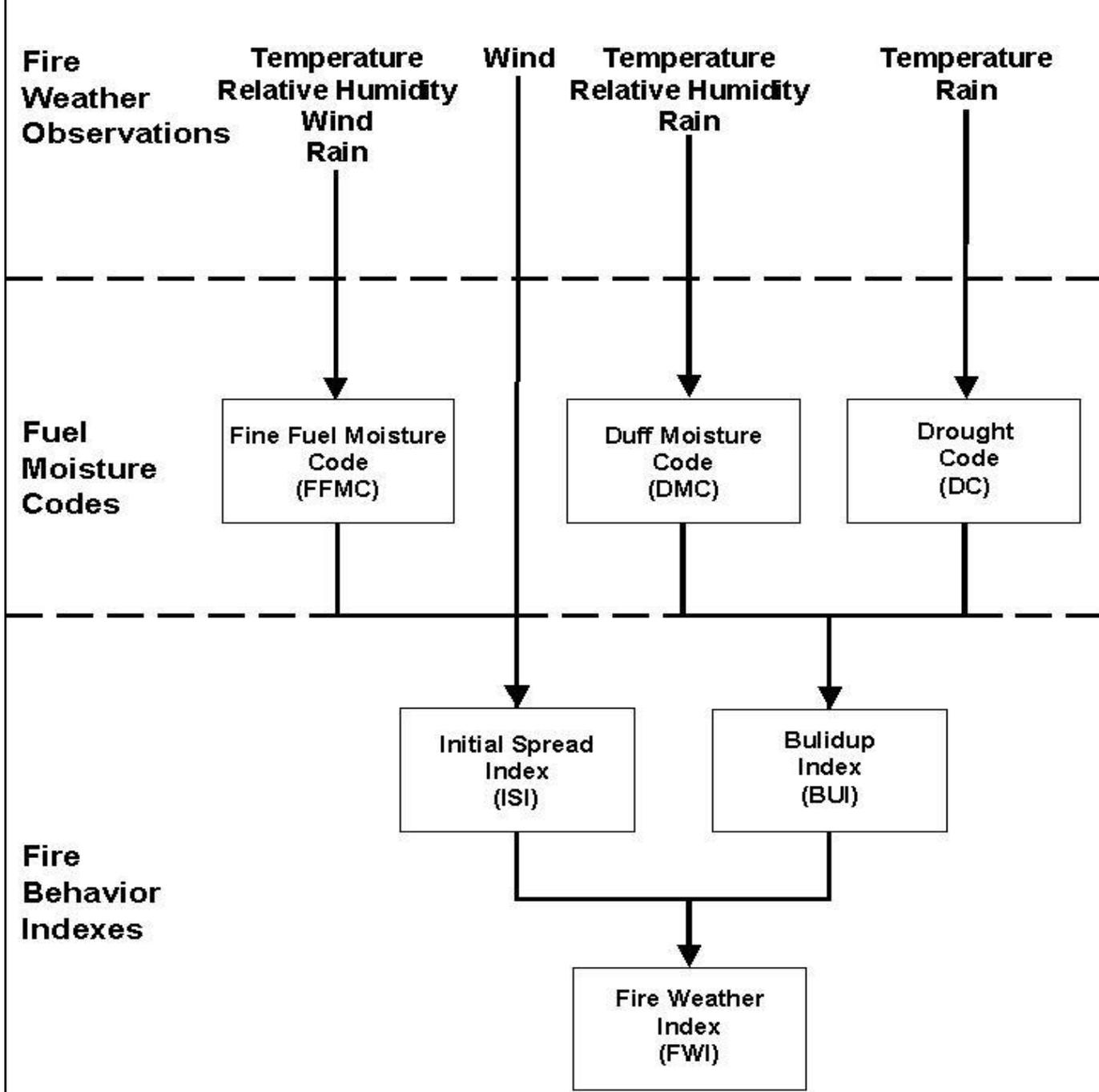
The FWI System provides relative numerical ratings of fire potential in a standard fuel type (i.e., mature pine stand) on level terrain.





Jack pine and lodgepole pine forests have continental distribution across Canada.

Structure of the Canadian Forest Fire Weather Index (FWI) System



Fire Weather Observations

Dry-bulb Temperature

Relative Humidity

33-ft Open Wind Speed

24-hr Accumulated Rainfall

Calculation of the FWI System

components is based on consecutive daily fire weather observations.

Therefore, an unbroken daily weather record is required.

The FWI System fuel moisture codes are dynamic "bookkeeping" systems that account for each day's wetting and drying effects.

- Fine Fuel Moisture Code (FFMC)**
- Duff Moisture Code (DMC)**
- Drought Code (DC)**



Fine Fuel Moisture Code (FFMC)

A numerical rating of the moisture content of litter and other cured fine fuels. This code is an indicator of the relative ease of ignition and flammability of fine fuel.

Weather inputs: Temp, RH, WS, Rain

Scale: 0-101 (fixed)

Rainfall threshold: 0.02 in.

Timelag: 2/3 day or 16 hours

Nominal depth: 0.5 in.



Duff Moisture Code (DMC)

A numerical rating of the average moisture content of loosely compacted organic layers of moderate depth. This code gives an indication of fuel consumption in moderate duff layers and medium-sized woody material.

Weather inputs: Temp, RH, Rain (+ Month)

Scale: technically open ended

Rainfall threshold: 0.06 in.

Timelag: 15 days

Nominal depth: 2.8 in.



Drought Code (DC)

A numerical rating of the average moisture content of deep, compact, organic layers. This code is a useful indicator of seasonal drought effects on forest fuels, and amount of smoldering in deep duff layers and large logs.

Weather inputs: Temp, Rain (+ Month)

Scale: technically open ended

Rainfall threshold: 0.11 in.

Timelag: 53 days

Nominal depth: 7.1 in.



FWI System Fuel Moisture Codes

"rough rules of thumb"

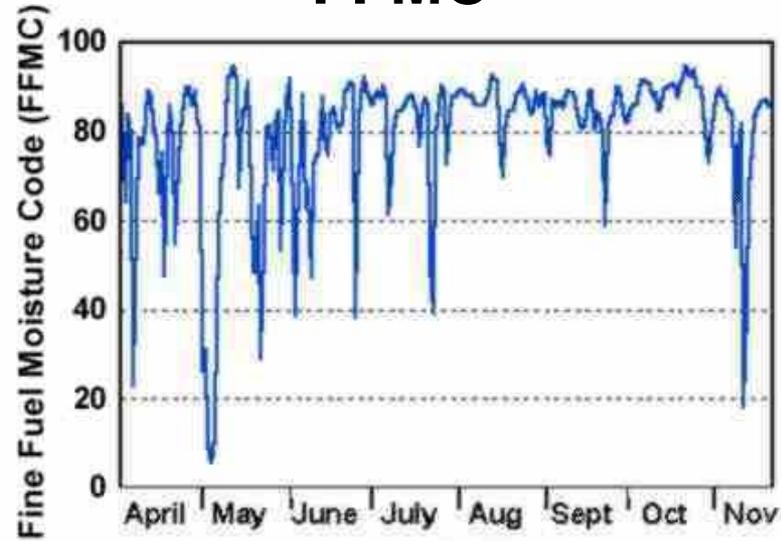
An **FFMC** of at least **75** (i.e., ~25-30% moisture content) is typically required for ignition and fire spread in fine fuels in many forest fuel complexes.

Duff doesn't normally become involved in combustion until the **DMC** reaches ~ **20**. A DMC of 20 is also regarded as a threshold for lightning fire starts.

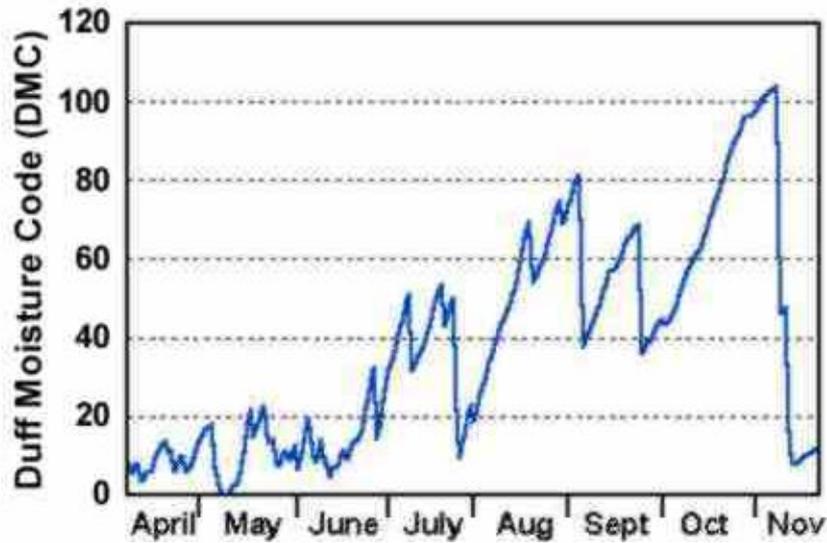
In many forest fuel complexes a **DC** of around **300** is generally considered a critical point or threshold for the onset of significant ground or sub-surface fire persistence or activity and in turn mop-up problems.

Portland, Maine - 1947

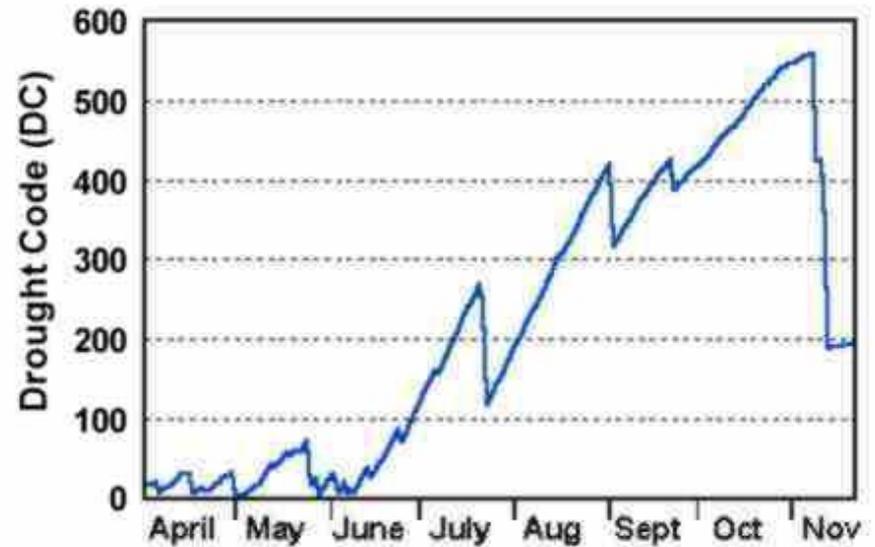
FFMC



DMC



DC



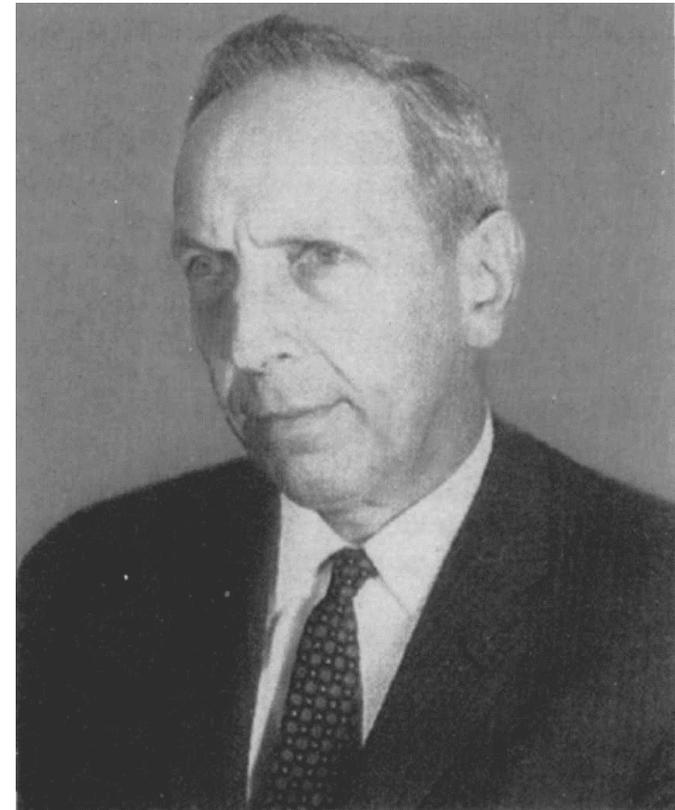
The FWI System's fire behavior indexes are patterned after Bryam's fire intensity concept.

$$I = H \cdot w \cdot r$$

↑ ↑ ↑ ↑

FWI constant BUI ISI

- Initial Spread Index (ISI)
- Buildup Index (BUI)
- Fire Weather Index (FWI)



G.M. Bryam

Initial Spread Index (ISI)

A numerical rating of the expected rate of fire spread. It combines the effects of wind and FFMC on rate of spread without the influence of variable quantities of fuel.

