C5 FOREST MANAGEMENT PLAN 2006–2026

APPENDIX 10A. FIRE REGIME ANALYSIS

Fire Regime Study
C5 FMU, Alberta

Prepared for:
Alberta Sustainable Resources Development
Forest Protection Branch

Prepared by:
Marie-Pierre Rogeau, M.Sc.
Wildland Disturbance Consulting
P.O. Box 2421, Banff, AB, T1L 1C2
mprogeau@telusplanet.net

March 2005

DISCLAIMER

Funding for this project was provided by Alberta Sustainable Resource Development (ASRD) and the Foothills Model Forest (FMF).

The views, conclusions and recommendations are those of the author and do not necessarily imply endorsement by ASRD or the FMF. The exclusion of certain manufactured products does not necessarily imply disapproval, nor does the mention of other products necessarily imply endorsement by ASRD or the FMF.

ASRD and the FMF understand the limitations of the data and results and, that conclusions and recommendations are based on statistical probabilistic events. The author cannot be held liable for timber loss or revenue as a result of fire or mis-use of data and results.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

The natural vegetation mosaic of the boreal, sub-boreal and mountainous forests of Canada has largely been shaped by wildfires for thousands of years. In fire regulated ecosystems, such as the District of Kananaskis, the patterns and physical effects of fire are needed to maintain the biodiversity and to preserve the ecological integrity of these systems. Natural forest systems however, are now rare, due to forest harvesting and fire suppression. It is widely believed that fire exclusion policies and campaigns towards fire prevention (i.e. Smoky the Bear) have considerably reduced the number and size of fires over the past 50 years (Heinselman 1973, Houston 1973, Tande 1979). A consequence of prolonged lack of significant fires, beyond the natural fire cycle endemic to an ecosystem, is the promotion of an increase in fuel build up. Ignitions occurring on such landscapes during extremely dry periods with windy conditions have a tendency to develop into high intensity fires that are extremely hard to contain and that burn extensive areas (ref Yellowstone fire 1988, Virginia Hills Fire, AB 1998, Lost Creek Fire, AB 2003). It is now being understood that this type of fuel build up is not likely the natural condition for the forest.

It is also believed that forest management practices, such as harvesting, are shifting the natural seral stage distribution of forest communities. In recent years, a better understanding of the ecological effects of natural disturbances has prompted Government and the forest industry to initiate a form of forest management that would attempt to replace the effect of wildfire by creating a sustainable forest mosaic reminiscent of that created by wildfire. Guidelines on forest patch sizes and rotation exist, but their general nature may not render a true portrait of historic disturbances within specific ecosystems. It is known that spatial distribution of wildfires is strongly affected by probabilities of ignitions, while fire spread is affected by topography such as valley orientation, aspect and elevation (Rogeau et al. 2004). Therefore, a more in depth analysis of historical natural disturbances is required for representative natural regions prior to implementing guidelines in an effort to emulate natural disturbance patterns.

An understanding of fire regimes is necessary to facilitate attempts at this replication and will also help managers to implement innovative and adaptive harvesting strategies. The fire regime is defined by the frequency, type (anthropogenic vs lightning caused), intensity (surface, passive crown fire, stand replacing) and, size of fires occurring on the landscape. An important concept is the approximation of the natural fire cycle(s)[1] endemic to the area, which can be obtained by assessing the natural range of variability of fire size, frequency and return intervals. In turn, a yearly disturbance rate of the forested land can be estimated and logging practices can be adapted accordingly in an attempt to emulate natural disturbance patterns.

The identification and extent of possible multiple fire regimes over the landscape is the initial step to studying natural disturbances. Fire regimes are mainly characterized by their disturbance types and frequencies, but also by their intensities and extent. It is therefore important to know if we are dealing with more than one regime, as subsequent analyses will need to be done for each fire regime. Running analyses on landscapes that have a homogeneous fire regime is beneficial for reducing the effects of some environmental factors. This research used a number of methods to

[1]The fire cycle is defined as the number of years it takes to burn an area equivalent in size to the study area, accounting for the fact that some areas may burn more than once while others may never burn (Johnson and Van Wagner 1985).

identify and document the fire regimes of the region. In summary, fire occurrence records from 1961 to 2003 were used to define the recent fire regime. Because increased land use and fire suppression have played an effect on fire occurrence and fire size in the last 60 years or so, it was important to also document the historical fire regime from the turn of the century. This was done by screening historical aerial photography for vegetation complexity and number of fires. Recent fires from 1930 to 1950, that had not been overlapped by subsequent burns, were also mapped using the historical photographs. All of the information collected was tabulated to determine spatial probabilities of ignition, lead cause of fire, seasonality of fire, and fire size distribution. The fire cycle and rate of disturbance were also calculated for both regime periods. Fire regime modelling, using a computerized fire-growth model, was also used as an additional tool to evaluate the range of variation in age-class distributions and fire cycles. Lastly, using results from this fire regime evaluation, the last chapter of this report presents recommendations for forest management and future research work. The general interpretation of analyses performed and the results obtained are presented in Chapter 4. This chapter will be helpful in understanding how to read and interpret the information given in the following Chapters.

2.0 RESEARCH OBJECTIVES

The main research goal was to identify the number of fire regimes existing within C5 FMU and to draw a profile for each regime. However, research objectives were aimed at the development of recommended harvesting guidelines for cutblock sizes and age-class distributions for C5 management subregions and fuel cover types.

1) To identify and describe the fire regime(s) of C5 FMU;

2) To assess the spatial distribution of age-classes;

3) To assess the natural variation of fire sizes; and

4) To assess the natural variation in fire cycle (i.e. yearly rate of disturbance);

5) To determine the seral age distribution by fuel cover type; and

6) To determine the patch size distribution by fuel cover type.

To meet these objectives, several hypotheses were tested.

2.1 Hypothesis Testing

Hypotheses addressing the number of fire regimes:

H_{01}: The fire regime is homogeneous throughout the entire District.

H_{02} :The chance of fire ignition is homogeneous throughout the entire District.

H_{03} :The chance of fire ignition is homogeneous within natural subregions.

Hypotheses addressing the spatial distribution of age-classes:

H_{04}: Mean simulated stand origin map shows homogeneous age-class across the landscape

Hypotheses addressing the variation in fire cycles:

H_{05}: The Mean-Fire-Return-Interval is homogeneous across the landscape.

H_{06}: The fire cycle values are homogeneous across the landscape.

Hypotheses addressing the natural variation of patch sizes (repeated for all fire regimes identified):

H_{07}: The range in cutblock sizes is not found within the historic range of natural disturbances sizes.

H_{08}: The variation in cutblock sizes is representative of the historic range of natural disturbances sizes.

Hypotheses addressing differences among fuel cover types:

H_{09}: The seral stage distribution is similar between fuel cover types.

H_{010}: The Mean-Fire-Return-Interval is similar between fuel cover types.

H_{011}: The patch size distribution is similar between fuel cover types.

3.0 DATA LAYERS AND DATA LIMITATIONS

A number of maps and data sets were used in the assessment of the fire regime. A description of the source of the data and its use are presented below. Data limitations, if any, are also discussed to advise caution when there is a concern with the reliability of the data, its results and any conclusions that have been drawn from those results.

All maps acquired for this project were imported into Idrisi Kilimanjaro GIS and were rasterised at a 20 m^2 resolution. Considering the generality of some data layers used and the large size of the study area (8,342 km^2 area), this level of resolution was considered appropriate for the level of detail required. The projection used was UTM Zone 11, NAD83.

3.1 FIRE OCCURRENCE DATABASE

Data use: - Assessment of several parameters of the recent fire regime (Chapter 6)

The Forest Protection Division (Edmonton) of Alberta Sustainable Resource Development (ASRD) provided provincial fire records from 1961 to 2003 in a spreadsheet format. This data set was used to determine the number of fires and burn area by cause, size and seasonality. The limitations associated with this data set are that, throughout this period, most fires have been subjected to different degrees of fire suppression. This has the effect of lengthening the fire cycle and reducing the size of the burn area to an unnatural state. Fire occurrence records from the 1960's may be incomplete which will affect the results, especially for fires that were small and remote. Information on burn area for 2003 fires had not been fully compiled and checked for errors at the time the analyses took place.

3.2 LIGHTNING STRIKE DATABASE

Data use: - Evaluation of probabilities of ignition (Chapter 6)

The lightning strike database, in a spreadsheet format, was also provided by the Forest Protection Division of ASRD. This database consists of a list of geographical coordinates for every strike recorded by lightning strike detection systems between 1990 and 2003. The Province has been collecting strike data since 1982, but the technology for direction finders was improved in the last decade and it is assumed that locations of strikes that occurred in the 1990's are more accurate than those of the 1980's. It should be noted that due to the broad separation of direction finders and high mountain ranges, the mean location error of a lightning strike can be as much as 10 km (Nimchuck 1989).

