Advanced Fuel Type Modeling

Unit III-B-Environmental Observations (Fuel Characteristics)
Wildland Fire Behavior Specialist Course
February 2008

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CENTRE INTERSERVICES DES FEUX DE FORÊT DU CANADA

Unit IV-A Objectives:

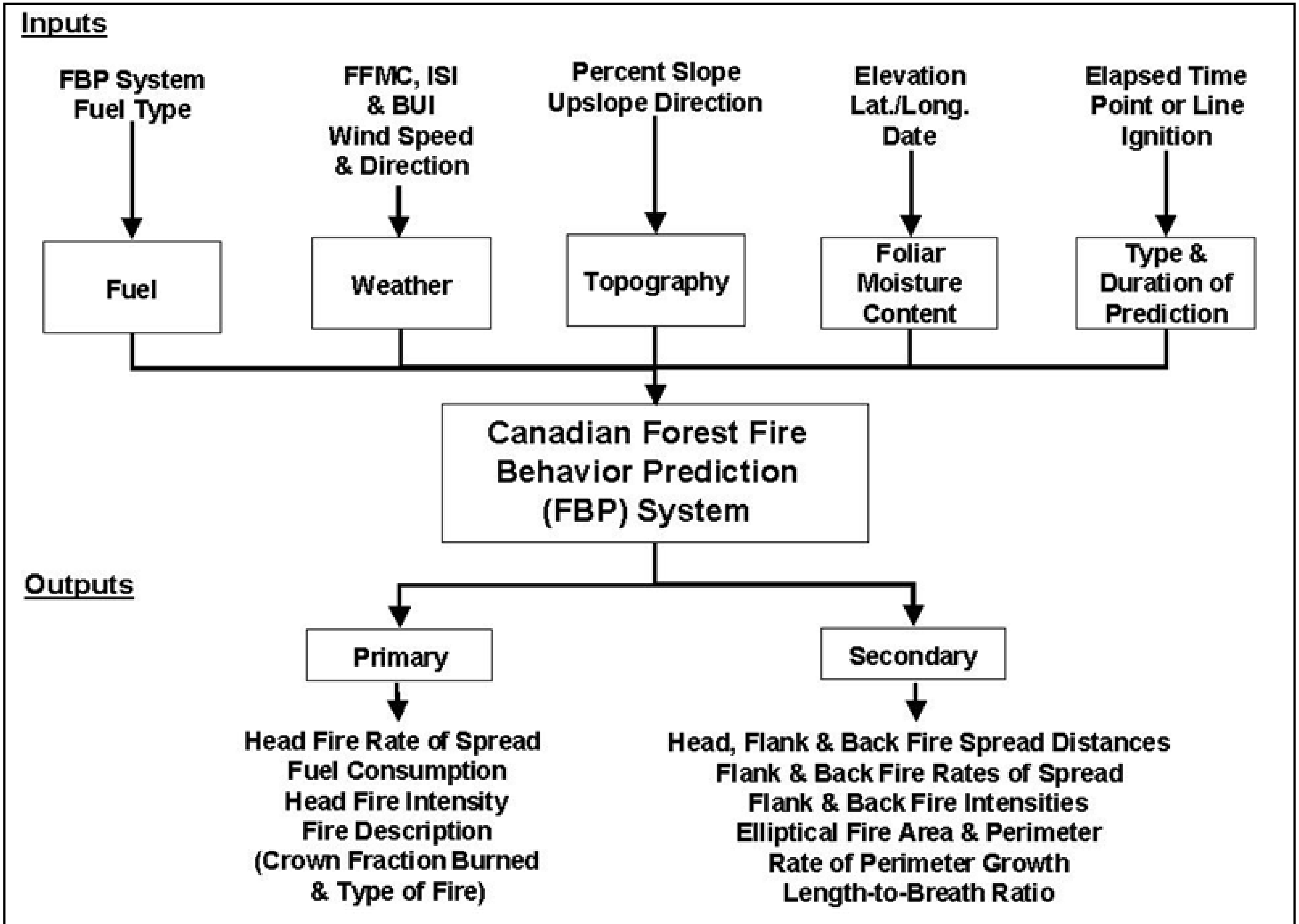
1. Explore in more depth the background and underlying assumptions of the Canadian Forest Fire Behavior Prediction (FBP) System fuel types as a basis for making adjustments. (Marty Alexander)

2. Examine a specific example of adapting the FBP System fuel type classification scheme to a non-standard fuel type. (Stan Harvey)

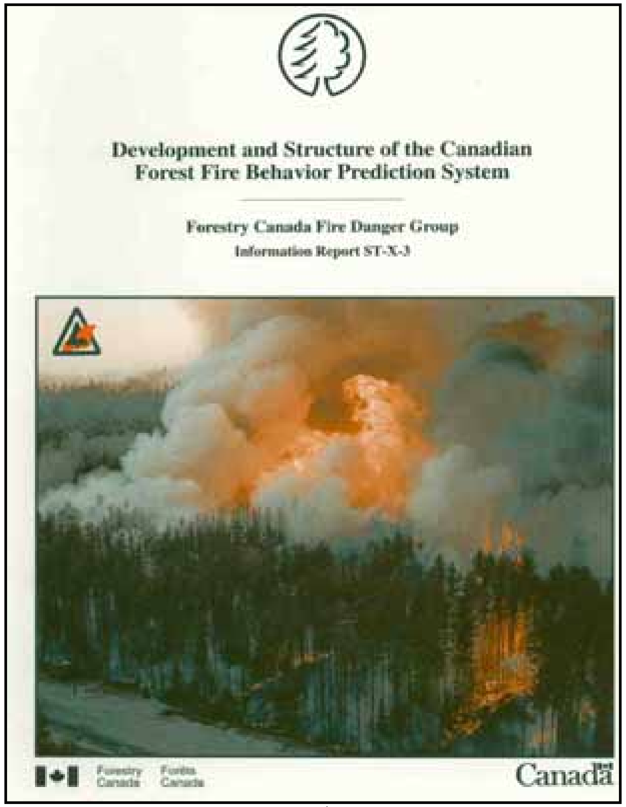
… the makeup of forest fuel complexes must be understood before the interactions between fire and its environment can be examined constructively. To achieve this, the student must be able to appraise forests and wildlands in general from the point of view of their fire potential. In figurative terms, it is like viewing the forest through a different pair of glasses, the kind word constantly by skilled fire control men.

Brown and Davis (1973)
Forest Fire: Control and Use
Second Edition

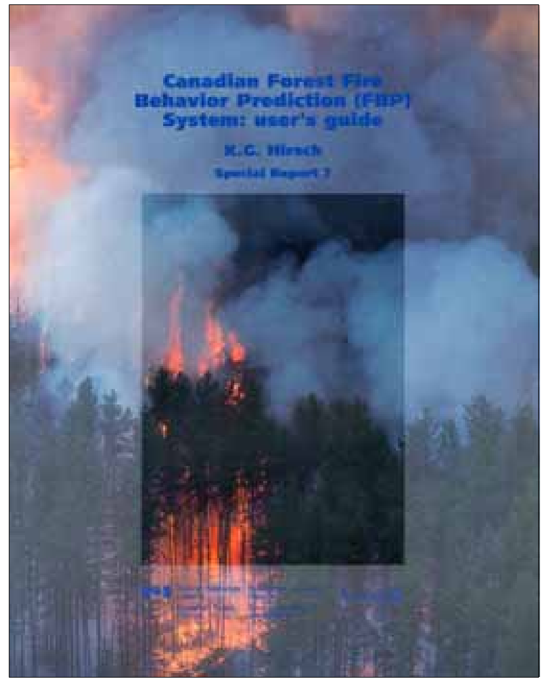
Structure of the Canadian Forest Fire Behavior Prediction (FBP) System

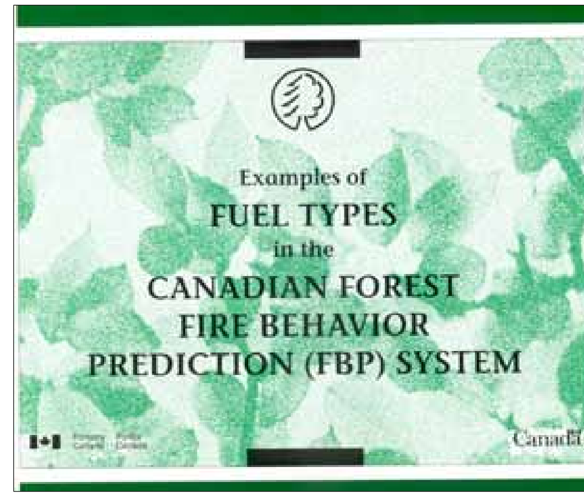


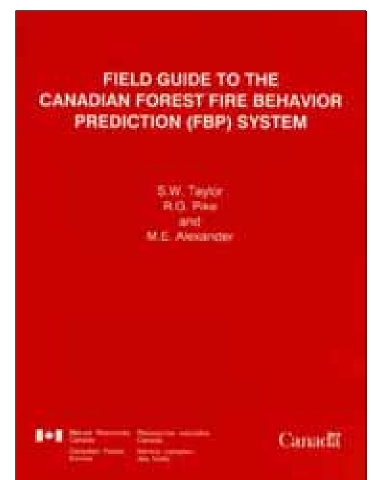
Canadian Forest Fire Behavior Prediction (FBP) System Fuel Type Reference Material