Inputs: FFMC, WS



Scale: technically open ended

ISI doubles for ~ 10 mph increase in wind speed. Double digits (i.e., $ISI > 10$) generally constitutes a significant threshold in most forest fuel complexes.

Buildup Index (BUI)

A numerical rating of the total amount of fuel available for combustion that combines DMC and DC.

Inputs: DMC, DC

Scale: technically open ended



In most boreal forest fuel complexes, a BUI > 80 represents a very significant level because given a nominal ISI of 10, extreme fire behavior is in turn quite likely.

Fire Weather Index (FWI)

A numerical rating of fire intensity that combines ISI and BUI. It is suitable as a general index of fire danger throughout the forested areas of Canada.

Inputs: ISI, BUI

Scale: technically open ended





FWI 9



FWI 14



FWI 15



FWI 17

Darwin Lake Project, Alberta - 1974



FWI 20



FWI 34



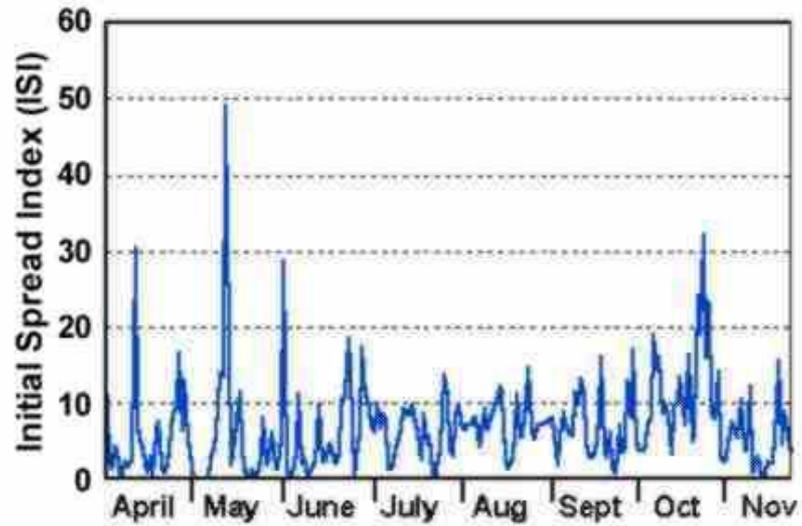
FWI 24



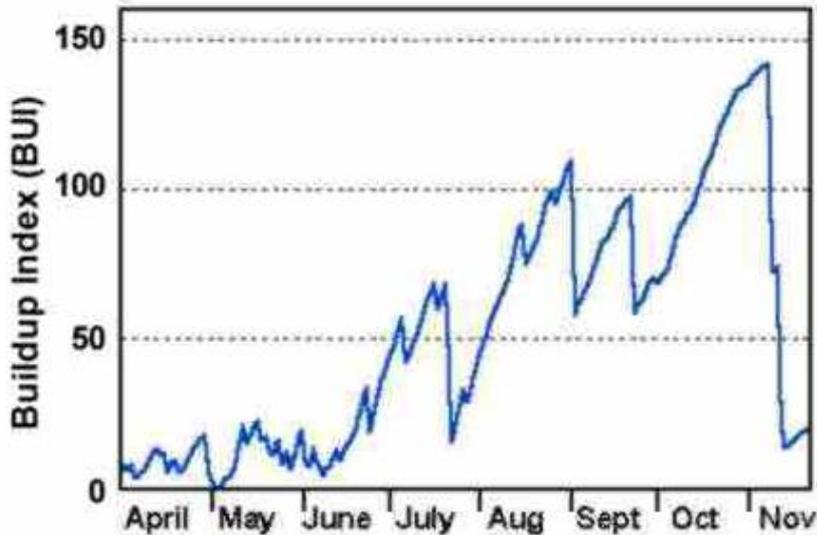
Darwin Lake Project, Alberta - 1974

Portland, Maine - 1947

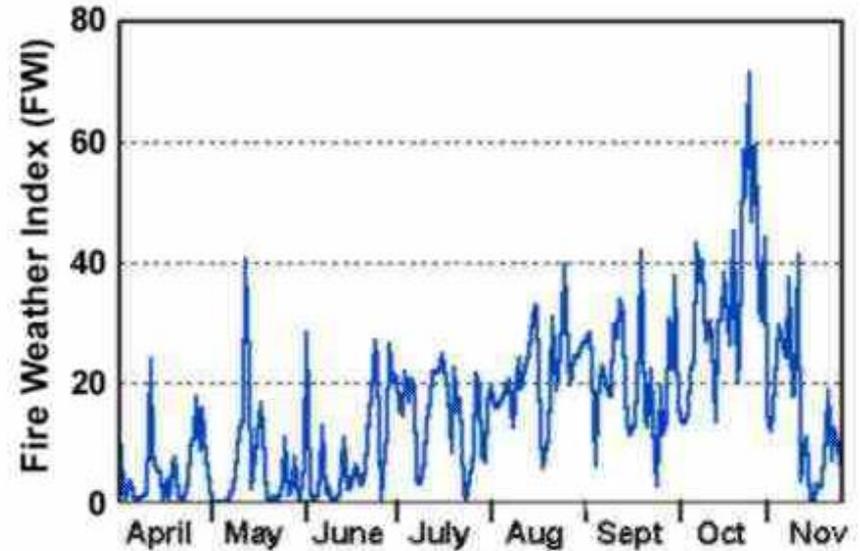
ISI



BUI



FWI



FWI System Calculations



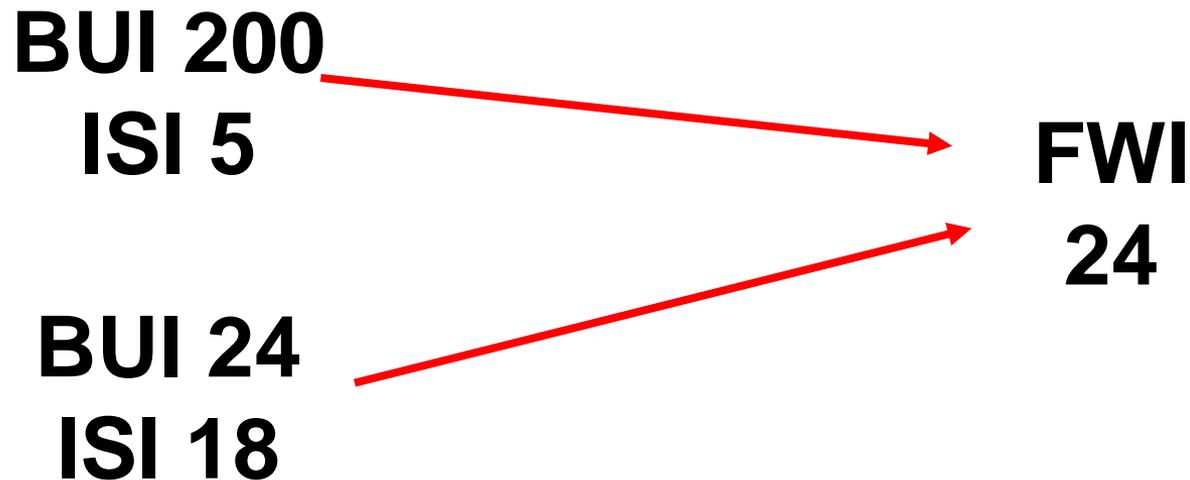
Tables



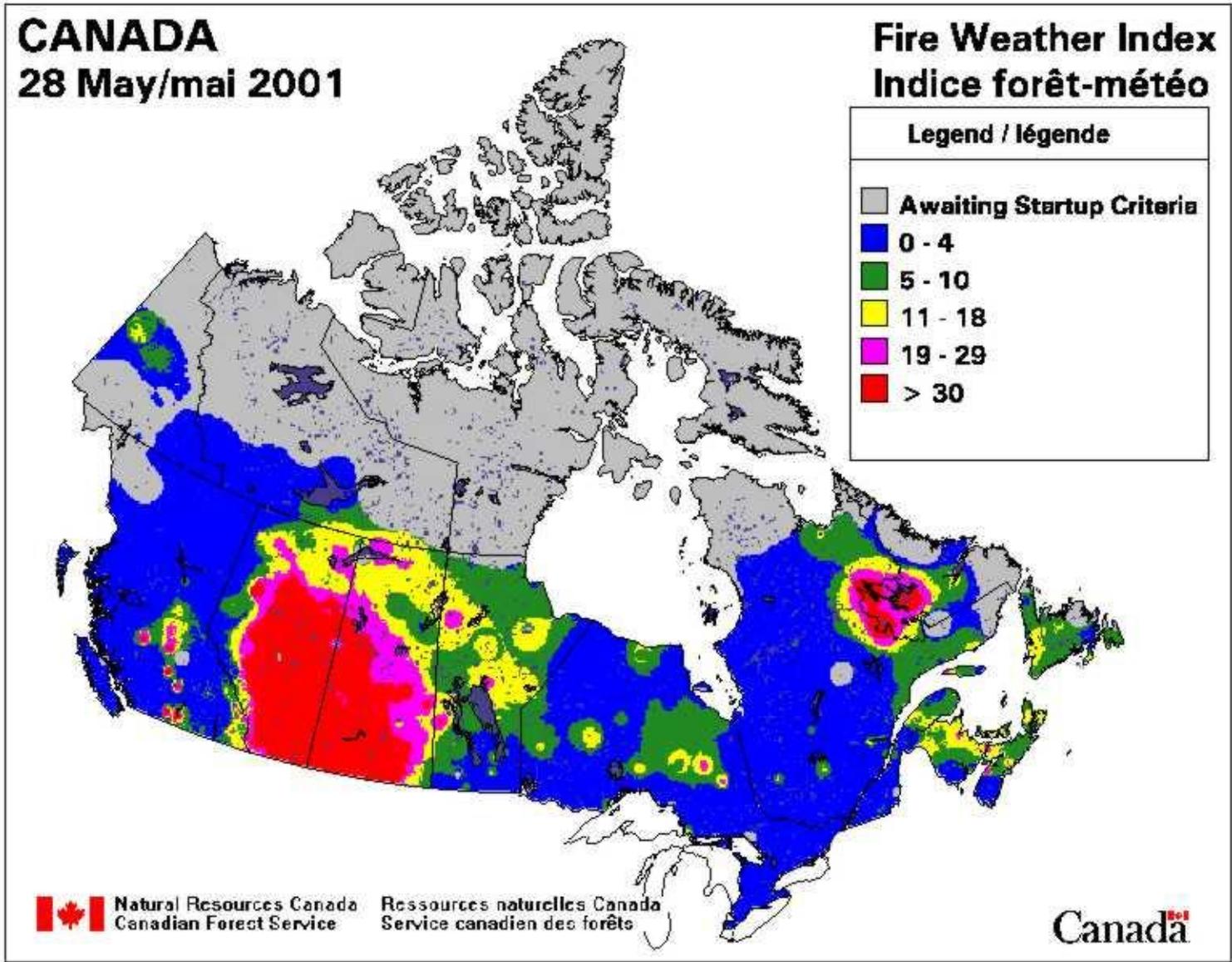
Computer

Different ISI and BUI combinations can result in the same FWI value.

