Alberta

Alberta Wildfire Regime Analysis

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Ecosystems are not defined so much by the objects they contain as by the processes, energy flow and material cycling that regulate them. Fire is clearly an integral part of these processes in many ecosystems.

— Ecological Consequences of the 1988 Yellowstone Fires
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Section I Introduction

An understanding of natural disturbance helps managers to better understand the management options available to conserve biodiversity. It also helps to ensure the sustainability of forest ecosystems, and the associated uses and values for Albertans. Burton et al. (2003) suggest that baseline conditions for natural disturbance (and other ecological processes) must first be understood before we can intelligently design and manage future desired forests. In Alberta, fire is a key natural disturbance process. Natural disturbance emulation models therefore require a thorough knowledge and understanding of both fire regimes, and the impact of fire.

Adamowicz and Burton (2003) provide a good overview of the concept of sustainability, the definitions and approaches to sustainable forest management, and the approaches used to measure sustainability. Although the idea of sustainability is simple (i.e., do not consume more than you produce), implementing it remains a challenge. In Alberta, forest companies have to some degree adopted the natural disturbance emulation approach as a strategy to implement sustainable forest management, and to minimize the risk of loss of biodiversity. This conforms to the policy described in the Alberta Forest Legacy document (Alberta Environmental Protection 2000).

There has been considerable work conducted in Alberta in the last 10 years to enhance our knowledge and understanding of fire as a natural disturbance, but most of these studies are spatially and temporally specific. No comprehensive provincial level study of fire regimes has been published.

This report was completed, in part, to address this need. As well as providing a provincial-level analysis, this report identifies data gaps within the province. A summary of fire regime studies was subsequently summarized and mapped (Section V, Appendix III).

A provincial fire regime analysis provides important scalar context for regional, and other larger scale analysis. Johnson et al. (2003) agree that an understanding of ecosystem dynamics cannot be attained unless natural disturbance is considered at different scales of space and time. The regime approach to emulating natural disturbance focuses on emulating landscape pattern. This is achieved by using various landscape pattern and stand level metrics to manage the natural range of variation (NRV) in ecosystems.

Fire regime is defined as "the kind of fire activity or pattern of fires that generally characterize a given area" (Canadian Interagency Forest Fire Centre 2003). Elements of this characteristic pattern include fire return interval (FRI), fire cycle, fire frequency, fire size, fire season, fire type, fire intensity, and fire severity. A fire regime analysis therefore contributes to understanding not only disturbance patterns, but also disturbance processes (e.g., fire severity influences duff consumption, which in turn impacts nutrient cycling and regeneration).

Fire regimes, however, are not static. They change as a result of changes in climate and human activities. Throughout the world, altered natural fire regimes have resulted in both fire-damaged ecosystems and fire-dependent ecosystems that are fire-starved. Integrated approaches to fire management must therefore recognize the need for ecosystem restoration to restore fire-damaged ecosystems, and re-establish natural fire regimes. In the working, or managed, forest in Alberta, forest management activities seek not to re-establish a natural fire regime, but to re-establish the patterns that a natural disturbance regime would have created, and where possible to use prescribed fire as a resource management tool.

Applying one statistic (i.e., a single value for fire cycle or burn rate) is often used to describe a fire regime, and then estimate age-class distributions and the abundance of older aged forests. An important component of sustainable forest management is a strategy to manage older aged forests. Although the disturbance rate is a key decision variable, other variables must also be considered. Estimating appropriate disturbance rates is critical because these rates in turn drive the estimates of the range of natural variability, and how much older aged forests should be retained over time and space.

Reaching an agreement on a single disturbance rate is difficult, however. Estimates for disturbance rates for the western boreal forest vary from 50 years to 250 years. Different methods produce different results. Fire cycle and NRV estimates can also vary depending on which temporal period and spatial extent are used. The shorter the time period and/or the smaller the spatial extent, the greater the unreliability of the fire cycle and NRV estimates. Futhermore, the natural fire cycle and NRV may be overestimated if the occurrences of human-caused fires are not removed, and underestimated if the effects of suppression are not accounted for.

White et al. (1995) suggest that aboriginal people periodically burned montane meadows in the spring in Banff National Park. This cultural burning may also have extended beyond the montane ecozone to include entire valleys. Early human-caused fires were an important disturbance in the Rocky Mountain and Foothills Natural Regions (NRs). These fires usually occurred in the spring outside the later lightning season.

The assumption of a constant burn rate to estimate a fire cycle is another challenge. Armstrong (1999) found burn rates to be highly variable in the boreal mixedwood forest of northeast Alberta, suggesting that equilibrium age distributions are unlikely. However, Armstong (1999) used only 35 years of data, and the correction factors used to calculate area burned without suppression need further review. Although there are serious flaws in using historical wildfire data (Murphy et al. 2000), the reported area burned in Alberta from 1919 to 1959 suggests there was a relatively constant higher background level of wildfire activity (area burned) compared to the 1960 to 2002 period.

Wildfire activity in Canada has, in recent years, increased significantly (Podur et al. 2002). The last 10 years suggest a climate change effect of increasing wildfire activity. However, climate warming alone is not responsible for the increased wildfire activity. Better detection, competing land use activities and in some areas, an increased fuel load may also be contributing factors.

Variability in burn rates over time adds risk to the method of estimating historical disturbance rates by "rolling back" age-class distributions. The assumption of proportionality applies the current age-class distribution to the areas of younger age classes that are "rolled back." The "roll-back" approach assumes that the current landscape metrics (age-class distribution) are similar to the past landscape metrics (age-class distribution).

Using paleoecological records of charcoal in lake sediment, Larsen and MacDonald (1998) estimated a mean fire return interval (MFRI; presuppression) of 69 years for northern Alberta. Using forest inventory age-class data and the negative exponential model, Van Wagner (1978) calculated a fire cycle (presuppression) of 60 years for conifer forests around Lesser Slave Lake, Alberta. Murphy (1985) used age-class data for northern Alberta to estimate a presuppression fire cycle of 46 years (mean burn rate of 2.2%). Problems associated with using age-class data from forest inventory data may result in an underestimation of the fire cycle. Old stands are often not adequately sampled and represented in the inventory. This results in a "missing tail" (Finney 1995). The effects of suppression also need to be accounted for.

Bergeron et al. (2004) used available forest fire history studies to compile historical burn rates for the Canadian boreal forest. These historical burn rates were then compared to current (i.e., 1959–1999) burn rates. The historical burn rates in most of the studies were significantly higher than the current burn rates. Interestingly, if the cordillera and eastern ecozones are removed, the historical burn rate for the western boreal forest increases from about 1% (FC = 100 years) to 1.6% (FC = 60 years).

In Alberta, the fire regime can be classified in general fire-load terms as high fire activity in the Boreal Forest NR (FC = 50–250 years), moderate fire activity in the Lower Foothills Natural Subregion (NSR; FC = 70), and the Upper Foothills NSR (FC = 85), and low fire activity in the Rocky Mountain NR (FC = 100–300). Fire cycle estimates assume that all fires are stand-replacing fires. However, in the Rocky Mountain and Foothills NRs, low-to moderate intensity fires also occurred.

Regional variations in wildfire activity occur within this broad provincial level fire regime classification. For example, in the Spray Lakes Sawmill (SLS) Forest Management Agreement (FMA) area, wildfire activity is lower in the Lower Foothills NSR than in the Upper Foothills NSR because of the higher occurrence of aspen.

Wong et al. (2003) summarized 11 different methods that have been used to estimate disturbance rates for stand-replacing fires and stand-maintaining fires. They recommended two methods to estimate disturbance rates for the boreal white and black spruce zone in British Columbia: the maximum likelihood estimate of disturbance frequency, and the roll-back of the time-since-disturbance distribution.

Rather than using a steady state target of disturbance, there is increasing consensus that a range of fire cycles or an estimate of the range of natural variability in fire frequency, intensity/severity, size, and season are more acceptable descriptors of landscape fire disturbance from both a scientific and management perspective. Variation is a natural component in fire-dependent ecosystems. Although describing this variation is possible, incorporating and managing it remains a challenge.

Simulation modeling of natural disturbance can be used to estimate a range of variability. Although simulation modeling is constrained by the inputs (i.e., the starting age-class distribution, the fire-size distribution, and the mode of percolating fire disturbances), they allow for sensitivity analysis of different scenarios, and also allow for the prediction of climate change effects.

This report does not endorse one single method for estimating disturbance rates. Each method has its own assumptions and limitations (see Section V). Implementing and comparing several methods may be the best approach.

Regardless of the approach used, the objective is the same: to better understand the variability within natural fire regimes. This understanding will subsequently help to accomplish the following objectives:

- Bridge land management and fire management.
- Improve fire and fuels management planning.
- Identify spatial and temporal variability in fire occurrence across the landscape, and in particular, areas of high probability of burning.
- Identify areas across the landscape that require wildfire threat mitigation.
- Identify opportunities for ecological management, including the use of alternative silvicultural systems, through the emulation of fire as a natural disturbance process.

Section II Policy and History

Bad fire seasons traditionally drive forest protection policy changes. The first major forest protection policy change occurred in 1952 after the disastrous 1950 fire season. In 1950, the firefighting policy stipulated that no suppression activities were permitted on any fire occurring outside the 10-mile firefighting limit in the Northern Alberta Forest District (NAFD). This limit was established along major transportation corridors (major roads and rivers), and around communities. On September 16, 1952, the 10-mile limit was dropped, thereby requiring forest rangers to action all fires regardless of their location.

In January, 1954, the Rocky Mountain Section of the Canadian Institute of Forestry presented to the Minister of Lands and Forests a brief entitled "Forest Fire Protection in Alberta: A Review and Recommendations." This brief strongly recommended that the Government of Alberta strengthen its fire prevention and fire suppression programs. The government responded by reorganizing the Forest Divisions and Forest Districts. Four branches were established in Edmonton, allowing Forest Protection to become its own Branch. As well as the reorganization, additional firefighting equipment was purchased and new lookout towers were added to enhance the overall Forest Protection Program.

Figure 4-2 highlights the major policy changes that occurred since 1961. After seven relatively quiet and manageable fire seasons, the 1968 fire season began with a flurry of approximately 250 fire starts in the spring. Most of these fires broke out on May 18. Despite deploying a record suppression effort, many fires burned out of control when south winds gusted to 40 mph (64 kph) on May 20. The majority of the 950,000 acres (384,750 ha) of forested land that burned during the 1968 fire season occurred during one week in May.

The 1968 Vega fire (also known as the Slave Lake fire), in particular, challenged the suppression efforts. Two thousand fire fighters and 200 bulldozers struggled to slow the advance of the fire as it approached the town of Slave Lake. The weather changed on May 24, allowing crews to contain the fire. The Vega fire resulted in several important changes in the Forest Protection Program. In central Alberta, land clearing fires set by farmers were responsible for most of the burned forest area. The Vega fire alone consumed 330,000 acres (133,650 ha). Controlling these human-caused spring fires became a priority after the 1968 fire season. The Vega fire also highlighted the need to develop an improved weather forecasting system.

In 1969, the Forest Service reorganized into six branches: Administration, Forest Protection, Forest Land Use, Timber Management, Construction and Maintenance, and Training. The Forest Service also opened a new fire control facility (called the Fire Control Depot) near the Edmonton City Centre Airport. The staff and resources at the Fire Control Depot significantly advanced the Forest Protection Program, and provided greater efficiencies for the coordinated initial attack of fires.

The 1968 Vega fire highlighted the need to strengthen the Forest and Prairie Protection Act. This Act was subsequently revised and tabled in the legislature in 1971. The fire control policy in 1971 was based on a number of objectives:

- Reduce the number of human-caused fires.
- Detect, control, and extinguish all "harmful" fires within the forest protection area.
- Ensure the rapid discovery of fires.
- Provide strong initial attack.
- Control at minimum size during the first day of burning.

Justifying the high costs of suppressing fires under this full fire control policy became difficult in some of the northern areas in Alberta. A limited-action policy was therefore established in 1972 in the Caribou-Cameron Fire Control Area, and other selected areas in northern Alberta. Initial attack resources were still deployed on all fires in these areas. However, if the initial attack failed, each fire was assessed individually to determine what suppression activity, if any, should be applied. This strategy remained in effect until 2003, when an Ecological Fire Management Zone was established in northern Alberta.

The fire control objectives in 1971 were later modified to include the following performance measures:

- Discover all fires at a size of 0.25 acres (0.1 ha) or less.
- Action all fires within 1 hour of discovery.
- Control all fires at a size of 3 acres (1.2 ha) or less.
- Maintain an annual allowable burn of 0.1% or less in the FPA (= 39,300 ha).

In 1981, four priority zones were used to assist fire managers with pre-suppression and suppression planning. Priority Zone 1 buffered communities within the FPA. Priority Zone 2 included the east slopes (watershed and recreation protection). Priority Zone 3 included the commercial forests in central and northern Alberta, and Priority Zone 4 included all other areas with low values at risk, including the Caribou-Cameron area in northern Alberta.

The 1970s were a relatively quiet decade with respect to area burned. Despite a 45% increase in the average number of fires during the 1970s compared to the 1960s, the area burned was reduced to 43,600 ha/yr.

Unlike the 1970s, the 1980s began with three consecutive bad fire seasons that led to major policy changes beginning in 1983. Below-average winter precipitation and an early, dry spring set the stage for a record fire season of 1,296 fires and 640,000 ha burned in 1980. Multiple ignition starts during high to extreme burning conditions resulted in many escaped fires that quickly became large fires. Since direct suppression efforts were largely ineffective, new indirect suppression strategies and tactics were used. An aerial ignition torch was used for the first time on a fire (DND-4-80) in the Cold Lake Air Weapons Range.

The disastrous spring fire season in 1980 was followed by another disastrous fire season in 1981 that occurred in late August and early September. When the snow finally arrived, a record 1.36 million ha had been burned.

Although the 1982 fire season started slowly, 120 new wildfire starts occurred on June 12. Dry burning conditions and high winds challenged suppression efforts, as escaped fires continued burning for the next month.

The 1980 and 1981 fire seasons prompted the development of a new pre-suppression preparedness system (PPS) that was tested in 1982. This was a province-wide, systematic system to determine initial attack resource requirements and deployment coverage needs. The objective was to minimize the potential for large fire losses by pre-positioning resources during high hazard periods, thereby reducing travel times. Initial attack resources were required to arrive at any new wildfire starts within 15 to 60 minutes, depending on the fire danger level. The PPS system was based on the objective of increasing resources, and strategically locating them to reduce travel times during periods of high fire danger.

The 1980, 1981, and 1982 fires also highlighted the need to initiate more advanced training, particularly fire weather and fire behaviour training.

In 1989, the Intelligent Fire Management Information System (IFMIS) was implemented to enhance the PPS system. The IFMIS changed the objective of using a fixed travel time and assuming a worst-case fuel type of black spruce to using actual fuel types and actual arrival times related to predicted fire behaviour (i.e., the time required for a fire to reach 1.2 ha using actual fuel, weather, and topography). In 1994, the IFMIS initial attack size objective of 1.2 ha was increased to 2.0 ha. The IFMIS was the precursor of the Spatial Fire Management System (SFMS) now used throughout Alberta.

The new PPS system paid dividends for the Department. From 1984 to 1994, the total area burned was 194,438 ha, despite an increase of 1,000 fires compared to the previous decade. However, the 1995 fire season arrived with an unprecedented number of spring lightning fires.

The 1995 fire season was characterized by record spring fire weather conditions, particularly in northern Alberta. The buildup index (BUI) averaged 120, and reached a maximum of 180 at High Level. A record number of 316 fire starts occurred in 22 days (May 27 to June 17). The majority (266) of the wildfires were successfully contained. The 50 fires that escaped initial attack, 8 fires became significant project fires. Four of these fires accounted for 95% of the area burned, resulting in $19 million in suppression costs.

A review of the 1995 fire season was conducted by staff from the British Columbia Forest Service, Forest Protection Program (Dunlop et al. 1996). The report included 11 recommendations.

Quiet fire seasons occurred in the following two years (1996 and 1997) as a result of above-normal precipitation. However, a dry winter, and the occurrence of fires in December, 1997, suggested that the 1998 fire season would be the same as the 1968, 1980, and 1995 spring fire seasons.

By early April, 1998, many areas in central Alberta were snow free. Fire managers were again faced with another unprecedented challenge of record spring drought codes, a record early spring fire load (255 fires from April 8 to May 7), low relative humidities, and high winds. Over 700,000 ha burned in central and northern Alberta. The Land and Forest Service commissioned a review of the Forest Protection Program in Alberta as a result of the disastrous 1998 fire season (Nash et al. 1999).

The 2001 Chisholm fire highlighted the need to improve community protection in Alberta. This 116,000 ha fire, which started on May 23, 2001, resulted in property loss in the hamlet of Chisholm. The Minister of Sustainable Resource Development established an independent committee to review the Chisholm fire (Chisholm Fire

Review Committee 2001). The committee identified the need to improve planning and communications between agencies, strengthen community protection, and enhance strategies to reduce the occurrence and impact of large, high-intensity fires. All five recommendations from the Review Committee were accepted by the Minister of Sustainable Resource Development.

The 2002 House River was another spring, wind-driven fire. This fire raged out of control from May 17 to June 7, 2002, becoming the second-largest fire (248,000 ha) in Alberta since 1961. The House River fire influenced how large fires would subsequently be managed in Alberta.

The 2003 Lost Creek fire in the municipality of Crowsnest Pass shifted attention from the boreal forest to the east slopes. This 22,000 ha fire started on July 23, 2003. For 31 days (during which a state of emergency was declared), the Lost Creek fire threatened the communities of Hillcrest and Blairmore.

Many changes were implemented as a result of the 2001 Chisholm fire, the 2002 House River fire, and the 2003 Lost Creek fire. These included implementing unified incident command; improving collaboration with municipalities, other government departments, and industry partners; and implementing effective communication strategies.

Section III Data

The data used in this analysis include historical wildfire occurrence data, historical weather and fire weather data, fire spread data, fuel data, ecological classification data, and other geographical data, including Forest Protection Area (FPA), Wildfire Management Area (WMA), Forest Management Agreement (FMA) areas, and Forest Management Units (FMUs). Each of these data categories will be discussed in this section individually with consideration of the potential problems with respect to using these data.

3.1 Historical Fire Data

3.1.1 Wildfire Records

The Alberta Forest Service assumed responsibility for recording wildfires after the 1930 transfer of resources (The Alberta Natural Resources Act). Provincial records begin in 1931, the first fire season under provincial jurisdiction. Over time, these records have been recorded, stored, updated, and made available in different formats for various time periods:

- **1931 to 1968:** Actual wildfire reports are available on microfilm. One set of the microfilm is maintained at the Provincial Forest Fire Centre (PFFC) in Edmonton.
- **1961 to 1982:** Wildfire incidence data are available in electronic format, along with a data structure file and a data dictionary. The original hard copies of the wildfire reports are available for the period from 1969 to 1982.
- **1983 to 1995:** Wildfire incidence data are available in electronic format, along with a data structure file and a data dictionary. The original hard copies of wildfire reports are available for the period 1983 to 1995.
- **1996 to 2002:** Beginning in 1996, hard copies of wildfire incidence (fire reports) were no longer available. The wildfire incidence data were entered digitally into a central database (i.e., Oracle tables) integrated with the Fire Information Resource System called FIRES. FIRES uses a client server architecture employed over a wide area network.

3.1.2 Wildfire Report Changes

The wildfire incidence report form was revised over time. Some fields were dropped and revised, and other fields were added. There are three major changes that impacted the analysis completed in this study:

1) Unit of the wildfire size

   Before 1983, wildfire size was recorded in acres. The adoption of the metric system in 1983 resulted in the unit of wildfire size changing from acres to hectares. For this study, the wildfire sizes for fires prior to 1983 have been converted from acres to hectares.

2) Wildfire numbers

   - From 1931 to 1953, wildfires were identified by names (e.g., Horse Creek fire), or by a combination of a name and a number (e.g., Heart Lake #5).
   - From 1954 to 1964, wildfires were identified by a unique identifier that combined the district, a wildfire number, and the wildfire year. For

example, wildfire 39-3-61 indicates District 39, wildfire number 3, and the year 1961.

- From 1965 to 1996, wildfires were identified using the format DFN-nnn-YY, where D, representing district, is a default standard included in every wildfire number; F is a forest ID code defined as the first letter of the forest name (F = Footner Lake); N indicates the district number; nnn indicates the sequential fire number (three digits with leading zeros); and YY is the last two digits of the wildfire year. For example, DA1-001-1981 indicates wildfire number 001 in District 1 within the Athabasca forest for the year 1981.

- From 1996 to 2000, wildfires were identified using the format DFNnnn, where D is the region identifier; FN is the district identifier (two-digit number); and nnn is the wildfire sequence number for the year (three digits with leading zeros). For example, E01001 indicates wildfire 001 in District 01 in the northeast boreal region.

- From 2001 to 2003, wildfires were identified using the format XXXnnn, where the first three digits indicate the WMA ID, and the last three digits indicate the sequential fire number. For example, CWF-001 indicates wildfire number 001 in the Calgary WMA.

Since 1996, the wildfire year has been excluded from the wildfire number. From 1961 to 2001, a year represented a calendar year (January 1 to December 31). This changed in 2002 to represent a fiscal year (April 1 to March 31). The 2001 year, however, is a transition year that includes 15 months (January 1 to March 31).

3) Wildfire causes

The codes for general causes also changed through the years. The codes used for documenting wildfires are listed in Table 3.1.

Before 1983, a cause code of 5 indicated "public project." During the period between 1983 and 1995, this code was dropped. Since 1996, the cause code of 5 was added to indicate "prescribed burn." A code of "?" was also added to indicate "Cause under investigation."

Since 1990, additional information has been added in the wildfire report. For example, fuel type, wildfire type, and wildfire spread rate are all now recorded. Since 1996, all changes in wildfire sizes and status are also recorded in FIRES.

Table 3.1 Wildfire cause (1996–2002)

Code	Cause
0	Other Industries
1	Lightning
2	Resident
3	Forest Industries
4	Railroad
5	Prescribed Burn
6	Recreation
7	Incendiary
8	Miscellaneous Known
9	Unknown
?	Cause under Investigation

3.1.3 Wildfire Perimeter (Polygon) Data

Digitized wildfire perimeters for Class E (> 200 ha) wildfires since 1931 are available in

ARC/INFO polygon coverages. Beginning in 1998, all wildfires greater than 12 ha were digitized and included in the provincial wildfire perimeter data set. In 2000, the 12-ha size limit was further reduced to 2 ha.

Attributes for the wildfire perimeter data set include area, perimeter, wildfire number, wildfire class, burn code, year, wildfire name, capture date, and source. Wildfire perimeters were obtained from a variety of sources, including Global Positioning System (GPS), and remote sensing, historical fire incidence maps, aerial photography, and thermal infrared imagery. The Public Lands and Forests Division uses aerial photography to map burned areas to update the vegetation inventory and assess fire losses. Wildfire perimeters digitized from remote sensing data (primarily aerial photographs and satellite imagery) allow for the classification of burned and unburned areas. Fire mapping from aerial photographs also allows for the classification of partial burned areas.

Historical wildfire incidence data from 1961 to 2002 was the primary data used in this analysis. Class E wildfires were available from 1931 to 2002. This data was included in the historical area burned mapping analysis. The 2003 wildfire incidence data was not included because the data was not available at the time of analysis.

The historical wildfire data was compiled spatially for all size class wildfires from 1961 to 2002 in a single point source data set. A single polygon coverage was also created for all wildfire perimeters captured from 1931 to 2002. Wildfire data from 1996 to 2002 were extracted from the FIRES program to update the single point source data set as a result of burned area discrepancies in the data.

A common problem with historical wildfire incidence data is that not all wildfires were documented, particularly in the remote areas with limited access and detection ability. Wildfire occurrence and area burned may therefore be underestimated in some areas before 1953, when the 10-mile firefighting limit was in use. Since large fires are difficult to miss through remote sensing, it is presumed that all large fires since 1950 have been accounted for.

During the analysis, several problems were encountered with a small portion of the wildfire incidence data. For example, some wildfires had missing information, while other wildfires had different burned areas from different data sources. For the missing data, some assumptions were made to fill in the missing information. For example, if the wildfire start date was missing, the wildfire report date was used as the start date. If the wildfire cause was missing, a wildfire cause of “unknown” was assumed. If burned area discrepancies occurred between the wildfire point data, and the wildfire perimeter (polygon) data, the burned areas from the wildfire perimeter data were assumed to be correct. As burned area is one of the most important fire regime characteristics, efforts are continuing to ensure that burned area statistics are current and accurate.

3.2 Weather Data

3.2.1 Weather Stations and Observations

The Forest Protection Division operates a network of about 200 fire weather stations to collect daily weather data. Thirty-nine of these stations also collect hourly data. The spatial distribution of the weather stations is illustrated in Figure 3.1. The basic weather observations include temperature, relative humidity, wind direction, wind speed, and precipitation.

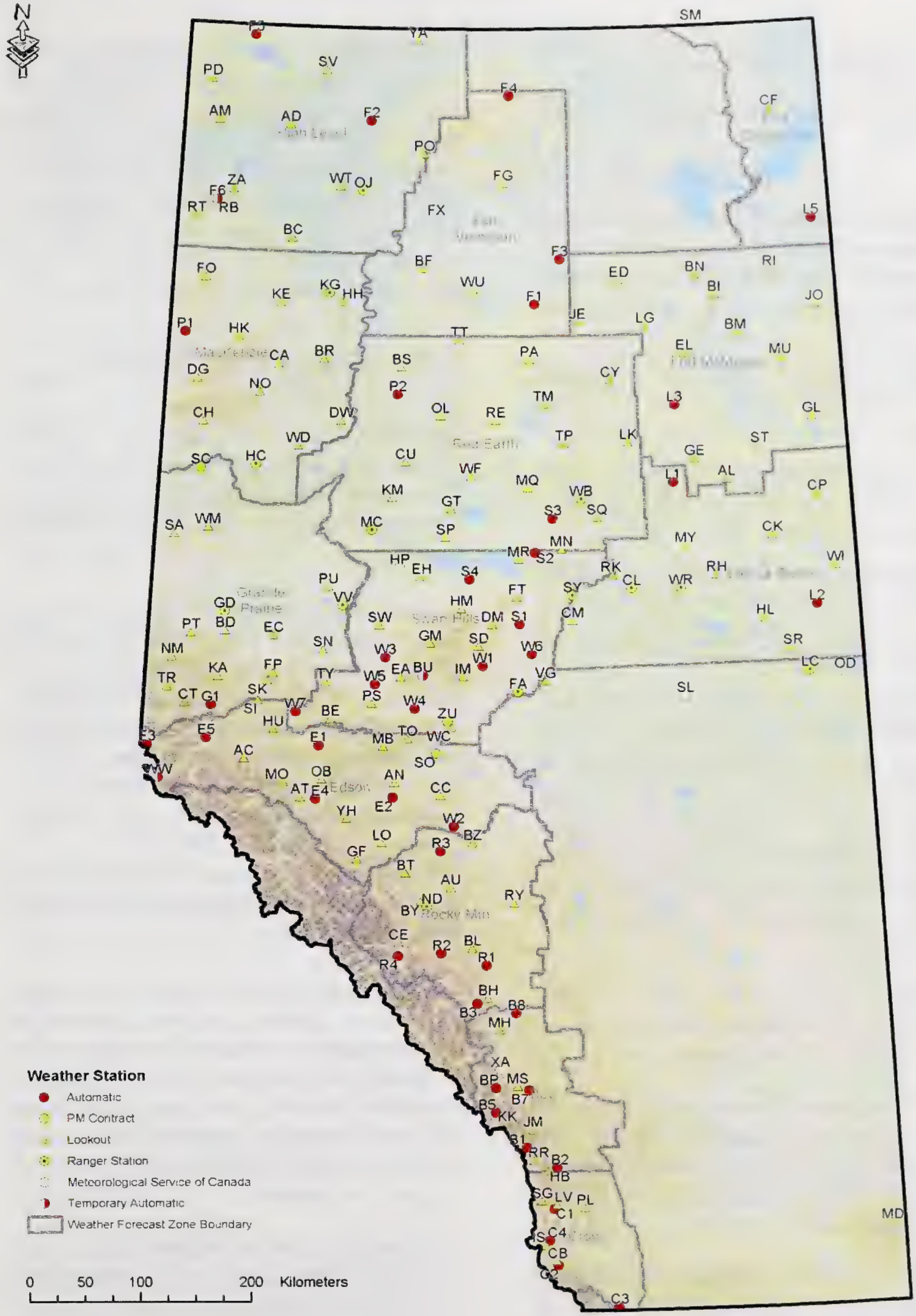

Figure 3.1 Distribution of weather stations in Alberta

3.2.2 Weather Station Type

There are six primary types of weather stations:

Lookout Towers (LO): Report weather twice a day at 6 a.m. and 12 p.m. (Mountain Standard Time, or MST). Currently there are 125 lookout towers in operation.

Ranger Stations (RS): Report weather once a day at 12 p.m. (MST). Currently there are 19 ranger stations in operation.

Contract Stations (RZ): Report weather once a day at 12 p.m. (MST). Currently, there are 5 contract stations in operation.

Environment Canada METARS (MET): Report weather once a day at 12 p.m. (MST). Currently, there are 8 stations in operation.

Permanent Automatic Weather Stations (PAWS): Report weather hourly at MST. Currently, there are 39 PAWS in operation.

Temporary Automatic Weather Stations: Report weather hourly at MST. These stations are usually installed to support wildfire and prescribed burn operations.

In addition to the basic fire weather observations recorded at noon local time, supplementary data are also recorded:

- The lookout towers and automatic stations report a morning observation at 07:30 (MST) to indicate overnight precipitation, and the potential fire danger later in the day.
- The manned weather stations report additional parameters daily, such as visibility, current weather, cloud type, and maximum and minimum temperature.

In addition to the six station types, the Forest Protection Division also manages a network of approximately 117 Sacramento Rain Gauges. These gauges measure over-winter precipitation, which is required to calculate start-up values for the drought code. The rain gauge measurements are usually taken on or near March 31 and October 31 each year.

3.2.3 Historical Weather and Fire Weather Data

Weather is one of the key variables influencing fire behaviour. Fire weather observation data from 1968 to the present are available from the Forest Protection Division.

Fire weather observations since 1973 have been entered into a database and into the FIRES program. The weather observations before 1973 are available as hardcopies. These data are currently being entered into a database and into FIRES. Fire Weather Index (FWI) values are calculated for the period beginning in 1975.

The morning (a.m.) and afternoon (p.m.) weather observation variables include the following variables:

The a.m. data format (6 a.m.): Station name, date, maximum temperature, minimum temperature, present temperature, relative humidity, wind direction, wind speed and wind gust, overnight precipitation including rain, snow and hail (18-hour), and dew point temperature.

The p.m. data format (12 p.m.): Station name, date, present temperature, relative humidity, wind direction, wind speed and wind gust, precipitation including rain, snow, hail (6-hour for lookout towers and automatic stations and 24-hour otherwise), dew point temperature, fine fuel moisture code (FFMC), duff moisture code (DMC), drought code (DC), initial spread index (ISI), buildup index (BUI), daily severity rating (DSR), and fire weather index (FWI).

The FFMC, DMC, DC, ISI, BUI, DSR, and FWI are components of the Fire Weather Index (FWI) system. In the current weather database, only the period from 1984 to 2003 includes the FWI code and indices based on the p.m. weather observation. The FWI values need to be calculated for the weather observations obtained before 1984. The analysis in this study is based on the 1984–2003 period.

3.2.4 Weather Data Analysis

To complete the weather percentile analysis, weather station data was used only if more than 20 years of observations were available, and if less than two years of data was missing. Since FWI values are only available after 1983, analysis was completed for the 1984–2003 period. The weather analysis included maximum temperature, wind direction and speed, relative humidity, precipitation, and the calculated FWI values.

Because of regional weather conditions, different weather stations start operating at different times. Some weather stations start operating as early as April, while others do not start until early June. The discontinuities in the data result in fewer total observations during the spring period compared to the other seasons.

The temporary automatic weather stations installed to support wildfire and prescribed burn operations have a mast height of 3 m (versus the 10 m standard for permanent weather stations). The wind speeds observed from the temporary weather stations were increased by 35% (Turner and Lawson 1978).

3.2.5 Climatology

Climatology is the study of climate. The Forest Protection Division compiles and distributes monthly climate graphs and maps using 18 active climate stations (Table 3-2). The graphs and maps are completed at the end of the summer season (April 1–Sept. 30) and at the end of the winter season (Oct. 1–March 31).

Table 3.2 Climate stations

Code	Station Name	Starting Year
FA	Fort Assiniboine (no data in winter)	1985
SO	Shining Bank	1967
KG	Keg River	1976
WR	Wandering River (no data in winter)	1962
CL	Calling Lake	1976
BQ	Blairmore	1976
ND	Nordegg	1976
GD	Grovedale	1978
EG	Edmonton	1973
VV	Valleyview	1974
OJ	High Level	1957
HC	Hines Creek	1957–85 2003
WB	Wabasca	1915
SM	Fort Smith	1960
YC	Calgary	1967
OD	Cold Lake	1976
MM	Fort McMurray	1961
SC	Sneddon Creek	2000

Thirty-year averages of climatic data are generally used to calculate anomalies. Appendix I lists the graphs and maps that are completed for each climate station. An analysis of climatic data allows for the comparison of the season relative to history. April and May precipitation anomalies are included in this report for 7 large fires that occurred in May (Table 3.3). The final fire perimeters are overlaid on the precipitation anomaly maps for the month of May (see Appendix II, Figures AII-3, AII-5, AII-7, and AII-9).

Table 3.3 Spring large fire analysis

Year	Fire Number	Start Date	Area (ha)
1995	DF2-011-95	May 27	33,562
1995	DF1-013-95	May 27	129,423
1995	DL1-009-95	May 28	132,686
1998	N03-018	May 2	151,940
1998	W05-015	May 2	40,001
2001	LWF063	May 23	109,637
2002	LWF031	May 17	242,176

3.2.6 Lightning Data

Lightning is an important causal agent in Alberta. To detect and track lightning activity, the Forest Protection Division operates 11 lightning detection finders across the province (Figure 3.2). One additional lightning detector is located in Fort Smith in the Northwest Territories.

The lightning detection system utilizes the time when the signal arrives at the sensors, along with GPS and triangulation techniques, to estimate the location of a lightning strike. The initiation of the cloud-to-ground strike releases an intense, short burst of electrical energy. This rapid burst of energy travels through the atmosphere in a similar manner to radio waves. The most unique characteristic of the waveform is its extremely rapid rise to peak energy. This distinctive feature of cloud-to-ground lightning provides the means for real-time detection.

When a valid lightning signal is detected, its exact time, intensity, polarity (negative or positive), number of return strokes, and true bearing from the station are recorded in real time. The precision and accuracy in locating lightning strikes from triangulation is dependent on the number and location of the detection finders.

This study did not include a provincial lightning analysis. However, three studies were conducted on lightning, and lightning wildfires in the Cordillera region in western Canada (Wierzchowski et al. 2002), the boreal forest in Alberta (Krawchuk et al. 2005), and the southern Rockies in Alberta (Alberta Environment, 2000). The results from these three studies are discussed later in this report.

3.3 Daily Wildfire Spread Data

Since 1996, most Class E large wildfires have daily wildfire progression data. Burned area estimates are usually obtained by GPS or thermal infrared mapping. If GPS is not available, Forest Protection staff estimate the area burned. The status of the wildfire is also documented ("out of control," "being held under control," or "extinguished"). Some of the larger wildfires also have multiple wildfire progression data for the burning period. The wildfire progression data provide valuable wildfire behaviour information. In this study, wildfire spread was linked to hourly weather data to analyze the relationship between wildfire growth and wind events. This analysis was completed using several large fires with good fire progression data.

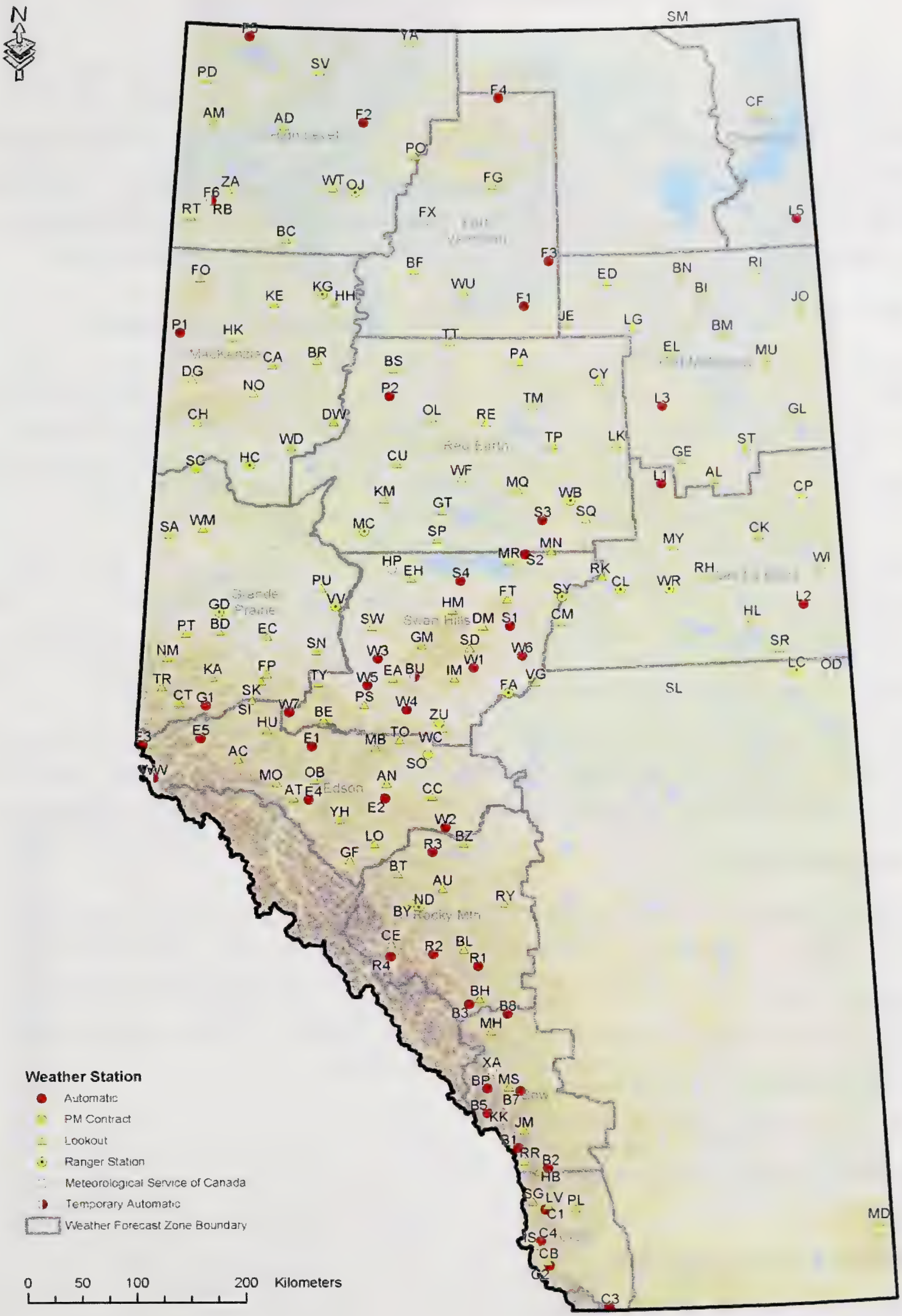

Figure 3.2 Distribution of lightning detection finders in Alberta

large wildfires with good fire progression data. Although the time when the fire progression data is captured is usually after the time of the spread event, it is still valuable information that can be used to analyze the occurrence and characteristics of spread events.

3.4 FBP Fuel Type Data

Fire Behaviour Prediction (FBP) fuel type is one the three primary variables (fuel, weather and topography) that influence wildfire behaviour. The Alberta FBP fuel type database is stored as raster grids at 100, 500, 1000, and 5000 meter resolutions for the entire FPA (Figure 3.3). The FBP fuel type database is derived primarily from a reclassification of the Alberta Vegetation Inventory (AVI; Tymstra and Ellehoj 1994). A stand-alone computer program called AVI2FBP assesses the AVI attribute data and then assigns a "best fit" FBP fuel type to the stand. The reclassification is based on wildfire behaviour potential rather than the qualitative description of the fuel type.

3.5 Topography Data

Topography is one of the of the three primary factors influencing wildfire behaviour. A 25 m digital elevation grid (interpolated from the 100 m photo-interpreted elevation heights) is available for the entire province. Slope, slope azimuth, and elevation grids are derived from the digital elevation model (DEM). These grids can be combined with the FBP fuel type grid and percentile weather data to build fire intensity maps.

3.6 Ecological Classification Data

A natural region (NR) and natural subregion (NSR) classification was developed by Alberta based on climate, vegetation, and soil (Strong 1992). There are 6 NRs and 20 NSRs in Alberta (Table 3-4). The spatial coverage of NRs and NSRs used in this analysis is at a scale of 1:1,000,000 (Figure 3.4). The NRs and NSRs are the primary analysis units used in this study. A new draft classification has been proposed but was not available when this project commenced.

3.7 Administrative Boundaries

The FPA is the area where the provincial government has sole responsibility for forest protection (Figure 3.5). It is about 40 million ha in area. This covers all of the commercial forested area. The FPA is available as a 1:20000 scale digital coverage.

There are also 10 WMAs in the province (Figure 3.5). The WMA is the administration unit for forest protection in Alberta. The WMAs are available as a 1:1000000 scale digital coverage.

The Forest Management Agreements (FMA) and FMUs are the administration units for forest management in Alberta. These areas are available as a 1:20000 scale digital coverage.

The administrative areas were used only for display purposes. They were not used for analysis because the boundaries are subject to change, and they do not reflect fire regime patterns as well as an ecological classification.

