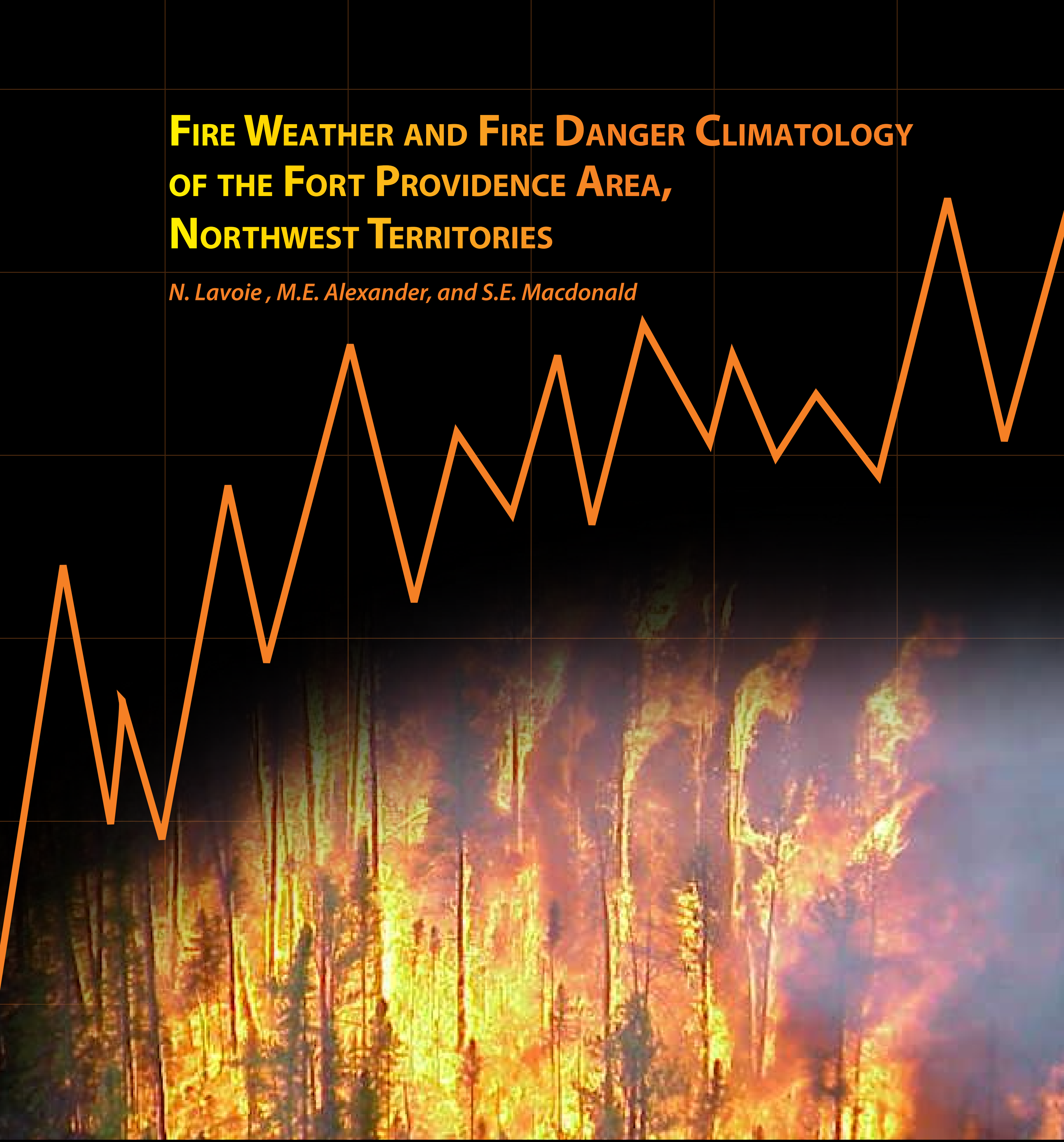
FIRE WEATHER AND FIRE DANGER CLIMATOLOGY OF THE FORT PROVIDENCE AREA, NORTHWEST TERRITORIES

N. Lavoie , M.E. Alexander, and S.E. Macdonald



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The cover photo shows an experimental crown fire conducted as part of the International Crown Fire Modeling Experiment (ICFME), which ran from 1995 to 2001. The ICFME project was carried out at a site 50 km northeast of Fort Providence, Northwest Territories.

Cover photo courtesy of Nathalie Lavoie, B.C. Ministry of Forests and Range, Fire Management Section.

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N. Lavoie[1], M.E. Alexander, and S.E. Macdonald[2]

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ABSTRACT

The main goal of this project was to define conditions that could be used in different modeling scenarios to represent moist, moderate, dry, and extreme burning conditions. This study also allowed description of fire weather in a way that could be useful for various research and fire management activities in the part of the Northwest Territories where the study took place. To obtain information on the weather-related burning conditions in the study area during the peak fire season (mid-June to mid-August), historical data for fire weather and Canadian Forest Fire Weather Index System components from three weather stations were analyzed. To better illustrate the influence of fire weather on fire behavior, results are presented, whenever possible, in a way that makes them compatible for direct use with the field guide to the Canadian Forest Fire Behavior Prediction System.

RÉSUMÉ

Ce projet avait pour but principal de définir les paramètres qui pourraient s’appliquer à divers scénarios de modélisation des conditions de risque d’incendie («humide», «modéré», «sec» et «extrême»). Il a également permis d’établir une typologie des conditions météo propices aux incendies de forêt, pour l’usage des personnels de recherche et de gestion incendie s’agissant de la zone des Territoires du Nord-Ouest à l’étude. Les données historiques sur les conditions météo propices aux incendies de forêt et des données établies à partir de la Méthode canadienne de l’indice forêt-météo (IFM) concernant trois stations météo ont été analysées pour obtenir de l’information sur les conditions météo propices aux incendies de forêt s’agissant de la zone à l’étude, durant la période critique de la saison des feux de forêt (comprise entre la mi-juin et la mi-août). Pour mieux illustrer l’influence des conditions météo concernées sur les caractéristiques des feux de forêt, les résultats du projet ont été formalisés de manière à pouvoir être utilisés de pair avec le guide pratique de la Méthode canadienne de prévision du comportement des incendies de forêt.

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INTRODUCTION

> Many decisions in forest fire control are based on subjective considerations, and experience must, therefore, play an important role … The value of a fire danger rating system depends in large part on how well the fire control officer can associate index values with management functions and operational procedures. Climatological information can assist in this task.
>
> —Nikleva (1973)

Most fire management activities are affected by fire behavior, either in its immediate form or through the fire regime of an area. Given that fire behavior is the product of the environment in which a fire burns (Countryman 1972), any assessment looking at past, present, or forecasted fire behavior should consider the three main environmental elements influencing that behavior: fuels, weather, and topography.

Weather is the component of the fire environment that is most changeable, both spatially and temporally. Moreover, the state of the atmosphere can be described by several variables that vary continually, all of which influence fuel conditions. This characteristic of weather presents challenges for fire managers who want to describe, quantify, and ultimately use information about weather in strategic planning and decision making.

As part of a larger project looking at the flammability of mixed stands of jack pine (*Pinus banksiana* Lamb.) and black spruce (*Picea mariana* (Mill.) BSP) in a portion of the Hay River District, Northwest Territories, Canada (Lavoie 2004), the fire weather and fire danger, and in turn the fire potential climatology of the study area were analyzed.

Climatological summaries of standard weather elements are not unusual, but analyses of fire danger are sparser, despite a clear need for such analyses (Pearce et al. 2003; Pearce 2006). Although a few related studies are available for other parts of Canada (e.g., Nikleva 1973, 1989; Hawkes 1983; Harvey et al. 1986; Pouliot 1993; McAlpine et al. 1999), and for Canada as a whole based on representative weather stations (e.g., Simard and Valenzuela 1972; MacHattie 1973; Harrington et al. 1983; McAlpine 1990), to the authors' knowledge, none have previously been performed in the area studied here.

Climatological information adapted to fire management has high value and a wide variety of applications (Pearce et al. 2003), including development of systems to assist fire management activities (e.g., prevention, preparedness, fire suppression, planning of prescribed fires), description of fire activity, illustration of seasonal trends in fire danger, determination of length of the fire season, delineation of fire climate zones, and assessment of the impacts of El Niño oscillation events and climate change.

Therefore, the detailed analyses presented here could benefit various research and fire management activities in the region of interest. Moreover, the methods described here could help in the design of similar projects elsewhere, and the results presented could be compared with those of other regions.

METHODS

Although the study of individual weather elements is pertinent from the perspective of fire research, the components of the Canadian Forest Fire Weather Index (FWI) System (Van Wagner 1987) have the added advantage of representing the cumulative effect of the weather as it relates to fuel moisture and potential fire behavior. It is therefore preferable to look at the historical distribution of both types of variables through the period of interest, specifically, the peak fire season. Here, a brief description of the FWI System precedes the description of the methods used to analyze the weather and FWI System components.

Canadian Forest Fire Weather Index System

The FWI System is one of the two main subsystems of the Canadian Forest Fire Danger Rating System (Fig. 1) (Stocks et al. 1989; Alexander et al. 1996; Taylor and Alexander 2006), the second being the Canadian Forest Fire Behavior Prediction (FBP) System (Forestry Canada Fire Danger Group 1992; Taylor et al. 1997).

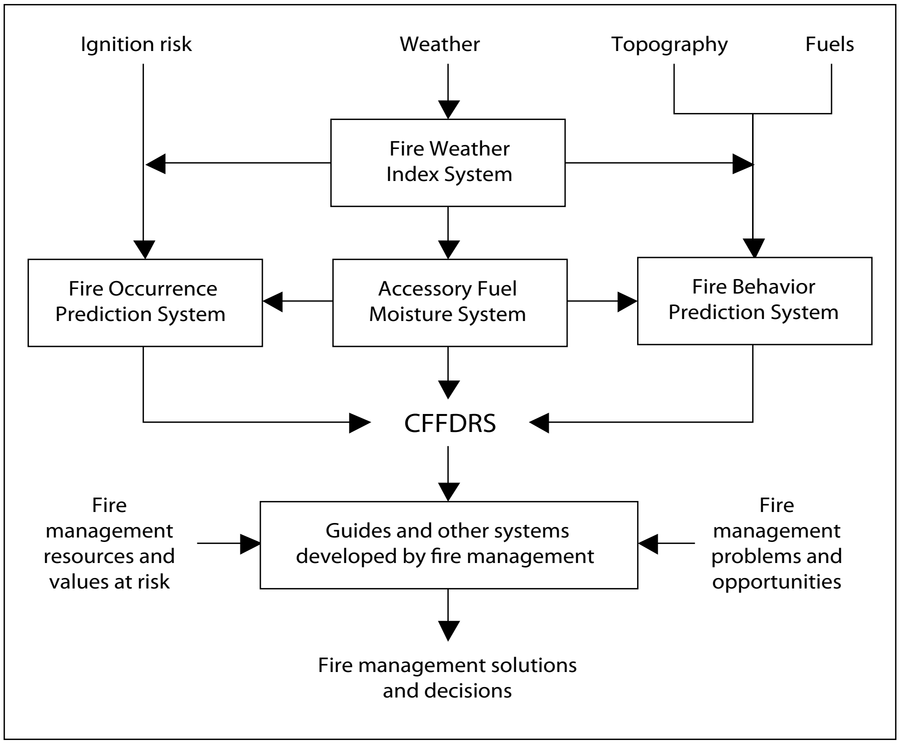


Figure 1. **Simplified structure diagram for the Canadian Forest Fire Danger Rating System (CFFDRS), illustrating the linkage to fire management actions (adapted from Stocks et al. 1989 and Alexander et al. 1996).**

The FWI System (Van Wagner 1987) (Fig. 2) allows assessment of relative fire potential (Stocks et al. 1989). Although it refers specifically to a standard pine fuel type, the FWI System is useful as a general measure of forest fire danger in Canada (Van Wagner 1987). It is composed of three fuel moisture codes (Fine Fuel Moisture Code [FFMC], Duff Moisture Code [DMC], and Drought Code [DC]) and three fire behavior indexes (Initial Spread Index [ISI], Buildup Index [BUI], and Fire Weather Index [FWI]). These components are calculated from four weather observations: air temperature, relative humidity, 10-m open wind speed, and rain accumulated over the previous 24-h period. Although the weather observations are recorded daily at noon (local standard time [LST] or 1300 daylight saving time [DST]), the FWI System represents the conditions generally encountered at the peak burning period (around 1600 LST) (Van Wagner 1987). Given the manner in which the three fuel moisture codes are calculated, the FWI System takes into account the cumulative effect of the weather during the fire season.

Each component of the FWI System has its own scale, but for all of them a higher value indicates more severe burning conditions (Canadian Forestry Service 1984; De Groot 1988). More details on each component of the FWI System are presented in the Results section of this report.

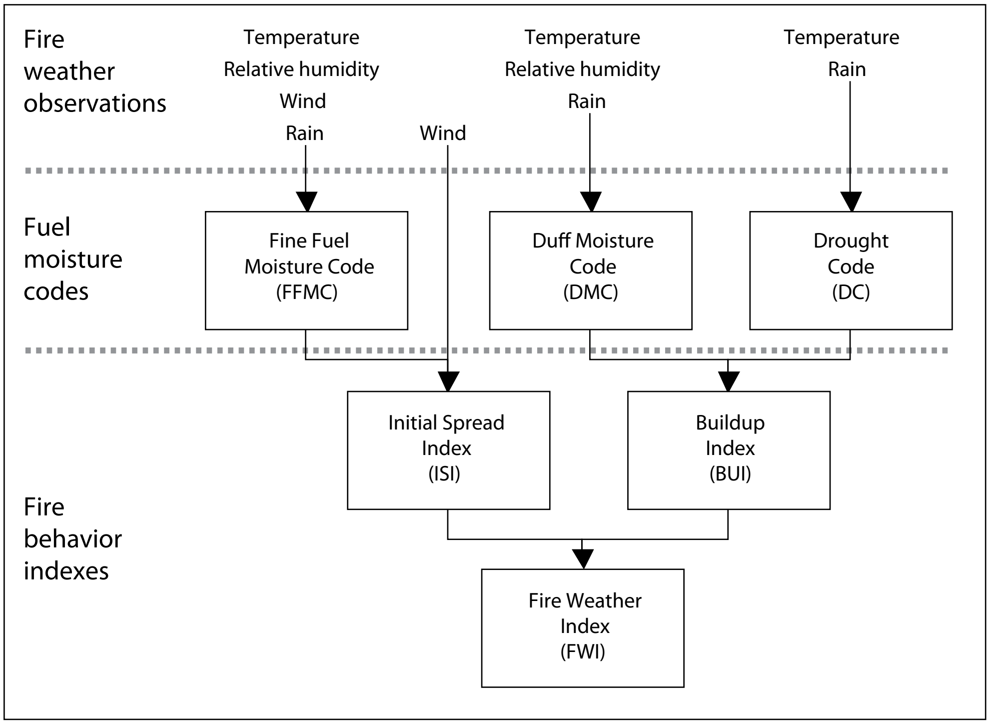


Figure 2. Structure of the Canadian Forest Fire Weather Index System (source: Canadian Forestry Service 1984).

Fire Weather Observations

The study area was located in the Hay River District, Northwest Territories, Canada, within the rectangular zone delimited by 61°36'00"N, 117°12'00"W and 61°03'06"N, 119°11'01"W (Fig. 3). For the fire weather analyses, weather stations within that area or nearby were selected.

Data from three weather stations (Fort Providence, Caen Lake Tower, and Kimble Tower), graciously provided by the Government of the Northwest Territories' Department of Resources, Wildlife and Economic Development (now the Department of Environment and Natural Resources), were used for the study (Table 1).

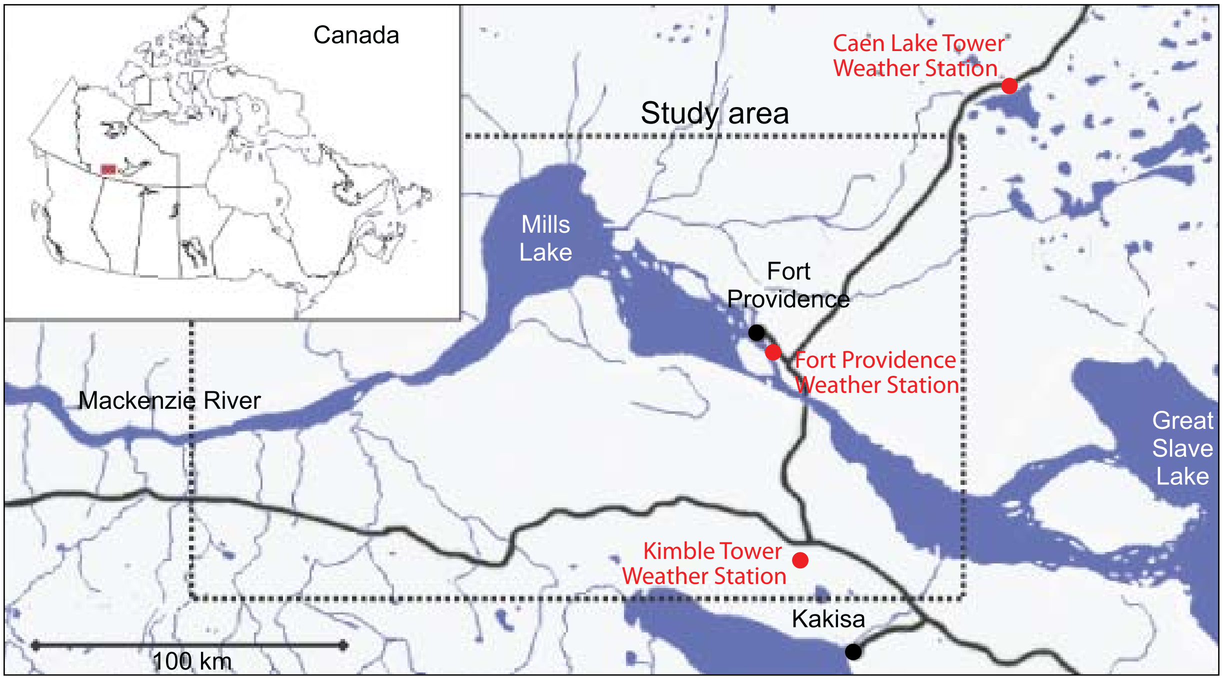


Figure 3. Map of the study area.

Table 1. Characteristics of the weather stations selected for this project and years of weather data available

Weather station	Latitude	Longitude	Elevation[a] (m)	No. of years of data	List of years
Fort Providence	61°21'N	117°40'W	160	19	1982–1983, 1985–2001
Caen Lake Tower	61°40'N	116°58'W	220	11	1990–1991, 1993–2001
Kimble Tower	61°03'N	117°33'W	260	20	1982–2001

[a] Approximation from a 1:250 000 scale topographic map of the area, according to the latitude and longitude of the station.

Fire weather observations were available for various periods between 1982 and 2001 (Table 1), depending on the weather station. All of the stations had at least 10 years of records, which is traditionally considered a reasonable sample of past annual weather (Van Wagner 1988). The weather observations used in the analyses were all obtained at noon LST (or 1300 DST) and were collected according to the standards presented by Turner and Lawson (1978). The analyses were performed for the period 15 June to 15 August, the time of year that usually coincides with the peak fire season in the Northwest Territories (Lanoville and Mawdsley 1990) and also with the convective storm season of June and July (Kochtubajda et al. 2001), when lightning activity typically occurs.