For example:



Canadian Wildland Fire Information System



<http://fms.nofc.cfs.nrcan.gc.ca/cwfiis/>

"Operationalizing" of the FWI System components

- Personal experience linking indices to wildfire & prescribed fire activity**
- Examining historical summaries**
- Historical wildfire & prescribed fire case studies**
- Comparison to statistical data from fire reports**
- Recent wildfire case studies**
- Experimental & operational burning trials**



Informing the Public of Impending Fire Danger



Yukon Territory

Fire Danger Index Equivalencies



Canadian

- **FFMC**
- **DMC/BUI**
- **DC**
- **ISI**
- **FWI**



U.S.

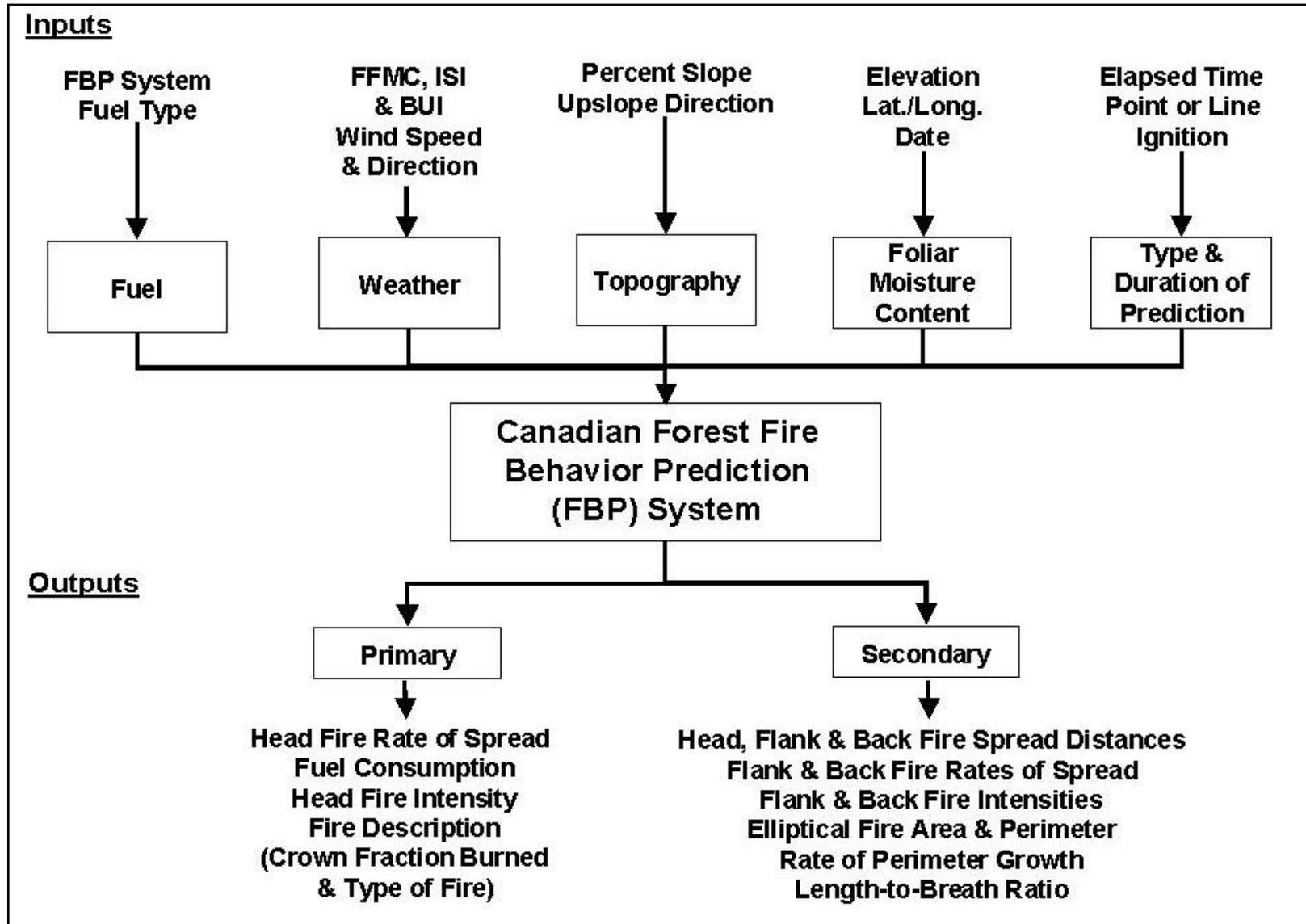
- **IC**
- **ERC**
- **KBDI**
- **SC**
- **BI**

Fire Behavior Prediction Module or Subsystem

In contrast to the FWI System, the FBP System provides quantitative outputs of selected fire behavior characteristics for several major Canadian fuel types and topographic situations.



Structure of the Canadian Forest Fire Behavior Prediction (FBP) System



FBP System Fuel Types

General Category	Fuel Type	Input Modifier
Coniferous	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	Live Crown Base Height
	C-7 Ponderosa Pine/Douglas-fir	-
Deciduous	D-1 Leafless Aspen	-
Mixedwood	M-1 Boreal Mixedwood-Leafless	% Softwood/Hardwood
	M-2 Boreal Mixedwood-Green	% Softwood/Hardwood
	M-3 Dead Balsam Fir/Mixedwood-Leafless	% Dead Fir
	M-4 Dead Balsam Fir/Mixedwood-Green	% Dead Fir
Slash	S-1 Jack or Lodgepole Pine Slash	-
	S-2 Spruce/Balsam Slash	-
	S-3 Coastal Cedar/Hemlock/Douglas-fir Slash	-
Open	O-1a Matted Grass	% Degree of Curing
	O-1b Standing Grass	% Degree of Curing

FBP System Fuel Types



C-1



C-2



M-1



M-2



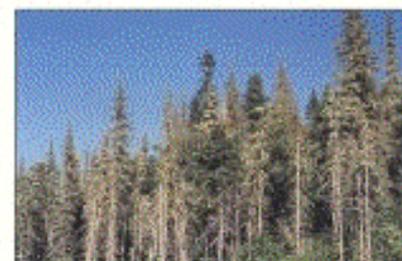
C-3



C-4



M-3



M-4



C-5



C-6



S-1



S-2



C-7



D-1



S-3



O-1

FBP System Fuel Type C-2 (Boreal Spruce)

This fuel type is characterized by pure, moderately well-stocked black spruce stands on lowland (excluding Sphagnum bogs) and upland sites. Tree crowns extend to or near the ground and dead branches are typically draped with bearded lichens (Usnea sp.). The flaky nature of the bark on the lower portion of stem boles is pronounced. Low to moderate volumes of down woody material are present. Labrador tea (Ledum Groenlandicum Oeder) is often the major shrub component. The forest floor is dominated by a carpet of feather mosses and/or ground-dwelling lichens (chiefly Cladonia). Sphagnum mosses may occasionally be present, but they are of little hindrance to surface fire spread. A compact organic layer commonly exceeds a depth of 23-30 cm (9 - 12 in.).