3.3 Digital Elevation Model

Data uses: - Evaluation of probabilities of ignition (Chapter 6)
- Fire regime modelling (Chapter 9)

The digital elevation model was obtained from Forest Protection Division of ASRD. The DEM file provided was already in a raster format at a 20 m resolution. The DEM comes from Terrain Resource Information Management (TRIM) files at a scale of 1:20,000.

The DEM was used to create an elevation map at 100m intervals and an aspect map that was classified into eight cardinal directions. The DEM was also used as one of the base layers in the fire propagation model STANDOR.

3.4 Natural Subregion Map

Data uses: - Evaluation of recent and historical fire regime (Chapters 6 & 7)
- Evaluation of probabilities of ignition (Chapter 6)
- Fire regime modelling (Chapter 9)

The Natural Subregion map for the Province was used to determine any relationships with fire regime type. This map was obtained from ASRD in a vector format.

3.5 Land Use and Transportation Maps

Data uses: - Landscape reference points for all maps created
- Probability of ignition model (Chapter 9)

All GIS layers pertaining to geopolitical boundaries, transportation corridors, hydrography network, campgrounds and other recreation areas were obtained from the Edmonton Forest Protection Division of ASRD. Town boundaries were obtained from the Southern Rockies District Forest Protection Division of ASRD.

3.6 AVI Stand Origin Map

Data uses: - Evaluation of historical fire regime (Chapter 7)

The Alberta Vegetation Inventory stand origin map for the C5 FMU was provided by the Edmonton Forest Protection Division of ASRD. The main issue with this GIS layer is the poor reliability of stand dates due to different stand dating methods and the small number of trees sampled in comparison to fire history stand aging methods. Any interpretation made from this map must be done with care.

3.7 WATERSHED MAP

Data uses: - Identification of historical fire regimes (Chapter 7)
- Fire regime modelling (Chapter 9)

This map layer was created by the author and digitized by The Forestry Corp in Edmonton. The watershed map was created with 1:50,000 topographic maps by outlining the height of land as watershed boundaries. Watersheds identified were as a minimum, 6 to 8 km long. The watershed map was also built with the purpose of representing valley orientation, which is an important topographic variable affecting fire behaviour. Valley orientation was found to be one of the most important factors of fire distribution on the east slopes of the Canadian Rockies (Rogeau et. al. 2004). Because of this, some watersheds had to be parted in their middle to capture the changes in valley orientation. As a result, 84 polygons were created.

3.8 FUEL TYPE MAP

Data use: - Fire regime modelling (Chapter 9)

The fuel type map was obtained from Alberta Sustainable Resource Development - Forest Protection Office - in Edmonton. The map received was an AVI polygon map with FBP and cover type attribute fields. Modifications were made to the map to reclassify non-forested features such as roads, as burnable fuels because STANDOR does not have a fire spotting feature and fires would simply stop burning against a fuel break. To avoid fire spread abnormalities from roads, which largely did not exit a century ago, these features were reclassified as grass (O1a). Also, due to the large number of cutblocks on the landscape, and not knowing what was "underneath" them prior to harvesting, they were reclassified from a grass fuel type to an immature pine forest This was done by changing the FBP field to C4 for MOD1_YR > 1979 and COVTYPE = HG.

3.9 COVER TYPE MAP

Data use: - Assessment of fire regime simulation results by cover type (Chapter 12)

The cover type attributes were provided in the same AVI polygon map as the FBP fuel types (Section 3.8). The cover type map is to be used to assess age-class distribution, patch size distribution and mean-fire-return-intervals by cover type and seral stages. Because fires are grown using the FBP map to emulate fire behaviour and fire growth in the best way possible, it was important that cover types be classified in a similar fashion as the FBP, so that results were representative of the cover types as well. To ascertain this, the two polygon layers (FBP and cover types), were overlaid together. Unfortunately, it was found that there were a large number of discrepancies between the two maps due to the large number of rules used to classify each map, which are different at times. To fix this problem, a new cover type field was created to assign cover type values based on a combination of elements that would make the cover type similar to the FBP fuel types. The field COVTYPE was used as is to designate all coniferous fuel type groups. Based on the SOFTWOOD and HARDWOOD fields, which show the proportion of each on a scale from 1 to 10, the F_COVTYPE field seemed to be more appropriate to use for designating the CD, DC, and D cover types. Those were also more in line with the FBP values given in the FBP field. The

HG cover type, which is a grass fuel type, was matched to the O1a FBP fuel type. Overall, there are still some variances between the FBP and cover type maps, but it is much better than it was. The most important discrepancies are found between the M1 / D1 fuel types and CD / DC cover types as shown in Table 3-1. About half of the CD cover type will have fire behaviour tendencies closer to pine and spruce forests than mixedwood forests. This will be reflected in the simulation outcome. Similarly, the DC fuel type has been largely associated with a D1 fuel type rather than mixedwood. It's simulation results will thus exhibit similarities with pure deciduous stands.

Table 3-1 Cross-tabulation results between the FBP fuel map and the cover type map for the C5 region (beyond the C5 FMU boundaries). Values expressed in percent land base.

	Fa/La	Fd	Px	Sx	CD	DC	D	grass	NF
C1	40.82	0.00	0.03	15.55	5.48	0.00	0.00	0.00	0.00
C2	54.94	0.00	6.66	82.13	13.69	0.00	0.04	0.04	0.00
C3	4.09	0.00	91.27	2.31	20.76	0.00	0.03	0.09	0.03
C4	0.00	0.00	1.16	0.00	0.00	0.00	0.00	1.37	0.00
C7	0.00	100.00	0.88	0.00	2.77	0.00	0.05	0.00	0.00
D1	0.15	0.00	0.00	0.00	1.61	57.23	99.81	0.05	0.00
M1	0.00	0.00	0.00	0.00	53.58	42.77	0.00	0.00	0.00
O1a	0.00	0.00	0.00	0.00	2.12	0.00	0.06	98.44	0.00
Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.79
NF	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	93.18

4.0 REPORT INTERPRETATION

This Chapter is included at the beginning of this report to facilitate the understanding of the study results and how this report should be read and interpreted. Different methods were used to document the various fire regimes of the C5 FMU and this created a large amount of information and results, which at times may seem repetitive. Unfortunately there is not one method better than the other as they are meant to complement each other. Truthfully, the application of these findings into forest management practices will seem overwhelming as different pieces of information from different chapters will need to be pooled together. The type of information needed will also vary depending on the forest management objective. I am providing some suggestions below and summarizing some of the chapter conclusions to help the reader understand how the information can be used.

4.1 RECENT FIRE REGIME (CHAPTER 6)

This method looked at recent (1961-2003) fire occurrence data. Using parameters such as fire frequency, fire cause, and spatial probabilities of ignition, by natural and management subregion, it was useful in determining if there was more than one fire regime on the landscape. Four fire regimes emerged from this exercise: Porcupine Hills, Continental Divide North, Livingstone and the combined Continental Divide South and Castle subregions. In terms of forest management application in a context of ecosystem restoration or harvest planning that emulates historical levels of natural disturbances, this is the only important information to retain. Subsequent chapters will define in better details the characteristics of each regime. This means that forest management practices will be tailored to each fire regime.

Another application of the recent fire regime review is the use of the probability of ignition map in FireSmart planning. Zones of greater probabilities of ignition should be assessed against the values at risk map in order to determine the proper course of action in terms of fuel reduction and fuel modification.

4.2 HISTORICAL FIRE REGIME (CHAPTER 7)

This is one of the most valuable chapter in this report. It may not provide concrete fire cycle values and fire size distribution, but the information gained from the air photo screening process is invaluable in determining the type of burning (full stand replacing or intermittent fire activity) that was taking place in the early 1900's. The vegetation complexity map and information listed in Table 7-1 by watershed, will give insight on the way timber should be removed: high intensity fires or clear cuts, versus lighter intensity burns or island remnants within a harvest patch. Results from the historical fire regime assessment are in agreement with those of the recent fire regime review. Four fire regimes prevail on the C5 FMU.

The information from this chapter will have to be used in conjunction with simulation results from Chapter 9. The fire growth model used can only emulate stand replacing fires. The fire size obtained may be appropriate, but forest planners need to go back to the descriptive notes about the vegetation complexity to determine how “bare” harvest patches should be and how intricate the cut block design should be. If fire is used as a tree removal agent, mechanical thinning may need to take place prior to burning so as to not burn a stand completely. Because of fire suppression and the increased amount of fuel on the ground, fires with an intensity that is too high is a highly possible outcome. The ecology of Douglas fir forests for example, call for lower intensity fires where towering, veteran trees can survive fires for centuries. The sub-dominant canopy is now so dense and high from the prolonged lack of fire that a prescribed fire in those stands could be lethal to those veteran trees.

