



Fire Technology Transfer Note

Number - 25

June 2002

A pocket card for predicting fire behaviour in grasslands under severe burning conditions¹

M.E. Alexander and L.G. Fogarty

Abstract

The grassland fire behaviour pocket card recently developed for use by wildland and rural firefighters in Canada and New Zealand is reviewed. The pocket card offers a practical field guide for quickly estimating the near worst case fire behaviour potential in grasslands. At the same time it reinforces an awareness of the need for adopting safe work practices when attempting to contain grass fires in an effort to avoid burnovers and entrapments thereby eliminating firefighter injuries and fatalities.

Introduction

Many firefighters are surprised to learn that tragedy and near-miss incidents occur in fairly light fuels, on small fires, or on isolated sectors of large fires, and that fire behaviour is relatively quiet just before the incident. Most of us believe that the high-intensity crown fire in timber or heavy brush is what traps and kills forest firefighters. Yet, with rare exceptions ... most fires are innocent-appearing just before the accidents.

Wilson and Sorenson (1978).

In 1997, a pocket card entitled "A SIMPLE FIELD GUIDE FOR ESTIMATING THE BEHAVIOUR AND SUPPRESSION REQUIREMENTS OF FIRES DRIVEN BY WIND COMING FROM A CONSTANT DIRECTION, IN OPEN, FULLY CURED GRASSLANDS AT LOW FUEL MOISTURE" (Alexander and Fogarty 1997)

was jointly developed by the Canadian Forest Service (CFS) and the New Zealand Forest Research Institute (Figure 1). This was followed by *Fire Technology Transfer Note* No. 20 by Fogarty and Alexander (1999) describing the derivation and use of the Alexander and Fogarty (1997) grassland fire behaviour pocket card; a copy of this publication, as well as the French translation can be downloaded from the CFS fire research website (see **Downloads** at <http://nofc.cfs.nrcan.gc.ca/fire/frn/>).

Why is the Grassland Fire Behaviour Pocket Card Needed?

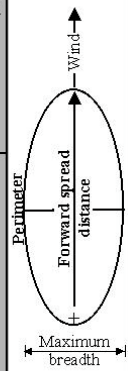
In comparison to free-burning fires occurring in other wildland fuel complexes, fires spreading through grass fuels are far more responsive to changes in wind and/or slope. This is especially so when the grasslands are in a fully cured state (Garvey and Millie 2000), and the fuels are critically dry due to high air temperatures, low relative humidity and a lack of recent wetting rain (Cheney and Sullivan 1997). This has important implications for firefighter safety with respect to the potential for burn injuries or even death (Figure 2). Grass fires can move surprisingly quickly, and so firefighters need to have a full appreciation and a healthy respect for this fact as evident by a significant number of fatalities associated with grassland fires in the United States (Wilson and Sorenson 1978;

¹ This *Fire Technology Transfer Note* is based on an oral presentation made by M.E. Alexander at the 2000 International Wildfire Safety Summit sponsored by the International Association of Wildland Fire held in Edmonton, Alberta, October 10-12, 2000, and represents a slightly modified version of the original paper that appeared as pages 8-19 in Butler and Shannon (2000).

A SIMPLE FIELD GUIDE FOR ESTIMATING THE BEHAVIOUR AND SUPPRESSION REQUIREMENTS OF FIRES DRIVEN BY WIND COMING FROM A CONSTANT DIRECTION, IN OPEN, FULLY CURED GRASSLANDS AT LOW FUEL MOISTURE.

Caution: Flame heights at the fire's head will be greater than 2.5 metres. Under NO circumstances should direct attack be mounted on the head fire. Any containment action must begin from a secured anchor point and progress along the flanks toward the head as the fire edge or perimeter is "knocked down".