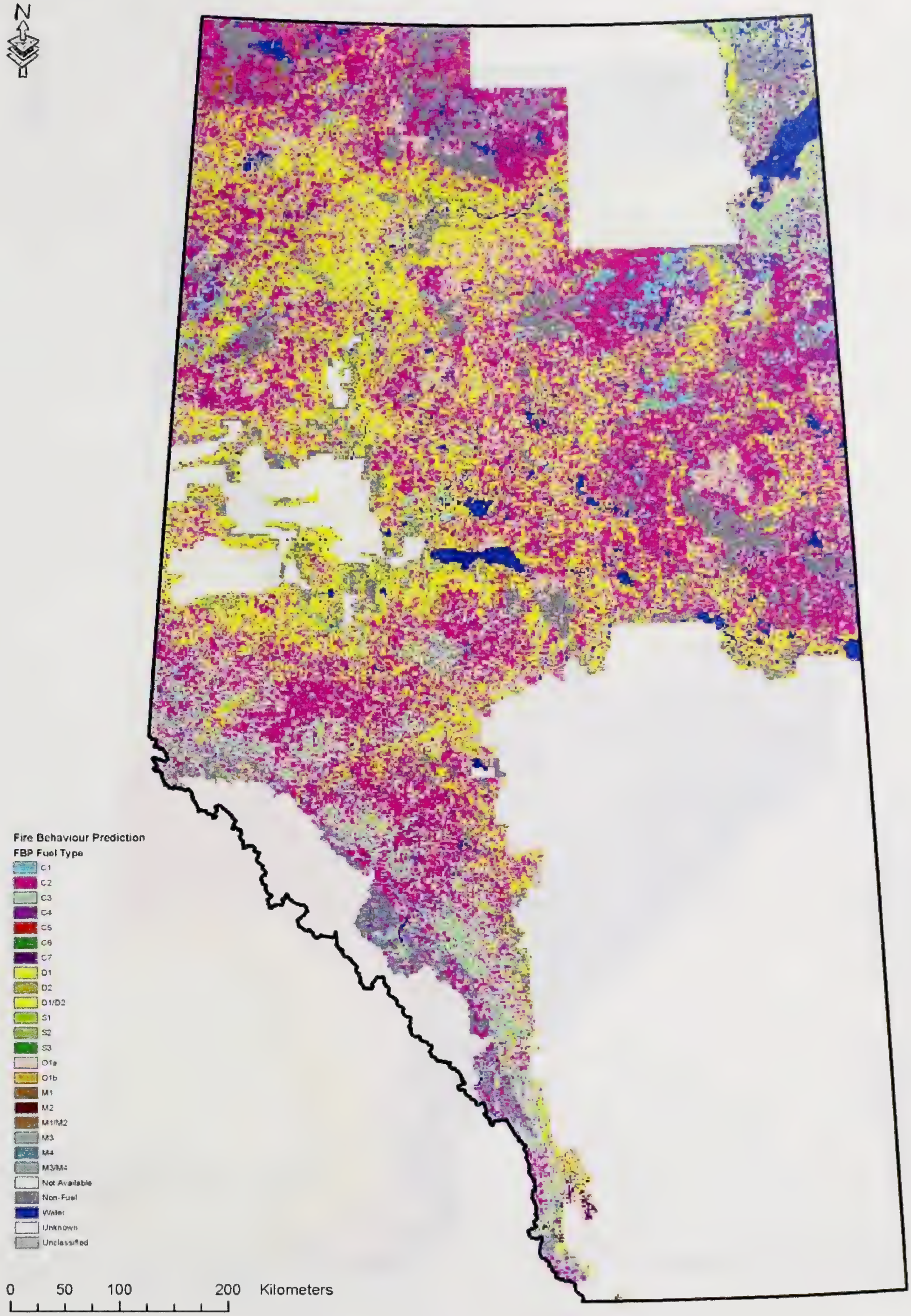

Figure 3.3 Canadian Forest Fire Behaviour Prediction (FBP) System fuel types for Alberta

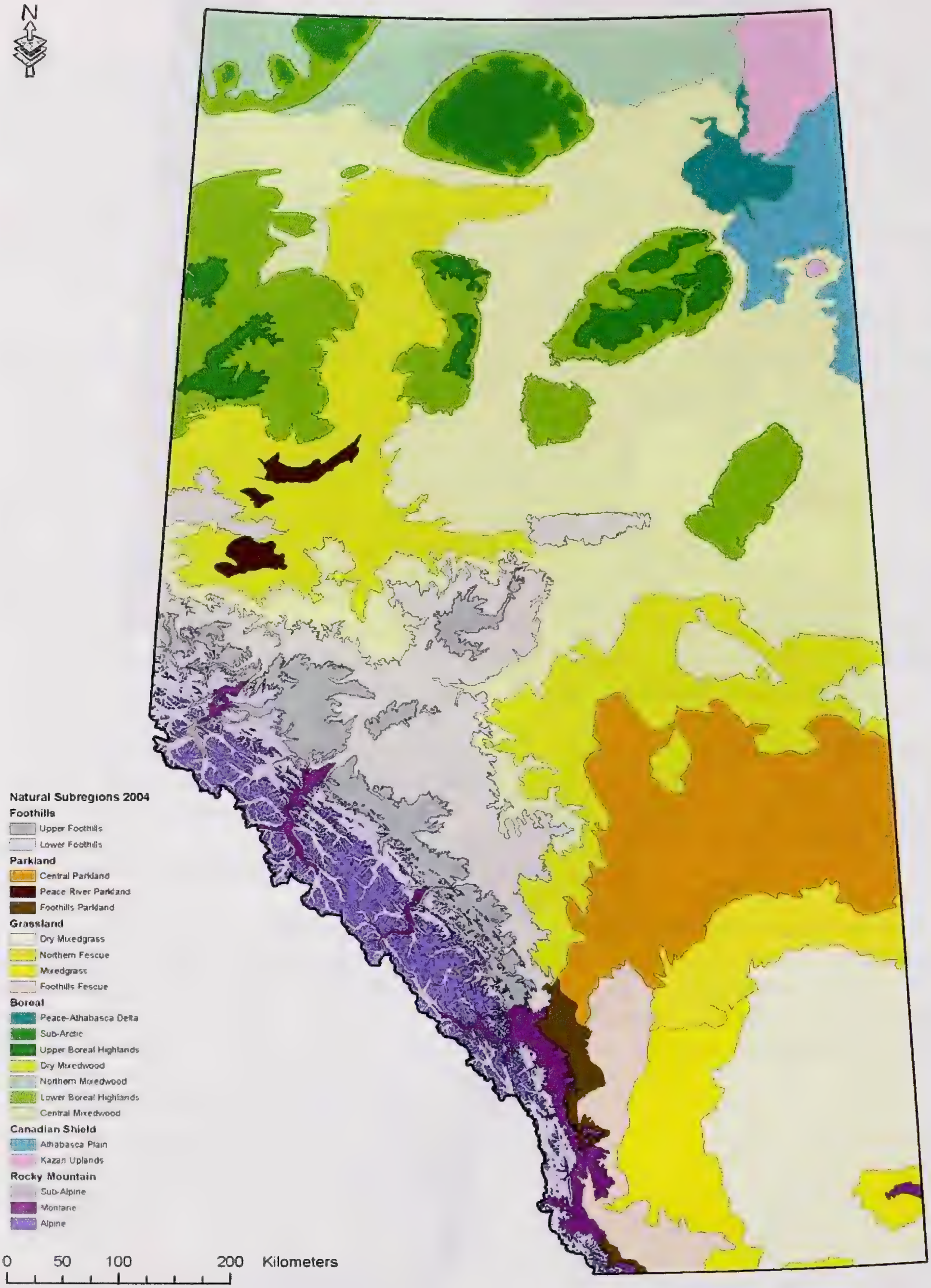

Figure 3.4 Natural region and natural subregion classification of Alberta

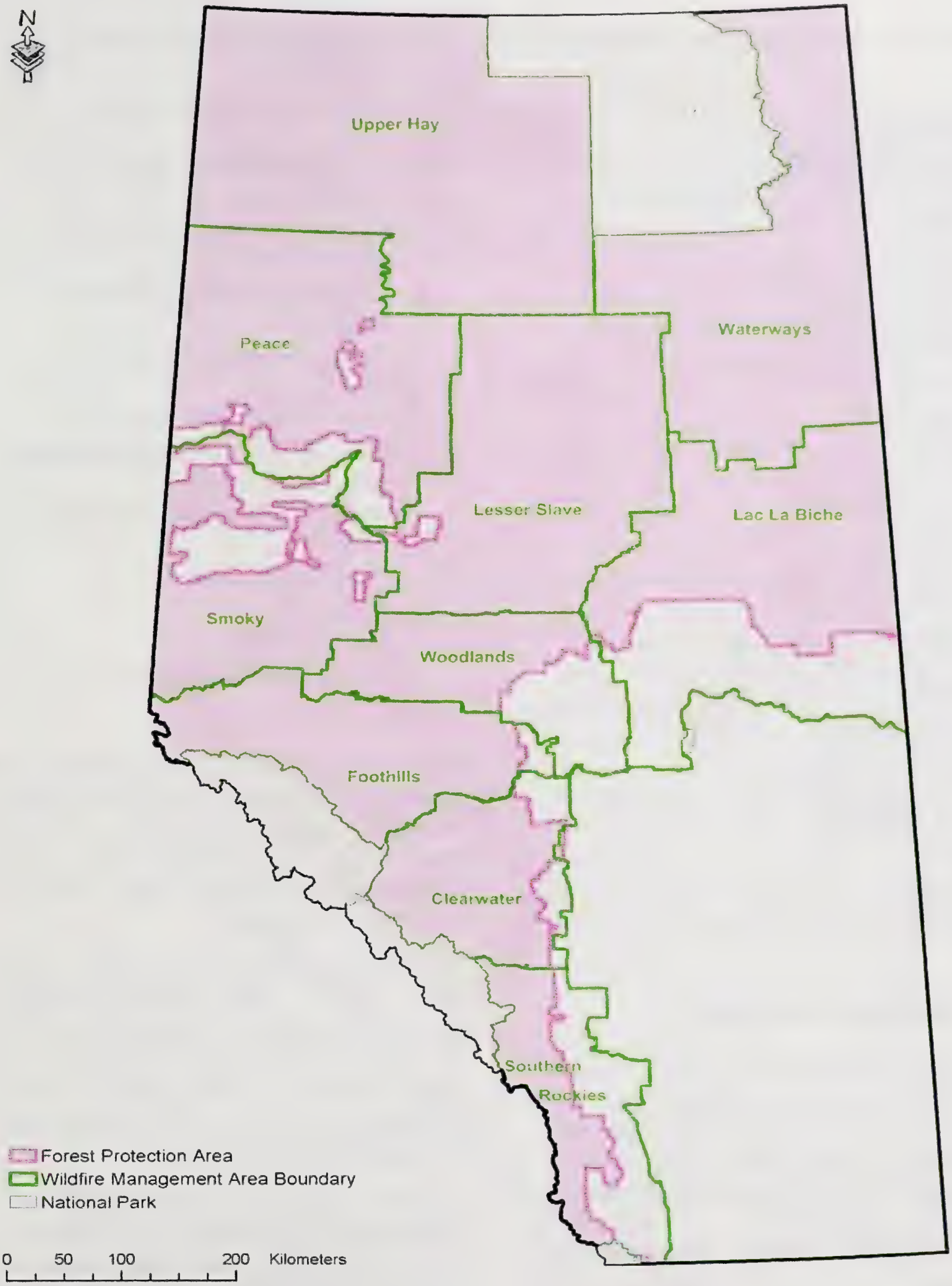

Figure 3.5 Alberta Forest Protection Area (FPA) and Wildfire Management Areas (WMA)

Table 3.4 Natural regions and subregions

Boreal Forest
Central Mixedwood
Dry Mixedwood
Wetland Mixedwood
Sub-Arctic
Peace River Lowlands
Boreal Highlands
Canadian Shield
Athabasca Plain
Kazan Upland
Foothills
Lower Foothills
Upper Foothills
Grassland
Dry Mixedgrass
Foothills Fescue
Mixedgrass
Northern Fescue
Parkland
Central Parkland
Foothills Parkland
Peace River Parkland
Rocky Mountain
Alpine
Montane
Subalpine

3.8 1957 Forest Cover Map

The 1957 forest cover map (Figure 3.6) is the first provincial scale forest cover map completed for Alberta. Since effective suppression is considered to have started in 1960, the 1957 forest cover map provides an interesting perspective of the pre-suppression fire activity throughout the province.

The map includes a forest classification legend with 13 classes.

- Coniferous stands: Up to 60' in height.
- Coniferous stands: Over 61' in height.
- Mixedwood stands: Up to 60' in height.
- Mixedwood stands: Over 61' in height.
- Deciduous stands: Up to 60' in height.
- Deciduous stands: Over 61' in height.
- Burns: 1941–1956, inclusive.
- Old burn and brushland/productive and non-productive.
- Agricultural and other improved lands.
- Muskeg and marsh.
- Rock barren.
- Hay meadows.
- Barren above timberline.

The 1941 to 1956 burns account for approximately 4.5 million ha of area burned. The 1950 Chinchaga River fire is missing from the 1957 map, since the aerial photography was flown in this area just before the fire occurred.

The majority of the large fires that occurred from 1958 to 2002 burned the large continuous coniferous stands identified on the 1957 forest cover map. Fire (human- and lightning-caused) has been such a prevalent disturbance on the boreal landscape that older aged forests are uncommon.

The fire regime in the east slopes is in comparison characterized by infrequent, high-intensity fires that usually occur in August and September. Fire history studies suggest that forest fires burned large areas of the east slopes during the 1889–1891 period.

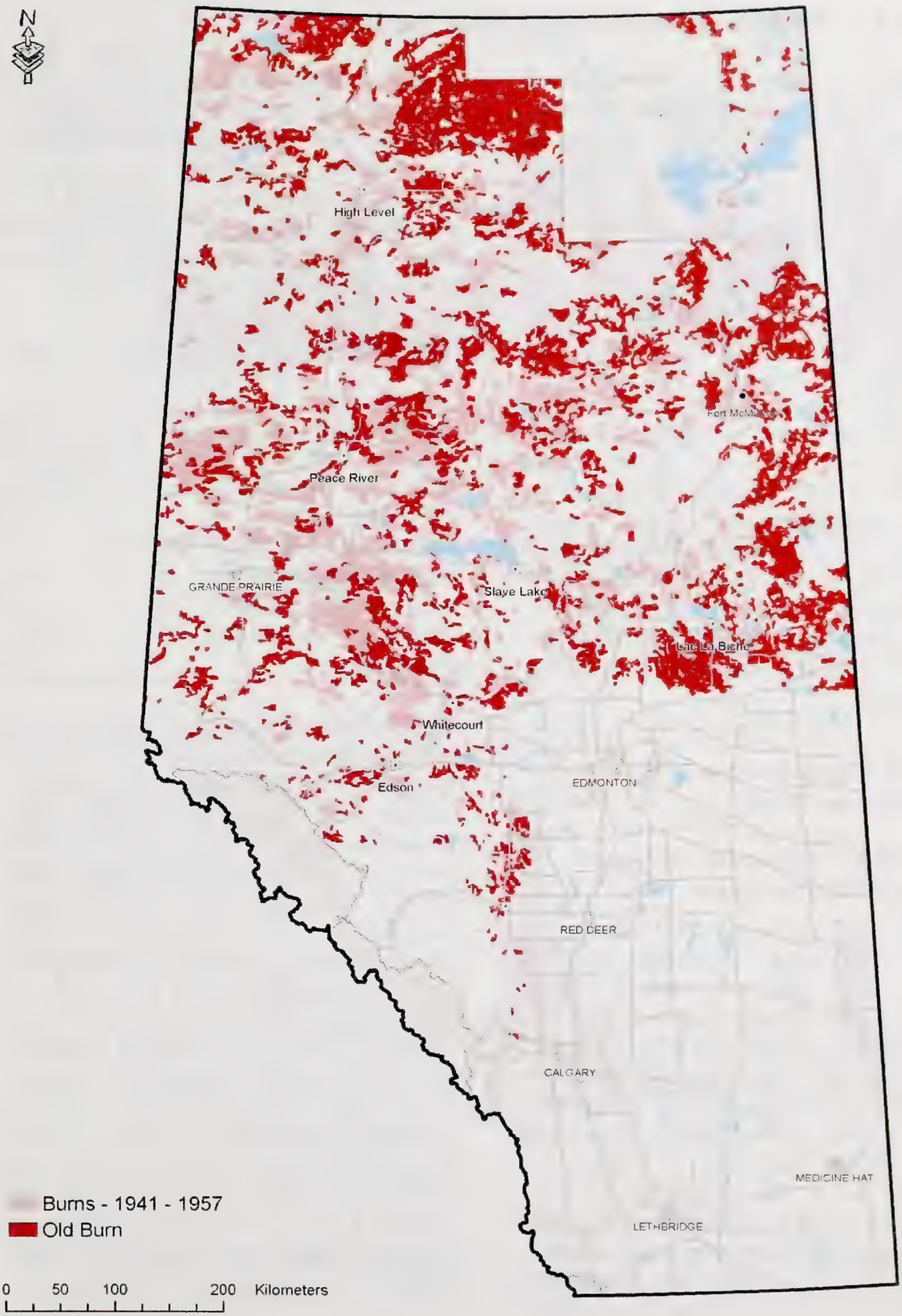

Figure 3.6 1957 forest classification of Alberta: Burn classes

Section IV Wildfire Occurrence and Area Burned

Fire regime is defined as "the kind of wildfire activity or pattern that generally characterizes a given area" (Canadian Interagency Forest Fire Centre 2003). The general elements include fire frequency (i.e., fire cycle, or fire interval, and the number of wildfires), fire intensity, fire severity, fire size (i.e., the area burned), fire season, and the type of fire (Weber and Flannigan 1997).

This section describes the fire regime of Alberta at the provincial and natural subregion levels based on historical wildfire occurrence and area-burned data in Alberta from 1961 to 2002. This analysis focused on wildfire occurrence, area burned, season, size distribution, cause, and the interactions between season, size-class distribution, and cause at the provincial and natural subregion levels. Temporal and spatial patterns of the above fire regime characteristics were also investigated.

4.1 Fire Regime Analysis at the Provincial Level

4.1.1 Wildfire Occurrence and Area Burned from 1961 to 2002

Wildfires are a common natural disturbance in nearly every part of Alberta. For the period between 1961 and 2002, an annual average of 843 wildfires occurred, with an annual average burned area of 142,793 ha. Only 2% of the wildfires were "Class E" (>= 200 ha) wildfires, but they accounted for 98% of the total area burned. On average between 1961 and 2002, 17 Class E wildfires burn a total of 139,350 ha each year. About 1% of all wildfires exceed 1,000 ha in size; and although only 9 such fires occur on average each year, they account for almost 95% of the total annual burned area in Alberta.

Averages however, do not provide a full picture, since wildfires are highly variable in both time and space, as shown in Table 4.1 and Figures 4.1 and 4.2. The mean and median wildfire sizes in Table 4.1 are significantly different, and the average area burned is skewed strongly by a few wildfires that are very large in size.

Table 4.1 Basic wildfire statistics in Alberta (1961–2002)

Wildfire Statistics	Value
Total Fire Count	35,414
Total Area Burned (ha)	5,997,324
Mean Fire Size (ha)	169
Median Fire Size (ha)	0.1
Standard Deviation (ha)	4,313
Minimum Fire Size (ha)	0.1
Maximum Fire Size (ha)	409,144
Skewness	50.8

Both wildfire occurrence and area burned vary significantly from year to year (Figures 4.1 and 4.2). The arrows in Figure 4.2 indicate the years when major forest protection policy changes occurred. The 1962 fire season had the lowest annual wildfire occurrence (279 wildfires), while the 1998 fire season recorded the highest annual wildfire occurrence (1,702 wildfires). The 1962 fire season also had the lowest area burned (1,752 ha). The highest area burned (1,357,312 ha) occurred during the 1981 fire season. The variability in annual area burned is much greater than the variability in wildfire occurrence. The years with the large area burned ("spikes") are distributed unevenly over time (Figure 4.2). Figures 4.3 and 4.4 further illustrate the uneven, "clumpy" distribution of the Class E wildfires.

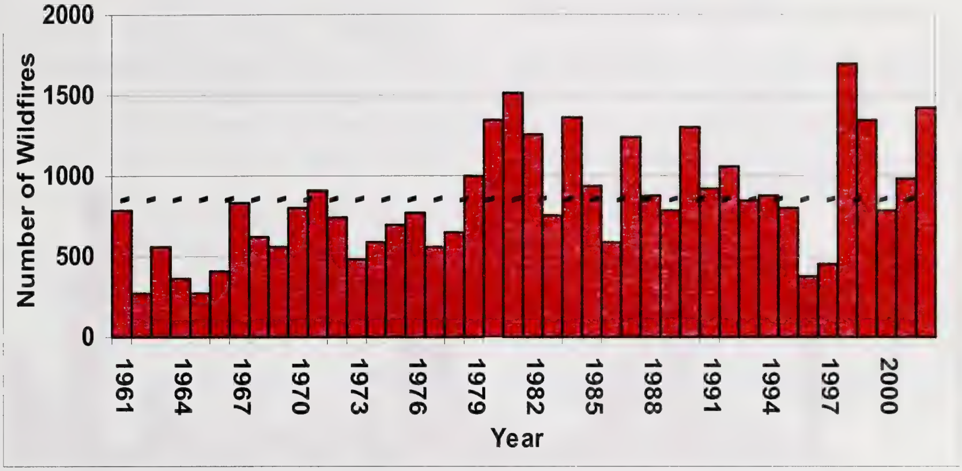

Figure 4.1 Wildfire occurrence in Alberta (1961–2002). The dashed line represents the mean wildfire occurrence value.

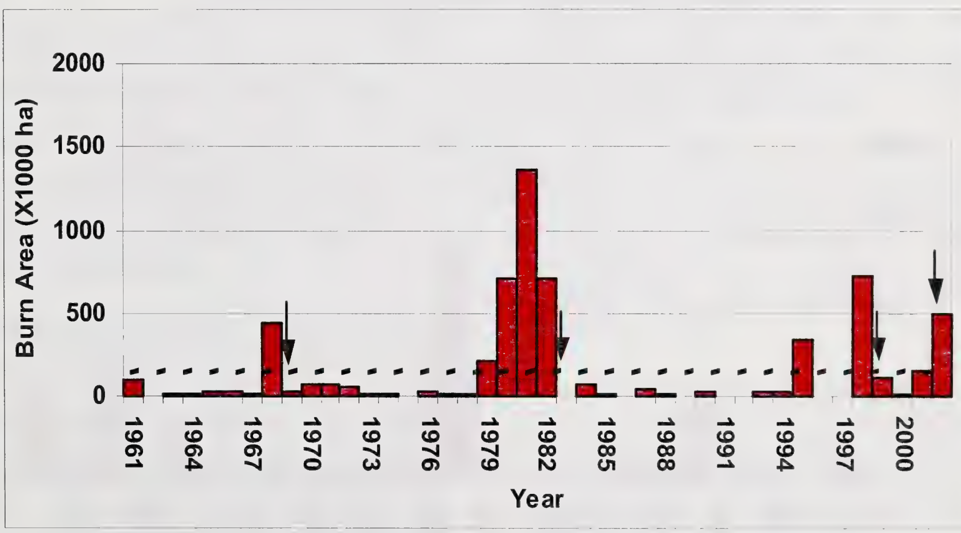

Figure 4.2 Wildfire area burned in Alberta (1961–2002). The arrows indicate when major forest protection policy changes occurred, and the dashed line represents the mean area burned.

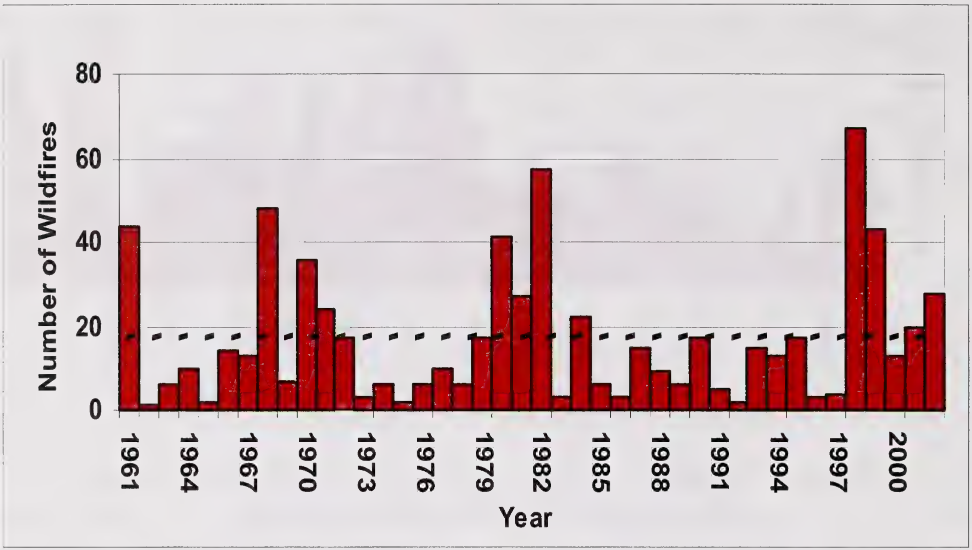

Figure 4.3 Class E wildfire frequency in Alberta (1961–2002). The dashed line represents the mean occurrence value.

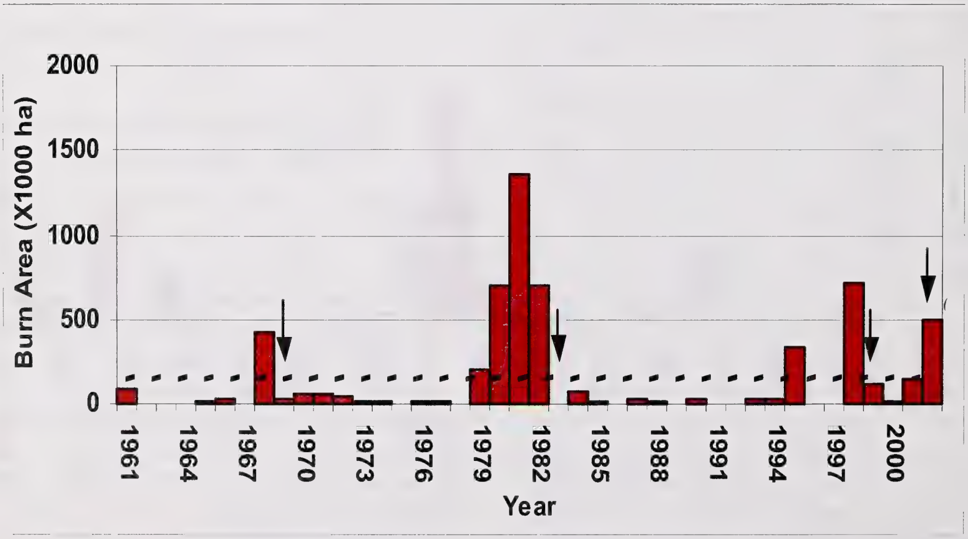

Figure 4.4 Class E wildfire area burned in Alberta (1961–2002). The arrows indicate when major forest protection policy changes occurred, and the dashed line represents the mean area burned.

A major El Nino-Southern Oscillation (ENSO) event occurs every 2 to 10 years (Environment Canada 2005). Although summer precipitation deficiencies in western Canada are associated with these anomalies (Shabbar and Skinner 2004), no correlation was found between area burned and El Nino events in Alberta.

Different geographic regions of Alberta also have distinctive wildfire characteristics. Figure 4.5 shows the spatial wildfire occurrence from 1931 to 2002. Figure 4.6 maps the area burned for Class E wildfires from 1931 to 2002. Figure 4.6 shows two distinct fire regimes: the boreal forest fire regime (frequent, high-intensity fires), and the east slopes fire regime (infrequent, high-intensity fires). Most of the area burned from 1931 to 2002 has occurred in the north half of the province. In comparison, very little area has burned in the east slopes.

Geographic differences in wildfire occurrence and burned area are related to regional differences in climate, topography, vegetation (fuel type), and land-use activities. The spatial variation in wildfire occurrence and area burned is discussed in more detail in Section 4.2, with reference to fire regime characteristics by natural region and natural subregion.

During the 1950s, many new lookout towers were built in Alberta. Nevertheless, not all wildfires were detected and recorded. Small wildfires in remote areas escaped detection, resulting in errors in the final number of wildfires and area burned. These errors, however, are not considered significant because the large wildfires were by 1960, recorded and mapped. The Phase 1 forest inventory program began in 1949 and continued until 1956. In 1956, the Phase 2 forest inventory program began. The aerial photography that supported these programs was used to also map any large wildfires not recorded by staff.

The low amount of burned area from 1983 to 1994, and again in 1996 and 1997 is a result of a cool and wet weather. As well, wildfire suppression effectiveness changed in 1983 (Cumming 2005).

4.1.2 Wildfire Size Class Distribution

As shown in Table 4.1, wildfires in Alberta are highly variable in size. The difference between the mean and median wildfire sizes indicates the size distribution is not symmetrical about the mean.

Wildfire frequency plotted against wildfire size approximates a negative exponential distribution with many small wildfires, and very few large wildfires (Table 4.1, Figure 4.7). The wildfire frequency declines exponentially as the wildfire size class increases. From 1961 to 2002, approximately 87% of all wildfires were less than or equal to 4 ha in size. Less than 2% of wildfires exceed 200 ha in size.

Alberta Sustainable Resource Development strives to contain 90% of all wildfires at 4 ha or less in size (Alberta Sustainable Resource Development 2004). This target is a 3% increase in the actual containment attained from 1961 to 2002.

The distribution of area burned is almost the mirror image of burn size (Table 4.2, Figure 4.8). This fits a positive exponential distribution where large wildfires contribute to the majority of the area burned. As the wildfire size class increases, area burned increases exponentially (Figure 4.8). Small (Class A and Class B) wildfires only account for 0.25% of the total area burned, whereas Class E wildfires account for 98% of the total area burned (Table 4.2).

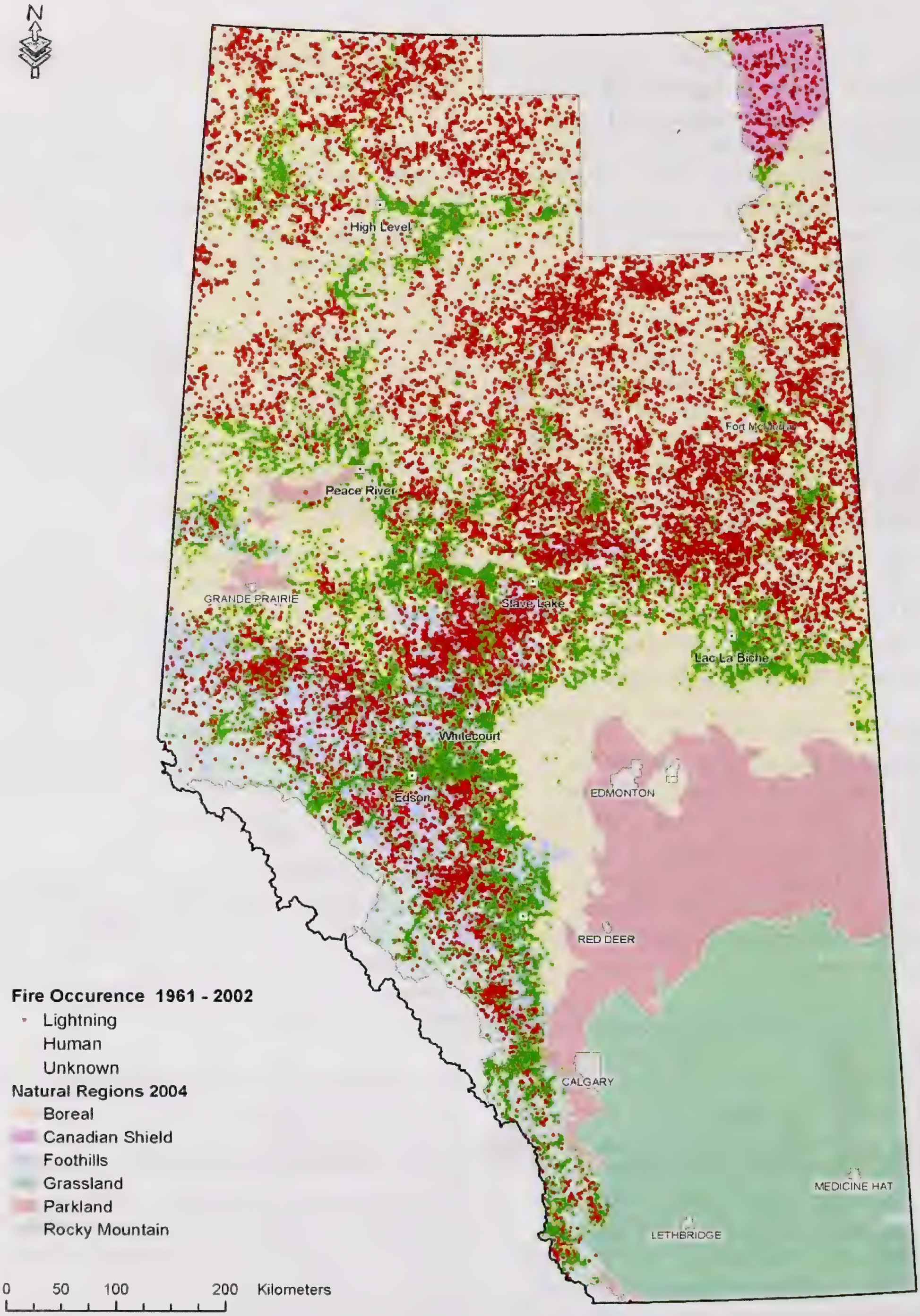

Figure 4.5 Wildfire occurrences by cause in Alberta (1961–2002)

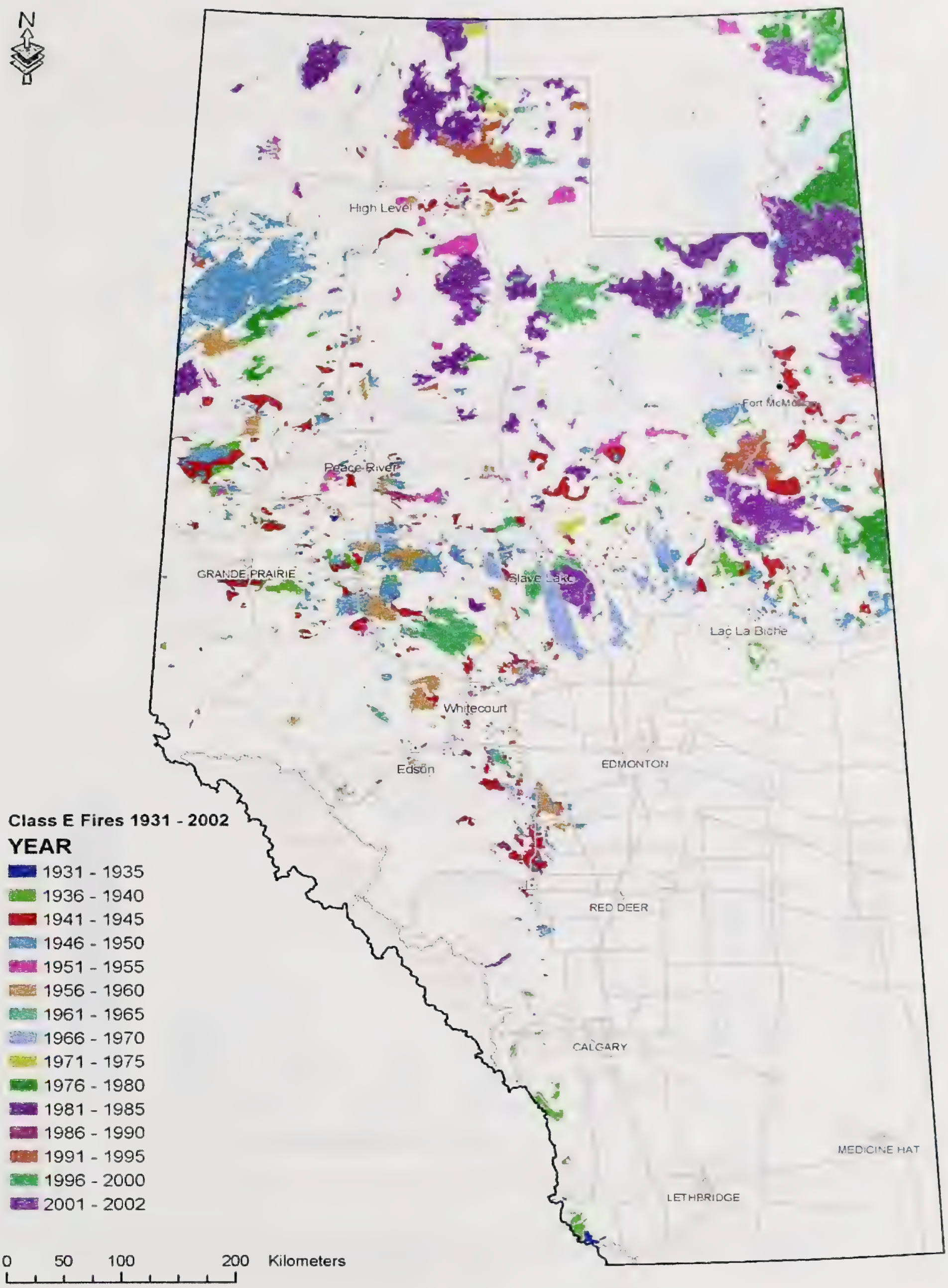

Figure 4.6 Area burned by Class E (> 200 ha) wildfires in Alberta (1931–2002)

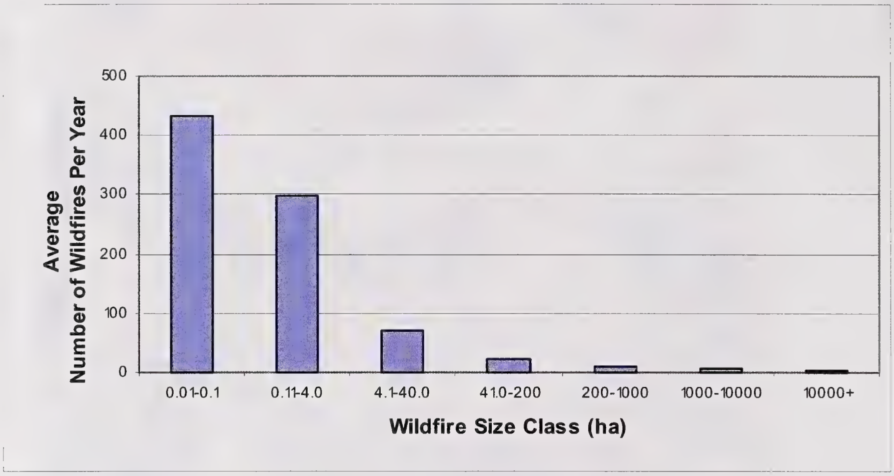

Figure 4.7 Size-class distribution of wildfire occurrence in Alberta (1961–2002)

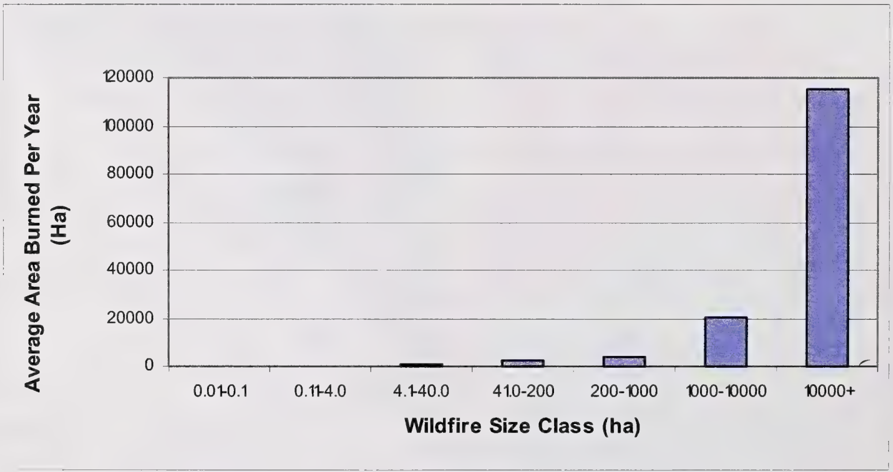

Figure 4.8 Size-class distribution of area burned in Alberta (1961–2002)

Table 4.2 Wildfire size class distribution in Alberta (1961–2002)

Class Size	Size (ha)	Number	%	Area (ha)	%
A	0.01–0.1	18,203	51.40	809	0.01
B	0.11–4.0	12,584	35.53	14,068	0.24
C	4.1–40.0	2,941	8.30	42,049	0.70
D	40.1–200.0	984	2.78	87,695	1.46
E	>200.0	702	1.98	5,852,704	97.59
Total		**35,414**	**100.0**	**5,997,325**	**100.0**

Table 4.3 Wildfire occurrence in Alberta by ignition source

Source	Number	%	Area Burned (ha)	%
Lightning	17,458	49.3	4,472,588	74.6
Human	17,119	48.3	1,503,455	25.0
Unknown	837	2.4	21,281	0.4
Total	**35,414**	**100.0**	**5,997,325**	**100.0**

Table 4.4 Distribution of human-caused wildfires in Alberta by general cause

General Cause	Number	%	Area Burned (ha)	%
Other Industries	2,400	14.0	557,343	37.1
Resident	4,237	24.7	465,983	31.0
Forest Industries	676	4.0	8,171	0.5
Railroad	591	3.5	108,229	7.2
Prescribed Burn	326	1.9	11,543	0.8
Recreation	4,922	28.8	119,012	8.0
Incendiary	2,196	12.8	72,792	4.8
Miscellaneous Known	1,771	10.3	160,382	10.6
Total	**17,119**	**100.0**	**1,503,455**	**100.0**

4.1.3 Wildfire Cause

In Alberta during the period between 1961 and 2002, 49.3% of wildfires were lightning-caused, and 48.3% were human-caused. Unknown sources accounted for 2.4% of all wildfires (Table 4.3). However, lightning-caused wildfires account for approximately 75% of the total area burned. This is due, in part, to the fact that the response time following wildfire detection is generally greater for lightning caused wildfires because they occur in less accessible areas.

Human-caused wildfires account for 25% of the total area burned, and less than 1% of the total area burned is a result of wildfires of unknown cause. The annual wildfire occurrence and area burned from 1961 to 2002 by lightning- and human-caused wildfires are summarized in Figures 4.9 to 4.12.

Of all human-caused wildfires, recreation (28.8%), resident (24.7%), and other industries (14.0%) cause the largest number of wildfires. Wildfires caused by other industries (37.1%) and by resident (31.0%) contribute the most to the total area burned (Table 4.4).

A comparison of Tables 4.3 and 4.5 indicates the main cause of Class E wildfires is lightning, with humans as a secondary contributor, whereas both human- and lightning-caused wildfires contribute equally to the total number of wildfires. From 1961 to 2002, lightning-caused wildfires accounted for 66.8% of the Class E wildfires, whereas human-caused wildfires accounted for 31.2% of the Class E wildfires. Since the Class E wildfires contribute 98% of the total area burned, the distribution by cause of Class E wildfires is similar to the area burned distribution by cause for all wildfires.

The percentage of human-caused Class E wildfires decreased during the five-year period from 1998 to 2002 from 31% (for the entire time period, 1961–2002) to 19%.

However, the area burned by human-caused wildfires increased from 24% to 31% of the total area burned due to several large human-caused wildfires (e.g., the 1998 Mitsue wildfire, the 2001 Chisholm wildfire, and the 2002 House River wildfire).

The spatial pattern of wildfire occurrence by cause is illustrated in Figure 4.5. Human-caused wildfires generally occur close to roads, residences, and recreation areas. The spatial distribution of wildfires caused by residents, forest industries, railroad, recreation, other industries, and incendiary (Figures 4.13 to 4.18) indicates a spatial pattern directly associated with the general cause category. For example, wildfires caused by railroads are all distributed along railroads, and resident-caused wildfires are close to towns and settlements.

4.1.4 Wildfire Season

In Alberta, the peak wildfire season occurs from May to August (Table 4.6, Figure 4.19). From 1961 to 2002, 77% of all wildfires occurred during this period. April, September, and October typically account for a very small proportion of the total number of wildfires. On average, about 8% of wildfires occur in April, while less than 5% of wildfires occur in September and in October.

The lower number of lightning wildfires and associated area burned prior to 1980 (Figures 4-9 and 4-11) is likely due to a reduced lightning detection capability.