4.3 Recent fire mapping (Chapter 8)

Entertaining at best, this chapter will not bring anything to the forest planner. It does offer a fire cycle value, but it is mainly for the subalpine natural subregion and it focuses on a narrow time period of 20 years, between 1930 and 1950. As such, it does not provide any range of natural variation (temporal or spatial). This process was conducted so that a range of fire sizes, under limited fire suppression measures, could be obtained. The mean fire size from this method was used as a benchmark value in the computer-based fire regime simulation process (Chapter 9).

4.4 Fire Regime Modelling (Chapter 9)

This is a long chapter that explains how the fire regime simulations were achieved. At the end of the Chapter, a series of simulated stand origin and fire count maps are provided. They show the spatial distribution of age-classes on the landscape as well as frequency of fire return interval though the fire count map. The spatial outputs of this map will be provided in a digital format to ASRD. Following these maps are tables showing the age-class distributions by natural subregions and management subregions. They are provided in 10-year increments up to 300 years, and then 300+ years. This information can be re-classified into broader age-classes by the forest planner based on the application objectives and the appropriate generalization of the age information.

The proportions of land base in each age-class are those that should be maintained on the landscape. The fire cycle values and yearly rate of disturbance presented in Chapter 11 will indicate the number of hectares that should be disturbed every year by subregion. This number of hectares should then be subdivided proportionally to maintain the age-class distribution. The age-class distributions given are mean distributions from 10 simulated age-class distributions. Also listed is the natural range of variation as per the standard deviation around the mean. In other words, there is room for fluctuation in the proportionality of disturbances that should be attributed to each age-class or given seral stages.

That said, a real stand origin map must be used to apply the appropriate disturbance proportions to the different age-classes. The stand origin map currently available for C5 was created from inventory ages and likely has serious problems with stand dating from fire origin. The lumping into broad age-classes such as seral stages would reduce the problem with dating errors. However, the best thing would be to conduct a stand age validation program using the fire history method of stand dating since this whole principle of forest management is based on natural disturbances (i.e. fire).

4.5 Natural variation in fire size and fire cycle (Chapters 10-11)

Results presented in these two chapters are from three separate methods: assessment of the provincial fire occurrence data set, recent fire mapping, and fire simulations. Overall, it is the output from simulations that offers the best information because of the large data set it provided and the range of variation that could be established.

The proportions of fire given by fire size class, as well as the burn area associated with each fire size class, give a sense of how different current harvest block sizes are from fire related disturbances. When considering that cut block sizes are all less than 250 ha in size in the Southern Rockies, it is a large bridge to gap in terms of emulating natural disturbances. While it would be inconceivable to harvest the forest in patches as large as fires, measures are needed to create a different way of harvesting and allow for larger size disturbances to take place. Larger size disturbances actually allow forest planners to be more creative with the harvesting process by allowing consideration for other fire regime characteristics such as intermittent harvesting that leaves a number of trees and island remnants within a harvest block (information from Chapter 7). Such an approach is also more in line with the landscape visual appeal (as opposed to the square and bare blocks) and insures a form of wildlife corridor preservation at the same time.

The fire cycle values obtained from the simulation process are also the best ones to use as a benchmark to establish the number of hectares that should be disturbed every year in each subregion. That number of hectares to be disturbed simply have to be divided among the seral stages in similar proportions to those given for the simulated age-class distributions (Chapter 9).

4.6 Vegetation cover types and fire (Chapter 12)

This chapter takes fire simulation results and re-evaluates them by vegetation cover type. More specifically, age-class distributions are re-classified into seral stages specific to each cover type, and polygon patch size distribution by seral stage is also evaluated.

This is a slightly different way of looking at the information where vegetation cover types per subregion and seral stages dictate how the amount of disturbed land should be divided. This is a way at looking at the information that is more limiting in terms of forest planning because it would not allow as much flexibility in the spatial distribution of cut blocks or prescribed burns. Fires do cross cover type boundaries, especially those narrow patches found within a larger, more dominant cover type.

In the mountains, location of seral stages is strongly dependent on topography. Old growth forests tend to be found at higher elevations, on north facing slopes, and at the headwaters of watersheds, especially those along the Continental Divide. No testing for the effect of topography was done for the C5 FMU, but topography likely affects burn patterns in a way similar to what was found in Banff National Park (Rogeau *et. al.* 2004). Using cover types to define where disturbances should be distributed may take into account some of the topographic elements. For example, the subalpine fir/ alpine larch cover type is typically found at higher elevations, and thus should be older and be rarely disturbed. Spruce forests may also be found at higher elevations and on cooler aspects and should represent older aged forests. Although this is a logical way of thinking, the STANDOR model may not have been able to capture the full scope of the effect of topography. As a consequence, results between the different cover types may not appear to be that dissimilar.

5.0 STUDY AREA

The management subregions of the C5 FMU are the central core of this study. However, because fires cross geopolitical boundaries, it is important to study fire regimes in a slightly larger context than the target area. The different methods used to assess the fire regimes also involved looking at fire information at a different scale. The recent fire regime assessment, which included the creation of a probability of ignition map, was done for the largest land base as shown in Figure 5-1. It was defined roughly by using a rectangular area that would include the entire FMU. The UTM coordinates(NAD83, Zone 11) of the lower left and upper right corners used are: E659000 - N5446860 and E729110 - N5589030. This area is bound to the west by the British Columbia / Alberta boundary and to the south by Waterton Lakes National Park. It extends as far north as the big bend in the Highwood River, and roughly follows Range 29, immediately east of the Porcupine Hills, for its eastern boundary. The north portion of this land base overlaps the study area used for the Kananaskis Fire Regime Study (Rogeau 2004). Note that no information from British Columbia was used and that the B.C. portion of the rectangular land base was not included in the analyses. In total, the size of the larger study area is 834,191 ha or 8,342 km^2. The C5 FMU covers an area of 351,887 ha, which corresponds to 42% of the greater land base.

The assessment of the historical fire regime, which made use of 1950 aerial photography, was done by watershed. The watersheds used for this exercise were those found within the C5 FMU, the Crowsnest corridor between the north and south subregions, as well as the land between the Livingstone and Porcupine Hills subregions. This was done so that a continuous land base would be covered. This sub-study area ended up being smaller than the greater land base. It covers a total area of 340,138 ha.