ST-X-3 Report

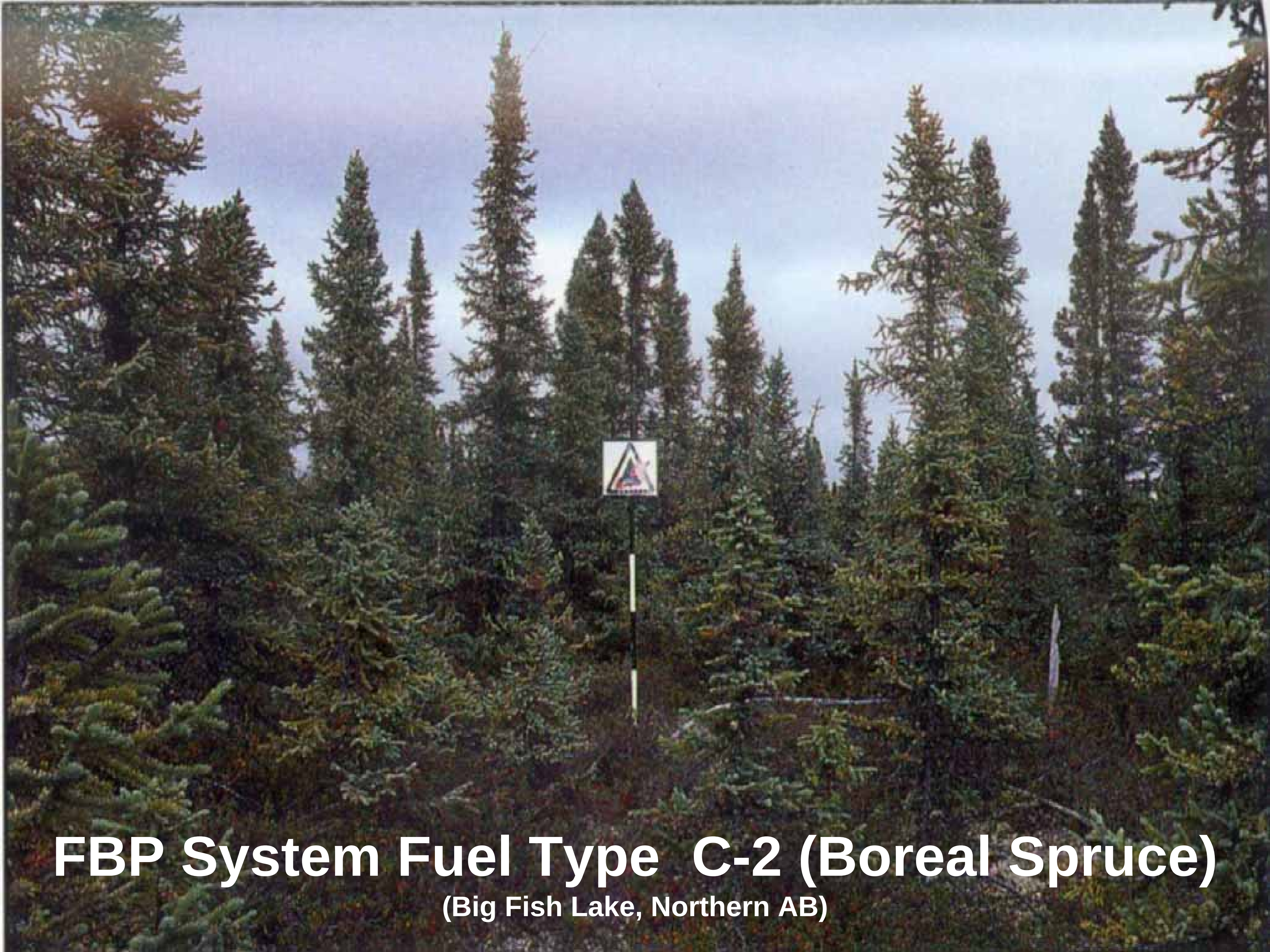






FBP System Fuel Types

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	% Conifer/Hardwood
	M-2 Boreal Mixedwood-Green	% Conifer/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

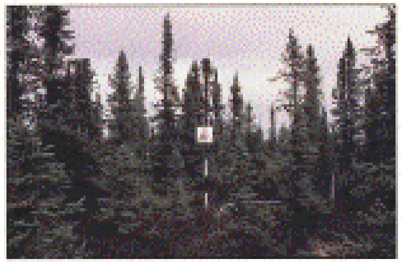


FBP System Fuel Type C-2 (Boreal Spruce)

(Big Fish Lake, Northern AB)