Other factors in selection of this analysis period were the fact that the stations did not start collecting data on the same date in each year and also the fact that the start date for each station varied from year to year; selection of this period resulted in a relatively constant number of days in the analyses for each year and for all stations. This procedure also removed some of the uncertainty concerning the start-up values for the FWI System components in any given year, especially for the stations that started collecting data late. The number of days between the first day of operation of a station and 15 June was generally large enough to allow self-correction of the FFMC and the DMC, both of which incorporate data from earlier dates, to compensate for any erroneous start-up values. The start-up values provided in the fire weather database were used without further adjustments, such as over-winter adjustment of the spring starting value for the DC (Turner and Lawson 1978). It was assumed that the required computations had already been done by the territorial fire management agency, since the database had been used operationally during the years for which these analyses were performed.

Fire Weather Elements

The analyses of fire weather presented here concentrated on the four fire weather observations required for calculation of the FWI System components (Van Wagner 1987): air temperature, relative humidity, 10-m open wind speed, and rain accumulated over the previous 24-h period. These elements influence the ease with which fires can start, their rate of spread and difficulty of control, and their effect on the environment (Turner and Lawson 1978). Wind direction (also for 10-m open wind), a quantity that is not used in the FWI System but that is used in the FBP System, was also pertinent for this project and was included in the analyses.

The historical variation of each weather variable during the peak fire season (15 June to 15 August) was examined on the basis of observations for all of the years available for each weather station. For each day of the period of interest, the minimum, average, and maximum values of each variable were identified. In addition, the overall average of each variable was calculated for the period, as were the averages for the highest and lowest values. Finally, the cumulative frequency and selected percentiles were computed for each variable.

Rain accumulated over the previous 24-h period was further analyzed in terms of the magnitude of rain events and their frequency according to four different accumulation thresholds: 0.01 mm, 0.5 mm, 1.5 mm, and 2.8 mm. Except for the first threshold, which was chosen for comparison purposes, these values correspond to the quantities of rain that must be ignored before that variable starts to influence the calculation of the fuel moisture codes of the FWI System (Turner and Lawson 1978; Canadian Forestry Service 1984; Van Wagner 1987): 0.5 mm for the FFMC, 1.5 mm for the DMC, and 2.8 mm for the DC. Three different analyses related to those values were performed. First, for each day over all years analyzed, the time elapsed since the last rain event greater than the thresholds was determined. The cumulative frequency of those elapsed times (in days) was derived for the period of interest. Second, for each day of the peak fire season, the average number of days since the last rain event larger than the values indicated was calculated. For the third analysis, the frequency of various periods without rain accumulation greater than these thresholds was determined.

For wind direction, the percentage of days on which the predominant wind direction fell into each of eight main categories (north, northeast, east, southeast, south, southwest, west, and northwest) was computed for the entire period and for four 2-week segments within that period.

Canadian Forest Fire Weather Index System Components

The analyses of the FWI System components covered the three fuel moisture codes (FFMC, DMC, and DC) and the three fire behavior indexes (ISI, BUI, and FWI) mentioned above. As for the fire weather observations, the historical variation of each variable during the peak fire season was examined for all years for which data were available from the three weather stations. For each day of the peak fire season, the minimum, average, and maximum values of each variable were identified. The overall average for each component was also calculated for the entire period, as were the averages of the minimum and maximum values. Cumulative frequency and selected percentiles were also computed for each variable.

Following the individual analyses of each FWI System component for the peak fire season, selected combinations of these components were studied. The ISI and BUI values were grouped into the same classes as those presented in the field guide to the FBP System (Taylor et al. 1997), and the percentage of days in each combined class was calculated. This information allowed identification (according to the tables provided by Taylor et al. [1997]) of the percentage of days in each fire intensity class, for the main conifer fuel types of the FBP System present in the study area.

Through a similar procedure, percentages were obtained for each of the "probability of sustained ignition" classes presented by Lawson and Dalrymple (1996) (a scientific and technical description of the equations is given in Lawson et al. [1994a] and illustrated by Lawson et al. [1994b]) for the "Dry" and the "Moist" Lodgepole Pine forest types, the two fuel types in that reference that most closely correspond to the stands in the study area used here.

The percentage of days with different combinations of FFMC, DMC or BUI, and FWI classes was examined. There were five FWI classes: low (FWI 0–4), moderate (FWI 5–12), high (FWI 13–18), very high (FWI 19–24), and extreme (FWI > 25) (Stocks et al. 1989).

Fire Danger Scenarios

Finally, an attempt was made to define the four burning condition periods, as illustrated by Horn (1976) (see Fig. 4), in terms of fire danger ratings. To the authors' knowledge, there has been no previous attempt to define these conditions for a given area. The four scenarios, representing moist, moderate, dry, and extreme burning conditions in the study area, were defined in terms of fire weather and FWI System components according to the analyses described above.

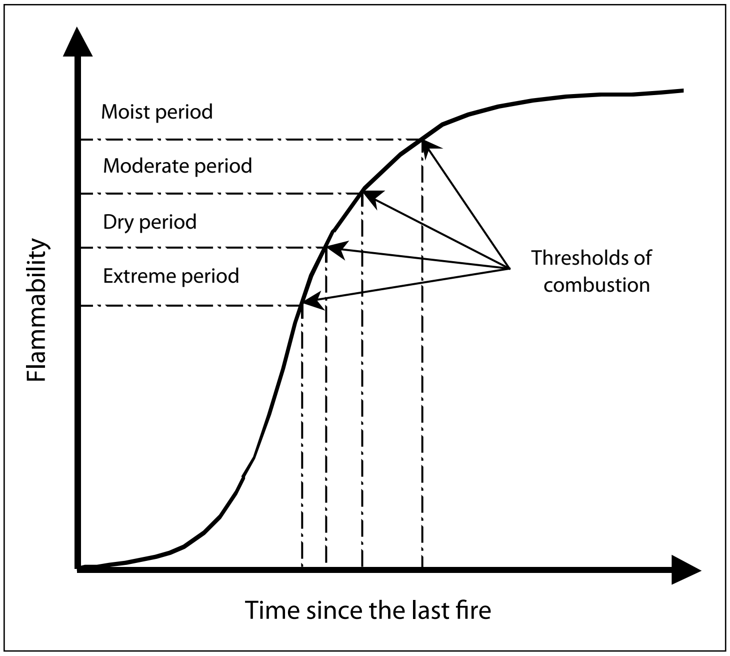


Figure 4. **Representation of the hypothetical model of flammability versus time since the last fire in relation to the four burning conditions (adapted from Horn 1976).**

After the results of the analyses on fire weather and FWI System components (described above) had been examined, it was decided that the scenario representing moist conditions should be loosely based on the 25th percentile and the average of the minimum values recorded for the different FWI System components during the peak fire season. Similarly, the 50th percentile and the average value for each FWI System component were used for the moderate scenario. The 97th percentile and the average of the maximum values recorded for the various FWI System components were used to define the dry scenario. The extreme scenario was selected to have values at the limit of the ranges observed for the different weather stations over the years analyzed.

For all of the stations, it was often impossible to select the exact value as calculated with either the percentile or the average, because some combinations of the different FWI System components were never observed in the study area or were impossible to obtain, given the inputs required for their calculation. The frequency analysis for the different combinations of FFMC–DMC–FWI or FFMC–BUI–FWI helped in refining selection of the value to use for each FWI System component in the different scenarios. Overall, an attempt was made to select scenarios that were in different FWI System component categories and that allowed at least some fire potential (which put a limit on the lowest value of FFMC that could be used).

RESULTS AND DISCUSSION

Although weather observations and FWI System components are intimately related, these categories are presented and discussed separately here, and each element of each category is examined individually. This approach was adopted to facilitate access to these data by those interested in the results for only some of the variables. Some of the data presented in the figures and tables are identified and discussed in the text as examples to assist the reader with interpreting the information.

Fire Weather Elements

Weather is the state and the changing nature of the atmosphere surrounding the earth (Schroeder and Buck 1970). The specific interest here in air temperature, relative humidity, 10-m open wind speed, and rain accumulated over the previous 24-h period was prompted by the direct and cumulative effect of these variables on the moisture content of forest fuels and the ensuing influence on fire behavior as expressed by the components of the FWI System. Good drying days are characterized by high temperature, low relative humidity, high wind speed, and lack of precipitation.

The results of the analyses are presented mainly as seasonal graphs to better depict the general character of the fire season (Main et al. 1990). Tables summarizing important values and other figures are also used as appropriate.

Temperature

On average, the air temperature during the peak fire season fluctuated around 20°C in the study area, and half of the days had a temperature higher than that value (Figs. 5 and 6, Table 2). Daily averages fluctuated between 16.0°C and 24.0°C, depending on the date and the weather station. In general, the lowest noon temperature recorded on each day of the peak fire season fluctuated around 12.0°C (range 0.0°C to 17.5°C), and the highest noon temperature fluctuated around 28.0°C (range 23.0°C to 36.5°C). Noon temperatures higher than 28.0°C occurred on only 3% of the days during the years analyzed (i.e., this value represents the 97th percentile).

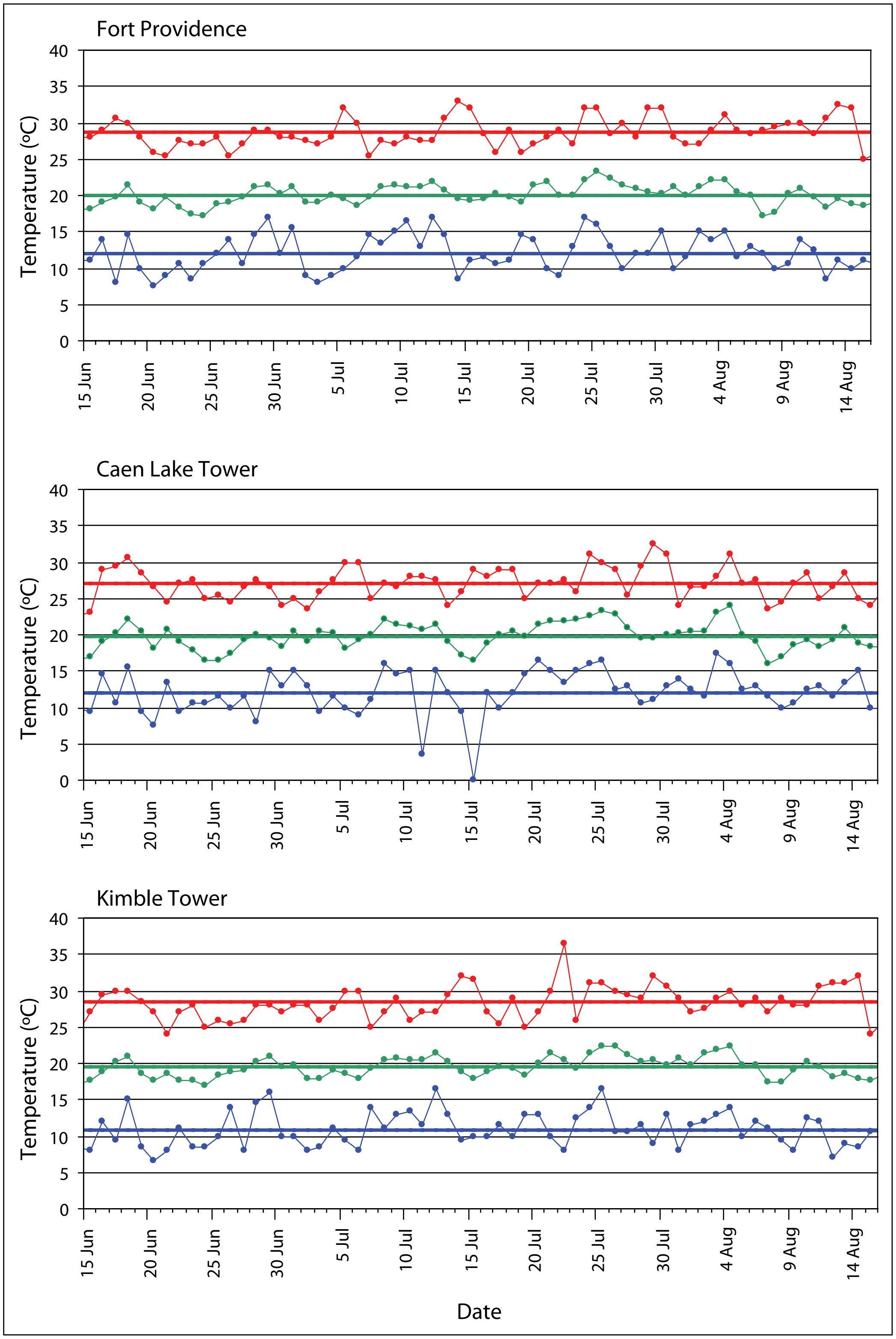


Figure 5. Minimum (blue), maximum (red), and average (green) noon (local standard time) air temperature for each day of the peak fire season and associated total averages for the period (see Table 1 for years of data available for each weather station).

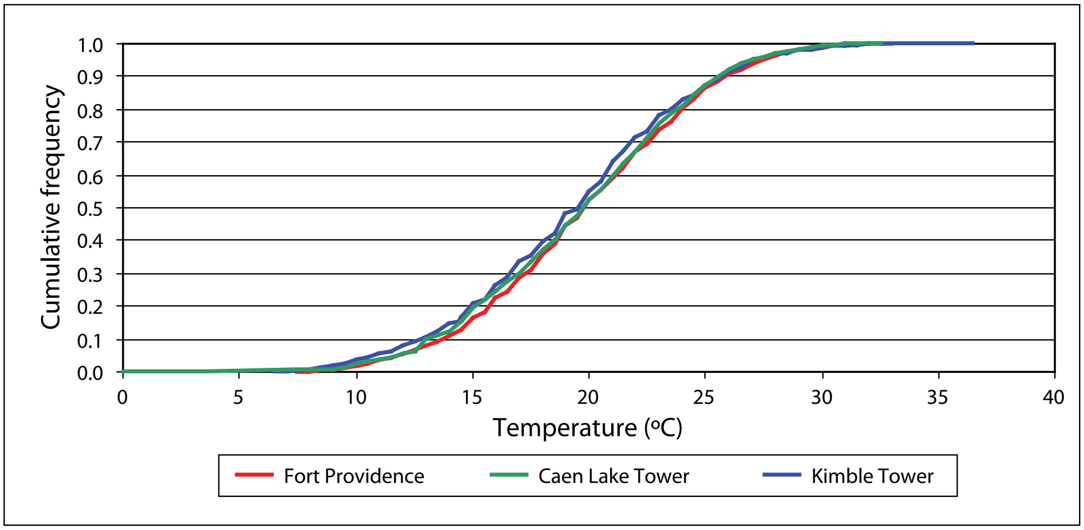


Figure 6. Cumulative frequency of the noon (local standard time) air temperature for the three weather stations.

Table 2. Selected percentiles and average values[a] for the seasonal daily observations of minimum, average, and maximum noon (local standard time) weather conditions during the peak fire season (15 June to 15 August) for three weather stations located within or near the study area

	Percentile[b]							Mean		
Weather station	25 (1)	50 (3)	75 (5)	90 (10)	95 (25)	97 (50)	99 (75)	Min.	Avg.	Max.
Air temperature (°C)										
Fort Providence	16.6	19.8	23.2	25.8	27.5	28.3	30.3	12.1	20.1	28.7
Caen Lake Tower	16.1	19.7	22.9	25.6	27.1	28.0	29.9	12.1	19.8	27.1
Kimble Tower	15.9	19.6	22.7	25.7	26.9	27.9	30.0	10.9	19.5	28.4
Relative humidity (%)										
Fort Providence	27	32	34	39	44	54	67	33	57	92
Caen Lake Tower	27	30	33	37	44	53	65	34	56	87
Kimble Tower	24	28	31	34	41	52	66	29	55	95
10-m open wind speed (km/h)										
Fort Providence	4.3	7.8	11.6	15.5	17.9	19.8	24.4	0.4	8.8	21.5
Caen Lake Tower	7.6	10.1	14.0	15.6	19.1	19.9	24.0	4.0	11.1	19.0
Kimble Tower	8.1	11.8	16.0	19.9	22.9	24.6	31.1	2.0	12.7	25.5
Rain accumulated over the previous 24-h period (mm)										
Fort Providence			0.9	4.9	9.0	12.7	19.5	0.0	1.6	12.6
Caen Lake Tower			0.7	4.2	9.6	13.1	18.8	0.0	1.5	9.0
Kimble Tower			1.0	6.1	12.0	17.0	26.3	0.0	2.0	16.7

[a] Based on data over several years; see Table 1.

[b] Percentile values in parentheses apply to relative humidity.

The cumulative frequency graph represents the fraction (or percentage) of all days during the peak fire season that had a temperature lower than or equal to the one selected. Conversely, the percentage of days on which a higher temperature was recorded can be determined by subtracting the cumulative frequency (or percentage) from the number 1 (or 100). The 90th and 97th percentiles are often used in fire management (Main et al. 1990), although other values (or even the shape of the cumulative frequency curve) may also be useful, depending on the application. Table 2 lists selected percentiles, whereas Fig. 6 presents the curves for cumulative frequency of temperature measured at the three weather stations. Other percentiles can be obtained from these curves as needed.

It is important to note that the noon LST air temperature was not necessarily the maximum temperature reached during the day, but was the temperature used in calculation of the FWI System components. Temperatures recorded later in the afternoon were often higher than the noon temperature, although that variable was not analyzed for this project. Moreover, the high latitude of the study area, with low angles of incident solar radiation but very long days during the fire season, had an important effect on the progression of the temperature (and relative humidity) curve during the day (Van Wagner 1977; Beck and Armitage 2004). As a reference, there were approximately 19.5 h between sunrise and sunset by mid-June at Fort Providence and 16 h around mid-August (List 1951). Consequently, normal daily fluctuations in fuel moisture might not have been as pronounced as for more southerly areas, and nighttime recovery might not have occurred. Ward and Mawdsley (2000) indicated that in the Northwest Territories, fires may continue to burn throughout the night with very little change in fire behavior.

Relative Humidity

The average relative humidity at noon LST for the study period, over all years analyzed, was about 56% (depending on the weather station) (Fig. 7, Table 2). The seasonal daily averages varied within the range 44% to 68%, and a little more then half of the days had relative humidity below that value (Fig. 8, Table 2). The highest noon relative humidity recorded on each day of the peak fire season ranged between 60% and 100%, with an average of about 91%. Several days over the fire season never recorded a high value of relative humidity at noon (Fig. 7). The lowest observed relative humidity for each day of the peak fire season fluctuated between 11% and 54%, with an average close to 32%, depending on the weather station. In general, between 3% and 5% of the days had a relative humidity lower than that value.