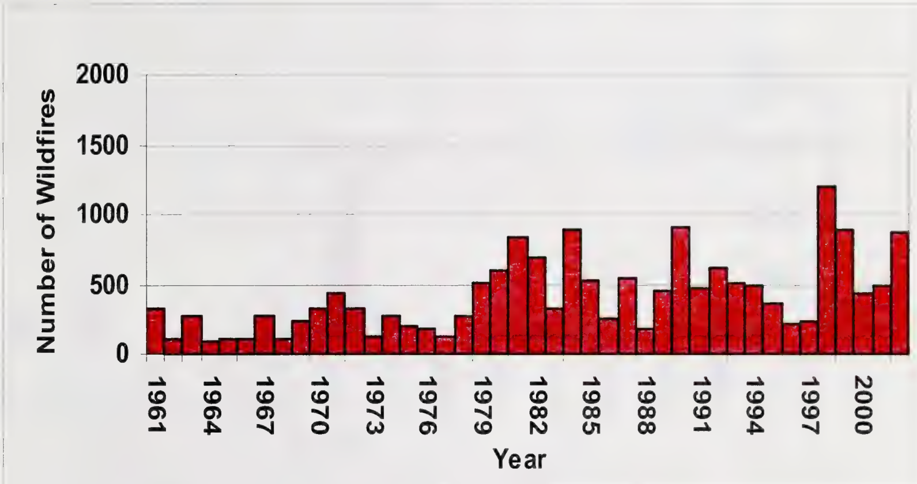

Figure 4.9 Lightning-caused wildfire occurrence in Alberta (1961–2002)

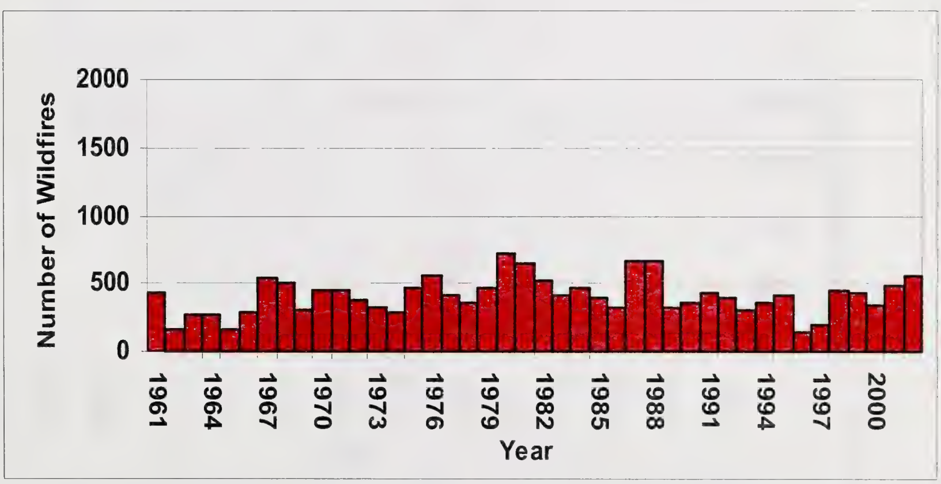

Figure 4.10 Human-caused wildfire occurrence in Alberta (1961–2002)

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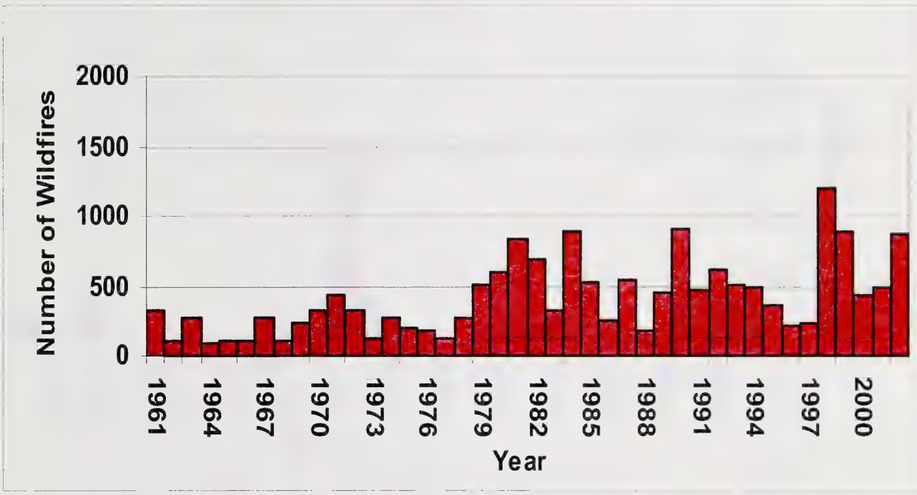

Figure 4.9 Lightning-caused wildfire occurrence in Alberta (1961–2002)

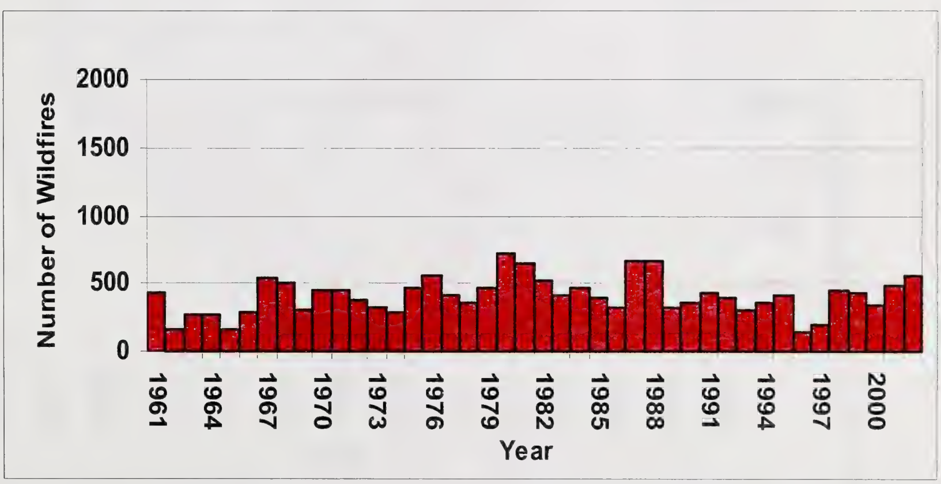

Figure 4.10 Human-caused wildfire occurrence in Alberta (1961–2002)

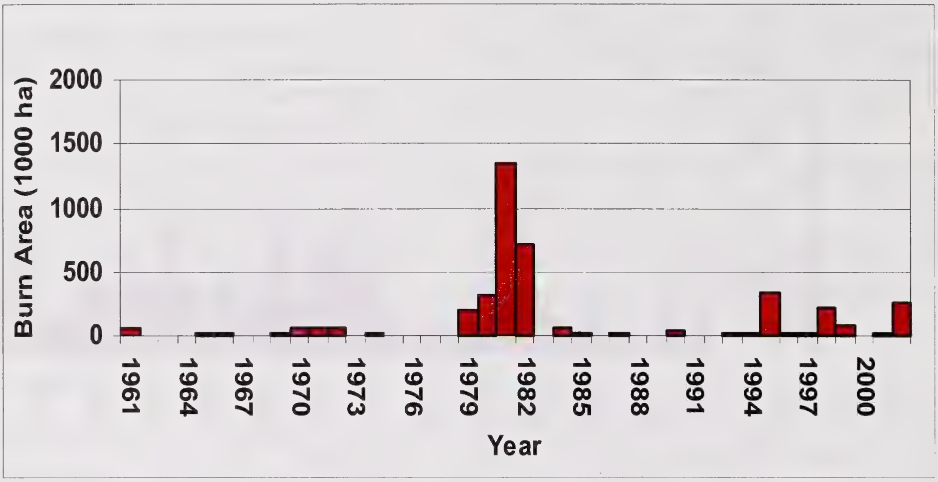

Figure 4.11 Lightning-caused wildfire area burned in Alberta (1961–2002)

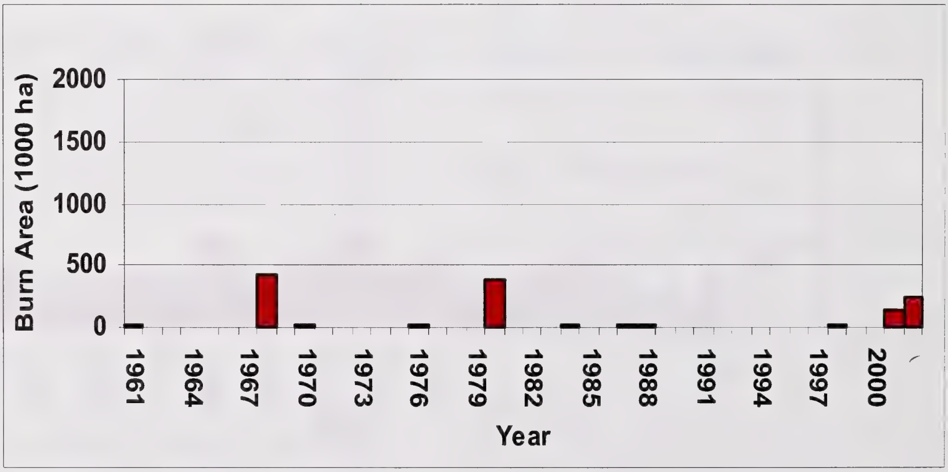

Figure 4.12 Human-caused wildfire area burned in Alberta (1961–2002)

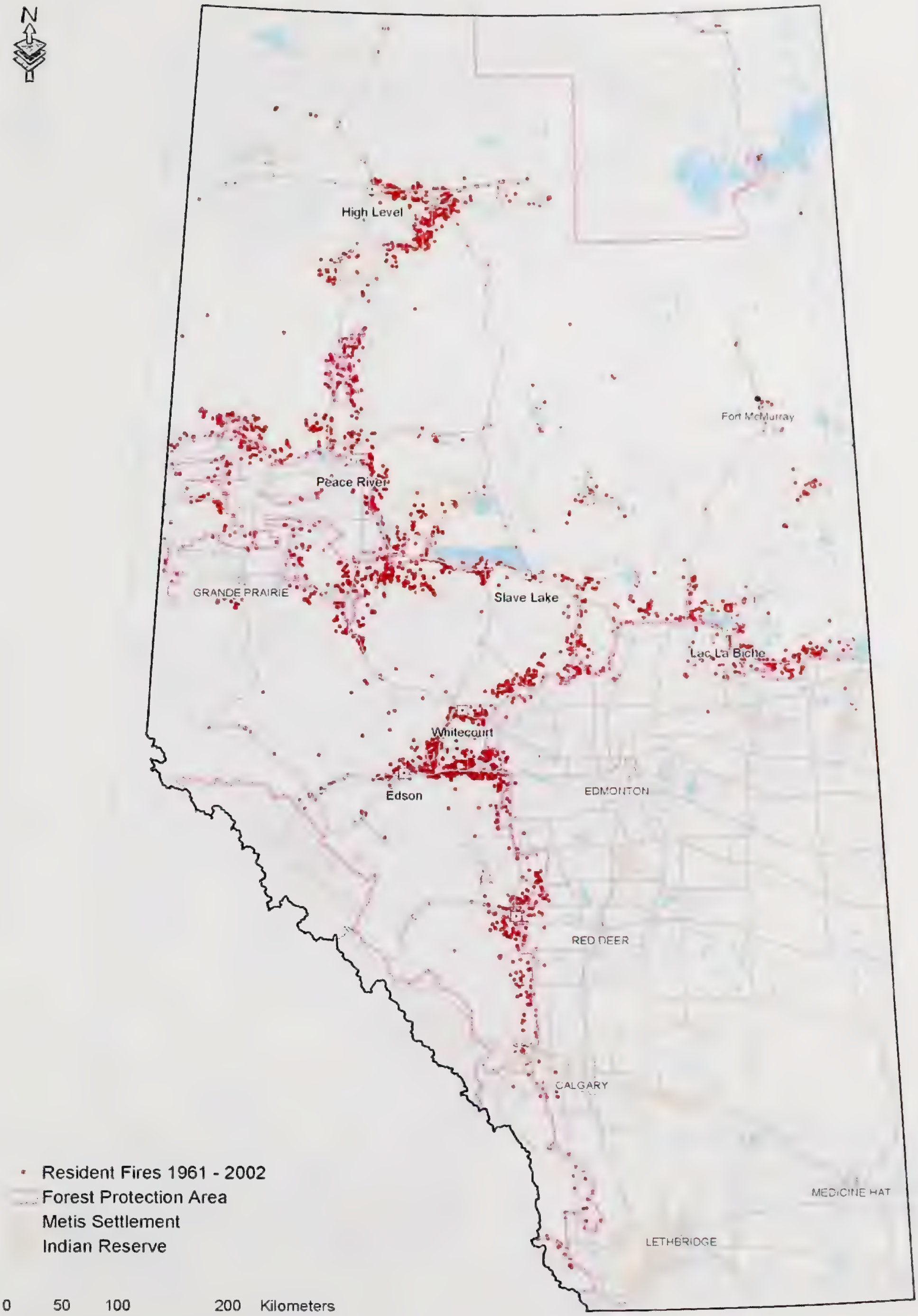

Figure 4.13 Residence-caused wildfires in Alberta (1961–2002)

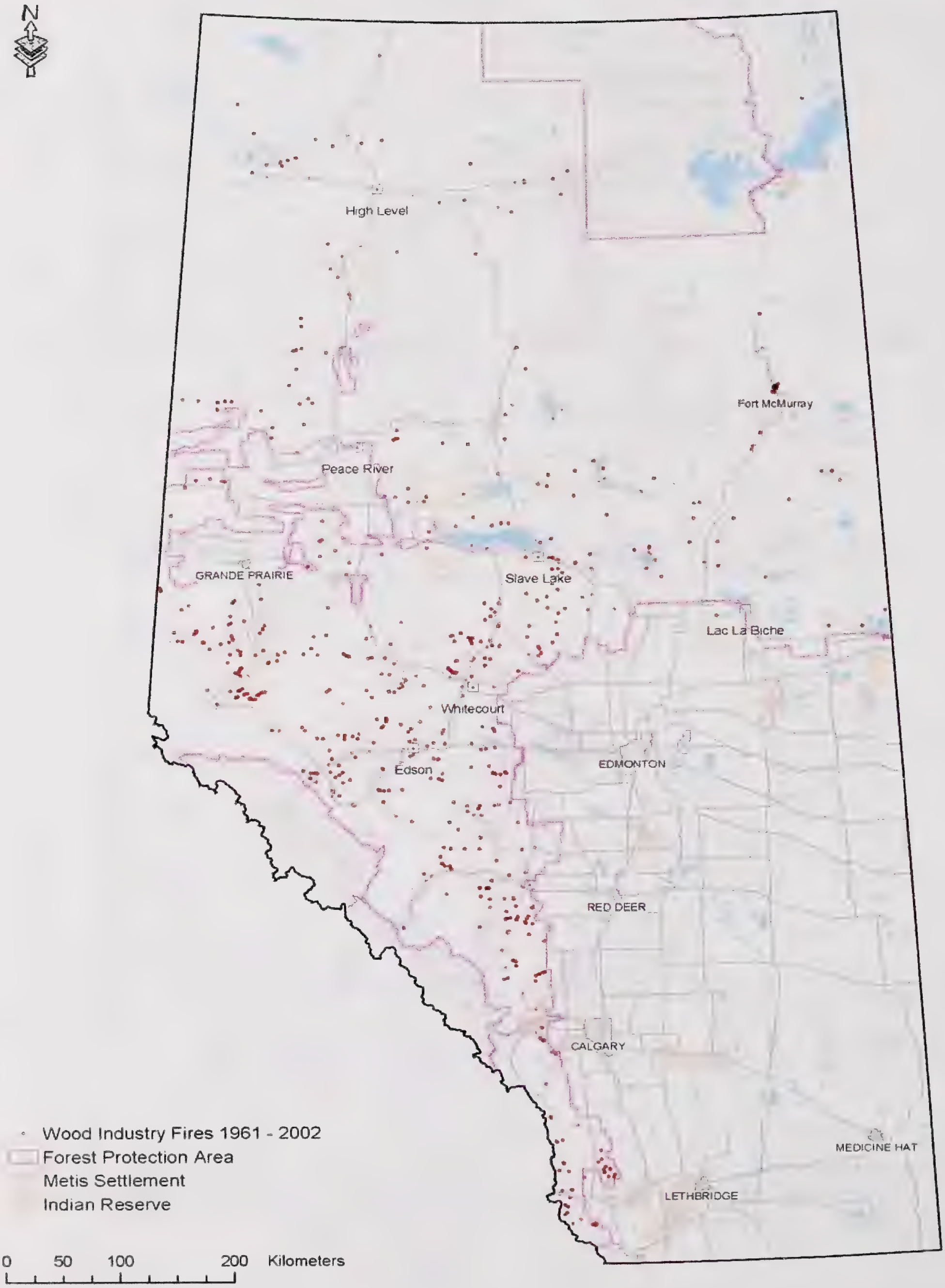

Figure 4.14 Wood-industry-caused wildfires in Alberta (1961–2002)

Figure 4.15 Railroad-caused wildfires in Alberta (1961–2002)

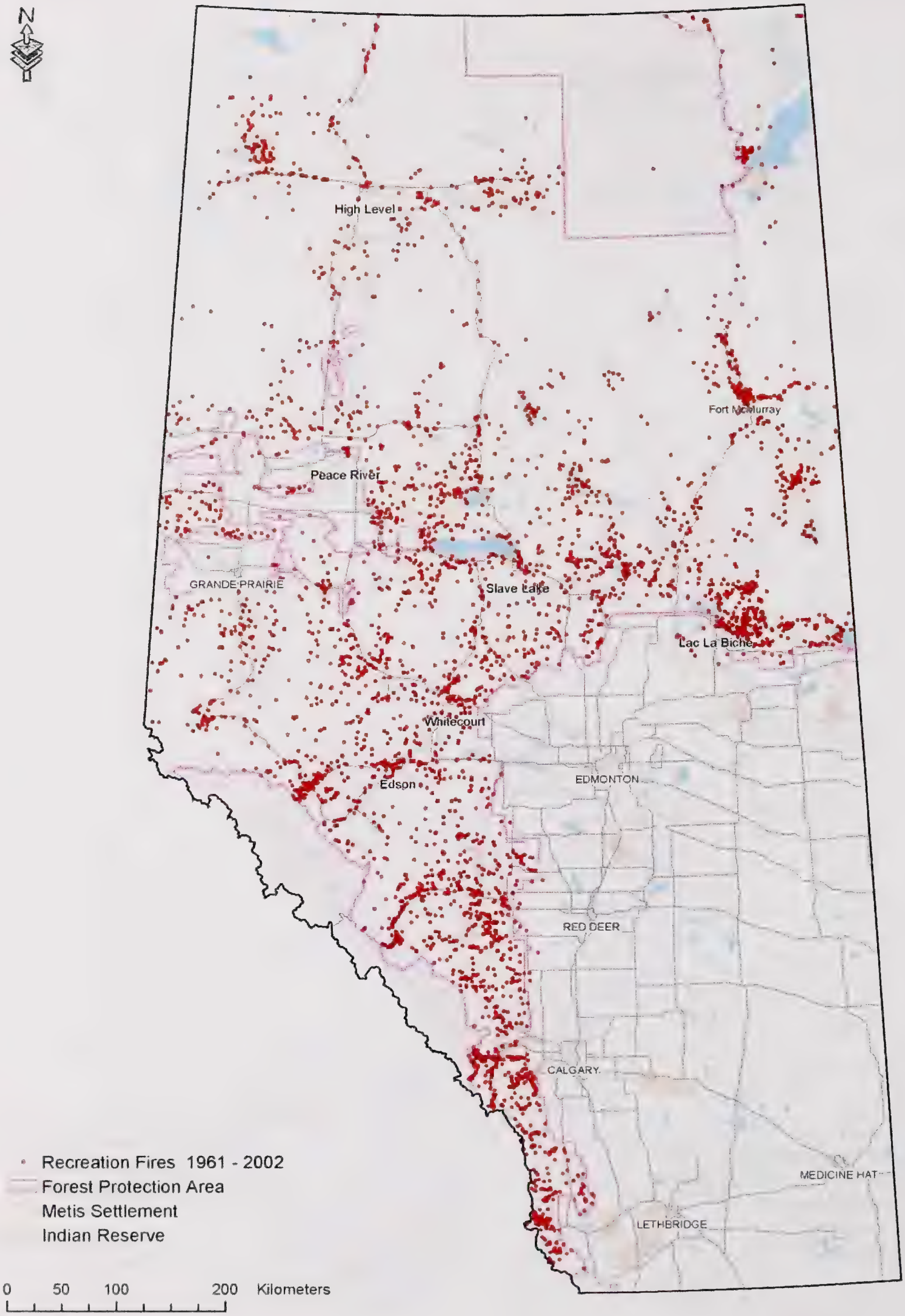

Figure 4.16 Recreation-caused wildfires in Alberta (1961–2002)

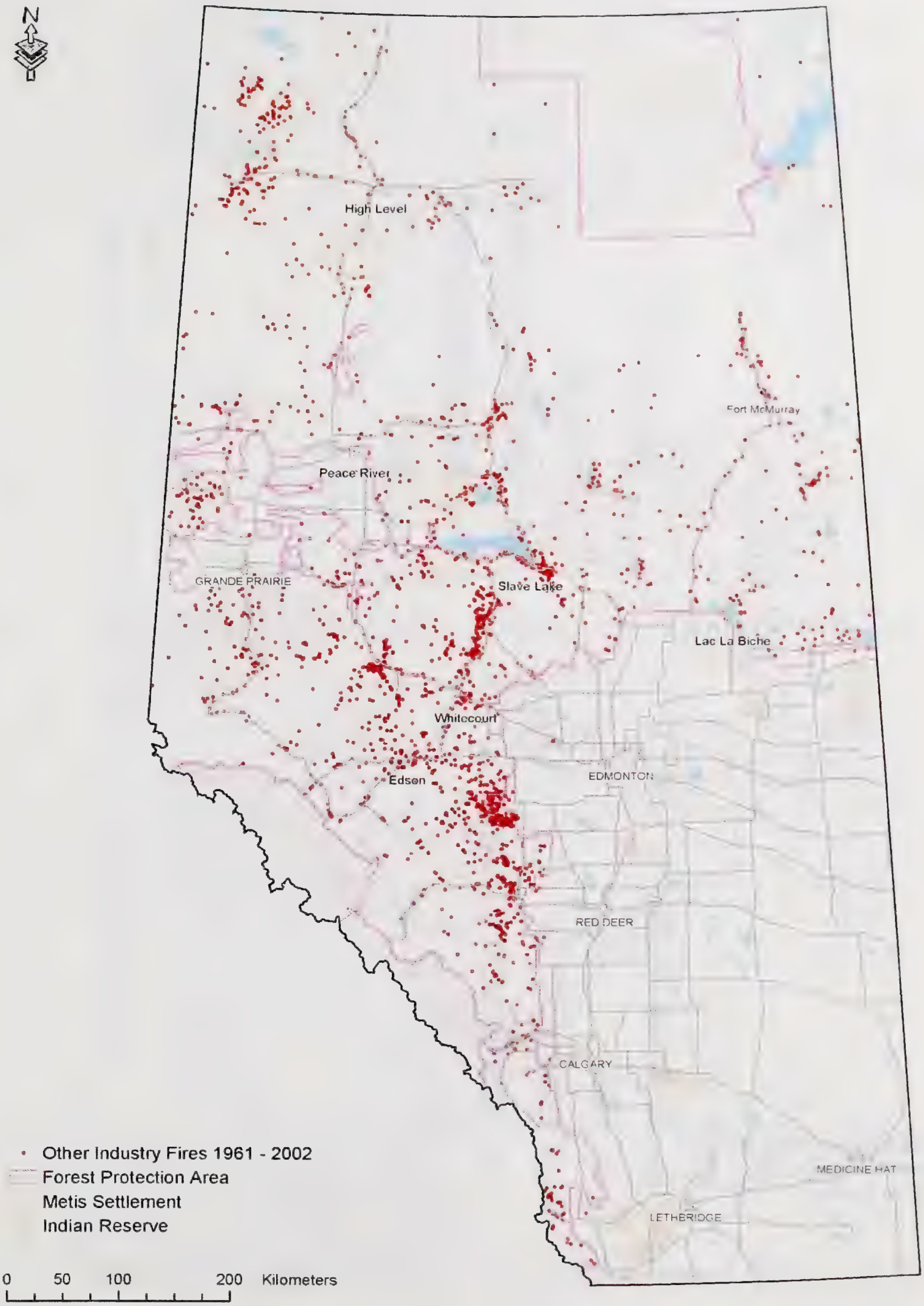

Figure 4.17 Other-industry-caused wildfires in Alberta (1961–2002)

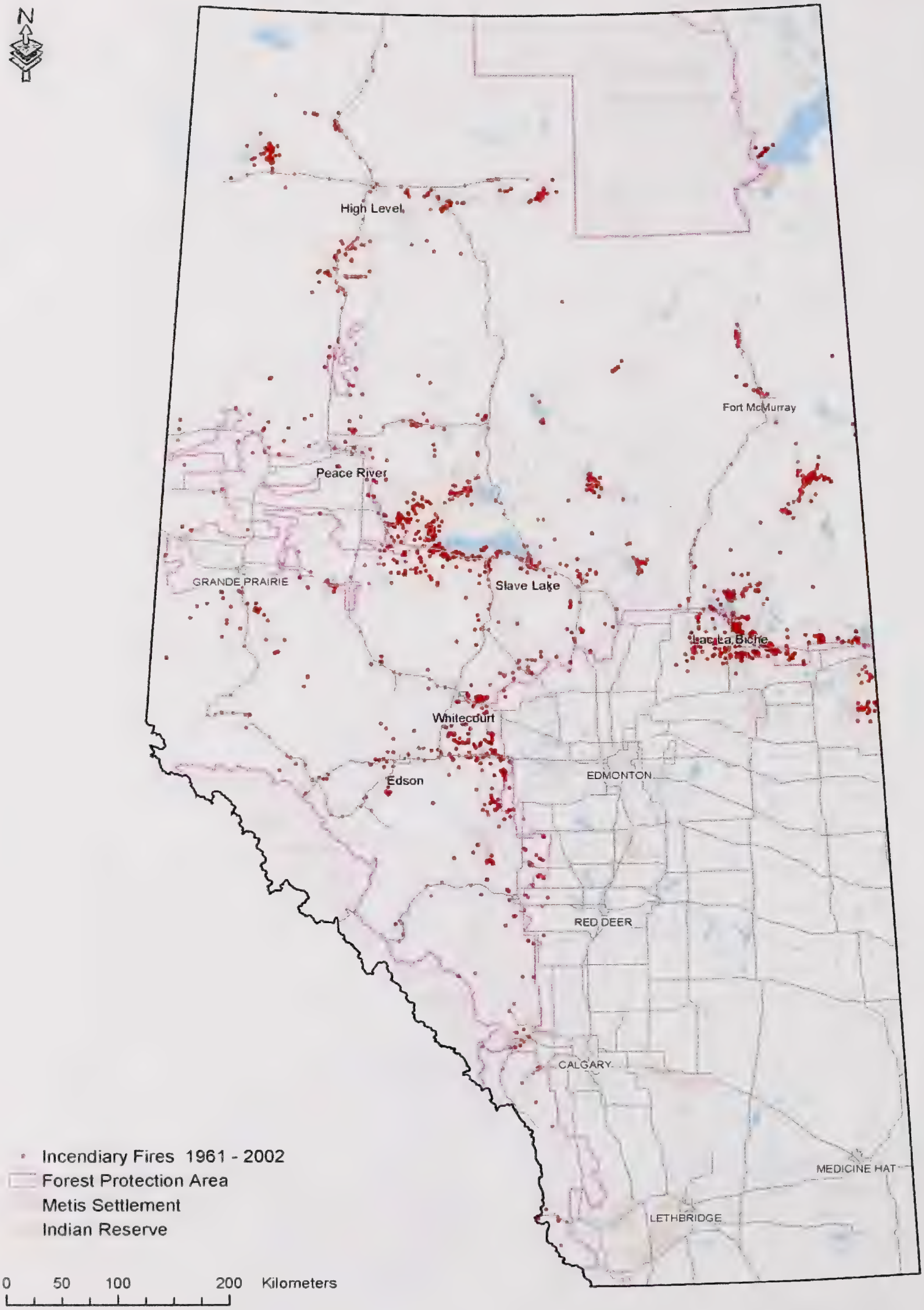

Figure 4.18 Incendiary-caused wildfires in Alberta (1961–2002)

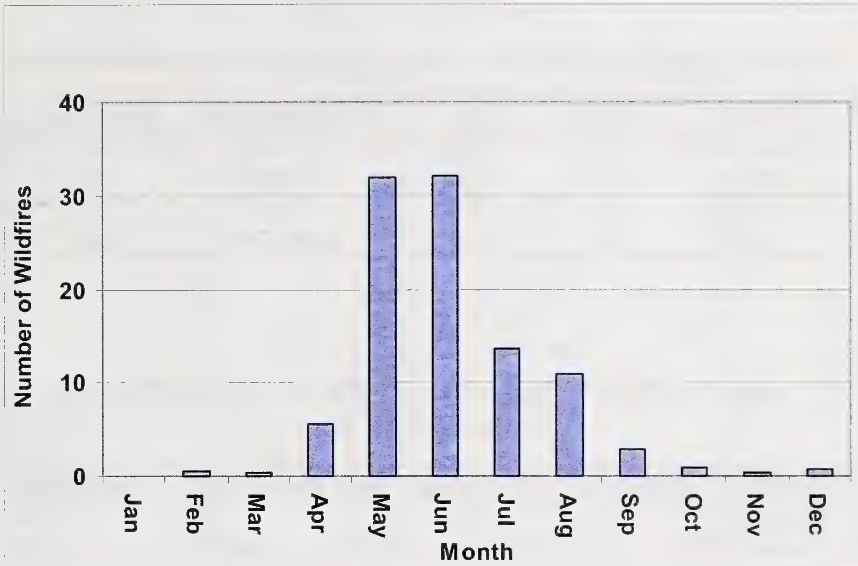

Figure 4.19 Distribution of wildfire occurrence by month in Alberta (1961–2002)

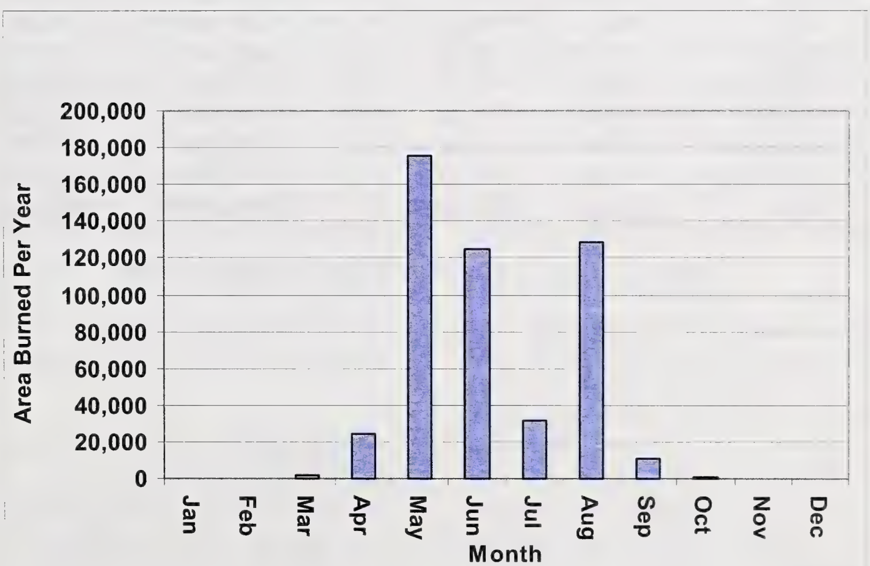

Figure 4.20 Distribution of area burned by month on average in Alberta (1961–2002)

Table 4.5 Distribution of Class E wildfires by cause in Alberta (1961–2002)

Cause	Number	%	Area Burned (ha)	Percentage
Lightning	469	66.8	4,416,607	75.4
Human	219	31.2	1,419,678	24.3
Unknown	14	2.0	16,419	0.3
Total	**702**	**100.0**	**5,852,704**	**100.0**

Table 4.6 Wildfire frequency and area burned distributions by month in Alberta (1961–2002)

Month	Frequency[†]	Percentage	Area Burned (ha)	Percentage
January	270	0.76	515	0.01
February	241	0.68	4,662	0.08
March	501	1.42	16,677	0.28
April	2,865	8.09	291,553	4.87
May	7,284	20.57	2,105,570	35.16
June	7,516	21.22	1,493,722	24.94
July	6,811	19.23	384,828	6.42
August	5,735	16.20	1,547,294	25.83
September	1,690	4.77	127,349	2.12
October	1,518	4.29	9,300	0.16
November	715	2.02	2,989	0.05
December	266	0.75	4,580	0.08
Total	**35,412**	**100.00**	**5,989,039**	**100.00**

[†]Note: Two Class E fires in 1970 have a missing fire date.

Table 4.7 Class E wildfire frequency and area burned distributions by month in Alberta (1961–2002)

Month	Frequency[†]	Percentage of Total Frequency	Area Burned (ha)	Percentage of Total Area	Average Fire Size
January	0	0	0	0	0
February	4	0.57	3,949	0.07	987
March	2	0.29	14,971	0.26	7,485
April	39	5.57	268,635	4.60	6,888
May	224	32.00	2,054,677	35.15	9,173
June	225	32.14	1,468,441	25.13	6,526
July	96	13.71	367,790	6.29	3,831
August	77	11.00	1,533,608	26.24	19,917
September	20	2.86	122,722	2.10	6,136
October	6	0.86	4,300	0.07	717
November	2	0.29	1,316	0.02	658
December	5	0.71	4,011	0.07	802
	700	**100.00**	**5,844,415**	**100.00**	**8,349**

[†]Note: Two Class E wildfires in 1970 have a missing fire date.

In terms of area burned, May, June, and August are the peak months, while May has the highest area burned percentage (35.2%). (Table 4.6, Figure 4.20). Large fires in May are typically boreal spring wildfires driven predominantly by strong southeast winds. Many of the larger lakes are still frozen at this time, thereby limiting the use of amphibious air tankers. A lack of green-up, minimum foliar moisture levels ("spring dip"), and little night-time relative humidity recovery often challenge suppression efforts to contain these early season human-caused fires.

July accounts for 19.2% of the total wildfire frequency, but only contributes 6.4% of the total area burned. This is because the highest monthly precipitation occurs during July. Understorey and overstorey green-up has also occurred by July, thereby reducing the flammability of grass and deciduous and mixedwood stands.

The seasonal frequency distribution of Class E wildfires shows a different pattern from the seasonal frequency distribution for all wildfires (Table 4.7, Figure 4.21). However, in terms of area burned, the distributions of Class E wildfires and wildfires of all classes have a very similar pattern (Figure 4.20, Figure 4.22), since Class E wildfires contribute the most to the total area burned.

About 64% of the Class E wildfires occur in May and June, and account for more than 60% of the total area burned (Table 4.7). July and August experience about 14% and 11% respectively of the Class E wildfires. Although only 11% of Class E wildfires occur in August, they account for 26% of the total area burned in a year. The average wildfire size in Table 4.7 also shows that August has the highest average Class E wildfire size.

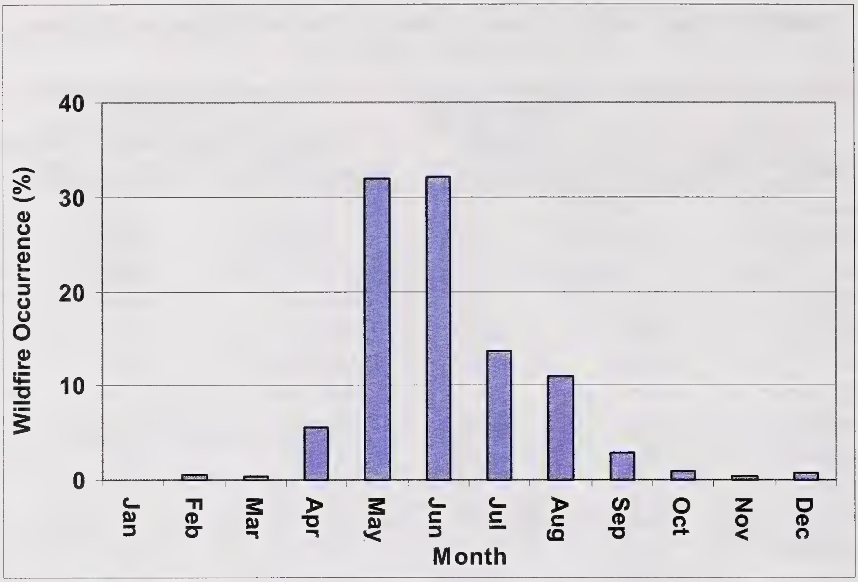

Figure 4.21 Class E wildfires: Percentage frequency of occurrence by month in Alberta (1961–2002)

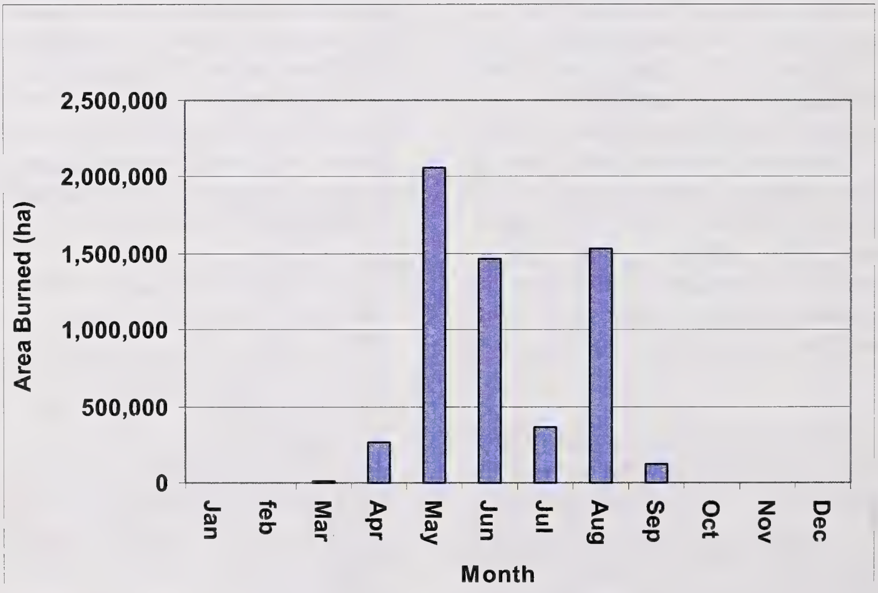

Figure 4.22 Class E wildfires: Total area burned by month in Alberta (1961–2002)

During the 1981 fire season, several wildfires that started in August exceeded 100,000 ha in size.

4.1.5 Seasonal Distributions by General Cause

Wildfire causes also demonstrate seasonal patterns. Human-caused wildfire frequency peaks in early spring. In April and May, 94 and 71% of wildfires respectively are human-caused (Figure 4.23). Lightning-caused wildfire frequencies peak from June through August, accounting for 76% of the wildfires during the summer months (Figure 4.23). More than half of the wildfires with unknown causes occur from April to June, peaking in May.

Lightning-caused wildfires contribute more than 90% of the total burned area in June through August. In September, 75% of the total area burned is due to lightning-caused fires, but the total area burned is very small. Human-caused wildfires burn the largest areas in April and May (Figure 4.24).

During April and May, 98 and 53% respectively of the area burned are due to human-caused wildfires. Because the area burned in May is larger than the area burned in any other month, the area burned in May due to human activity accounts for 75% of the total annual human-caused area burned. The area burned from October to March is mostly human-caused, but the total area burned during these months is minimal.

4.2 Fire Regimes by Natural Region and Natural Subregion

4.2.1 Overall Wildfire Occurrence and Area Burned

Wildfires occur in all natural regions and subregions in Alberta (Tables 4.8 through and 4.10). Wildfire occurrence and area burned vary between Natural Region (NR) and Natural Subregion (NSR) due to differences in vegetation, climate, topography, and land-use patterns (Figures 4.25 to 4.28). The spatial distributions of wildfire frequency and area burned by natural subregion are shown in Figures 4.29 and 4.30, respectively. Since some of the NRs and NSRs are largely non-forested areas, the Forest Protection Area (FPA) boundary was used to include only those wildfires within the FPA in the analysis.

4.2.1.1 Wildfire Occurrence and Area Burned within Natural Regions

Wildfire occurrence and area burned in each natural region is summarized in Table 4.8 as both total areas and percentages. From 1961 to 2002 in Alberta, 61% of wildfires occurred in the Boreal Forest NR, 31% in the Foothills NR, 6% in the Rocky Mountain NR, less than 2% in the Canadian Shield NR, and very small proportions in the Grassland and Parkland NRs.

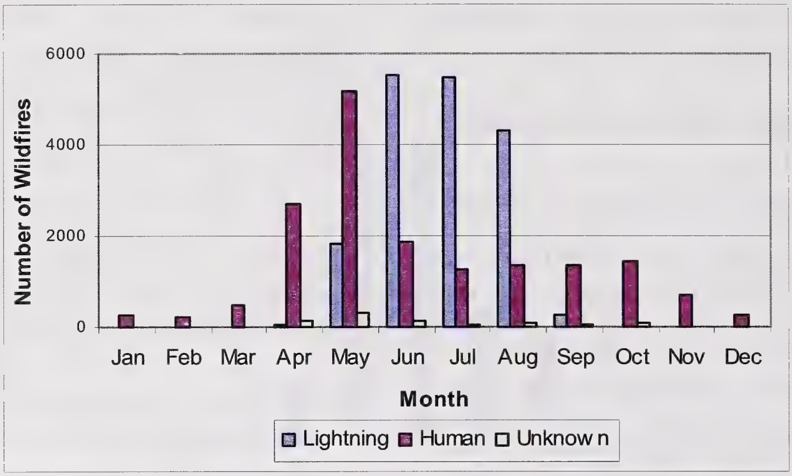

Figure 4.23 Wildfire frequency by month and cause in Alberta (1961–2002)

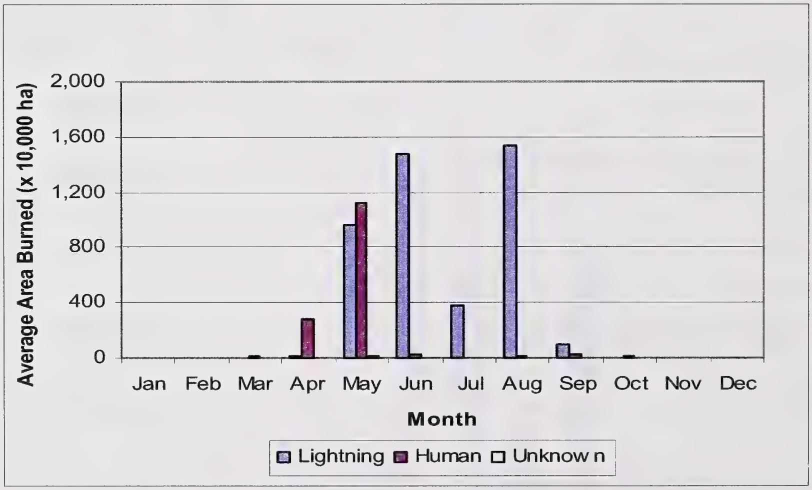

Figure 4.24 Area burned by month and by cause in Alberta (1961–2002)

Trends in area burned do not parallel trends in wildfire frequency in natural regions, except for in the Boreal Forest NR, which ranks first in both wildfire frequency and overall area burned (73%). The Canadian Shield NR ranks second in total area burned (14%), and the Foothills NR ranks third (13%). The Grassland, Parkland, and Rocky Mountain NRs together account for less than 1% of the total area burned.

The Canadian Shield and the Rocky Mountain NRs have notable statistical differences for wildfire occurrence and area burned. The Canadian Shield NR contributes less than 2% of the total wildfire occurrence but accounts for 14% of the total area burned, indicating low wildfire frequency but very large wildfire sizes. The Rocky Mountain NR accounts for 6% of the total number of the wildfires but less than 1% of the total area burned, suggesting the occurrence of small-size wildfires.

Average wildfire sizes listed in Table 4.8 further illustrate wildfire regime differences between the natural regions. The Canadian Shield NR has the largest average wildfire size (1,555 ha), while the Rocky Mountain NR has the smallest average wildfire size (about 10 ha). The Boreal Forest, Foothills, Grassland, and Parkland NRs have average wildfire sizes of 203 ha, 70 ha, 18 ha, and 12 ha respectively.

Table 4.8 Wildfire occurrence and area burned distribution by natural region in Alberta (1961– 2002)

Natural Region	Frequency	% of Total Frequency	Area Burned (ha)	% of Total Area Burned	Average Wildfire Size (ha)
Boreal Forest	21,129	61.19	4,291,561	72.76	203.11
Canadian Shield	536	1.55	833,475	14.13	1,554.99
Foothills	10,650	30.85	751,564	12.74	70.57
Grassland	22	0.06	403	0.01	18.32
Parkland	73	0.21	893	0.02	12.23
Rocky Mountain	2,121	6.14	20,249	0.34	9.55
Total	**34,531**	**100.00**	**5,898,145**	**100.00**	**311.46**

Table 4.9 Wildfire frequencies by cause in each natural subregion from 1961–2002

Size Class	Boreal Forest						Cdn. Shield		Foothills		Grass -land	Parkland		Rocky Mountain			Total
	Boreal Highlands	Central Mixedwood	Dry Mixedwood	Peace River Lowlands	Sub-Arctic	Wetland Mixedwood	Athabasca Plain	Kazan Upland	Lower Foothills	Upper Foothills	Foothills Fescue	Foothills Parkland	Peace River Parkland	Alpine	Montane	Subalpine	
Human-Caused Fires																	
A	64	2,421	1,450	46	13	283	17	11	2,159	852	9	12	10	18	589	435	**8,389**
B	32	1,841	1,873	47	14	261	12	23	1,374	278	2	21	16	3	306	92	**6,195**
C	4	426	810	5	4	57	1	1	312	43	2	6	6	1	38	20	**1,736**
D	1	128	306	2	0	11	0	2	100	10	1	2	5	0	6	6	**580**
E	0	58	100	0	0	11	1	0	33	5	0	2	0	0	1	7	**218**
Total	**101**	**4,874**	**4,539**	**100**	**31**	**623**	**31**	**37**	**3,978**	**1,188**	**14**	**43**	**37**	**22**	**940**	**560**	**17,118**
Lightning-Caused Fires																	
A	347	3,395	445	17	269	423	24	104	2,349	1,665	6	4	5	15	116	330	**9,514**
B	355	2,706	339	21	556	631	84	160	754	303	5	2	0	3	26	64	**6,009**
C	56	540	48	2	135	117	15	35	112	32	1	0	0	0	0	4	**1,097**
D	17	161	9	0	55	40	9	13	41	14	0	0	1	0	2	7	**369**
E	41	219	10	1	65	20	8	21	57	17	0	0	0	0	1	9	**469**
Total	**816**	**7,021**	**851**	**41**	**1,080**	**1,231**	**140**	**333**	**3,313**	**2,031**	**12**	**6**	**6**	**18**	**145**	**414**	**17,458**
Unknown-Caused Fires																	
A	2	93	62	4	1	12	0	0	84	20	0	0	2	0	12	8	**300**
B	1	109	130	3	2	17	0	0	83	16	0	0	1	0	14	4	**380**
C	2	25	55	0	1	1	0	0	15	2	0	0	0	0	6	1	**108**
D	0	9	21	0	0	0	0	0	3	1	0	0	0	0	1	0	**35**
E	0	6	5	0	0	1	0	0	1	2	0	0	1	0	0	0	**16**
Total	**5**	**242**	**273**	**7**	**4**	**31**	**0**	**0**	**186**	**41**	**0**	**0**	**4**	**0**	**33**	**13**	**839**
SUM	**922**	**12,137**	**5,663**	**148**	**1,115**	**1,885**	**171**	**370**	**7,477**	**3,260**	**26**	**49**	**47**	**40**	**1,118**	**987**	**35,415**
%	**2.6**	**34.3**	**16.0**	**0.4**	**3.1**	**5.3**	**0.5**	**1.0**	**21.1**	**9.2**	**0.1**	**0.1**	**0.1**	**0.1**	**3.2**	**2.8**	**100.0**

Natural regions are large and variable ecological units. The spatial variability within these units may obscure important trends (Parisien et al. 2004). Since natural subregions are climatically and geographically distinct subdivisions of natural regions, they have different wildfire patterns. For example, within the Boreal Forest NR, most of the wildfires (about 81%) occur in the Central and Dry Mixedwood NSRs. In the Rocky Mountain NR, wildfires are uncommon and limited in size because of topography (i.e., lightning shadow, valley orientation, fuel type, and fuel breaks). Most Rocky Mountain wildfires occur in the Montane and Sub-Alpine NSRs. In the Canadian Shield NR, 68% of the wildfires occur in the Kazan Upland NSR, while the Athabasca Plain NSR, which includes Lake Athabasca, accounts for the other 32%.

4.2.1.2 Wildfire Occurrence and Area Burned within Natural Subregions

Various natural subregions show different patterns of wildfire occurrence and area burned (Table 4.10). The contribution of each natural subregion to overall wildfire frequency and area burned is shown in Table 4.10. The distributions of the wildfire occurrence and area burned by subregion and the distribution of area burned by subregion are also summarized in Figure 4.25 and Figure 4.26, respectively.

As evident in Table 4.10, the three NSRs with the highest proportions of wildfire occurrence overall are the Central Mixedwood (35%), Lower Foothills (21%), and Dry Mixedwood (14%). The Wetland Mixedwood NSR accounts for about 5% of the total wildfire occurrence. The remaining natural subregions contribute a minor proportion of the total wildfire frequency.

The three NSRs with the greatest area burned are the Central Mixedwood (41%), Boreal Highlands (11%), and Sub-Arctic (11%) NSRs. Although the Lower Foothills and Dry Mixedwood NSRs have the second- and third-highest proportions of wildfires in terms of frequency, they only account for 10 and 3%, respectively, of the total area burned. In contrast, the Kazan Upland and Athabasca Plain NSRs collectively contribute less than 2% of the overall wildfire occurrence; however, each NSR contributes about 7% to the total area burned.

When combined, the wildfire occurrence and burned area statistics reveal some subregion-level wildfire regimes. For example, the Montane NSR accounts for 3% of the total wildfire occurrence but a negligible amount (1%) of the total area burned. This indicates that wildfires have been frequent but restricted in size, perhaps because of light fuel loading and topographic barriers to the spread of wildfire. Wildfires in the montane NSR are easier to access, and the occurrence of grassland meadows and aspen stands reduce the fire behaviour potential during green-up.

In contrast, the Athabasca Plain NSR has less than 0.5% of the total wildfire occurrence, but accounts for about 7% of the total area burned. This indicates that wildfires are infrequent but extensive, possibly due to a continuous fuel load, a dry summer season, and a lower suppression priority. The Kazan Upland NSR shows a similar frequency-size pattern to the Athabasca Plain NSR, probably due to the same reasons.

Table 4.10 Wildfire occurrence and area burned by natural subregion in Alberta (1961–2002)

NSR	Wildfire Frequency	% of Total Wildfire Frequency	Area Burned (ha)	% of Total Area Burned	Average Wildfire Size (ha)
Boreal Highlands	921	2.67	662,194	11.23	719.00
Central Mixedwood	12,116	35.09	2,399,562	41.44	198.05
Dry Mixedwood	4,970	14.39	179,799	3.20	36.18
Peace River Lowlands	137	0.40	9,151	0.16	66.80
Sub-Arctic	1,113	3.22	639,953	10.84	574.98
Wetland Mixedwood	1,872	5.42	347,254	5.89	185.50
Athabasca Plain	168	0.49	409,125	7.02	2,435.27
Kazan Upland	368	1.07	419,351	7.11	1,139.44
Lower Foothills	7,402	21.43	567,354	9.62	76.65
Upper Foothills	3,248	9.41	183,886	3.12	56.62
Foothills Fescue	22	0.06	403	0.01	18.32
Foothills Parkland	43	0.12	500	0.01	11.63
Peace R. Parkland	30	0.09	331	0.01	11.03
Alpine	40	0.12	1,388	0.02	34.70
Montane	1,102	3.19	2,837	0.05	2.57
Subalpine	979	2.83	15,194	0.27	15.52
Total	**34,531**	**100.00**	**5,838,282**	**100.00**	**169.07**

The wildfire regimes can be further characterized by the average wildfire sizes. In Alberta, the average wildfire size shows extreme variation, from 2,435 ha in the Athabasca Plain NSR to just 3 ha in the Montane NSR. The largest average wildfire sizes occur in the Canadian Shield NR, where the Athabasca Plain and Kazan Upland NSRs have very large average wildfire sizes of 2,435 ha and 1,139 ha respectively. The Boreal Highlands and Sub-Arctic NSRs also have relatively high average wildfire sizes at 719 and 575 ha respectively. The Central and Wetland Mixedwood NSRs have an average wildfire size of just under 200 ha. Other NSRs have average wildfire sizes of under 100 ha.