FBP System Fuel Types


C-1


C-2


M-1


M-2


C-3


C-4


M-3


M-4


C-5

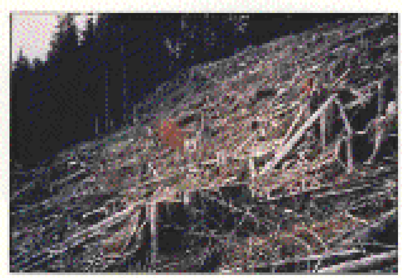

C-6


S-1


S-2

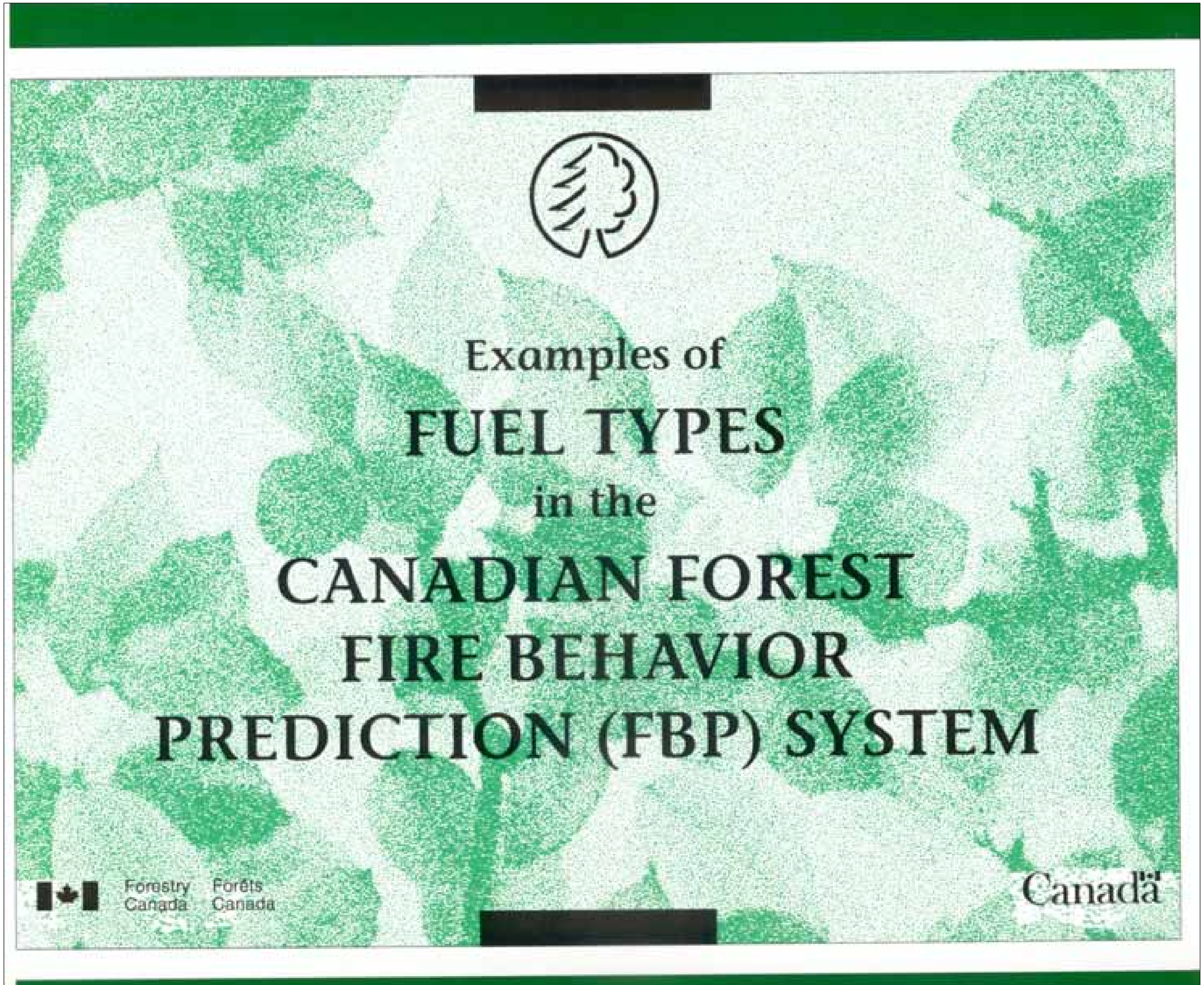

C-7


D-1


S-3

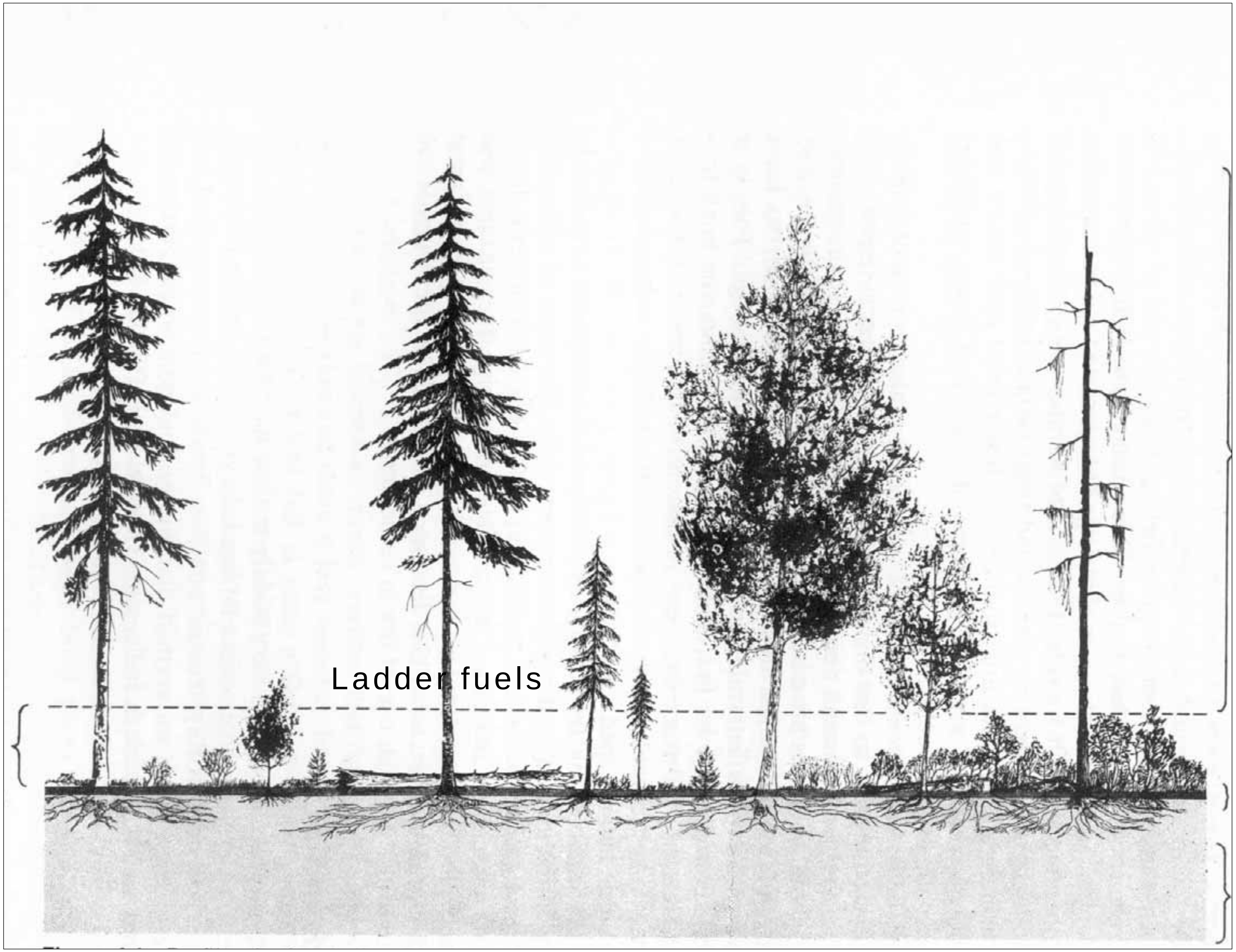

O-1

FBP System Fuel Type Poster



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.



Forest Fuel Complex Profile

Table 3 in the ST-X-3 report contrasts the FBP System Fuel Types in terms of the:

- Forest floor & organic layer
- Surface & ladder fuels
- Stand structure/composition

Table 3. Summary of Canadian Forest Fire Behavior Prediction (FBP) System fuel type characteristics.

Forest floor and organic layer	Surface and ladder fuels	Stand structure and composition
Fuel Type C-1 (Spruce–Lichen Woodland)		
Continuous reindeer lichen; organic layer absent or shallow, uncompacted.	Very sparse herb/shrub cover and down woody fuels; tree crowns extend to ground.	Open black spruce with dense clumps; assoc. sp. jack pine, white birch; well-drained upland sites.
Fuel Type C-2 (Boreal Spruce)		
Continuous feather moss and/or *Cladonia*; deep, compacted organic layer.	Continuous shrub (e.g., Labrador tea); low to moderate down woody fuels; tree crowns extend nearly to ground; arboreal lichens, flaky bark.	Moderately well-stocked black spruce stands on both upland and lowland sites; *Sphagnum* bogs excluded.
Fuel Type C-3 (Mature Jack or Lodgepole Pine)		
Continuous feather moss; moderately deep, compacted organic layer.	Sparse conifer understory may be present; sparse down woody fuels; tree crowns separated from ground.	Fully stocked jack or lodgepole pine stands; mature.

FBP System Fuel Type Characteristics

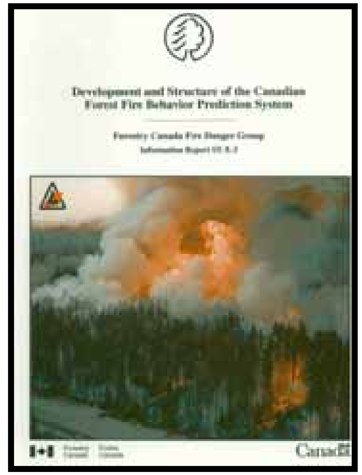
Fuel Type	Max. Surface Fuel Consumption (t/ha)	Crown Base Height (m)	Crown Fuel Load (t/ha)
C-1 Spruce-Lichen Woodland	15.0	2.0	0.75
C-2 Boreal Spruce	50.0	3.0	0.80
C-3 Mature Jack or Lodgepole Pine	50.0	8.0	1.15
C-4 Immature Jack or Lodgepole Pine	50.0	4.0	1.20
C-5 Red and White Pine	50.0	18.0	1.20
C-6 Conifer Plantation	50.0	7.0	1.80
C-7 Ponderosa Pine/Douglas-fir	35.0	10.0	0.50
D-1 Leafless Aspen	15.0	-	-
M-1 Boreal Mixedwood-Leafless	50.0	6.0	0.80
M-2 Boreal Mixedwood-Green	50.0	6.0	0.80
M-3 Dead Balsam Fir/Mixedwood-Leafless	50.0	6.0	0.80
M-4 Dead Balsam Fir/Mixedwood-Green	50.0	6.0	0.80
S-1 Jack or Lodgepole Pine Slash	80.0	-	-
S-2 Spruce/Balsam Slash	160.0	-	-
S-3 Coastal Cedar/Hemlock/Douglas-fir Slash	320.0	-	-
O-1a Matted Grass	3.0	-	-
O-1b Standing Grass	3.0	-	-

The existing list of FBP System fuel types "…represents as broad a range of conditions in Canadian fuel types as allowed by the existing fire behavior database … The list of fuel types is not intended to be comprehensive or fixed for the future; additions and refinements will be made as data become available.

From page 3 of ST-X-3 report on the FBP System

Creating the basic FBP System database

Experimental Fire

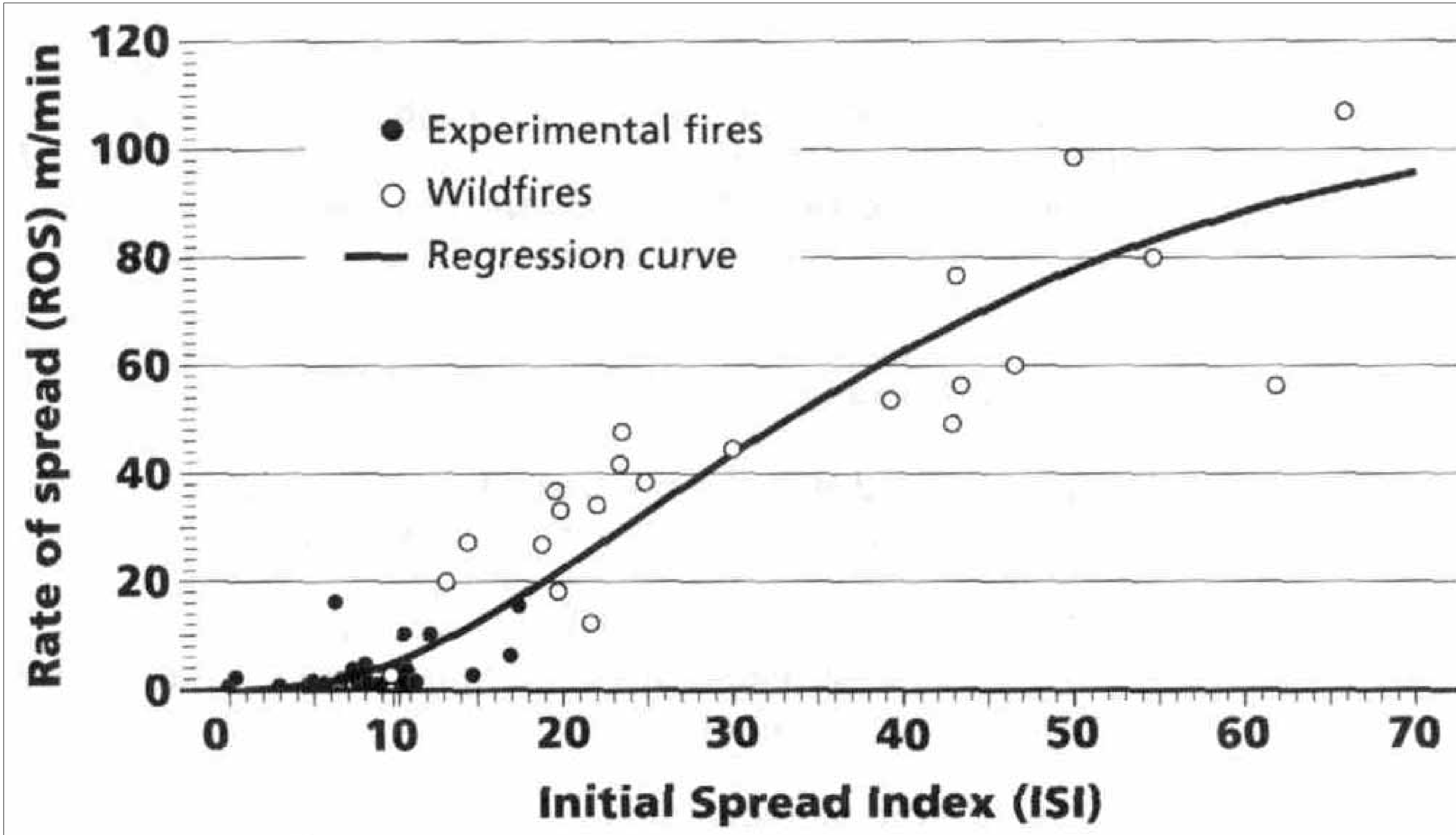


See video:
"Mounting the Attack on Wildfire"