Beaufort Wind Force ^a	Forward spread distance/perimeter length/maximum breadth versus elapsed time since ignition				Head fire intensity --kW/m--	Head fire flame length --metres--	Minimum firebreak width required to stop head fire ^b	
	-----kilometres-----						-----metres-----	
	0.5 hour	1 hour	1.5 hour	2 hour			Trees absent	Trees present
0-1	0.7/2.4/0.4	1.3/4.9/0.7	2.0/7.3/1.1	2.6/9.8/1.4	2300	2.7	5	12
2	1.0/2.7/0.4	2.0/5.5/0.7	2.9/8.2/1.1	3.9/10.9/1.5	3450	3.3	6	13
3	1.6/3.7/0.4	3.2/7.4/0.8	4.8/11.1/1.2	6.3/14.8/1.6	5550	4.1	7	15
4	2.7/5.7/0.6	5.3/11.5/1.1	8.0/17.2/1.7	10.7/22.9/2.2	9350	5.2	8	30+
5	4.4/9.1/0.8	8.7/18.2/1.5	13.1/27.3/2.3	17.5/36.4/3.1	15 300	6.5	10	30+
6	6.1/12.5/1.0	12.2/25.0/1.9	18.2/37.5/2.9	24.3/50.0/3.8	21 300	7.6	12	30+
7	7.2/14.8/1.0	14.5/29.5/2.0	21.7/44.3/3.1	28.9/59.1/4.1	25 300	8.2	13	30+
8 & higher	7.5/15.2/1.0	15.0/30.5/2.1	22.5/45.7/3.1	30.0/60.9/4.1	26 200+	8.4+	14+	30+



^a See reverse side for details on the Beaufort Wind Scale.

^b The "Trees absent" and "Trees present" classes refer to the absence or presence of trees/scrub within 20 meters of the windward side of the firebreak. The presence of trees or scrub has a significant influence on firebreak effectiveness because they supply woody material for firebrands which can spot across the break.

Beaufort Wind Scale for estimating 10 - m open wind speed over land

Beaufort Wind Force	Descriptive Term	10 - m wind speed --km/h--	Observed wind effects
0	Calm	< 1	Smoke rises vertically.
1	Light air	1 to 5	Direction of wind shown by smoke drift but not by wind vanes.
2	Light breeze	6 to 11	Wind felt on face; leaves rustle; ordinary vanes moved by wind.
3	Gentle breeze	12 to 19	Leaves and small twigs in constant motion; wind extends light flags.
4	Moderate breeze	20 to 28	Wind raises dust and loose paper; small branches are moved.
5	Fresh breeze	29 to 38	Small trees in leaf begin to sway; crested wavelets form on inland waters.
6	Strong breeze	39 to 49	Large branches in motion; whistling heard in telephone wires; umbrellas used with difficulty.
7	Moderate gale	50 to 61	Whole trees in motion; inconvenience felt when walking against wind.
8	Fresh gale	62 to 74	Breaks twigs off trees; generally impedes progress.
9	Strong gale	75 to 88	Slight structural damage occurs (e.g., TV antennas and tiles blown off).
10	Whole gale	89 to 102	Seldom experienced inland; trees uprooted; considerable structural damage.

Note: Fire behaviour predictions in this guide are based on head fire rate of spread in fully cured standing grasslands (Fire Behavior Prediction System Fuel Type O-1b) on flat to undulating terrain, assuming a fuel load of 3.5 t/ha, a Fine Fuel Moisture Code of 93.2, and the midpoint of the wind speed range associated with each Beaufort Wind Force. Use of the Guide is at the reader's sole risk.



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Figure 1. The (a) front and (b) back sides of the Alexander and Fogarty (1997) grassland fire behaviour pocket card. Actual dimensions are 11.5 x 17.2 cm (4.5 x 6.75 in.).



Figure 2. The emphasis of the pocket card is on providing basic fire behaviour information in very simplistic terms to ensure safe wildland firefighting operations. Photos from NFPA (1992).

NWCG 1996; NWCG Safety and Health Working Team 1997). A major switch in wind direction can cause the relatively quiet flank of a grass fire to suddenly become a much wider and larger and more vigorous high-intensity “head” from what previously existed. Similarly, any increase in wind speed above the average velocity will result in a corresponding escalation in a fire’s overall rate of spread and intensity or flame size.

How Did the Grassland Fire Behaviour Pocket Card Come About?