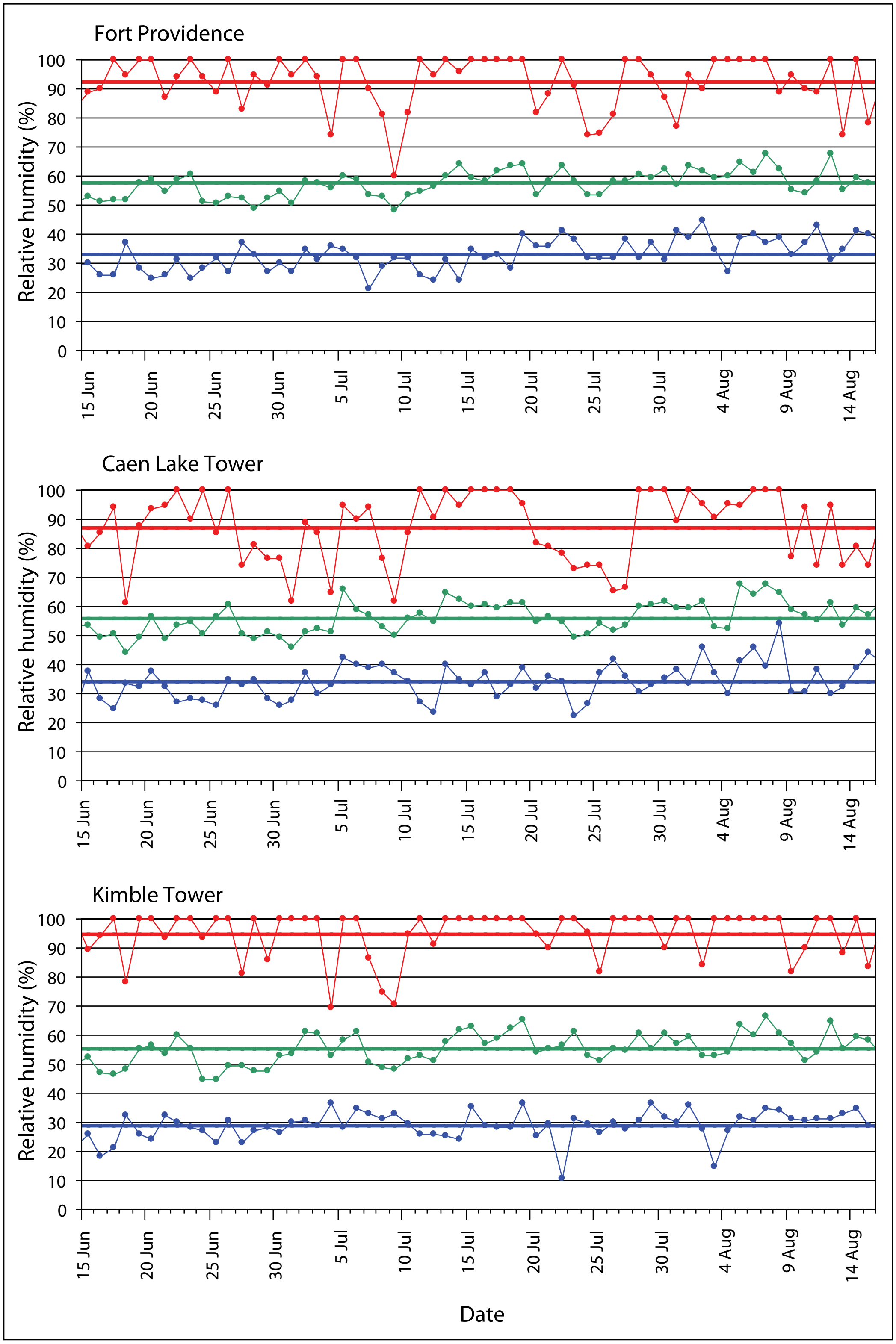


Figure 7. Minimum (blue), maximum (red), and average (green) noon (local standard time) relative humidity for each day of the peak fire season and associated total averages for the period (see Table 1 for years of data available for each weather station).

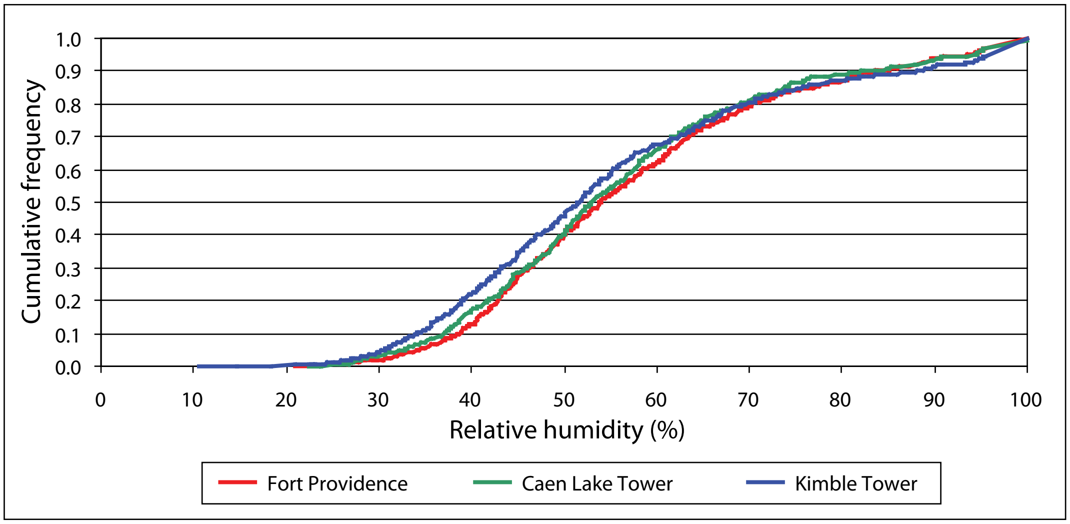


Figure 8. **Cumulative frequency of the noon (local standard time) relative humidity for the three weather stations.**

Wind Speed and Direction

On average, the noon LST wind speed in the study area fluctuated around 11 km/h, with the average being approximately the same as the 50th percentile (median) (Figs. 9 and 10, Table 2). The lowest values recorded on each day of the peak fire season varied between 0 and 10 km/h, with an average around 2 km/h, depending on the weather station. The highest wind speed measured on each day over all years fluctuated around 22 km/h and ranged between 15 and 45 km/h. Less than 10% of the days had a wind speed greater than 15 km/h at noon LST, and on only 3% of the days was it higher than 20 km/h. It is important to keep in mind that wind speed often increases in the afternoon because of convective activity, which will influence fire behavior accordingly during the peak burning period. This factor was not considered in the analyses reported here.

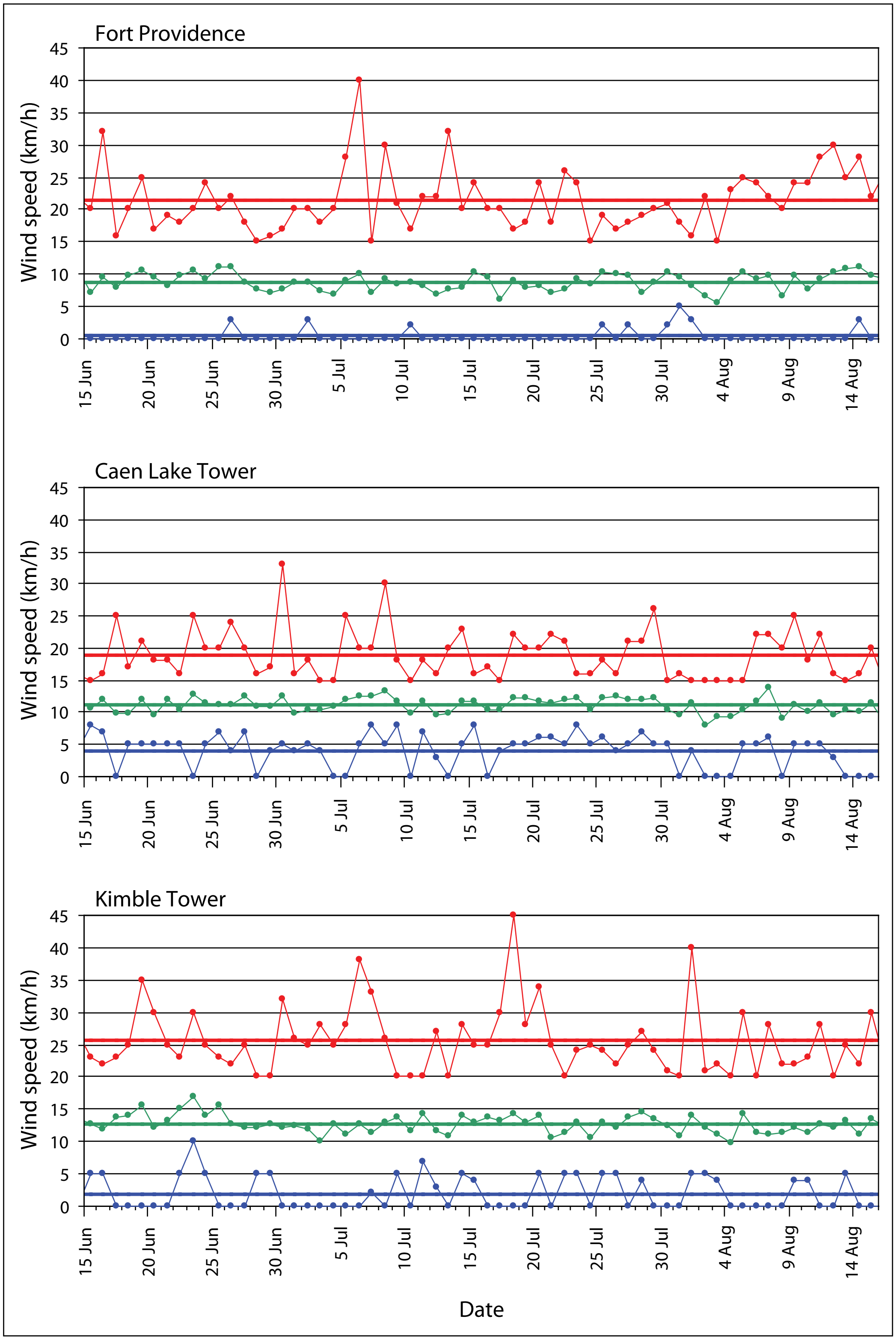


Figure 9. Minimum (blue), maximum (red), and average (green) noon (local standard time) 10-m open wind speed for each day of the peak fire season and associated total averages for the period (see Table 1 for years of data available for each weather station).

The analysis of wind direction (Fig. 11) showed that the percentage of days dominated by each wind direction at the Fort Providence weather station was almost equal over the peak fire season, with a slightly lower frequency of days with prevailing northeast, southwest, and northwest winds. The other two stations, Caen Lake Tower and Kimble Tower, had predominantly north winds (22% and 25%, respectively) and south winds (23% and 16%, respectively) between 15 June and 15 August.

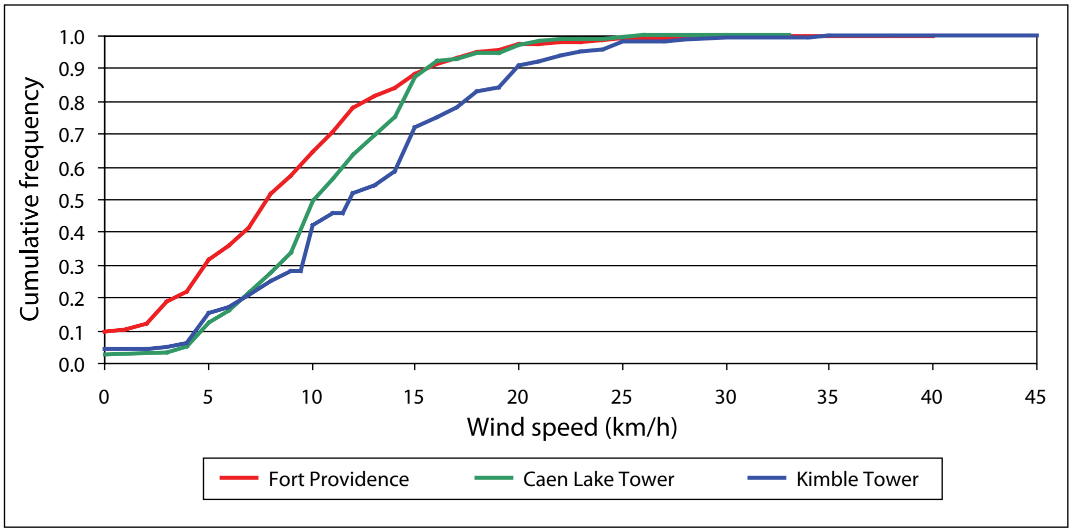


Figure 10. Cumulative frequency of the noon (local standard time) 10-m open wind speed for the three weather stations.

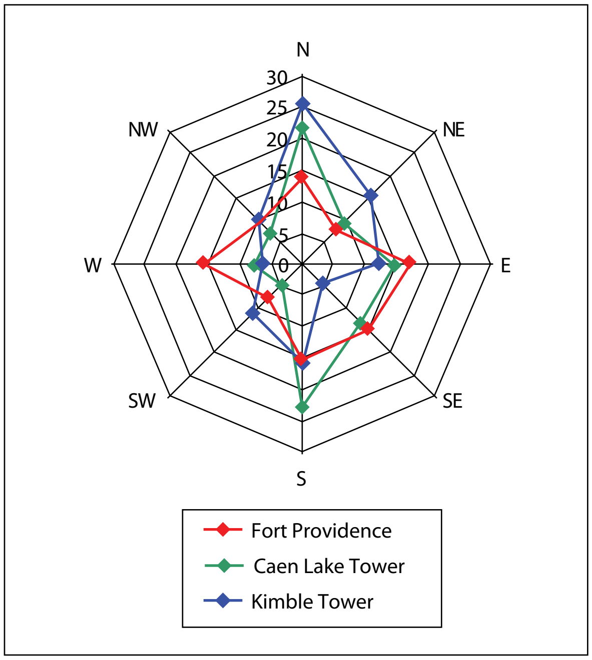


Figure 11. Percentage of days, during the peak fire season, in each wind direction category for the noon (local standard time) observation.

Over consecutive 2-week periods, the percentage of days in each wind direction category was similar to that for the entire peak fire season at the Fort Providence weather station, with slightly more days with prevailing east winds during the first half of July and southeast winds during the first half of August (Fig. 12). The Caen Lake Tower and Kimble Tower weather stations had the same dominance of north and south winds in each 2-week period as observed for the entire season. North winds were predominant during the last half of June and the first half of August at the Caen Lake station, whereas south winds were observed more frequently at other times. An eastern component was observed in all of the 2-week periods, but it was complemented by western winds during the first week of August at that station. At the Kimble Tower weather station, north winds were more frequent in all of the 2-week periods, and the proportion of days with south winds was almost constant. The only exception was the first 2 weeks of July, when the percentage of days with south winds was slightly lower and that with east winds slightly higher than during the other three periods.

Precipitation

The maximum amount of rain accumulated over 24 h varied around 13 mm, ranging from 0.2 to 52.0 mm (Figs. 13 and 14, Table 2). At each weather station, some days during the peak burning season never had large accumulations of rain over the years analyzed (Fig. 13), and each day of the peak burning season had at least one occurrence, over the years analyzed, when no rain fell. Although the average amount of rain during each 24-h period was between 1.5 and 2.0 mm in the study area during the peak burning season, depending on the weather station, in reality approximately 65% of the days had no rain at all (Fig. 14, Table 2).

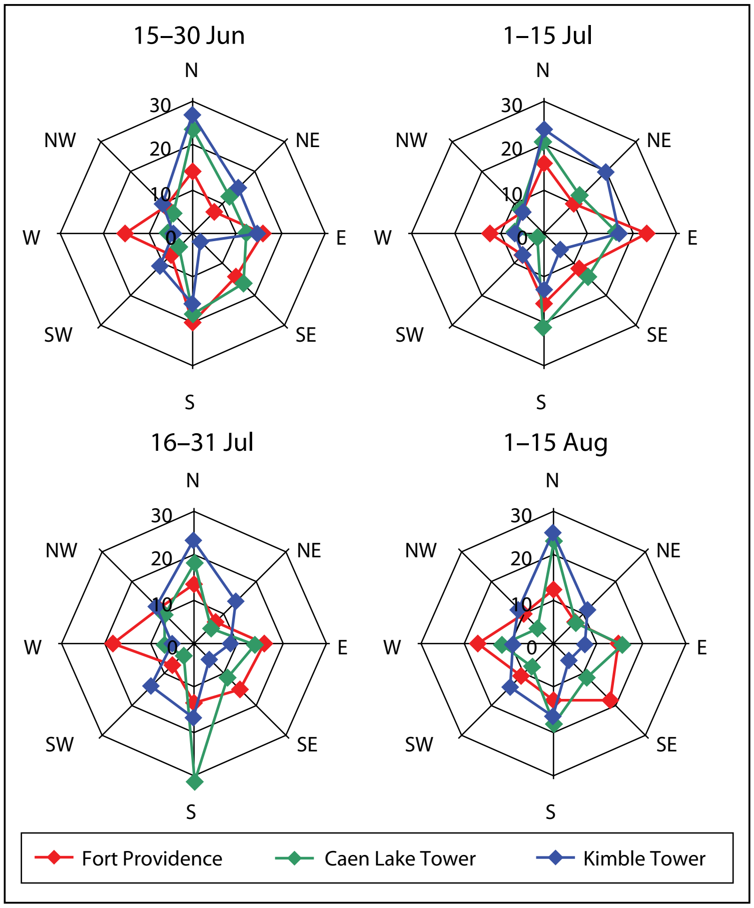
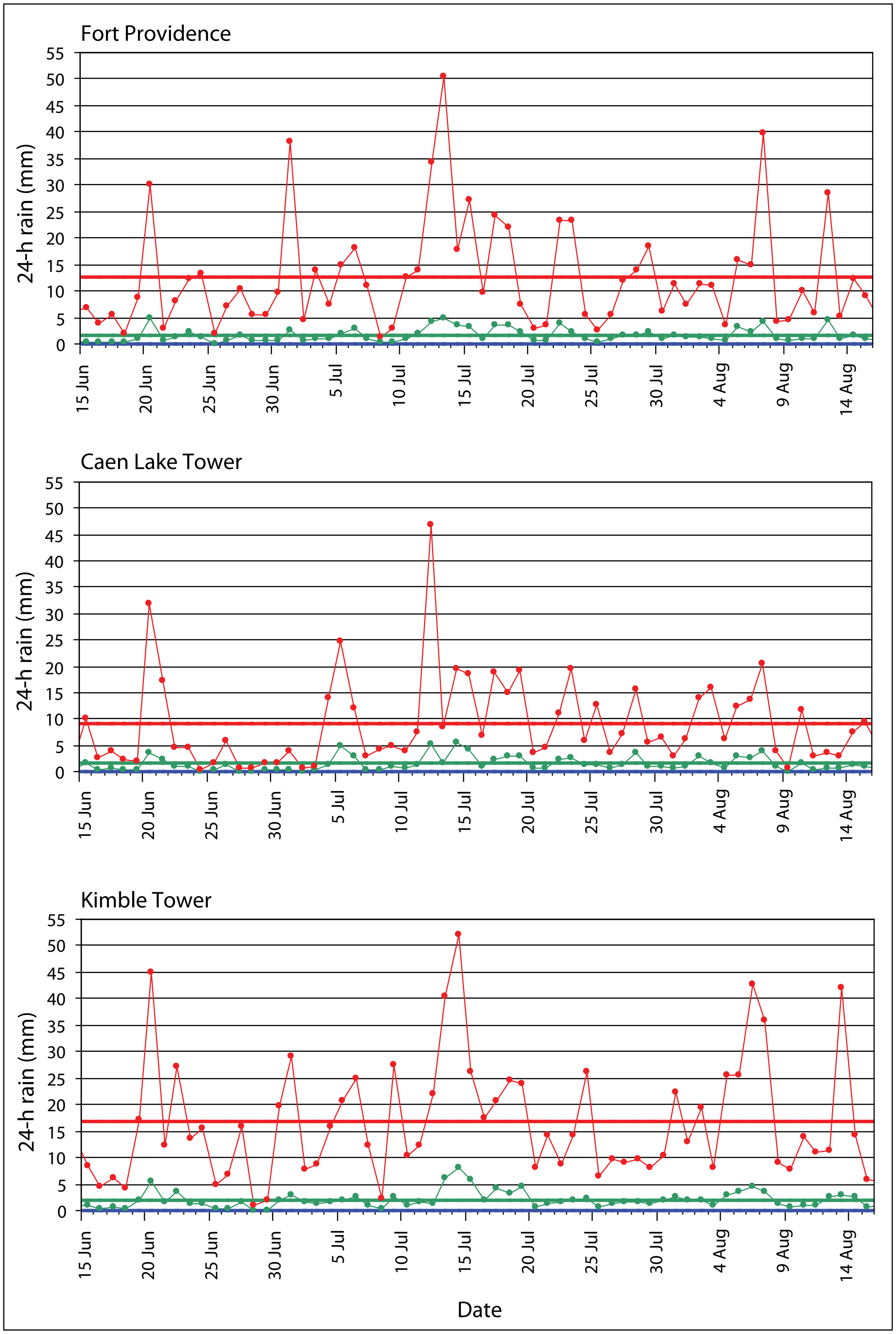


Figure 12. Percentage of days, for four 15- or 16-day periods of the peak fire season, in each wind direction category for the noon (local standard time) observation.