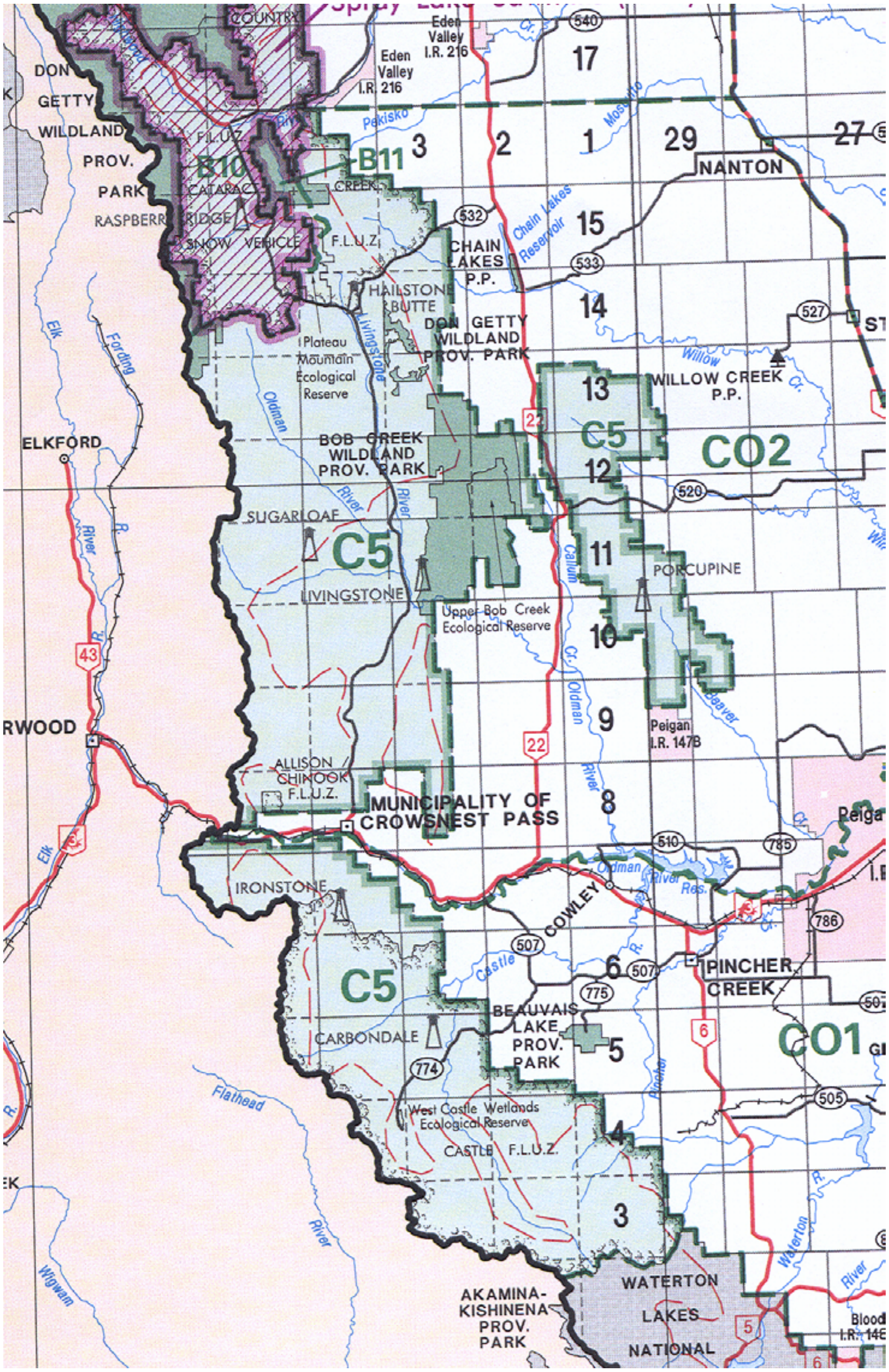

Figure 5.1 Approximate extent of the C5 FMU region. The study area does not include any land in British Columbia.

6.0 RECENT FIRE REGIME

This chapter is composed of two sections:

1) an overview of the recent fire regime based on fire occurrence data from 1961 to 2003; and

2) a comparison of the fire regime results from the C5 FMU with other fire regime studies.

6.1. Recent Fire Regime Overview

Fire occurrence data was obtained from ASRD to conduct a series of analyses. The data set covers a 43 year period, from 1961 to 2003. The 2003 fire records had not been fully reviewed by ASRD at the time the analyses were performed and could possibly hold errors. To characterize the fire regime of the C5 FMU, fire records were assessed by decade, cause, month, natural subregion and management subregion. Fire size distribution was calculated and amount of burn area was reviewed by fire size class and by decade.

Using lightning strike data from 1990 to 2003, also provided by ASRD, the density distribution of lightning-caused fires was determined against the density distribution of lightning strikes. The distribution of lightning-caused fires was also assessed by elevation strata, aspect classes and natural subregions. Results from these analyses were used to create a probability of lightning ignition model.

6.1.1 Fire frequency and area burned by decade

Table 6-1 Fire frequency and area burned by decade.

Decade	Count	Area burned
2000 to 2003	144	25,323.05
1990 to 1999	92	295.18
1980 to 1989	179	2,972.09
1970 to 1979	210	159.72
1960 to 1969	150	316.64

Yearly fire occurrence statistics:

Minimum: 2
Maximum: 55
Average: 18

6.1.2 Fire cause

Table 6-2 Classification of fire occurrence by cause.

Cause_id	Cause - description	Count	% occ.
1	Lightning	188	24.26
	People (all causes)	587	75.74
0	Other industry	42	7.16
2	Resident	40	6.81
3	Forest industry	42	7.16
4	Railroad	51	8.69
5	Public project (1961-82)	15	2.56
6	Recreation	309	52.64
7	Incendiary	11	1.87
8	Misc. known	57	9.71
9	Unknown	20	3.41

6.1.3 Seasonality of fire occurrence

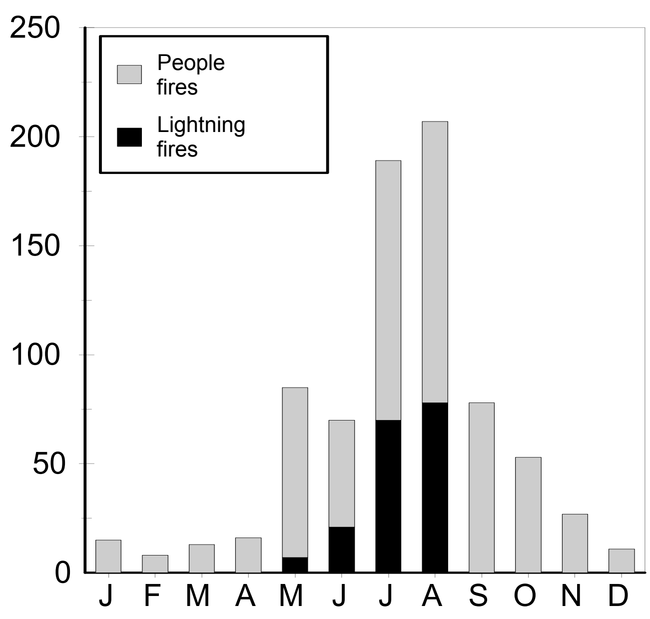

Figure 6-1 Number of fires per month and cause.

6.1.4 Seasonality of area burned

Table 6-3 Percent of fire occurrence by cause and area burned per month since 1961 for the C5 FMU region.

Month	% occ_all	% occ_lgt	% occ_man	Area (ha)	% area
January	1.94	0.00	2.52	11.17	0.04
February	1.04	0.00	1.34	2,234.22	7.69
March	1.68	0.00	2.18	287.30	0.99
April	2.07	0.00	2.68	29.03	0.10
May	11.01	3.98	13.09	560.54	1.93
June	9.07	11.93	8.22	10.38	0.04
July	24.48	39.77	19.97	21,392.49	73.60
August	26.81	44.32	21.64	2,073.74	7.13
September	10.10	0.00	13.09	441.14	1.52
October	6.87	0.00	8.89	1,823.08	6.27
November	3.50	0.00	4.53	74.43	0.26
December	1.42	0.00	1.85	129.16	0.44
	100	100	100	29,066.68	100

Due to the small number of large size fires that have occurred on the C5 FMU since 1961, and due to the strong impact of the 2003 fire events, which overshadows the area burned in other months, it is difficult to draw sensible conclusions in the tendencies of monthly area burned. Before the large 2003 fires, the portions of area burned were just as great in February and October than in July and August.

6.1.5 Fire size and burn area distributions

Table 6-4 Fire size distribution and associated burn area (ha).

Size class	Count	% occ	Burn area (ha)	% area
< 1 ha	704	91.67	72.40	0.25
1 - 10 ha	38	4.95	143.85	0.49
11 - 100 ha	16	2.08	673.53	2.32
101 - 200 ha	4	0.52	656.41	2.26
201 - 500 ha	2	0.26	652.49	2.24
501 - 1000 ha	0	0.00	0.00	0.00
1001 - 5000 ha	3	0.39	5,705.00	19.63
> 5000 ha	1	0.13	21,163.00	72.81
	768	100	29,066.68	100

Largest fires on record:

2,100 ha, February 1987, resident

1,900 ha, August 2000, lightning

21,163 ha, July 2003, under investigation

1,705 ha, October 2003, under investigation

0.8% of fires cause 95% of the area burned

6.1.6 Fire cycle

Based on 43 year of fire records, a total of 29,067 ha of forests burned. This is an average of 676 ha/yr or 0.25% of the forested area. The forested area in C5 is estimated at 271,758 ha and this gives us a fire cycle of 402 years. The forested area was estimated using areas that had a stand origin date on the AVI map.

To get an idea of the impact of fire suppression on fire cycles, the cycle was recalculated without the 2003 large size fires. Between 1961 and 2002, very few large size fires had occurred, which is contrary to the tendencies of this region. Based on documentation from the turn of the century forest reports and fire patterns detected during the preliminary stand origin mapping of Middle Ridges, it would appear that the Crowsnest Region was highly susceptible to large size blazes in the past. Without the 2003 fires, the average yearly area burned was estimated at 144 ha/yr, or 0.053% of the forested area. This corresponds to a fire cycle of 1,887 years. The 2003 fire events have significantly contributed to the shortening of the fire cycle, which is more in line with the historical fire cycle. However a 402 year cycle is likely longer than the historical one.

6.1.7 Fire occurrence by natural subregion

Table 6-5 Fire occurrence by natural subregion.

Ignition type	Alpine	Subalpine	Montane	F. Parkland	F. Fescue
Lightning	0.00	34.29	64.66	0.00	0.00
People	1.70	31.39	67.46	0.00	0.00
All	1.22	32.21	66.67	0.00	0.00
%Area of C5	7.20	61.26	31.05	0.42	0.06

Due to the fact that the amount of area allocated to each natural region varied a great deal, fire occurrence was calculated over normalized areas of 50,000 ha (arbitrarily chosen) to avoid any interpretation bias. Prior to normalizing, it appeared that the Subalpine was more prone to fire of all kinds than the Montane. This was due to the fact that the Subalpine region was twice the size of the Montane, thus being able to capture a greater number of fires. When using normalized areas, it is now clear that the Montane is significantly more fire prone.

6.1.8 Fire occurrence by management subregion

Table 6-6 Fire occurrence by management subregion.