Inputs and Outputs of the FWI System used in the FBP System

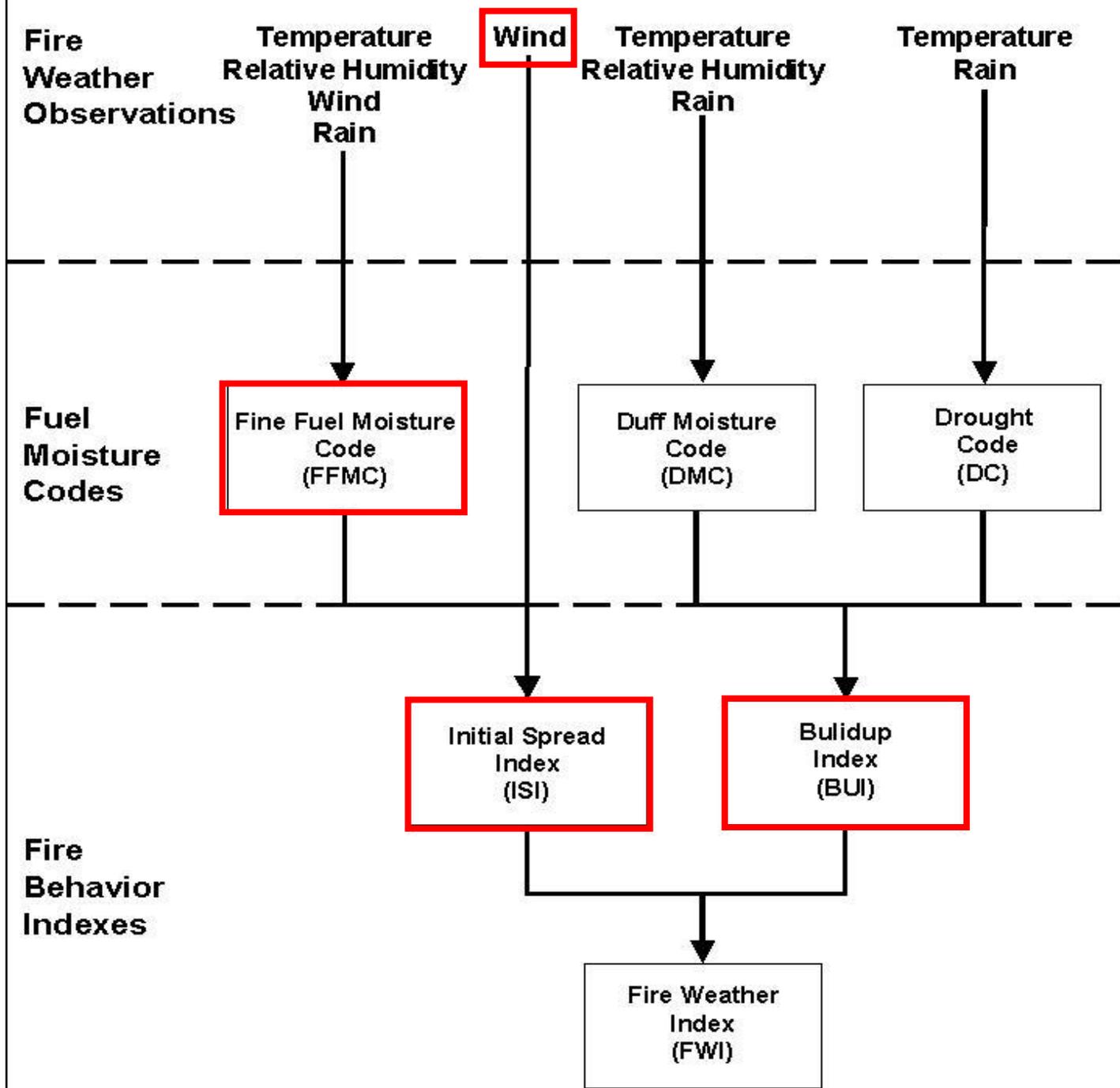
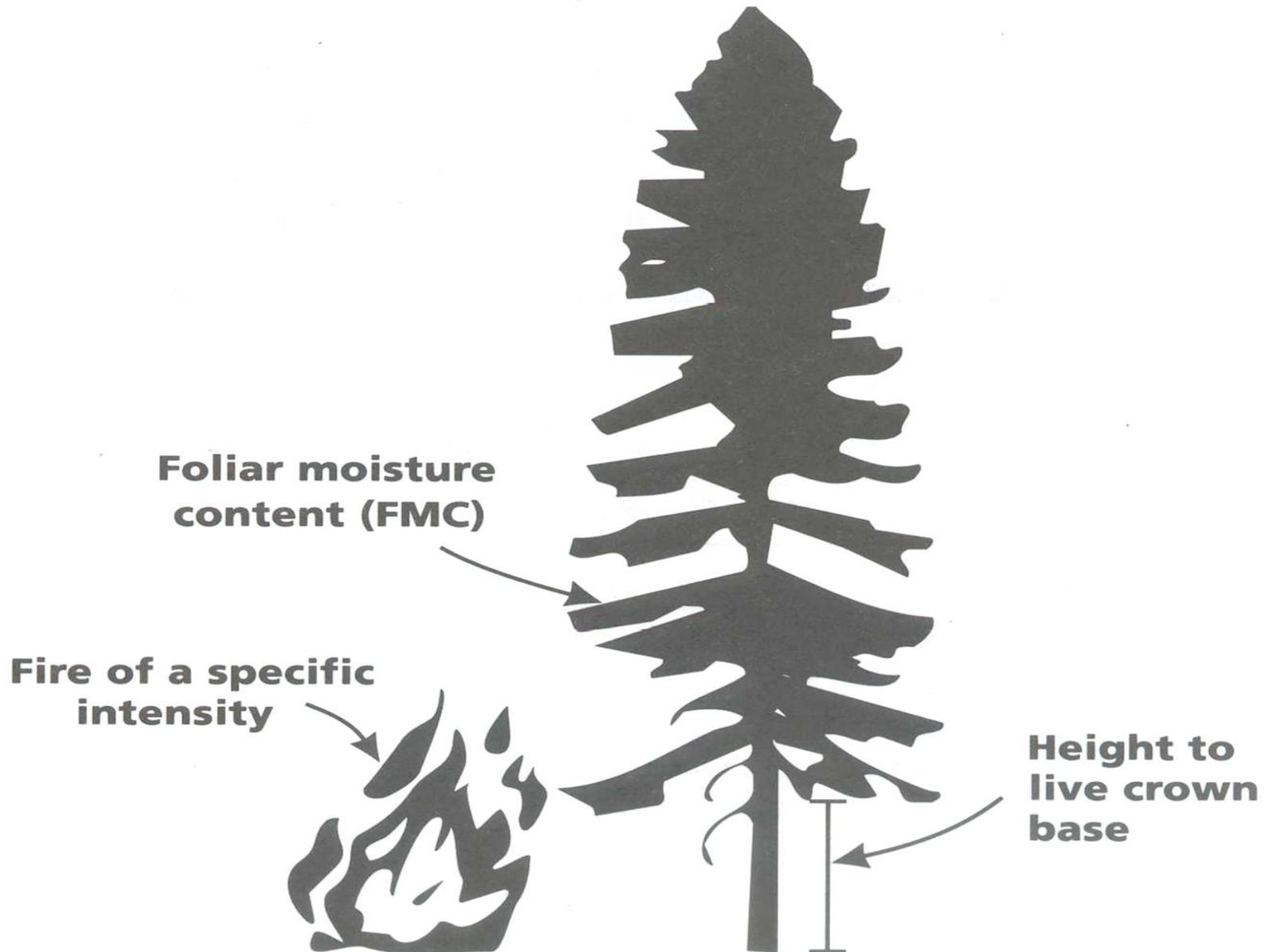
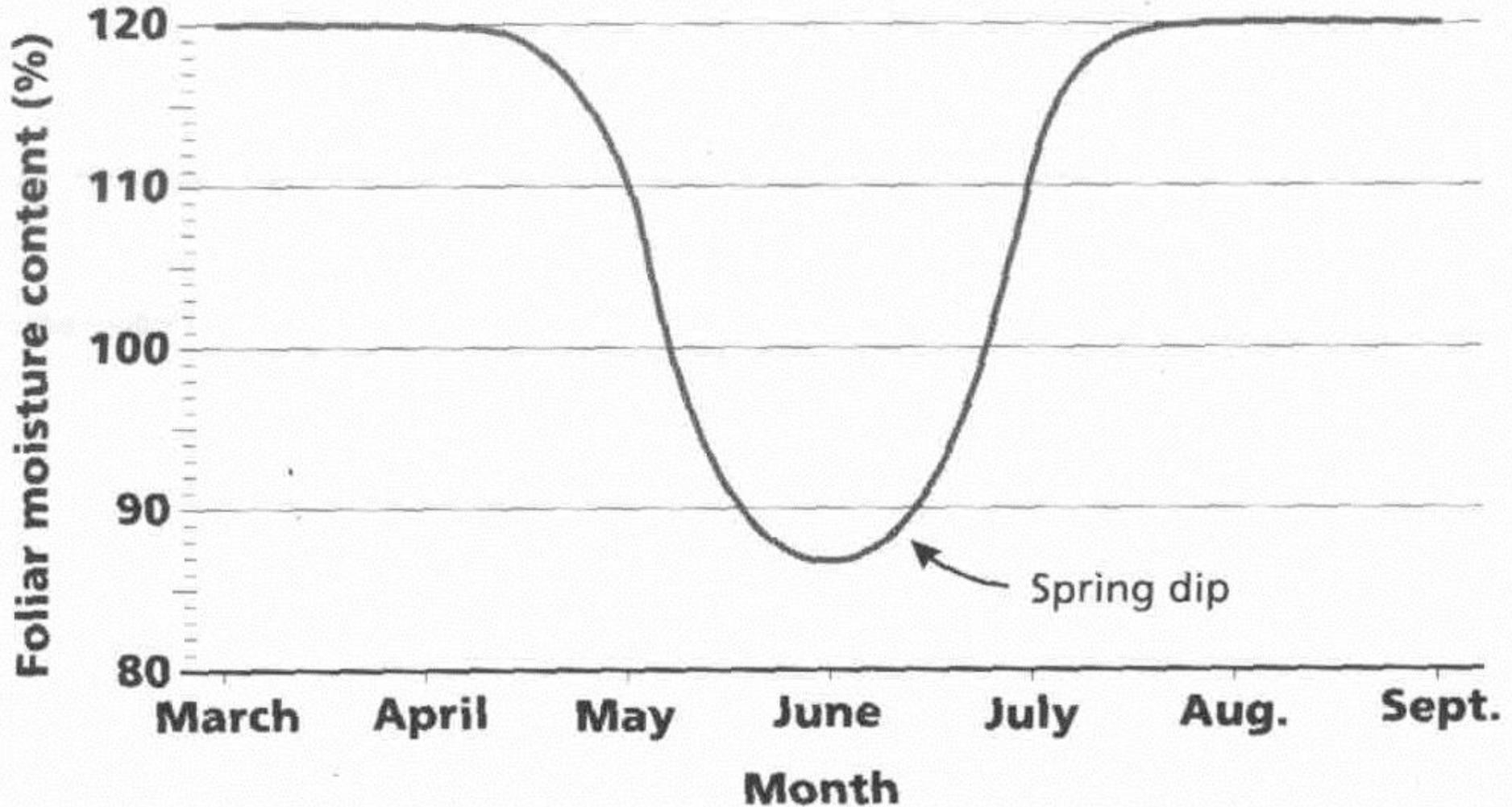


Illustration of the parameters influencing the prediction of crown fire initiation

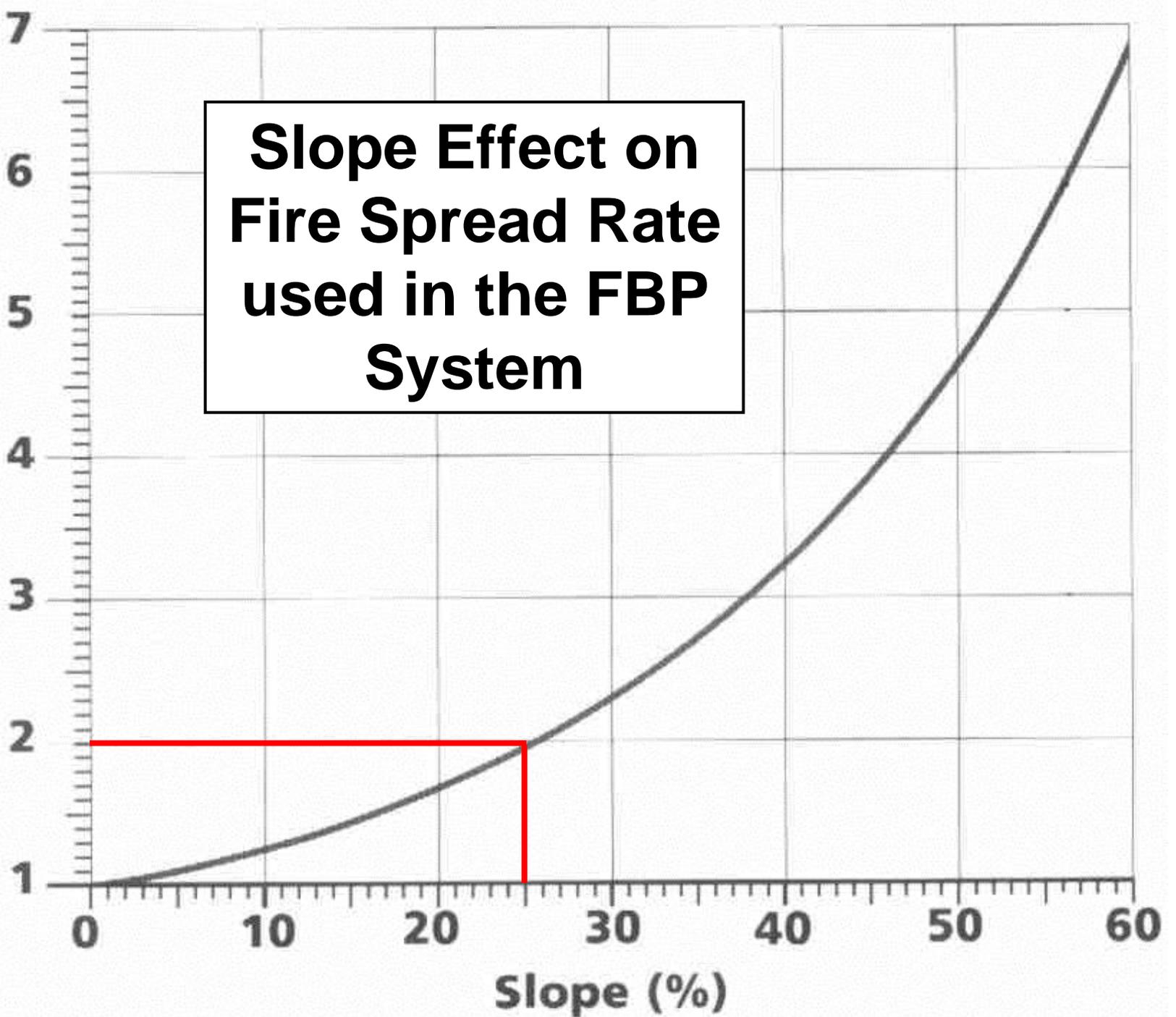


Conceptual example of the seasonal trend in the foliar moisture content of conifer foliage