Fort Providence

Caen Lake Tower

Kimble Tower

Figure 13. Minimum (blue), maximum (red), and average (green) noon (local standard time) 24-h rain accumulation for each day of the peak fire season and associated total averages for the period (see Table 1 for years of data available for each weather station).

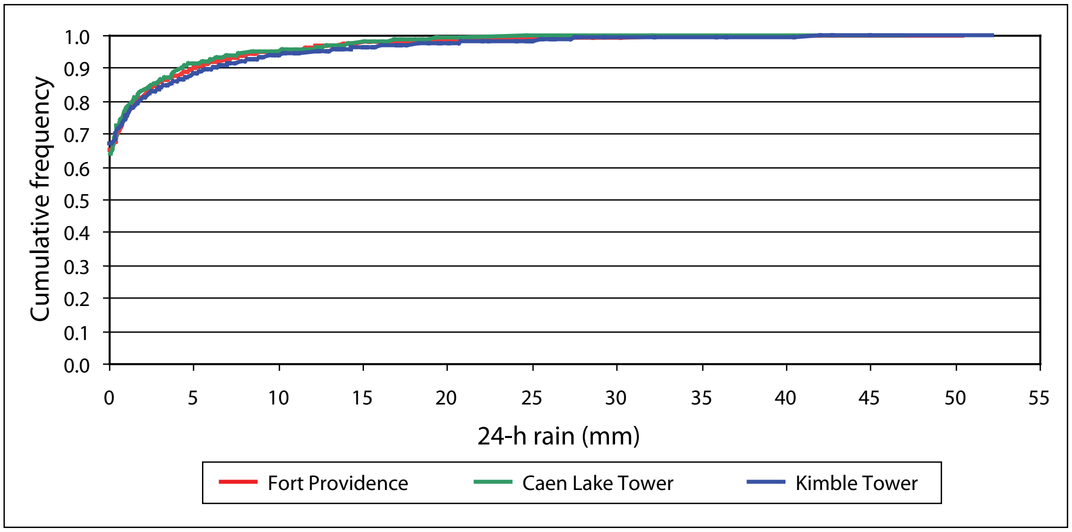


Figure 14. Cumulative frequency of the noon (local standard time) 24-h rain for the three weather stations.

In general, more than 25% of the days in the peak fire season had rain accumulations of more than 1 mm (Fig. 14, Table 2), an amount large enough to lower the FFMC. Only about 10% of the days had accumulations of more than 5 mm, and less than 1% of the days had rain events of more than 20 mm. The Kimble Tower weather station had slightly greater rain accumulations than the two other stations, which are located on the other side of the Mackenzie River.

Another way to examine rainfall patterns is to look at the number of days since the last rain event of some determined importance. The choices of 0.5, 1.5, and 2.8 mm for this purpose (and 0.01 mm for comparison) represented the thresholds above which the 24-h period rain accumulation starts to influence one of the fuel moisture codes of the FWI System.

For each day of the peak fire season using each year with weather observations (Table 1), the average number of days since the last rain event larger than each of the four thresholds was determined (Fig. 15). Oscillations were observed throughout the period for all of the thresholds.

For more than half of the days, there had been at least one preceding day without rain (Fig. 16, Table 3), whereas for only 25% of the days, had there been at least 3 or 4 days without rain. In general, only 5% of the days were preceded by periods of 7–11 days or more without rain, depending on the weather station; the percentage decreased sharply for longer periods without rain. For rain events larger than 0.5 mm (i.e., those that would significantly affect the FFMC), the numbers resembled but were slightly higher than those mentioned above. This suggests that the amount of rain falling on a given day was often sufficient to reduce the FFMC in the study area.

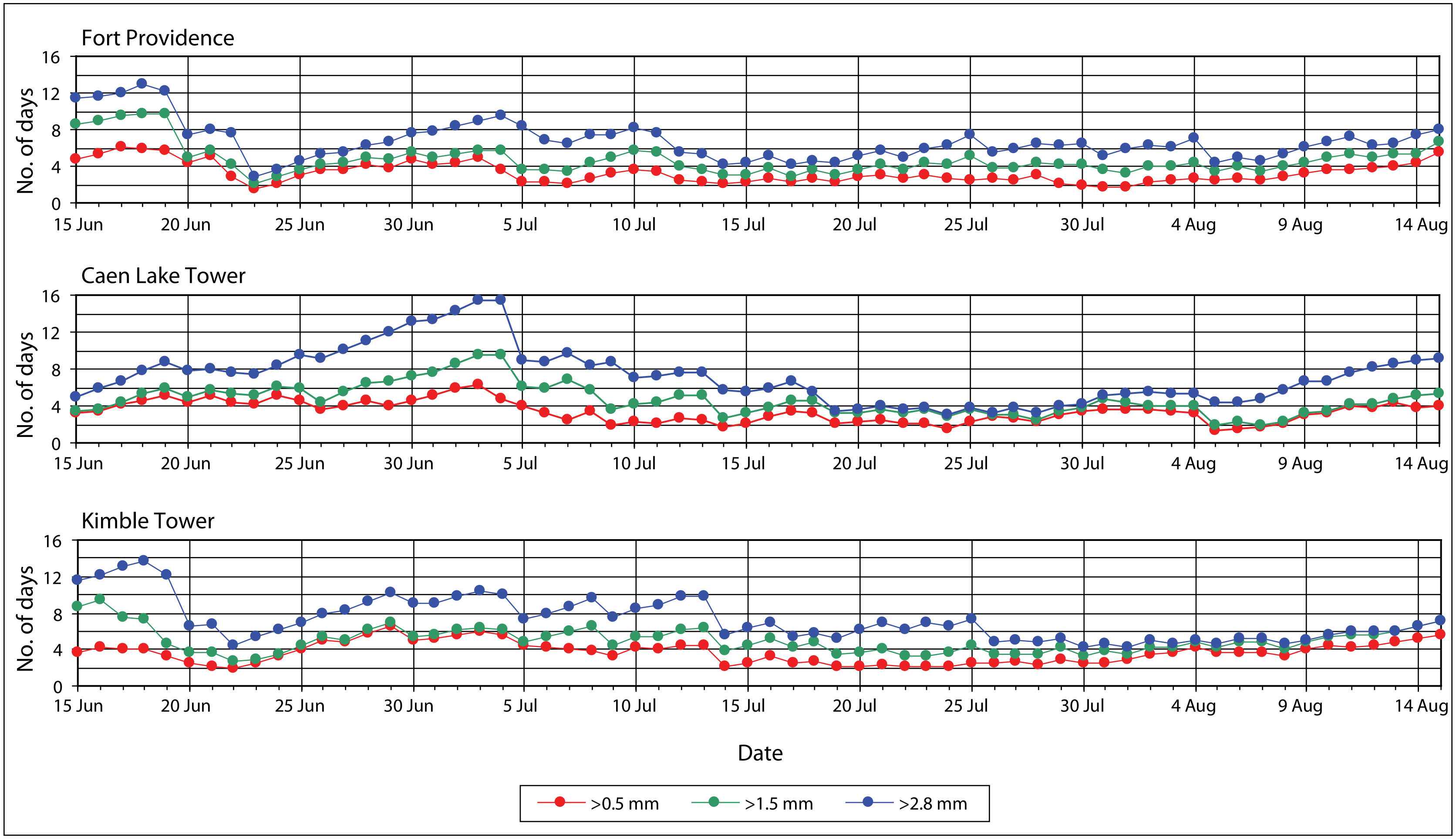


Figure 15. Average number of days since the last rain event of the magnitude mentioned for each day of the peak fire season (see Table 1 for years of data available for each weather station).

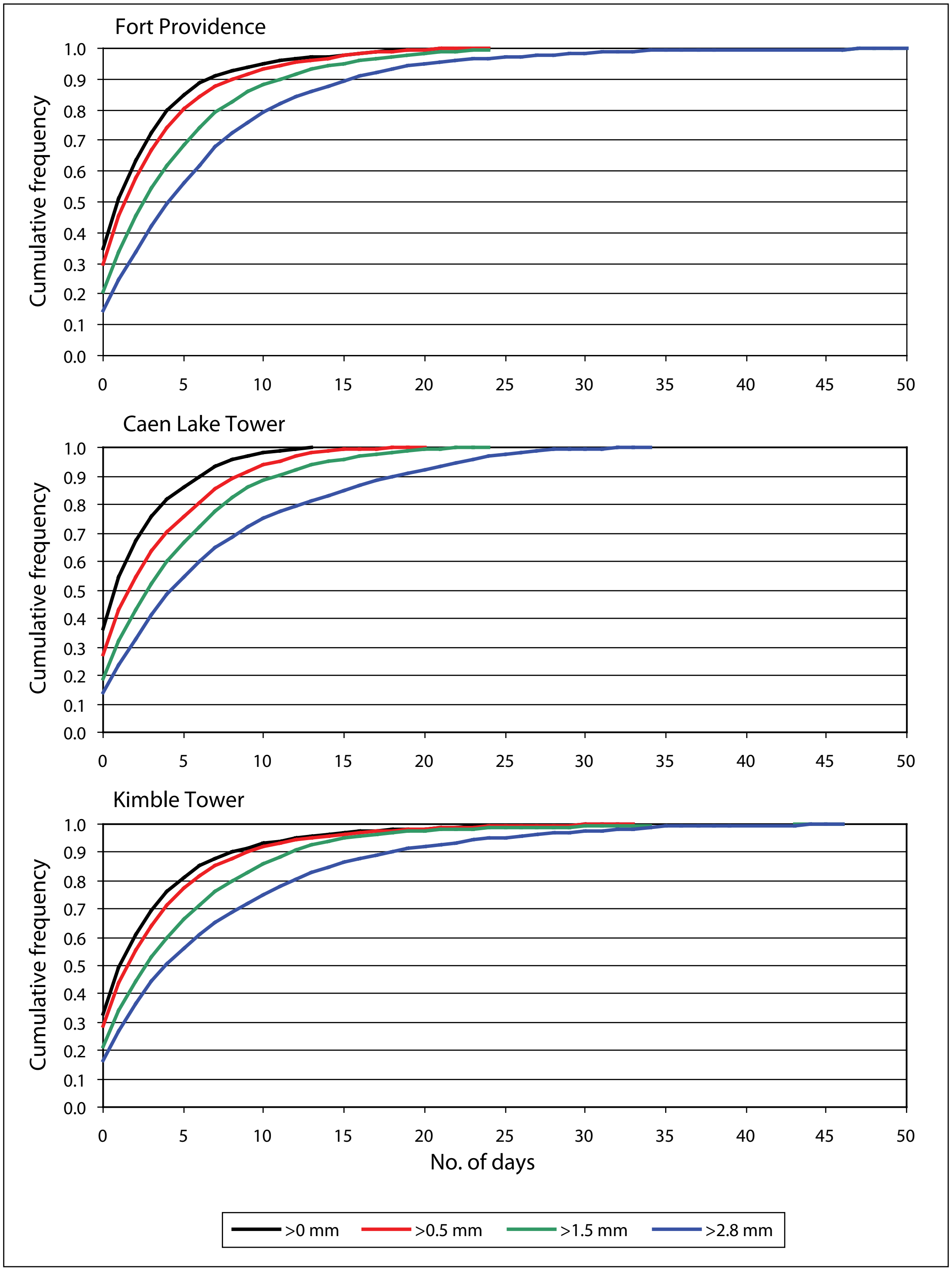


Figure 16. Cumulative frequency of the number of days since the last rain event of the magnitude mentioned for the three weather stations (see Table 1 for years of data available for each weather station).

Table 3. Percentiles of the number of days since the last rain event of the magnitude mentioned during the peak fire season for each day of the peak fire season (15 June to 15 August) for three weather stations located within or near the study area[a]

Rain event	Weather station	Percentile					
		50	75	90	95	97	99
>0.01 mm[b]	Fort Providence	0.9	3.3	6.5	10.1	13.0	17.3
	Caen Lake Tower	0.7	2.9	6.1	7.7	8.9	11.0
	Kimble Tower	1.1	3.8	7.9	11.8	15.0	22.4
>0.5 mm	Fort Providence	1.3	4.1	8.1	11.6	14.2	17.8
	Caen Lake Tower	1.6	4.8	8.3	10.7	12.1	14.4
	Kimble Tower	1.5	4.6	8.9	12.7	15.8	22.7
>1.5 mm	Fort Providence	2.5	6.2	10.9	15.0	17.6	21.8
	Caen Lake Tower	2.8	6.5	10.8	14.0	16.1	19.4
	Kimble Tower	2.6	6.7	11.7	14.9	18.2	28.0
>2.8 mm	Fort Providence	4.1	8.8	15.4	20.3	24.5	32.6
	Caen Lake Tower	4.2	9.9	18.3	22.3	24.4	27.8
	Kimble Tower	3.9	9.9	17.8	24.2	28.7	34.4

[a] Based on data over several years; see Table 1.
[b] This value is arbitrary and for comparative purposes only.

More than 50% of the days had not received more than 1.5 mm of rain (the amount sufficient to reduce the DMC) for at least 2.5 days, and the percentage decreased to 5% for an interval of 14 days or more since a rain event of 1.5 mm. Furthermore, on more than half of the days, it had been at least 4 days since the last rain event with an accumulation of 2.8 mm, sufficient to reduce the DC, and for only 5% of the days had been more than 20 days since that amount fell (Table 3, Fig. 16). In general, the Kimble Tower weather station, located south of the other stations, had longer periods between rain events of various magnitudes than the other stations.

The average frequency of periods without rain accumulation above the various thresholds were also determined (Table 4). Periods of more than 10 days without rain accumulation above these thresholds occurred, on average, only every second year during the peak fire season.

Table 4. **Average number of occurrences of a given interval between rain events of a given magnitude for the peak fire season (15 June to 15 August) for three weather stations located within or near the study area**[a]

Rain event	Weather station	No. of days between rain event											
		0	1–3	4–6	7–9	10–12	13–15	16–18	19–21	22–24	25–27	28–30	>30
>0.01 mm[b]	Fort Providence	21.5	5.5	3.2	0.8	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0
	Caen Lake Tower	22.4	7.9	1.6	1.3	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0
	Kimble Tower	20.5	5.5	2.6	0.8	0.5	0.3	0.1	0.0	0.1	0.0	0.0	0.1
>0.5 mm	Fort Providence	18.3	5.2	2.6	1.0	0.6	0.2	0.1	0.2	0.0	0.0	0.0	0.0
	Caen Lake Tower	16.9	5.4	1.3	1.6	0.5	0.6	0.0	0.1	0.0	0.0	0.0	0.0
	Kimble Tower	17.8	4.6	2.3	1.1	0.5	0.3	0.2	0.0	0.0	0.0	0.0	0.1
>1.5 mm	Fort Providence	12.7	3.4	1.6	1.6	0.8	0.3	0.2	0.2	0.1	0.0	0.0	0.1
	Caen Lake Tower	11.6	3.4	1.5	1.6	0.6	0.5	0.1	0.3	0.1	0.0	0.0	0.0
	Kimble Tower	13.2	3.5	1.6	1.2	0.6	0.6	0.3	0.1	0.0	0.0	0.0	0.2
>2.8 mm	Fort Providence	9.0	1.7	1.3	1.4	0.8	0.4	0.4	0.2	0.0	0.1	0.1	0.2
	Caen Lake Tower	8.7	1.5	1.5	1.2	0.6	0.2	0.2	0.1	0.2	0.0	0.3	0.1
	Kimble Tower	10.1	2.5	1.3	0.8	0.5	0.5	0.3	0.1	0.1	0.1	0.1	0.3

[a] Based on data over several years; see Table 1.

[b] This value is arbitrary and for comparative purposes only.

Canadian Forest Fire Weather Index System Components

Similar to the weather analyses presented above, the FWI System components are presented mainly as seasonal graphs, complemented by tables summarizing important values and by other figures as necessary. Some information on each component is also provided for quick reference and to assist in the interpretation of the results from a fire management perspective.

Fine Fuel Moisture Code

The FFMC is a numeric rating of the moisture content of litter and other cured fine fuels with a nominal fuel depth and load of 1.2 cm and 0.25 kg/m^2, respectively (Van Wagner 1987). An indicator of the relative ease of ignition and flammability of fine fuels (Canadian Forestry Service 1984), it is calculated daily from the four weather observations described above. The FFMC has a time lag of two-thirds of a day, which indicates that it would take that amount of time for the fine fuels to lose about two-thirds of their free moisture above equilibrium on a standard drying day (Van Wagner 1987). This component of the FWI System has a short-term "effective memory" and reflects only the weather conditions that have occurred during the past 3 to 5 days (De Groot 1988; Canadian Forest Service 1996).

The FFMC ranges between 0 and 101. In general, fires are not likely to spread in the surface litter when the FFMC is less than about 74 (Stocks et al. 1989), and fires will not start in most fine fuels at a moisture content above 25% to 30%, equivalent to an FFMC of approximately 78 (Canadian Forest Service 1996). The potential for fire increases exponentially with an increase in FFMC values at the high end of the scale, reaching a high potential at FFMC values of 86 to 89 in the boreal forest (De Groot 1988). An FFMC of 90 or more indicates a high probability that spot fires will develop (Alexander and Cole 2001).

The average FFMC value for the peak fire season was close to 77 in the study area, with values fluctuating between 61 and 87 depending on the day and the weather station (Fig. 17, Table 5). The lowest value recorded on each day varied between 0 and 81, for an average between 22 and 45, depending on the weather station. This is an indication that on some days, the FFMC never reached very low values over all the years analyzed (Fig. 17). The highest value recorded on each day varied between 87 and 97, with an average of 92. Substantially less daily variation was observed for the daily high values of FFMC, than was the case for the daily low values.

According to the cumulative frequency data for the FFMC (Fig. 18, Table 5), fires were likely to spread in the surface litter (FFMC > 74) on almost 75% of the days during the peak fire season, and there was a high potential for fire ignitions (FFMC > 89) on approximately 25% of the days. Only 3% of the days between 15 June and 15 August had an FFMC above 92, and 1% of the days reached a value higher than 93.

Days with FFMC values higher than the average for the peak fire season generally occurred more often at the beginning of the period, before July 11. A few isolated days later in the season also had high FFMC values.