Ignition type	P. Hills	Castle	C.D.S	Living.	C.D.N
Lightning	36.94	20.67	17.56	15.25	9.89
People	23.16	20.52	20.65	20.63	15.50
All	27.42	20.57	19.69	18.96	13.76
% Area of C5	11.20	15.35	18.85	43.43	11.16

For the same reason given for the natural subregions, the evaluation of fire occurrence was done over normalized areas of 50,000 ha. There are interesting tendencies in lightning-caused fire distribution, with the Porcupine Hills Unit being the most subjected to lightning fires, whereas the Continental Divide North Unit is strongly affected by the lightning strike shadow. Note that all of the C5 FMU lies in the lightning strike shadow, but we can observe spatial variation within it. People-caused fires almost have an equal distribution among the units with the exception of the Continental Divide North Unit. Due to the low number of ignitions in this Unit, it is more likely to find larger areas of old forests in the Continental Divide North Unit.

6.1.9 Lightning fire distribution

The spatial distribution of lightning-caused fires over the landscape was evaluated to identify zones that are more prone to lightning-caused fires. Risks associated with people-caused fires are highly correlated with the amount of human use on the landscape, which can be more easily addressed than risks from lightning-caused fires. Although the fire regime of C5 is dominated by people-caused fires, historically, lightning-caused fires would have played a more important role in shaping the vegetation mosaic due to the lesser amount of human activity on the land.

Separate work done for the District of Kananaskis and the Spray Lake Sawmills FMA showed that areas prone to lightning-caused fires coincide with areas of high to very high vegetation complexity. The vegetation complexity was evaluated from 1950 aerial photography. A high complexity is normally associated with areas that tend to have repeat burning at short intervals and / or with intermittent crown fire activity as a result of lower fire intensities. Probabilities of ignition and vegetation complexity thus provide additional information about the fire regime, but in an indirect manner.

6.1.9.1 Relationship with lightning strike density distribution

Lightning strike data from 1990 to 2003 was obtained from ASRD. The density of strikes was recorded for cells of 5 km x 5 km (25 km^2). The average yearly density of strikes ranged from 1 to 40 and was classified into five density zones: very low, low, moderate, high and very high.

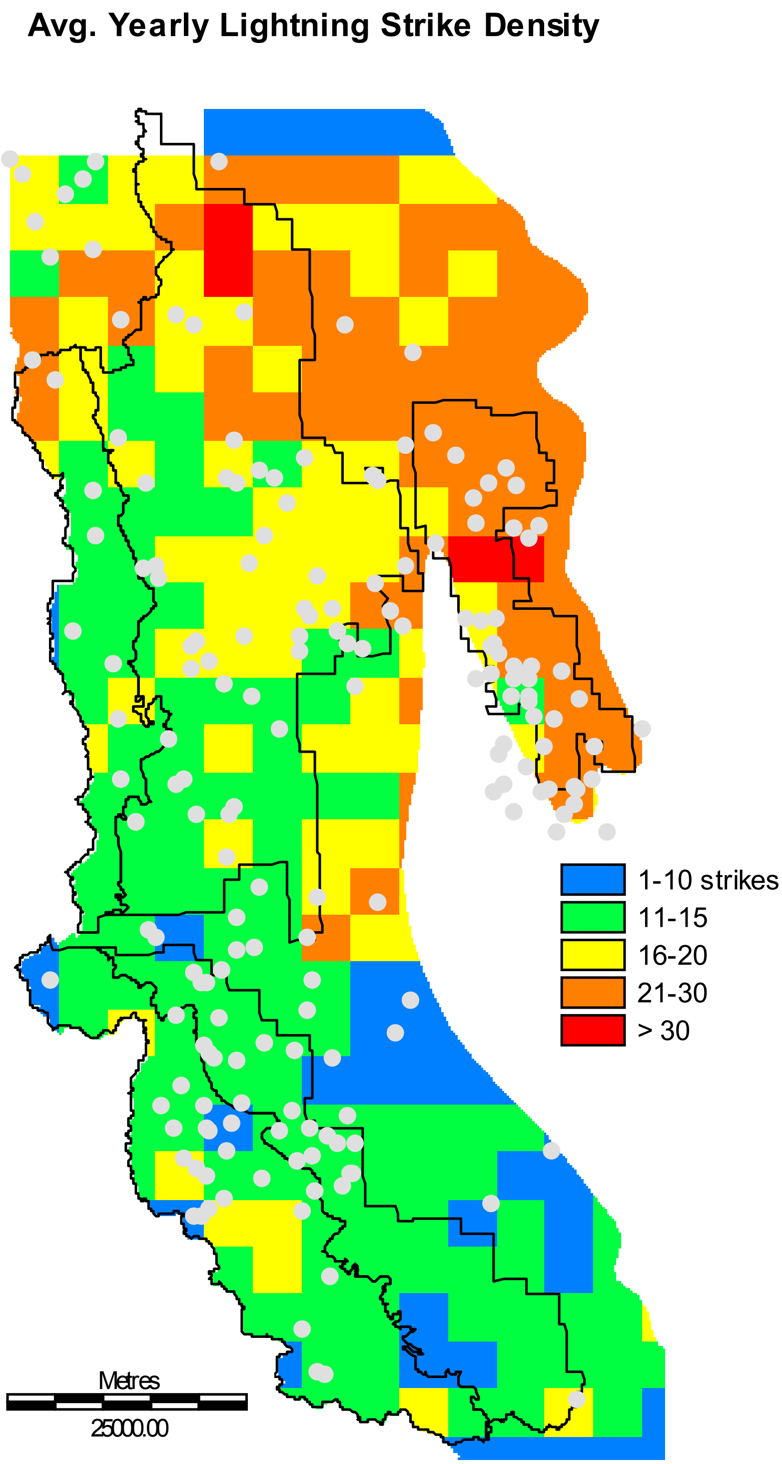

Figure 6-2 Yearly average lightning strike density. Grey dots represent all lightning-caused fires between 1961 and 2003.

The density of lightning-caused fires from 1961 to 2003 was also recorded over a 25 km^2 grid map. The density ranged from 0 to 7 fires over a 43 year period. The density values were also classified into five density zones: very low, low, moderate, high and very high. Both lightning fire and lightning strike density zone maps were cross-tabulated to evaluate the relationship between these two variables. Logically, zones of high lightning strike density should correspond with zones of higher occurrence of lightning-caused fires. Unfortunately, in this case, lightning strike density appears to be a poor indicator of lightning-caused fire occurrence as shown in the table below. For this reason, lightning strike density was not considered in the probability of ignition model from lightning (see Section 1.10).

Table 6-7 Percent area of lightning fire density zones by lightning strike density zones.

	Lightning fire density				
Strike density	**V. Low** (0-1)	**Low** (2-3)	**Mod.** (4)	**High** (5)	**V. High** (6-7)
V. Low (1-10)	11.23	11.74	0.00	0.00	0.00
Low (11-15)	38.99	47.26	39.61	75.02	100.00
Mod. (16-20)	25.52	18.01	19.52	0.00	0.00
High (21-30)	22.88	19.05	40.87	24.98	0.00
V. High (>30)	1.37	3.94	0.00	0.00	0.00

6.1.9.2 Relationship with elevation

The number of lightning-caused fire occurrences was recorded by elevation strata to determine if some elevation zones are more prone to lightning ignition than others. Fire occurrence was then recalculated over a 50,000 ha normalized area (N) to avoid any interpretation bias due to differences in area based. It was found that 70% of lightning-caused fires occur at mid elevations ranging from 1400m to 1800m, with a prevalence between 1500m and 1600m.

Table 6-8 Normalized fire distribution by elevation class.

Elevation	Area	% area	Count	% occ	Count N	% occ. N
<1200m	75,645	7.59	0	0.00	0.00	0.00
1200 - 1300m	102,925	10.33	2	1.06	0.97	1.38
1300 - 1400m	138,365	13.89	15	7.98	5.42	7.68
1400 - 1500m	130,531	13.10	35	18.62	13.41	18.99
1500 - 1600m	105,848	10.62	43	22.87	20.31	28.77
1600 - 1800m	163,901	16.45	53	28.19	16.17	22.90
1800 - 2000m	140,138	14.07	21	11.17	7.49	10.61
>2000m	138,977	13.95	19	10.11	6.84	9.68
	996,330	100	188	100	70.61	100

6.1.9.3 Relationship with aspect

The number of lightning-caused fire occurrences was recorded by aspect classes to determine if some cardinal directions were more prone to fire than others. It was found that lightning-caused fires are almost evenly distributed among aspect classes, with a percent lightning fire occurrence ranging from 10 to 14. With the bulk of lightning-caused fires occurring in July and August, all aspects tend to be equally dry and susceptible of fire ignition, even the cooler aspects.

Table 6-9 Normalized fire distribution by aspect class.