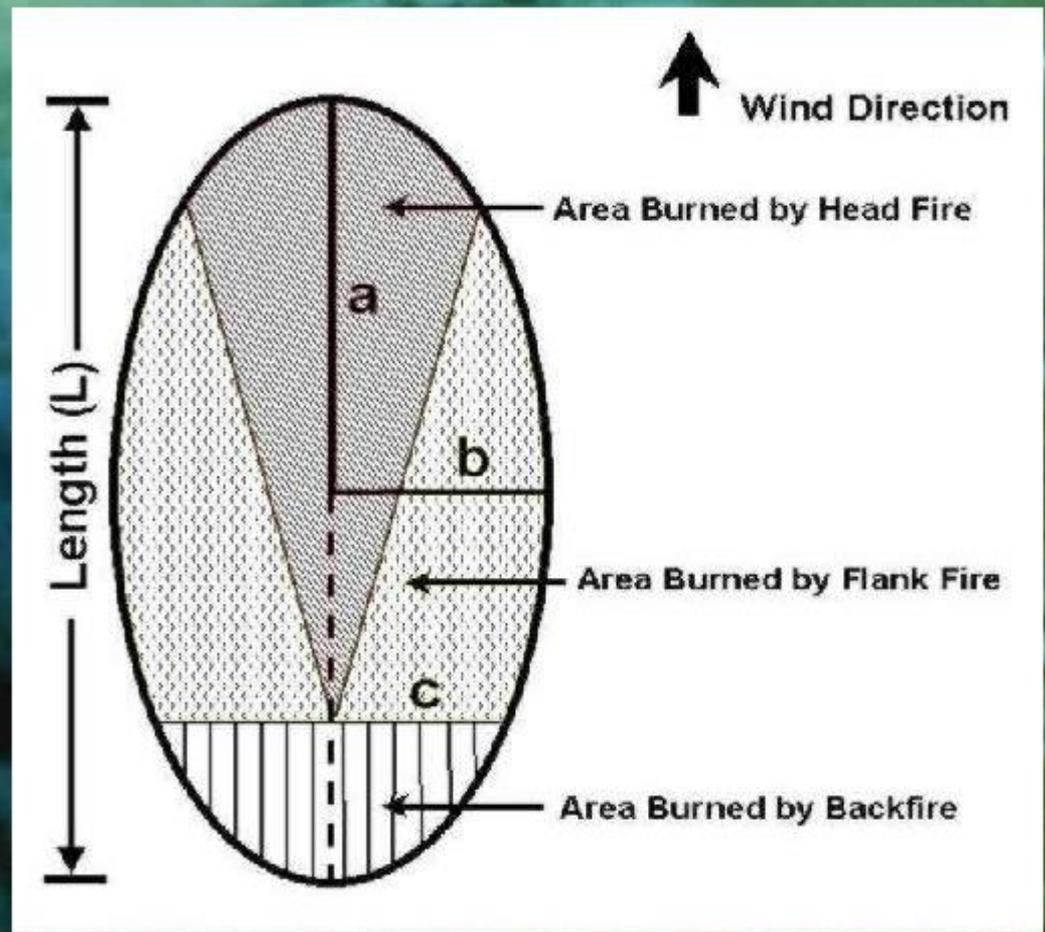


**Slope Effect on
Fire Spread Rate
used in the FBP
System**

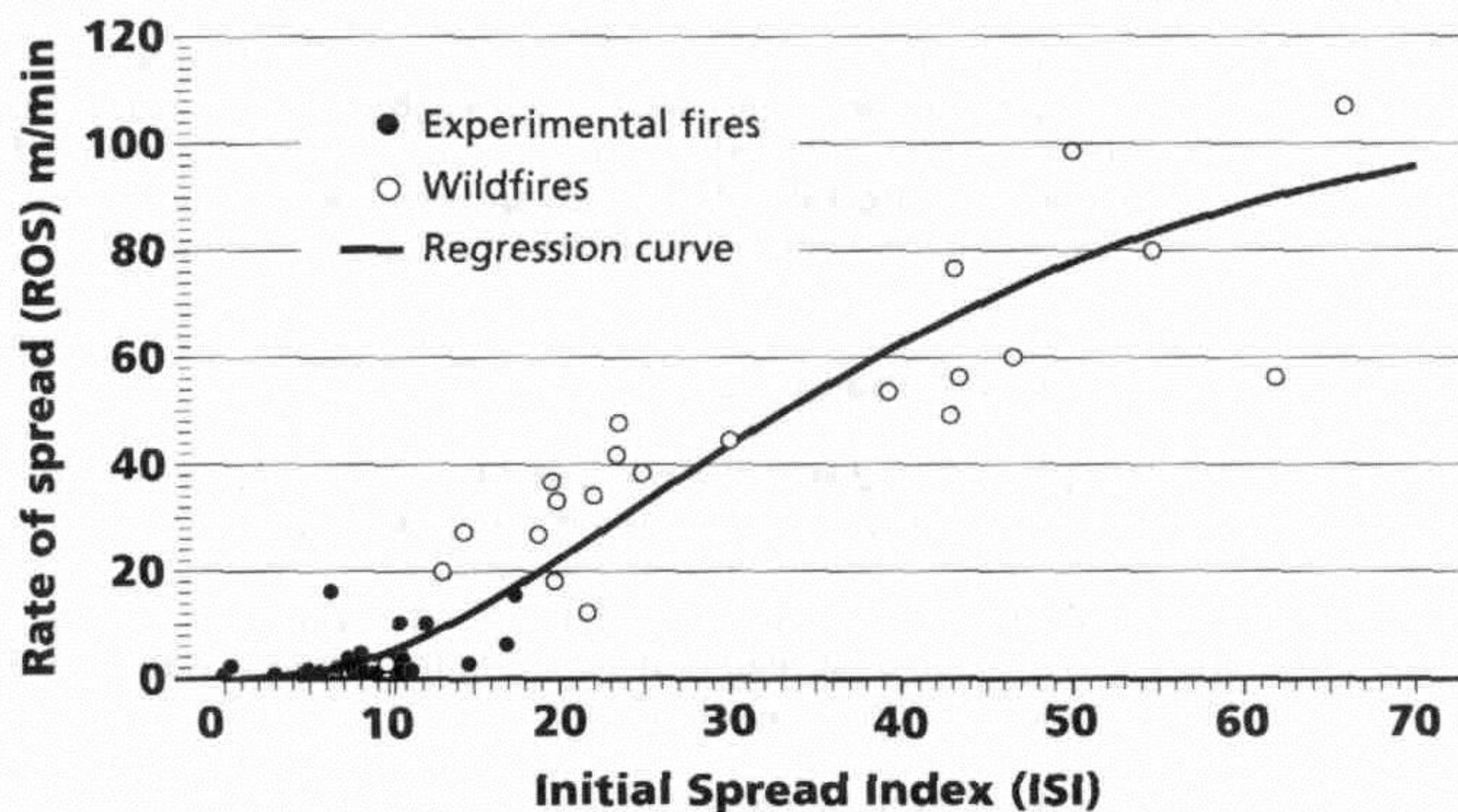
Spread factor



**A Simple
Elliptical
Fire
Growth
Model is
Employed
in the FBP
System**



Basic rate of spread curve for FBP System Fuel Type C-3 (Mature Jack or Lodgepole Pine)



Experimental Fire



The mathematical relationships in the FBP System are based on three different data sources



Operational Prescribed Fire



Wildfire



Experimental fire in spruce budworm-killed balsam fir fuel complex, NE Ontario

Canadian Wildland Fire Information System

CANADA

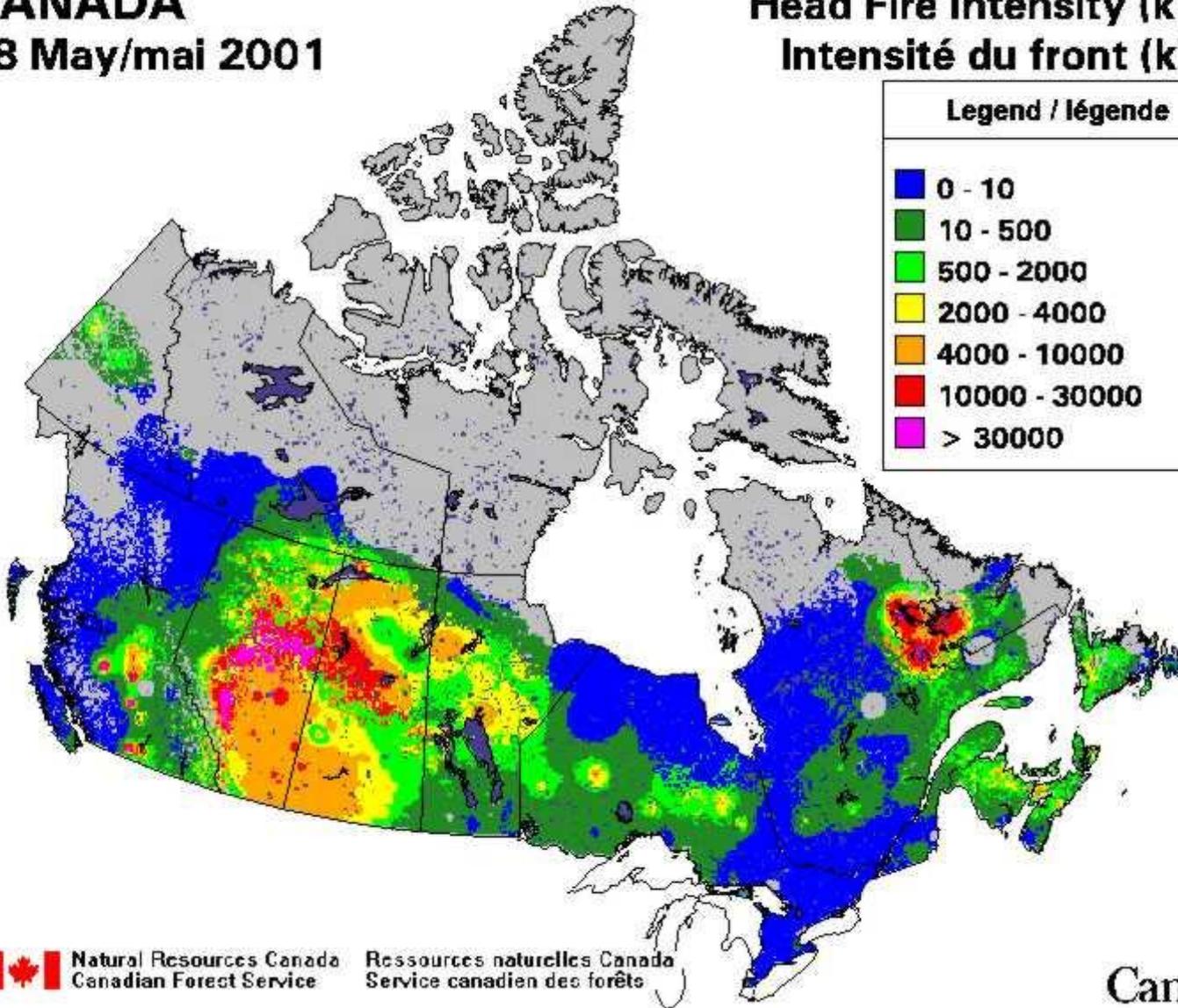
28 May/mai 2001

Head Fire Intensity (kW/m)