Operational Prescribed Fire

Wildfire

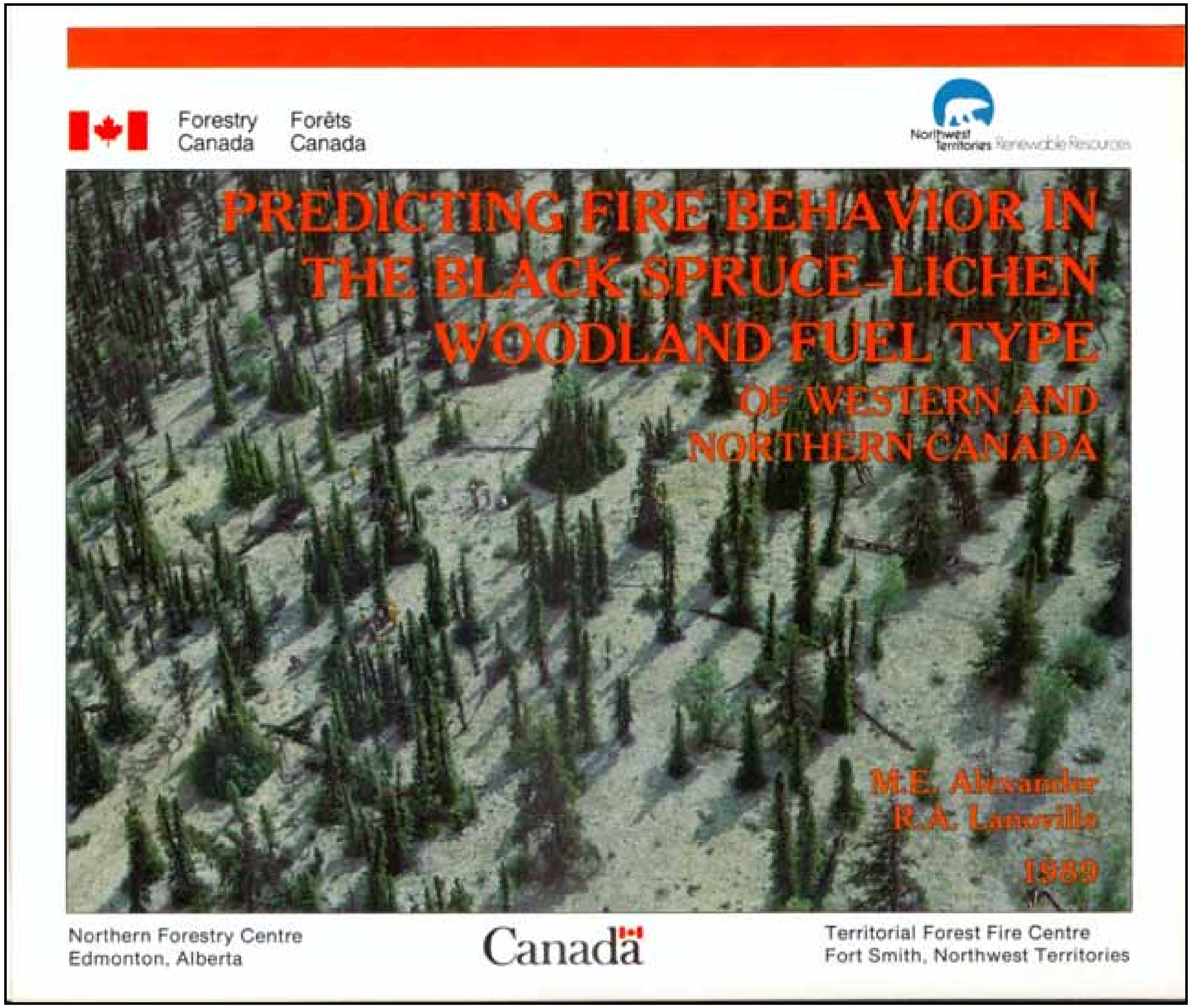
Basic rate of spread curve for FBP System Fuel Type C-3 (Mature Jack or Lodgepole Pine)

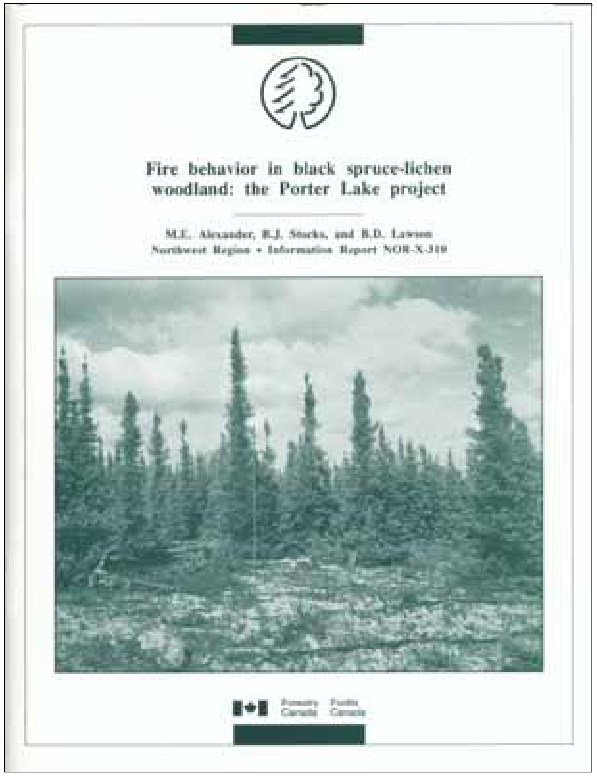


C-1 Fuel Type (Spruce-Lichen Woodland)

Porter Lake, Caribou Range, Northwest Territories

Alexander & Lanoville (1989) wall poster and Alexander et al. (1991) report (on WFBS CD)





C-2 Fuel Type (Boreal Spruce)

Big Fish Lake, Footner Lake Forest, Northern AB

C-3 Fuel Type
(Jack and Immature Lodgepole Pine)

Darwin Lake Project, NE Alberta - 1974

Darwin Lake Poster
(on WFBS CD)

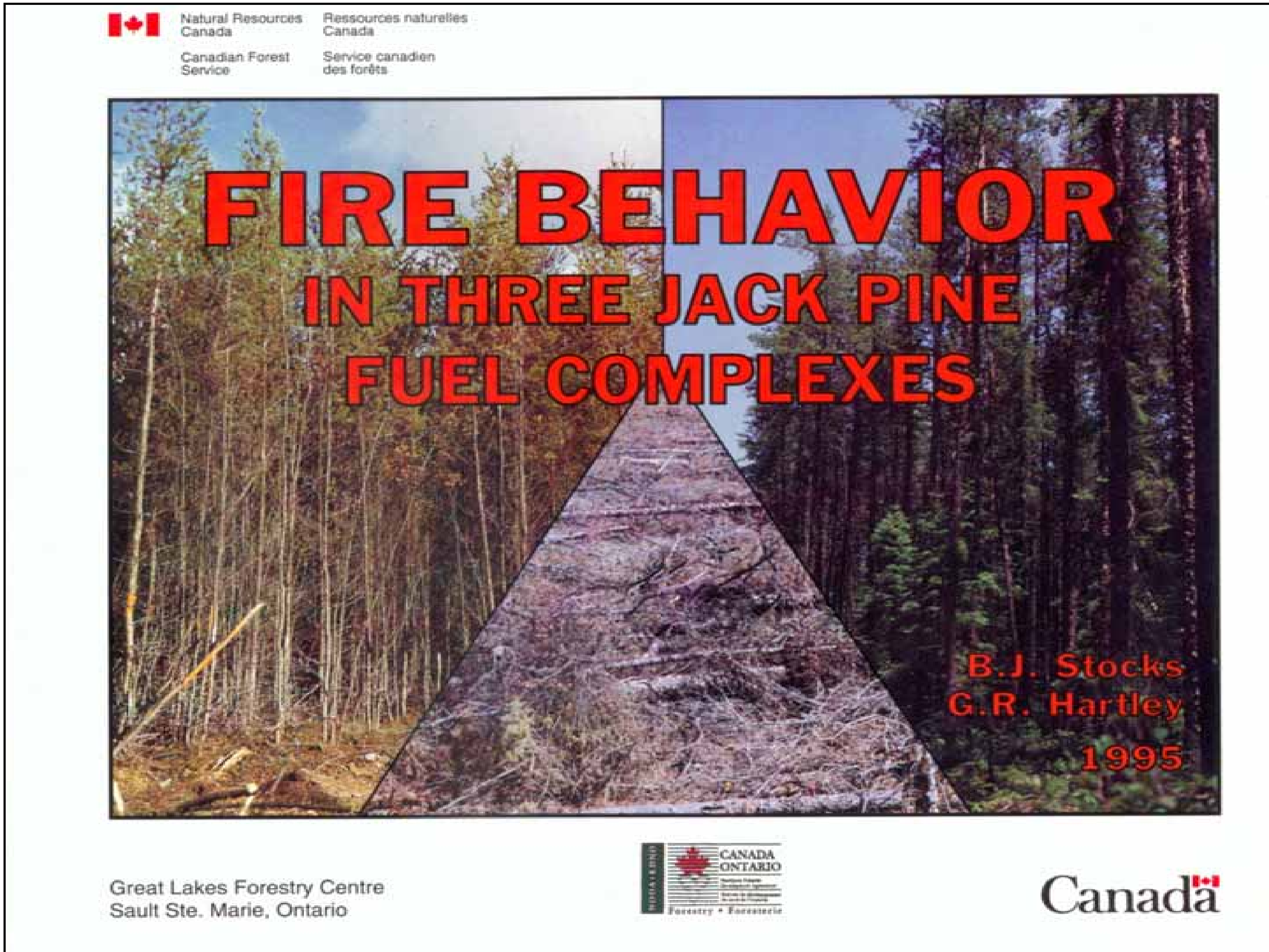
C-3 Fuel Type
(Mature Jack and Lodgepole Pine)

Lodgepole Pine, Prince George, BC

C-4 Fuel Type
(Immature Jack and Lodgepole Pine)

Jack Pine Stand, Sharpsand Creek Fire, NE Ontario

Stocks & Hartley (1995) Poster
(on WFBS CD)



C-5 Fuel Type (Red and White Pine)