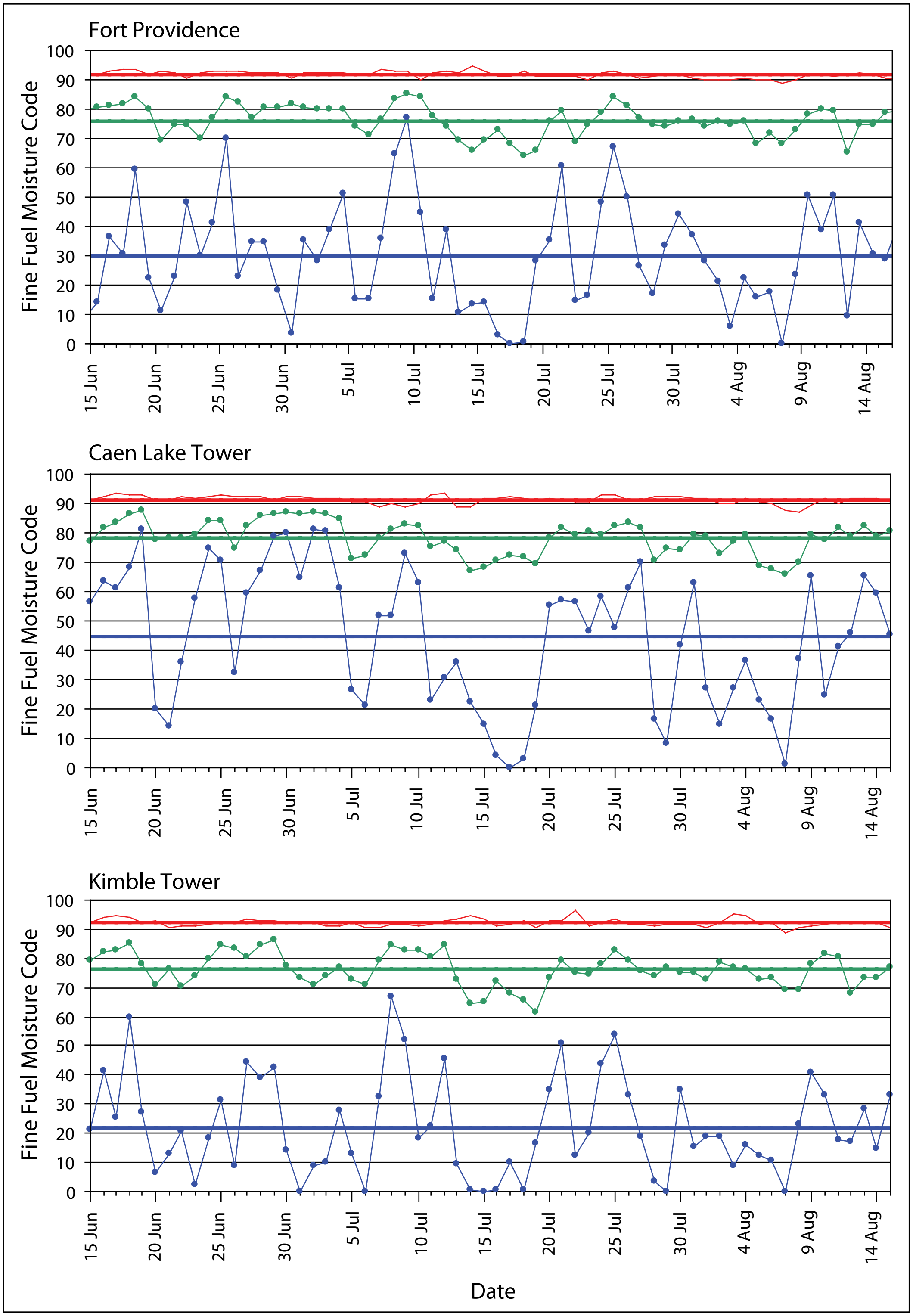


Figure 17. Minimum (blue), maximum (red), and average (green) standard daily Fine Fuel Moisture Code for each day of the peak fire season and associated total averages for the period (see Table 1 for years of data available for each weather station).

Table 5. Selected percentiles and average values[a] for the seasonal daily calculations of minimum, average, and maximum noon (local standard time) fuel moisture codes and fire behavior indexes during the peak fire season (15 June to 15 August) for three weather stations located within or near the study area

Code or index and	Percentile							Mean		
weather station	25	50	75	90	95	97	99	Min.	Avg.	Max.
Fine Fuel Moisture Code										
Fort Providence	71	85	88	90	91	92	93	30	76	92
Caen Lake Tower	76	85	89	90	92	92	93	45	78	91
Kimble Tower	72	86	89	91	92	92	93	22	76	92
Duff Moisture Code										
Fort Providence	19	33	54	76	87	94	103	9	39	96
Caen Lake Tower	21	38	60	78	87	92	99	13	42	86
Kimble Tower	16	29	49	71	82	89	105	8	36	91
Drought Code										
Fort Providence	317	410	493	565	619	645	670	222	412	630
Caen Lake Tower	342	409	512	584	642	671	704	247	424	616
Kimble Tower	262	331	405	471	529	572	606	145	337	573
Initial Spread Index										
Fort Providence	0.9	3.0	5.3	7.3	8.8	10.0	12.9	0.1	3.5	10.3
Caen Lake Tower	1.4	3.9	6.2	8.4	10.5	11.4	13.6	0.5	4.2	10.3
Kimble Tower	1.2	4.1	7.2	10.3	12.5	14.6	17.7	0.1	4.8	14.5
Buildup Index										
Fort Providence	34	54	83	111	122	127	139	16	61	131
Caen Lake Tower	36	61	89	112	124	131	141	23	64	124
Kimble Tower	29	48	73	99	111	120	135	14	53	121
Fire Weather Index										
Fort Providence	2	9	17	24	28	30	35	0	11	31
Caen Lake Tower	4	12	20	26	30	34	38	1	13	30
Kimble Tower	3	11	20	28	32	34	41	0	13	35

[a] Based on data over several years; see Table 1.

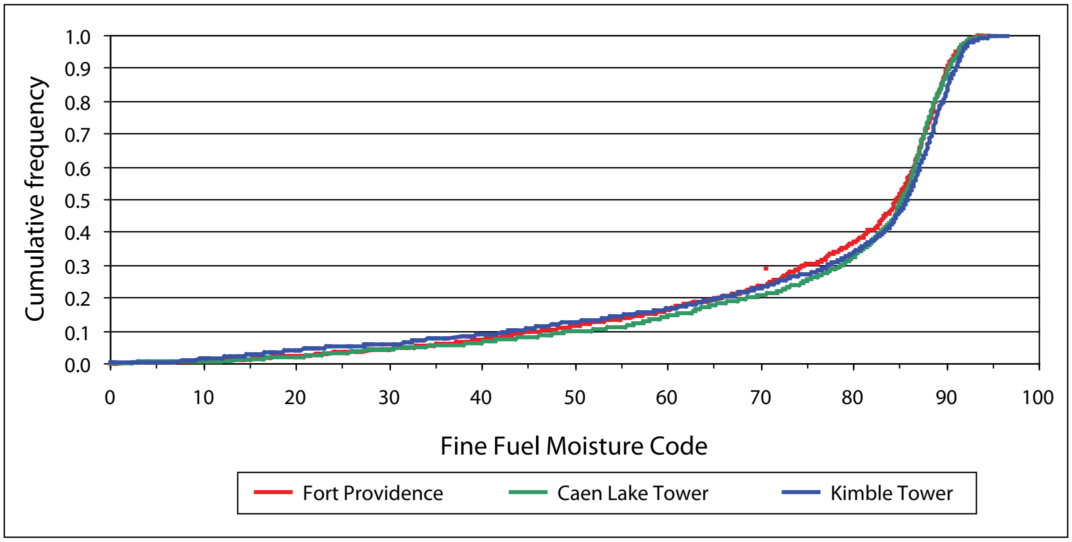


Figure 18. Cumulative frequency of the standard daily Fine Fuel Moisture Code for the three weather stations.

Duff Moisture Code

The DMC is a numeric rating of the average moisture content of loosely compacted decomposing organic matter of moderate depth and load—nominally 7.0 cm and 5.0 kg/m^2, respectively (Van Wagner 1987). The code has a time lag of 15 days (Lawson et al. 1997a) and is calculated using three of the noon LST weather observations (air temperature, relative humidity, and rain accumulated over the previous 24-h period) and the month of observation. The latter takes into account the changing day length in the calculation of the drying phase (Van Wagner 1987).

The DMC indicates fuel consumption in moderate duff layers and medium-size woody material (Canadian Forestry Service 1984) and is often used in predicting lightning-ignited fire starts (De Groot 1988). It is generally thought that the duff layer does not contribute to frontal fire intensity and is not involved in combustion until the DMC reaches 20 or 25 (Van Wagner 1972; Stocks et al. 1989; Canadian Forest Service 1996; Alexander and Cole 2001). The scale of this code does not have an upper limit, but at a value of 150 to 200 the duff will have lost most of its available moisture (Van Wagner 1987; Canadian Forest Service 1996). Lawson et al. (1997b) identified thresholds for smoldering ignition based on moisture content (indicated by the DMC) in upper feather moss and combined reindeer lichen and feather moss material. For a probability of smoldering ignition of at least 0.5 (assuming that the moisture content at 50% probability could be interpreted as the moisture ignition limit for each duff type), upper feather moss had to reach a moisture content of 76% or less and combined reindeer lichen and feather moss required a moisture content of 116% or less, which can be converted to DMC values of at least 58 and 39, respectively, using an equation developed specifically for each of those duff types.

Over all of the years analyzed, the average DMC for the peak fire season was between 36 and 42, depending on the weather station (Fig. 19, Table 5). The overall average on each day varied between 25 and 66. The lowest value on each day was between 0 and 30, with an average of about 10, whereas the highest value varied between 61 and 159 and averaged 91. Approximately 75% of the days had a DMC higher than the threshold value of 20 associated with the onset of duff consumption (Fig. 20, Table 5). Approximately 22% and 42% of the days, respectively, were above the threshold probabilities of smoldering ignition in the upper feather moss and the reindeer lichen and feather moss material based on the DMC values mentioned above (i.e., 58 and 39, respectively). Finally, a DMC higher than 92 was observed on approximately 3% of the days, and close to 1% of days had a value above 100. In general, the DMC was higher than the average during the first half of the peak fire season.

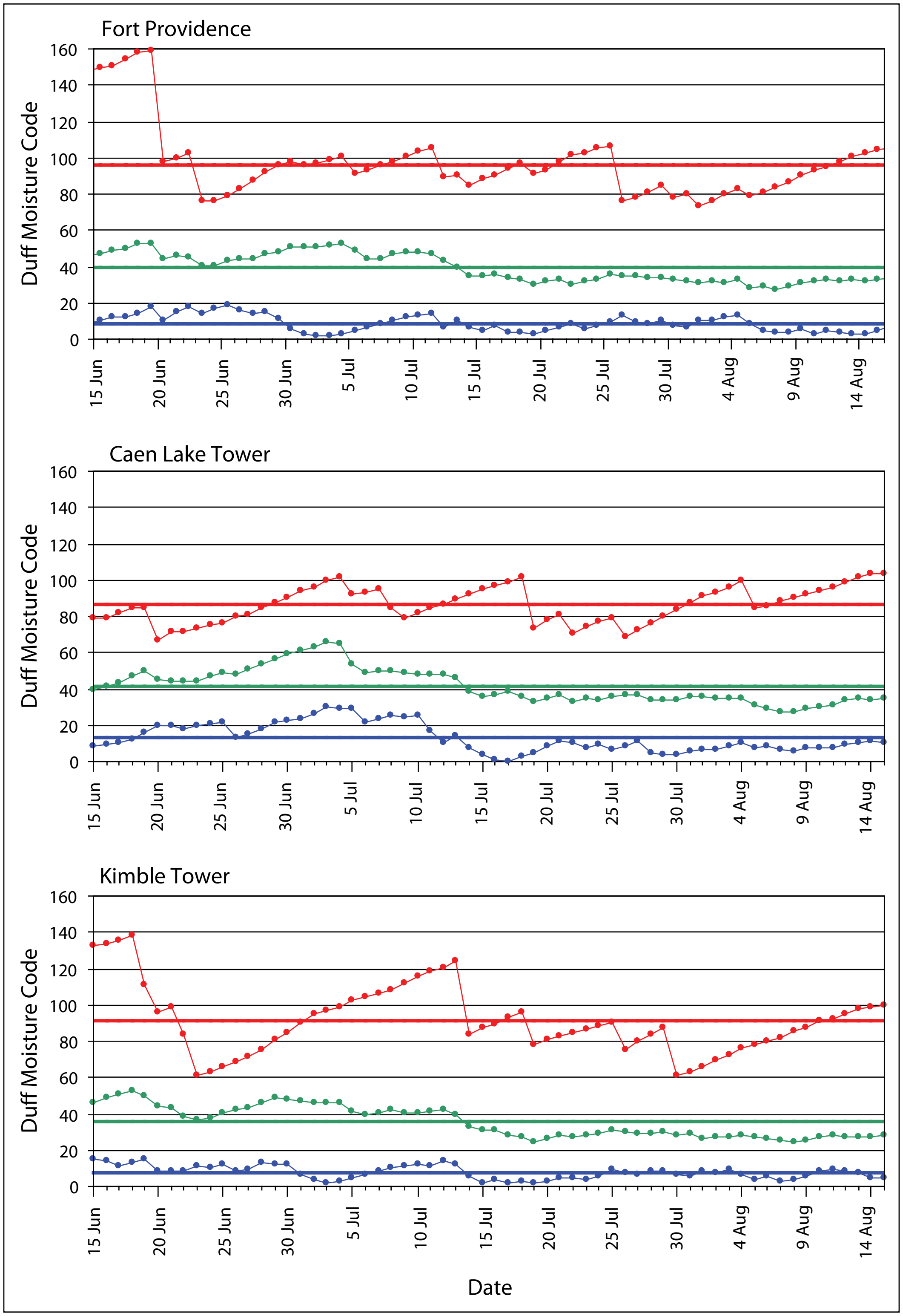


Figure 19. Minimum (blue), maximum (red), and average (green) standard daily Duff Moisture Code for each day of the peak fire season and associated total averages for the period (see Table 1 for years of data available for each weather station).

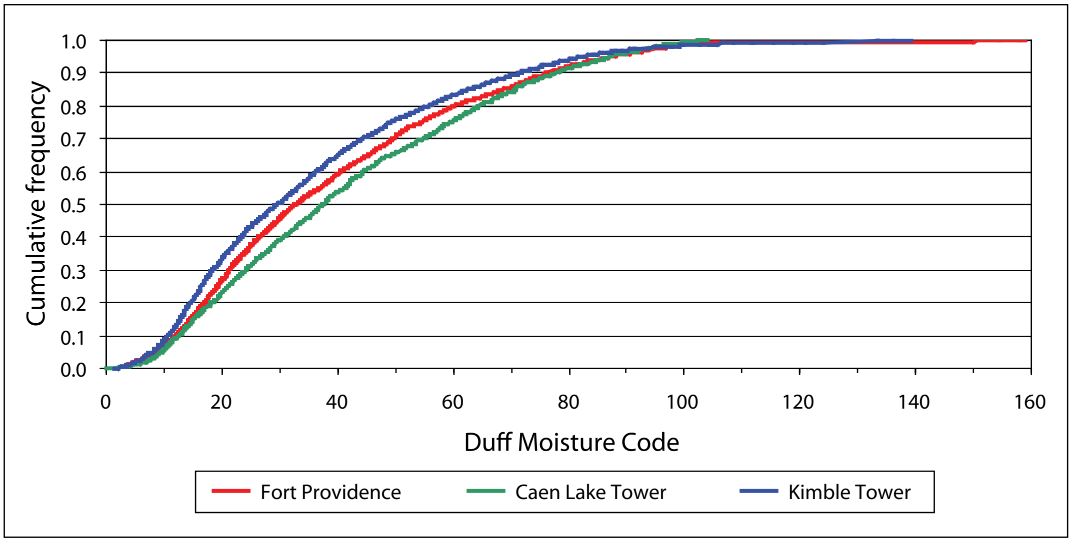


Figure 20. Cumulative frequency of the standard daily Duff Moisture Code for the three weather stations.

Drought Code

The DC is a numeric rating of the average moisture content of a deep layer of compacted, decomposed organic matter about 18 cm deep and weighing about 25 kg/m^2 when dry (Van Wagner 1987). The weather inputs for its calculation are the noon LST air temperature and rain accumulated over the previous 24-h period. The month is also used, for the same reasons as stated above for the DMC (Van Wagner 1987). With its time lag of 53 days (Lawson et al. 1997a), the DC is an indicator of seasonal drought effects on forest fuels and of the expected amount of smoldering in deep duff layers and large woody debris (Canadian Forestry Service 1984).

A DC value of 300 is often considered the threshold at which the moisture content starts to decrease with depth in the humus (De Groot 1988; Alexander and Cole 2001), whereas persistent ground fire activity was observed at values higher than 400 (Stocks et al. 1989). Lawson et al. (1997b) identified a moisture content threshold of 81%, equivalent to DC of 482 using an equation developed for white spruce duff, to reach a probability of smoldering ignition of at least 0.5 in lower feather moss material.

There were relatively large differences in the overall average DC calculated for each of the weather stations (Fig. 21, Table 5). The lowest value was observed at the Kimble Tower weather station, which had an average DC of 337 for the peak fire season, and the highest average value (424) was calculated for the Caen Lake Tower weather station. The DC at the Fort Providence weather station (average 412) was intermediate. In general, the average value for all three stations recorded on each day of the peak fire season varied between 285 and 485. The lowest DC value recorded on each day ranged between 73 and 308, with an average close to 205. Conversely, the highest DC value on those days fluctuated between 494 and 725, with an average of about 606. Individual average values for each station are presented in Table 5.

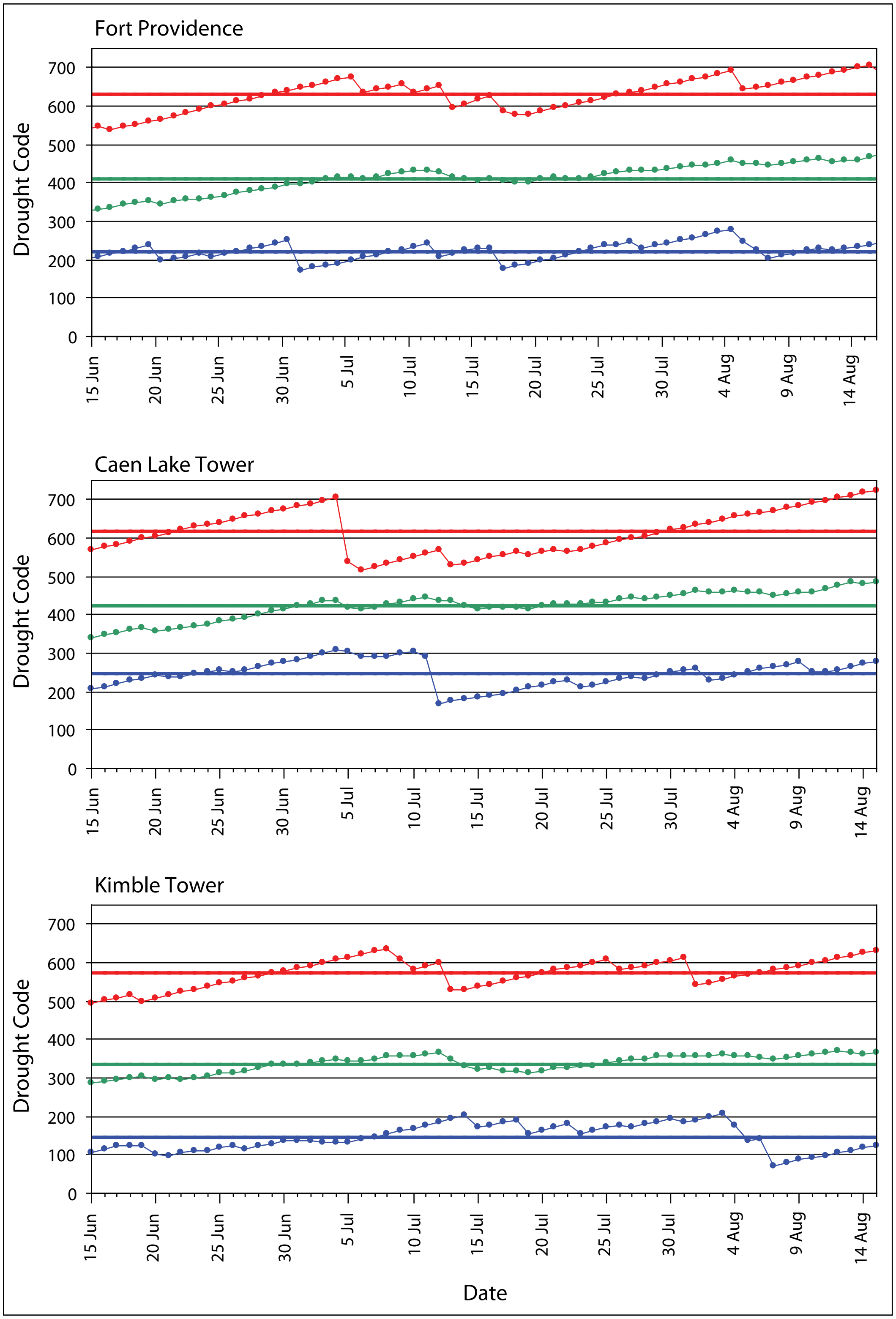


Figure 21. Minimum (blue), maximum (red), and average (green) standard daily Drought Code for each day of the peak fire season and associated total averages for the period (see Table 1 for years of data available for each weather station).