Intensité du front (kW/m)

Legend / légende

■	0 - 10
■	10 - 500
■	500 - 2000
■	2000 - 4000
■	4000 - 10000
■	10000 - 30000
■	> 30000



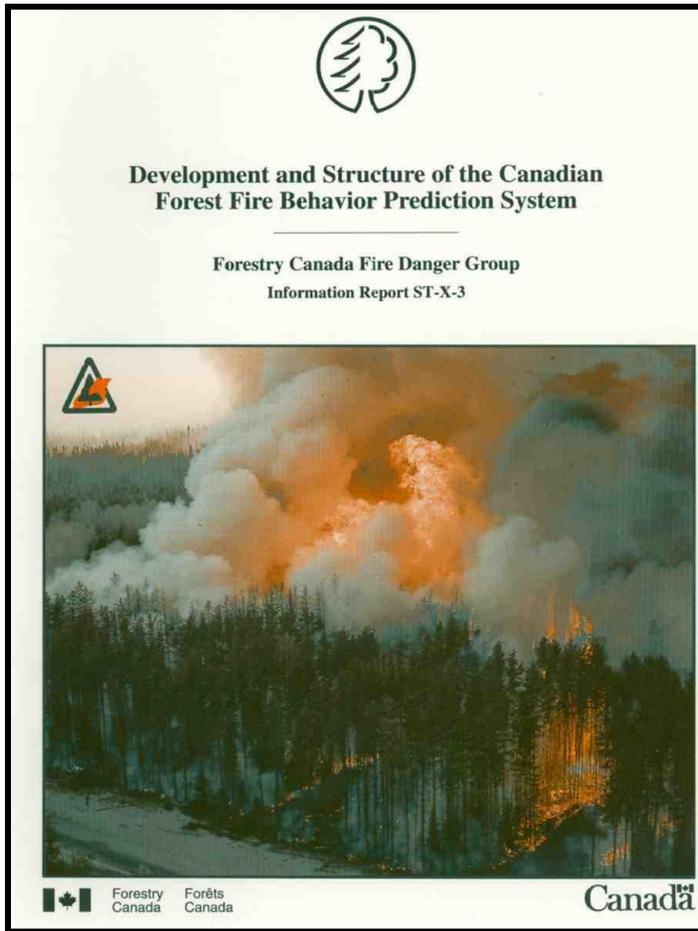
Natural Resources Canada
Canadian Forest Service

Ressources naturelles Canada
Service canadien des forêts

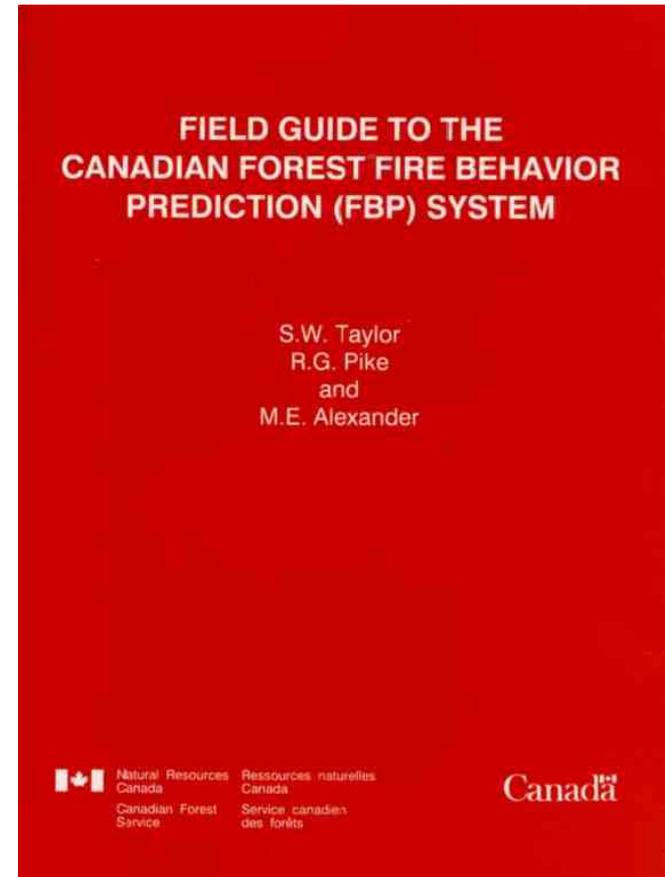
Canada

<http://fms.nofc.cfs.nrcan.gc.ca/cwfis/>

“Operationalizing” the FBP System



**Technical & Scientific
Documentation**



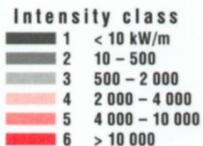
**Operational Field Manual
(FBP System “Red Book”)**



Table 4.1

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

C-1 spruce-lichen woodland



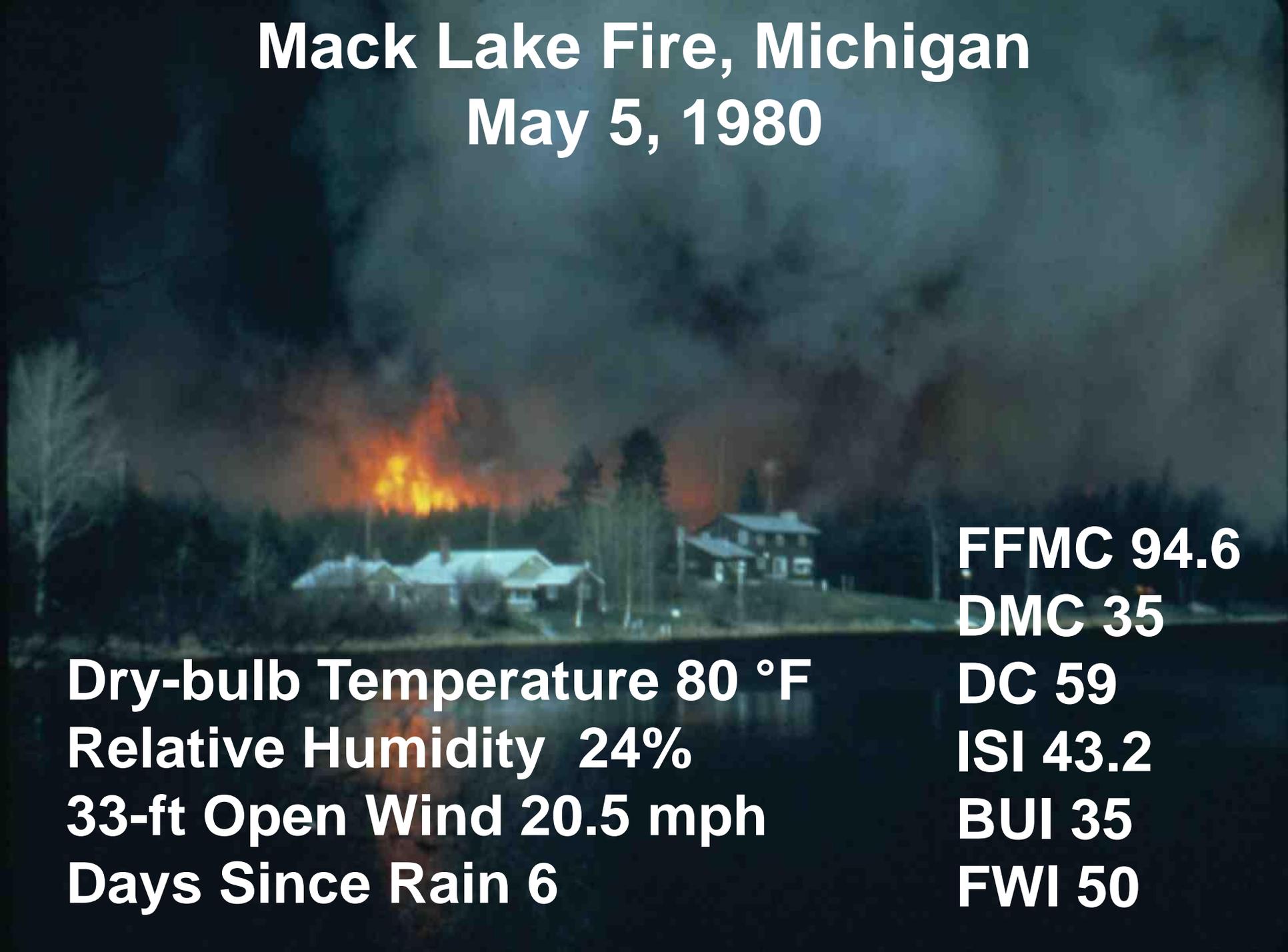
ISI	BUI							
	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
1	0	0	0	0	1	0	0	0
2	0	0	0	0	0	0	0	0
3	0	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
5	0.2	0.2	0.3	0.3	2	0.3	0.3	0.3
6	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.6
7	0.6	0.8	0.9	0.9	1	1	1	1
8	1	1	1	1	2	2	2	2
9	1	2*	2*	2*	3	2*	2*	2*
10	2*	3*	3*	3*	3*	3*	3*	3*
11	3*	4*	4*	4*	4	4*	4*	5*
12	4*	5*	5*	5*	5*	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%.

Sample page
from
FBP System
“Red Book”

Mack Lake Fire, Michigan

May 5, 1980



Dry-bulb Temperature 80 °F
Relative Humidity 24%
33-ft Open Wind 20.5 mph
Days Since Rain 6

FFMC 94.6
DMC 35
DC 59
ISI 43.2
BUI 35
FWI 50

Mack Lake Fire, Michigan May 5, 1980

The following comparisons are based on the major run of the Mack Lake Fire that occurred between 1230 and 1600 hours EDT on May 5, 1980 using FBP System Fuel Type C-4, a 0% Slope and 100% Foliar Moisture Content:

<u>Fire Behavior Characteristic</u>	<u>Predicted</u>	<u>Observed</u>
Head Fire Rate of Spread (ft/min)	187	184
Head Fire Intensity (Btu/sec-ft)	9731	8890
Forward Spread Distance (mi)	7.1	7.5
Area Burnt (Acres)	6262	6778
Fire Perimeter (mi)	15.4	12.4

Predicted Type of Fire at the "Head" :

Continuous Crown Fire (100% Crown Fuel Involvement)