Red and White Pine, Petawawa Forest Experiment Station, Ontario

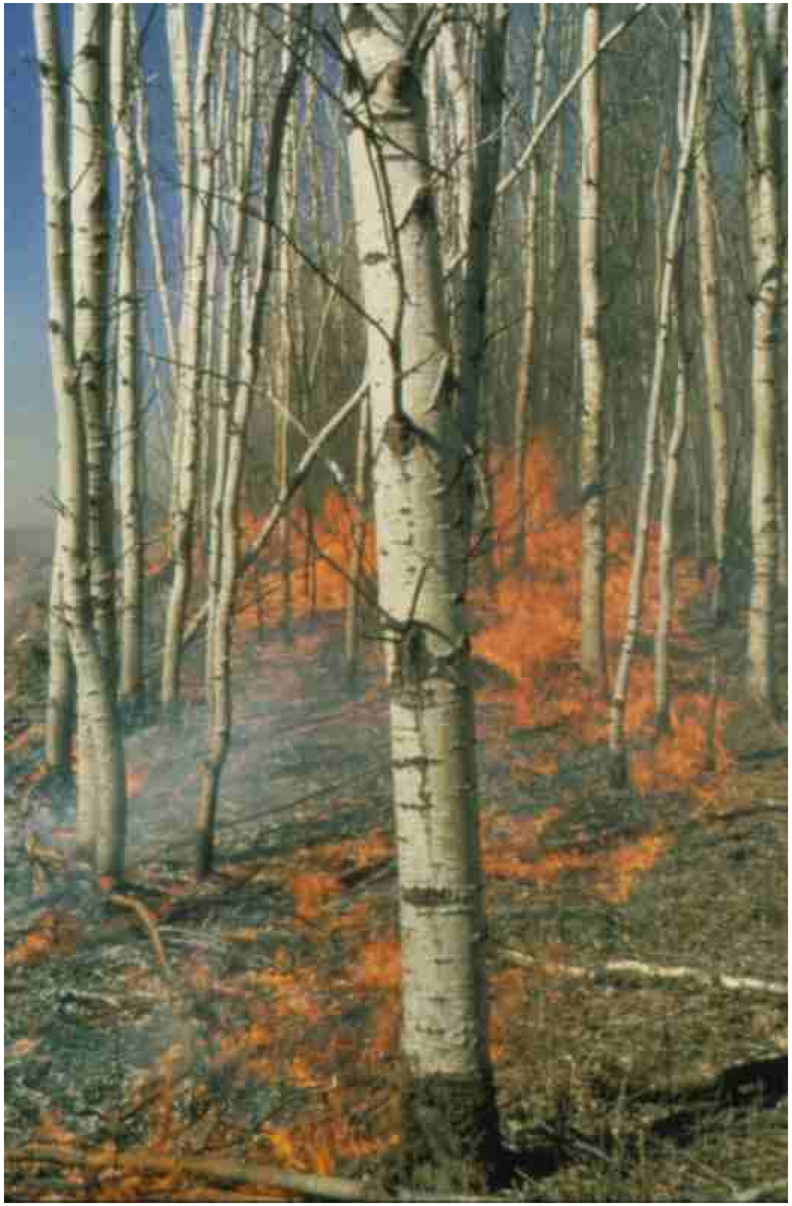
C-6 Fuel Type (Conifer Plantation)

Red Pine Plantation, Petawawa Forest Experiment Station, Ontario

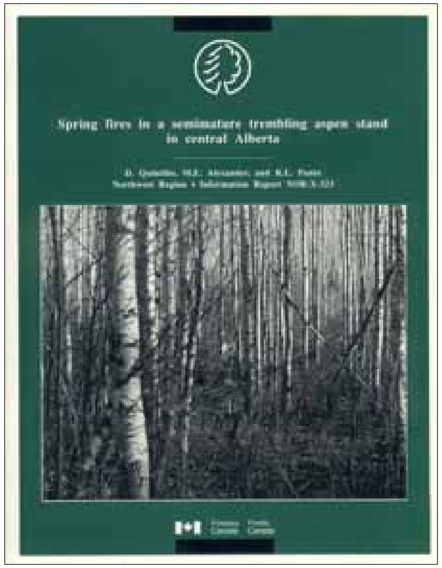
C-7 Fuel Type
(Ponderosa pine/Douglas-fir)

Various experimental fires in BC undertaken by UBC researchers (R. Strang and A. Johnson)

D-1 Fuel Type (Leafless Aspen)



Semi-mature Aspen Stand, Hondo, AB



D-2 ? (20% of D-1)

S-1 Fuel Type
(Jack and Lodgepole Pine Slash)

Jack Pine Slash, NE Ontario

S-1 Fuel Type
(Jack and Lodgepole Pine Slash)

Lodgepole Pine Slash, Kananaskis FES, Alberta

S-2 Fuel Type
(White Spruce/Balsam Slash)

Principally experimental fire studies in BC

S-3 Fuel Type (Coastal Cedar/Hemlock/Douglas-fir Slash)

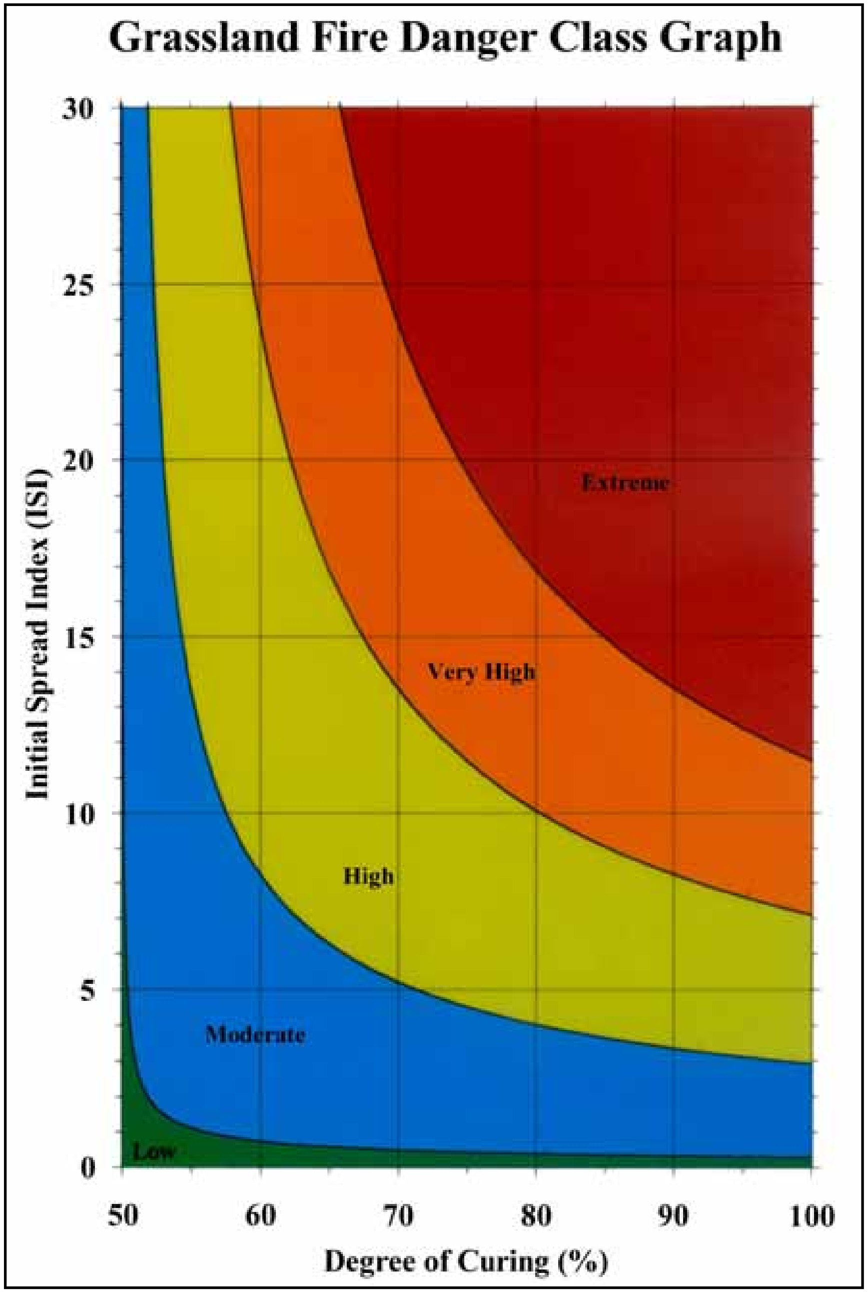
Experimental fire studies in BC

M-3/M-4 Fuel Types (Dead Balsam Fir/Mixedwood – Leafless & Green)

Spruce budworm-killed balsam fir, Aubinadong River, NE Ontario

FBP System O-1a & O1-b Fuel Types (Matted Grass and Standing Grass)

Northern Territory, Australia



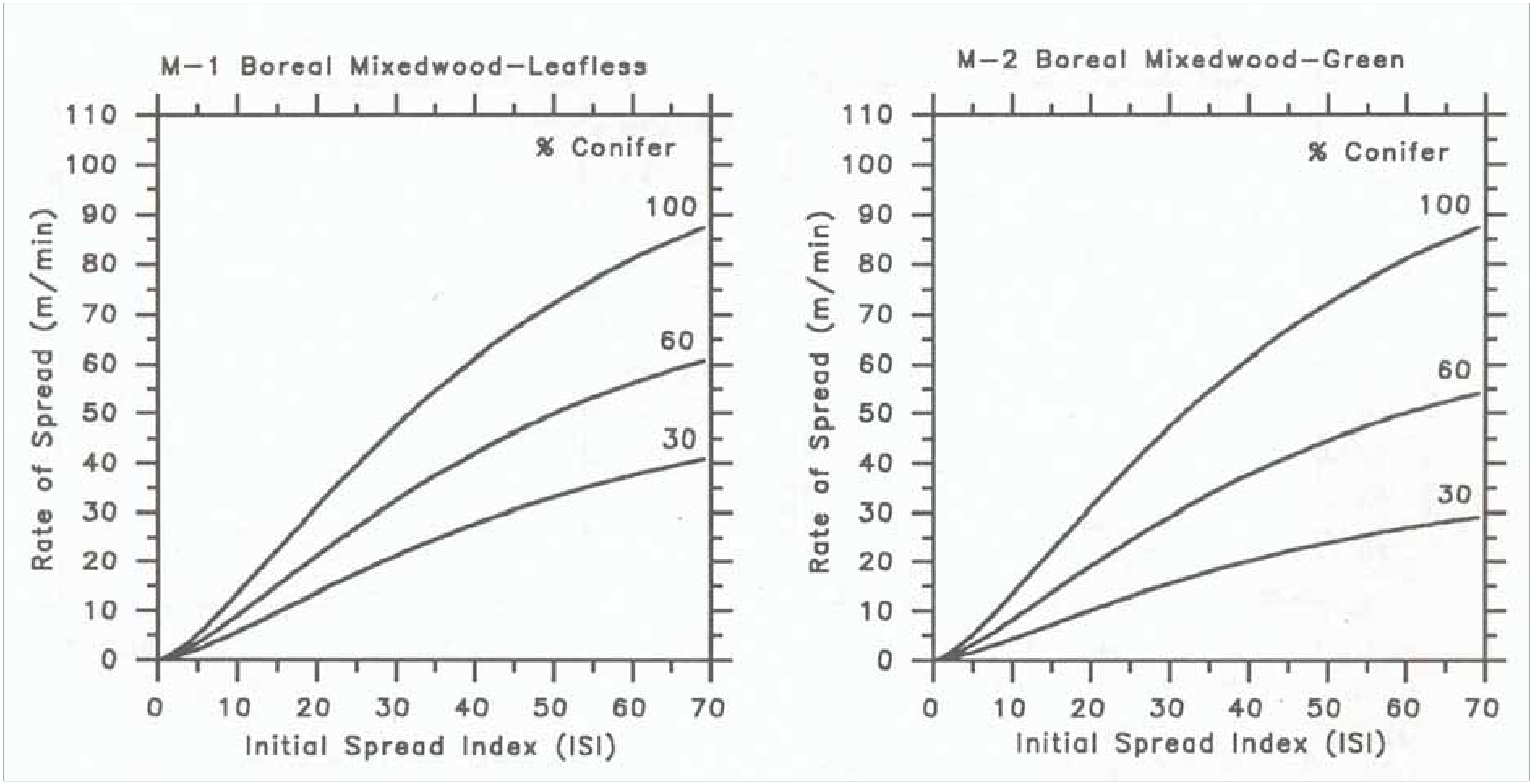
Seasonal changes in the fuel complex (e.g., degree of curing in grasslands) can also drastically influence fire behavior.