The inspiration for this field guide to predict grassland fire behaviour under severe burning conditions came about as the result of one of the authors (MEA) undertaking an investigation of a burnover incident in grasslands that occurred near the town of Anerley, Saskatchewan, Canada, on October 2, 1993 (Alexander 1998; ETC and CIFFC 2000). A rural volunteer firefighter eventually died as a result of the burns he sustained while engaged in firefighting operations on this grass fire.

An initial draft of the grass fire behaviour pocket card was prepared by the first author (MEA) as part of the technical review of a case study involving a “near miss” incident occurring on a wildfire in grasslands on New Zealand’s North Island in early 1991 (Rasmussen and Fogarty 1997). The final version of the pocket card was completed by the second author (LGF) and is included as an appendix in Rasmussen and Fogarty’s (1997) publication.

What is the Purpose of the Grassland Fire Behaviour Pocket Card?

The principle intent of the pocket card is to provide wildland and rural fire suppression personnel with very basic information on grassland fire behaviour such as forward spread distance and fire size (area and perimeter) in relation to elapsed time since ignition, in addition to flame front characteristics (Figure 1a), in as simple a manner as possible. However, at the same time it stresses the importance of adhering to traditional safe work practices and fire suppression strategies/tactics (Figures 3 and 4).

DIRECT ATTACK FLANKING ACTION

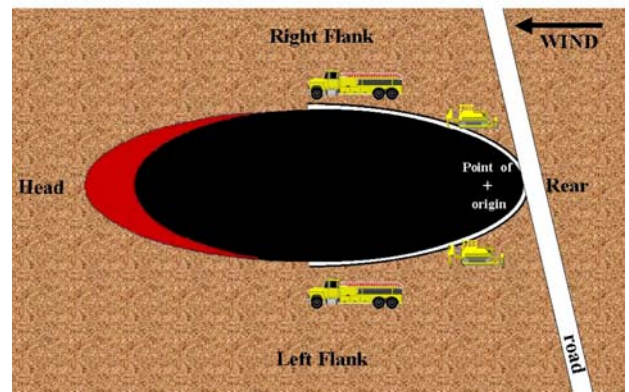


Figure 3. The pocket card explicitly states that the only safe fire suppression strategy/tactic is direct attack flanking action starting from the rear of the fire while being ever mindful of the possibility for rekindling, the value of a “black line”, and the necessity for preparing a mineralized fireguard.



Figure 4. Safe work practices when engaged in grassland fire suppression include “anchor and flank” and “one foot in the green, one foot in the black”. Photo from NWCG (1990).

The release of the 1996 California Division of Forestry video “A Firefighter’s Return From a Burnover: the Kelly York Story” (Anon. 1997) has reinforced the need for such a reminder in the form of a handy aid or guide like the grassland fire behaviour pocket card. The concept of “making a stand” (Fogarty 1996) at a road, firebreak or other narrow barrier to fire spread (Figure 5) is certainly not recommended because of the potential for disastrous consequences, such as demonstrated by the major burn injuries sustained to a wildland firefighter on the 1989 Eagle Fire in northern California (NWCG 1993).



Figure 5. The pocket card stresses that under no circumstances should a frontal assault on an advancing grass fire be undertaken. Photo from Clayton *et al.* (1987).

What is the Basis of the Grassland Fire Behaviour Pocket Card?

The Alexander and Fogarty (1997) pocket card distills a large amount of research knowledge on wildland fire behaviour in general and specifically as it pertains to grasslands (Wilson 1988; Cheney and Sullivan 1997²) that is both directly and indirectly relevant to the issue of firefighter safety (Figure 6). For example, the information presented on the front side of the pocket card (Figure 1a) enables one to judge whether or not a firebreak, a road or a prepared fireguard downwind of a spreading grass fire will stop the advancing flame front (Figure 7). Firefighters can accordingly develop or adjust their control strategy without jeopardizing their own well-being as a result of feeling compelled to take the fire “head on” in order to protect a value-at-risk (e.g., a farm house) or to stop the fire at all costs.