According to the cumulative frequency of the DC values (Fig. 22, Table 5) conditions on approximately 50% of the days were likely to be conducive to persistent ground fire activity (DC of 400 or more) in the northern part of the study area, whereas only 25% of days at the Kimble Tower weather station, located south of the Mackenzie River, had these high DC values. The 482 threshold identified by Lawson et al. (1997b) for a probability of smoldering ignition of at least 50% in the lower feather moss material was reached on more than 28%, 33%, and 9% of the days at the Fort Providence, Caen Lake Tower, and Kimble Tower weather stations, respectively (Fig. 22). The DC generally increased as the fire season progressed, and values higher than the average for the peak fire season started to appear during the second week of that period, with lower values occurring between July 14 and 20.

Initial Spread Index

Combining the effects of wind and FFMC, the ISI is a numeric rating of the expected rate of fire spread that does not take into account the influence of variable quantities of fuel (Van Wagner 1987). Its value generally doubles with every 14 km/h increase in wind speed, for a constant FFMC (Van Wagner 1987). The ISI is used in association with the BUI (or with the degree of curing, in the case of grass fuel types) in the FBP System (Forestry Canada Fire Danger Group 1992) to provide numeric values for fire behavior for predetermined forest and slash fuel types.

The lowest ISI value recorded on each day of the peak fire season was between 0 and 2.7, with an average of 0.2 (Fig. 23, Table 5). Conversely, the highest ISI values fluctuated around 12, ranging between 4.6 and 35.4. On average, the index was about 4 in the study area during the years analyzed, the daily average varying between 1.9 and 7.4. Less than 50% of the days had an ISI value higher than the average recorded at each weather station (Fig. 24, Table 5). ISI values above 10 were observed on 3%, 5%, and 10% of days at the Fort Providence, Caen Lake Tower, and Kimble Tower weather stations, respectively. ISI values higher than the average for the peak fire season were more frequent during the first half of the study period.

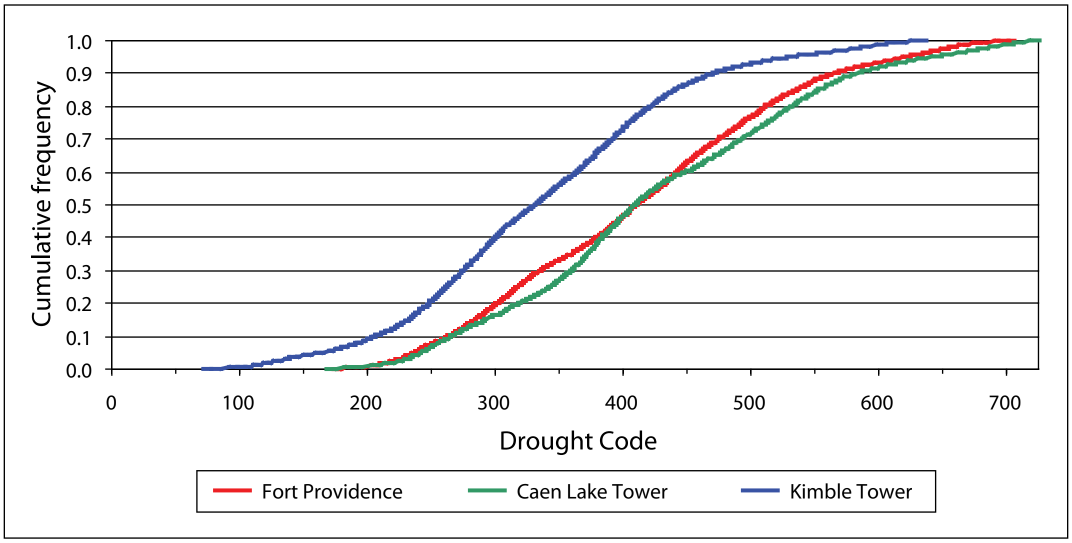


Figure 22. Cumulative frequency of the standard daily Drought Code for the three weather stations.

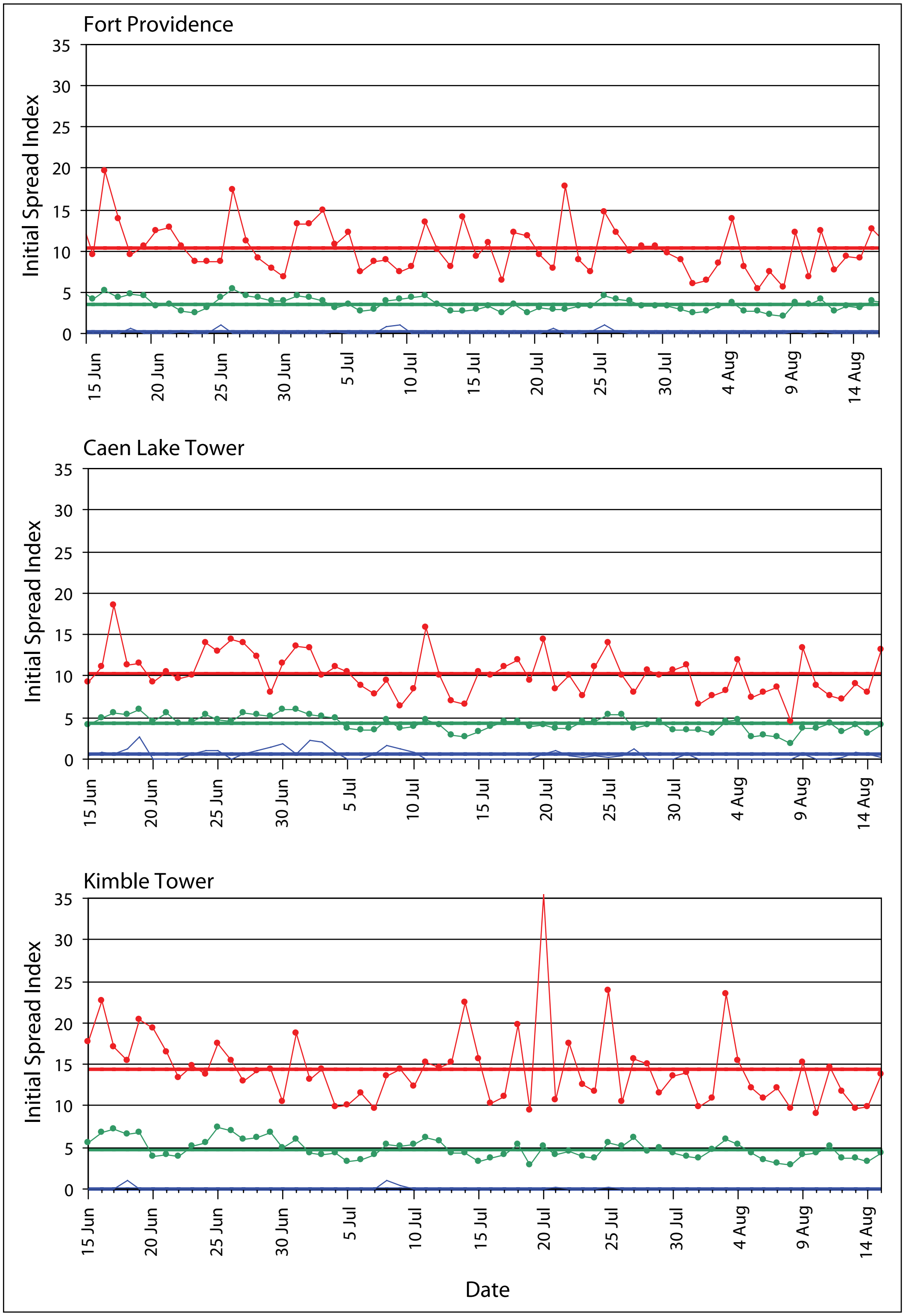


Figure 23. Minimum (blue), maximum (red), and average (green) standard daily Initial Spread Index for each day of the peak fire season and associated total averages for the period (see Table 1 for years of data available for each weather station).

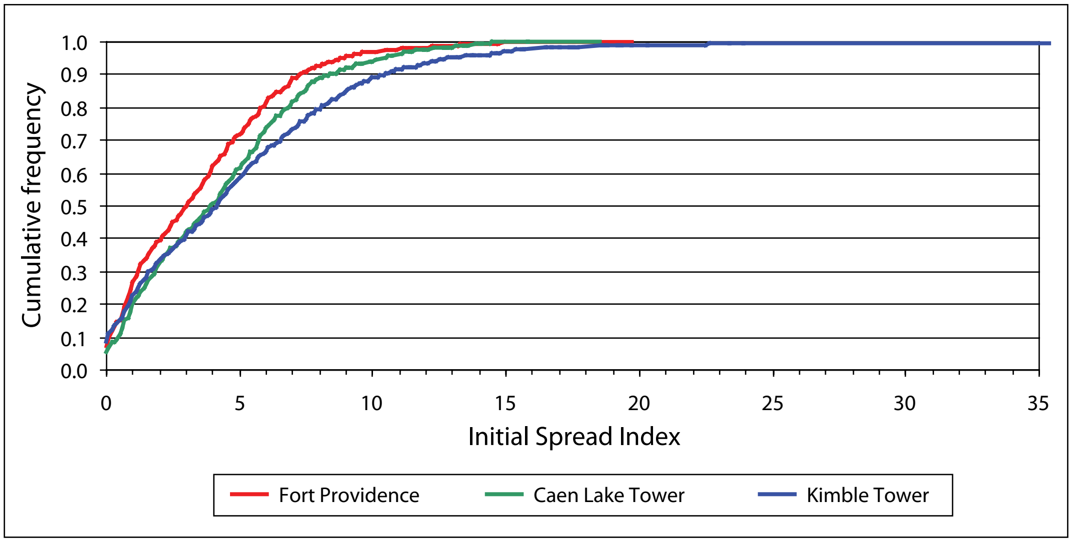


Figure 24. Cumulative frequency of the standard daily Initial Spread Index for the three weather stations.

Buildup Index

Calculated from the DMC and the DC, the BUI is a numeric rating of the total amount of fuel available for combustion in a spreading fire (Canadian Forestry Service 1984; Van Wagner 1987). It is often used as a general guide to fire potential (De Groot 1988; Alexander and Cole 2001).

The lowest BUI value recorded on each day of the peak fire season for all stations ranged between 0 and 49, with an average close to 17 (Fig. 25, Table 5). The highest BUI value averaged 125 and fluctuated between 84 and 180 during the same period. On average, however, the BUI was close to 59 in the study area, and the daily averages fluctuated between 39 and 94.

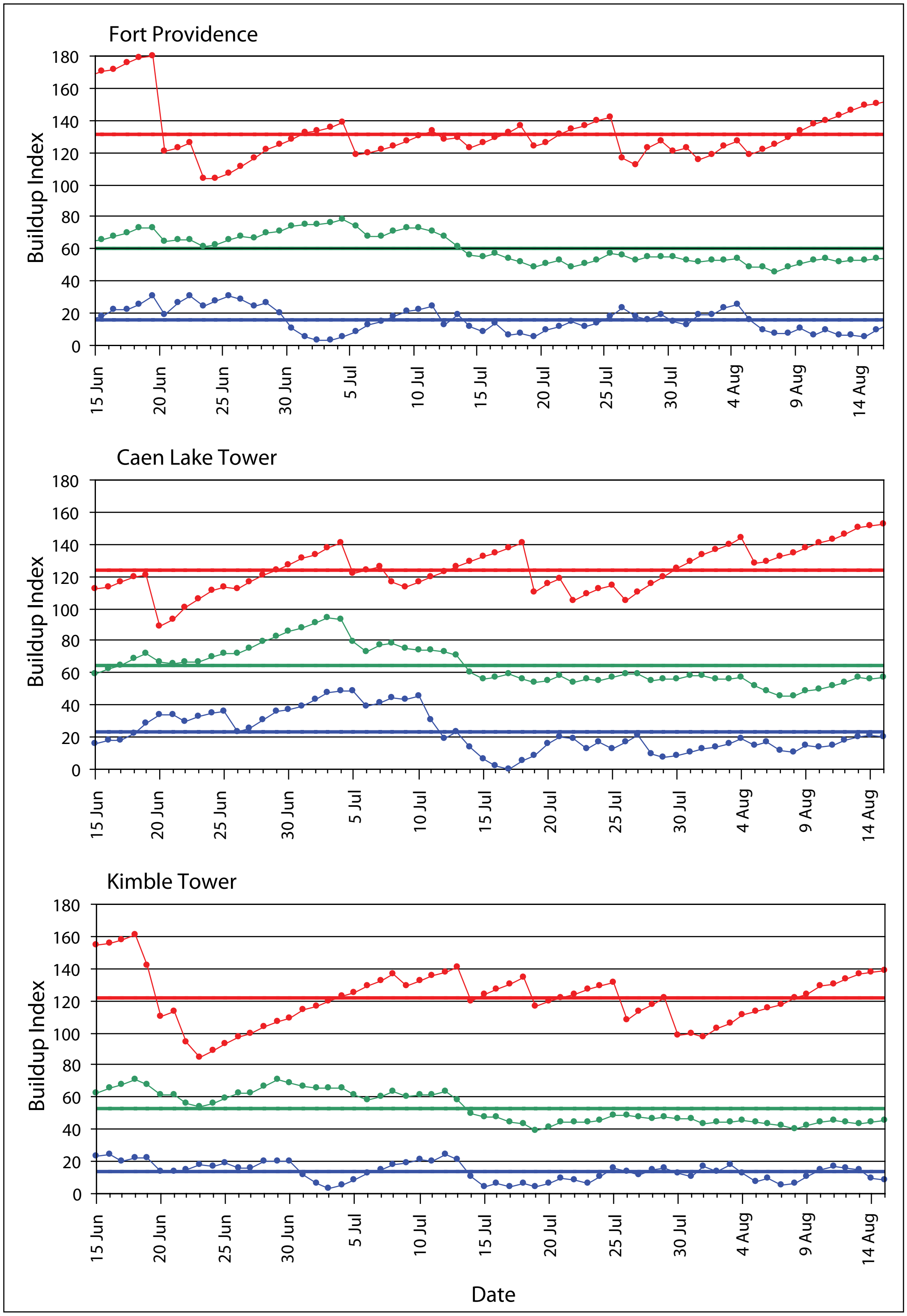


Figure 25. Minimum (blue), maximum (red), and average (green) standard daily Buildup Index for each day of the peak fire season and associated total averages for the period (see Table 1 for years of data available for each weather station).

In general, the Fort Providence and Caen Lake Tower weather stations had similar BUI values; the index was somewhat lower at the Kimble Tower weather station. At the first two stations, approximately 3% of the days had a BUI above 130, whereas little more than 1% reached the same value at the Kimble Tower station (Fig. 26, Table 5). Similar to the DMC, the BUI was generally higher than the average for the entire peak fire season during the first half of that period.

Fire Weather Index

Used as a general index of fire danger throughout Canada, the FWI is a numeric rating of fire intensity calculated from the ISI and the BUI (Canadian Forestry Service 1984). The combination of ISI, a numeric rating of the expected rate of spread, and BUI, a numeric rating of the total amount of fuel available for combustion, was conceived to represent Byram's (1959) frontal fire intensity (Van Wagner 1987). It can be used for the determination of fire-suppression requirements and as a tool to inform the public about fire danger conditions (De Groot 1988). FWI values between 19 and 24 are generally considered very high in the Northwest Territories, and values any larger fall into the extreme category (Stocks et al. 1989).

On average, the FWI was close to 12 in the study area over the years analyzed, the daily average fluctuating between 6 and 20 (Fig. 27, Table 5). The average FWI calculated for the three weather stations in this study was slightly higher than the FWI of 9–11 presented on the map prepared by Simard (1973) from FWI values obtained for the months of June, July, and August in the period 1957 to 1966. According to the classification of Simard (1973), the average FWI of 12 puts the study area used here in the fire weather zone "5 – High" (out of a total of seven zones across Canada); this zone is found primarily in western and southern Canada.

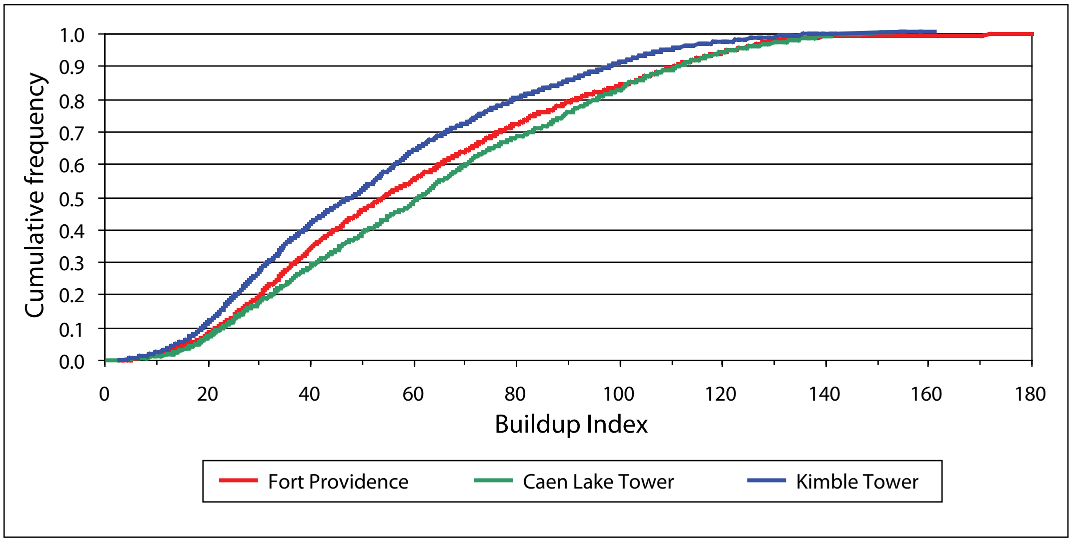


Figure 26. Cumulative frequency of the standard daily Buildup Index for the three weather stations.