Current and Ongoing Studies

- **Mature White Spruce-Subalpine Fir – near Quesnel, BC - ???**
- **Mountain Pine Beetle-killed Stands, Prince George region, BC - 2004**
- **Validation of M-1 and M-2 “two fuel type” modelling assumptions – LaFoe Creek, ON – started in early 90s**
- **International Crown Fire Modelling Experiment, near Fort Providence, NT – 1995-2001**

Joint BCFS/CFS Mountain Pine Beetle Fire Behavior Study

Basic rate of spread curves for the Boreal Mixedwood (M-1 & M-2) Fuel Types



1986 Terrace Bay Fire, Ontario
M-1 50C:50H
ROS Obs. 20 m/min vs. Pred. 21 m/min

See Stocks (1988) case study sent out with pre-course material

M-1 and M-2 FBP System Fuel Types

% Conifer (C)

% Hardwood (H)

The % should be based on the % area occupied by C vs. H

The "Two Fuel Type" Concept Applied to FBP System M-1 Fuel Type

Fuel Type	FFMC	Wind	ISI	ROS*
C-2	89	20	10	14 m/min
D-1	89	20	10	3 m/min

Sample Computation for M-1 75%C:25%H (Spring):

ROS = [14 m/min x 0.75] + [3 m/min x 0.25]

= 10.5 m/min + 0.75 m/min = 11.25 m/min

***BUI 70.**

The "Two Fuel Type" Concept
Applied to FBP System Fuel Type M-2

Fuel Type	FFMC	Wind	ISI	ROS*
C-2	89	20	10	14 m/min
D-1	89	20	10	3 m/min

Sample Computation
for M-2 50%C:50%H (Summer):

ROS = [14 m/min x 0.5] + [(3 x 0.2) x 0.5]

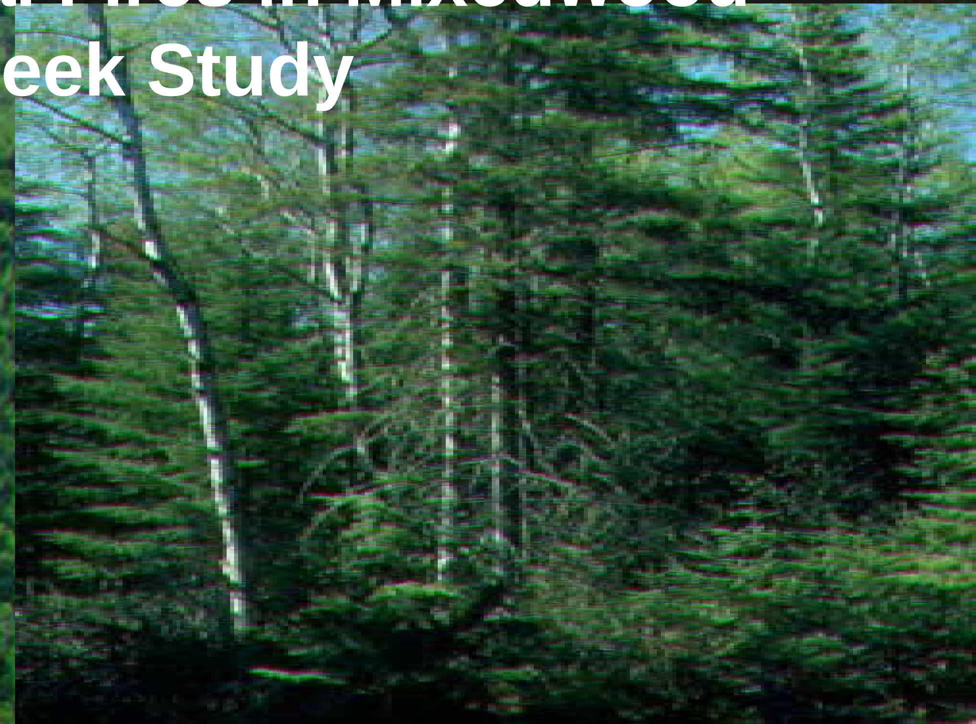
7.0 m/min + 0.3 m/min = 7.3 m/min

*BUI 70.

H in Summer: 20% of D-1

Ontario Experimental Fires in Mixedwood
LaFoe Creek Study



Ontario Experimental Fires in Mixedwood*

Fire behavior	Plot 1	Plot 2	Plot 3
Observed			
ROS (m/min)	8.84	12.876	3.72
HFI (kW/m)	2236	3420	789
Area Burned (ha)	1	1	1
FPB Predictions			
ROS (m/min)	8.51	11.65	7.17
HFI (kW/m)	3538	7522	1939
Area Burned (ha)	1.04	0.99	4.94
BEHAVE Predictions			
ROS (m/min)	1	<0.1	<0.1
HFI (kW/m)	121	15	12
Area Burned (ha)	<0.01	<0.01	<0.01

***from Hely et al. (2001) Canadian Journal of Forest Research**

The "Two Fuel Type" Concept
Applied to Mixed Jack Pine & Aspen Stand

Fuel Type	FFMC	Wind	ISI	ROS*
C-3	89	20	10	5 m/min
D-1	89	20	10	3 m/min

Sample Computation

for 50% Mature Jack Pine & 50% Aspen (Spring):

ROS = (5 m/min x 0.5) + (3 m/min x 0.5)

= 2.5 m/min + 1.5 m/min = 4.0 m/min

***BUI 70.**

International Crown Fire Modelling Experiment (ICFME)

ICFME Fuel Complex: 13 m tall Jack Pine Overstory/Black Spruce Understory

ICFME Fuel Complex


Plot A - July 1, 1997


Plot 5 - July 4, 1997


Plot 6 - July 6, 1997


1997:
3 Fires
Plot 6
Plot A
Plot 5

Phase II 1998: Only 2 Fires!!!

1998 certainly tested our Resolve

Aspen Plot - June 17, 1999

Plot I1- June 18, 1999

Plot 9 - June 19, 1999

Phase III
1999

Continued...

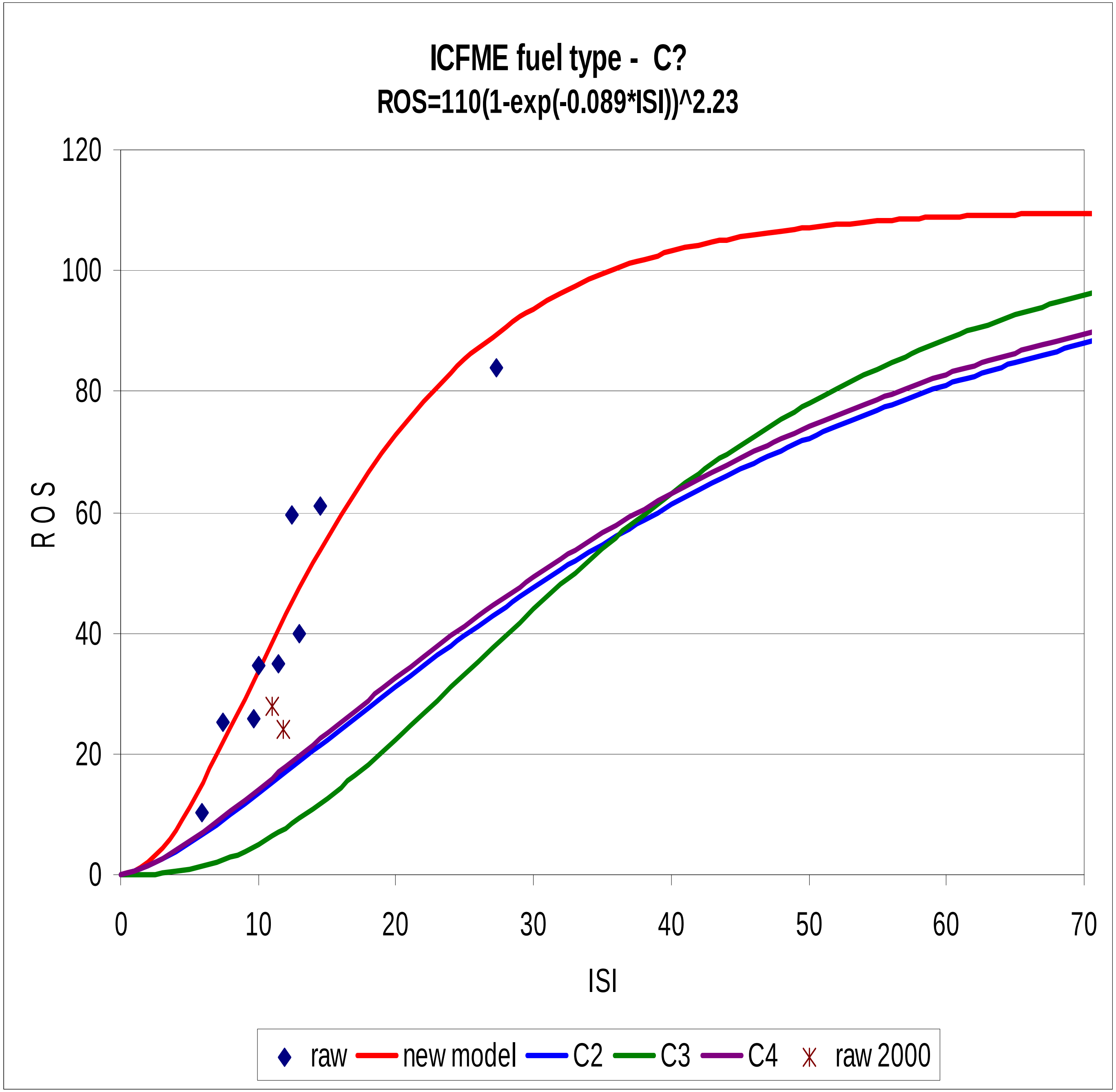
1999:
6 Fires in total

Phase IV
2000

Continued...