In contrast to the fire danger index climatology derived pocket card of Andrews *et al.* (1998), the estimates of the various fire behaviour characteristics incorporated into the grassland fire behaviour pocket card are based on the quantitative predictions obtained from the Canadian Forest Fire Behaviour Prediction (FBP) System (Forestry Canada Fire Danger

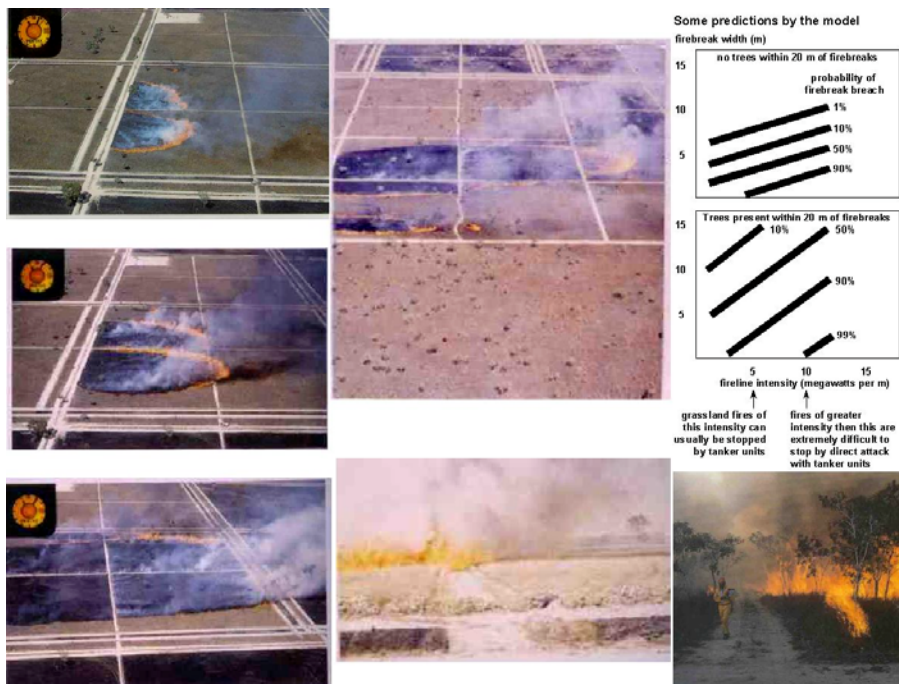


Figure 6. The pocket card has incorporated both the basic fire behaviour data gathered from the experimental fires carried out in the Northern Territory of Australia by the CSIRO bushfire research group and the firebreak effectiveness model developed from this study. Photos from Davidson (1988) and CSIRO Division of Forestry and Forest Products Annual Report.

² Cheney and Sullivan’s (1997) book constitutes a *tour de force* in the field of wildland fire behaviour and is recommended reading for anyone involved in grassland fire suppression.



Figure 7. The pocket card provides guidance on the minimum firebreak width necessary to halt a grass fire's forward progress. Photo courtesy of D.R. Page, Woods and Forests Department of South Australia.

Group 1992). The predictions for fire spread and flame front intensity were obtained from the rate of spread model for the standing grass fuel type (O-1b) in the FBP System (Figure 8) assuming a constant fuel load (3.5 t/ha), degree of curing (100%), moisture content (Fine Fuel Moisture Code 93.2, equating to <6% in fully cured grass), and a zero slope as stated on the back of the pocket card (Figure 1b). The fire area and perimeter estimates are based on the FBP System's simple elliptical fire growth model (Figure 9). For more information on the technical basis of the grassland fire behaviour pocket card one should consult Fogarty and Alexander (1999).



Figure 8. The fire spread and intensity estimates in the pocket card are based on Canadian Forest Fire Behaviour Prediction System Fuel Type O-1b (Standing Grass). Photo from De Groot (1993).