Aspect	Area	% area	Count	% occ	Count N	% occ. N
N: 337.5-360, 1 - 22.5	80602	8.09	17	9.24	10.55	13.17
NE: 22.5 - 67.5	124133	12.45	20	10.87	8.06	10.06
E: 67.5 - 112.5	170620	17.12	35	19.02	10.26	12.81
SE: 112.5 - 157.5	117173	11.76	27	14.67	11.52	14.39
S: 157.5 - 202.5	108786	10.91	19	10.33	8.73	10.91
SW: 202.5 - 247.5	102473	10.28	18	9.78	8.78	10.97
W: 247.5 - 292.5	131810	13.22	27	14.67	10.24	12.79
NW: 292.5 - 337.5	95925	9.62	17	9.24	8.86	11.07
uncl.	65232	6.54	4	2.17	3.07	3.83
	996754	100	184	100	80.06	100

6.1.10 Probability of lightning ignition model

Using relationship results between lightning-caused fire distribution and elevation (Section 1.8), aspect (Section 1.9), natural regions (Section 1.7) and using the lightning-caused fire density distribution map, a probability of lightning ignition model was developed.

Results from the lightning-caused fire density distribution (Section 6.1.9.1), and occurrence of lightning-caused fires by elevation (Section 6.1.9.8), aspect (Section 6.1.9.9) and natural subregions (Section 6.1.7) were used in a GIS weighing and ranking system to estimate probabilities of ignition on the landscape. The weighing process consisted of rating, in percentage value, the importance of each variable (GIS layer) used, while the ranking process ranked the variable classes on a scale of 1 to 5, with 5 representing the highest likelihood of getting an ignition. The weighing and ranking of the information was done as follow:

40% **Density of lightning-caused fires**

1 - Very low density (< 2% chance of fire / yr)
2 - Low density (3 to 7%)
3 - Moderate density (8 to 9%)
4 - High density (10 to 12%)
5 - Very high density (13 to 16%)

30% **Natural subregions**

1 - Foothills
2 - Alpine
3 - Subalpine
5 - Montane

20% **Elevation**

1 - < 1300 m
2 - 1300 - 1400 m
3 - > 1800 m
4 - 1400 - 1500 m, 1700 - 1800 m
5 - 1500 - 1600 m

10% **Aspect**

1 - unclassified
3 - NE, NW, S, SW
4 - E, W, N
5 - SE

p_ignition = ([lgt_fire_distribution*40] + [lgt_nsr*30] + [lgt_elev*20] + [lgt_aspect*10]) / 5

This map manipulation process resulted in a range of probabilities of ignition that vary spatially over the landscape from 16 to 100%. The probability of ignition map is shown below.

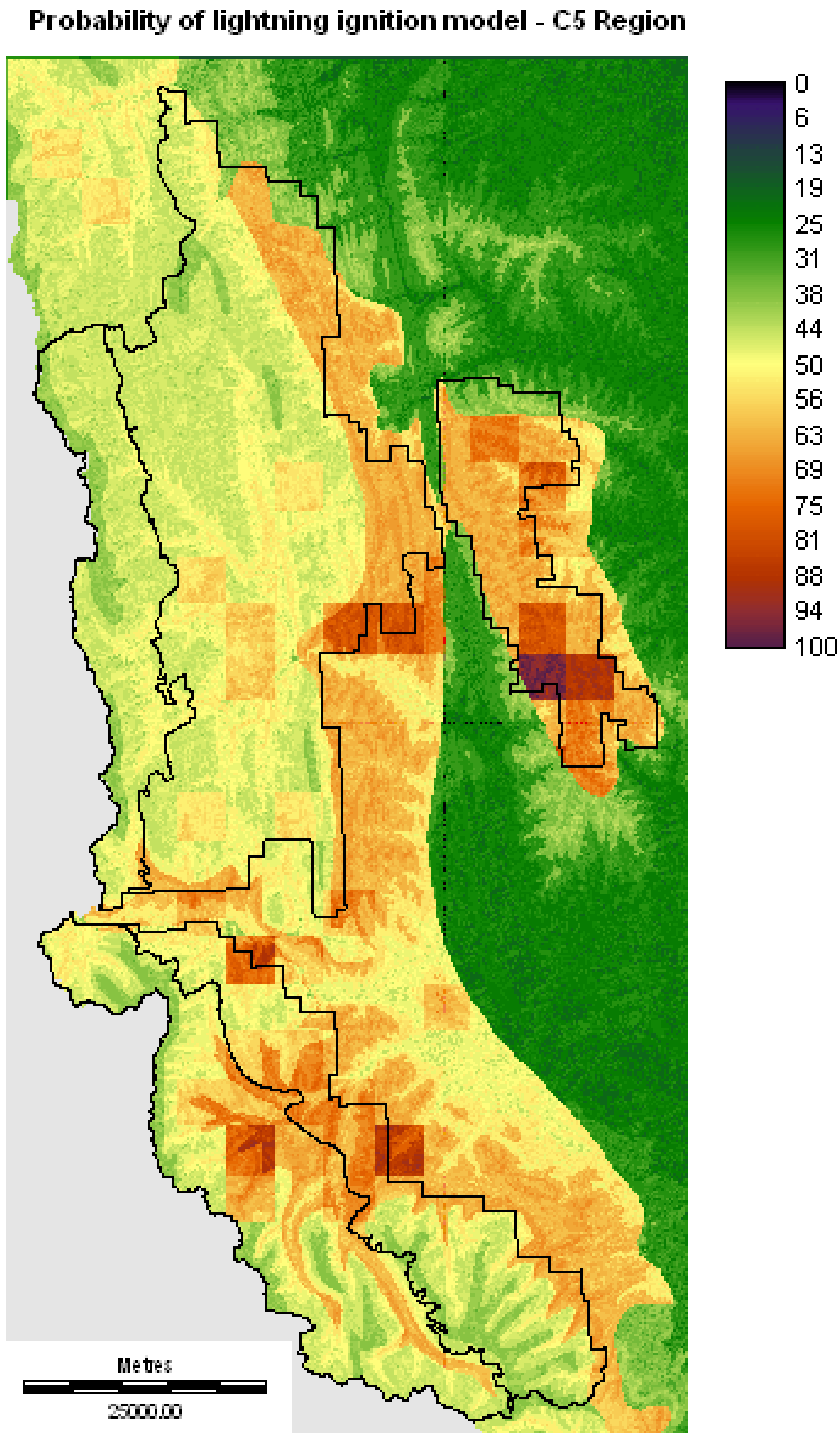

Figure 6-3

Probability of lightning ignition model for the C5 FMU region.

As shown in the table below, probabilities of ignition reflects the differences in the fire regime amongst the management subregions. The Porcupine Hills Region is the most prone to lightning-caused fires, followed by the Castle and Continental Divide South Regions. The interpretation of these percent chances of ignition must be done carefully. Areas of very high percentages of ignition does not mean that a fire will occur every year. The values must be compared in relation to other values. Zones with higher percent value of ignition simply indicate that these zones will see fires on a more frequent basis: shorter fire return interval. As mentioned previously, zones of high likelihood of ignitions tend to be associated with greater vegetation complexity: greater number of patches, generally of smaller size and more intricate. This information can be applied to the harvest planning process.

It must also be emphasized that probabilities of ignition are different than probabilities of burning. Zones of low probabilities of ignition should not be interpreted as regions that do not burn often. Some of these zones, especially those adjacent to high probability of ignition zones may burn almost as frequently due to fire spread, which can be quite extensive under severe fire weather. In an effort to FireSmart the landscape, fuel management should be undertaken in zones of high probabilities of ignition to reduce the risk of fire spread.

Table 6-10 Percent land cover by subregion and probability of ignition class.

Percent chance of ignition	P. Hills	Castle	C.D.S.	Living.	C.D.N.
10 to 19	0.00	0.00	0.00	0.00	0.00
20 to 29	0.96	0.00	0.00	0.03	0.00
30 to 39	7.14	6.01	5.94	2.05	6.80
40 to 49	3.71	**40.19**	**43.01**	**51.93**	**80.26**
50 to 59	4.58	21.86	22.35	26.77	11.99
60 to 69	**53.91**	20.31	21.83	17.34	0.95
70 to 79	15.45	10.11	5.28	1.08	0.00
80 to 89	8.40	1.25	1.29	0.81	0.00
90 to 100	5.85	0.27	0.30	0.00	0.00

6.2 Conclusions

The series of assessments related to different fire regime parameters were conducted to provide a better understanding of the fire regime since the 1960's. Not all parameters could be evaluated spatially due to the lack of representative data (i.e. number of large size fires), but fire cause and occurrence could be explored in a spatial context. These results led to the conclusion that the first three hypotheses addressing the homogeneity of the fire regime had to be rejected. It was found that both lightning and anthropogenic fires are not distributed randomly over the landscape. Zones of higher likelihoods of lightning-caused fires were identified and anthropogenic fires were associated with land use corridors, especially those related to recreational activities. The probability of ignition model reflects perfectly the spatial variability of ignition. Although spatial variability does exist within natural and management subregions, four distinct fire regimes could be identified. They are tied to these management subregions: Porcupine Hills, Continental Divide North, Livingstone and the combined Continental Divide South and Castle subregions. Using pre-defined management subregions makes it easy to develop and apply fire and forest management tactics. It is likely that underlying elements, such as topography and vegetation type, contribute to micro-variation of the fire regime within each subregion, but more in-depth analyses would be required to test this assumption.