4.2.2 Wildfire Density and Annual Area-Burn Rate

Differences in wildfire occurrence and area burned may be influenced by the size of the natural subregion. For example, the Central Mixedwood NSR contributes the most to both wildfire occurrence and area burned, but it is also the largest NSR in the province.

To control the influence of area on comparisons between subregions in terms of wildfire frequency and burn area so that these statistics can be compared, a standardized unit base was calculated.

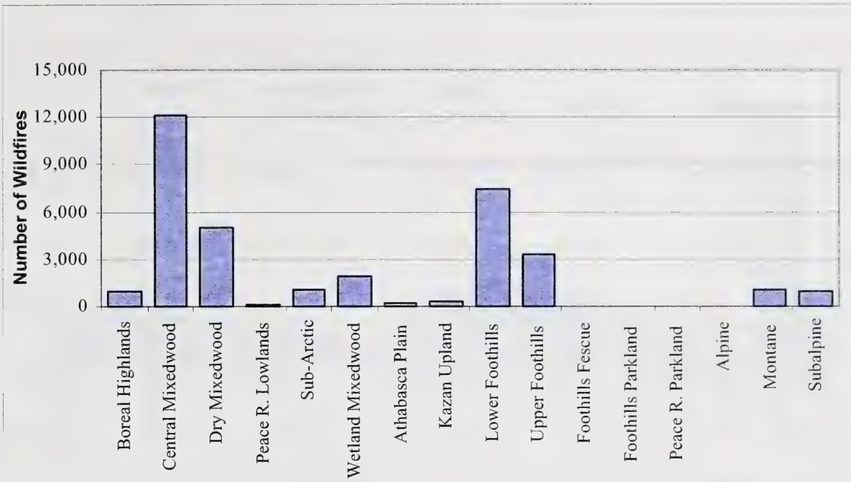

Figure 4.25 Wildfire occurrence by natural subregion in Alberta (1961–2002)

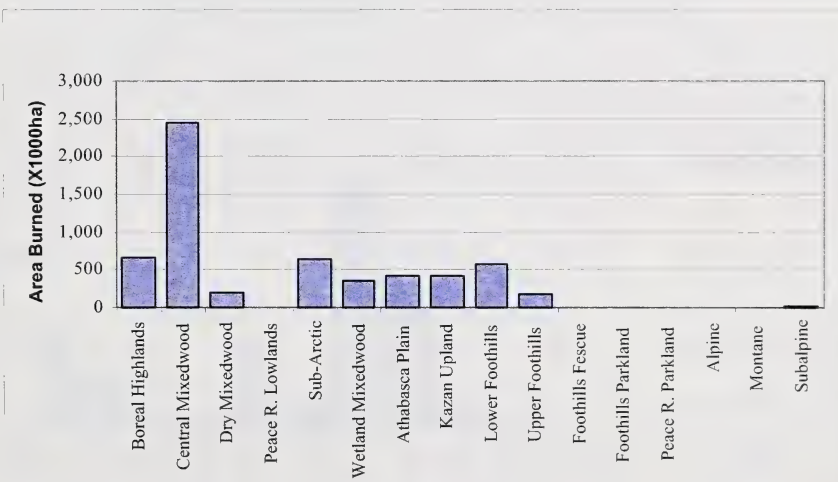

Figure 4.26 Total area burned by natural subregion in Alberta (1961–2002)

Table 4.11 Number of wildfires, area burned, and annual area-burn rate in each natural subregion (1961–2002)

NR	Subregion	# of Fires	Total Area (ha)	Area Covered by Lakes and Major Rivers	Area Burned (1961–2002)	# of Fires/Yr / 10^6 ha	% Burned/ Yr
Boreal Forest	Boreal Highlands	921	2,005,508	46,855	662,194	11.20	0.80
	Central Mixedwood	12,116	13,530,665	364,837	2,399,562	21.91	0.43
	Dry Mixedwood	4,970	4,974,980	236,375	179,799	24.97	0.09
	Peace R. Lowlands	137	258,403	37,788	9,151	14.79	0.10
	Sub-Arctic	1,113	2,079,778	88,843	639,653	13.31	0.76
	Wetland Mixedwood	1,872	3,053,284	19,886	347,254	14.69	0.27
Canadian Shield	Athabasca Plain	168	671,115	228,514	409,125	9.04	2.20
	Kazan Upland	368	878,872	64,550	419,351	10.76	1.23
Foothills	Lower Foothills	7,402	6,461,442	39,970	567,354	27.45	0.21
	Upper Foothills	3,248	2,748,295	4,153	183,886	28.18	0.16
Grassland	Foothills Fescue	22	20,399	0	403	25.68	0.05
Parkland	Foothills Parkland	43	64,788	253	500	15.86	0.02
	Peace R. Parkland	30	62,840	649	331	11.49	0.01
Rocky Mountain	Alpine	40	570,183	53	1,388	1.67	0.01
	Montane	1,102	330,829	10,884	2,837	82.01	0.02
	Subalpine	979	1,736,658	3,830	15,194	13.45	0.02
Total		**34,531**	**39,448,039**	**1,147,440**	**5,837,982**	**326.46**	**6.38**

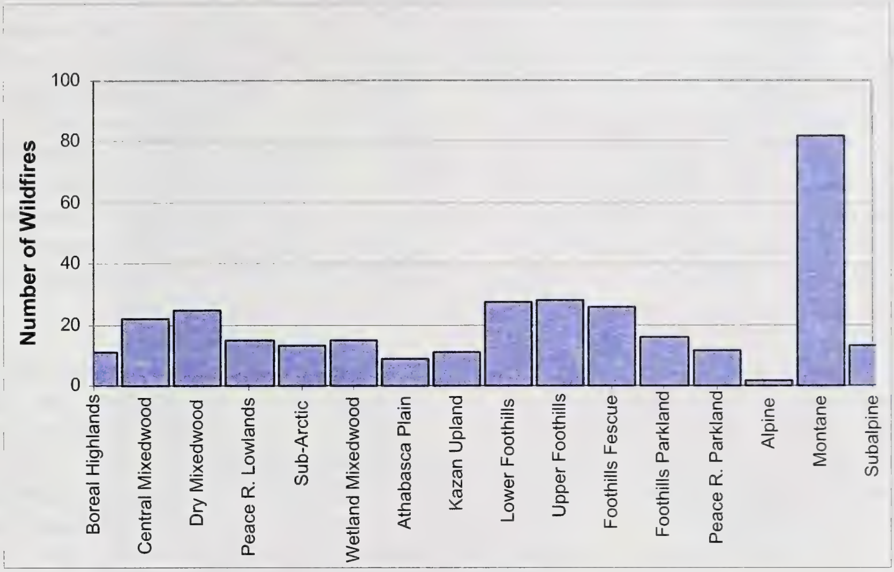

Figure 4.27 Number of wildfires/year/million ha

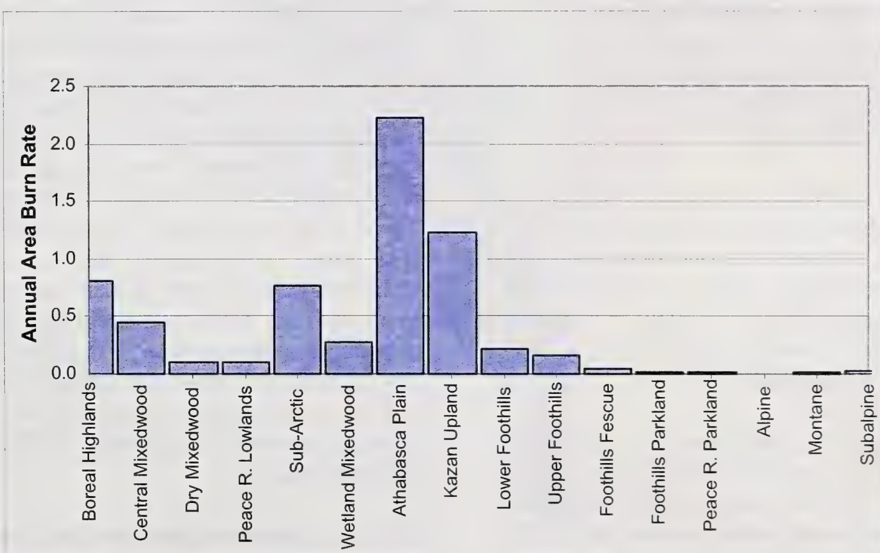

Figure 4.28 Annual area-burn rate by natural subregion

The net area was calculated for each NSR by excluding the lakes and major rivers from the total area (Table 4.11). The number of wildfires per year per million ha and the annual burned rate in percent for each NSR were calculated and are listed in Table 4.11.

In Alberta, the annual number of wildfires per million ha per year is 25, but the number ranges from 2 wildfires/million ha (in the Alpine NSR) to 82 wildfires/million ha (in the Montane NSR; see Table 4.11 and Figure 4.27).

There are also large frequency and burn rate differences between the Montane and Subalpine NSRs. These are likely due to differences in vegetation features and human activities. The Montane NSR is on a yearly average 2° C warmer than the Subalpine NSR (Strong 1992); the higher grass cover and heavier human use also makes the Montane NSR prone to frequent small human-caused wildfires. The Upper Foothills, Lower Foothills, Foothills Fescue, Dry Mixedwood, and Central Mixedwood NSRs also have relatively high wildfire occurrences per unit area (20 to 30 wildfires per year per million ha).

The Montane NSR is usually confined to the valley bottoms, and for its size, it is densely populated. Three Montane NSR zones in Alberta are major corridors for vehicle and rail transportation. These corridors experience a correspondingly high number of human caused fires.

The annual burn rate indicates how much forest will be replaced yearly by wildfire (Figure 4.28). In Alberta, the annual burn rate ranges from 0.01% (Alpine) to 2.20% (Athabasca Plain NSR) with a provincial average of 0.37% (see Table 4.10 and Figure 4.28). In the Canadian Shield NR, the Athabasca Plain and Kazan Upland NSRs have the highest annual burn rates of 2.20% and 1.23% respectively. The annual burn rates for the Boreal Highlands and Sub-Arctic NSRs are also relatively high at just under 1%. The annual burn rate for the Central Mixedwood NSR is about 0.5%, while the annual area-burn rate for the Wetland Mixedwood, Upper Foothills, and Lower Foothills NSRs are between 0.1 and 0.25%. All other subregions have an annual burn rate of less than 0.1%.

Land use and land fragmentation may influence the annual area-burn rate. Natural subregions in remote areas with poor access and fewer human activities all have relatively high area-burn rates, such as the Athabasca Plain, Kazan Upland, Boreal Highlands, and Sub-Arctic NSRs, while NSRs with higher levels of human development have relatively low area-burn rates, such as the Dry Mixedwood, Peace River Lowlands, and Peace River Parkland NSRs. The Central Mixedwood and Dry Mixedwood NSRs provide another example of how land use might affect annual burn rates. These two subregions have similar wildfire occurrence per year per million ha; however, the annual burn rate in Central Mixedwood NSR (0.43%) is much higher than the Dry Mixedwood NSR (0.09%). In the Dry Mixedwood NSR, roads, agricultural lands, and human settlements occur in much greater densities than in the Central Mixedwood NSR. Wildfires in the Dry Mixedwood NSR are easier to detect and are more quickly suppressed; as well, clearings provide fuel breaks to interrupt wildfire spread.

Wildfire suppression may also contribute to the average annual area-burn rate. Because life and community protection are the two highest forest protection priorities in

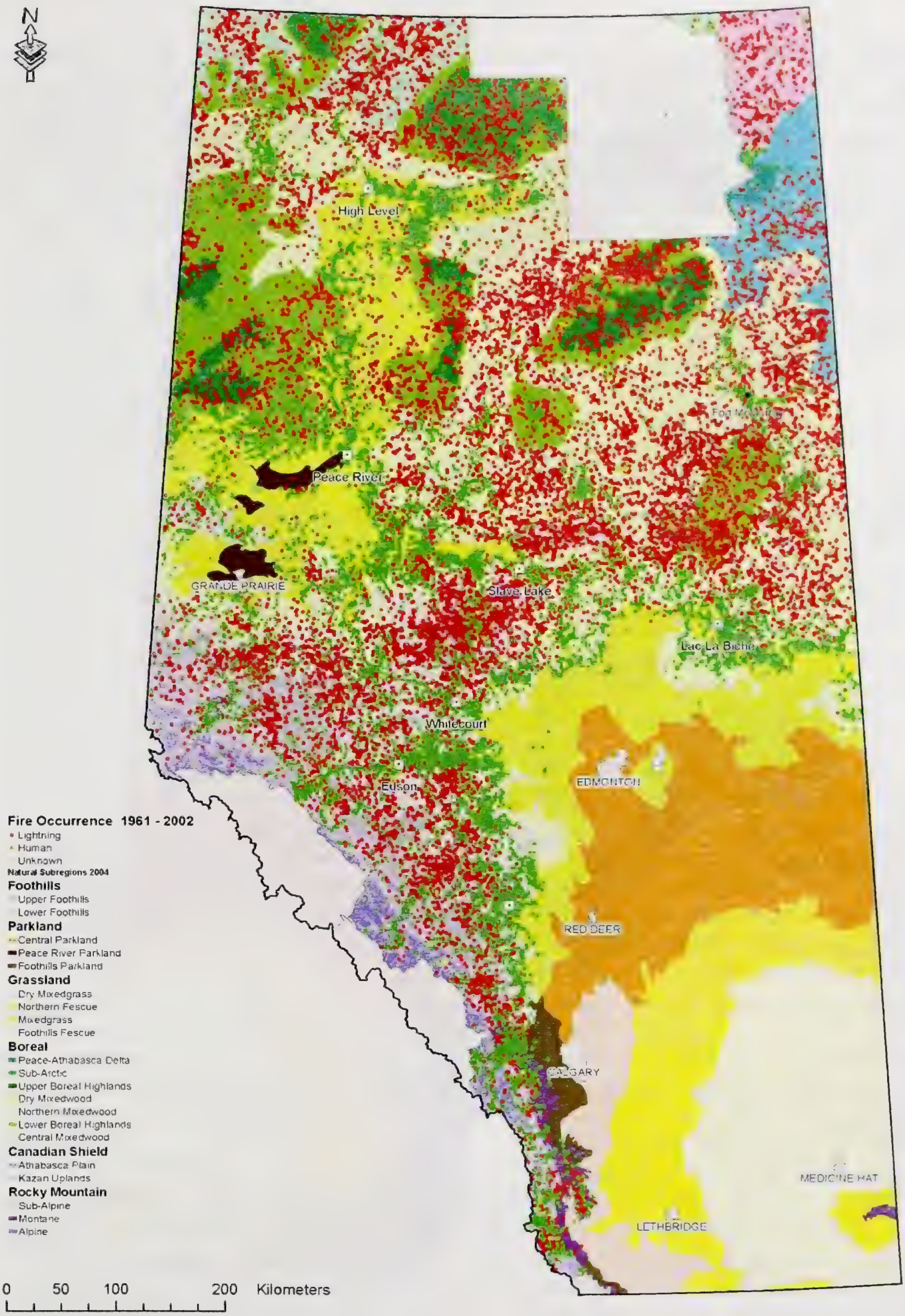

Figure 4.29 Wildfire occurrence by natural subregion

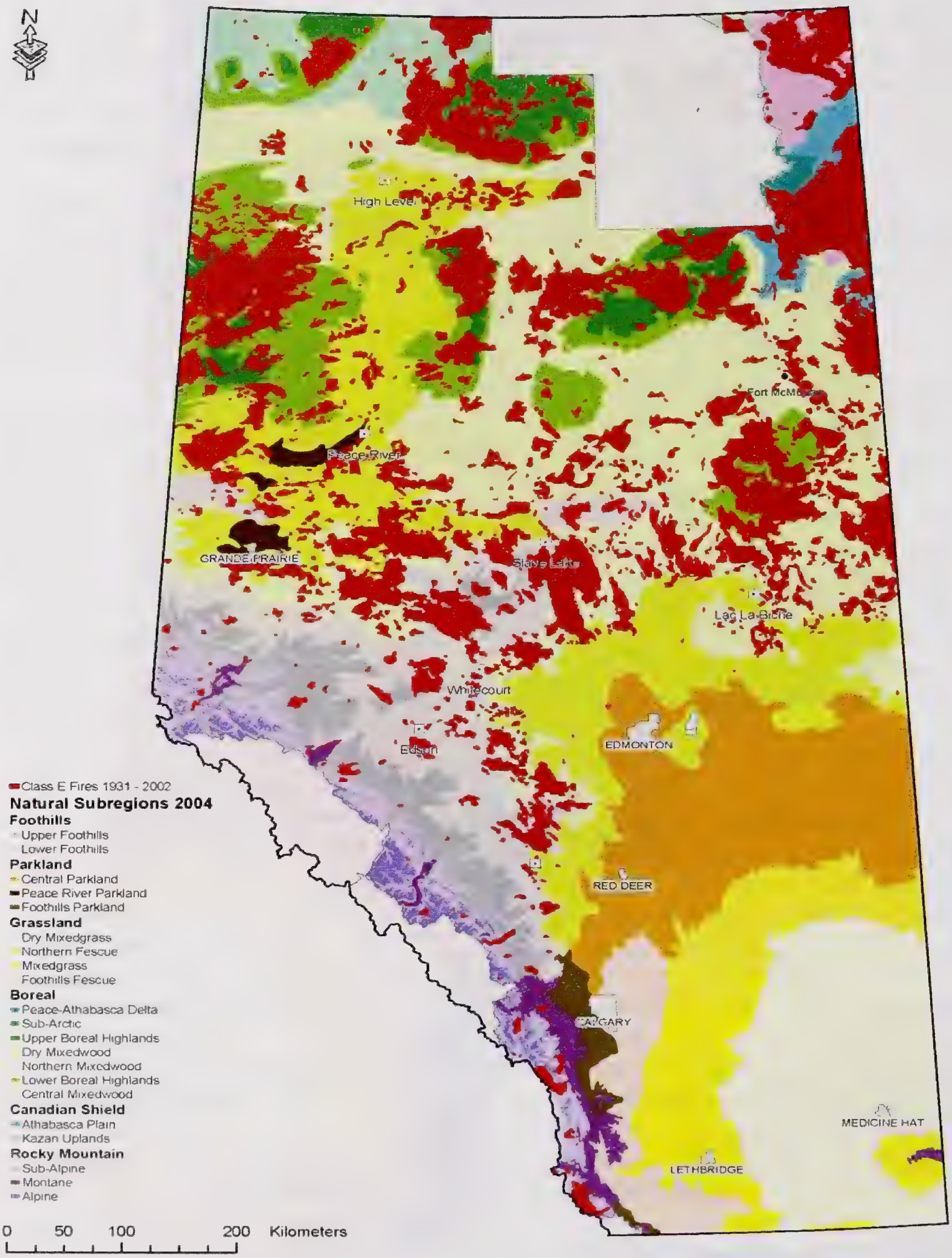

Figure 4.30 Area burned by Class E (> 200 ha) wildfires in Alberta by natural subregion (1931–2002)

Alberta, areas with more human development tend to receive higher suppression efforts. Ward et al. (2001) showed how wildfire suppression reduced the average annual area burn in the intensive fire management zone compared to the extensive fire management zone in Ontario.

Although the effectiveness of fire suppression in the boreal forest has been questioned (Miyanishi and Johnson 2001, and Johnson et al. 2001), Cumming (2005) provided empirical evidence indicating that wildfire suppression is effective in reducing the area burned.

Fuel type and topography also influence the annual area-burn rate. Although the Montane NSR has the highest wildfire frequency per unit area among all of the subregions due to the heavy recreation activities in the area, the annual area-burn rate is very low. The steep and rough topography influence the spread of wildfire, and coniferous and deciduous stands tend to be distributed in patches.

The inverse of the annual area burn is called the fire cycle (NRCC 1987). The provincial average annual burn rate of 0.37% means that on average it will take about 250–300 years to burn completely over a given area of Alberta. In the Alpine NSR, burning across the subregion may never occur, and the fire cycle is thousands of years long. In the Athabasca Plain NSR, however, the annual burn rate of 2.2% means that any unit of terrain would be burned in a fire cycle of 40–50 years.

Fire cycle and annual burn rate are two important characteristics that are frequently referenced in forest management plans to determine the annual harvest rate and harvest rotation. As the annual burn rates and fire cycles differ between natural subregions, annual harvest rate and harvest rotation should be adjusted accordingly. It is also important to note that the annual burn rates and fire cycles could be different if a different period of data is used, because of the extreme variability in area burned over a period of years. Johnson and Gutsell (1994) suggested that data covering at least two to three times the estimated length of the fire cycle is needed to produce a reasonable estimate of fire cycle. Because this type of data is not available for Alberta, limitations to implement the annual area-burn rates and fire cycles of this study have to be considered.

4.2.3 Annual Wildfire Occurrence and Area Burned

Both wildfire occurrence and area burned also vary over the years in each natural subregion (see Figures 4.31a to Figure 4.32b). All natural subregions show annual variations in wildfire occurrence and area burned. The area-burned statistics change much more dramatically than the annual wildfire occurrence statistics.

The area burned within the Central Mixedwood NSR shows an increasing trend since the 1980s, as compared to the previous decades. No such trend can be observed in Dry Mixedwood NSR. The annual area burned shows even greater variability than the annual wildfire frequency. A random sequence of spikes in area burned is a common feature among natural subregions, but the spikes occur at different times depending on the subregion. For example, the Central Mixedwood NSR displays spikes in area burned in 1968, 1981–82, and in the last five years; the Dry Mixedwood NSR also shows a spike in 1968, but has no spikes after that. In the Lower Foothills NSR, area-burn spikes occurred in 1968, 1981, 1982, and 1998, but in the Upper Foothills NSR, only one area-burn spike occurred in 1998. As the high area-burned years greatly impact the age distribution and species composition of the forests, the temporal differences in area burned within subregions will determine the age-class distribution of patches within each subregion.

4.2.4 *Wildfire Cause*

Wildfires in different subregions have various ignition sources. Land uses and topographic features are two major factors influencing the ignition source (see Table 4.9 and Figure 4.33). Wildfires caused by humans are significant in NSRs that experience frequent human activities, such as the Dry Mixedwood, Peace River Lowlands, Wetland Mixedwood, and Lower and Upper Foothills NSRs, as well as in the Grassland, Parkland, and Rocky Mountain NRs. The proportion of human-caused wildfires decreases as human activities decrease. In NSRs with less access and lower intensities of human activity, the majority of the wildfires are caused by lightning (e.g., in the Boreal Highlands, Central Mixedwood, Sub-Arctic, Athabasca Plain, and Kazan Upland NSRs).

The influence of human activities on human-caused wildfire occurrence can be explained by general landscape pattern in the comparison of the Central Mixedwood and the Dry Mixedwood regions. In the Dry Mixedwood NSR, where the forested landscape is heavily dissected by agricultural activities, human activities are more likely to contribute to fires, and 80% of fires occurring in the Dry Mixedwood NSR are human-caused. In the Central Mixedwood NSR, where human activity is generally restricted to river corridors and the southernmost portions of the subregion, and where landscapes are mostly continuous forest on the uplands, only 40% of the wildfire is human-caused.

Topography is another major factor that can affect the influence of causal factors such as lightning. The lower number of lightning-caused wildfires in the Rocky Mountain region is due to the subsidence of air masses as they cross the Continental Divide. This causes a lightning shadow on the east side of the Continental Divide. Lightning strikes also tend to strike on ridge tops, where there is little or no fuel.

4.2.5 *Wildfire Size*

Wildfire size distribution also shows variations between natural subregions (Table 4.10). Because of the important influence of Class E wildfires on wildfire frequency and area-burned statistics, only the distributions of Class E wildfires by natural subregion are discussed here.

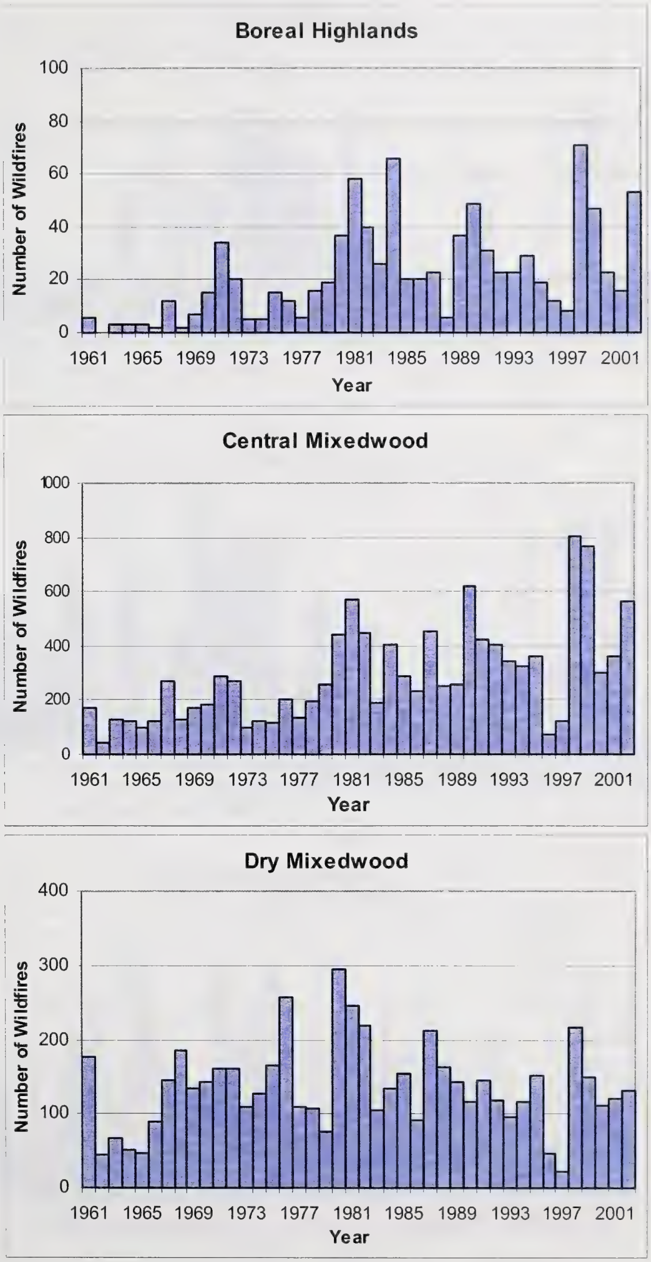

Figure 4.31a Annual wildfire occurrence by natural subregion

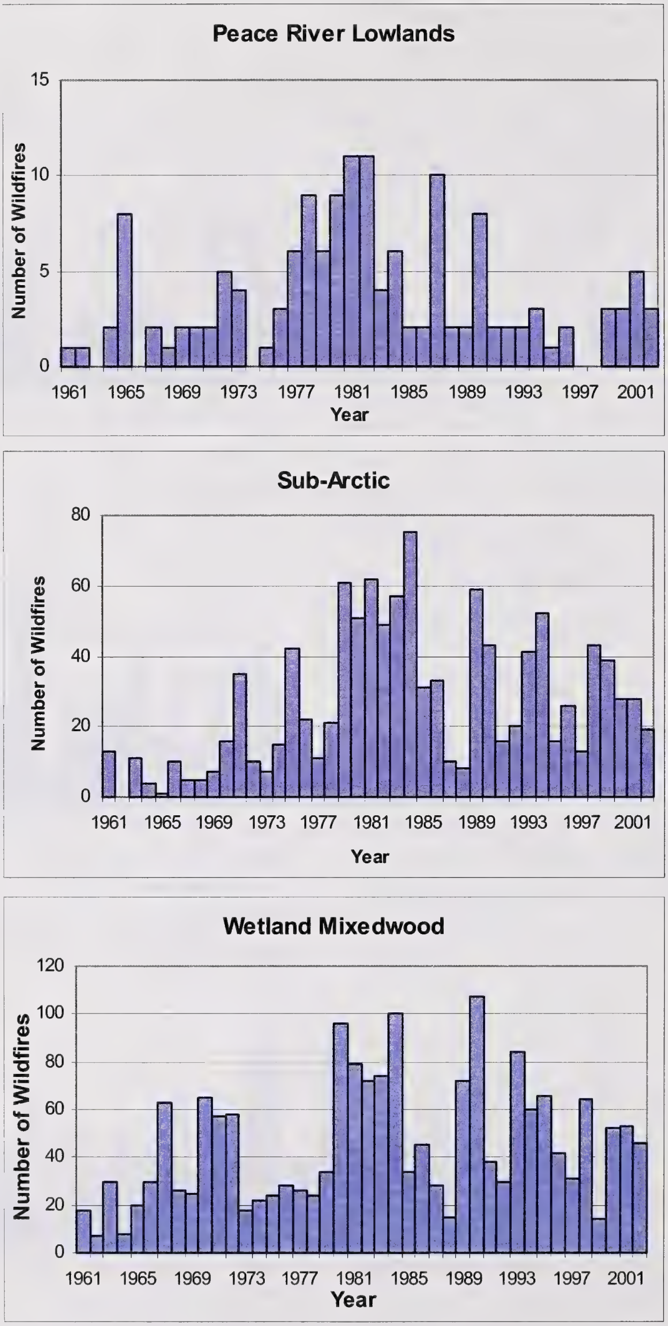

Figure 4.31b Annual wildfire occurrence by natural subregion

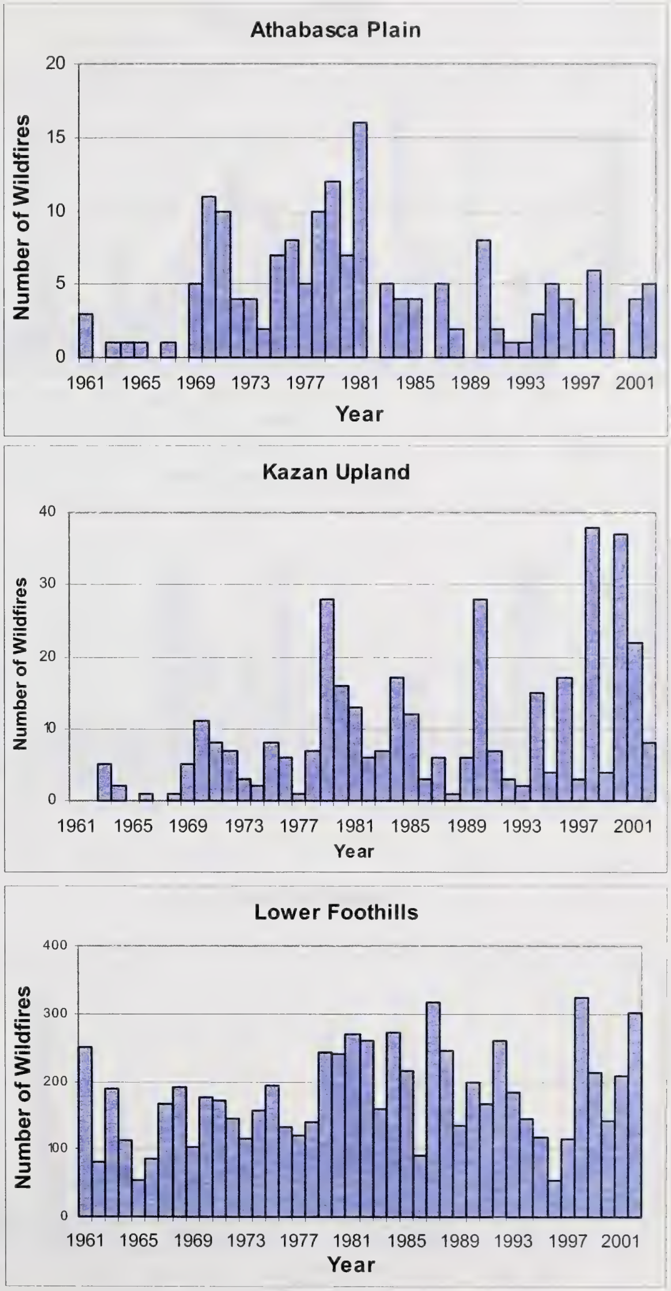

Figure 4.31c Annual wildfire occurrence by natural subregion

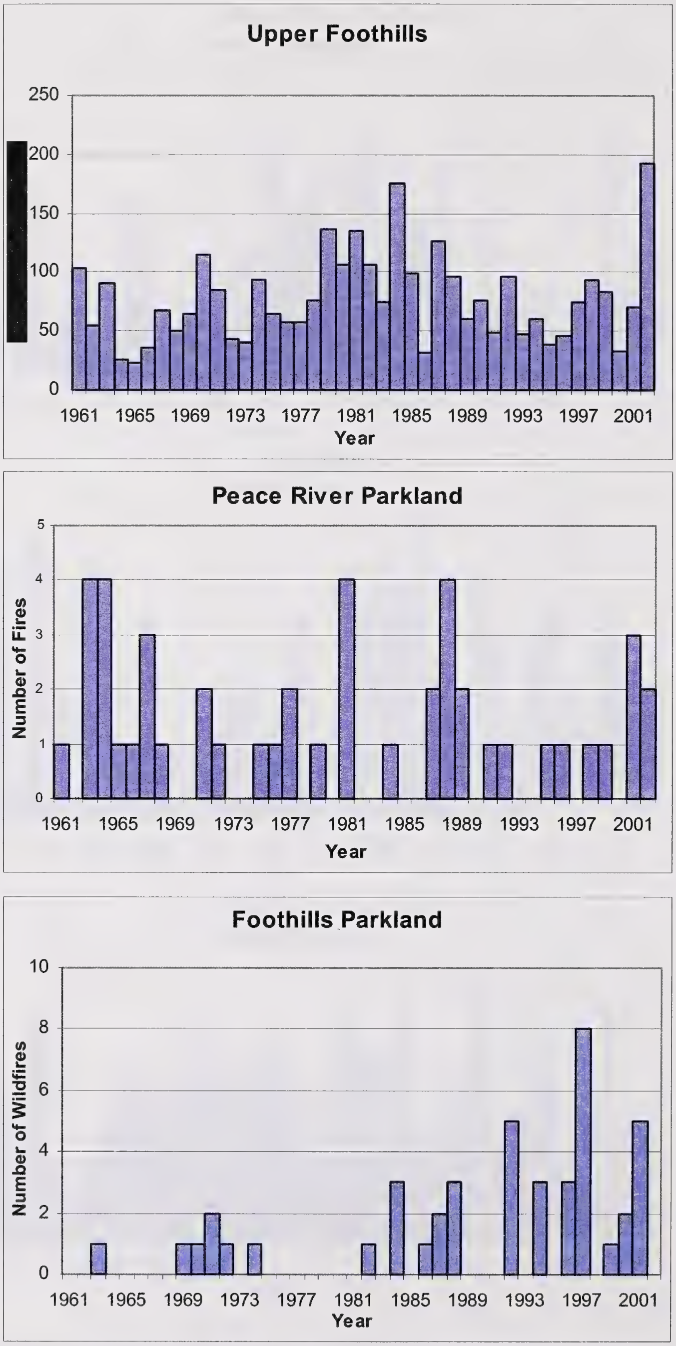

Figure 4.31d Annual wildfire occurrence by natural subregion

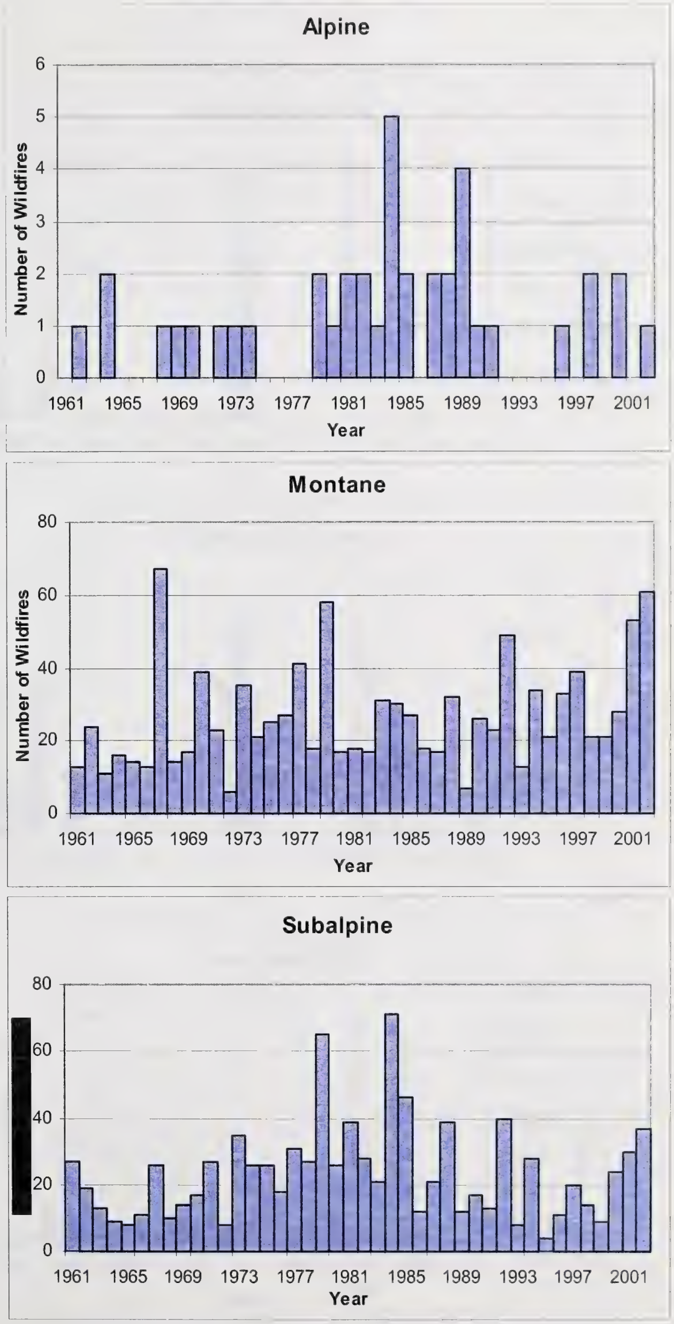

Figure 4.31e Annual wildfire occurrence by natural subregion

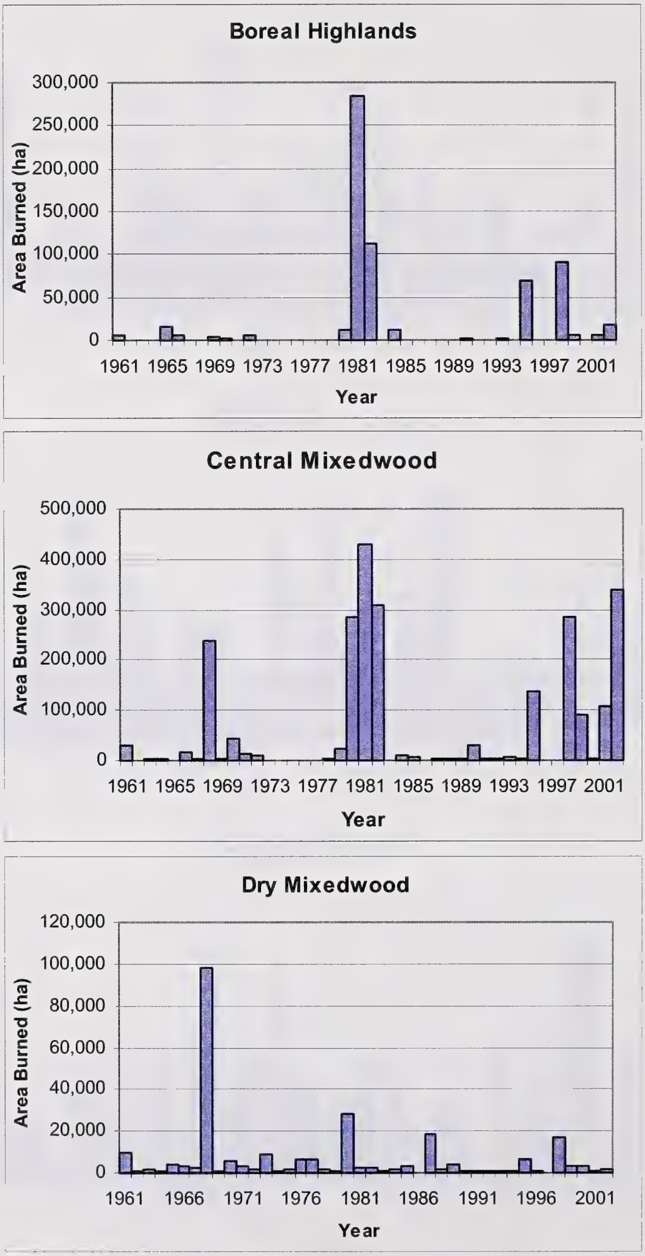

Figure 4.32a Annual area burned by natural subregion

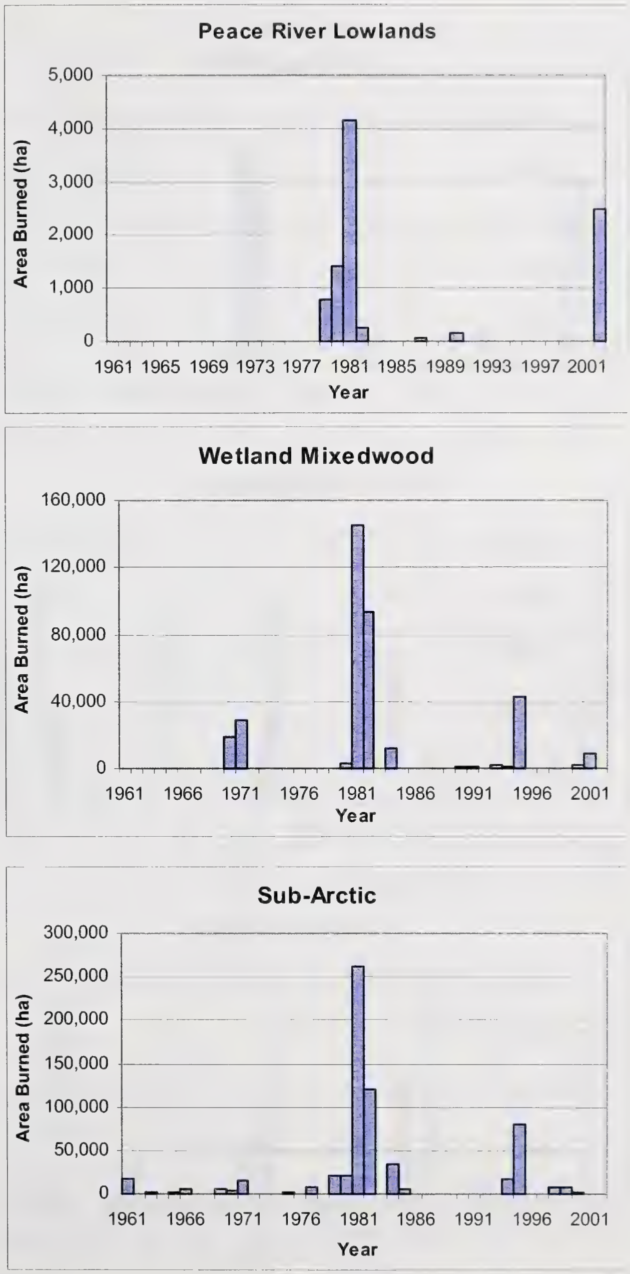

Figure 4.32b Annual area burned by natural subregion

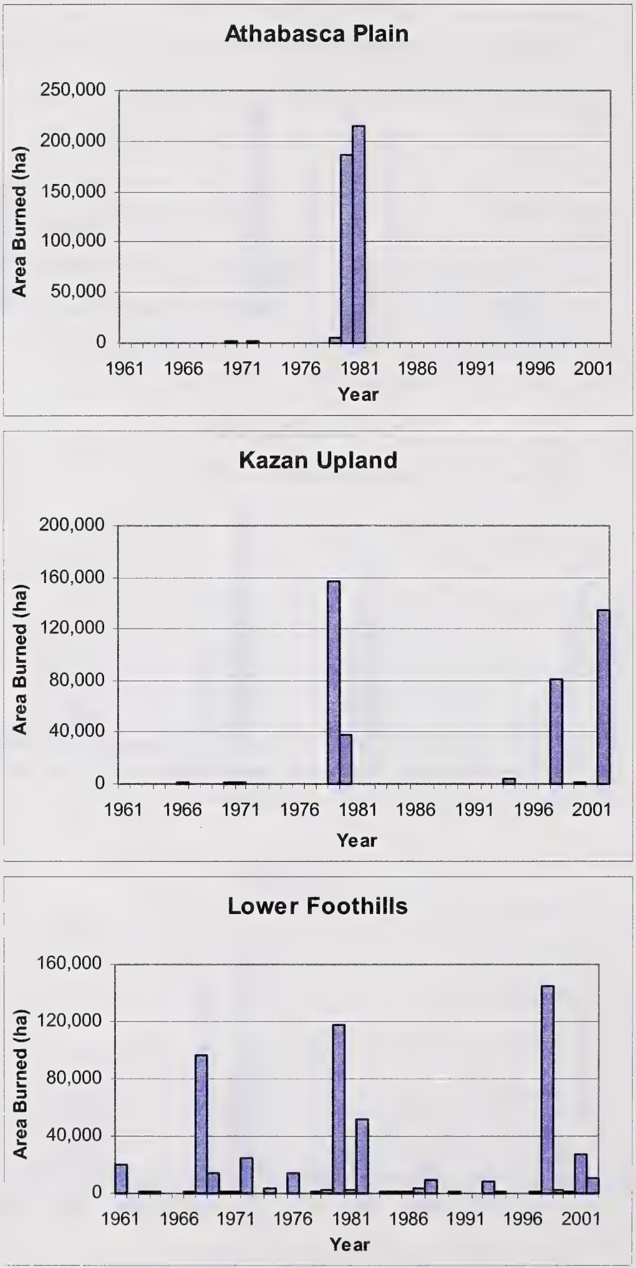

Figure 4.32c Annual area burned by natural subregion

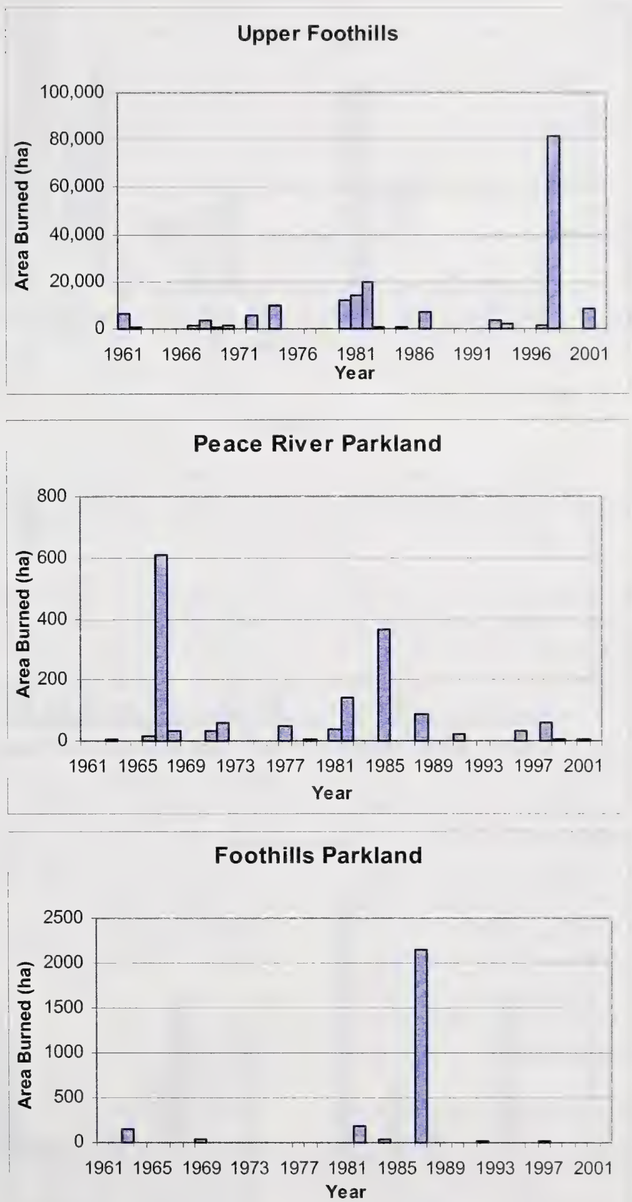

Figure 4.32d Annual area burned by natural subregion

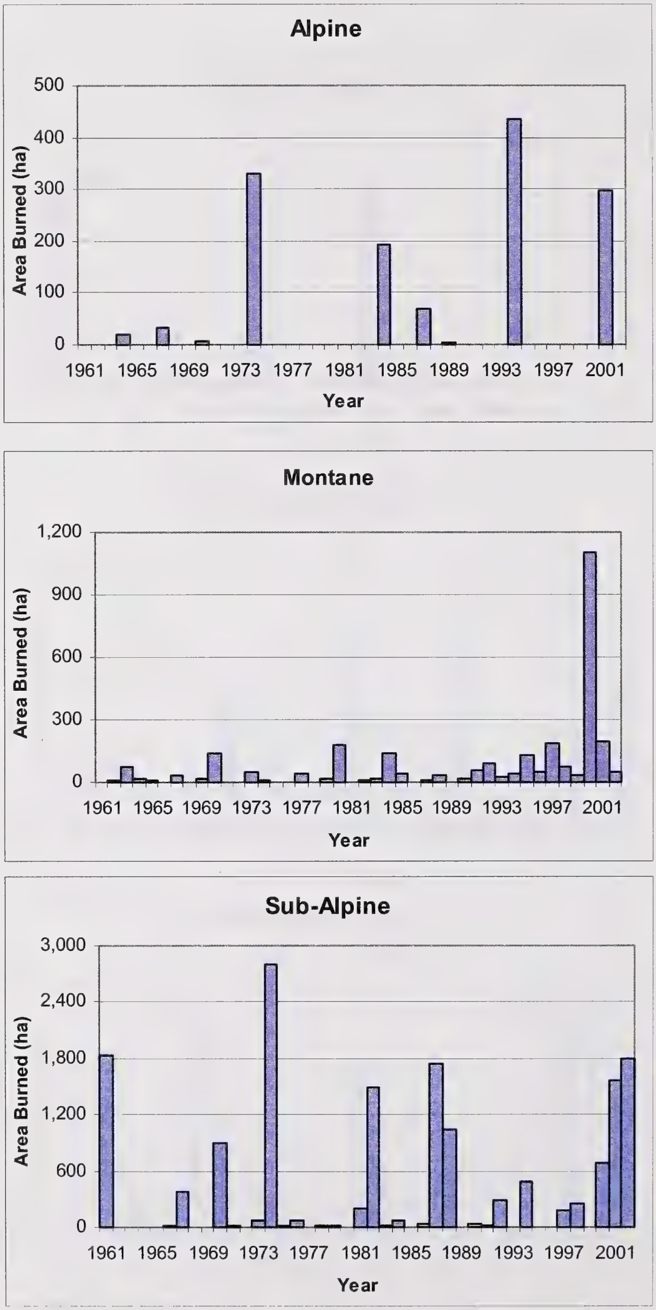

Figure 4.32e Annual area burned by natural subregion

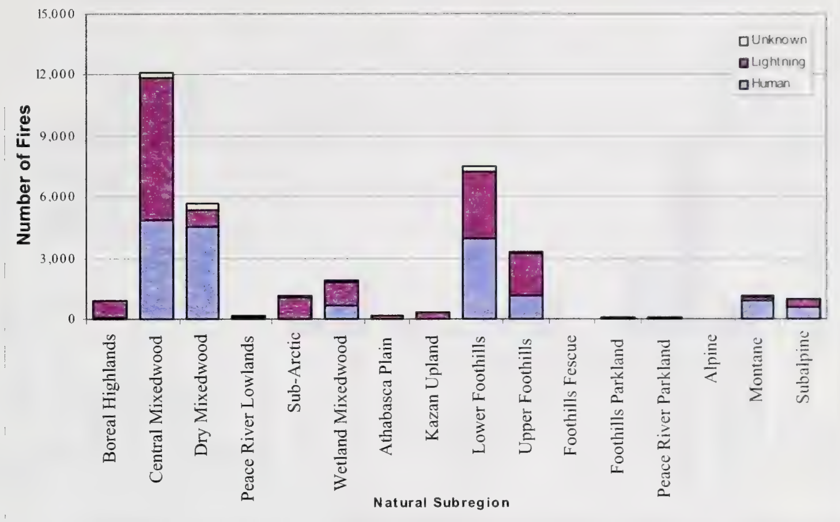

Figure 4.41 Wildfire occurrence by general cause and by natural subregion (1961–2002)

The frequency distribution of Class E wildfires by cause and by natural subregion is summarized in Figure 4.42. Class E wildfires are unevenly distributed across natural subregions. The Central Mixedwood NSR has the highest number of Class E wildfires among all the subregions from 1961 to 2002, and accounts for 40% of the Class E wildfires in the province. The Dry Mixedwood NSR has 16% and the Lower Foothills has 13% of the total Class E wildfires in the province. The remaining subregions include less than 10% of the Class E fires.