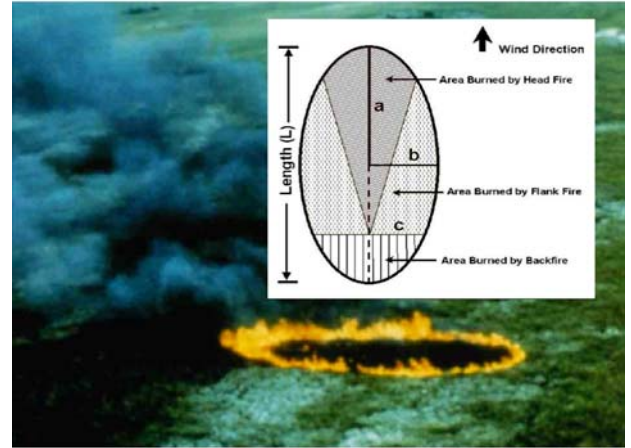


Figure 9. The fire growth projections in the pocket card assume an elliptical fire shape. Photo courtesy of D.D. Wade, USDA Forest Service.

How Does the Grassland Fire Behaviour Pocket Card Work?

The pocket card requires only one input, namely an on-site estimate of wind speed (Figure 10) based on the Beaufort Wind Scale (List 1951, p. 119), which is reproduced on the back side of the card (Figure 1b); a measured or forecasted value could be used as well. Given the associated fire behaviour predictions, a map and general knowledge of the area (e.g., road widths), and knowing what the prevailing wind direction is, fire suppression personnel are able to make assessments as to how far a grass fire is likely to advance. In turn, they are able to determine very early on whether warnings should be issued to residents and landowners downwind of the fire so that they can evacuate safely and/or make preparations to protect their assets. Simply put, the pocket card gives the initial attack fire boss or incident commander a means of making an initial estimate of potential worst case fire behaviour which can be factored into the fire suppression strategy (e.g., the size or magnitude of the fire problem in terms of the resources that will be required to contain the fire). A detailed example of how to use the grassland fire behaviour pocket card, suitable for training purposes, is given in Fogarty and Alexander (1999).



Figure 10. An estimate of the probable fire behaviour characteristics in grasslands can be obtained from the pocket card based solely on an on-site estimate of the prevailing wind speed. Photo courtesy of J. McMeeking, New Zealand Department of Conservation.

Where Can I Get a Copy of the Grassland Fire Behaviour Pocket Card?

Copies of the Alexander and Fogarty (1997) grassland fire behaviour pocket card, as well as the associated *Fire Technology Transfer Note* 20 (Fogarty and Alexander 1999) and the publication by Rasmussen and Fogarty (1997), are available upon request from: Forest & Rural Fire Research Programme, *Forest Research*, P.O. Box 29237, Christchurch, New Zealand (email: grant.pearce@forestresearch.co.nz).

Furthermore, a poster (Alexander and Fogarty 2001) on the grassland fire behaviour pocket card that utilizes all the illustrations contained in this *Fire Technology Transfer Note* is also available upon request (see back cover).

Acknowledgements

The review comments on the original version of this paper by G.J. Baxter, then of *Forest Research* are gratefully acknowledged. The assistance of H.G. Pearce of *Forest Research* in the preparation of this *Fire Technology Transfer Note* is duly acknowledged.

About the Authors

Dr. Marty Alexander is a Senior Fire Behaviour Research Officer with the Canadian Forest Service (CFS) based at the Northern Forestry Centre in Edmonton, Alberta. Marty held a Visiting Fire Research Scientist position at New Zealand's *Forest Research* in Rotorua

during a one-year secondment from the CFS in 1992-93; he was in turn made a Honorary Member of the Forest and Rural Fire Association of New Zealand FRFANZ for "his contributions to vegetation fire management in New Zealand". He has continued to serve as an advisor and collaborator to the *Forest Research* forest and rural fire research programme since his return to Canada in April 1993.

Liam Fogarty was employed as a Forest and Rural Fire Research Scientist at *Forest Research* in Rotorua from July 1993 to March 1998; he was also made an Honorary Member of FRFANZ for the many contributions he had made to New Zealand vegetation fire management. At the time the manuscript on which this *Fire Technology Transfer Note* was prepared, Liam was employed as a Fire Management Consultant to the Berau Forest Management Project, Kalimantan Timur, Indonesia. He is currently a Senior Forester with Greenfield Resource Options Pty. Ltd., Brisbane, Queensland.