6.3. Other Fire Regime Studies

This Section presents general results from fire regime / history studies done in Alberta for natural regions similar to those found on the C5 FMU. This exercise was performed to find out if the C5 FMU fire regime has similarities with other study areas, and if such is the case, can fire information from other studies be borrowed and applied to the forest management of C5 FMU.

The Rocky Mountain Natural Region of Alberta is by far the best documented in terms of fire history and fire regime information. Stand origin mapping, following standard procedures of fire history data collection, has been done for a large portion of the Central and Southern Rockies. Regions covered, description of method and references are provided in the following table.

Study Area	Description	Reference
Jasper National Park	Stand origin map from fire history data collection	no documentation, produced by JNP staff around 1989.
Jasper National Park	Fire history data collection and complete mapping of all fires by layers. Montane area around Jasper Townsite	Tande, 1979
Foothill Model Forest Jasper National Park	Detailed fire history mapping of two small Montane areas east of Jasper Townsite	Rogeau, 1999b
Foothills Model Forest FMU E5, E11 Weldwood FMA	Fire history data collection and stand origin mapping, fire cycle assessment	Rogeau, 1996 Rogeau, 1997 Andison, 1997
Whitegoat & Siffleur Wilderness Areas, and portion of R11 FMU	Fire history data collection and stand origin mapping, fire regime analysis	Rogeau, 1999a
Banff National Park	Fire history data collection and stand origin mapping, fire occurrence assessment	Rogeau and Gilbride, 1994 White, 1985
Spray Lakes Provincial Park	Fire history data collection and stand origin mapping	Rogeau, 1994
Peter Lougheed Provincial Park	Fire history data collection, Mean Fire Return Interval assessment	Hawkes, 1980

Study Area	Description	Reference
Kananaskis Valley	Fire history data collection and stand origin mapping, fire cycle calculation	Johnson and Fryer, 1987
Banff National Park, Spray Lakes P.P., Peter Lougheed P.P, Kananaskis Valley	Effect of topography on fire distribution	Rogeau et al, 2001
North portion of C5 FMU	assessment of avi ages, calculation of weighted mean ages	Olson and Diehl, 1998
Waterton Lake National Park	Transect sampling of fire history data, no mapping. Fire return intervals.	Barrett, 1996
Spray Lake Sawmills FMA and Kananaskis District	Fire regime study, mapping of recent fires only, proposed fire history data collection for 2004-2005	Rogeau, 2004 (in progress)

Work references:

Andison, D.W. 1997. Landscape fire behaviour patterns in the Foothills Model Forest. Foothills Model Forest, Hinton, Alberta. 63 p.

Barrett, S.W. 1996. The Historic Role of Fire in Waterton Lakes National Park, Alberta. Prepared for Parks Canada. 27 p.

Hawkes, B.C. 1980. Fire history of Kananaskis Provincial Park - mean fire return intervals. Pages 42-45 *In* M.A. Stokes and J.H. Dieterich (technical editors). Proceedings of the fire history workshop. General Technical Report RM-81, U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Tucson, AZ.

Johnson, E.A. and G.I. Fryer. 1987. Historical vegetation change in the Kananaskis Valley, Canadian Rockies. Canadian Journal of Botany 65: 853-858.

Olson, D. and S. Diehl. 1998. Disturbance and Pattern Analysis. The Southern Rockies Landscape Planning Pilot Study. Prepared for Alberta Environmental Protection, Lands and Forests Service, Forest Management Division.

Rogeau, M-P. 1999a. Fire History Study of the Central Rockies Ecosystem Inter-Agency North-Saskatchewan Unit. Banff National Park, Box 900, Banff, AB. T0L 0C0. 61 p.

Rogeau, M-P. 1999b. Detailed Disturbance History Mapping of the Montane, Jasper National Park: 1997-1998. Foothills Model Forest, Box 6330, Hinton, AB. T7V 1X3.

Rogeau, M-P. 1997. Landscape Disturbance Project, Stand Origin Mapping 1997. Foothills Model Forest, Box 6330, Hinton, AB. T7V 1X3. 69 p.

Rogeau, M-P. 1996a. Landscape Disturbance Project, Stand Origin Mapping 1996. Foothills Model Forest, Box 6330, Hinton, AB. T7V 1X3. 50 p. + 6 map sheets.

Rogeau, M-P. 1994. Fire History Study of the Spray Lakes Area, Alberta. Central Rockies Ecosystem Inter-agency Liaison Group, Operation Branch, Kananaskis Country. 12 p. + one map sheet.

Rogeau, M-P. and D. Gilbride 1994. Stand Origin Mapping of Banff National Park. Resource Conservation Branch, Banff National Park, Alberta. 70 p. + 8 map sheets.

Rogeau, M-P., I. Pengelly, and M-J.Fortin. 2001. Using a topography model to map historical fire cycles and monitor current fire cycles in Banff National Park. *In* R.T. Engstrom and W.J. de Groot, (eds.). Proceedings of the 22nd Tall Timbers Fire Ecology Conference: Fire in Temperate, Boreal, and Montane Ecosystems. Tall Timbers Research Station, Tallahassee, FL.

Tande, G.F. 1979. Fire history and vegetation patterns of coniferous forests in Jasper National Park, Alberta. Canadian Journal of Botany 57: 1912-1931.

White, C. 1985b. Wildland fires in Banff National Park, 1880-1980. Occasional Paper No.3. National Parks Branch, Parks Canada, Environment Canada. Catalogue No.: R61 2/8- E. 108 p.

Some of the studies listed above were conducted differently than what was done for the C5 FMU. To assess the similarities between the fire regime of C5 and other studies, two sets of comparisons were performed. The first one was to compare fire regime parameters with studies that had information available for the same parameters, whereas the second comparison was made between weighted mean ages by natural subregions.

Comparison of fire regime parameters

Parameter	C5 FMU	CRE East Slopes[a]	Whitegoat & Siffleur	Kananaskis District
Lightning fire occurrence	24%	33%	17%	26%
Lead causes people fires	recreation: 53% misc: 10%	recreation: 30% misc: 12%	recreation: 66% misc: 10%	recreation: 49% resident: 23%
Percent of fires > 200 ha[b]	0.8%	0.65%	1.7%	0.36
largest fire on record (ha)	21,163	10,250	2,700	9,214
months with most fire occurrence	July/Aug.: 51%	July/Aug.: 41%	July/Aug.: 42%	July/Aug.: 40%
months with most lgt. fire occ.	July/August	June/July/Aug.	July/August	July/August
months with greatest occ. of large size fires	July/August/ February/Oct.	July/Aug./Sept.	n/a	Aug./Sept.

a. Central Rockies Ecosystem East Slopes includes Banff National Park, Spray Lakes Provincial Park, Peter Lougheed Provincial Park, Kananaskis Valley, Whitegoat and Siffleur Wilderness Areas and portions of the North Saskatchewan Valley between the two wilderness areas.

b. This information was extracted from the fire occurrence database dating from 1961 up to the date the study was conducted. All regions were under fire suppression and these values are likely deflated by a few percent.

The study from Waterton Lake National Park, which is adjacent to the C5 FMU, did not provide sufficient fire regime parameters to make sensible comparisons. However, the report from Barrett (1996) did mention that 78% of the fires were caused by people, which is in line with the other mountain regions that also lie in the lightning strike shadow.

All studies, with the exception of Kananaskis District (Rogeau, 2004), did not assess the fire regime by natural subregion. To counteract this, stand origin maps from fire history data collection or inventory ages (AVI) were used to calculate the weighted mean ages for the Alpine, Subalpine and Montane Subregions. Weighted mean ages are indicative of the length of the fire cycle and the amount of burning that took place historically.

Subregion	C5*	North portion of C5*	Kan. District*	Kan. Valley Spray Lakes P.P Peter Lougheed P.P	Whitegoat & Siffleur	Foothills Model Forest (JNP, E5, E11, Weldwood FMA)	Banff National Park
Alpine	139	---	114	210	271	228	260
Subalpine	118	108	110	165	197	182	216
Montane	90	85	93	n/a	130	142	147

* AVI ages

It can be observed that there are significantly more old aged forests in the Alpine than in the Subalpine subregion, and that there are significantly more younger aged forests in the Montane than in the Subalpine Subregion. All mean ages calculated from fire history data are greater than those from AVI, which is indicative that the forest ages from inventory data are likely underestimated. The weighted mean age from the combination of Kananaskis Valley, Spray Lakes and Peter Lougheed Provincial Parks is less than the other regions from which good fire history data was available. This is due to the fact that this region was affected by very large size fires (1936 and 1895) in comparison to the overall size of the region.