The percentage of the Class E wildfires to all wildfires in each natural subregion is displayed in Figure 4.43. On average, about 2% of the total wildfires are Class E wildfires within the FPA from 1961 to 2002. In natural subregions with less access and human activities, (e.g., the Boreal Highlands, Sub-Arctic, Athabasca Plain, and Kazan Upland NSRs), the percentages of Class E wildfires are all over 4% which is significantly higher than the provincial average. The percentages of Class E wildfires in the Central Mixedwood, Dry Mixedwood, Wetland Mixedwood, Peace River Parkland, and Subalpine NSRs are close to the provincial average. The remaining subregions, most of which are developed (e.g., the Peace River Lowlands, Lower Foothills, Upper Foothills, Foothills Fescue, Alpine, and Montane NSRs), have a Class E wildfire proportion that is much lower than the provincial average. This is likely due, in part, to earlier detection and suppression of wildfires, lower lightning incidence, and less flammable fuel types.

In most subregions, the majority of the Class E wildfires are caused by lightning, except in the Dry Mixedwood NSR, where 87% of the Class E wildfires from 1961 to 2002 are human-caused, probably because of more intensive agricultural and industrial land-use activities in this subregion.

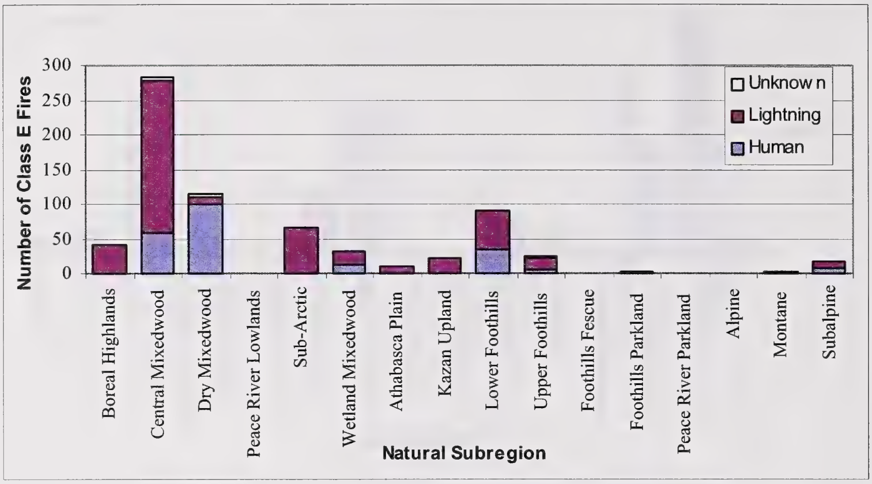

Figure 4.42 Class E wildfire frequency by general cause and by natural subregion (1961–2002)

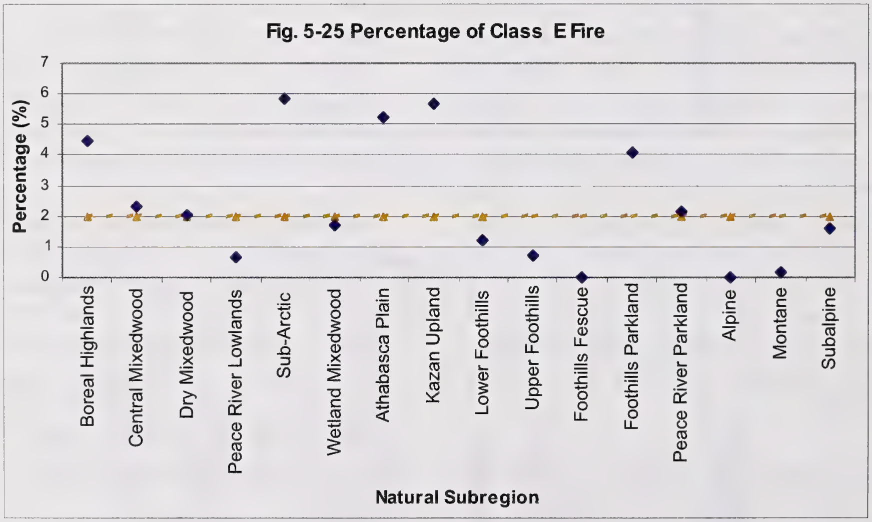

Figure 4.43 Percentage of Class E wildfires by natural subregion. The dashed line represents the mean value.

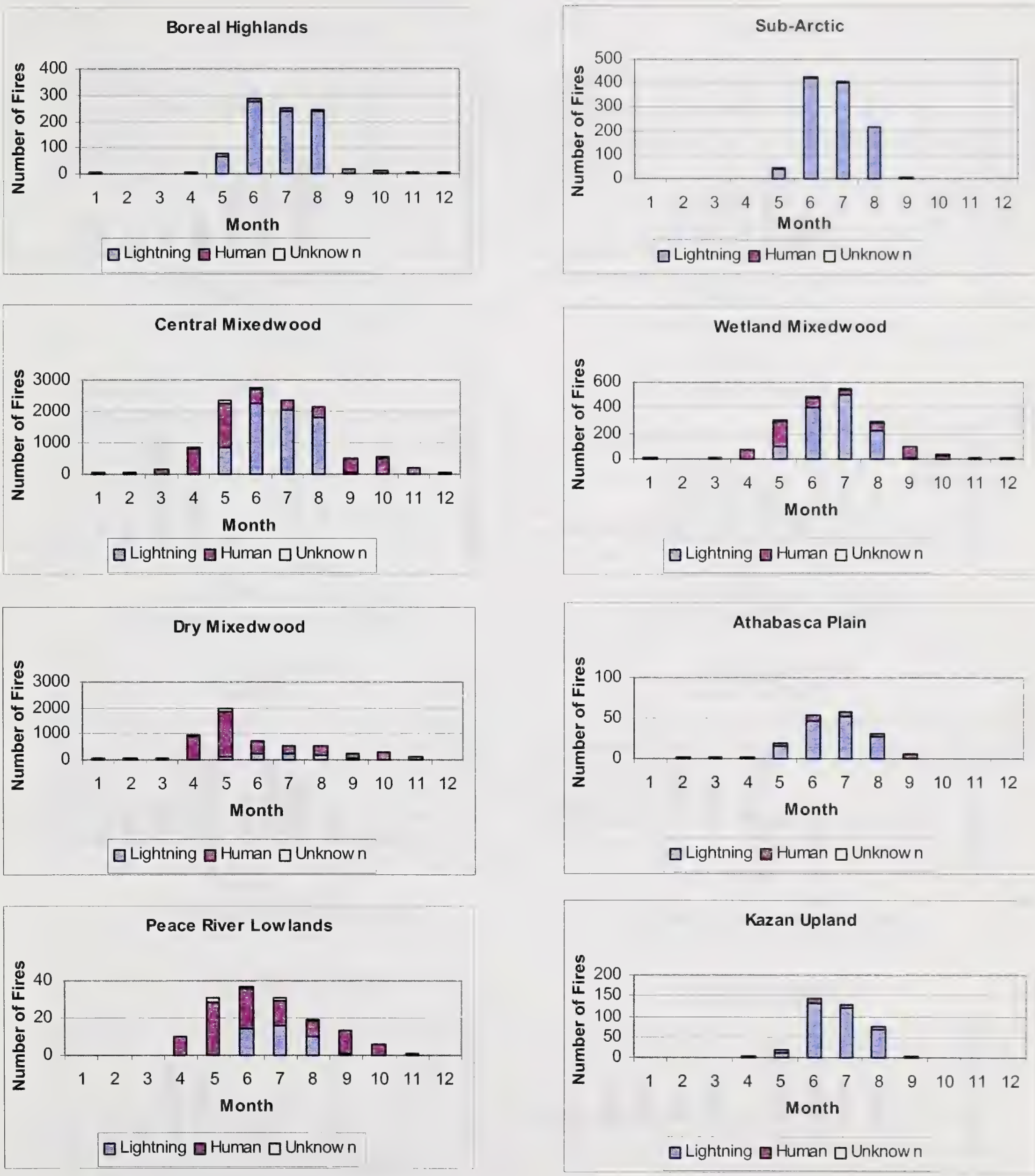

Figure 4.44a Monthly wildfire occurrence by cause in each natural subregion

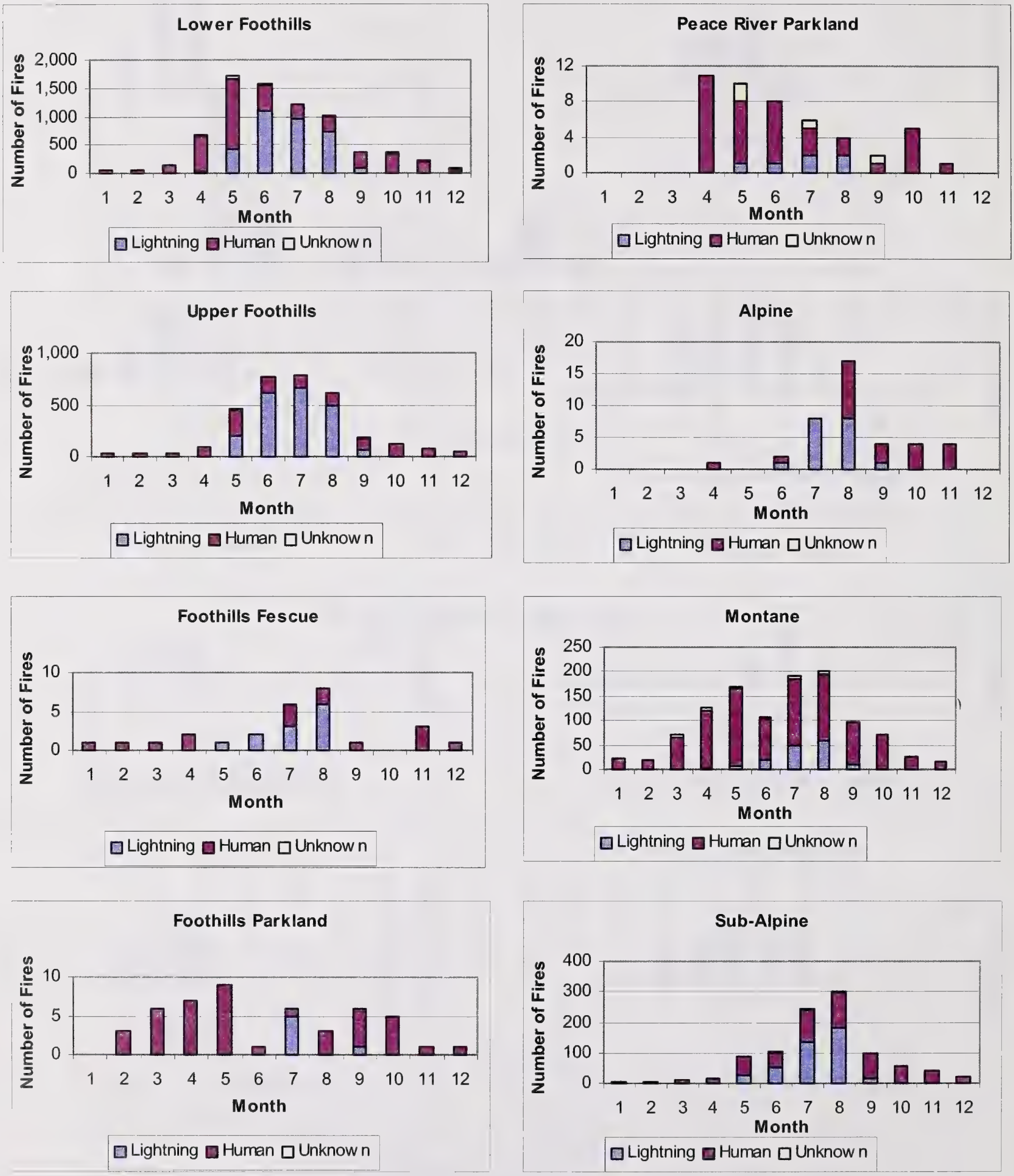

Figure 4.44b Monthly wildfire occurrence by cause in each natural subregion

Figure 4.45a Monthly area burned by cause in each natural subregion

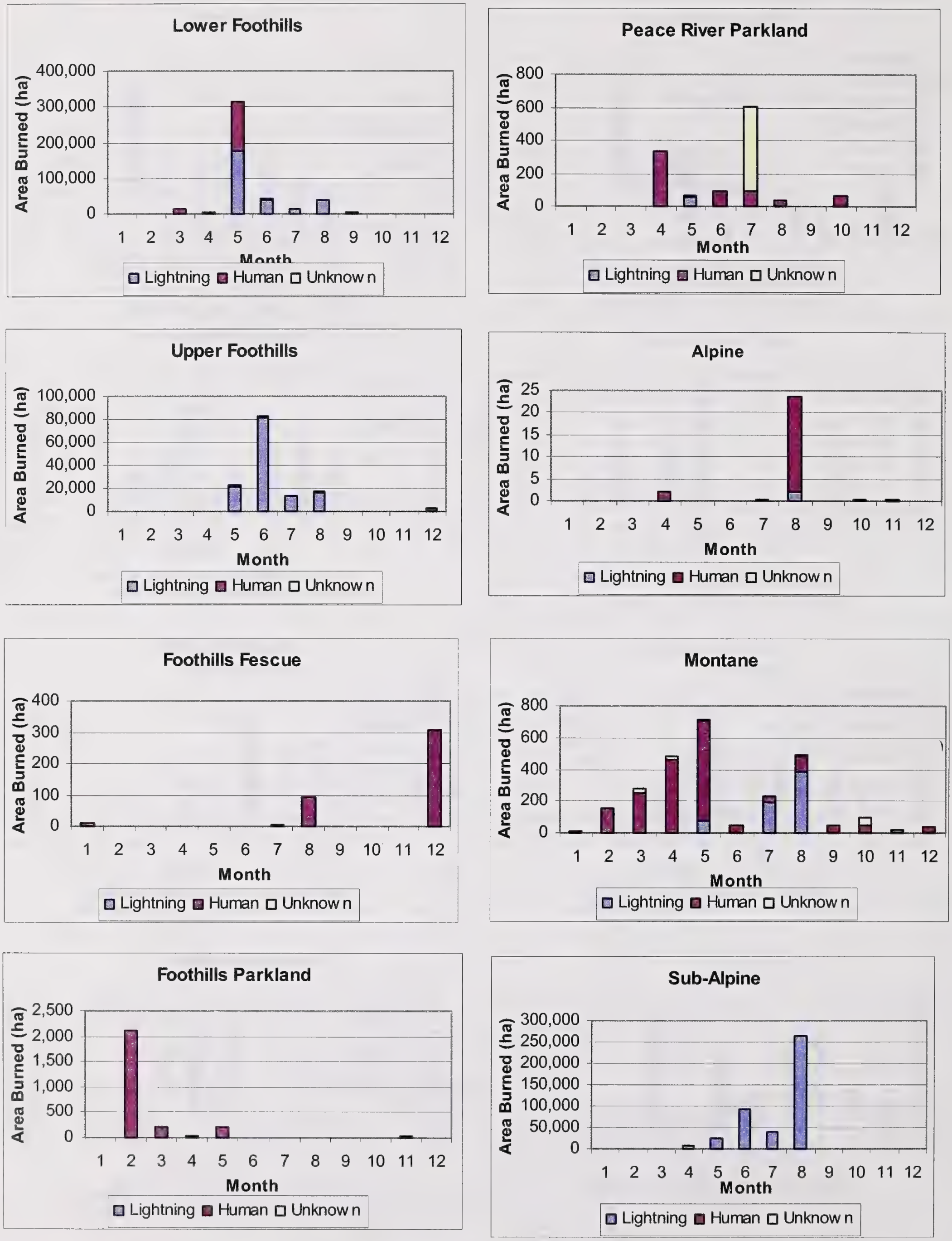

Figure 4.45b Monthly area burned by cause in each natural subregion

To summarize, the percentage of Class E wildfire varies among the natural subregions; the provincial average is 2%. In the remote natural subregions, the percentages are all over 4%; in the developed areas, the percentages are all lower then the provincial average. In most of the natural subregions, the majority of the Class E wildfires are caused by lightning, but this is not the case in the Dry Mixedwood NSR.

4.2.6 Seasonal Wildfire Frequency and Area Burned Distribution

The seasonal wildfire frequency and area burned from 1961 to 2002 for each natural subregion are presented in Figures 4-44a to 4-45b.

In most subregions, the peak fire season is from May to August. Spring wildfires are mostly human-caused; summer wildfires in June, July, and August are mostly lightning-caused. The exceptions are the Dry Mixedwood, Peace River Lowlands, Peace River Parkland, and Montane NSRs, where human-caused wildfires are still dominant in summer due to the high level of human activity in these areas.

As spring wildfires are mostly human-caused, areas with low access and low levels of human activity had very few spring fires (e.g., the Sub-Arctic, Kazan Upland, Athabasca Plain, Wetland Mixedwood, and Boreal Highlands NSRs). In contrast, the Dry Mixedwood, Foothills Parkland, Peace River Parkland, and Montane NSRs all have significant spring wildfires.

The seasonal area-burned distributions vary considerably from one subregion to another, even within the same natural region. This is shown for the Boreal Forest NR when the Central Mixedwood and the Dry Mixedwood NSRs are compared. In the Central Mixedwood NSR, the peak area-burned months are May, June, and August. More than half of the area burned in May is due to human-caused wildfires, and areas burned in July and August are almost all due to lightning-caused wildfires. In the Dry Mixedwood NSR, the peak area-burned month is June, and is mostly due to human-caused fires. Another example of regional variability is found within the Foothills NR. In the Lower Foothills NSR, the peak area-burned month is May, with 60% of the area burned due to lightning-caused fires, while in the Upper Foothills, the peak area-burned month is June, and is almost entirely lightning-caused.

Overall, the monthly variations in wildfire distribution and area burned are closely related to land-use pattern and climate. In the areas with heavy human activities, the peak wildfire occurrence is in spring, and the fires are mostly human-caused. In comparison, in less accessible areas with low human populations (mostly northern areas), summer lightning-caused wildfires are prevalent.

Section V Overview of Wildfire Regime Methodologies

5.1 General

This section presents the methodologies that apply to the Alberta landscape and its wildfire regimes. It is divided into four subsections. The first subsection outlines the different wildfire regime methods available, issues to consider, and the strengths and weaknesses of each method. The second subsection provides a general review of wildfire cycle calculation methods, while the third subsection identifies fire data gaps in the province. A summary of fire history and stand age data available at the provincial scale is presented spatially as well as in a table format (see Appendix III). The last part of this section discusses the use of landscape disturbance models. Five models have been applied to different landscapes in Alberta. Their purposes, features, and technical aspects are described. This last subsection was included to make forest managers aware of the additional tools available to help them better understand and describe wildfire distributions on the landscape.

Wildfire history and wildfire regime studies are often interchanged and viewed as being similar. However, they are not the same. To clarify the differences, the following definitions are provided:

> *Wildfire history* is the study of uncovering, dating, and mapping historical wildfires. It involves the compilation of evidence (such as historical documents, wildfire reports, fire scars, tree growth rings, and charcoal deposits), that records the occurrence of past wildfires for an area (Canadian Interagency Forest Fire Centre 2003). Wildfires are tabulated in a chronological order and are used to quantify the fire frequency or mean fire return interval (MFRI) of a study area. The wildfire history study is most often a component of the wildfire regime study.
>
> ***Wildfire regime*** is the study of defining and characterizing the pattern and kind of fire activity for an area. Fire parameters that define a fire regime include the frequency, cause, size, season, type, and intensity of fire that characterize an area (Canadian Interagency Forest Fire Centre 2003)). From these parameters, an MFRI and a fire cycle can be calculated.

The most common research goals for undertaking a wildfire regime study are directly associated with the mandate of forest management stakeholders.

1) *Protected parks* (federal and provincial) and *wilderness areas* must maintain ecological integrity by protecting biodiversity, and favouring the occurrence of natural disturbances. While wildfires have been suppressed successfully for several decades, the knowledge gained from wildfire history and wildfire regime studies is used to write fire prescriptions and determine when and where burning should occur or be re-introduced to the landscape.

2) The *forest industry*, while not desiring wildfire on the landscape, has been using wildfire regime parameters to determine how frequently and where wildfire has occurred in the past, so that harvest practices can be planned accordingly. There is also increasing interest in harvesting the forest in a manner that is more aligned with naturally occurring wildfire patterns. This can promote biodiversity, reduce the impact on wildlife habitat, and be more visually appealing. Wildfire regime parameters provide information on location, patch-size distribution, and harvest rate.

3) *Communities* surrounded by flammable forest areas that are implementing FireSmart initiatives also benefit from wildfire regime information. Aside from facilitating the planning of a fuel reduction program, most importantly the information from the wildfire regime analysis will help with public education. With knowledge comes understanding and acceptance.

Despite the different research goals, wildfire regime methodologies tend to remain similar; there are only a few methods to choose from. The choice of method is dictated by the wildfire data available, the wildfire regime parameters needed, the size of the study area, and the types of wildfire observed on the landscape.

5.2 Wildfire Regime Methodologies

Although wildfire history is a component of the wildfire regime analysis, this section focuses on wildfire regime methods rather than on the tree sampling methods associated with wildfire history studies. When beginning the detective work of uncovering historical wildfires, there are more methods to choose from, along with a vast number of scientific publications and research reports to provide further information and methodology details. Some of the issues pertaining to stand dating in a wildfire history context are, however, addressed in this section.

Six wildfire regime analysis methods, based on the wildfire data type available, are presented in Table 5.1. This table outlines the objectives of each method, the recommended study area size, wildfire parameters that can be quantified, and which natural regions in Alberta are best suited to apply the method. Each method is addressed separately, and includes a brief summary of the procedure, issues to consider, and the pros and cons of their application.

Table 5.1 Summary of wildfire regime analysis methods. FRI = fire return interval, MFRI = mean fire return interval.

Method	Objectives	Size of Area	Fire Parameters	Landscape Type /Natural Region
1) Fire history study: stand origin (polygon) dating and mapping	1. date and map historical fires 2. assess spatial patterns of fire on the landscape 3. determine probability of burning on the landscape	500 to 10,000 km^2	frequency size FRI MFRI fire cycle [a]	Subalpine (upper and lower) Montane Upper Foothills (rugged terrain)
2) Fire history study: point sampling and dating	1. date historical fires 2. assess some spatial patterns if large number of sample points	no restrictions [b]	frequency FRI MFRI	all regions
3) Provincial fire occurrence data set: fire records since 1961	1. identify recent fires 2. determine the cause of ignition 3. develop a probability of ignition model 4. draw a recent fire regime profile	no restrictions	frequency cause probability of ignition size FRI MFRI fire cycle season	all regions
4) Provincial lightning strike data set: position of lightning strikes since 1983	1. assess relationship between lightning fire occurrence and density of lightning strikes 2. develop a probability of ignition model	no restrictions	probability of ignition	all regions
5) Predictive modeling	1. predict patterns of stand origin distribution 2. predict spatial variation in fire cycle on the landscape	> 1,000 km^2	age-classes fire cycle	all regions, but better predictive ability in mountain landscapes due to the effect of topography on fire distribution
6) Simulation modeling with repetitions	1. determine the natural range of variation of age-class distributions and fire cycles 2. model temporal and spatial changes in the fire regime	5 to 10 times larger than the area burned in a specific time period (i.e., 10 years)	age-classes fire size fire cycle frequency (per pixel)	all regions

a: Make note of issues to consider.

b: The larger the landscape, the better. A greater number of fires can be detected on larger landscapes, and a clearer picture of the fire history and fire regime can be drawn.

5.2.1 Wildfire History Data: Stand Origin Mapping

This method documents the wildfire regime by using wildfire history data sampled directly from the study area. This process involves an assessment of historical aerial photography (1:40,000, 1948–52) and preliminary stand origin mapping (wildfire boundaries with no stand dates). As well, tree age sampling along each detected wildfire boundary, and within large patches of homogeneous forest, is done to ensure that all wildfires are documented. It is recommended that a minimum of four trees on each side of the wildfire boundary be sampled. Trees bearing the evidence of wildfire such as fire scars and remnant trees showing a release in the ring growth pattern, which can be linked to an important stand replacing disturbance event, are favoured in the sampling process. Tree cross-sections are taken back to the lab for drying, sanding and reading using a powered dissecting scope. Tree origin and wildfire events are dated, then mapped on the preliminary stand origin map. Wildfire boundary lines are also adjusted (erased, modified, or added) with the help of the fire data collected.

Although a large number of published fire history studies are available, several articles are relevant to the procedures listed above, and applicable to mountain and boreal landscapes. For a complete fire mapping process, of individual fires reconstructed underneath subsequent burns (multiple map sheet process), see Heinselman (1973) and Tande (1979). For a fire origin mapping technique (one map layer), refer to Johnson and Gutsell (1994). For a point sampling approach (see Section 5.2.2) using transects, Arno et al. (1993) provides a full description. As for general wildfire age sampling techniques and the evaluation of tree ring growth for scars and releases, Arno and Sneck (1977), Barrett and Arno (1982), Lorimer (1985), and McBride (1983) provide further information.

Issues to Consider

Stand origin mapping is by far the most time consuming and costly approach to recording historical wildfires and "draws a portrait" of the landscape wildfire regime(s). For this reason, many researchers use forest inventory ages as a substitute for wildfire history data. Unfortunately, validation studies in British Columbia, Alberta, and Saskatchewan highlighted several critical problems when using this approach (Andison et al. 2002, Rogeau 2001a, Rogeau 2001b). The resulting discrepancies are explained below:

- The oldest photos are not always used, thereby preventing the interpreter from identifying old fires.
- Sample plots are limited to easily accessible areas.
- Many stand ages are predicted based on a small number of sample plots.
- Relationships between stand height and age are used to predict stand ages. This creates dating problems, especially where stands do not grow at the same rate due to harsh environmental conditions.
- Tree selection differs between the inventory and fire history method.
- The inventory method samples the tree at breast height, whereas the wildfire history method samples as close to the ground as possible. General correction aging factors are not always applicable to the landscape sampled.

- The inventory method often dates the tree directly in the field from increment cores, which leads to dating errors.

- The inventory age-class maps are lumped into very broad classes for ages greater than 140 years, whereas fire age-class map uses regular interval age-classes, normally of 10 years, throughout the lifespan of the forest.

Due to these combined sources of error, the use of inventory ages to create a wildfire or stand origin map is not the preferred method.

Another important issue is the use of the Weibull model (or negative exponential model, which is a special case of the Weibull), to calculate the wildfire cycle from the age-class distribution obtained from the stand origin map. A number of issues have been raised with regards to the method proposed by Johnson and Van Wagner (1985) and Johnson and Gutsell (1994). These issues are discussed at length in several publications and therefore are not addressed in this section.

Because of the controversy surrounding this method, and its inability to calculate an accurate wildfire cycle for most landscapes, a combination of methods and tools is recommended to estimate wildfire cycles. These alternate approaches are presented in the following subsections.

Table 5.2 Strengths and weaknesses of the wildfire history study: Stand origin mapping approach

Strengths	Weaknesses
Real data, does not rely on predicted data	Most expensive method
Local representation of fire, not borrowed from another study	Most time consuming
Quantifies fire frequency and MFRI	Provides a sample of one, no natural range of variation
Evaluates spatial relationships between stand origin and topography, fuel type, or other environmental variables	Unreliable fire cycle value if the Weibull model is used
Quantifies probabilities of burning spatially	
Used as a base layer to develop predictive models (i.e., stand age distribution for similar landscapes)	

5.2.2 Wildfire History Data: Point Sampling

This wildfire history method is very similar to the stand origin mapping approach, with the exception that no wildfire or stand origin mapping is involved. The study area is not entirely sampled, and as a result, a sampling design must be established. The number of plots and their distribution follows the level of details required, the types of wildfire on the landscape (i.e., stand replacing, intermittent, or surface fire) and the research objectives. For example, are relationships between stand ages and an independent variable such as topography, fuel type, or distance from water bodies important in the understanding of the wildfire regime? Will predictive models be built from the wildfire information collected? If such is the case, a well thought out sampling design will be needed, as well as a large number of sample plots to ensure landscape representativeness to obtain results that are statistically defendable.

The sampling and dating techniques are similar to that of the stand origin mapping method.

Issues to Consider

This approach also suffers from a number of concerns that need to be considered. For the same reasons as stated above, point age data should not be borrowed from a forest inventory age map. Field sampling is therefore recommended. The desired sampling design, and size of the study area, can result in significant costs. However, the cost can be reduced significantly by eliminating the mapping process, minimizing the sampling area, and/or minimizing the number of sample plots.

Table 5.3 Strengths and weaknesses of the wildfire history study: Point sampling approach

Strengths	Weaknesses
Not as costly as stand origin mapping	Cost depends on the number of plots
Real data, does not rely on predicted data	Time consuming
Local representation of fire, not borrowed from another study	Sampling design is required
Quantifies fire frequency and MFRI	Lacks fire size data to calculate the fire cycle
If large number of sample plots, evaluates spatial relationships between stand origin and topography, fuel type, or other environment variable	
If large number of sample plots, quantifies probabilities of burning spatially	
If large number of sample plots, used as a base layer to develop predictive models (i.e., stand age distribution for similar landscapes)	

If a wildfire cycle value is required, this method alone is not recommended, since wildfire sizes are not recorded. Thus, some form of mapping may be necessary (i.e., recent burns that have not been overlapped), or wildfire size data must be derived from other data sets (i.e., fire occurrence data, as described in Section 5.2.3).

5.2.3 Provincial Fire Occurrence Data

Alberta Sustainable Resource Development, Forest Protection Division, in Edmonton, has been keeping track of wildfires at the provincial level since 1961. A number of fire parameters are recorded and can be used to profile wildfire regimes. It is from this data set that the wildfire regimes defined by natural regions and subregions have been evaluated and presented in this report (see Section IV).

Issues to Consider

The major consideration with this data set is recognizing that not all wildfires have been recorded. This is particularly true for the 1960s and 1970s in less populated areas. Older wildfire locations were also not recorded as accurately as they are today. Sometimes only a range-township-section reference was given. Many wildfires have also received suppression measures that would have affected the burn area. Historically, fires would smoulder for weeks, and not until there was more favourable fire weather would additional fire runs be started (Murphy and Tymstra 1986). These additional fire runs significantly increased the wildfire size and total area burned.

Because of these factors, it is likely that this data set would overestimate (lengthen) the wildfire cycle due to the number of wildfires missed and reduced wildfire sizes.

Table 5.4 Strengths and weaknesses of the provincial fire occurrence data set approach

Strengths	Weaknesses
Low-cost method	Data gaps
Real data, does not rely on predicted data	Precision in recording location of old fires
Data exists province-wide	Short time span: just over 40 years
Burn area is mapped for fires > 200 ha	Fire size affected by suppression
Quantifies the minimum, average, and maximum value of fire cycle	
Addresses the seasonality of fires	
Causal factors of ignition can be addressed	
Establishes probabilities of ignition	

Bridge (2001) used actual fire records to calculate fire cycles across Ontario. These estimates, averaged for the period from 1921 to 1995, were similar (within 5%) but consistently lower than the fire cycles estimated by using the time-since-fire age distribution.

5.2.4 Provincial Lightning Strike Data

The positions of lightning strikes have been recorded province-wide since 1983. Details of the process can be found in Nimchuk (1989). This data set is used to determine the average lightning strike density over the landscape. Some areas, such as just east of the Continental Divide, are in a "lightning shadow," and do not receive many lightning strikes or lightning fires. Other areas, such as the Porcupine Hills and the Swan Hills regions, receive higher densities of lightning strikes. By overlaying the lightning-caused fires onto the lightning-strike density map, relationships between the number of strikes and the number of lightning fires can be established. Depending on the strength of the relationships, the strike data map, along with the density map of lightning fires, can be used in a predictive model of fire ignition.

Issues to Consider

Regions with a lower number of lightning detection towers will have an increased positioning error of the strike location. In many regions the positioning error can be as high as 5 to 16 km, especially in mountain landscapes. Due to an increased number of towers and better technology, the positioning error has decreased since 1992. Prior to using the lightning strike data, it is recommended that the proper authority be contacted with regards to the magnitude of the positioning error expected for the study area.

Table 5.5 Strengths and weaknesses of the provincial lightning strike data set approach

Strengths	Weaknesses
Low-cost method	Strike positioning errors of great magnitude in some regions
Data exists province-wide	Relationships between strike data and lightning-caused fires are not always strong
Collected since 1983	
Produces yearly average lightning strike density maps	
Establishes relationships with lightning-caused fires	
Contributes to the ignition prediction model	

5.2.5 Predictive Fire Modeling

When dealing with large landscapes (> 1,000 km^2), it may be too costly to undertake a detailed wildfire history of the entire study area. With good wildfire history data from an area that is representative of a specific landscape and wildfire regime, it is possible to establish a number of relationships between stand ages (wildfire dates) and environmental variables that may be used as predictive elements for fire distribution and patterns on the landscape. The predictive stand age model can in turn be applied to similar landscapes with similar wildfire regimes. For instance, the wildfire history data from a large area of the east slopes of the Canadian Rockies (8,100 km^2) revealed strong relationships between stand age patterns and topography in the mountains. Valley orientation, elevation, proximity to the Continental Divide, and aspect explained 64% and 70% of stand age patterns in the subalpine and montane zones respectively (Rogeau et al. 2001). If additional analyses are conducted using relevant environmental variables for benchmark study areas, additional predictive models can be developed and applied to similar landscapes lacking wildfire history data.

Issues to Consider

The main concern prior to establishing relationships between stand ages and variables is the quality of the wildfire history data and stand origin map. These issues have been discussed in Section 5.2.1.

Table 5.6 Strengths and weaknesses of the predictive fire modeling approach

Strengths	Weaknesses
Leads to learning about trends of fire distribution	Time consuming
Makes stand age predictions for a larger landscape	Relies on continuous cover of stand origin data
Obtains several fire cycle values that vary with topographic locations	Age data must be reliable

5.2.6 Computer Wildfire Simulations

Landscape disturbance models, and wildfire growth models, can be used to emulate the wildfire regime(s) of a specific type of landscape. It is not essential that these models mimic natural fire behaviour. Of importance is the end pattern on the landscape after decades or centuries of burning. The model must be able to replicate burn patterns and produce an age-class map reminiscent of what is seen today or of what was there historically.

These models should preferably use known age-class distribution data and wildfire regime parameter data for a particular landscape. The modeling approach is one not defining a wildfire regime, but rather of using the known parameters of the wildfire regime to simulate it. The modeling approach allows for multiple iterations of the simulation, thus providing a series of stand origin maps and age-class distributions. The series of output allows for an assessment of the generated natural range of variation (NRV). NRV is an important component for forest management that is often lacking from wildfire history data (i.e., a sample of one stand origin map and one age-class distribution). Section 5.4 provides information about the desired features and data inputs and outputs that a landscape disturbance model should incorporate.

Issues to Consider

Data entries for the model must come from a sound knowledge of the wildfire regime that is being simulated. It is desirable that the computer program provides a visual of the wildfire growth in order to address the potential occurrence of odd wildfire spread events. For instance, is the wildfire burning through water bodies or non-fuel types? Caution should also be exercised when interpreting the output, and the establishment of new wildfire pattern relationships with fuel, topography, or other variables should be avoided. The results should reflect the data inputs, and are driven by the model algorithms of ignition and spread.

Table 5.7 Strengths and weaknesses of the computer wildfire simulations approach

Strengths	Weaknesses
Alternate approach to produce a stand origin map	Requires a sound knowledge of the fire regime, probabilities of fire ignition, and type of fire spread
Replication = multiple stand origin maps and age-class distributions	Time consuming; model may need to be calibrated several times until it reflects realistic burning patterns
Assesses the natural range of variation of age-class areas and fire sizes	It is a model, it is not like real data. Caution should be exercised when using model results for forest management.
Keeps track of all burned areas before being overlapped	
Calculates the true fire cycle	
Keeps track of fire information for a specific watershed or jurisdiction as fires are grown throughout the landscape	

5.3 Wildfire Cycle Calculation

Wildfire cycles have been estimated for a number of Alberta landscapes using a variety of methods, including the Weibull model or negative exponential model, the maximum likelihood estimate (i.e., with the weighted mean forest age), the rolling back of age-classes, or by summing all burn areas of the study area. The following subsections present an overview of each wildfire cycle calculation method. This is not a technical review of each method, and it does not provide equations or step-by-step processes. Rather, a brief description is provided for each method, as well as some cautionary advice about the required wildfire data and information related to interpreting the results. It is recommended that additional reference material be reviewed, should any of the methods be applied.

5.3.1 Weibull (Negative Exponential) Model Method

The Weibull and negative exponential models are well described by Van Wagner (1978), Johnson and Van Wagner (1985), and Johnson and Gutsell (1994). The wildfire data input to use with these models is an age-class distribution derived from a time-since-fire map or a stand origin map. The percent area per age-class is cumulated on the Y-axis, while the time-since-fire is plotted on the X-axis. The negative exponential model is actually a special case of the Weibull model.

An age-class distribution that perfectly fits a negative exponential distribution reflects a forest with a risk of burning that is constant through time, or that is age invariant. If the data does not fit to a negative exponential curve, then the wildfire risk of a forested landscape increases or decreases with its age. The scale and shape parameters of the Weibull model define the wildfire cycle, whereas the slope of the negative exponential curve corresponds to the wildfire cycle. The weighted mean age, which is also referred to as the maximum likelihood parameter estimate (Johnson and Gutsell 1994), can be used as a surrogate value for the wildfire cycle when the age-class distribution follows a negative exponential slope. However, prior to using these models, the forested landscape should have a homogeneous wildfire regime, or probability of burning, that is constant through space and time. There are several rules of thumb when selecting a study area. The period of time should be short enough to avoid changes in climate, but long enough to accommodate the length of a few wildfire cycles. The study area should also be a minimum of three times the size of the largest amount of area burned during a time period (i.e., the burn area in a 10-year age-class). A landscape that is not homogeneous through time will have different slopes (or show a break in the curve) once plotted on Weibull paper; this is an indication that the wildfire cycle has changed.

Since the publication of these studies, questions have been raised by a number of wildfire researchers with regards to the accuracy of the method to estimate the wildfire cycle. Huggard and Arsenault (2001, 1999) claim it is a mistake to plot the age-class distribution in a reverse cumulative form, and that the empirical data should be analyzed in their standing form (area of age-class over time-since-fire) to determine the mortality rate. Finney (1995) suggests the old age tail, which runs to infinity in the negative exponential distribution, should be censored to allow for a better fit of the empirical data.

Lastly, Rogeau et al. (2004) and Rogeau (1996a) argue that the homogeneity assumption of the fire regime cannot be respected in mountainous terrain or for large landscapes due to the effect of topography on fire distribution and because the probabilities of ignition are not random, nor homogeneous. Computer-simulated age-class distributions under a homogeneous fire regime, both in space and time, revealed "breaks" in the simulated age-class distributions, indicating that the wildfire cycle had falsely changed over time.

All of these arguments suggest the wildfire cycle values calculated using the Weibull or negative exponential models can only provide relative estimates of the wildfire cycle. Considering the above issues, and coupling them with the poor quality and inaccuracies of some stand origin maps, the resulting wildfire cycle values could severely mislead managers in their choice of forest management options. It is therefore recommended that if such models are to be used, they should be applied only to reliable time-since-fire data and to areas that have been tested spatially and temporally for their homogeneity in wildfire regime characteristics.

5.3.2 Roll-Back Method

This method uses the age-class distribution, also derived from a time-since-fire or stand origin map, to determine the burn rate of the forest by decade, 20-year, or 40-year period (Andison 2000a, 1997). The poorer the quality and accuracy of the age-data, the wider the time period should be. The roll-back method consists of "peeling-off" age-class layers, starting with the most recent age class. The total area burned during the youngest age-class is removed and its area is redistributed to all other age-classes in similar proportions as to what is found on the landscape today.