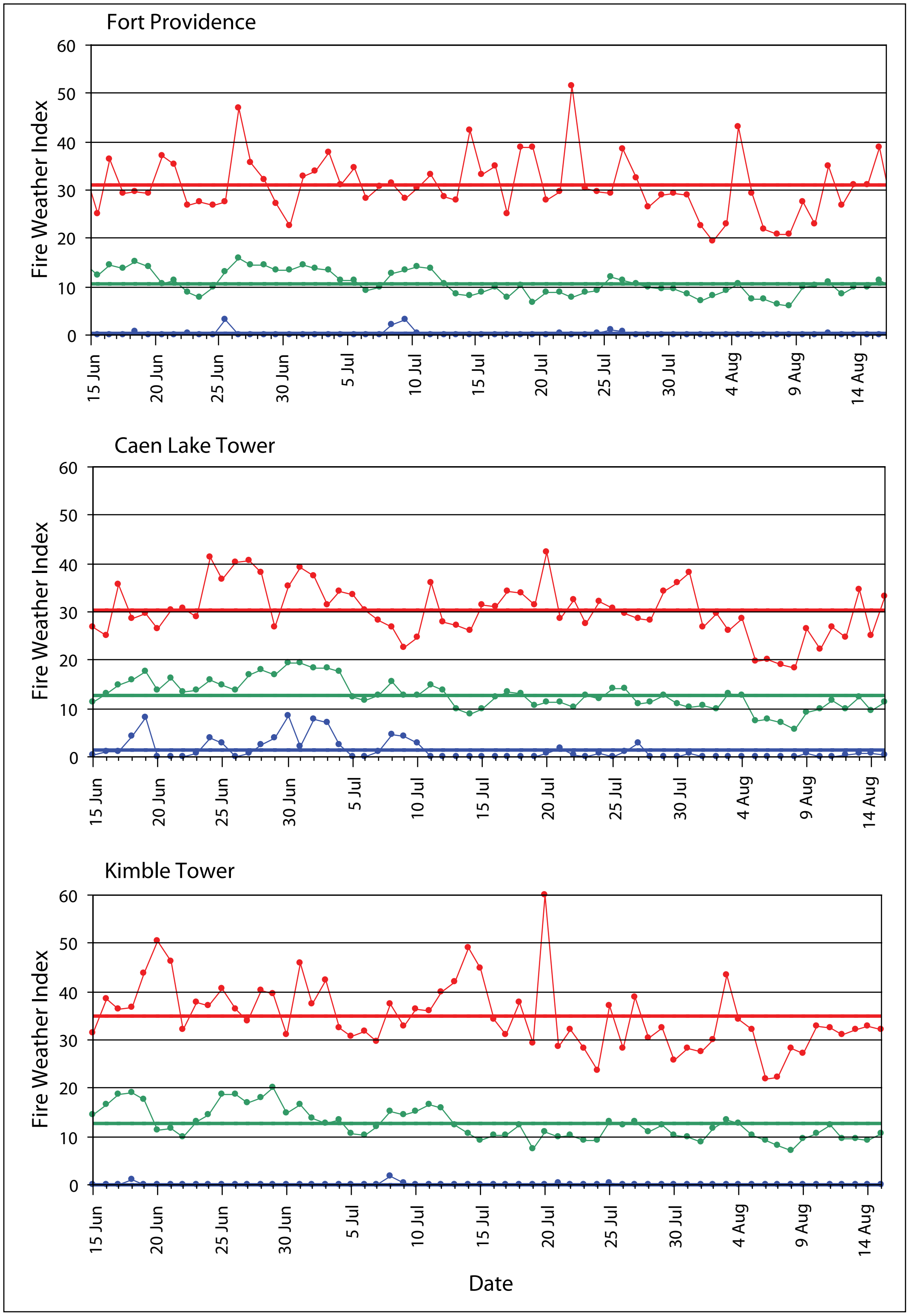


Figure 27. Minimum (blue), maximum (red), and average (green) standard daily Fire Weather Index for each day of the peak fire season and associated total averages for the period (see Table 1 for years of data available for each weather station).

The minimum FWI value recorded on each day of the peak fire season varied between 0 and 8.5, with the average approaching 0.5 for the area. The maximum value varied between 18 and 60, for an average of approximately 32. More than 25% of the days had very high (FWI at least 19) or extreme (FWI at least 25) values; only 10% of the days had extreme FWI (Fig. 28, Table 5). Similar to several of the other components of the FWI System, there were more occurrences of higher-than-average FWI during the first half of the peak fire season.

The Daily Severity Rating (DSR) is a rescaling of the FWI component, achieved by weighting the FWI sharply as it rises (Van Wagner 1987). The DSR was designed to reflect more directly the difficulty of controlling fires and to provide an objective basis for comparison. Harvey et al. (1986) provided several examples using FWI System severity analyses, such as objective comparisons between different weather stations or fire seasons, development of fire danger climatologies, comparisons of monthly or yearly severity ratings in relation to several fire characteristics (area burned, fire incidence, etc.), and rationalization of proposed levels of fire-suppression funding.

The DSR is more suitable for averaging than the FWI. When the DSR is averaged over a whole fire season, it is designated as the Seasonal Severity Rating (SSR) (Van Wagner 1970). Conditions favorable for extensive burning are represented by any severity rating greater than 2.0, especially averaged over longer time periods such as a month (Stocks et al. 1981; Harvey et al. 1986). Stocks et al. (1998) reported that, in general, "SSR values above 7 represent extreme fire behavior potential, values between 3 and 7 represent high to very high potential, values between 1 and 3 constitute moderate fire potential, and values <1 equate low fire potential." In the present study area, the mean SSR for the Fort Providence, Caen Lake Tower, and Kimble Tower weather stations over all the years analyzed (see Table 1) was 3.49, 2.56, and 3.59, respectively. The study area is thus located in a region with relatively high fire potential. The SSR values in this study were slightly higher

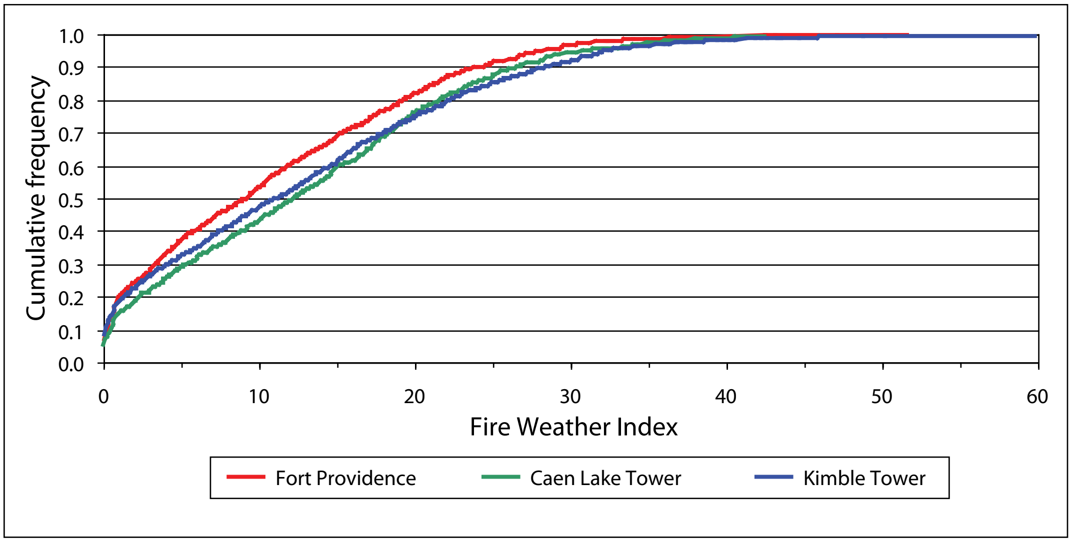


Figure 28. Cumulative frequency of the standard daily Fire Weather Index for the three weather stations.

than those mapped by Stocks et al. (1998) for the period 1980–1989; in that earlier study, the current area of interest was classified as region 4, with an average SSR between 2.01 and 3.00. Compared with the rest of the country, especially the portion usually associated with the distribution of the boreal forest, the average SSR values calculated here were relatively high.

Combinations of Initial Spread Index and Buildup Index

As mentioned previously, the ISI and the BUI are used in the FBP System (Forestry Canada Fire Danger Group 1992) for the calculation of several fire behavior characteristics because they correlate well, for most Canadian fuel types, with the rate of spread (ISI) or the amount of fuel available for combustion (BUI), two variables used in the calculation of Byram's (1959) frontal fire intensity. In the field guide for the FBP System prepared by Taylor et al. (1997), various characteristics of fire behavior were predicted from the relevant ISI and BUI according to a table provided for each fuel type.

By comparing the frequency tables for the different ISI–BUI combinations (Tables 6–8) with the tables presented in Taylor et al. (1997) for selected fuel types, it was possible to determine the percentage of days, for the years analyzed, that fell in each fire intensity class during the peak fire season. The four fuel types selected were C-1 (Spruce–Lichen Woodland), C-2 (Boreal Spruce), C-3 (Mature Jack or Lodgepole Pine), and C-4 (Immature Jack or Lodgepole Pine) (De Groot 1993; Taylor et al. 1997). The first two of these fuel types were identified by Ward and Mawdsley (2000) as the most common fuel types in the north. Other fuel types could have been used, but additional considerations (such as the percentage of deciduous and coniferous trees in mixed stands, which is best assessed on the basis of individual stands) would have complicated the analyses. In general, the four conifer fuel types selected are the forest fuel types that exhibit the most severe fire behavior for given conditions of ISI and BUI in the study area. Logging activities are not substantial enough in that region of the Northwest Territories to justify the use of the slash fuel types. Nevertheless, those interested in the percentage of days in each intensity class for other fuel types can obtain the information by using the data in Tables 6 to 8 in combination with the appropriate fuel type tables in Taylor et al. (1997).

Table 6. Average percentage of days in each combined class of Initial Spread Index (ISI) and Buildup Index (BUI) for the Fort Providence weather station

ISI	BUI								Total
	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200	
0	4.7	3.1	2.4	2.1	1.1	1.4	0.0	0.0	14.8
1	2.5	4.4	3.1	3.8	3.0	1.8	0.0	0.0	18.5
2	0.5	1.6	2.8	2.4	1.6	1.4	0.2	0.1	10.6
3	0.4	1.0	2.1	2.7	1.8	2.0	0.4	0.1	10.6
4	0.1	0.5	1.9	3.6	1.9	2.8	0.8	0.1	11.6
5	0.1	0.4	0.8	2.5	2.1	2.7	1.3	0.1	10.0
6	0.0	0.5	0.8	1.0	2.1	3.6	0.3	0.1	8.3
7	0.0	0.2	0.4	1.0	1.5	2.1	0.9	0.0	6.2
8	0.0	0.0	0.0	0.5	0.4	1.4	0.8	0.0	3.1
9	0.1	0.0	0.3	0.3	0.7	1.2	0.2	0.0	2.7
10	0.0	0.0	0.2	0.1	0.1	0.3	0.0	0.0	0.7
11	0.1	0.0	0.0	0.2	0.3	0.3	0.0	0.0	0.9
12	0.0	0.0	0.1	0.1	0.0	0.4	0.1	0.0	0.7
13	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.4
14	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.3
15	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.2
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.2
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1
21–25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26–30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31–35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36–40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41–45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	8.4	11.8	14.8	20.6	17.1	21.9	5.0	0.4	100.0

Note: Totals may not add up due to rounding.

Table 7. **Average percentage of days in each combined class of Initial Spread Index (ISI) and Buildup Index (BUI) for the Caen Lake Tower weather station**

ISI	BUI								Total
	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200	
0	3.1	2.4	1.5	1.5	0.7	0.1	0.0	0.0	9.3
1	3.1	3.2	2.7	3.5	1.6	1.6	0.1	0.0	15.9
2	0.6	2.7	1.5	1.6	2.4	2.7	0.4	0.0	11.8
3	0.4	0.9	1.0	1.8	1.0	2.2	0.4	0.0	7.8
4	0.1	0.9	1.6	1.8	2.7	2.8	0.6	0.0	10.5
5	0.1	0.9	0.1	2.2	3.1	3.5	0.9	0.0	10.9
6	0.0	0.1	1.2	2.5	1.9	4.0	1.2	0.0	10.9
7	0.0	0.0	0.4	1.9	1.9	2.2	1.0	0.0	7.5
8	0.0	0.1	0.3	1.3	1.3	1.9	0.3	0.0	5.3
9	0.0	0.0	0.0	0.7	1.3	0.7	0.3	0.0	3.1
10	0.0	0.0	0.0	0.1	0.3	1.2	0.0	0.0	1.6
11	0.0	0.0	0.1	0.3	0.6	1.0	0.3	0.0	2.4
12	0.0	0.0	0.0	0.1	0.1	0.4	0.1	0.0	0.9
13	0.0	0.0	0.0	0.1	0.1	0.6	0.0	0.0	0.9
14	0.0	0.0	0.0	0.1	0.0	0.6	0.0	0.0	0.7
15	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1
16	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21–25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26–30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31–35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36–40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41–45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	7.5	11.2	10.5	19.9	19.3	25.8	5.8	0.0	100.0

Note: Totals may not add up due to rounding.

Table 8. Average percentage of days in each combined class of Initial Spread Index (ISI) and Buildup Index (BUI) for the Kimble Tower weather station

ISI	BUI								Total
	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200	
0	5.8	3.7	1.8	2.4	0.5	0.1	0.0	0.0	14.2
1	2.8	4.2	2.1	2.2	1.1	1.0	0.1	0.0	13.4
2	1.2	2.0	1.4	1.9	1.5	0.7	0.1	0.0	8.7
3	0.6	1.7	1.2	1.5	1.3	1.1	0.2	0.0	7.7
4	0.9	1.4	1.9	1.9	1.5	1.5	0.2	0.0	9.2
5	0.2	0.9	1.1	2.9	1.7	1.5	0.7	0.1	9.3
6	0.1	0.7	0.7	2.1	1.5	1.5	0.4	0.0	7.1
7	0.2	0.6	1.0	1.2	1.5	1.6	0.6	0.0	6.7
8	0.2	0.3	1.1	1.3	1.2	1.5	0.0	0.0	5.7
9	0.1	0.1	0.7	1.2	1.0	1.7	0.5	0.0	5.2
10	0.0	0.2	0.2	0.7	0.7	1.3	0.0	0.0	3.3
11	0.0	0.1	0.3	0.5	0.4	0.7	0.1	0.0	2.1
12	0.0	0.2	0.2	0.4	0.8	0.6	0.0	0.0	2.1
13	0.0	0.0	0.0	0.3	0.2	0.6	0.0	0.0	1.1
14	0.0	0.0	0.1	0.2	0.2	0.3	0.0	0.0	0.7
15	0.0	0.1	0.1	0.4	0.4	0.7	0.0	0.0	1.6
16	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.2
17	0.0	0.0	0.2	0.1	0.1	0.1	0.0	0.0	0.4
18	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.2
19	0.0	0.1	0.0	0.0	0.0	0.3	0.0	0.0	0.4
20	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.2
21–25	0.0	0.1	0.0	0.2	0.1	0.0	0.0	0.0	0.3
26–30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
31–35	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1
36–40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41–45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	12.0	16.3	14.2	21.7	15.9	17.0	2.9	0.1	100.0

Note: Totals may not add up due to rounding.

The head fire intensity class was selected for comparative purposes. The classes were defined according to Taylor et al. (1997), as follows: class 1, <10 kW/m; class 2, 10–500 kW/m; class 3, 500–2000 kW/m; class 4, 2000–4000 kW/m; class 5, 4000–10 000 kW/m; and class 6, >10 000 kW/m. Although the rate of spread and the type of fire were also available from the tables in the field guide (Taylor et al. 1997), the head fire intensity variable was selected for its convenience and the limited but representative (in terms of fire behavior and suppression activities) number of classes it offers. Several decision aids, based on fire intensity classes and fuel type, have been developed in Canada (e.g., Beck et al. 2002; Alexander and Cole 1995; Cole and Alexander 1995; Alexander and De Groot 1988; Alexander and Lanoville 1989). It is important to note that various combinations of ISI and BUI will yield the same fire intensity but will differ in certain fire behavior characteristics because of the variation in rate of spread or quantity of fuels consumed (Alexander 1982).

The results presented in Table 9 were obtained by summing the percentage of days in each fire intensity class (Tables 6 to 8) for the four fuel types analyzed. In general, for the Spruce-Lichen Woodland (C-1) fuel type, 90% to 97% of the days were in the first three fire intensity categories, depending on the weather station. Fires showing this degree of head fire intensity have moderately slow (Alexander and Lanoville 1989) rates of spread (between 0 and 4 m/min) and will become intermittent crown fires at ISI values between 9 and 12, for any BUI category. Such fires are fairly easy to moderately difficult to control (Alexander and Lanoville 1989).

Table 9. Percentage of days in each fire intensity class for the main conifer fuel types of the Canadian Forest Fire Behavior Prediction System in the study area[a]

Fuel type[b]	Weather station	Fire intensity class[c]						Total
		1	2	3	4	5	6	
C-1	Fort Providence	44.4	46.3	6.6	1.5	0.9	0.3	100.0
	Caen Lake Tower	37.5	47.2	10.0	3.4	1.8	0.1	100.0
	Kimble Tower	36.9	39.6	14.1	4.5	4.0	1.0	100.0
C-2	Fort Providence	14.8	19.5	18.8	14.7	21.0	11.2	100.0
	Caen Lake Tower	9.3	18.1	17.0	12.4	26.1	17.1	100.0
	Kimble Tower	14.2	17.7	15.2	12.6	20.3	20.1	100.0
C-3	Fort Providence	36.0	35.1	18.4	5.6	4.1	0.8	100.0
	Caen Lake Tower	29.1	31.0	25.5	7.4	5.0	2.1	100.0
	Kimble Tower	32.4	30.0	20.1	7.2	6.9	3.5	100.0
C-4	Fort Providence	17.2	21.5	22.0	7.5	20.6	11.1	100.0
	Caen Lake Tower	12.4	18.3	18.1	8.4	25.8	17.0	100.0
	Kimble Tower	17.0	19.4	17.5	7.2	19.7	19.3	100.0

[a] Based on data over several years; see Table 1.

[b] Fuel types: C-1 = Spruce-Lichen Woodland, C-2 = Boreal Spruce, C-3 = Mature Jack or Lodgepole Pine, and C-4 = Immature Jack or Lodgepole Pine (Taylor et al. 1997; Forestry Canada Fire Danger Group 1992).

[c] Fire intensity classes: 1, <10 kW/m; 2, 10–500 kW/m; 3, 500–2000 kW/m; 4, 2000–4000 kW/m; 5, 4000–10 000 kW/m; and 6, >10 000 kW/m.

The Mature Jack or Lodgepole Pine (C-3) fuel type showed a similar pattern in terms of distribution of days among the different head fire intensity classes. Between 83% and 90% of the days were in the first three intensity classes over the years analyzed, depending on the weather station. For that fuel type, such intensities could mean rates of spread up to 29 m/min, depending on the ISI, with no crown involvement (i.e., surface fires). Fires in intensity classes 1 and 2 can generally be controlled by ground crews, whereas for head fire intensity class 3, heavy equipment is generally needed to construct fireguards and thereby to control the fire (Alexander and De Groot 1988; Alexander and Lanoville 1989; Alexander and Cole 1995; Cole and Alexander 1995).