Black Tiger Fire, Colorado July 9, 1989

Dry-bulb Temperature 98 °F

Relative Humidity 24%

33-ft Open Wind 12 mph

Days Since Rain 13

FFMC 95.2

DMC 111

DC 269

ISI 24.5

BUI 111

FWI 59



Black Tiger Fire, Colorado July 9, 1989

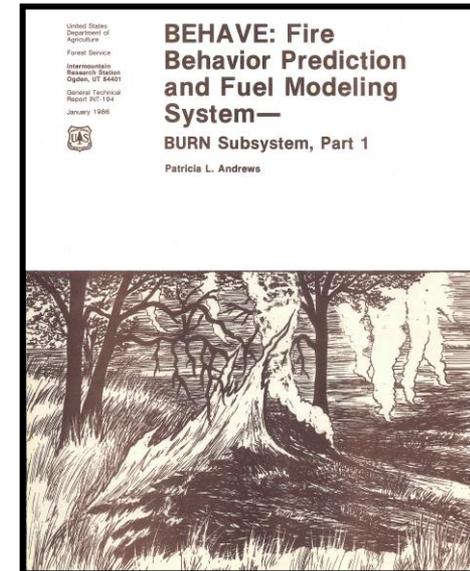
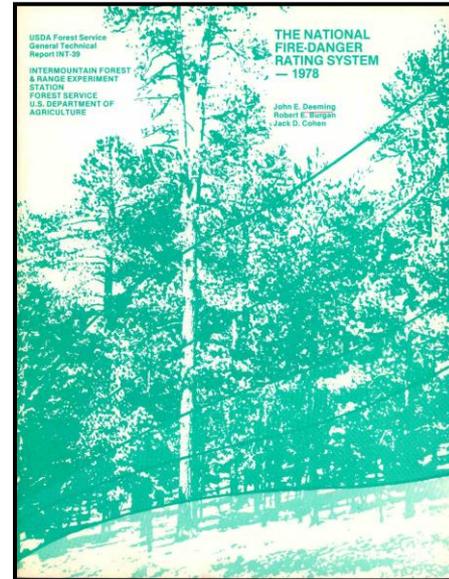
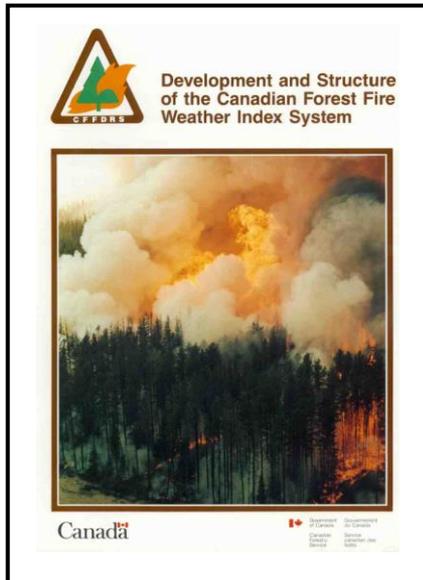
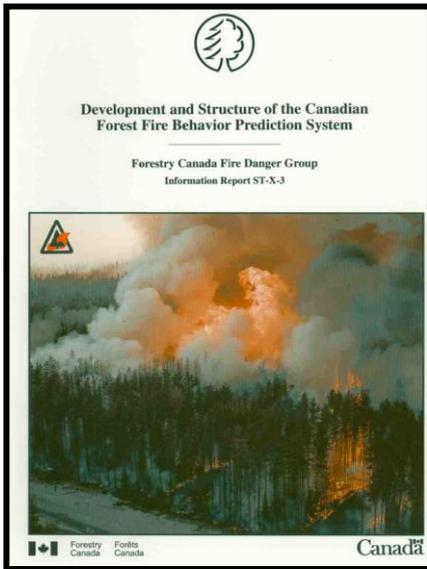
The following comparisons are based on the major run of the Black Tiger Fire that occurred between 1235 and 1800 hours MDT on July 9, 1989 using FBP System Fuel Type C-7, a 23% Upslope Projection and 110% Foliar Moisture Content:

<u>Fire Behavior Characteristic</u>	<u>Predicted</u>	<u>Observed</u>
Head Fire Rate of Spread (ft./min)	19	14
Head Fire Intensity (Btu/sec-ft)	6199	N/A
Forward Spread Distance (mi.)	3.8	2.9

Predicted Type of Fire at the "Head " :

Continuous Crown Fire (95% Crown Fuel Involvement)

Basic Similarities & Differences Between Canadian & U.S. Systems



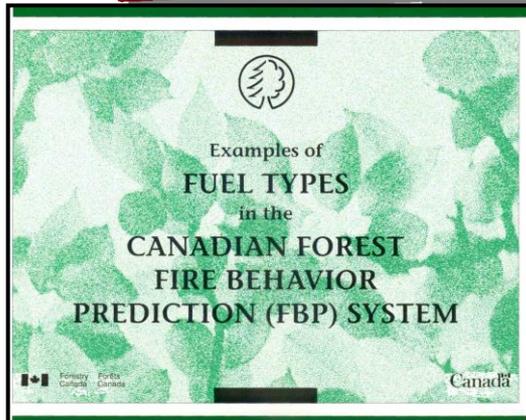
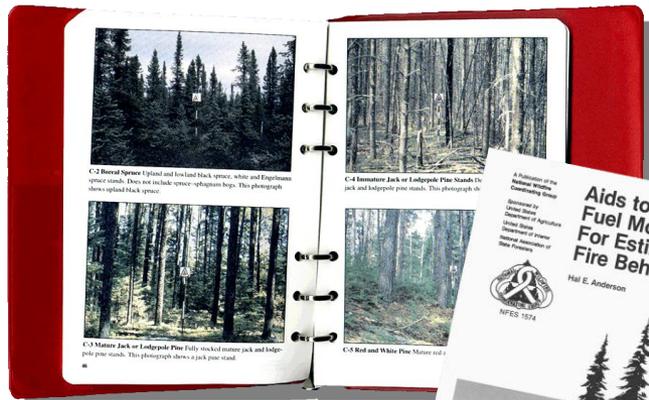


Fire Environment Inputs: Fuels



- **Canadian**
 - **16 Fuel Types**

- **U.S.**
 - **13 Fire Behavior Fuel Models**
 - **20 Fire Danger Fuel Models**
 - **Customized Fuel Models**





Fire Environment Inputs: Live Fuel Moisture



- **Canadian**

- **Conifer Foliar Moisture Content Estimated From Calendar Date, Location (Lat./Long.) and Elevation**



- **U.S.**

- **Understory Live Moisture Content (Herbaceous & Woody) Estimates Based on Phenology Required for Certain Fuel Models.**





Fire Environment Inputs: Dead Fuel Moisture



- **Canadian**

- **FWI System Fuel Moisture Codes**
Dependent on the Continuity of Daily Weather Readings
- **Emphasis on Forest Floor Layer**



- **U.S.**

- **Dead Fuel Moisture Content (1-hr, 10-hr, 100-hr, 1000-hr TL's)**
Calculated From Current Weather Observations Plus Other Environmental Variables
- **Emphasis on Herbaceous & Woody Vegetation & Dead-Down Roundwood Fuels**

Fire Environment Inputs:



Topography



- **Canadian**

- **Considers the Mechanical Effects of % Slope on Fire Behavior**
- **Uses a Vectoring Approach For Cross-Slope Situations**

- **U.S.**

- **Considers the Mechanical Effects of % Slope on Fire Behavior**
- **Uses Basic Vectoring for Cross-Slope Situations**



Fire Environment Inputs: Weather



- **Canadian**

- **Open Wind
Measured at 10-m
Height**



- **U.S.**

- **Open Wind
Measured at 20-ft
(6.1-m) Height**
- **Open Wind Adjusted
for Vegetative Cover
& Topographic
Position to “Mid-
flame” Wind Speed**



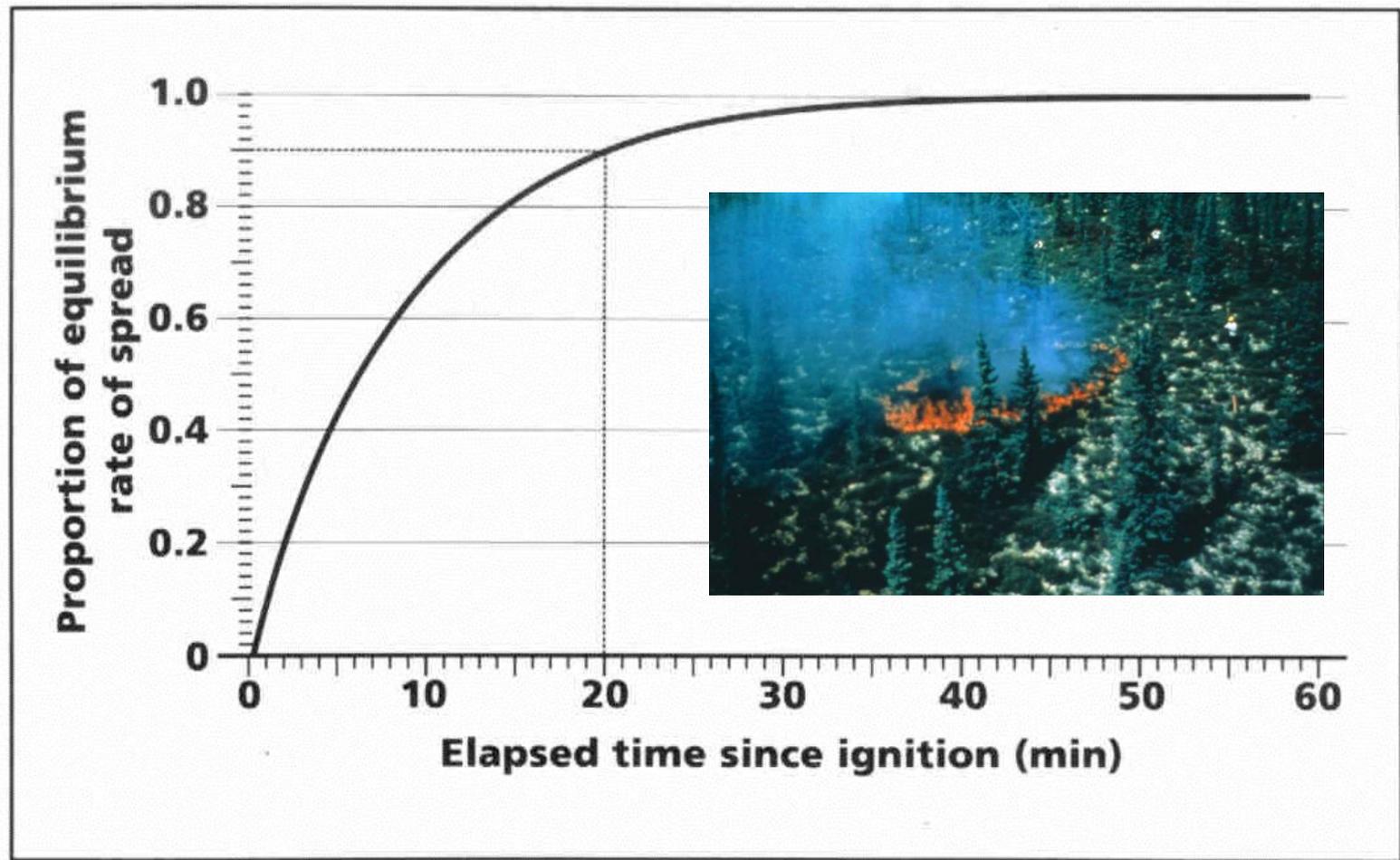
Fire Behavior Outputs



- **Canadian**
 - Produces Estimates of ROS & Intensity
 - Predicts both Surface & Crown Fire Within a Given Fuel Type
 - Predicts Fuel Consumption
 - Allows for Acceleration From A Point Source Ignition
- **U.S.**
 - Produces Estimates of ROS & Intensity/Flame Length
 - Primary Prediction by Fuel Model is for Surface Fire
 - No Estimates of Fuel Consumption
 - No Allowance for Acceleration



Acceleration curve for open canopy fuel types showing the proportion of equilibrium rate of spread as a function of elapsed time since ignition.