This method provides a percent of area burned by time period from which the wildfire cycle can be estimated. This process is a reversal of the Weibull or negative exponential models, where the annual burn rate is determined from the wildfire cycle value. In this case, it is the burn rates by time period that are used to estimate the wildfire cycles. This is not a perfect method due to the uncertainty of the size of old area burned as a result of overlapping wildfires, but it provides a range of variation of the wildfire cycle estimates over a temporal scale. It is recommended that this method not be applied to data older than 200 years due to the increasing inaccuracies in area burned. These inaccuracies increase as the roll-back time period is extended.

5.3.3 Burn-Area Summation Method

This is the simplest and most accurate method. It consists of using empirical data of burn areas (i.e., wildfire size), and summing them until they equal the size of the study area. The shortcoming of this method is that reliable, complete burn-area data is only available since 1961 from the provincial wildfire records. Class E (> 200 ha) wildfires have also been mapped from 1931 to 1961, but this data set is likely incomplete, especially for remote areas. If a stand origin map is used, and it is known that wildfires are complete (i.e., not overlapped by subsequent burns), it is possible to have a reasonably reliable data set dating back to the 1900s.

The studies completed by Tande (1979) and Heinselman (1973) are good examples of constructing wildfire maps for long periods of time. Using wildfire data only from recent time periods will result in a wildfire cycle that reflects a wildfire regime influenced by humans, either by suppression efforts or by an increase in the number of human-caused wildfires during periods of settlement. Unless a region has not been subjected to wildfire suppression due to its remoteness, and includes few human-caused wildfires, wildfire cycles using this method are not likely to reflect the natural wildfire regime.

5.3.4 Wildfire Size and Frequency Distributions Method

This is another simple approach to estimate a broad range of wildfire cycles that can be used for the entire area of interest. It consists of using the mean wildfire frequency and wildfire size to determine the average wildfire cycle. A range in wildfire cycle values can be obtained by calculating the wildfire cycle using the standard deviation around the mean of wildfire frequency and wildfire size. The provincial wildfire records can be used for these calculations, but this method is also subject to the same shortcomings listed in the above section. Due to its general nature, this method is best applied to a very large landscape. This method was used to estimate the wildfire cycle of each natural region and subregion of Alberta (Section 6.2).

5.4 Wildfire History Data in Alberta

5.4.1 Background Information

Many forest and wildfire management goals and practices rely on the known wildfire history data available for a particular landscape. It is therefore important to document all of the small-scale wildfire history and wildfire regime research projects completed in the province. Some of these projects involved field collection of wildfire origin data, which provides a wildfire information period much longer than that of the provincial fire records (1961 to present). Knowing what wildfire history is available for the different landscapes, and how this information was collected, will benefit forest and resource management planners. Summarizing these projects also allows for an identification of knowledge gaps, and where additional wildfire research is needed.

A survey was distributed to all forest management agencies in the province to assess whether wildfire histories or wildfire regime studies had been completed, or if there were future plans to acquire this information. Each agency was asked to forward copies of documents pertaining to these projects, as well as information about the number of stand age related plots available in their management area. Although inventory sampling is completed with a different objective, some sampling designs are similar to those used for wildfire history sampling. This means some inventory ages are more reliable than others for wildfire dating. All of the information received was tabulated by NR, NSR, FMA, and protected park. The subregion coverage (percentage) within the FMA, Forest Management Unit (FMU), or park was also recorded. This allowed for a more detailed assessment of the location of the data gaps within the province.

Although there is a large number of wildfire related research projects in the province, this exercise focused strictly on wildfire history data, and wildfire regime parameters, and did not include any work related to wildfire effects on soil, plants or wildlife, wildfire behaviour, wildfire climate, and landscape metrics such as patch size distribution, natural range of variation of disturbances, or island remnants. To obtain this information, the following agencies should be contacted: the Canadian Forest Service, the Northern Forestry Centre in Edmonton, the FERIC Wildland Fire Operations Research Centre in Hinton, the Foothills Model Forest in Hinton, the Alberta Research Council in Vegreville, the University of Alberta, and the University of Calgary.

The results of the survey are summarized in Appendix III, with one table per natural region. A land base representing less than 1% of a subregion was removed to reduce the length of the summary tables, unless pertinent work was done for that subregion. Wildfire history and age data, as well as wildfire regime methods, are summarized. The references for each work are also provided.

One wildfire regime parameter that surfaced in many documents was the wildfire cycle or burn rate (i.e., the percentage of area burned each year). For this reason, it was included as a mean to compare numbers from one landscape to another. However, the methods used varied depending on the investigator, and the estimated wildfire cycle values also varied according to the approach used. Wildfire cycles have been estimated using a variety of methods, including the Weibull (or negative exponential) model, the maximum likelihood estimate, the weighted mean forest age, the regression slope, or by summing all burn areas of the study area.

Wildfire cycles were calculated either for the whole area, by natural region, by fuel type, by topographic location, or by time period. Some researchers used wildfire history data from a wildfire origin map (time-since-fire map) or wildfire history point samples, while others used inventory ages either from the AVI or the older Phase III inventory. The wildfire cycle values, or burn rates presented, should be used as ballpark figures, as these values could easily differ by as much as 30 years depending on the method used (Rogeau 1996a). In worst-case scenarios, values could differ by as much as 100 years, especially if the less reliable inventory ages were used. Regardless of the method used, wildfire cycle and burn rate values should be used only as guidelines. A range of fire cycle values within the NRV should be the benchmark from which to work. To date, the best way to obtain an estimate of the NRV is through landscape disturbance modeling (see Section 5.5). Lastly, the final attribute of the data gap table is the wildfire data period. It represents the period of time from which wildfire information is available. In the case of wildfire history data, it defines the period between the oldest fire detected, and either the most recent wildfire or the year the study was completed.

The information is presented by FMA, protected park, and the Green or White Area. The Green Area includes forested areas managed by the province of Alberta. The White Area includes settled and agricultural areas that do not have any commercial forests, but may have forest patches. Due to the large number of FMUs within the Green and White Areas, they were divided into four portions: NW, NE, SW, and SE, using Edmonton as the centre of the cardinal directions.

5.4.2 Identification of Data Gaps

A data gap represents an area without any information pertaining to the history of wildfire or to its wildfire regime. It is clearly symbolized by the empty lines in the tables. The significance of the data gap in a natural region is reflected by the number of empty lines. Synthesizing the information by percentage of subregion (Table 5-8), allows for the identification of what kind of data gaps occur in the province, and where they are located.

Overall the majority of wildfire origin mapping and wildfire history data collected has occurred in the Rocky Mountain NR. The Alpine NSR has the best coverage, with over 75% of the area represented by wildfire history/wildfire regime data. The Subalpine NSR follows with just over 50% of the area represented by wildfire information collected, while the Montane NSR falls short with a 70% area data gap. The Peace River Lowlands NSR of the Boreal Forest NR is also well covered with only a 20%

Table 5.8 Percentage of land base in a subregion that has wildfire history data and wildfire regime data available. Land bases that contribute to the data gap by having more than 5% of their managing area in that subregion are listed. CM = Central Mixedwood, DM = Dry Mixedwood, WM = Wetland Mixedwood, SA = Sub-Arctic, PRL = Peace River Lowlands, BH = Boreal Highlands, Salp. = Subalpine, Mont. = Montane, AP = Athabasca Plain, KU = Kazan Upland, FH = Foothills Parkland, P = Peace River Parkland, C = Central Parkland, RM = Rocky Mountain, Foot = Foothills, CS = Canadian Shield.

	Natural Subregion															
	CM	DM	WM	SA	PRL	BH	Alpine	Salp.	Mont.	Upper	Lower	AP	KU	FH	P	C
Nat. Region	Boreal	Boreal	Boreal	Boreal	Boreal	Boreal	RM	RM	RM	Foot.	Foot.	CS	CS	Park.	Park.	Park.
Fire History	12	0	22	5	80	12	80–85	50–55	30	21	35	0	0	2	0	0
Fire Regime	21	7	22	5–10	74	12	75	45–50	30	23	22	0	0	0	0	0
Land Base	Tolko Green	Tolko Green White	Tolko Green	Tolko Green	Green	Tolko Green	Green	Wey.-G.P. Green	Green White	ANC SLP Sund. Wey.-Dray-ton & Edson & G.P Green.	Man-ning SLP Wey.-Dray-ton & Edson & G.P. Green	Green	Green	White	White	White

area data gap. However, this wildfire history data is considered very limited, with only 166 random plots distributed in Wood Buffalo National Park, an area close to 45,000 km^2. All of the wildfire history data accounted for in the Boreal Forest NR is from this national park.

The most important knowledge gaps reside in the Canadian Shield and Parkland NRs, as no form of wildfire history or wildfire regime work has been completed for these regions. The Dry Mixedwood NSR of the Boreal Forest NR also lags behind in terms of available wildfire information. Over 75% of this NSR is located in the White Area (settled portion), suggesting that this wildfire regime has been strongly influenced by human use of this landscape.

Data gaps are also represented in a map format in Figure 6.1 for a better visualization of their spatial distribution on the landscape. The kind of fire data information available for each FMU and park was categorized into five classes:

1) Fire Origin Map: Implied tree data collection and fire dating.
2) Fire History Point Data: Implied tree data collection and fire dating, but no mapping.
3) Fire Regime Analysis: Some or all fire regime parameters were assessed using the provincial fire records.
4) Fire Regime Analysis & Fire Data: Fire regime analysis was done in combination with fire dating using polygon data (map) or point data.
5) Fire Data Gap: No fire data collection or fire regime assessment.

Although some regions are identified as having a wildfire data gap, wildfire cycle estimates have been made using inventory ages, provincial fire records, or landscape disturbance modeling output.

5.4.3 Future Considerations

Aside from the mountain parks (federal and provincial) and the Foothills Model Forest studies, very little wildfire history data have been collected in the province. The wildfire regime knowledge that is available comes largely from wildfire records collected over a relatively short period of time (since 1961). This, however, represents a time period when the wildfire regime has been influenced the most by humans (i.e., by suppression effects and more human-caused fires).

Where data gaps exist, consideration should be given to initiate wildfire history work, perhaps in a partnership with neighbouring land managers that are part of the same data gap region. Wildfires obviously cross jurisdiction boundaries, and it is often easier to disregard such boundaries for work related to wildfire history. Areas of study do not need to be extremely large. It is more beneficial to have several small-scale studies (~1,000 km^2) distributed over representative areas of a subregion to provide replication, and to capture natural variation in age-class distributions and wildfire cycle values.

The results in Section IV and VI can be used as a guideline to identify those subregions that can be combined to undertake wildfire history data collection. Historical wildfire data are useful to calculate historical burn rates, which can be compared to the burn rates calculated from recent wildfire occurrence records (post-1961).

This information is needed to answer important questions. For example, are today's current forest management practices, and wildfire suppression strategies and tactics, modifying the wildfire cycles and associated yearly burn rates? Are today's forest disturbance rates (determined by wildfire, prescribed burning and harvesting) equivalent to the natural–wildfire-only historical burn rates? Managing forest landscapes in ways that are reminiscent of historical disturbance rates is more likely to maintain ecosystems at an equilibrium state, where biodiversity can be maintained and ecological integrity conserved. Biodiversity is, in part, a product of the availability and range of habitat types, which are in turn driven by the frequency and size of disturbances.

5.5 Landscape Disturbance Models

Landscape disturbance models have been used as tools to complement existing information about a wildfire regime. They are especially useful to address the problems associated with a sample of one wildfire origin map. Models allow for multiple repetitions of the simulation process, thus providing a range of variation of wildfire patterns on the landscape, as well as a range of variation of stand age distributions, wildfire cycles, and disturbance rates. As such, landscape disturbance models allow for a defensible statistical process, and can be a powerful tool to explore different wildfire and forest management options or scenarios.

Five landscape disturbance models have been applied to different Alberta landscapes. Their applications and technical aspects are listed in turn in Appendix IV. Although each model is designed to meet different goals, they all include a form of wildfire regime emulation process to achieve their respective goals. Each of the developers recognize that their models could be redesigned to some extent, or modified to address different or more specific management objectives.

The FEENIX and TARDIS models focus on answering questions related to economic and ecological forest management issues. The LANDIS model is used in a biodiversity and forest succession context, whereas both the LANDMINE and STANDOR models emulate long-term natural disturbance processes on the landscape. The LANDMINE and STANDOR models provide a range of variation of wildfire patterns and age-class distributions.

If it is important to emulate the natural wildfire regime as closely as possible, a landscape disturbance (wildfire) model should include several basic features. First, it should rely on empirical data to define the wildfire frequency, as well as the spatial variability in the probabilities of ignition. Very few systems (i.e., processes) in nature function randomly. Since the published literature suggests that wildfire is not a random process, landscape disturbance models are then constrained by the input data.

The probabilities of ignition are defined by the spatial distribution of lightning-caused fires, as well as human-caused fires, on the landscape. It is discretionary to include human-caused wildfires, since it depends on the objectives of the study, the time period for which the wildfire regime is modeled (pre- or post-settlement), and upon our definition of "natural" wildfire regime (i.e., should aboriginal wildfires be included or not). The model should also involve elements to define the probabilities of wildfire spread on the landscape. Interestingly, all of the models reviewed apply these features, sometimes using very different methods and parameters.

All of the models except STANDOR emulate wildfire extinction by using a predetermined wildfire size curve with a maximum wildfire size. STANDOR has the option of growing wildfires like a "real-time" wildfire growth model by using local fire weather data and the FBP System fuel types. Despite the means of achieving the needed results, any model needs some form of calibration (that is, simulation test runs), in order to evaluate whether the disturbance outputs are either reminiscent of the natural fire regime (with regards to fire distribution, frequency, size, and patterns) or that they meet predetermined wildfire regime parameters.

Section VI Conclusion and Management Implications

Alberta has variable wildfire regimes, due to variations in vegetation, climate, topography, and land-use patterns. Frequent large lightning-caused wildfires occur in the northern remote areas. Based on the 1961-2002 wildfire records frequent, small, high-intensity wildfires, and infrequent, large wildfires occur throughout most of the Boreal Forest NR. The Foothills and Rocky Mountain NRs experience infrequent small human-caused wildfires, and very infrequent large high-intensity wildfires. However, evidence suggests that historically, larger wildfires occurred in some areas as often as every 13 years (Rogeau 2004). Multiple fire-start scenarios are a common occurrence in the Boreal Forest NR, but are a relatively rare occurrence in the Foothills and Rocky Mountain NRs.

6.1 Provincial Wildfire Regime

Wildfire is a common natural disturbance in most of Alberta's forests. The only exceptions are the Alpine NSR and some areas in the upper Subalpine NSR. Since the alpine area is by definition the area above the treeline, it experiences very few wildfires.

Lightning- and human-caused wildfires have similar proportions (approximately 50% each) of the total wildfire occurrence, but the majority of the area burned is caused by lightning wildfires. Nationally, lightning accounts for 70% of all Class E (> 200 ha) wildfires, and 85% of the total area burned by all Class E wildfires in Canada (Stocks et al. 2002).

In general, human-caused wildfires in Alberta occur in areas with frequent human activities. In the remote, less accessible areas, lightning-caused wildfires are dominant.

Wildfires in Alberta have seasonal patterns. Generally, the peak wildfire period is April and May. However, due to differences in climate, vegetation, and human activity, spatial variations in seasonal pattern are observed across Alberta. Spring grass fires are common in April and May in areas with grass fuel types (e.g., in the Grassland and Parkland NRs and in developed areas). In the deciduous dominated Central Mixedwood NSR, wildfires peak in May just before green-up. In the northern and high elevation areas, the peak wildfire period occurs from June to August (because of later snow melt and longer day length). Wildfires in the Montane and Subalpine NSRs occur in August and September, both historically and today.

The vast majority of the wildfires in Alberta do not exceed 200 ha in size. Only 2% of the total wildfires are Class E (>200 ha) wildfires. However, 98% of the area burned is caused by Class E wildfires.

Wildfires in Alberta also exhibit high temporal variations in both wildfire occurrence and area burned. The temporal variations in area burned are much greater than the wildfire occurrence. The majority of the area burned occurs during very short time periods (spread events). The years with large area burned (often referred to as "spikes") are distributed unevenly over time. This uneven flow of fire on the landscape can significantly disrupt the forest industry target of an even flow of fibre (Boychuk and Martell 1996).

Spatial wildfire distribution pattern is evident in Alberta. The regions with the highest level of human activity usually have the highest number of wildfires, but the area burned is generally very low. Land fragmentation, early detection, and effective suppression also contribute to this pattern. The Dry Mixedwood NSR is a typical example of this pattern.

In the more northern remote areas, frequent large stand-replacing wildfires occur. The number of wildfires is not very high, but the area burned is considerably so. Lower values at risk, and hence lower suppression priorities, are important factors contributing to the large area burned. Because life and community protection is the first forest protection priority in Alberta, areas with more communities receive higher suppression priority. In northern Alberta, an Ecological Wildfire Management Area (EWMA) was created to allow fire to be an integral ecological process in this ecosystem. Since the EWMA is located within the FPA, all wildfires are still initially attacked. However, if a wildfire escapes initial attack, and there are no values at risk, modified suppression strategies may be used to manage the wildfire. Each wildfire is assessed and managed individually.

In the mountain areas, small wildfires are very common, but few of these fires become large in size. Spatial variation in wildfire occurrence is also observed among the three NSRs in the foothills and east slopes. The Montane NSR has the highest wildfire occurrence rate in the province due to its heavy recreation activities. Most of the wildfires in the Montane NSR are human-caused spring wildfires. In the Subalpine NSR, there are more lightning-caused wildfires during the summer compared to the Montane NSR.

Within an NSR, spatial variations may also be evident. For example, most of the Central Mixedwood NSR experiences lightning-caused wildfires. However, in areas near river corridors, roads, and communities, human-caused wildfires are more common.

The basic provincial wildfire statistics are as follows:

- Average wildfires/year: 843.
- Average area burned/year: 142,793 ha.
- Average Class E wildfires/year: 17.
- Percentage by cause: 48.3% human, 49.3% lightning, 2.4% unknown.
- Peak fire season: May to August.
- Average wildfires/10^6 ha /yr: 21.47.
- Average wildfire size: 171 ha.
- Annual area-burn rate: 0.37%.
- Fire cycle: 273 years.

Wildfire regime: The wildfire regime in Alberta is characterized by frequent large high-intensity wildfires in the Boreal Forest NR, and infrequent large high-intensity wildfires on the east slopes. Low- to moderate-intensity fires were historically more prevalent in the east slopes.

It is important to use normalized data (e.g. per million ha) rather than raw data when interpreting the data, and making sensible comparisons between NRs and NSRs. The fire return interval and fire cycle estimates can be misleading if normalized data are not used because of the large size differences of the NRs and NSRs. It is also important to remove water bodies and other non-fuel types from the area analysis.

6.2 Wildfire Regime at the Natural Subregion Level

6.2.1 Boreal Highlands

The Boreal Highlands NSR occupies the high elevation area in the Boreal Forest NR.

This NSR has a large proportion of flammable conifer stands. Due to its remote and northern location, human activity and human-caused wildfires are limited. The majority of wildfires and area burned in this NSR are lightning-caused. Fuel continuity, and the occurrence of flammable black spruce stands, combined with fewer values at risk, have resulted in a disproportionately large burned area, and higher than average annual area-burn rate.

The basic wildfire statistics for the Boreal Highlands NSR are as follows:

- Average wildfires/year: 22.
- Average area burned/year: 15,767 ha.
- Average Class E wildfires/year: 1.
- Percentage by cause: 11.0% human, 88.5% lightning, and 0.5% unknown.
- Peak fire season: May to August.
- Average wildfires/10^6 ha /yr: 11.2.
- Average wildfire size: 719 ha.
- Annual area-burn rate: 0.80%.
- Fire cycle: 124 years.

Wildfire regime: Infrequent, lightning-caused, large wildfires.

6.2.2 Central Mixedwood

The Central Mixedwood NSR accounts for one-third of the total FPA. Proportionally, it has 35% of the total wildfire occurrence, and 41% of the total area burned. The main vegetation types are aspen and aspen-white spruce stands. The majority of the human-caused wildfires occur in the spring. May is a critical month because the aspen and aspen mixedwood stands often do not reach green-up until late May. Lightning-caused fires occur predominately during the summer months.

The basic wildfire statistics for the Central Mixedwood NSR are as follows:

- Average wildfires/year: 288.
- Average area burned/year: 58,199 ha.
- Average Class E wildfires/year: 7.
- Percentage by cause: 40.2% human, 57.8% lightning, and 2.0% unknown.
- Peak fire season: April to August.
- Average wildfires/10^6 ha /yr: 21.9.
- Average wildfire size: 198.0 ha.
- Annual area-burn rate: 0.44%.
- Fire cycle: 226 years.

Wildfire regime: Areas with infrequent, large wildfires, and areas with frequent, small wildfires.

6.2.3 Dry Mixedwood

The Dry Mixedwood NSR, located between the Wetland Mixedwood and Lower Foothills NSRs on the west side, and the Central Mixedwood NSR on the east side, is the subregion with the most human development in the Boreal Forest NR. The vast majority of the wildfires are human-caused and peak sharply in the spring. Due to the fragmented fuel distribution, and effective detection and suppression, the area burned is disproportionately small compared to the number of wildfire occurrences. The estimated fire cycle is high because of the effect of suppression.

The basic wildfire statistics for the Dry Mixedwood NSR as follows:

- Average wildfires/year: 118/135.
- Average area burned/year: 4,499 ha.
- Average Class E wildfires/year: 3.
- Percentage by cause: 80.2% human, 15.0% lightning, and 4.8% unknown.

- Peak fire season: April to August.
- Average wildfires/10^6 ha /yr: 25.0.
- Average wildfire size: 36.2 ha.
- Annual area-burn rate: 0.09%.
- Fire cycle: 1,053 years.

Wildfire regime: Frequent, human-caused small, wildfires.

6.2.4 Peace River Lowlands

This subregion constitutes a very small proportion of the FPA. Both wildfire occurrence and area burned are relatively low. Most of the wildfires in this subregion are human-caused.

The basic wildfire statistics for the Peace River Lowlands NSR are as follows:

- Average wildfires/year: 3.
- Average area burned/year: 218 ha.
- Average Class E wildfires/year: 0.
- Percentage by cause: 67.6% human, 27.7% lightning, and 4.7% unknown.
- Peak fire season: April to August.
- Average wildfires/10^6 ha /yr: 14.8.
- Average wildfire size: 66.8 ha.
- Annual area-burn rate: 0.10%.
- Fire cycle: 1,013 years.

Wildfire regime: Infrequent, small wildfires.

6.2.5 Sub-Arctic

The Sub-Arctic NSR is located in the highlands in the north portion of Alberta (Strong 1992). Most of this subregion is characterized by the occurrence of a permafrost layer. The short wildfire season is compensated for by long day lengths that often extend the burning period during the summer months. Open black spruce stands are the most common vegetation type in this subregion. Mosses and lichens dominate the ground cover (Strong 1994). The permafrost layer and poor access limit human land use of this area. As a result, spring wildfires are uncommon in this subregion. The vast majority of the wildfires are lightning-caused. This subregion has both a higher than average area-burn rate and average fire size because of its continuous conifer fuel type and possible dry period in summertime.

The basic wildfire statistics for the Sub-Arctic NSR are as follows:

- Average wildfires/year: 27.
- Average area burned/year: 15,230 ha.
- Average Class E wildfires/year: 2.
- Percentage by cause: 2.8% human, 96.9% lightning, and 0.4% unknown.
- Peak fire season: June to August.
- Average wildfires/10^6 ha /yr: 13.3.
- Average wildfire size: 575 ha.
- Annual area-burn rate: 0.76%.
- Fire cycle: 132 years.

Wildfire regime: Infrequent, lightning-caused, large wildfires.

6.2.6 Wetland Mixedwood

The Wetland Mixedwood NSR has similar wildfire regime characteristics to the Central Mixedwood NSR. The Wetland Mixedwood NSR has slightly lower wildfire occurrence and area burned rates than the Central Mixedwood NSR because of the occurrence of wetlands and the higher percentage of mixedwood and balsam poplar forests. Lightning-caused wildfires are the main causal agent.

The basic wildfire statistics for the Wetland Mixedwood NSR are as follows:

- Average wildfires/year: 45.
- Average area burned/year: 8,268 ha.

- Average Class E wildfires/year: 1.
- Percentage by cause: 33.1% human, 65.3% lightning, and 1.6% unknown.
- Peak fire season: May to August.
- Average wildfires/10^6 ha /yr: 14.7.
- Average wildfire size: 185.5 ha.
- Annual area-burn rate: 0.27%.
- Fire cycle: 367 years.

Wildfire regime: Infrequent, lightning-caused, medium-sized wildfires.

6.2.7 Athabasca Plain

The Athabasca Plain NSR is one of the two subregions in the Canadian Shield in Alberta. This subregion has the second-highest annual area-burn rate and proportion of Class E wildfires in the province. Continuous open Jack pine stands dominate the landscape. Since human land-use activities are limited, human-caused wildfires are insignificant in this subregion. Spring wildfires are not common. The peak wildfire season is during the summer months. The wildfire season is relatively short but the days (and the resulting amount of daylight) are long. This subregion experiences frequent large lightning-caused wildfires. The lower values at risk result in a lower suppression priority that contributes to wildfires becoming larger in size.

The basic wildfire statistics for the Athabasca Plain NSR are as follows:

- Average wildfires/year: 4.
- Average area burned/year: 9,860 ha.
- Average Class E wildfires/year: 0.
- Percentage by Cause: 18.1% human, 81.9% lightning, and 0.0% unknown.
- Peak fire season: May to August.
- Average wildfires/10^6 ha /yr: 9.0.
- Average wildfire size: 2,435 ha.
- Annual area-burn rate: 2.23%.
- Fire cycle: 45 years.

Wildfire regime: Infrequent, lightning-caused, large wildfires.

6.2.8 Kazan Upland

The Kazan Upland is another NSR in the Canadian Shield NR. This subregion has the highest annual area-burn rate, and the highest proportion of Class E wildfires in Alberta. The wildfire regime in this subregion is very similar to the Athabasca Plain NSR. However, this subregion has less influence from Athabasca Lake. The annual burn rate and average wildfire size are higher in this subregion than in the Athabasca Plain NSR. The majority of the wildfires are lightning-caused and occur during the summer months. The wildfire season is relatively short, but longer day lengths extend the burning period. The occurrence of continuous flammable conifer stands creates a very fire-prone environment. Low values at risk and a low wildfire suppression priority contribute to the proportionally large area burned in this subregion.

The basic wildfire statistics for the Kazan Upland NSR are as follows:

- Average wildfires/year: 9.
- Average area burned/year: 9,985 ha.
- Average Class E wildfires/year: 1.
- Percentage by cause: 10.0% human, 90.0% lightning, and 0.0% unknown.
- Peak fire season: June to August.
- Average wildfires/10^6 ha /yr: 10.8.
- Average wildfire size: 1,139 ha.
- Annual area-burn rate: 1.23%.
- Fire cycle: 82 years.

Wildfire regime: Infrequent, lightning-caused, large wildfires.

6.2.9 Lower Foothills

The Lower Foothills NSR is the second-largest subregion in Alberta (Strong 1992). It accounts for 21% of the total wildfire occurrence in Alberta, but less than 10% of the total area burned. It is also the most productive forest area in Alberta. Mixedwood stands dominate this subregion. It has relatively warm winters, and cool and moist summers. Forest operations and oil and gas activities are common in this subregion. Human-caused spring wildfires are common, with a sharp peak in May. Lightning wildfires occur predominantly in the summer. Fuel discontinuities, and relatively cool and moist summers, restrict wildfire spread during the summer months. As a result, the area-burn rate is at a very moderate level. Human-caused spring wildfires are the main concern within this subregion.

The basic wildfire statistics for the Lower Foothills NSR are as follows:

- Average wildfires/year: 176.
- Average area burned/year: 13,516 ha.
- Average Class E wildfires/year: 2.
- Percentage by cause: 53.2% human, 44.3% lightning, and 2.5% unknown.
- Peak fire season: April to August.
- Average wildfires/10^6 ha /yr: 27.5.
- Average wildfire size: 77 ha.
- Annual area-burn rate: 0.21%.
- Fire cycle: 475 years.

Wildfire regime: Frequent, medium-sized wildfires.

6.2.10 Upper Foothills

The Upper Foothills NSR has similar wildfire regime characteristics to the Lower Foothills NSR, except that it experiences more lightning-caused wildfires. The Upper Foothills NSR has less human activity compared to the Lower Foothills. The majority of the area burned is caused by lightning wildfires during the summer, with a sharp peak in June. Although the Upper Foothills NSR has more conifer fuel types than in the Lower Foothills, the Upper Foothills NSR has a lower annual area-burn rate, and lower average wildfire size. However, the Upper Foothills NSR receives higher precipitation, and more days with measurable precipitation during the summer months (Strong 1992). Topography also has a greater influence on wildfire spread in the Upper Foothills NSR than in the Lower Foothill NSR.

The basic wildfire statistics for the Upper Foothills NSR are as follows:

- Average wildfires/year: 77.
- Average area burned/year: 4,378 ha.
- Average Class E wildfires/year: 1.
- Percentage by cause: 36.5% human, 62.3% lightning, and 1.2% unknown.
- Peak fire season: May to August.
- Average wildfires/10^6 ha /yr: 28.2.
- Average wildfire size: 57 ha.
- Annual area-burn rate: 0.16%.
- Fire cycle: 627 years.

Wildfire regime: Mostly lightning-caused, frequent, medium-sized wildfires and infrequent, large wildfires.

6.2.11 Subregions in the Grassland and Parkland Natural Regions

The Foothills Fescue, Foothills Parkland, and Peace River Parkland are three subregions that include grasslands. These subregions have very small portions in the area of the FPA. Both wildfire occurrence and area burned in these subregions are very small. All of them exhibit infrequent small wildfire regimes.

6.2.12 Alpine

The Alpine NSR includes the areas above the treeline in the Rocky Mountain NR. The treeline is defined as the zone where contiguous forest stops and isolated islands of trees begin (Ogilvie 1976). It is characterized by scattered, low-growing vegetation. The terrain and lack of fuel result in very few wildfires occurring in this subregion.

6.2.13 Montane

The Montane NSR is situated below the Subalpine NSR. The Montane NSR includes steep and rough topography (Strong 1992). Many areas in this subregion are included within parks and natural reserves. Besides recreation activities, grazing and forestry are common activities outside the park areas. As a result of the high human use, the Montane NSR has the highest wildfire occurrence rate in the province. Moreover, the vast majority of the wildfires are human-caused ones that peak in the spring. Grass, pine, and aspen stands are the dominant vegetation types in this subregion. Wildfire spread is limited in the Montane NSR because the fire load is low, and suppression efforts are very successful in the pine fuel types. Therefore, the annual area burned and the average wildfire size are both small. Historically, large, high-intensity wildfires have been wind driven events occurring in the fall. Human-caused spring wildfires are the main concern.

The basic wildfire statistics for the Montane NSR are as follows:

- Average wildfires/year: 26.
- Average area burned/year: 68 ha.
- Average Class E wildfires/year: 0.
- Percentage by cause: 84.1% human, 13.0% lightning, and 3.0% unknown.
- Peak fire season: March to October.
- Average wildfires/10^6 ha /yr: 82.0.
- Average wildfire size: 3 ha.
- Annual area-burn rate: 0.02%.
- Fire cycle: 4,736 years.

Wildfire regime: Frequent, small, human-caused wildfires.

6.2.14 Subalpine

The Subalpine NSR is located below the Alpine NSR and above the Montane NSR. Conifer is the dominant vegetation type but is distributed in clumps because of its topography feature. Summer is cool and rainy in this subregion. Because of its elevation and complex topography, a significant portion of this subregion is undeveloped.

Although spring wildfires exist, the majority of the wildfire occurrence and area burned are in late summer, with a peak in August. Lightning causes slightly more wildfires than humans do in this subregion, but lightning-caused wildfires account for the most of the total area burned. Due to the fuel and landscape discontinuity, the wildfire spread is limited. As a result, the wildfires in the Subalpine NSR are usually small in size.

The basic wildfire statistics for the Subalpine NSR are as follows:

- Average wildfires/year: 23.
- Average area burned/year: 382 ha.
- Average Class E wildfires/year: 0.
- Percentage by cause: 56.7% lightning, 41.9% human, and 1.3% unknown.
- Peak fire season: May to September.
- Average wildfires/10^6 ha /yr: 13.5.
- Average wildfire size: 16 ha.
- Annual area-burn rate: 0.02%.
- Fire cycle: 4,542 years.

Wildfire regime: Infrequent, small, wildfires, and very infrequent, large, high-intensity wildfires.

6.3 Ecological Role of Fire

Designing and managing future designed forests requires an understanding of natural disturbance, and in particular, the baseline conditions of natural disturbance. A wildfire regime analysis contributes to the understanding of fire as an important ecological process in the forest ecosystems in Alberta.

Wright and Heinselman (1973) provided a summary of the ecological role of fire in the conifer forests of western and northern North America. They identified six main roles of fire, as described below.

6.3.1 Fire as an Influence on the Physical-Chemical Environment

- Releases nutrients.
- Increases decomposition.
- Reduces plant cover, thereby increasing insolation.
- Increases soil temperature.
- Alters permafrost layers.

6.3.2 Fire as a Regulator of Dry-Matter Accumulation

- Recycles carbon.
- Regulates organic accumulation.

6.3.3 Fire as a Controller of Plant Species and Communities

- Triggers the release of seeds.
- Alters seedbeds.
- Stimulates sprouting.
- Eliminates or reduces competition.
- Influences re-trajectory of succession.
- Selectively eliminates part of a plant community.
- Fire frequency influences composition and succession.

6.3.4 Fire as a Determinant of Wildlife Habitat Patterns, and Populations

- Increases food for herbivores.
- Increases yields of many berry-producing shrubs.
- Eliminates forage plants characteristic of old forests.
- Regulates many insect populations.
- Controls landscape mosaic.

6.3.5 Fire as a Controller of Forest Insects, Parasites, Fungi, etc.

- Eliminates hosts for spruce budworm, mountain pine beetle, and other insects.
- Regulates the age structure of forest stands.
- Interacts with insect outbreaks.
- Temporarily eliminates plant parasites (e.g., Mistletoe).

6.3.6 Fire as the Controller of Major Ecosystem Processes and Characteristics

- Contributes to nutrient cycling and energy flow.
- Controls the total mosaic of stand age classes and successional stages.
- Maintains diversity (mix of successional stages).
- Influences long-term system productivity.
- Contributes to ecological stability.

Table 6.1 Summary of provincial coverage of wildfire history and wildfire regime data

Study Area	Reference
AlPac Study Area	Cumming 1997, 2000a, 2001b Andison 2003
Alberta Newsprint Company	Andison D.W. 2000a
Blue Ridge Lumber Inc.	Rogeau 1999a
C5 Study Area	Olson and Diehl. 1998 Alberta Environment 1998, 2000 Rogeau 2005
Canadian Forest Products Ltd.	Olympic Resource Management 2000
Daishowa-Marubeni International Ltd.	Stelfox and Wynes 1999
Kananaskis Study Area	Johnson and Fryer. 1987 Rogeau 2004
Millar Western Forest Products Ltd.	Hirsch and de Groot 1999
North Athabasca Lake Study Area	Beverly and Qamanirjuaq Caribou Management Board. 1994a, 1994b. Brungs-Simard 2001
R11 Study Area	Rogeau 1999b
Spray Lake Sawmills	Rogeau 2004
Sunpine Forest Products Ltd.	Trees Consulting Inc. 2002 Andison *In progress*.
West Fraser Timber Company Ltd.	Andison 1997, 2000a. Rogeau 1996b, 1997
Banff National Park	Rogeau 1994, 1996a, 2001a, 2001b White 1985a, 1985b Wierzchowski, Heathcott, and Flannigan. 2002
Jasper National Park	Andison 1997, 2000a Tande 1979 Rogeau 1999c
Waterton Lakes National Park	Barrett 1996
Wood Buffalo National Park	Larsen 1996, 1997
Cypress Hills Provincial Park	Strauss 2002
Peter Lougheed and Spray Valley Provincial Parks	Hawkes 1980 Rogeau 1994
Whitegoat–Siffleur Wilderness Areas	Rogeau 1999b

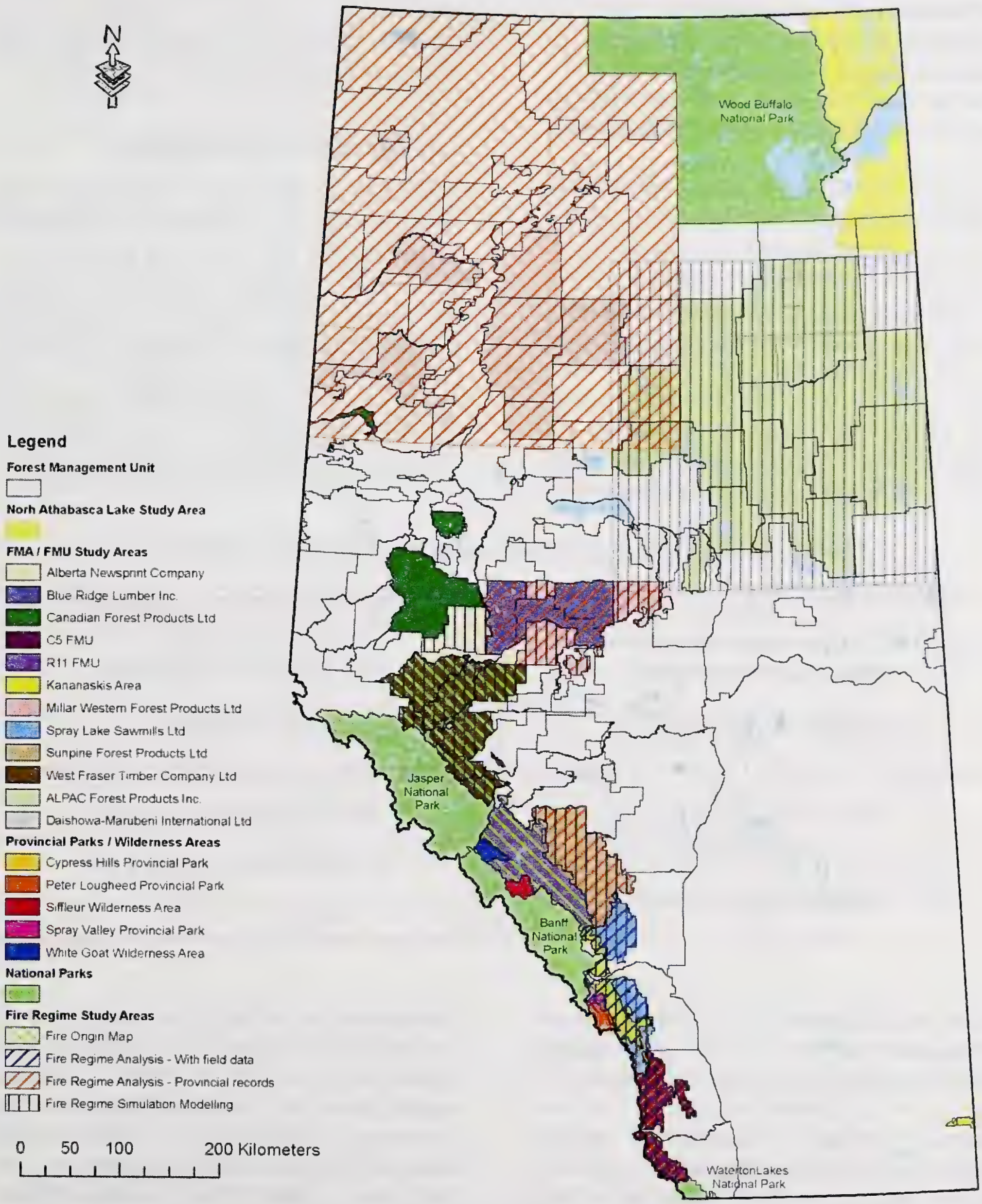

Figure 6.1 Provincial coverage of wildfire history and wildfire regime data

Historically, wildfire management focused on suppressing all wildfires. Although the protection of life and communities, and the maintenance of a strong suppression capability, are still a priority, ecological management today embraces the need to consider both the impacts of wildfire (both negative and positive), and the absence of wildfire. Less wildfire activity occurs today compared to the presuppression era, but the impacts of wildfire today have changed substantially because of increased resource management activities on the land base. Land use managers need to understand if wildfire is an additive or a compensatory process on the landscape.

The effects of wildfire are complex and variable. They depend on the site conditions and the wildfire regime characteristics of frequency, wildfire type, intensity, severity, size, and season. Although it is often said that no two fires are alike, spatial wildfire patterns do occur. A wildfire regime analysis attempts to capture common fire effects and spatial patterns.

6.4 Management Implications

Incorporating fire regime information into forest management remains a challenge, particularly at the landscape level. At the stand level, variable retention harvesting, and variable cutblock shapes and sizes drive the emerging natural disturbance emulation paradigm for sustainable forest management. Increasing variability is the key. But how much and where? How much retention or older aged forest is enough, and where should they be located to ensure ecological integrity. Fire regime studies help to answer these important questions.

Table 6.2 Spatial landscape assessment of the ecological impact of fire

Fire is ecologically good **High to severe constraints** **No wildfire/No prescribed fire**	**Fire is ecologically good** **Low to moderate constraints** **Prescribed fire**
Fire is ecologically good **No constraints** **Wildfire/Prescribed fire**	**Fire is not ecologically good** **No wildfire/No prescribed fire**

Mapping a desired format of the wildfire regime information is important so that it can be integrated with other data layers. One method to spatially assess how wildfire regime information can be used is to classify landscapes into four classes (Table 6.2) based on whether fire is ecologically good and whether there are any constraints. This classification can also be refined by wildfire regime type (i.e., with reference to the frequency and intensity of wildfire). For example, high-intensity wildfires are not ecologically good in the Porcupine Hills in southwest Alberta, but frequent low-intensity wildfires are ecologically desirable. Whether the impact of wildfire is positive or negative depends on the wildfire regime characteristics and the resource management objectives.

Burn probability models such as Burn-P3 (Parisien et al. 2004) and Burnpro (Davis and Miller 2004) use fire regime information to spatially estimate the burn probability over a landscape. They use historical ignition and historical weather information as inputs into the models.

In the United States, landscape assessments have been completed using fire regime condition classes. Five natural fire regimes are used (Table 6.3). Three fire regime condition classes describe the level of departure from the natural fire regimes. Condition class 1 is considered to be within the natural (historical) range of variability. Condition class 2 represents a moderate departure from the NRV. Areas classified as condition class 2 have departed from historical conditions by one or two return intervals. Areas classified as condition class 3 have departed significantly from historical conditions. These areas are high priority areas for ecosystem restoration.

Maintaining a natural wildfire regime is not possible when multiple values at risk need to be protected. It is nevertheless important to understand how landscapes are shaped by wildfire. If biota are adapted to stand and landscape structures shaped by natural disturbance events such as fire, insects, disease, and flooding, then future desired forest landscapes that approximate these structures should lead to the greater likelihood of conserving biodiversity.

Table 6.3 Fire regimes used for fire regime condition classification

Fire Regime	Frequency	Severity
I	0–35 years	Low (surface fires most common) to mixed severity (less than 75% of the dominant overstorey vegetation replaced)
II	0–35 years	High (stand replacement) severity (greater than 75% of the dominant overstorey vegetation replaced)
III	35–100+	Mixed severity (less than 75% of the dominant overstorey vegetation replaced)
IV	35–100+	High (stand replacement) severity (greater than 75% of the dominant overstorey vegetation replaced)
V	200+	High (stand replacement) severity

The intent of this report is not to provide single, definitive estimates of disturbance rates by wildfire in Alberta, or definitive prescriptions to emulate these disturbances. Rather, this report provides a summary of the current state of knowledge and understanding of wildfire regimes and their spatial variations across Alberta. It is important that this information be considered in resource management planning (e.g., forest management planning and park management planning). Although it is not possible to completely emulate wildfire, we should nevertheless strive to learn from wildfire, and try to get closer to it.

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Appendix I

Anomaly graphs and maps are completed for each Alberta active climate station. Below is a list of the type of graphs, average graphs, and maps that are compiled by the Weather Section.

Graphs

- Monthly maximum temperature
- Monthly maximum temperature anomalies
- Historical summer maximum temperature
- Historical summer maximum temperature anomalies

- Monthly number of days with precipitation
- Monthly number of days with precipitation anomalies
- Historical summer number of days with precipitation
- Historical summer number of days with precipitation anomalies

- Monthly total precipitation
- Monthly precipitation anomalies
- Historical summer total precipitation
- Historical summer precipitation anomalies
- Monthly snow on ground (October 1–April 30)

Average Graphs

- Monthly average precipitation
- Monthly average precipitation anomalies
- Historical summer precipitation
- Historical summer precipitation anomalies
- Average snow on ground

- Monthly number of days with precipitation
- Monthly number of days with precipitation anomalies
- Historical summer number of days with precipitation
- Historical summer number of days with precipitation anomalies

- Monthly average maximum temperature
- Monthly average maximum temperature anomalies
- Historical summer maximum temperature
- Historical summer maximum temperature anomalies

Maps

- Monthly precipitation anomalies (amount of precipitation in mm, above or below NORMALS)

- Monthly number of days with precipitation anomalies (number of days with precipitation above or below NORMALS)

- Snow on ground (on the last day of a month) anomalies (amount of snow on ground in cm, above or below NORMALS)

- Monthly maximum temperature anomalies (in ˚C above or below NORMALS)

- Summer maximum temperature anomalies (in ˚C above or below NORMALS)

- Summer precipitation anomalies (amount of precipitation in mm above or below NORMALS)

- Summer number of days with precipitation anomalies (number of days with precipitation above or below NORMALS)

- Winter mean temperature anomalies (in ˚C above or below NORMALS)

- Winter precipitation anomalies (amount of precipitation in mm above or below NORMALS)

- Winter number of days with precipitation anomalies (number of days with precipitation above or below NORMALS)

- Winter average snow on ground anomalies (in cm above or below NORMALS)

Appendix II

Large spring wildfires illustrated on the April and May precipitation anomaly maps for Alberta.