The distribution of days among the various head fire intensity classes for the two remaining fuel types, Boreal Spruce (C-2) and Immature Jack or Lodgepole Pine (C-4), was more uniform than for the fuel types discussed above. There was, therefore, a greater percentage of days in each fire intensity class when potential fire behavior was more severe. In general, the percentage of days in each category varied between 7% and 26%, and the highest fire intensity classes were not necessarily the ones with the lowest number of days. Between 40% and 56% of the days were in the last three fire intensity categories, a percentage much higher than for the C-1 and C-3 fuel types. Under those critical conditions, firefighting becomes very difficult if not impossible.

The probability of sustained flaming ignition can be useful in gauging the likelihood of fire starts or fire arrivals and in judging the potential for spot-fire ignition (Lawson and Dalrymple 1996). Although it is not a standard output of the FBP System, it is included here to provide a more complete representation of the fire potential in the study area. For this analysis, two forest types, which Lawson and Dalrymple (1996) considered as variants of the C-3 FBP System fuel type, were selected: the Dry (S1.1) and Moist (S1.2) Lodgepole Pine forest types. The inputs for the probability of sustained flaming ignition in the Dry (S1.1) Lodgepole Pine forest type are FFMC and wind speed. However, for the Moist (S1.2) Lodgepole Pine forest type, the inputs are the ISI and BUI, as for the FBP System fuel types. The probability of sustained flaming ignition was low (0–49%) for approximately half of the days during the peak fire season over the years analyzed (Table 10). The remaining days were divided more or less equally between the other two classes (medium, 50-75%; high, 76-100%), depending on the weather station and the forest type. The percentage of days in the high-probability category was slightly greater for the S1.1 forest type, whereas the percentage of days in the medium-probability class was slightly greater for the S1.2 forest type.

Table 10. Percentage of days in each probability of sustained ignition class for the dry and moist lodgepole pine forest types[a]

Forest type[b]	Weather station	Probability of sustained ignition class[c]			Total
		Low	Medium	High	
S1.1	Fort Providence	53.2	26.3	20.6	100.0
	Caen Lake Tower	43.8	25.8	30.4	100.0
	Kimble Tower	42.4	21.0	36.7	100.0
S1.2	Fort Providence	63.2	24.6	12.2	100.0
	Caen Lake Tower	52.7	29.4	18.0	100.0
	Kimble Tower	53.6	23.0	23.4	100.0

[a] Based on data over several years; see Table 1.

[b] Forest types: S1.1 = Dry Lodgepole Pine, S1.2 = Moist Lodgepole Pine (Lawson and Dalrymple 1996).

[c] Probability of sustained ignition class: Low = 0–49%, Medium = 50–75%, and High = 76–100%.

Fire Danger Scenarios

The results of the analyses of frequency (percentage) of days in each combination of FFMC, DMC or BUI, and FWI classes (Tables 11 to 13), complemented by the analyses presented above, were used in this project to define the four levels of burning conditions suggested by Horn (1976) as illustrated in Fig. 4. The final FWI System components selected for each scenario are presented in Table 14.

Although different combinations of ISI and BUI can lead to the same FWI value, in these fire danger scenarios, an increase in the FWI was accompanied by increases in both ISI and BUI, caused in turn by increases in the FFMC, DMC, and DC values.

The percentage of days during the peak fire season that had more severe conditions in terms of FFMC and DMC or BUI than those selected (based on the categories used for each of these FWI system components in Tables 11 to 13, rather than on the individual values (Table 15) were very similar, regardless of whether DMC or BUI was used. In general, approximately 60% of the days had more severe conditions than the ones described by the "moist" scenario in that analysis. That percentage decreased to about 35% for the "moderate" scenario, and to less than 1% for the "dry" scenario. The "extreme" scenario had values that were never surpassed in the combined analysis.

The FWI System components integrate the effect of past weather conditions, so it seemed appropriate to have fixed values for air temperature, relative humidity, 10-m open wind speed, and 24-h rain accumulation for use in combination with the scenarios described above for the assessments involving different fuels. The conditions selected were temperature 25°C, relative humidity 33%, wind speed 20 km/h (which was used in the calculation of the ISI values above), and no rain accumulation. These nominal weather conditions are often representative of a good drying day and are conducive to vigorous fire behavior if the fuels are dry enough.

The value for the temperature was based on the 90th percentile for that variable and was slightly lower than the average maximum noon LST (1300 DST) value, on each day of the fire season, over the range of years for which information was available for each station (Table 2). The value for relative humidity was calculated from the average of the minimum noon LST (1300 DST) observation for that variable (Table 2). Finally, the 10-m open wind speed of 20 km/h was selected as per Lanoville and Mawdsley (1990). This value is also similar to the average of the maximum noon LST (1300 DST) wind speed recorded on each day of the peak fire season over the years analyzed (Table 2).

Table 11. Average percentage of days in each class of Fine Fuel Moisture Code (FFMC), Duff Moisture Code (DMC) or Buildup Index (BUI), and Fire Weather Index (FWI) for the Fort Providence weather station[a]

	DMC							
FFMC	0–20	21–40	41–60	61–80	81–100	101–120	121–140	141–160
0–75	16.6	8.7	4.2	1.2	0.2	0.0	0.0	0.0
76	0.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0
77	1.0	0.5	0.2	0.3	0.0	0.0	0.0	0.0
78	0.3	0.8	0.3	0.1	0.0	0.0	0.0	0.0
79	0.5	0.4	0.4	0.1	0.0	0.0	0.0	0.0
80	0.6	0.4	0.7	0.3	0.0	0.0	0.0	0.0
81	1.0	0.8	0.4	0.1	0.0	0.0	0.0	0.0
82	0.2	0.5	0.0	0.1	0.1	0.1	0.0	0.1
83	1.7	1.7	0.6	0.2	0.0	0.0	0.0	0.0
84	0.8	1.3	0.7	0.2	0.2	0.0	0.0	0.0
85	1.5	1.5	1.1	0.4	0.1	0.0	0.0	0.0
86	0.5	2.5	1.0	0.8	0.4	0.2	0.0	0.1
87	0.6	4.4	2.2	1.1	0.8	0.2	0.0	0.1
88	0.8	1.8	2.2	1.7	0.9	0.3	0.0	0.1
89	0.6	2.7	2.6	2.0	0.6	0.3	0.0	0.1
90	0.1	2.2	1.1	1.9	1.5	0.1	0.0	0.0
91	0.3	0.9	1.4	0.9	0.7	0.1	0.0	0.0
92	0.1	0.3	0.9	0.8	0.3	0.0	0.0	0.0
93	0.0	0.2	0.3	0.4	0.5	0.0	0.0	0.0
94	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0
95	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
97	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	BUI							
	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
0–75	6.9	7.1	5.0	5.3	3.6	2.9	0.0	0.0
76	0.0	0.2	0.1	0.2	0.2	0.0	0.0	0.0
77	0.3	0.6	0.3	0.3	0.2	0.3	0.0	0.0
78	0.1	0.1	0.2	0.7	0.2	0.2	0.0	0.0
79	0.0	0.3	0.4	0.3	0.3	0.2	0.0	0.0
80	0.2	0.0	0.6	0.3	0.4	0.4	0.1	0.0
81	0.1	0.6	0.5	0.5	0.4	0.2	0.0	0.0
82	0.1	0.0	0.3	0.2	0.1	0.2	0.1	0.1
83	0.2	0.6	1.3	1.2	0.6	0.3	0.0	0.0
84	0.3	0.3	0.6	0.8	0.7	0.3	0.2	0.0
85	0.1	1.0	1.2	0.5	0.8	1.1	0.0	0.0
86	0.0	0.3	0.7	1.8	1.0	1.3	0.5	0.1
87	0.3	0.3	1.2	2.8	2.0	2.0	0.7	0.1
88	0.0	0.3	1.0	1.1	1.4	2.9	0.8	0.1
89	0.0	0.1	1.1	1.9	2.0	2.9	0.8	0.1
90	0.0	0.1	0.1	1.8	1.2	2.6	1.1	0.0
91	0.0	0.1	0.2	0.7	1.0	2.0	0.3	0.0
92	0.0	0.0	0.1	0.1	0.8	1.2	0.2	0.0
93	0.0	0.0	0.0	0.2	0.1	0.8	0.3	0.0
94	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.0
95	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
97	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FWI classes:				Low	Moderate	High	Very High	Extreme

[a] FWI classes are the standard fire danger classes used in the Northwest Territories (see Stocks et al. 1989). The cells with a black border are those representing the combinations for the four fire danger scenarios identified in this project.

Table 12. Average percentage of days in each class of Fine Fuel Moisture Code (FFMC), Duff Moisture Code (DMC) or Buildup Index (BUI), and Fire Weather Index (FWI) for the Caen Tower weather station[a]

	DMC							
FFMC	0–20	21–40	41–60	61–80	81–100	101–120	121–140	141–160
0–75	13.4	8.0	2.7	1.0	0.1	0.0	0.0	0.0
76	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
77	0.7	0.1	1.0	0.1	0.0	0.0	0.0	0.0
78	0.3	0.6	0.1	0.0	0.1	0.0	0.0	0.0
79	0.4	0.7	0.3	0.6	0.0	0.0	0.0	0.0
80	1.0	0.9	0.1	0.1	0.1	0.0	0.0	0.0
81	1.0	0.4	0.0	0.9	0.3	0.0	0.0	0.0
82	0.7	0.7	0.4	0.3	0.3	0.0	0.0	0.0
83	1.0	1.5	0.6	0.3	0.0	0.4	0.0	0.0
84	0.4	0.3	0.3	0.6	0.1	0.0	0.0	0.0
85	1.5	2.4	1.0	0.7	0.4	0.0	0.0	0.0
86	0.6	1.3	0.7	0.6	0.4	0.0	0.0	0.0
87	0.7	3.2	3.4	2.9	0.6	0.0	0.0	0.0
88	1.0	2.4	3.1	1.8	0.9	0.1	0.0	0.0
89	0.0	2.7	2.8	1.6	2.2	0.0	0.0	0.0
90	0.0	3.2	2.1	0.3	1.2	0.1	0.0	0.0
91	0.0	1.0	0.9	1.8	0.1	0.0	0.0	0.0
92	0.0	0.7	1.5	1.8	0.7	0.0	0.0	0.0
93	0.0	0.3	0.7	0.4	0.0	0.0	0.0	0.0
94	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
97	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	BUI							
	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
0–75	6.3	5.3	4.0	5.2	2.4	1.9	0.1	0.0
76	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
77	0.1	0.4	0.1	0.1	0.6	0.6	0.0	0.0
78	0.0	0.3	0.3	0.3	0.0	0.3	0.0	0.0
79	0.0	0.4	0.3	0.3	0.3	0.7	0.0	0.0
80	0.3	0.4	0.6	0.1	0.4	0.3	0.1	0.0
81	0.1	0.9	0.1	0.1	0.1	1.0	0.1	0.0
82	0.0	0.6	0.1	0.6	0.6	0.3	0.3	0.0
83	0.0	0.9	0.6	0.9	0.4	0.7	0.3	0.0
84	0.0	0.1	0.3	0.3	0.1	0.9	0.0	0.0
85	0.4	0.4	1.2	1.6	0.7	1.2	0.4	0.0
86	0.0	0.1	0.6	0.7	1.0	0.9	0.3	0.0
87	0.1	0.6	0.7	1.9	3.2	3.7	0.6	0.0
88	0.0	0.6	0.9	1.5	2.5	2.7	1.2	0.0
89	0.0	0.0	0.3	2.2	1.6	4.1	1.0	0.0
90	0.0	0.0	0.1	2.7	2.1	1.5	0.6	0.0
91	0.0	0.0	0.0	0.7	1.2	1.9	0.0	0.0
92	0.0	0.0	0.0	0.4	1.0	2.7	0.6	0.0
93	0.0	0.0	0.1	0.1	0.7	0.4	0.0	0.0
94	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
95	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
97	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FWI classes:				Low	Moderate	High	Very High	Extreme

[a] FWI classes are the standard fire danger classes used in the Northwest Territories (see Stocks et al. 1989). The cells with a black border are those representing the combinations for the four fire danger scenarios identified in this project.

Table 13. Average percentage of days in each class of Fine Fuel Moisture Code (FFMC), Duff Moisture Code (DMC) or Buildup Index (BUI), and Fire Weather Index (FWI) for the Kimble Tower weather station[a]

	DMC							
FFMC	0–20	21–40	41–60	61–80	81–100	101–120	121–140	141–160
0–75	18.4	6.9	2.4	0.3	0.0	0.2	0.0	0.0
76	0.1	0.0	0.2	0.0	0.0	0.0	0.0	0.0
77	1.0	0.6	0.2	0.2	0.1	0.0	0.0	0.0
78	0.5	0.3	0.0	0.1	0.1	0.0	0.0	0.0
79	1.1	0.2	0.2	0.1	0.0	0.0	0.1	0.0
80	0.4	0.7	0.3	0.1	0.0	0.0	0.0	0.0
81	0.9	1.0	0.2	0.1	0.0	0.0	0.0	0.0
82	0.9	0.2	0.5	0.1	0.1	0.0	0.0	0.0
83	0.9	0.7	0.3	0.1	0.1	0.0	0.0	0.0
84	1.6	1.4	0.3	0.1	0.1	0.0	0.0	0.0
85	1.3	1.1	1.2	0.4	0.1	0.1	0.1	0.0
86	1.5	2.2	0.7	1.0	0.4	0.0	0.1	0.0
87	1.4	3.4	1.5	1.1	0.2	0.0	0.1	0.0
88	1.1	2.8	2.0	1.5	0.7	0.1	0.0	0.0
89	1.2	3.0	2.6	1.1	0.5	0.2	0.2	0.0
90	0.8	2.5	1.9	1.8	0.7	0.2	0.0	0.0
91	0.2	2.2	1.6	1.0	0.6	0.1	0.0	0.0
92	0.2	1.6	1.4	1.5	0.5	0.0	0.0	0.0
93	0.1	0.2	0.2	0.4	0.2	0.0	0.0	0.0
94	0.0	0.2	0.2	0.1	0.2	0.0	0.0	0.0
95	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
97	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
	BUI							
	0–20	21–30	31–40	41–60	61–80	81–120	121–160	161–200
0–75	8.9	7.7	3.8	5.1	1.9	0.8	0.1	0.0
76	0.0	0.1	0.0	0.0	0.1	0.1	0.0	0.0
77	0.3	0.4	0.6	0.2	0.2	0.3	0.0	0.0
78	0.2	0.2	0.2	0.1	0.1	0.2	0.0	0.0
79	0.2	0.6	0.4	0.1	0.2	0.1	0.1	0.0
80	0.2	0.2	0.2	0.6	0.3	0.1	0.0	0.0
81	0.3	0.6	0.4	0.6	0.1	0.2	0.0	0.0
82	0.3	0.6	0.0	0.2	0.4	0.2	0.0	0.0
83	0.3	0.5	0.2	0.4	0.3	0.2	0.1	0.0
84	0.2	1.1	0.6	0.9	0.4	0.2	0.1	0.0
85	0.2	0.7	0.7	0.7	1.3	0.5	0.2	0.0
86	0.1	0.9	1.0	1.5	1.0	1.1	0.4	0.0
87	0.3	0.6	1.4	2.3	1.5	1.5	0.1	0.1
88	0.2	0.6	1.2	2.0	1.5	2.0	0.5	0.0
89	0.0	0.8	1.2	2.1	2.3	1.6	0.7	0.0
90	0.1	0.4	1.0	1.6	1.9	2.5	0.5	0.0
91	0.0	0.2	0.3	2.0	0.9	2.3	0.1	0.0
92	0.0	0.1	0.7	1.0	1.1	2.3	0.1	0.0
93	0.0	0.1	0.1	0.1	0.2	0.7	0.0	0.0
94	0.0	0.1	0.1	0.2	0.1	0.2	0.0	0.0
95	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
97	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
FWI classes:				Low	Moderate	High	Very High	Extreme

[a] FWI classes are the standard fire danger classes used in the Northwest Territories (see Stocks et al. 1989). The cells with a black border are those representing the combinations for the four fire danger scenarios identified in this project.

Table 14. Fire Weather Index System components[a] selected for the four fire danger scenarios

Scenario	FFMC	DMC	DC	ISI	BUI	FWI
Moist	83	20	142	4	30	9
Moderate	87	39	325	8	60	20
Dry	92	93	492	16	127	46
Extreme	95	160	514	24	180	66

[a] FFMC = Fine Fuel Moisture Code, DMC = Duff Moisture Code, DC = Drought Code, ISI = Initial Spread Index, BUI = Buildup Index, FWI = Fire Weather Index.

Table 15. Percentage of days during the peak fire season of the years analyzed with higher values for combinations of Fine Fuel Moisture Code and Duff Moisture Code (DMC) or Buildup Index (BUI) than each of the four fire danger scenarios[a]

	Moist		Moderate		Dry		Extreme	
Weather station	DMC	BUI	DMC	BUI	DMC	BUI	DMC	BUI
Fort Providence	56.9	57.3	34.2	33.5	0.6	0.3	0.0	0.0
Caen Lake Tower	60.9	60.5	41.6	41.2	0.0	0.0	0.0	0.0
Kimble Tower	60.4	59.3	37.0	33.8	0.3	0.0	0.0	0.0

[a] Based on Tables 11 to 13.

CONCLUSIONS

In this study, the noon LST (1300 DST) weather observations obtained at three different weather stations located within or near the study area, and the FWI System components calculated from those observations, were analyzed from the perspectives of fire danger and potential fire behavior. Although the study of individual weather elements is pertinent from the perspective of fire research and fire management, the FWI System components have the added advantage of taking into account the cumulative effect of weather as it relates to fuel moisture and potential fire behavior. It is therefore advantageous to look at both types of variables.

The results of the frequency analysis on each variable for the peak fire season, summarized as percentile values, have been presented here in both graphic and tabular forms. Detailed figures showing the seasonal distribution of the minimum, average, and maximum values for each variable, for each day of the same period, over all of the years analyzed, have also been provided. Finally, figures and tables summarizing the general wind direction (for the period of 15 June to 15 August as a whole, and for 2-week intervals during that period), the pattern of rain accumulation in reference to four predetermined thresholds, and the combined analyses of different FWI System components were created and presented.

An overview of these results indicates that the FWI System components had, on average, higher values during the first half of the peak fire season, before the week of July 14, the DC being the main exception to this general rule. During the week of July 14 to July 20, most fire weather variables and FWI System components exhibited values indicative of less severe burning conditions than the preceding or subsequent periods. On other days of the peak fire season, the values for individual variables were often lower (or higher, in the case of the relative humidity and rain) than the average for the season, but never all at the same time, as was the case during that week. Overall, the analyses involving the SSR indicated that this study area has high fire behavior potential, with relatively higher SSR values than the rest of the country and, in particular, the portion of the country usually associated with the distribution of the boreal forest.

In terms of identifying the four levels of burning conditions (i.e., moist, moderate, dry, and extreme) as envisioned by Horn (1976), it was possible to identify these levels in terms of combinations of FWI System components. In several cases, the FWI System components approached but never reached the values for extreme conditions during the study period. However, with climate change and general warming trends (Flannigan et al. 1998; Stocks et al. 1998), it is possible that these thresholds will be surpassed in the near future.

The FWI System components integrate the effect of past weather conditions, and it therefore seemed appropriate to have fixed values for air temperature, relative humidity, 10-m open wind speed, and rain accumulated over the previous 24-h period to be used in combination with the fire danger scenarios described above for an assessment involving different fuel types.

The detailed analyses of fire weather, fire danger, and fire potential climatology presented here will have added benefit in terms of their potential use for other research and fire management activities in the area of interest.

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