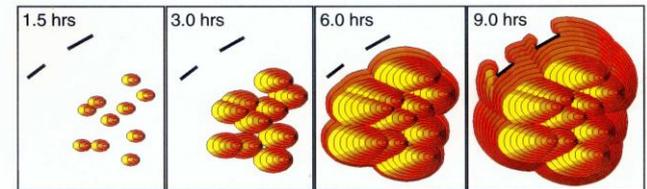
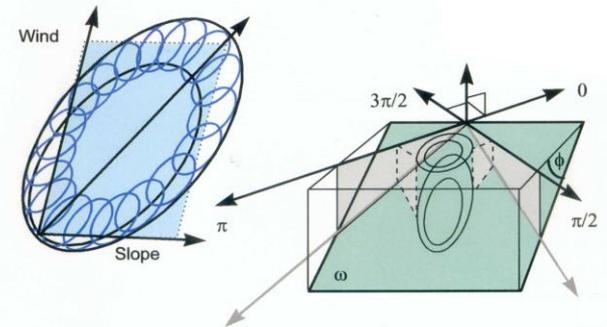




USDA United States Department of Agriculture
Forest Service
Rocky Mountain Research Station
Research Paper RMRS-RP-4
March 1998
UAS

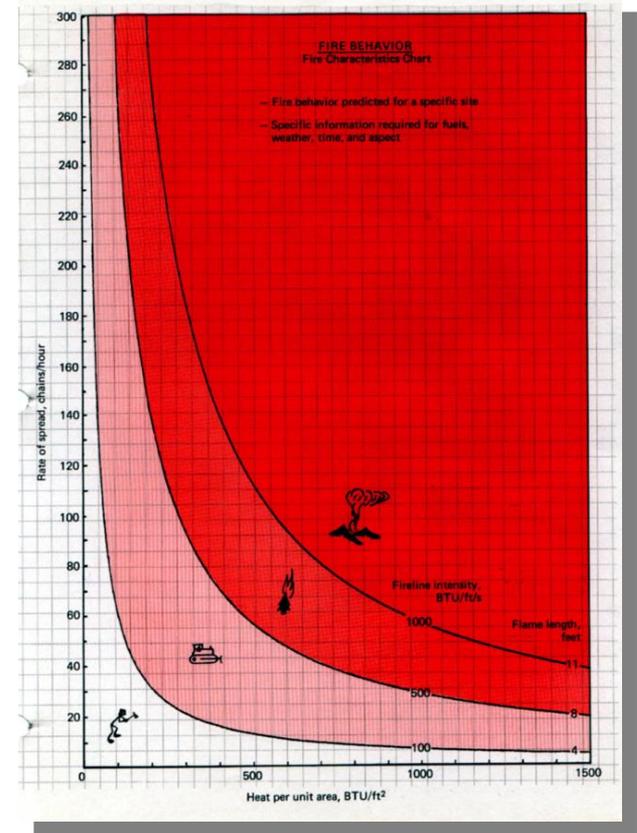
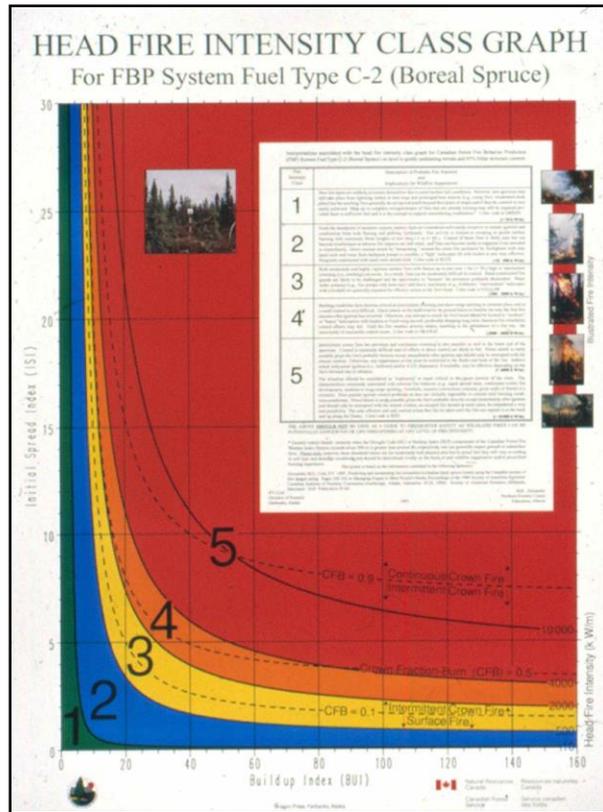
FARSITE: Fire Area Simulator—Model Development and Evaluation

Mark A. Finney



<http://www.firegrowthmodel.com/>

Fire Behavior Outputs: Fire Intensity Class Graphs vs. Hauling Charts





Technical Basis



- **Canadian**
 - **System Largely Derived From Empirical Data Coupled With Simple Logic**

- **U.S.**
 - **System Based on Laboratory Fires & Physical Theory**

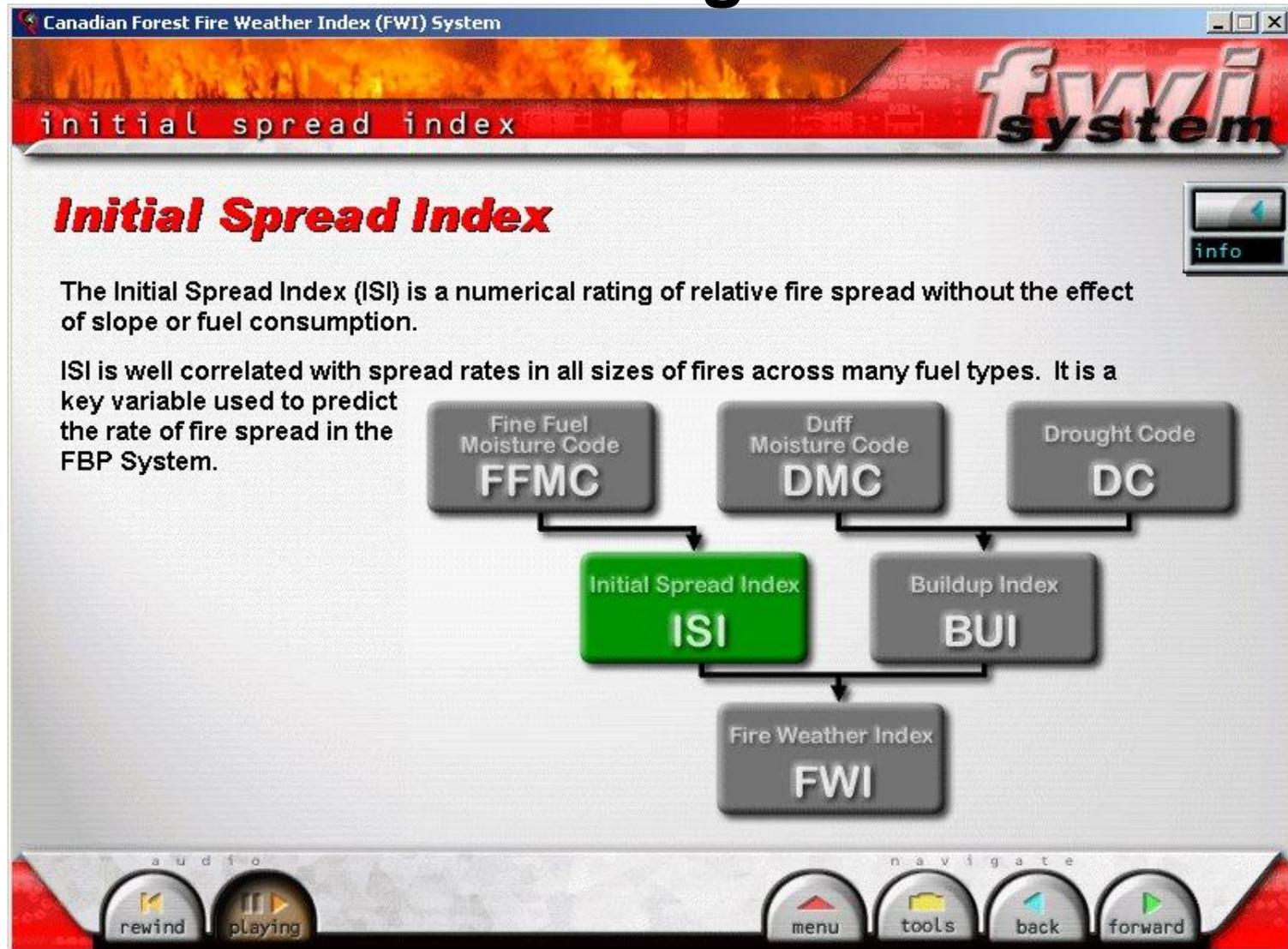


In his comparison of the 1972 National Fire Danger Rating System and the Canadian FWI System, Van Wagner (1975) concluded that:

The American system is probably at its best in the open, grassy forests or brush types with little or no duff layer common in many parts of the United States, but not well represented in Canada. The Canadian system, on the other hand, is at its best in forests with fairly complete canopy and a substantial layer of litter and duff but no marked seasonal variation in herbaceous vegetation.

Understanding the FWI System

CD-ROM based training course available



Canadian Forest Fire Weather Index (FWI) System

initial spread index

Initial Spread Index

The Initial Spread Index (ISI) is a numerical rating of relative fire spread without the effect of slope or fuel consumption.

ISI is well correlated with spread rates in all sizes of fires across many fuel types. It is a key variable used to predict the rate of fire spread in the FBP System.

Fine Fuel Moisture Code
FFMC

Duff Moisture Code
DMC

Drought Code
DC

Initial Spread Index
ISI

Buildup Index
BUI

Fire Weather Index
FWI

info

audio: rewind, playing

navigate: menu, tools, back, forward

Availability: Raincoast Distributors

FBP System Training Materials

**Canadian Forest Fire
Behavior Prediction (FBP)
System: user's guide**

**K.G. Hirsch
Special Report 7**



 Natural Resources Canada
Canadian Forest Service

 Ressources naturelles Canada
Service canadien des forêts



CD-ROM

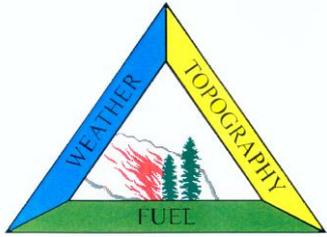


Availability:

Raincoast Distributors

<http://www.raincoastbooks.com>

← **Workbook**



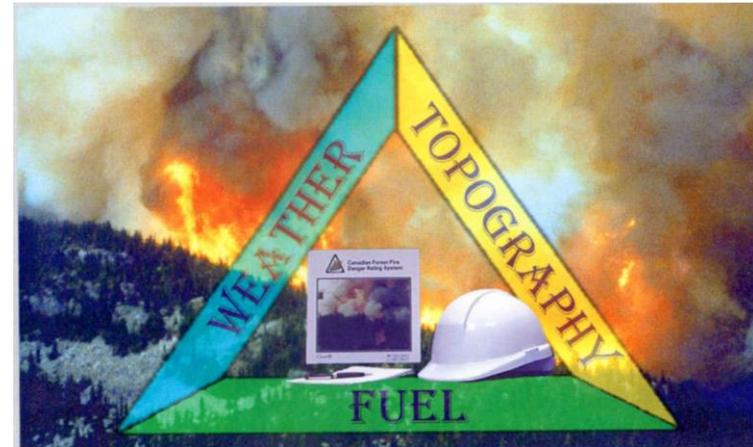
CIFFC

Advanced Wildland Fire Behavior Course

- Delivered regionally (West, East + French)

Wildland Fire Behavior Specialist Course

- Delivered Nationally



Course Dates & Locations Advertised on Canadian Interagency Forest Fire Centre web site: <http://www.ciffc.ca>

CFFDRS Commercial Software



<http://www.remsoft.com/fire/index.html>

THE END



ANY QUESTIONS?