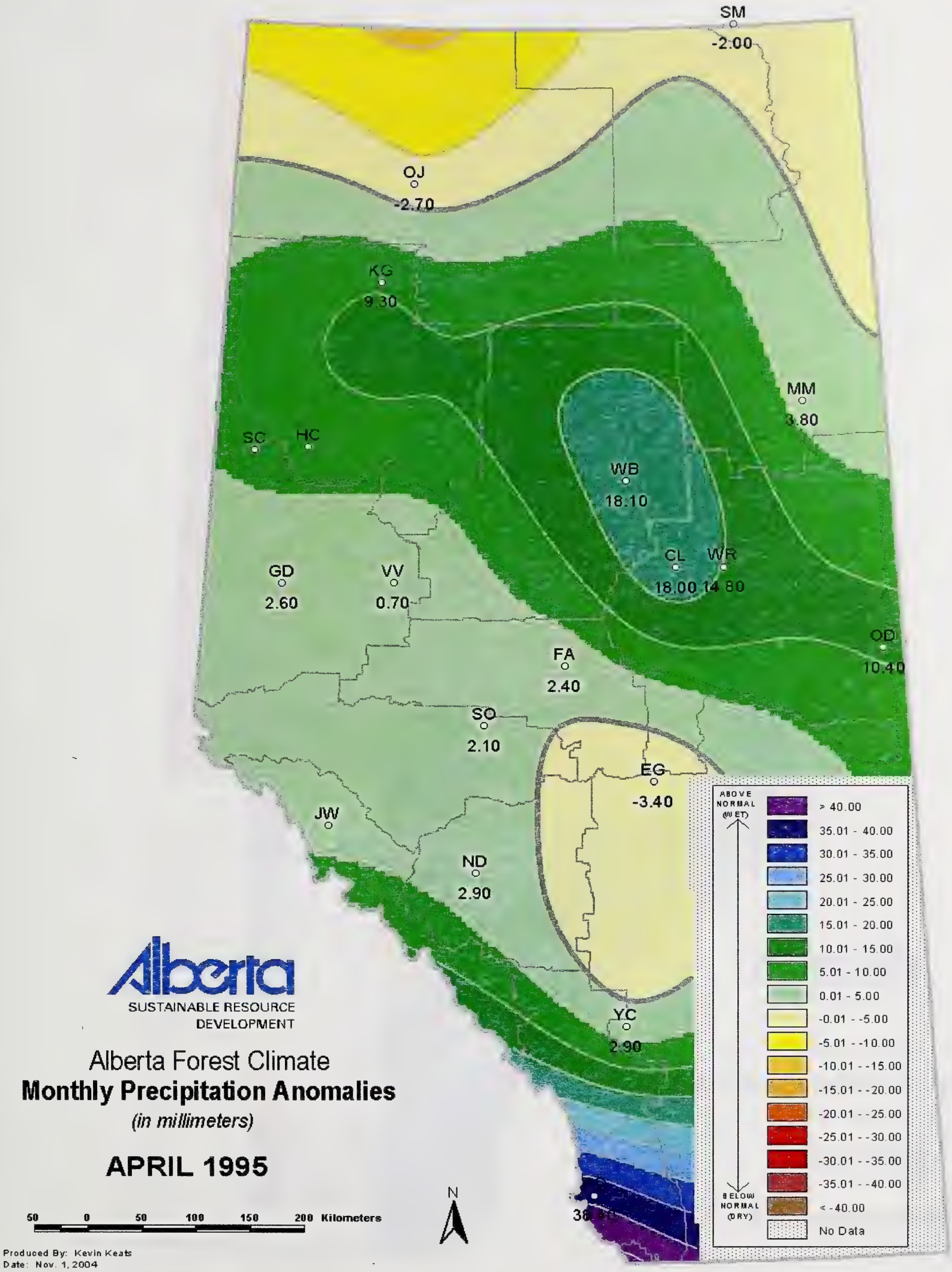

Figure AII-1 April 1995 precipitation anomaly

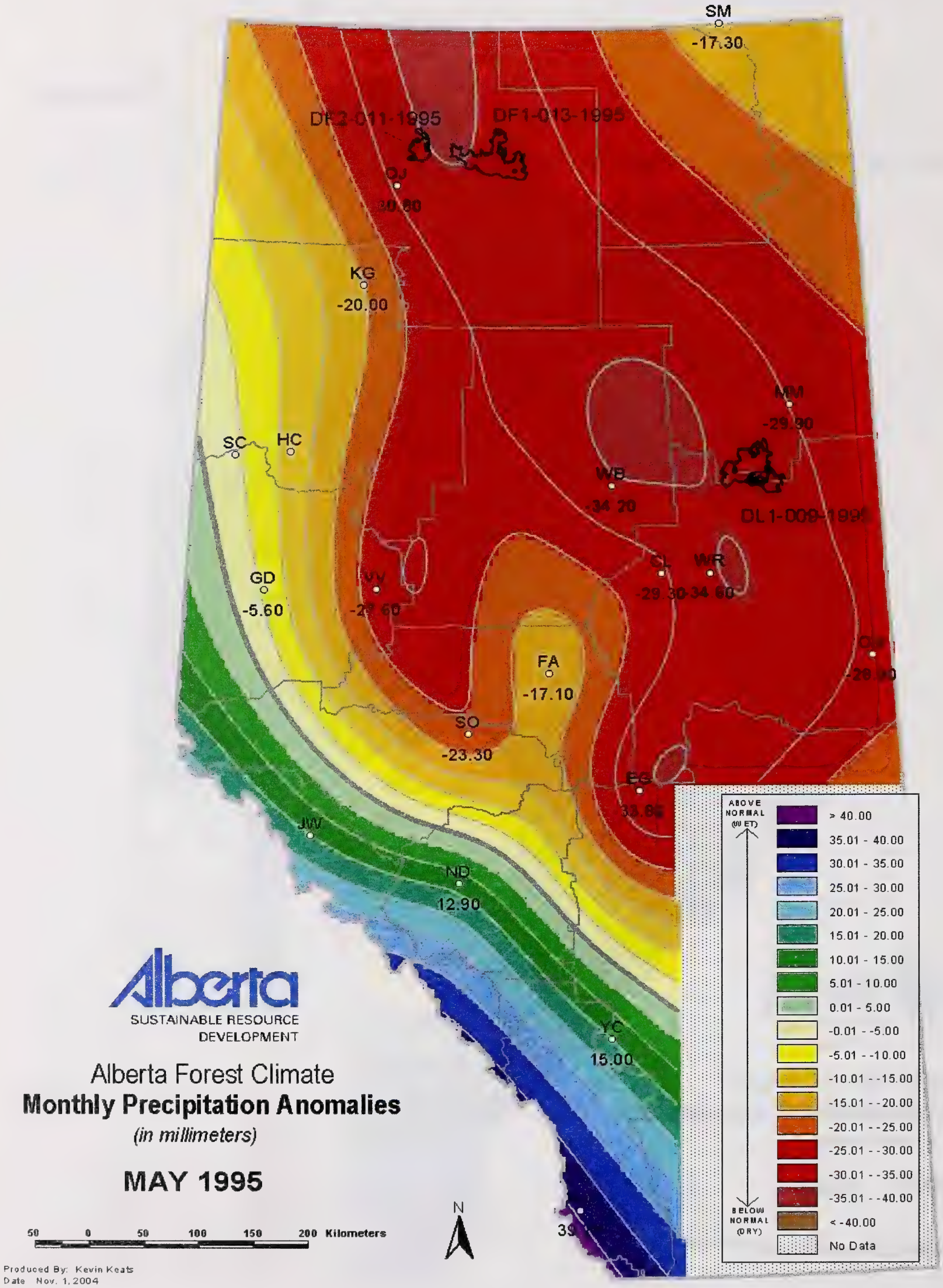

Figure AII-2 May 1995 precipitation anomaly and 1995 spring wildfires DF2-011-95, DF1-013-95, and DL1-009-95

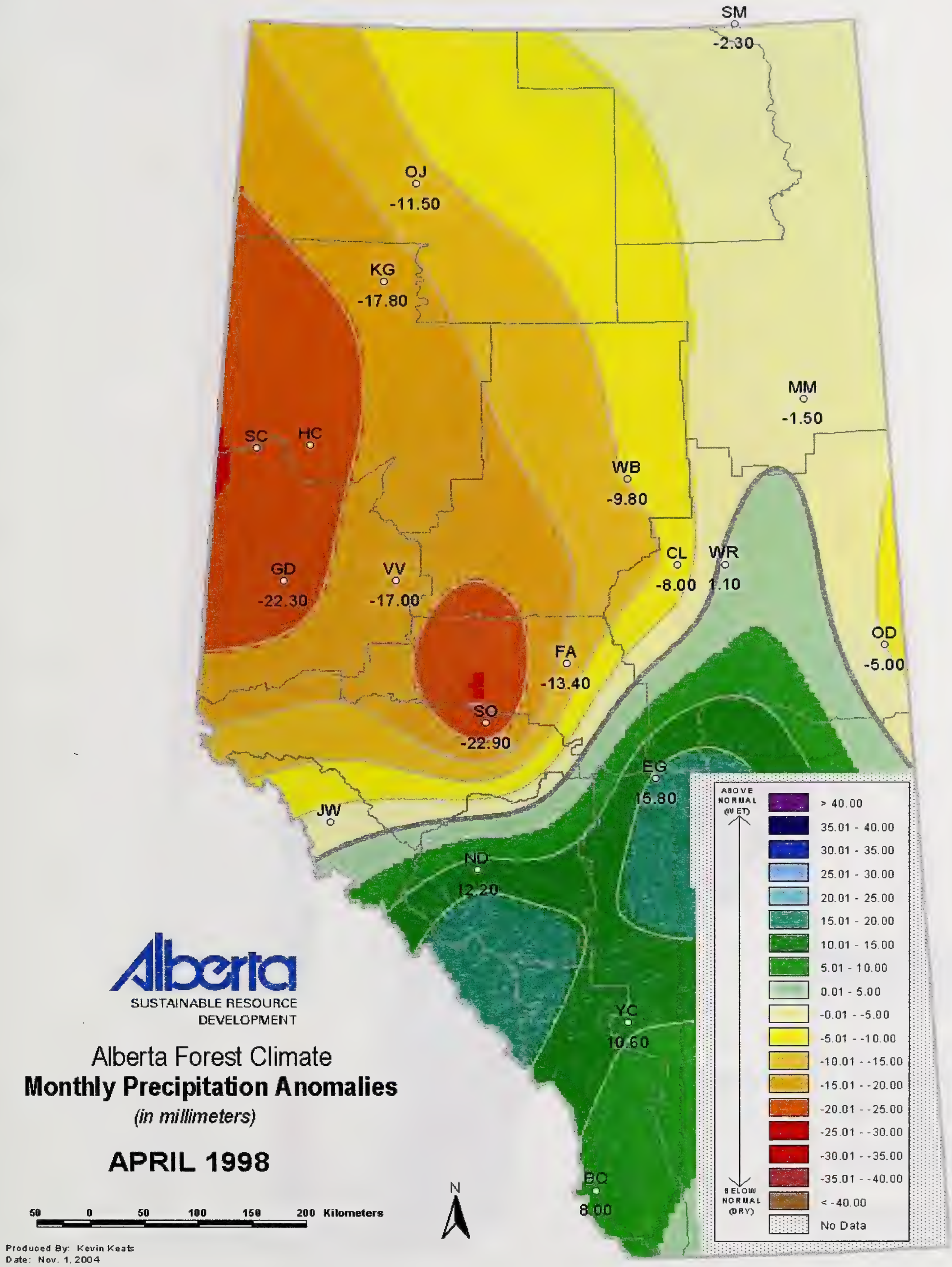

Figure AII-3 April 1998 precipitation anomaly

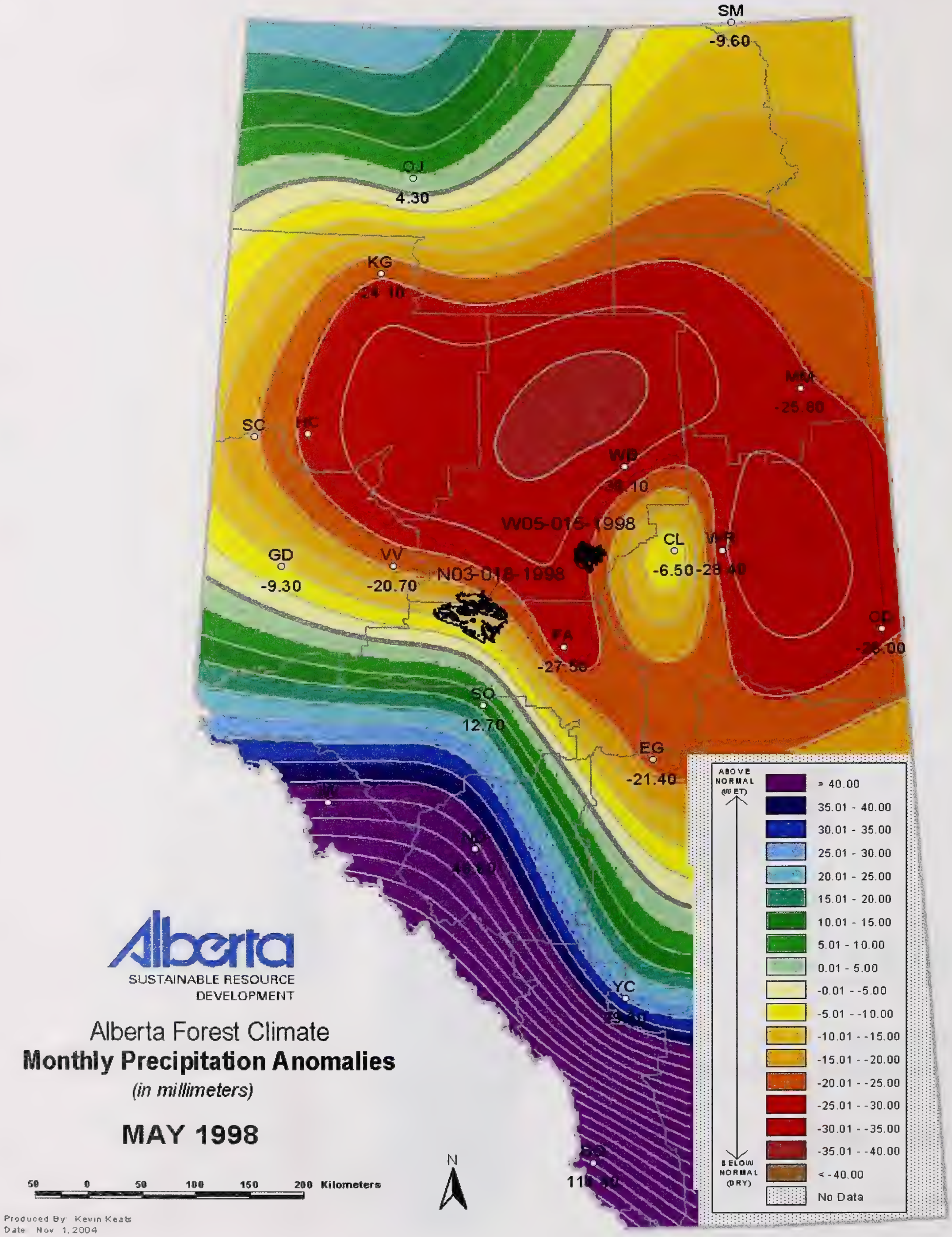

Figure AII-4 May 1998 precipitation anomaly and 1998 spring wildfires N03-018 and W05-015

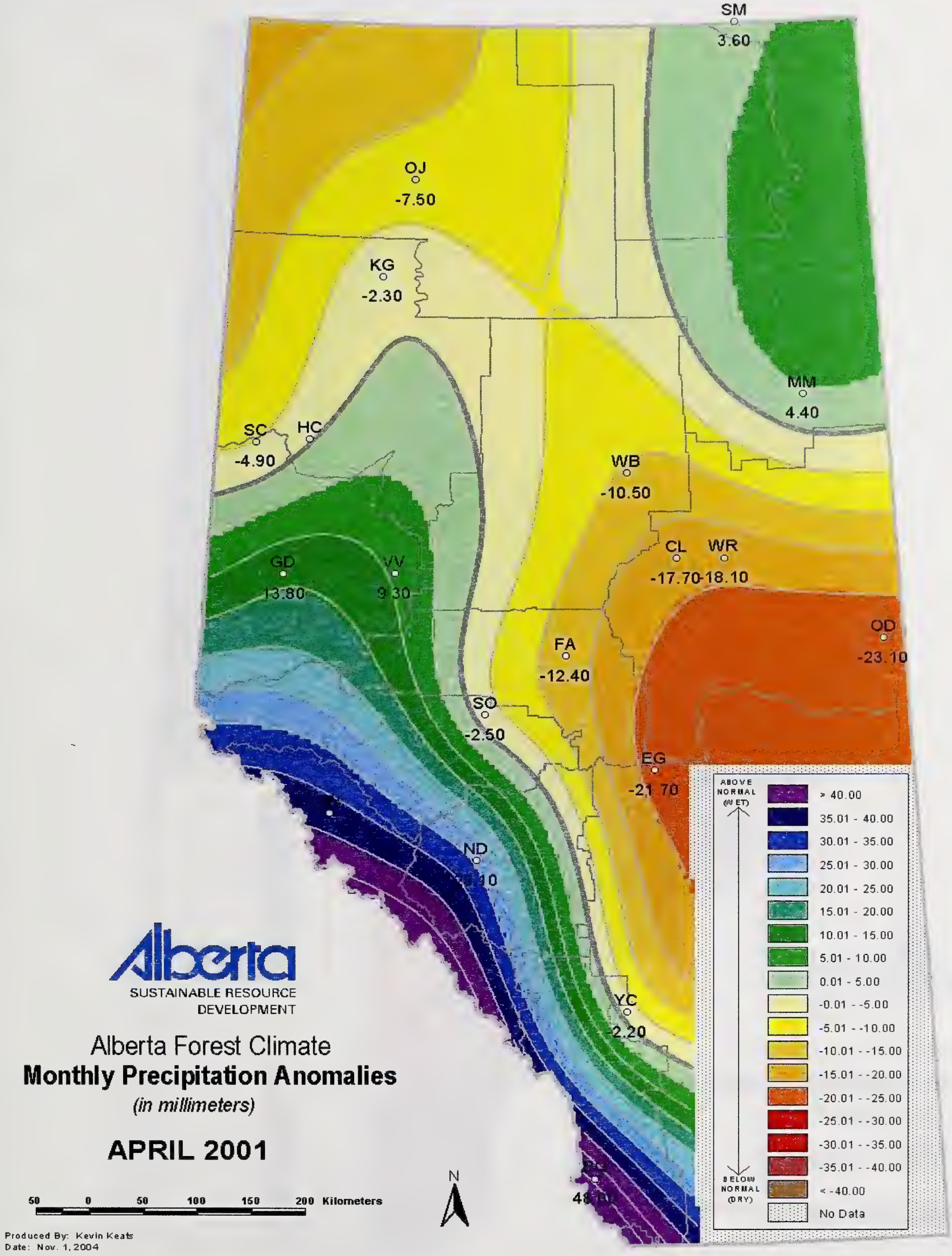

Figure AII-5 April 2001 precipitation anomaly

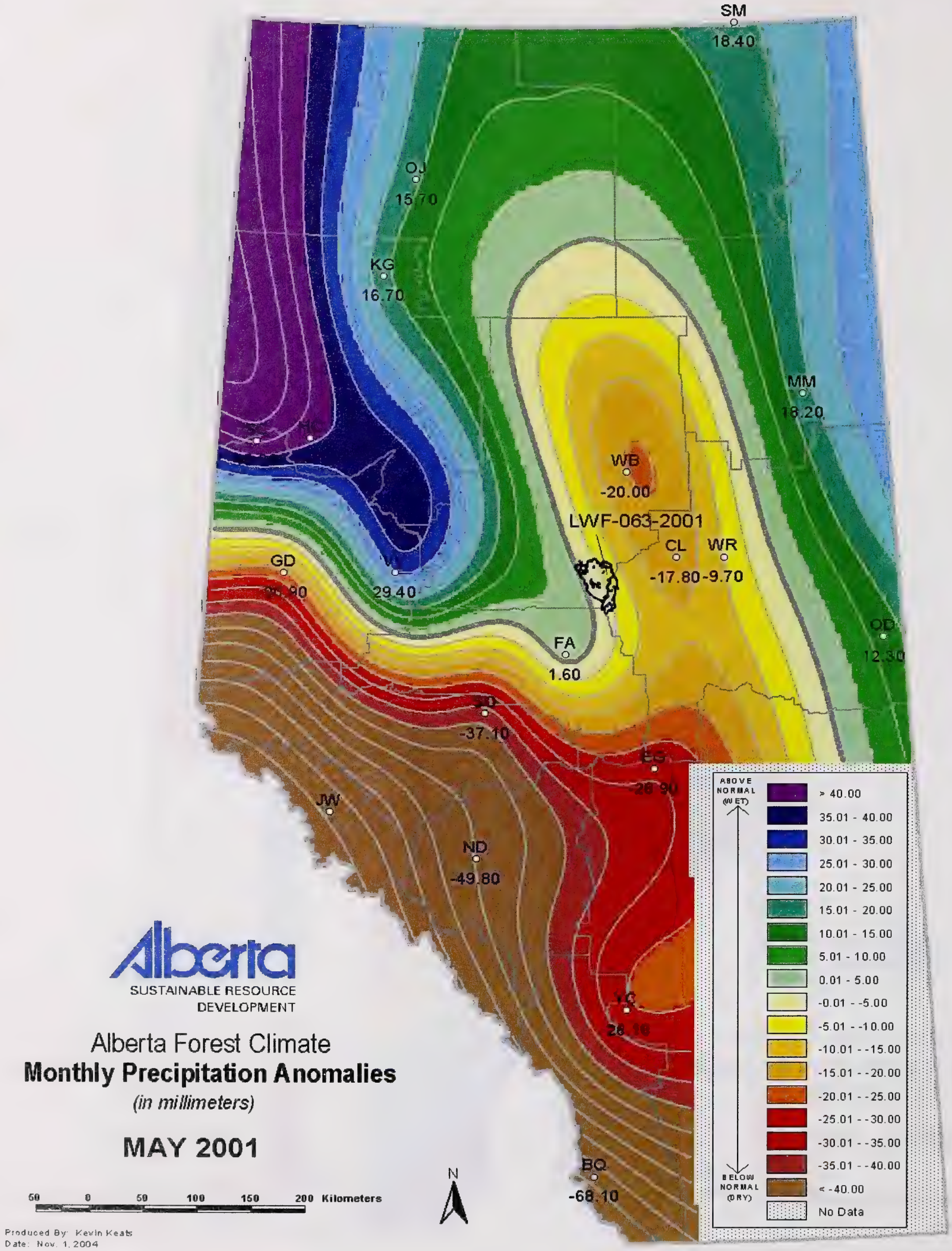

Figure AII-6 May 2001 precipitation anomaly and 2001 spring wildfire LWF063

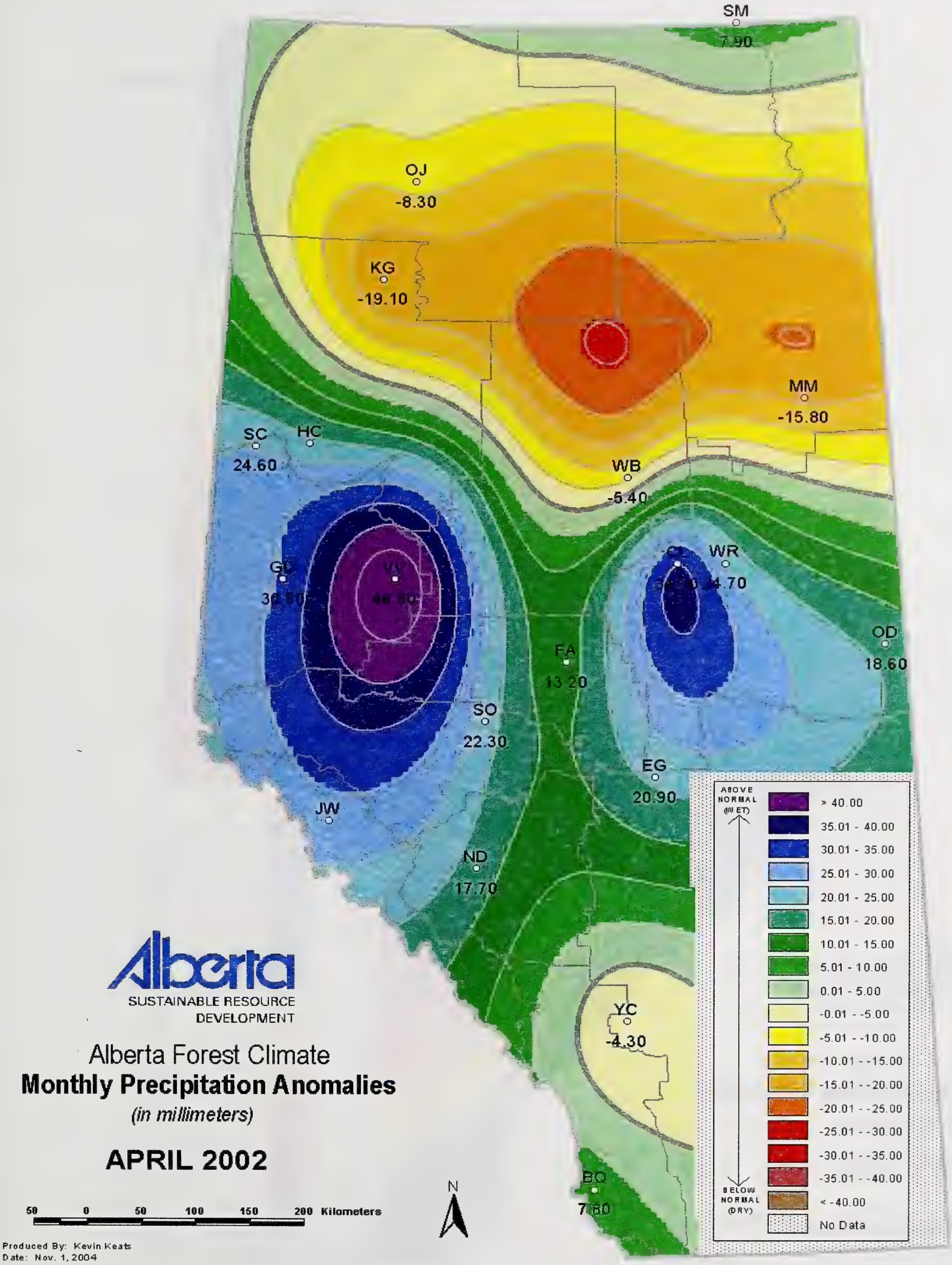

Figure AII-7 April 2002 precipitation anomaly

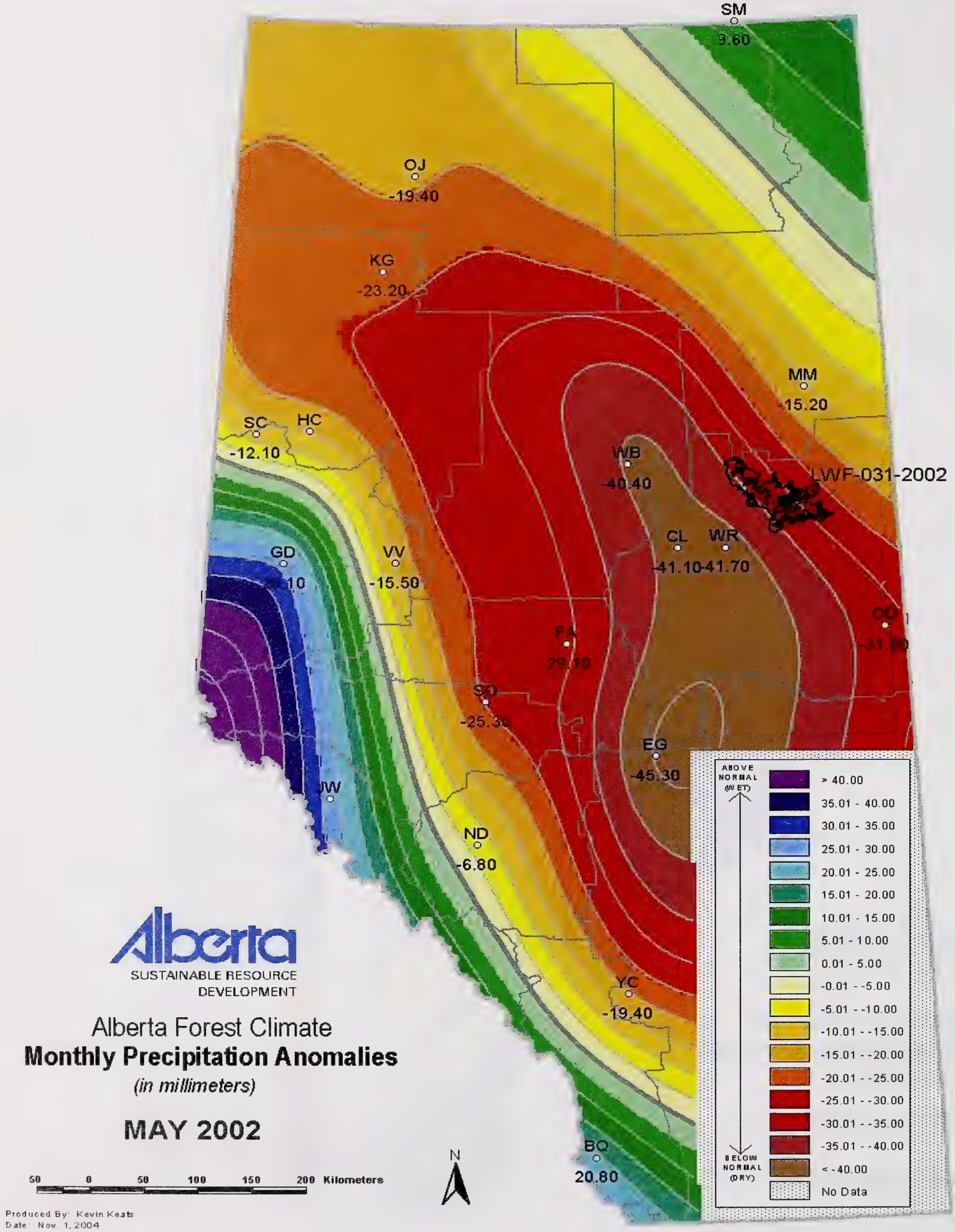

Figure AII-8 May 2002 precipitation anomaly and 2002 spring wildfire LWF031

Appendix III

Summary of the fire regime and fire history studies completed in Alberta.

BOREAL FOREST NATURAL REGION: 34,692,927 ha

Jurisdiction (Area)	% Area	FMUs	Fire History Data	Fire Regime Method	Authors	Fire Cycle/ Burn Rate	Data Period
CENTRAL MIXEDWOOD SUBREGION: 15,466,284 ha							
Alberta Pacific (69,045 km^2)	37.88	A4, A5, A7, A8, A14, L1, L2, L3, L8, L11, S7, S11, S18, S22	2,215 TSPs, 202 PSPs.	Summing areas of all known fires.	Cumming 2000a	476 yrs/0.21%	1961–1996
				Summing areas of all known fires and applying a fire suppression correction factor.	Cumming 1997	244 yrs/0.41%	1940–1993
				Disturbance rates and fire cycles calculated as input values for landscape disturbance modeling. Estimated from 40 yr age-class AVI origin map, using the roll-back method.	Andison 2003	0.47 to 2.67%; average rate: 2.1% or 48 yr fire cycle	1911–1970
Blue Ridge Lumber (6,687 km^2)	1.16	W2, W3, W4	Air photo screening assessment: 1948–52, 1:40,000 scale. Preliminary stand origin map (lines, no dates). W2: 600 inventory plots from SRD, 1000 check plots taken at DBH with an increment borer, 350 cross-sections from deciduous & 300 from conifers.	Causal factors of ignition, size of fire and seasonality of fire based on the Provincial Fire Occurrence data set. Lightning strike density map, historical and present-day probability of ignition models.	Rogeau 1999a		1961–1995
CanFor (6,324 km^2)	1.57	G2, G5	Age-class map from inventory. 841 PSPs and NIVMA plots.	Weibull and negative exponential models applied. Age data rolled back to 1950. Data not spatially contiguous.	O.R.M. 2000	85–90 45–48 (rolled back)	~1820–1999

Jurisdiction (Area)	% Area	FMUs	Fire History Data	Fire Regime Method	Authors	Fire Cycle/ Burn Rate	Data Period
Daishowa–Marubeni (25,042 km^2)	6.34	F1, P3, P4, P5, S15	1,317 volume sampling plots in clusters of 3 subplots (prism sweep plots) randomly distributed across veg. types. Others: 53 plots in young fire origin stands, 76 plots in F1, 61 plots in older conifer stands of P1 to breakup the age-class of older stands.	Complete and thorough fire regime assessment using the Provincial fire occurrence data set, lightning strike data, AVI data and fire weather data. Parameters of fire frequency, cause, area burned, month of burning, fuel type, FWI, fire intensities, and fire cycles addressed by natural regions.	Stelfox and Wynes 1999	Whole Area: 285 yrs/0.35% Central Mixedwood: 288 yrs/0.35%	1961–1995 1750–1990
Gordon Buchanan (2,476 km^2)	0.95	S21	See Tolko.				
Millar Western (4,770 km^2)	1.23	W11, W13	189 PSPs on a density grid of 9 plots/twp.	Provincial fire occurrence data set: fire counts, size, cause, spatial distribution of ignition by cause, temporal distribution of fire, FBP fuel review, fire weather review.	Hirsch and de Groot 1999		1961–1998
Tolko (38,531 km^2)	5.02	F24, S19	19 PSPs randomly distributed.				
Weyerhaeuser–G.P. (14,278 km^2)	1.11	G1, G3, G4, G7	1,200 PSPs, systematic grid basis: 12 plots/twp.				
Weyerhaeuser–S.L. (7,271 km^2)	3.02	A6, A9, A10, A11, A12, L9					

Jurisdiction (Area)	% Area	FMUs	Fire History Data	Fire Regime Method	Authors	Fire Cycle/ Burn Rate	Data Period
Green Area–NE (39,978 km^2)	10.49	A6, A9, A10, A11, A12, L9					
Green Area–NW (61,940 km^2)	11.37	F11, F23, G12, G14, M3, M4, S7, S9, S10, S14, S16					
White Area–NE (27,249 km^2)	2.33	LO1					
White Area–NW (63,799 km^2)	4.92	FO1, GO1, GO2, GO4, PO1, SO1, SO2, WO1, WO2, WO3					
Wood Buffalo N.P. (44,870 km^2)	11.90		Time-since-last fire determined for 166 stands from point sample estimates using a stratified random sampling design.	Fire occurrence records, fire counts, cause and seasonality, annual area burned, mean annual percent area burned determined from the life-table approach.	Larsen 1996		1950–1989 (annual) and 1850–1989 (decadal)
				Fire cycle estimates from accelerated hazard survival model by tree species.	Larsen 1997	Pj: 39 yrs At: 39 yrs Sb: 78 yrs Sw: 96 yrs	1850–1989

Jurisdiction (Area)	% Area	FMUs	Fire History Data	Fire Regime Method	Authors	Fire Cycle/ Burn Rate	Data Period
DRY MIXEDWOOD SUBREGION: 10,057,337 ha							
Alberta Pacific (69,045 km^2)	37.88	A4, A5, A7, A8, A14, L1, L2, L3, L8, L11, S7, S11, S18, S22	2,215 TSPs, 202 PSPs.	Summing areas of all known fires.	Cumming 2000a	476 yrs/0.21%	1961–1996
				Summing areas of all known fires and applying a fire suppression correction factor.	Cumming 1997	244 yrs/0.41%	1940–1993
				Disturbance rates and fire cycles calculated as input values for landscape disturbance modeling. Estimated from 40 yr age-class AVI origin map, using the roll-back method.	Andison 2003	0.47 to 2.67% average rate: 2.1% or 48 yr fire cycle	1911–1970
CanFor (6,324 km^2)	0.84	G2, G5, G8	Age-class map from inventory 841 PSPs and NIVMA plots.	Weibull and negative exponential models applied. Age data rolled back to 1950, data not spatially contiguous.	O.R.M. 2000	69 yrs 29 yrs (rolled back)	~1830–1999
Daishowa–Marubeni (25,042 km^2)	6.85	F1, P3, P4, P5, P10, P13	1,317 volume sampling plot in clusters of 3 subplots (prism sweep plots) randomly distributed across veg. types. Others: 53 plots in young fire origin stands, 76 plots in F1, 61 plots in older conifer stands of P1 to breakup the age-class of older stands.	Complete and thorough fire regime assessment using the provincial fire occurrence data set, lightning strike data, AVI data and fire weather data. Parameters of fire frequency, cause, area burned, month of burning, fuel type, FWI, fire intensities, and fire cycles addressed by natural regions.	Stelfox and Wynes 1999	Whole Area: 285 yrs/0.35% Dry Mixedwood: 1,623 yrs/0.06%	1961–1995 1750–1990

Jurisdiction (Area)	% Area	FMUs	Fire History Data	Fire Regime Method	Authors	Fire Cycle/ Burn Rate	Data Period
Tolko ($38,531\ km^2$)	4.50	F24, F25, S19	19 PSPs randomly distributed.				
Green Area – NW	6.29	F11, F23, G9, G10, G11, G12, G13, M3, M4, P11, S16					
White Area – NE	22.03	LO1, M7, M9, M10	50 sample plots scheduled for completion by end of Nov. 2005 in the Cooking Lake/Beaver Hills Region.	Review of historical fire regime using 1950 aerial photography and thorough archive research. Fire history sampling.	Rogeau, *In progress.*		
White Area – NW	45.18	FO1, GO1, GO2, GO3, GO4, M1, PO1, PO2, PO3, SO1, SO2, WO1, WO2					
White Area – SW	8.20	B02, RO1					
Elk Island National Park ($194\ km^2$)	0.19		96 PSPs contained within 12 bio-monitoring units of 500 m x 2 km. Predominantly aspen types.				

Jurisdiction (Area)	% Area	FMUs	Fire History Data	Fire Regime Method	Authors	Fire Cycle/ Burn Rate	Data Period
WETLAND MIXEDWOOD SUBREGION: 3,837,985 ha							
Daishowa–Marubeni ($25,042 km^2$)	1.40	P10	1,317 volume sampling plot in clusters of 3 subplots (prism sweep plots) randomly distributed across veg. types. Others: 53 plots in young fire origin stands, 76 plots in F1, 61 plots in older conifer stands of P1 to breakup the age-class of older stands.	Complete and thorough fire regime assessment using the provincial fire occurrence data set, lightning strike data, AVI data, and fire weather data. Parameters of fire frequency, cause, area burned, month of burning, fuel type, FWI, fire intensities, and fire cycles addressed by natural regions.	Stelfox and Wynes 1999	Whole Area: 285 yrs/0.35% Wetland Mixedwood: 214 yrs/0.47%	1961–1995 1750–1990
Manning ($5,956 km^2$)	2.41	P9	530 PSPs, random distribution using a grid-based system.				
Tolko ($38,531 km^2$)	53.67	F25	19 PSPs randomly distributed.				
Green Area–NW ($61,940 km^2$)	20.95	F10, F11, F14, F21					
White Area - NW ($63,799 km^2$)	1.06	M1, PO3					

Jurisdiction (Area)	% Area	FMUs	Fire History Data	Fire Regime Method	Authors	Fire Cycle/ Burn Rate	Data Period
Wood Buffalo National Park (44,870 km^2)	20.36		Time-since-last fire determined for 166 stands from point sample estimates using a stratified random sampling design.	Fire occurrence records, fire counts, cause and seasonality, annual area burned, mean annual percent area burned determined from the life-table approach.	Larsen 1996	1950–1989 (annual) and 1850–1989 (decadal)	Wood Buffalo National Park (44,870 km^2)
			Time-since-last fire determined for 166 stands from point sample estimates using a stratified random sampling design.	Fire cycle estimates from accelerated hazard survival model by tree species.	Larsen 1997	Pj: 39 yrs At: 39 yrs Sb: 78 yrs Sw: 96 yrs	1850–1989
SUB-ARCTIC SUBREGION: 2,198,598 ha							
Daishowa–Marubeni (25,042 km^2)		No FMU identified, but 1999 research shows information for this subregion.	1,317 volume sampling plot in clusters of 3 subplots (prism sweep plots) randomly distributed across veg. types. Others: 53 plots in young fire origin stands, 76 plots in F1, 61 plots in older conifer stands of P1 to breakup the age-class of older stands.	Complete and thorough fire regime assessment using the provincial fire occurrence data set, lightning strike data, AVI data and fire weather data. Parameters of fire frequency, cause, area burned, month of burning, fuel type, FWI, fire intensities, and fire cycles addressed by natural regions.	Stelfox and Wynes 1999	Whole Area: 285 yrs/0.35% Sub-Arctic: 195 yrs/0.51%	1961–1995 1750–1990
Tolko (38,531 km^2)	7.47	F24, F25	19 PSPs randomly distributed.				
Green Area–NE (39,978 km^2)	16.15	A9, A10					

Jurisdiction (Area)	% Area	FMUs	Fire History Data	Fire Regime Method	Authors	Fire Cycle/ Burn Rate	Data Period
Green Area–NW (61,940 km^2)	70.93	F10, F20, F23					
Wood Buffalo National Park (44,870 km^2)	5.38		Time-since-last fire determined for 166 stands from point sample estimates using a stratified random sampling design.	Fire occurrence records, fire counts, cause and seasonality, annual area burned, mean annual percent area burned determined from the life-table approach.	Larsen 1996		1950–1989 (annual) and 1850–1989 (decadal)
			Time-since-last fire determined for 166 stands from point sample estimates using a stratified random sampling design.	Fire cycle estimates from accelerated hazard survival model by tree species.	Larsen 1997	Pj: 39 yrs At: 39 yrs Sb: 78 yrs Sw: 96 yrs	1850–1989
PEACE RIVER LOWLANDS SUBREGION: 1,011,012 ha							
North Athabasca Lake Area (39,978 km^2)	23.07	A12, A13	A13, fire history study bound by WBNP and the Slave River. 595 km^2 (= 6% of the subregion). Fire history point sample data collected in 1995—96. 62 plots using a 4 km grid. Cross-section taken from largest tree (fire survivor). Rings counted with DendroScan.	Fire cycles estimated over a temporal scale by fitting a regression curve to cumulated percentage of sites by time-since-fire. Four different slopes in curve were identified. The slope value was used as a surrogate measure of fire cycle.	Brungs-Simard 2001	1865–1895: 181 yrs 1895–1935: 266 yrs 1935–1945: 29 yrs 1945–1995: 130 yrs	1865–1995
Green Area–NW (61,940 km^2)	2.91	F23					
Wood Buffalo National Park (44,870 km^2)	74.42		Time-since-last fire determined for 166 stands from point sample estimates using a stratified random sampling design.	Fire occurrence records, fire counts, cause and seasonality, annual area burned, mean annual percent area burned determined from the life-table approach.	Larsen 1996		1950–1989 (annual) and 1850 1989 (decadal)

Jurisdiction (Area)	% Area	FMUs	Fire History Data	Fire Regime Method	Authors	Fire Cycle/ Burn Rate	Data Period
			Time-since-last fire determined for 166 stands from point sample estimates using a stratified random sampling design.	Fire cycle estimates from accelerated hazard survival model by tree species.	Larsen 1997	Pj: 39 yrs At: 39 yrs Sb: 78 yrs Sw: 96 yrs	1850–1989
BOREAL HIGHLANDS SUBREGION: 2,121,711 ha							
Alberta Pacific (69,045 km^2)	37.88	A4, A5, A7, A8, A14, L1, L2, L3, L8, L11, S7, S11, S18, S22	2,215 TSPs, 202 PSPs.	Summing areas of all known fires.	Cumming 2000a	476 yrs/0.21%	1961–1996
				Summing areas of all known fires and applying a fire suppression correction factor.	Cumming 1997	244 yrs/0.41%	1940–1993
				Disturbance rates and fire cycles calculated as input values for landscape disturbance modeling. Estimated from 40 yr age-class AVI origin map, using the roll-back method.	Andison 2003	0.47 to 2.67%; average rate: 0.21% or 48 yr fire cycle	1911–1970
Daishowa–Marubeni (25,042 km^2)	6.47	F1, P4, P5, S15	1,317 volume sampling plot in clusters of 3 subplots (prism sweep plots) randomly distributed across veg. types. Others: 53 plots in young fire origin stands, 76 plots in F1, 61 plots in older conifer stands of P1 to break up the age-class of older stands.	Complete and thorough fire regime assessment using the provincial fire occurrence data set, lightning strike data, AVI data, and fire weather data. Parameters of fire frequency, cause, area burned, month of burning, fuel type, FWI, fire intensities, and fire cycles addressed by natural regions.	Stelfox and Wynes 1999	Whole Area: 285 yrs/0.35% Boreal Highlands: 212 yrs/0.47%	1961–1995 1750–1990
Tolko (38,531 km^2)	13.51	F24, F25	19 PSPs randomly distributed.				

Jurisdiction (Area)	% Area	FMUs	Fire History Data	Fire Regime Method	Authors	Fire Cycle/ Burn Rate	Data Period
Green Area–NE (39,978 km^2)	11.16	A9, A10					
Green Area–NW (61,940 km^2)	19.44	F10, F20, F23, S14					
Wood Buffalo National Park (44,870 km^2)	5.47		Time-since-last fire determined for 166 stands from point sample estimates using a stratified random sampling design.	Fire occurrence records, fire counts, cause and seasonality, annual area burned, mean annual percent area burned determined from the life-table approach.	Larsen 1996		1950–1989 (annual) and 1850–1989 (decadal)
			Time-since-last fire determined for 166 stands from point sample estimates using a stratified random sampling design.	Fire cycle estimates from accelerated hazard survival model by tree species.	Larsen 1997	Pj: 39 yrs At: 39 yrs Sb: 78 yrs Sw: 96 yrs	1850–1989

ROCKY MOUNTAIN NATURAL REGION: 4,626,107 ha							
Jurisdiction (Area)	**% Area**	**FMUs**	**Fire History Data**	**Fire Regime Method**	**Authors**	**Fire Cycle/ Burn Rate**	**Data Period**
ALPINE SUBREGION: 1,451,434 ha							
Kananaskis Improvement District (2,423 km^2)	6.57	B11	Scheduled for 2004.	Provincial fire occurrence and lightning strike data sets, fire counts, size, cause, month, spatial probability of ignition by cause, assessment done by natural region. Landscape disturbance modeling.	Rogeau 2004	N/A	1961–2003
Weldwood (9,994 km^2)	1.82	E4, E5	Fire origin map built from fire history stand origin mapping procedures. Fire origin map completion to fill in data gaps in 1996. W.A. Switzer Provincial Park and break-up ages of old forest patches on the FMA: 255 plots, 1,051 cross-sections, 118 scarred trees and 196 releases in ring growth. 1997: Fire origin map of old patch near Edson, and E4 in the provincial corridor between JNP and the FMA (1,387 km^2). 484 plots, 1,841 cross-sections, 74 scarred trees, 331 releases in ring growth.	Fire cycle calculations using the Weibull and maximum likelihood estimates using 5-yr age-classes as of 1950. Process was repeated using the roll-back method for 20-yr age-classes. This was done by natural regions. Lightning density patterns correlation with stand age and fire cycles.	Jack Right, 1960s (unpublished data) Rogeau 1996b Rogeau 1997 Andison 1997 Andison 2000a	Subalpine: 100 yrs 123 yrs (roll-back)	1500–1997
Weyerhaeuser–G.P. (14,278 km^2)	1.00	G3, G6	1,200 PSPs, systematic grid basis: 12 plots/twp.				