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A SIMPLE AID FOR PREDICTING FIRE BEHAVIOR IN GRASSLANDS UNDER SEVERE BURNING CONDITIONS

Marty Alexander, Canadian Forest Service & Liam Fogarty, New Zealand Forest Research Institute



A SIMPLE FIELD GUIDE FOR ESTIMATING THE BEHAVIOR AND SUPPRESSION REQUIREMENTS OF FIRES DRIVEN BY WIND COMING FROM A CONSTANT DIRECTION, IN OPEN, FULLY-CURED GRASSLAND AT LOW RELATIVE HUMIDITY.

Caution: Flame height at the fire's head will be greater than 2.5 times. Under 50% circumstances should direct attack be attempted on the head fire. An containment action must begin from a marked anchor point and progress along the flanks toward the head as the fire edge progresses to "backed down".

Weather Wind Speed	Forward spread distance (meters)				Flame intensity (kW/m²)	Flame height (m)	Minimum fireline width (m)	Minimum fireline length (m)	Minimum fireline perimeter (m)
	0.5 km/h	1 km/h	1.5 km/h	2 km/h					
0.1	0.50 ± 0.4	1.00 ± 0.7	2.00 ± 1.1	3.00 ± 1.4	2000	2.7	7	13	13
0.2	1.00 ± 0.4	2.00 ± 0.7	4.00 ± 1.1	6.00 ± 1.4	2400	3.0	8	14	14
0.3	1.50 ± 0.4	3.00 ± 0.8	6.00 ± 1.2	9.00 ± 1.5	2800	3.3	9	15	15
0.4	2.00 ± 0.5	4.00 ± 1.0	8.00 ± 1.3	12.00 ± 1.6	3200	3.6	10	16	16
0.5	2.50 ± 0.5	5.00 ± 1.1	10.00 ± 1.4	15.00 ± 1.7	3600	3.9	11	17	17
0.6	3.00 ± 0.6	6.00 ± 1.2	12.00 ± 1.5	18.00 ± 1.8	4000	4.2	12	18	18
0.7	3.50 ± 0.6	7.00 ± 1.3	14.00 ± 1.6	21.00 ± 1.9	4400	4.5	13	19	19
0.8	4.00 ± 0.6	8.00 ± 1.3	16.00 ± 1.6	24.00 ± 1.9	4800	4.8	14	20	20
0.9	4.50 ± 0.6	9.00 ± 1.4	18.00 ± 1.7	27.00 ± 2.0	5200	5.1	15	21	21
1.0	5.00 ± 0.6	10.00 ± 1.4	20.00 ± 1.7	30.00 ± 2.0	5600	5.4	16	22	22

* See reverse side for details on the Pocket Card Guide.

† The "Three down" and "Three up" observations only apply to the distance in grasslands within 20 meters of the windward side of the firebreak. The presence of trees or shrubs has a significant influence on firebreak effectiveness because they supply wood material for firebreaks which can spot across the break.

Weather Wind Scale for estimating 10-m open wind speed over land

Weather Wind Speed	Description	10-m open wind speed (km/h)	Observed wind effects
0	Calm	0-1	Smoke rises vertically.
1	Light air	1 to 3	Direction of wind shown by smoke drift but not by wind vanes.
2	Light breeze	4 to 11	Wind felt on face; leaves rustle; windward stream raised by wind.
3	Good breeze	12 to 19	Leaves and small twigs in constant motion; wind extends light flag.
4	Moderate breeze	20 to 29	Wind raises dust and loose paper; small branches are moved.
5	Brisk breeze	30 to 39	Small trees in leaf begin to sway; windward stream raised to waist level.
6	Strong breeze	40 to 49	Large branches in motion; windward board of telephone wires sways; surface water is white-capped.
7	Moderate gale	50 to 61	Whole trees in motion; windward surface of waves breaking against wharf.
8	Fresh gale	62 to 74	Branches break off trees; generally impedes progress.
9	Strong gale	75 to 88	Significant structural damage occurs (e.g., TV antennae and thin chimneys fall).
10	Whole gale	89 to 102	Roofs on unprotected islands; trees uprooted; considerable structural damage.

Notes: The following conditions in the table are based on land in open to fully wooded country, provided that relative humidity is between 60% and 90%. The wind speed scale is based on the 10-m open wind speed over land. The wind speed scale is based on the 10-m open wind speed over land. The wind speed scale is based on the 10-m open wind speed over land.