2000:
7 Fires + in total


Roof Test
Siding Test
Plot I1 House Fire
June 25, 2000
Fully Involved
House Fire Fails to Ignite Forest



ICFME fuel type - C?
ROS=110(1-exp(-0.089*ISI))^2.23
120
100
80
60
40
20
0
R O S
0
10
20
30
40
50
60
70
ISI
raw
new model
C2
C3
C4
raw 2000

Basic Reminders

- **Don’t get into the trap of fixating on the descriptive names because of the tree species (focus on fuel structure in relation to fire behavior).**

- **Carefully read the detailed fuel type descriptions given in ST-X-3**

- **Carefully study the photographic examples, especially the “standards”**

Some Personal Opinions

- We must recognize that we simply can’t assign an FBP System fuel type to every hectare in the country (there will be good matches, fair-poor matches and “unclassified” types).
- Don’t necessarily explicitly accept/trust FBP System fuel typing – recognize that most of this is done for preparedness planning/decision support system purposes

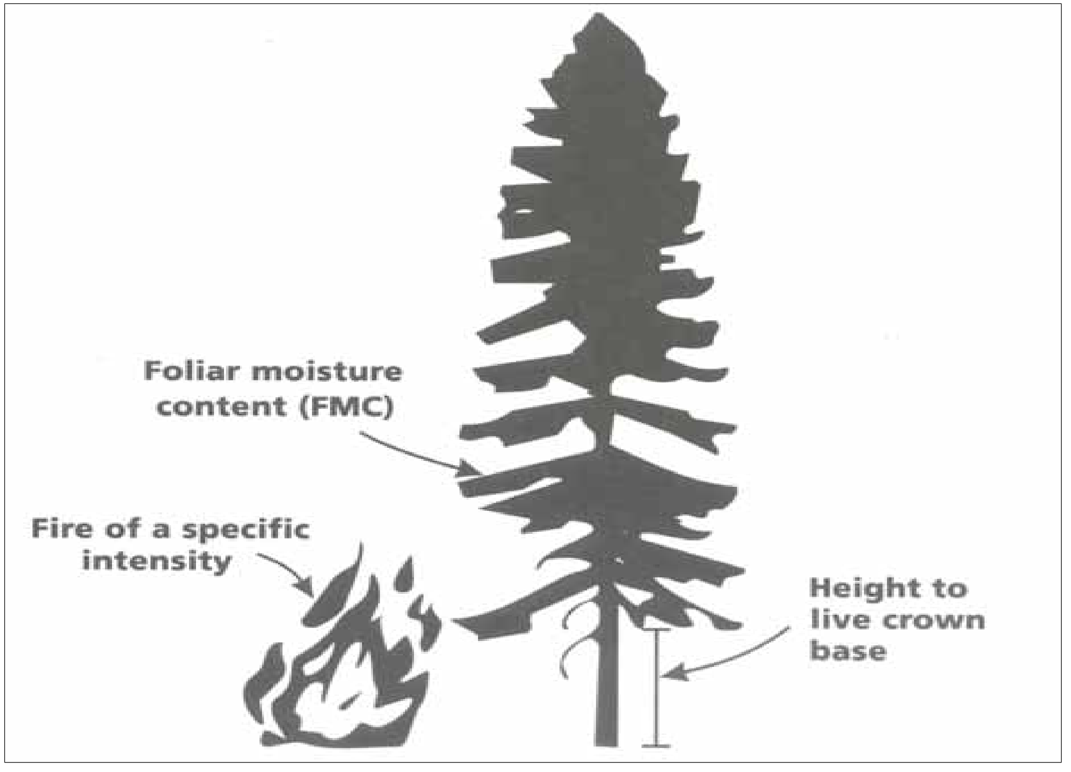
Some Personal Opinions (continued)

- There is not a nationally accepted "key" for translating forest/vegetation inventory criteria to FBP System fuel types.

- Their is effectively a "D-2" (Leafed out Aspen – Summer) fuel type (i.e., 1/5 or 20% of the D-1 rate of spread) but it has no real basis as this was simply a "gimmick" for M-2 computations.

Some Personal Opinions (continued)

- **Besides C-6, the REMSOFT FBP System software allows for changing the crown base height and foliar moisture content for all fuel types susceptible to crowning.**



Two crown fuel properties influence the prediction of crown fire initiation

Some Personal Opinions (continued)

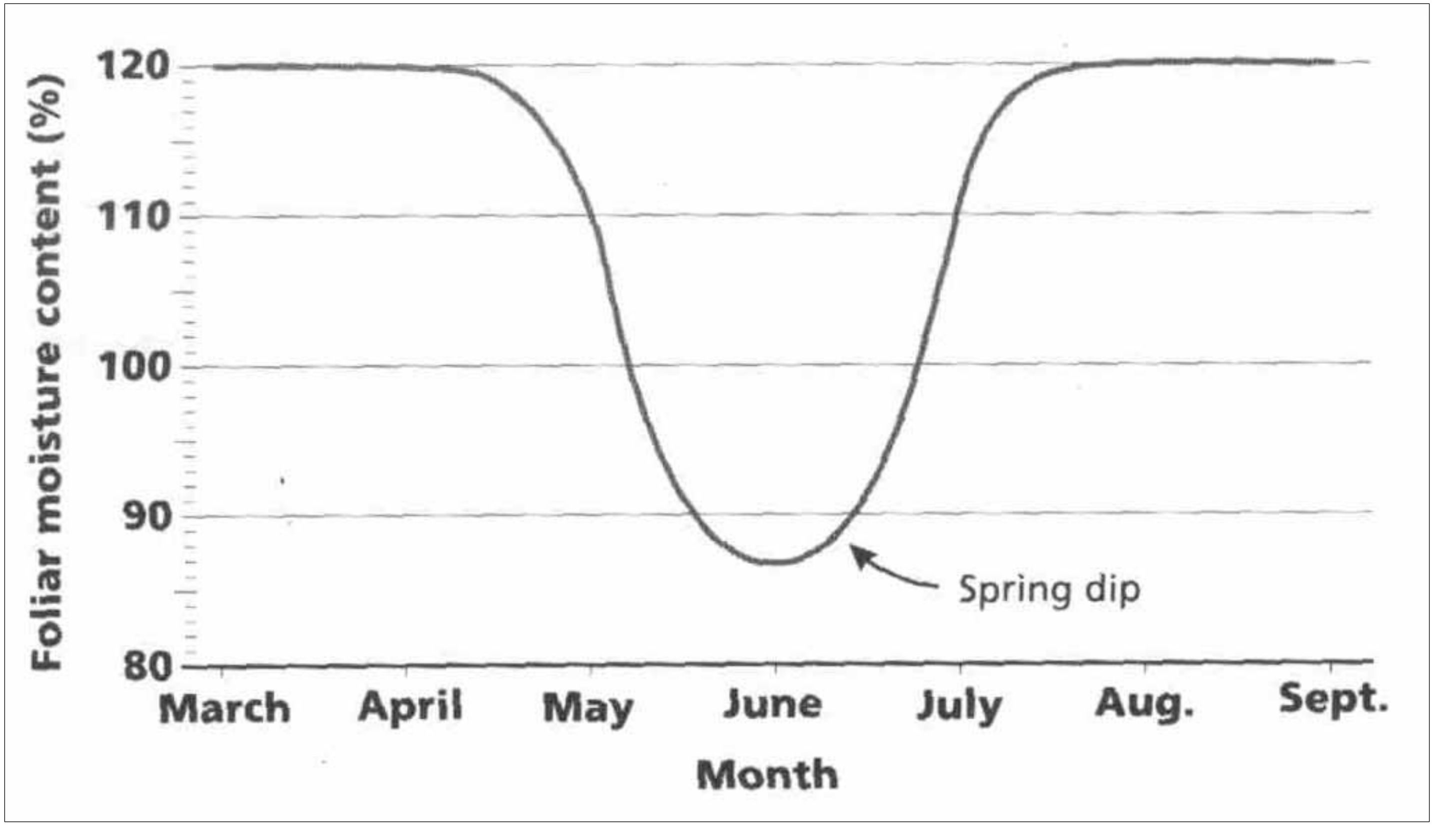
CHANGING THE CROWN BASE HEIGHT SHOULD BE UNDERTAKEN WITH EXTREME CAUTION* BECAUSE NO ALLOWANCE IS BEING MADE FOR THE REDUCTION IN GROUND LEVEL WIND SPEEDS!

(*Otherwise you may burn in hell)

Crown base height is a critical factor in the crowning criterion; however, the theory on which the crown fire criterion is based was itself dependent on empirical data for its final quantitative form. The crown base height assigned to each fuel type is therefore the result of some trial. While the independent fuel type description incorporates some indication of the crown base height, the assigned value for each fuel type had to match the general pattern of crown involvement. The final assigned crown base height values represent the real forest structure as well as possible.