ROCKY MOUNTAIN NATURAL REGION: 4,626,107 ha							
Jurisdiction (Area)	**% Area**	**FMUs**	**Fire History Data**	**Fire Regime Method**	**Authors**	**Fire Cycle/ Burn Rate**	**Data Period**
Green Area–SW (9,653 km^2)	1.1	C5, E11, R11	E11: Included in the Foothills Model Forest studies, see Weldwood FMA.				
	12.89		R11 between the Whitegoat & Siffleur wilderness areas.	Causal factors of ignition, size of fire, and seasonality of fire based on the Provincial Fire Occurrence data set. Lightning strike density map. Spatial distribution of ignitions. Effect of topography of stand age patterns. Fire cycles calculated for homogeneous terrain components using the weighted mean ages as a surrogate to fire cycle.	Rogeau 1999b	Subalpine: 100–300+ (varies due toopography)	1655–1998
			North portion of C5, 5,058 km. Stand origin from AVI data.	Fire cycles calculated by natural regions using the assumption of negative exponential fit and using the weighted mean age as a surrogate for fire cycle.	Olson and Diehl 1998	Whole area: 95 yrs Subalpine: 108 yrs	1600–1990
Spray Valley Provincial Park (134 km^2)	N/A		Fire origin map built from fire history stand origin mapping procedures as outlined in Section 8.2.1. 67 plots, 212 cross-sections, 18 scarred trees, 21 releases in ring-growth patterns.	See Banff National Park.	Rogeau 1994		1615–1994
Peter Lougheed Provincial Park (508 km^2)	N/A		Fire origin map built from fire history stand origin mapping procedures. Master fire chronology from 117 plots, 705 cores and 142 fire scars. Provincial fire records.	Effect of topography on MFRI on a point or stand basis.	Hawkes 1980	Whole Area: 90–187 Subalpine: 304 yrs	N/A

ROCKY MOUNTAIN NATURAL REGION: 4,626,107 ha

Jurisdiction (Area)	% Area	FMUs	Fire History Data	Fire Regime Method	Authors	Fire Cycle/ Burn Rate	Data Period
Kananaskis Valley (N/A km^2)	N/A		Fire origin map built from fire history stand origin mapping procedures. 1972 aerial photography used. 900 point samples of 5 ha.	Age-class distribution fitted to Weibull model. Temporal comparison of fire history and average fire interval.	Johnson and Fryer 1987	150 yrs	1730–1972
Whitegoat–Siffleur Wilderness Area (1,634 km^2)	N/A		Fire origin map built from fire history stand origin mapping procedures as outlined in Section 8.2.1. 155 plots, 587 cross-sections, 78 scarred trees, 149 releases in ring-growth patterns.	Causal factors of ignition, size of fire, and seasonality of fire based on the Provincial Fire Occurrence data set. Lightning strike density map. Spatial distribution of ignitions. Effect of topography of stand age patterns. Fire cycles calculated for homogeneous terrain components using the weighted mean ages as a surrogate to fire cycle.	Rogeau 1999b	Subalpine: 100–300+ (varies based on topography)	1470–1998
Banff National Park (6,287 km^2)	25.57		1980–82: fire scar sampling: 220 plots, 615 cross-sections.	Fire cause, size, month by 10-yr period from 1880 to 1980.	White 1985a White 1985b		
			1991–1994: Fire origin map built from fire history stand origin mapping procedures as outlined in Section 8.2.1. 1,538 plots, 4,836 cross-sections, 902 scarred trees, 145 releases in ring-growth patterns.	Weibull fit of age-class distributions to obtain fire cycles by main watersheds. Fire size distribution.	Rogeau 1996a	Park: 216 yrs Watersheds: 167–335 yrs	1285–1994
				Effect of topography on stand age patterns and fire cycles.	Rogeau 2001	Subalpine: 100–300 yrs (varies based on topography)	1285–1994
				Spatial distribution of lightning fires and lightning strike density.	Wierzchowski et al. 2002		

ROCKY MOUNTAIN NATURAL REGION: 4,626,107 ha

Jurisdiction (Area)	% Area	FMUs	Fire History Data	Fire Regime Method	Authors	Fire Cycle/ Burn Rate	Data Period
Jasper National Park (10,878 km^2)	34.45		Fire origin map built from fire history stand origin mapping procedures. 1950 aerial photography.	Fire cycle calculations using the Weibull and maximum likelihood estimates using 40-yr age-classes. Process was repeated using the roll-back method. Lightning density patterns correlation with stand age and fire cycles.	J.N.P. unpublished data Andison 1997 Andison 2000a	Alpine: 220 yrs 333 yrs (roll-back)	1300–1985
				Spatial distribution of lightning fires and lightning strike density.	Wierzchowski et al. 2002		
Waterton Lakes National Park (525 km^2)	0.46		Transect sampling of fire scars and stand ages on representative terrain. 171 plots, 1045 cores, 119 scars.	Mean fire intervals assessed on a temporal scale, by forest type and aspect/elevation. Fire cause.	Barrett 1996		1663–1995
SUBALPINE SUBREGION: 2,576,357 ha							
Kananaskis Improvement District (2,423 km^2)	5.00	B11	Scheduled for 2004.	Provincial fire occurrence and lightning strike data sets, fire counts, size, cause, month, spatial probability of ignition by cause, assessment done by natural region. Landscape disturbance modeling. Fire cycle calculated from recent fire mapping for the period of 1930 to 1950.	Rogeau 2004	Subalpine & Upper Foothills: 104 years	1961–2003
Spray Lake Sawmills (3,371 km^2)	4.10	B9, B10	Scheduled for 2004 and 2005. B10B: 1997 to 1999, 538 volume sampling plots as part of AVI	Provincial fire occurrence and lightning strike data sets, fire counts, size, cause, month, spatial probability of ignition by	Rogeau 2005	Subalpine & Upper Foothills: 104	1961–2003

ROCKY MOUNTAIN NATURAL REGION: 4,626,107 ha							
Jurisdiction (Area)	**% Area**	**FMUs**	**Fire History Data**	**Fire Regime Method**	**Authors**	**Fire Cycle/ Burn Rate**	**Data Period**
			were collected. Stands were selected randomly using proportional allocation based on appropriate crown density, species, and height classes. B9 & B9B: 1998 to 2000, 474 volume sampling plots following a multi-stage stratified-random sampling design.	cause, assessment done by natural region. Landscape disturbance modeling. Fire cycle calculated from recent fire mapping for the period of 1930 to 1950.		years	
Weldwood ($9,994\ km^2$)	6.00	E4, E5, E7	Fire origin map built from fire history stand origin mapping procedures as outlined in Section 8.2.1. Fire origin map completion to fill in data gaps in 1996. W.A. Switzer Provincial Park and break-up ages of old forest patches on the FMA: 255 plots, 1,051 cross-sections, 118 scarred trees and 196 releases in ring growth. 1997: Fire origin map of old patch near Edson, and E4 in the provincial corridor between JNP and the FMA ($1,387\ km^2$). 484 plots, 1841 cross-sections, 74 scarred trees, 331 releases in ring growth.	Fire cycle calculations using the Weibull and Maximum likelihood estimates using 5-yr age-classes as of 1950. Process was repeated using the roll-back method for 20-yr age-classes. This was done by natural regions. Lightning density patterns correlation with stand age and fire cycles.	Jack Right, 1960s (unpublished data) Rogeau 1996b Rogeau 1997 Andison 1997 Andison 2000a	Subalpine: 100 yrs 123 yrs (roll-back)	1500–1997
Weyerhaeuser–Grande Prairie	12.47	E8, G3, G6, G7	$14,278\ km^2$. 1,200 PSPs, systematic grid basis: 12 plots/twp.				
Green Area–NW ($61,940\ km^2$)	1.65	E10					

ROCKY MOUNTAIN NATURAL REGION: 4,626,107 ha

Jurisdiction (Area)	% Area	FMUs	Fire History Data	Fire Regime Method	Authors	Fire Cycle/ Burn Rate	Data Period
Green Area – C5 (9,653 km^2)	3.50	E11	Included in the Foothills Model Forest studies, see Weldwood FMA.				
	14.75	C5	North portion of C5, 5,058 km. Stand origin from AVI data.	Fire cycles calculated by natural regions using the assumption of negative exponential fit and using the weighted mean age as a surrogate for fire cycle.	Olson and Diehl 1998	Whole area: 95 yrs Subalpine: 108 yrs	1600–1990
				Provincial fire occurrence and lightning strike data sets, fire counts, size, cause, month, spatial probability of ignition by cause, assessment done by natural region. Landscape disturbance modeling. Fire cycle calculated from recent fire mapping for the period of 1930 to 1950.	Rogeau 2005	Subalpine: 80 yrs	1941–2004
Spray Valley Provincial Park (134 km^2)	N/A		Fire origin map built from fire history stand origin mapping procedures as outlined in Section 8.2.1. 67 plots, 212 cross-sections, 18 scarred trees, 21 releases in ring-growth patterns.	See Banff National Park.	Rogeau 1994		1615–1994
Peter Lougheed Provincial Park	N/A		Fire origin map built from fire history stand origin mapping	Effect of topography on MFRI	Hawkes 1980	90 – 187 yrs L. Subalpine:	N/A

ROCKY MOUNTAIN NATURAL REGION: 4,626,107 ha							
Jurisdiction (Area)	**% Area**	**FMUs**	**Fire History Data**	**Fire Regime Method**	**Authors**	**Fire Cycle/ Burn Rate**	**Data Period**
(508 km^2)			procedures. Master fire chronology from 117 plots, 705 cores and 142 fire scars. Provincial fire records.	on a point or stand basis.		101 yrs	
Kananaskis Valley (N/A km^2)	N/A		Fire origin map built from fire history stand origin mapping procedures. 1972 aerial photography used. 900 point samples of 5 ha.	Age-class distribution fitted to Weibull model. Temporal comparison of fire history and average fire interval.	Johnson and Fryer 1987	150 yrs	1730–1972
Whitegoat–Siffleur Wilderness Area (1,634 km^2)	N/A		Fire origin map built from fire history stand origin mapping procedures as outlined in Section 8.2.1. 155 plots, 587 cross-sections, 78 scarred trees, 149 releases in ring-growth patterns.	Causal factors of ignition, size of fire and seasonality of fire based on the Provincial Fire Occurrence data set. Lightning strike density map. Spatial distribution of ignitions. Effect of topography of stand age patterns. Fire cycles calculated for homogeneous terrain components using the weighted mean ages as a surrogate to fire cycle.	Rogeau 1999b	Subalpine: 100–300+ yrs (varies based on topography)	1470–1998
Banff National Park (6,287 km^2)	11.10		1980–82: fire scar sampling: 220 plots, 615 cross-sections.	Fire cause, size, month by 10-yr period from 1880 to 1980.	White 1985a White 1985b		
			1991–1994: Fire origin map built from fire history stand origin mapping procedures as outlined in Section 8.2.1. 1,538 plots, 4,836 cross-sections, 902 scarred trees, 145 releases in ring-growth patterns.	Weibull fit of age-class distributions to obtain fire cycles by main watersheds. Fire size distribution.	Rogeau 1996a	Park: 216 yrs Watersheds: 167–335 yrs	1285–1994
				Effect of topography on stand age patterns and fire cycles.	Rogeau 2001	Subalpine: 100–300 yrs (varies based on topography)	1285–1994

ROCKY MOUNTAIN NATURAL REGION: 4,626,107 ha							
Jurisdiction (Area)	**% Area**	**FMUs**	**Fire History Data**	**Fire Regime Method**	**Authors**	**Fire Cycle/ Burn Rate**	**Data Period**
				Spatial distribution of lightning fires and lightning strike density.	Wierzchowski et al. 2002		
Jasper National Park (10,878 km^2)	20.70		Fire origin map built from fire history stand origin mapping procedures. 1950 aerial photography.	Fire cycle calculations using the Weibull and maximum likelihood estimates using 40-yr age-classes. Process was repeated using the roll-back method. Lightning density patterns correlation with stand age and fire cycles.	J.N.P. unpublished data Andison 1997 Andison 2000a	Subalpine: 160 yrs 182 yrs (roll-back) Momtane: 85 yrs 91 yrs (roll-back)	1300–1985
				Spatial distribution of lightning fires and lightning strike density.	Wierzchowski et al. 2002		
Waterton Lakes National Park (525 km^2)	0.75		Transect sampling of fire scars and stand ages on representative terrain. 171 plots, 1,045 cores, 119 scars.	Mean fire intervals assessed on a temporal scale, by forest type and aspect/elevation. Fire cause.	Barrett 1996		1663–1995
MONTANE SUBREGION: 598, 316 ha							

ROCKY MOUNTAIN NATURAL REGION: 4,626,107 ha

Jurisdiction (Area)	% Area	FMUs	Fire History Data	Fire Regime Method	Authors	Fire Cycle/ Burn Rate	Data Period
Spray Lake Sawmills (3,371 km^2)	4.15	B9, B10	82 sampling sites/322 trees collected in the Bow Valley. 44 sampling sites/175 trees collected in the Ghost watershed. B10B: 1997 to 1999, 538 volume sampling plots as part of AVI were collected. Stands were selected randomly using proportional allocation based on appropriate crown density, species, and height classes. B9 & B9B: 1998 to 2000, 474 volume sampling plots following a multi-stage stratified-random sampling design.	Provincial fire occurrence and lightning strike data sets, fire counts, size, cause, month, spatial probability of ignition by cause, assessment done by natural region. Landscape disturbance modeling.	Rogeau 2005	Bow valley: FRI 1 to 11 yrs Ghost: FRI 3 to 14 yrs with MFRI of 7.6 yrs Overall fire cycle for allxof Kananaskis and SLS FMA between 1930 and 1950 is 104 yrs. Montane: 41 yrs	1850–2004
Weldwood (9,994 km^2)	2.18	E4, E6	Fire origin map built from fire history stand origin mapping procedures as outlined in Section 8.2.1. Fire origin map completion to fill in data gaps in 1996. W.A. Switzer Provincial Park and break-up ages of old forest patches on the FMA: 255 plots, 1,051 cross-sections, 118 scarred trees and 196 releases in ring growth. 1997: Fire origin map of old patch near Edson, and E4 in the provincial corridor between JNP and the FMA (1,387 km^2). 484 plots, 1841 cross-sections, 74	Fire cycle calculations using the Weibull and maximum likelihood estimates using 5-yr age-classes as of 1950. Process was repeated using the roll-back method for 20-yr age-classes. This was done by natural regions. Lightning density patterns correlation with stand age and fire cycles.	Jack Right, 1960s (unpublished data) Rogeau 1996b Rogeau 1997 Andison 1997 Andison 2000a	No fire cycle available for montane on the FMA, see J.N.P.	1500–1997

ROCKY MOUNTAIN NATURAL REGION: 4,626,107 ha							
Jurisdiction (Area)	**% Area**	**FMUs**	**Fire History Data**	**Fire Regime Method**	**Authors**	**Fire Cycle/ Burn Rate**	**Data Period**
			scarred trees, 331 releases in ring growth.				
Weyerhaeuser–G.P.	1.93	E8, G6, G7	$14,278\ km^2$. 1,200 PSPs, systematic grid basis: 12 plots/twp.				
Green Area–NW ($61,940\ km^2$)	1.83	E10					
Green Area–SW ($9,653\ km^2$)	21.99	C4, C5, E9, R11	E9: Included in the Foothills Model Forest studies, see Weldwood FMA: 58 plots, 287 cross-sections, 44 scarred trees, 2 releases in ring growth.				
			North portion of C5, $5,058\ km^2$. Stand origin from AVI data.	Fire cycles calculated by natural regions using the assumption of negative exponential fit and using the weighted mean age as a surrogate for fire cycle.	Olson and Diehl 1998	Whole area: 95 yrs Montane: 85 yrs	1600–1990
			C5 FMU	Evaluation of fire occurrence reports between 1961 and 2003, assessment of historical fire regime using 1950 aerial photography, fire mapping for the period of 1930-1950. Fire regime modeling.	Rogeau 2005	Whole area between 1930 and 1950: 85 yrs	1930-2003
White Area–SW ($31,855\ km^2$)	36.83	BO1, BO2, CO1, CO2					
Whitegoat–Siffleur Wilderness Area ($1,634\ km^2$)			Fire origin map built from fire history stand origin mapping procedures as outlined in Section	Causal factors of ignition, size of fire and seasonality of fire based on the Provincial Fire	Rogeau 1999b	Montane: 100–149 (varies based on	1470–1998

ROCKY MOUNTAIN NATURAL REGION: 4,626,107 ha

Jurisdiction (Area)	% Area	FMUs	Fire History Data	Fire Regime Method	Authors	Fire Cycle/ Burn Rate	Data Period
			8.2.1. 155 plots, 587 cross-sections, 78 scarred trees, 149 releases in ring-growth patterns.	Occurrence data set. Lightning strike density map. Spatial distribution of ignitions. Effect of topography of stand age patterns. Fire cycles calculated for homogeneous terrain components using the weighted mean ages as a surrogate to fire cycle.		topography)	
Banff National Park ($6,287 km^2$)	4.00		1980–82: Fire scar sampling: 220 plots, 615 cross-sections.	Fire cause, size, month by 10-yr period from 1880 to 1980.	White 1985a White 1985b		
			1991–1994: Fire origin map built from fire history stand origin mapping procedures as outlined in Section 8.2.1. 1,538 plots, 4,836 cross-sections, 902 scarred trees, 145 releases in ring-growth patterns.	Weibull fit of age-class distributions to obtain fire cycles by main watersheds. Fire size distribution.	Rogeau 1996a	Park: 216 yrs Watersheds: 167–335 yrs	1285–1994
				Effect of topography on stand age patterns and fire cycles.	Rogeau 2001	Montane: <50–300 yrs (varies based on topography)	1285–1994
				Spatial distribution of lightning fires and lightning strike density.	Wierzchowski et al. 2002		
Jasper National Park ($10,878 km^2$)	13.44		Fire origin map built from fire history stand origin mapping procedures. 1950 aerial photography, 1:50,000.	Fire cycle calculations using the Weibull and maximum likelihood estimates using 40-yr age-classes. Process was repeated using the roll-back method. Lightning density patterns correlation with stand age and fire cycles.	J.N.P. unpublished data Andison 1997 Andison 2000a	Montane: 85 yrs 91 yrs (roll-back)	1300–1985

ROCKY MOUNTAIN NATURAL REGION: 4,626,107 ha

Jurisdiction (Area)	% Area	FMUs	Fire History Data	Fire Regime Method	Authors	Fire Cycle/ Burn Rate	Data Period
				Spatial distribution of lightning fires and lightning strike density.	Wierzchowski et al. 2002		
			432 km^2 in the Athabasca, Maligne, and Miette Valleys. Master chronology from 664 fire scars on 435 trees. Mapping of all individual fires. 1:50,000.	MFRIs, effect of topography on fire frequency.	Tande 1979	MFRI: 18 to 27 yrs	1665–1971
			1997–1998, 27 km^2 Snaring River to Corral Cr and Jacques Range to Cinquefoil Cr. 1949 aerial photography, fire origin mapping at 1:20,000 over 1997 orthophoto. 180 plots, 1155 trees (cores & cross-sections), 121 scars.	MFRIs.	Rogeau 1999c	MFRI: 13 to 28 yrs	1700–1932
Waterton Lakes N.P. (525 km^2)	2.77		Transect sampling of fire scars and stand ages on representative terrain. 171 plots, 1,045 cores, 119 scars.	Mean fire intervals assessed on a temporal scale, by forest type and aspect/elevation. Fire cause.	Barrett 1996		1663–1995
Cypress Hills			Fire history study. Details unavailable at press time.		Strauss 2002		
			Some inventory ages from AVI and Phase II, no PSPs. Known inaccuracies between inventory ages and fire ages.				

FOOTHILLS NATURAL REGION: 9,486,985 ha

Jurisdiction (Area)	% Area	FMUs	Fire History Data	Fire Regime Method	Authors	Fire Cycle	Data Period
UPPER FOOTHILLS SUBREGION: 2,754,944 ha							
ANC Timber	5,24	W1, W8, W10	AVI age-class map.	Roll-back method of assessing disturbance rates by 20-yr period. Done by natural subregions.	Andison 2000a	61 yrs	1811–1950
Blue Ridge Lumber (6,687 km^2)	6.97	W2, W3, W4	Air photo screening assessment: 1948–52, 1:40,000 scale. Preliminary stand origin map (lines, no dates). W2: 600 inventory plots from SRD, 1,000 check plots taken at DBH with an increment borer, 350 cross-sections from deciduous & 300 from conifers.	Causal factors of ignition, size of fire, and seasonality of fire based on the Provincial Fire Occurrence data set. Lightning strike density map, historical and present-day probability of ignition models.	Rogeau 1999a		1961–1995
CanFor (6,324 km^2)	2.48	G5	Age-class map from inventory 841 PSPs and NIVMA plots.	Weibull and negative exponential models applied. Age data rolled back to 1950, data not spatially contiguous.	O.R.M. 2000	106 yrs 66 yrs (rolled back)	~1780–1999
Daishowa–Marubeni (25,042 km^2)	0.93	P13	1,317 volume sampling plot in clusters of 3 subplots (prism sweep plots) randomly distributed across veg. types. Others: 53 plots in young fire origin stands, 76 plots in F1, 61 plots in older conifer stands of P1 to break up the age-class of older stands.	Complete and thorough fire regime assessment using the provincial fire occurrence data set, lightning strike data, AVI data, and fire weather data. Parameters of fire frequency, cause, area burned, month of burning, fuel type, FWI, fire intensities, and fire cycles addressed by natural regions.	Stelfox and Wynes 1999	FMA: 285 yrs/0.35% Upper Foothills: 78 yrs/1.29%	1961–1995 1750–1990
Millar Western	1.45	W13		Provincial fire occurrence data	Hirsch and de Groot		1961–1998

FOOTHILLS NATURAL REGION: 9,486,985 ha

Jurisdiction (Area)	% Area	FMUs	Fire History Data	Fire Regime Method	Authors	Fire Cycle	Data Period
(4,770 km²)			189 PSPs on a density grid of 9 plots/twp.	set: fire counts, size, cause spatial distribution of ignition by cause, temporal distribution of fire, FBP fuel review, fire weather review.	1999		
Slave Lake Pulp (6,583 km²)	6.27	S20	40 PSPs, 2,690 TSPs randomly distributed. 198 sampling sites/746 trees collected in 2004.				
Spray Lake Sawmills (3,371 km²)	2.97	B9	B10B: 1997 to 1999, 538 volume sampling plots as part of AVI were collected. Stands were selected randomly using proportional allocation based on appropriate crown density, species, and height classes. B9 & B9B: 1998 to 2000, 474 volume sampling plots following a multi-stage stratified-random sampling design.	Provincial fire occurrence and lightning strike data sets, fire counts, size, cause, month, spatial probability of ignition by cause, assessment done by natural region. Landscape disturbance modeling.	Rogeau 2004 Rogeau 2005	FRI: 4 to 17 yrs MFRI: 9 yrs Overall fire cycle for allof Kananaskis and SLS FMA between 1930 and 1950 is 104 yrs.	1961–2003 1850 - 2004
Sundance (2,675 km²)	6.68	R13	98 PSPs located on twp corners, 17 PSPs for AVI.				
Sunpine (5,874 km²)	13.80	R10	250 PSPs, 5,500 TSPs. Stratified random sampling. Stand origin map produced from digitizing Phase III maps.	Provincial fire occurrence records. Assessment of lightning strike data. Fire counts by month, cause, size, probability of ignition by compartment	Treçs Consulting 2002		

FOOTHILLS NATURAL REGION: 9,486,985 ha							
Jurisdiction (Area)	**% Area**	**FMUs**	**Fire History Data**	**Fire Regime Method**	**Authors**	**Fire Cycle**	**Data Period**
				Disturbance rates and fire cycles calculated as input values for landscape disturbance modeling. Estimated from 40 yr age-class AVI origin map, using the roll-back method.	Andison *In progress*		
Weldwood ($9,994\ km^2$)	20.46	E3, E4, E5, E6, E7	Fire origin map built from fire history stand origin mapping procedures as outlined in Section 8.2.1. Fire origin map completion to fill in data gaps in 1996. W.A. Switzer Provincial Park and break up ages of old forest patches on the FMA: 255 plots, 1,051 cross-sections, 118 scarred trees and 196 releases in ring growth. 1997: Fire origin map of old patch near Edson, and E4 in the provincial corridor between JNP and the FMA ($1,387\ km^2$). 484 plots, 1,841 cross-sections, 74 scarred trees, 331 releases in ring growth.	Fire cycle calculations using the Weibull and maximum likelihood estimates using 5-yr age-classes as of 1950. Process was repeated using the roll-back method for 20-yr age-classes. This was done by natural regions. Lightning density patterns correlation with stand age and fire cycles.	Jack Right, 1960s (unpublished data) Rogeau 1996b Rogeau 1997 Andison 1997 Andison 2000a	U. Foothills: 95 yrs 101 yrs (roll-back)	1500–1997
Weyerhaeuser–Drayton ($5,548\ km^2$)	4.17	R2, R3, R4	240 PSPs, 2,600 TSPs, stratified random sampling.				
Weyerhaeuser–Edson ($6,800\ km^2$)	4.38	E1, E2, W6	141 PSPs, 2,000 TSPs, stratified random sampling.				
Weyerhaeuser–	13.12	E8, G3, G4,	$14,278\ km^2$.				

FOOTHILLS NATURAL REGION: 9,486,985 ha							
Jurisdiction (Area)	**% Area**	**FMUs**	**Fire History Data**	**Fire Regime Method**	**Authors**	**Fire Cycle**	**Data Period**
G.P.		G6, G7	1,200 PSPs, systematic grid basis: 12 plots/twp.				
Green Area–NW (61,940 km^2)	5.42	E10, P1, P7, P8					
Green Area–SW (9,653 km^2)	4.99	E11, H1, R11	E11 included in the Foothills Model Forest studies. See Weldwood FMA.				
LOWER FOOTHILLS SUBREGION: 6,732, 041 ha							
ANC Timber	2.60	W1, W8, W10	AVI age-class map.	Roll-back method of assessing disturbance rates by 20-yr period. Done by natural subregions.	Andison 2000a	52 yrs	1811–1950
Blue Ridge Lumber (6,687 km^2)	4.42	W2, W3, W4	Air photo screening assessment: 1948–52, 1:40,000 scale. Preliminary stand origin map (lines, no dates). W2: 600 inventory plots from SRD, 1,000 check plots taken at DBH with an increment borer, 350 cross-sections from deciduous & 300 from conifers.	Causal factors of ignition, size of fire, and seasonality of fire based on the Provincial Fire Occurrence data set. Lightning strike density map, historical and present-day probability of ignition models.	Rogeau 1999a		1961–1995
CanFor (6,324 km^2)	3.36	G5	Age-class map from inventory. 841 PSPs and NIVMA plots.	Weibull and negative exponential models applied. Age data rolled back to 1950, data not spatially contiguous.	O.R.M. 2000	97–103 61–66 (rolled back)	~1780–1999
Daishowa–Marubeni (25,042 km^2)	8.91	P10, P13	1,317 volume sampling plot in clusters of 3 subplots (prism sweep plots) randomly distributed across veg. types. Others: 53 plots in young fire	Complete and thorough fire regime assessment using the provincial fire occurrence data set, lightning strike data, AVI data, and fire weather data.	Stelfox and Wynes 1999	FMA: 285 yrs/0.35% Lower Foothills: 492 yrs/0.20%	1961–1995 1750–1990

FOOTHILLS NATURAL REGION: 9,486,985 ha							
Jurisdiction (Area)	**% Area**	**FMUs**	**Fire History Data**	**Fire Regime Method**	**Authors**	**Fire Cycle**	**Data Period**
			origin stands, 76 plots in F1, 61 plots in older conifer stands of P1 to break up the age-class of older stands.	Parameters of fire frequency, cause, area burned, month of burning, fuel type, FWI, fire intensities, and fire cycles addressed by natural regions.			
Manning ($5,956\ km^2$)	7.33	P6, P9	530 PSPs, random distribution using a grid-based system.				
Millar Western ($4,770\ km^2$)	3.56	W11, W13	189 PSPs on a density grid of 9 plots/twp.	Provincial fire occurrence data set: fire counts, size, cause spatial distribution of ignition by cause, temporal distribution of fire, FBP fuel review, fire weather review.	Hirsch and de Groot 1999		1961–1998
Slave Lake Pulp ($6,583\ km^2$)	5.74	S20	40 PSPs, 2,690 TSPs randomly distributed.				
Spray Lake Sawmills ($3,371\ km^2$)	1.76	B9, B10	B10B: 1997 to 1999, 538 volume sampling plots as part of AVI were collected. Stands were selected randomly using proportional allocation based on appropriate crown density, species, and height classes. B9 & B9B: 1998 to 2000, 474 volume sampling plots following a multi-stage stratified-random sampling design.	Provincial fire occurrence and lightning strike data sets, fire counts, size, cause, month, spatial probability of ignition by cause, assessment done by natural region. Landscape disturbance modeling.	Rogeau 2004 Rogeau 2005	Overall fire cycle for all of Kananaskis and SLS FMA between 1930 and 1950 is 104 yrs.	1961–2003 1850 - 2005
Sundance ($2,675\ km^2$)	1.16	R13	98 PSPs located on twp corners, 17 PSPs for AVI.				

FOOTHILLS NATURAL REGION: 9,486,985 ha

Jurisdiction (Area)	% Area	FMUs	Fire History Data	Fire Regime Method	Authors	Fire Cycle	Data Period
Sunpine (5,874 km^2)	2.85	R10	250 PSPs, 5,500 TSPs. Stratified random sampling. Stand origin map produced from digitizing Phase III maps.	Provincial fire occurrence records. Assessment of lightning strike data. Fire counts by month, cause, size, probability of ignition by compartment	Trees Consulting 2002		
				Disturbance rates and fire cycles calculated as input values for landscape disturbance modeling. Estimated from 40 yr age-class AVI origin map, using the roll-back method.	Andison *In progress*		
Tolko (38,531 km^2)	1.52	F25	19 PSPs randomly distributed.				
Weldwood (9,994 km^2)	3.59	E3, E4, E6, E7	Fire origin map built from fire history stand origin mapping procedures as outlined in Section 8.2.1. Fire origin map completion to fill in data gaps in 1996. W.A. Switzer Provincial Park and break up ages of old forest patches on the FMA: 255 plots, 1,051 cross-sections, 118 scarred trees and 196 releases in ring growth. 1997: Fire origin map of old patch near Edson, and E4 in the provincial corridor between JNP and the FMA (1,387 km^2). 484 plots, 1,841 cross-sections, 74 scarred trees, 331 releases in ring growth.	Fire cycle calculations using the Weibull and maximum likelihood estimates using 5-yr age-classes as of 1950. Process was repeated using the roll-back method for 20-yr age-classes. This was done by natural regions. Lightning density patterns correlation with stand age and fire cycles.	Jack Right, 1960s (unpublished data) Rogeau 1996b Rogeau 1997 Andison 1997 Andison 2000a	L. Foothills: 95 yrs 101 yrs (roll-back)	1500–1997

FOOTHILLS NATURAL REGION: 9,486,985 ha							
Jurisdiction (Area)	**% Area**	**FMUs**	**Fire History Data**	**Fire Regime Method**	**Authors**	**Fire Cycle**	**Data Period**
Weyerhaeuser–Drayton ($5,548\ km^2$)	6.38	R1, R2, R3, R4	240 PSPs, 2,600 TSPs, stratified random sampling.				
Weyerhaeuser–Edson ($6,800\ km^2$)	8.21	E1, E2, W5, W6	141 PSPs, 2,000 TSPs, stratified random sampling.				
Weyerhaeuser–G.P. ($14,278\ km^2$)	7.34	E8, G1, G3, G4, G6, G7	1,200 PSPs, systematic grid basis: 12 plots/twp.				
Weyerhaeuser–S.L. ($7,271\ km^2$)	3.04	S17	200 PSPs by cover type stratum, location in a stand defined randomly within a 75 x 75m grid.				
Green Area–NW ($61,940\ km^2$)	12.50	G11, G12, M4, P1, P7, P8					
White Area–NW ($63,799\ km^2$)	5.95	GO1, GO3, PO2, PO3, SO2, WO1, WO2					
White Area–SW ($31,855\ km^2$)	7.46	BO1, BO2, EO1, RO1					

CANADIAN SHIELD NATURAL REGION: 1,578,902 ha							
Jurisdiction (Area)	**% Area**	**FMUs**	**Fire History Data**	**Fire Regime Method**	**Authors**	**Fire Cycle/ Burn Rate**	**Data Period**
ATHABASCA PLAIN SUBREGION: 680,126 ha							
North Athabasca River area (39,978 km^2)	98.69	A10, A11, A12	Historical fire burns records and maps.	Small part of big caribou study. Fire cycle calculated based current age of forests or its age when last burned. Areas are classified into short, medium, and long fire cycles, only short and medium fire cycle area within Alberta.	The Beverly and Qamanirjuaq caribou management board, 1994a, 194b	Short: <81 yrs Medium: 81–140 yrs	
			A13, fire history study bound by WBNP and the Slave River. 595 km^2 (= 6% of the subregion). Fire history point sample data collected in 1995–96. 62 plots using a 4 km grid. Cross-section taken from largest tree (fire survivor). Rings counted with DendroScan.	Fire cycles estimated over a temporal scale by fitting a regression curve to cumulated percentage of sites by time-since-fire. Four different slopes in curve were identified. The slope value was used as a surrogate measure of fire cycle.	Brungs-Simard 2001	1865–1895: 181 yrs 1895–1935: 266 yrs 1935–1945: 29 yrs 1945–1995: 130 yrs	1865–1995
KAZAN UPLAND SUBREGION: 898,775 ha							
North Athabasca River area (39,978 km^2)	97.84	A12, A13	Historical fire burns records and maps.	Small part of big caribou study. Fire cycle calculated based current age of forests or its age when last burned. Areas are classified into short, medium, and long fire cycles, only short and medium fire cycles area within Alberta.	The Beverly and Qamanirjuaq caribou management board, 1994a, 1994b	Short: <81 yrs Medium: 81–140 yrs	
			A13, fire history study bound by WBNP and the Slave River. 595 km^2 (= 6% of the subregion). Fire history point sample data collected in 1995–96. 62 plots using a 4 km grid. Cross-section taken from largest tree (fire survivor). Rings counted with DendroScan.	Fire cycles estimated over a temporal scale by fitting a regression curve to cumulated percentage of sites by time-since-fire. Four different slopes in curve were identified. The slope value was used as a surrogate measure of fire cycle.	Brungs-Simard 2001	1865–1895: 181 yrs 1895–1935: 266 yrs 1935–1945: 29 yrs 1945–1995: 130 yrs	1865–1995

PARKLAND NATURAL REGION: 6,249,541 ha							
Jurisdiction (Area)	**% Area**	**FMUs**	**Fire History Data**	**Fire Regime Method**	**Authors**	**Fire Cycle/ Burn Rate**	**Data Period**
FOOTHILLS SUBREGIONS: 439,019 ha							
Green Area – C5 ($9,653 km^2$)	1.44	C5	North portion of C5, 5,058 km. Stand origin from AVI data.	Fire cycles calculated by natural regions using the assumption of negative exponential fit and using the weighted mean age as a surrogate for fire cycle.	Olson and Diehl 1998	Whole area: 95 yrs Foothills Parkland : 69 yrs Foothills Fescue : 69 yrs	1600–1990
White Area–SW ($31,855 km^2$)	91.01	BO1, BO2, CO1, CO2					
Waterton Lakes N.P. ($525 km^2$)	1.49		Transect sampling of fire scars and stand ages on representative terrain. 171 plots, 1,045 cores, 119 scars.	Mean fire intervals assessed on a temporal scale, by forest type and aspect/elevation. Fire cause.	Barrett 1996		1663–1995
PEACE RIVER PARKLAND (CONFIRM) SUBREGION: 465,686 ha							
Tolko ($38,531 km^2$)	2.30	S19	19 PSPs randomly distributed.				
Weyerhaeuser–G.P. ($14,278 km^2$)	0.99	G1	1,200 PSPs, systematic grid basis: 12 plots/twp.				
White Area–NW ($61,940 km^2$)	96.21	GO1, GO2, GO3, PO1, PO2, PO3					

PARKLAND NATURAL REGION: 6,249,541 ha							
Jurisdiction (Area)	**% Area**	**FMUs**	**Fire History Data**	**Fire Regime Method**	**Authors**	**Fire Cycle/ Burn Rate**	**Data Period**
CENTRAL PARKLAND SUBREGION: 5,344,835 ha							
White Area–NE (27,249 km^2)	2.79	LO1	50 sample plots collected by Nov. 2005 in the Cooking Lake/Beaver Hills Region.	Review of historical fire regime using 1950 aerial photography and archival research.	Rogeau. *In Progress.*		
White Area–NW (63,799 km^2)	3.46	WO2					
White Area–SW (31,855 km^2)	10.87	BO2, RO1					

Appendix IV

The application aspects of five landscape disturbance models used to model fire regimes on Alberta landscapes are summarized below.

Following this, the technical aspects of five landscape disturbance models used to model fire regimes on Alberta landscapes are summarized.

Application aspects of five landscape disturbance models used to model fire regimes on Alberta landscapes.

	FEENIX[1]	TARDIS[2]	LANDIS[3]	LANDMINE[4]	STANDOR[5]
Landscape(s)	L1 & L2 LMUs of Al-Pac FMA.	Al-Pac FMA.	Millar Western FMA. (Doyon & Duinker 2000)	Weldwood & Alberta Newsprint FMAs and Jasper National Park (Andison 2000), Al-Pac FMA (Andison 2003), and Sunpine FMA(in progress).	Spray Lake FMA and Kananaskis Improvement District (Rogeau in progress)
Primary Use	Simulate landscape dynamics and address complex ecological indicators such as abundance and spatial distribution of forest songbirds, or forest age/cover types, under alternate management scenarios.	Strategic level analysis of economic and ecological sustainability under alternate forest management options.	Simulate succession and disturbance over large heterogeneous landscapes and long periods.	Reproduce long-term natural patterns based on probabilistic burning conditions.	Emulate stand age patterns over large-size landscapes following long-term burning periods.
Secondary Uses	Calibrate estimators of the costs of individual forest fires applicable to strategic planning and operational fire management. Evaluate spatial ecology of white spruce in relation to the fire regime.	Simulate regional population dynamics (e.g., song birds) under natural disturbance and forest management regimes. Evaluate land zoning and reserve systems with respect to economics and biodiversity.	Simulates wind disturbance, timber harvesting, forest succession.	Operational planning for smaller areas; limited ignition to a point or area; compare fire patterns with harvesting patterns.	Modify the fire regime (up to 5 times) during the simulation period and assess how it affects resulting burn patterns, age-class distributions, and fire cycles.
Data Inputs	Raster layers of forest inventories, hydrography, elevation. Yield tables, SI curves, forest type specific probabilities of fire arrival, escape and growth, parameters for ecological sub-models (see dispersal, species abundance).	Land attribute tables, road network, lineal feature densities, haul distances, and spatial zoning by township. Yield tables, mill locations, annual allowable cut or quota volume, forest type-specific fire arrival probabilities, statistical models of fire size and composition, forest patch structure, species presence/absence.	Life history of tree and plant species, land type (geology, soil, climate, topography), size and frequency of windthrow and fire. Methods of seed dispersal and disturbance.	Raster layers of digital elevation model, fuel, hydrography, ecoregion; local knowledge of fire size distribution and burn rates.	Raster layers: DEM, FBP fuel, valley orientation, probability of ignition, probability of burning, weather zone. Fire frequency range, local fire weather data.

	FEENIX[1]	TARDIS[2]	LANDIS[3]	LANDMINE[4]	STANDOR[5]
Data Outputs	Application-specific maps and tabular summaries of periodic harvest volumes, annual allowable cut, burn rates, salvage volume, species abundances, spatial pattern metrics.	Application specific maps and regional means/totals/ distributions of various economic and ecological indicators (e.g., forest age and patch structure, harvest volumes, delivered wood cost, burn rates, species presence/absence).	Maps of disturbance patterns, tree species, age-classes, and stand types. Log files listing fires and windthrows that occurred during the simulation.	Tabular summaries of burning rate by time period; patch size and shape information, maps, 2 scale outputs for detailed information for smaller areas and non-spatial, general outputs for very large landscapes.	Stand origin map in predetermined age-classes (see time-step), frequency of burning per pixel map. Tabular summaries of area by age-class distribution, fire list with season of burning and size, cumulative fire size.
Limitations	Real-time fire growth, effects of streams, rivers and linear features on fire spread, inadequate for partial burns/harvest, no human-caused fires, fire management acts only through initial attack.	No dynamic model of linear features, no human-caused fires, no spatial variation in fire regime independent of vegetation structure.	Real-time fire growth as it does not use fire weather data, and size of fires are predetermined.	Real-time fire growth as it does not use detailed fire weather data, and size of fires are predetermined.	No spotting feature, does not include harvesting disturbances.

Technical aspects of five landscape disturbance models used to model fire regimes on Alberta landscapes.

	FEENIX[1]	**TARDIS**[2]	**LANDIS**[3]	**LANDMINE**[4]	**STANDOR**[5]
Programming LanguageOperating System	Visual Basic 6.0 IBM PC	C, Linux/Unix, Windows IBM PC/SUN Microsystems	Modular programming structure in C++ IBM PC, UNIX	C++ IBM P	Borland Turbo Pascal 7 IBM PC
GIS Compatibility	Yes	No	Yes	No	Yes
Fire Ignition	Vegetation-type specific, annual arrival probability of fire per cell.	Fire arrivals per cell per time-step are sampled from a Poisson distribution. Process is based on the function of the cells's forest composition and potentially other spatial factors.	Random selection of a site and determination of its disturbance probability (1.445 lightning strikes per km^2), which uses time-since-last fire and mean-return-interval of disturbance.	Varies: lightning data driven, purely random or by trial and error using both fire size and level of burning.	Random selection of a pixel, verification of its probability of ignition using the probability of ignition map, which is defined by the spatial density distribution of lightning and human-caused fires on the landscape modeled.

	FEENIX[1]	TARDIS[2]	LANDIS[3]	LANDMINE[4]	STANDOR[5]
Fire Spread	Vegetation-type specific spread probabilities, initial spread probability (out of ignition cell) models fire suppression by IA, ability to jump across large rivers or other fuel breaks.	Fire arrivals "escape" (exceed 3 ha in size) according to a probability that is estimated empirically. Fires that do not escape are ignored. Each escape is assigned a random size from a truncated Pareto distribution whose shape parameter can depend on forest composition or other spatial factors.	Spread depends on the disturbance probability of neighbouring cells.	Based on probabilities of movement to one of eight neighbours using a "scored" map, which is defined by input layers such as DEM, fuel type, and creeks. ROS represents moderately high burning conditions of the FBP fuel types.	Spread first depends on fuel availability of neighbouring cells and their probability value of burning based on their topographic location. Conditional probabilities of burning only apply to spring and fall burns when aspect and elevation affect fire spread. Differentiates between spring/fall and summer burns and uses appropriate fuel type for deciduous species.
Fire Extinction	Random, with a landscape-specific maximum fire size.	Predetermined size.	When the maximum disturbance size has been reached, or when there are no more cells that are available for burning. Fire size is determined from a size class distribution that uses the minimum, mean and maximum fire size of the region.	Fire size is predetermined, or it runs out of space on the landscape.	Several ways. When there is no fuel available for burning, the probabilities of burning are too low, the ROS is less than 1 m/min, the number of days with BUI values greater than 50 has ended, or the number of burning days allowed has been reached.
Fire Weather Codes and Indexes	No	No	No	Weather indexes used only for initial probabilities of fire spread.	Uses local fire weather data as far back in time as possible, fire weather is linked to weather zones on the landscape. FFMC, BUI, wind speed, and direction are used as inputs for calculation of spread rates using the FBP System.

	FEENIX[1]	TARDIS[2]	LANDIS[3]	LANDMINE[4]	STANDOR[5]
Fire Growth Model	Modified percolation model, 8 neighbours.	See fire spread.	Raster-based contagion model that spreads to 8 neighbouring cells.	Raster-based cellular automaton using multiple firelets.	16-5-7 asymmetric raster-based model. 16 fixed symmetric directions plus an additional 5 on each side of the downwind spread direction for a total of 26 spread directions.
Fire Behaviour Model	Does not use FBP System equations, from the Canadian Forest Service, to model fire spread based on the FBP fuel types.	Does not use the FBP System equations to model fire spread based on the FBP fuel types.	Does not use the FBP System equations to model fire spread based on the FBP fuel types.	Customized equations equivalent to those of the FBP System. Uses FBP fuel types.	Canadian FBP System.
Time-Step	1 yr.	5 yrs.	10 years.	Variable, normally 10 yrs.	Variable, normally 10 yrs.
Resolution	3 ha.	~10,000 ha (township).	25m, minimum patch size 1 ha.	4 ha.	Fire growth at 1 ha, visual output at 4 ha.
Island Remnants	Yes	No	No	Yes, the model can account for island remnants if need be.	No

Model authors and references:
1. & 2. Steve Cumming, Boreal Ecosystem Research Ltd. Edmonton, Alberta. (See Cumming 2000b.)

3. He, H.S.; Mladenoff, D.J. (See Doyon and Duinker 2000, Doyon 2000.)

4. David Andison, Bandaloop Landscape-Ecosystem Services, Belcarra, British Columbia. (See Andison 2003, Andison 2000b.)

5. Marie-Pierre Rogeau, Wildland Disturbance Consulting, Banff, Alberta, and Ugo Feunekes, Remsoft Inc., Fredericton, New Brunswick. (See Rogeau et al. 1996.)