Enlargement of the *Pocket Card* - Front (left) and back (right) sides

The *Pocket Card* offers a practical guide to fire behavior prediction in grasslands while at the same time reinforcing the need for safe work practices when attempting to contain free-burning grass fires.



The *Pocket Card* stresses that the only safe fire suppression tactic is flanking action starting from the rear of the fire

A SIMPLE FIELD GUIDE FOR ESTIMATING THE BEHAVIOR AND SUPPRESSION REQUIREMENTS OF FIRES DRIVEN BY WIND COMING FROM A CONSTANT DIRECTION, IN OPEN, FULLY-CURED GRASSLAND AT LOW RELATIVE HUMIDITY.

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0.5	2.50 ± 0.5	5.00 ± 1.1	10.00 ± 1.4	15.00 ± 1.7	3600	3.9	11	17	17
0.6	3.00 ± 0.6	6.00 ± 1.2	12.00 ± 1.5	18.00 ± 1.8	4000	4.2	12	18	18
0.7	3.50 ± 0.6	7.00 ± 1.3	14.00 ± 1.6	21.00 ± 1.9	4400	4.5	13	19	19
0.8	4.00 ± 0.6	8.00 ± 1.3	16.00 ± 1.6	24.00 ± 1.9	4800	4.8	14	20	20
0.9	4.50 ± 0.6	9.00 ± 1.4	18.00 ± 1.7	27.00 ± 2.0	5200	5.1	15	21	21
1.0	5.00 ± 0.6	10.00 ± 1.4	20.00 ± 1.7	30.00 ± 2.0	5600	5.4	16	22	22

* See reverse side for details on the Pocket Card Guide.

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Actual size of the *Pocket Card* - front (left) and back (right) sides

Weather Wind Scale for estimating 10-m open wind speed over land

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0	Calm	0-1	Smoke rises vertically.
1	Light air	1 to 3	Direction of wind shown by smoke drift but not by wind vanes.
2	Light breeze	4 to 11	Wind felt on face; leaves rustle; windward stream raised by wind.
3	Good breeze	12 to 19	Leaves and small twigs in constant motion; wind extends light flag.
4	Moderate breeze	20 to 29	Wind raises dust and loose paper; small branches are moved.
5	Brisk breeze	30 to 39	Small trees in leaf begin to sway; windward stream raised to waist level.
6	Strong breeze	40 to 49	Large branches in motion; windward board of telephone wires sways; surface water is white-capped.
7	Moderate gale	50 to 61	Whole trees in motion; windward surface of waves breaking against wharf.
8	Fresh gale	62 to 74	Branches break off trees; generally impedes progress.
9	Strong gale	75 to 88	Significant structural damage occurs (e.g., TV antennae and thin chimneys fall).
10	Whole gale	89 to 102	Roofs on unprotected islands; trees uprooted; considerable structural damage.

Notes: The following conditions in the table are based on land in open to fully wooded country, provided that relative humidity is between 60% and 90%. The wind speed scale is based on the 10-m open wind speed over land. The wind speed scale is based on the 10-m open wind speed over land.

Publication describing the *Pocket Card*



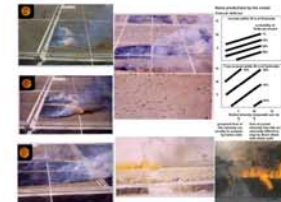
The *Pocket Card* provides guidelines on the minimum firebreak width necessary to halt a grass fire's forward progress



The emphasis of the *Pocket Card* is on providing basic fire behavior information in very simplistic terms to ensure safe wildland firefighting operations



An estimate of the probable fire behavior characteristics in grasslands can be obtained from the *Pocket Card* based solely on an on-site estimate of the prevailing wind speed.



The *Pocket Card* distills a vast amount of research knowledge on grassland fire behavior directly relevant to the issue of wildland firefighter safety



Spread and intensity estimates in the *Pocket Card* are based on the Canadian Forest Fire Behavior Prediction System's Fuel Type O-1b



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