From page 35 of ST-X-3 report

Idealized seasonal trend in the foliar moisture content (FMC) of conifer foliage



I think it is perfectly legitimate to input a sampled FMC provided the sampling is adequate

Some Personal Opinions (continued)

- **Although constant crown base height values have been assigned to each fuel type susceptible to crowning, in reality one should consider these as only nominal values and that there's actual a range in crown base height for each fuel type (e.g., for C-3, crown base height varies from 7-9 m rather than simply 8 m).**

Some Country-wide Observations & Personal Discussions w/ Fire Managers

- Suggestion to use C-5 in mature cedar-hemlock forests in BC (probably works OK except in major drought years when a BUI (or DC) threshold for extreme fire behavior is attained.
- Limit ground and surface fuel consumption influence when using C-3 for lodgepole pine in the Yukon (and central BC) due to shallow forest floor layers reflecting less site productivity.

Some Country-wide Observations & Personal Discussions w/ Fire Managers
(continued)

- **Discontinuous surface fuels-continuous crown fuel situations: DL3-18-95 Fire in Alberta (C-2 applicable to overstory in terms of crown fire spread but not ground surface which was dominated by sphagnum moss).**

Some Country-wide Observations and Personal Discussions with Fire Managers
(continued)

- **Alberta: aspen stands in the spring with cured grass rather than deciduous leaf litter – use O-1a but reduce the effective 10-m open wind by say 2/3rds to account for the overstory canopy (e.g., if the 10-m open wind is 15 km/h use 5 km/h for the ISI computation in O-1a to get the rate of fire spread).**

Aspen with Significant Cured Grass Understory in Spring

Fuel Type	FFMC	Wind	ISI	ROS
O-1a	89	15	8	21 m/min
Aspen w/grass	89	5*	5	11 m/min
VS.				
D-1	89	15	8	2 m/min

*Reduced 15 km/h by 2/3rds = 5 km/h

Some Country-wide Observations and Personal Discussions with Fire Managers
(continued)

- **Similar to Alberta aspen situation – for pre-commercially thinned stands use S-1 but reduce the effective 10-m open wind to allow for the overstory canopy (say reduce by 3/4ths)**

Pre-commercially (PC) Thinned Pine Stand

Fuel Type	FFMC	Wind	ISI	ROS
S-1	89	20	10	12 m/min
PC Thinned	89	5	5	6 m/min

***Reduce 20 km/h by 3/4ths = 5**

Some Country-wide Observations and Personal Discussions with Fire Managers
(continued)

- **Quebec – provincial fuel type map showed an enormous area of C-2 as a result of relying strictly on black spruce composition as the primary or sole criteria (more C-3 and M-1/M-2); Sept. 1997 one week site visit.**

C-2 Boreal Spruce (main standard)

C-2 Boreal Spruce (possible variant)

Some Country-wide Observations and Personal Discussions with Fire Managers
(continued)

• Maritimes: April 2002 workshop on FBP System held with reps from NS, NB and PEI; follow-up session with NS in Sept. 2003 – see separate document.

Some Country-wide Observations and Personal Discussions with Fire Managers (concluded)

- **FBP System Fuel Type C-7 assumes 100% degree of curing. This overrates the fire potential when the grass is less than fully cured. Judi Beck's simple solution: adjust the C-7 rate of spread downwards according to the degree of curing (DOC) relationship found in the O-1b rate of spread model.**

Adjusting Fuel Type C-7 for Degree of Curing (DOC)

Fuel Type	FFMC	Wind	ISI	ROS*
O-1b 100% DOC	89	20	10	29 m/min
O-1b 75% DOC	89	20	10	16 m/min
C-7 (100% DOC)	89	20	10	3 m/min

Sample Computation for C-7 @ 75% DOC:

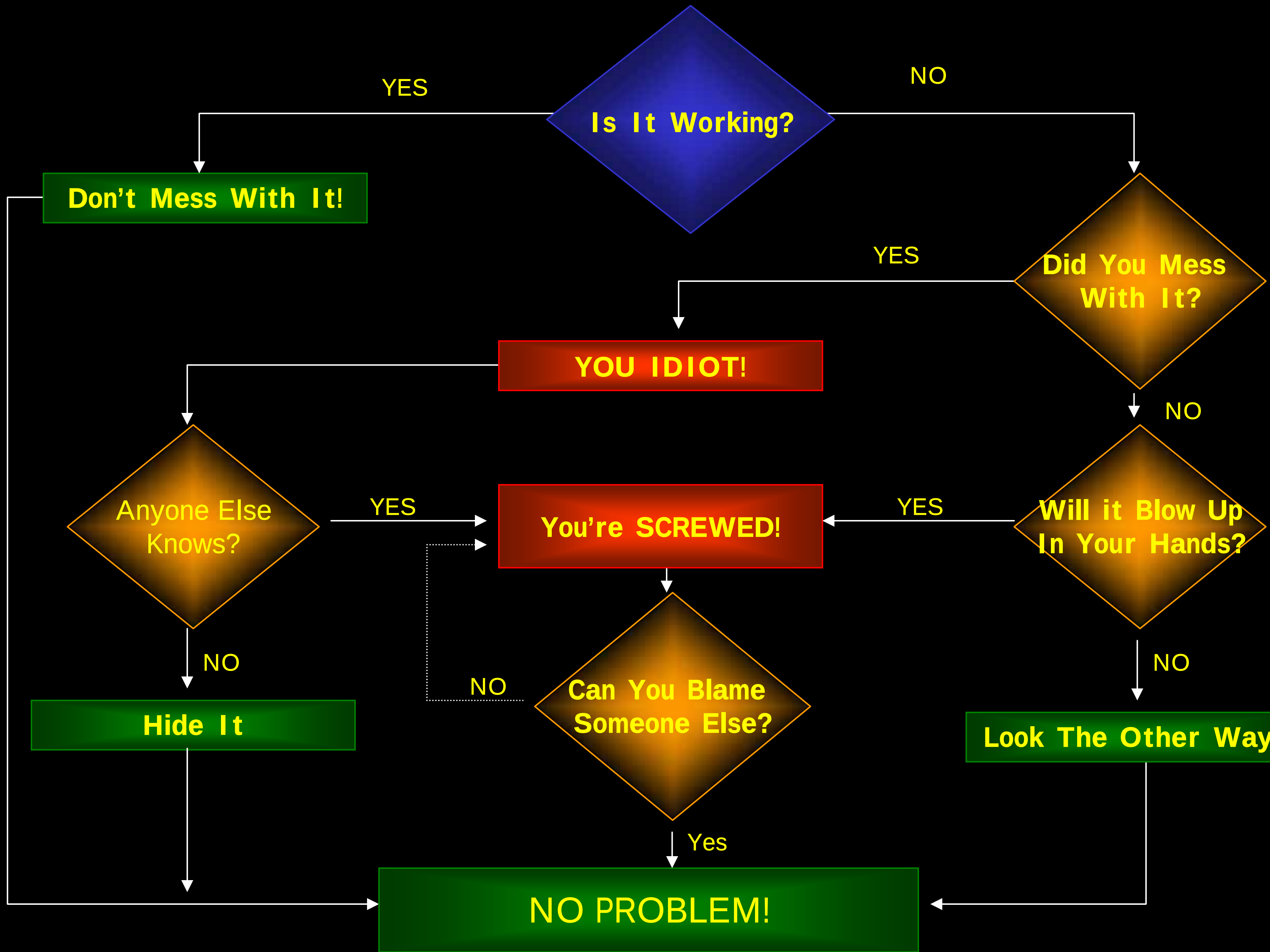
3 x 16 = 48/29 = 1.7 m/min

***BUI 100**

Conclusions

- **An alternative to the FBP System is not presently on the research drawing board at the moment – i.e., development of a physically-based model (with universal acceptance) that could accommodate any fuel complex is probably an intractable problem.**
- **FBP System fuel typing readily emphasizes the "art" side of predicting fire behavior.**

Flowchart For Problem Resolution



Conclusions (continued)

- **Adjustments or modifications of FBP System fuel type predictions to non-classified fuel types should be based on carefully thought out arguments and measurements (e.g., Stan Harvey's spruce-balsam "straw-man" fuel type).**

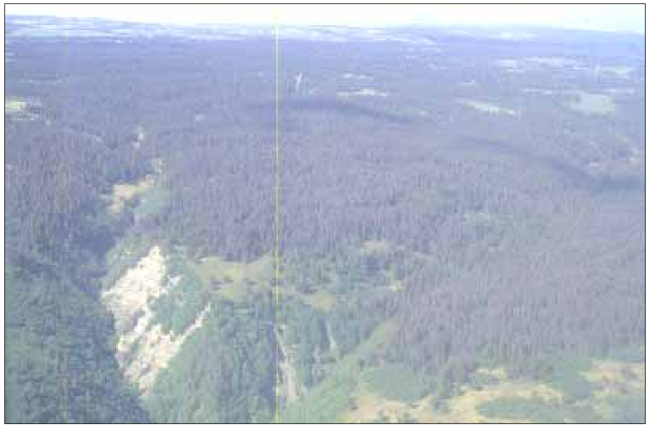
Conclusions (continued)

- **Most important things to consider:**
  - **factors controlling surface fire spread and intensity of fuelbed characteristics (e.g., cover and depth/load);**
  - **effectiveness of wind in relation to stand structure; and**
  - **overstory characteristics with respect to crown fire initiation.**

Conclusions (continued)

- **Most obvious knowledge gap is young, regenerating forests (perhaps considering a threshold for fire spread in terms of age/dryness from wildfire observations would be more appropriate than an a formal experimental fire study.**
- **Increasingly it appears that insect and disease impacted stands need to be addressed.**

Spruce Beetle-Killed Stands – Kenai, Peninsula, Alaska



Safety Alert for Wildland Firefighters: Fuel Conditions in Spruce-Beetle-Killed Forests of Alaska*

Martin E. Alexander and Joseph C. Stam

Look Up, Look Down, Look Around—and Look Out!

References

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This note is on the WFBS CD.

We need to openly acknowledge that we don’t know enough about fire behavior in certain fuel types.

THE END

ANY QUESTIONS?