Discussion

The observation of fire regime parameters alone suggest that the fire regime of the C5 FMU is comparable with the regimes of similar regions. We must keep in mind that the fire regime profile drawn from the fire occurrence data set represents recent fire regime conditions from the last 40 years or so. Although we can be confident that some parameters should be relatively stable over centuries, such as the amount of lightning-caused fires and seasonality of fire occurrence, other parameters such as area burned and distribution of people-caused fires may have changed drastically in the last sixty years as a result of fire suppression and increased recreational use of remote areas, respectively.

The comparison of weighted mean ages allows us to get a feel for the fire regime over a much longer period of time. Despite the fact that AVI mean ages are much lower than other studies with good fire history data, it is possible that the historical fire regime of the C5 FMU region was affected by a greater number of fires. In 1998, I was contracted by ASRD to create a preliminary stand origin map for the Middle Ridges Area of C5. A preliminary stand origin map is a map where the polygon work is done using 1950 aerial photography, but where no fire history data was collected and hence, a map without any stand origin dates. During the mapping process I had remarked on the high number of fires and intricate mosaic of forest patches these historical fires had produced on the landscape. To date I have mapped or have conducted aerial photo screening process for over 100,000 km^2 of forested land (largely mountainous terrain but also in the boreal forest), and I do not recall observing such burning patterns in the Subalpine or Montane subregions, which makes Middle Ridges somewhat unique. I have observed similar patterns in lodgepole pine forests but from the boreal region (Swan Hills Area) and the Upper Foothills of Kananaskis District (between the Trans-Canada Highway and the Red Deer River). The vegetation complexity observed in Middle Ridges does not likely apply entirely to the C5 FMU. The 1950 aerial photos used encroached slightly onto the Continental Divide North management subregion and I had noticed the more homogeneous and older aspects of the forests, more similar to what is found in Banff National Park for example. The probability of lightning ignition model, created in Section 6.1.10, shows that the Porcupine Hills is subjected to more ignitions and as such, it is likely to have a very complex vegetation mosaic and contain more younger aged forests than what was observed for Middle Ridges. For the management subregions lying against the Continental Divide, it would likely be safe to borrow stand origin work from Banff National Park, the Whitegoat and Siffleur Wilderness Areas to determine fire size distribution and patch size distribution by seral stages. However, a screening of the historical aerial photography for the entire C5 FMU would be a good idea to first verify the assumption of similarity with other mountain landscapes.

The Montane subregion of C5 FMU is unique in the sense that it is not influenced by highly used travel corridors. The Montane in Jasper National Park (Athabasca Valley) has a highway and a railroad, the Montane of the North-Saskatchewan River Valley also contains a highway, the Montane of Banff National Park and adjacent provincial land (Bow Valley) contains a highway and a railroad, as does the Crowsnest Valley. This would explain why the proportion of people-caused fires in the Montane can be as high as 90% (Kananaskis District fire occurrence data). All of these valleys were also historically used by fur traders and by natives, which were potential ignition sources. The proximity of the Crowsnest Valley to the Montane subregion of C5 would have likely contributed to some of the burning within the FMU, either to the north or south of Highway 3. However, the C5 FMU does offer a large extent of Montane subregion away from the highly used corridor, and as such it provides a good opportunity of understanding historical burning patterns endemic to this natural subregion.

7.0 HISTORICAL FIRE REGIME

The previous chapter assessed some fire regime parameters from fire records dating since 1961. On a fire history scale, this is a relatively short period of time. It is also a period that has been influenced the most by human disturbance through the increased use of the landscape by people, which could lead to more fires, and by fire suppression efforts that could have reduced the amount of area burned. Two key variables, frequency and area burned, that are used in the calculation of the fire cycle and yearly rate of forest disturbance.

7.1 AIR PHOTO SCREENING

To gain an even better understanding of the fire regime, and for an increased length of time, the use of historical aerial photography is an excellent tool. Most of the country was flown at a scale of 1:40,000 between the years of 1948 and 1952. These older photographs are perfect for uncovering historical fire boundaries that are no longer visible on today's landscape. Aerial photographs can also inform us of the number of fires, their size (before being overlapped by subsequent burns), relative age of the forest, and the intensity of burning, which is another important fire regime parameter. Intensity refers to the kind of fire encountered: surface, intermittent or crown. Fire intensity is directly linked to the level of patchiness (amount and size of forest patch residuals after a fire) found on the landscape, which is easily assessed from a visual screening of aerial photography. An air photo screening process was undertaken on a watershed basis to capture these fire parameters from the turn of the century. The accuracy of this information is best from circa 1900 to 1950, but deteriorates for forests originating prior to the 1900's. Fire boundaries from the mid 1800's are for the most part still visible, but the homogeneity of lodgepole pine forest cover originating prior to circa 1850 prevents the air photo interpreter from making confident assessments for disturbances dating prior to that time.

The screening process consisted of a visual analysis of the vegetation complexity in terms of the number of visible fires, burning patterns and level of patchiness. Differences in tones and textures of the forest cover were the key elements for assessing the number of visible fires and vegetation complexity. For each watershed, a series of fire related parameters were recorded. The number of potential fires was estimated, as well as the number of recent fires (1900 - 1950). The complexity of the burning patterns observed was rated as very low, low, moderate, high and very high. A high complexity most often reflects a greater number of fires that overlap one another, or lower burning intensities, generally on more gentle to flat terrain, that leave a large number of residual trees or small patches. Other attributes recorded include: the watershed ID number, which was used in the digitizing process; name of creek or river draining the watershed; the name of the main watershed basin; the fuel cover continuity (broken from rock outcrops) versus continuous (rolling terrain, continuous forest cover); the estimated age of the most recent burn; the estimated age of the oldest forest; and the valley orientation code. Valley orientation is the topographic variable that has the greatest effect on fire distribution in the East Slopes of the Rockies (Rogeau et al. 2001). The valley orientation coding reflects how two valleys (watersheds) intersect at their confluence. Some watersheds will contain more than one valley orientation when there is a significant change in the direction of valley flow.

7.2 Watershed Map Creation

Information from the air photo screening process was recorded on a watershed basis. The watershed map was created by outlining boundaries that followed the height of land. Watersheds identified were, as a minimum, longer than 6 km in length. The watershed map was also built with the purpose of representing valley orientation, which is an important topographic variable affecting fire behaviour (Rogeau et al. 2004). Some watersheds had to be parted in their middle to capture the changes in valley orientation.

As shown in Figures 7-1a and 7-1b, a total of 84 watersheds were identified. All fire attributes recorded from the photo screening process were attached to the digitized watersheds and are listed in Table 7-1. A series of maps were created and are presented in their respective sub-section.

7.3 Fuel Continuity

This variable has two categories. The broken fuel type represents those watersheds that are under an effect of containment by rocky ridges, while the continuous fuel type is associated with rolling terrain of uninterrupted forest cover. Figure 7-2 shows that the Livingstone and Crowsnest basins, as well as the Porcupine Hills, are largely dominated by the continuous fuel type category. The broken fuel type of landscape tends to be found closer to the Continental Divide and is more prevailing south of Highway 3 in the Castle and Continental Divide South subregions.

The fuel continuity map has some similarities with the natural subregion map (Figure 7-3) because most of the watersheds with broken fuel cover occur within the Subalpine natural subregion. However, many watersheds of continuous fuel cover are found in the Subalpine and are not restricted to the lower elevations of the Montane natural subregion.

7.4 Vegetation Complexity

The vegetation complexity ranks the level of patchiness of the forest caused by burning patterns. Clean burning with very few patches of remnant trees was rated as low. This usually occurs with more intense burning on steeper terrain or in watersheds encompassing a large cover of homogeneous looking forest. A forest that was subjected to frequent passive crown fire activity will show numerous individuals or patches of unburnt trees and was rated as high. A mixture of low and high vegetation complexity, or a complexity that is not low or high, was rated as moderate. As a general rule, the level of patchiness tends to increase with greater fire frequency.

Figure 7-4 shows the distribution of vegetation complexity rating across the landscape. Note that the vegetation complexity categories used were the same as for Kananaskis District (Rogeau 2004). In comparison with Kananaskis District, no very low complexity rating was identified within the C5 FMU. As well, the spatial distribution of complexity rating is not as strongly linked with a west to east gradient. Rather, the complexity rating distribution appears to be more strongly associated with fuel continuity where watersheds surrounded by rocky ridges show the lesser complex burn patterns.

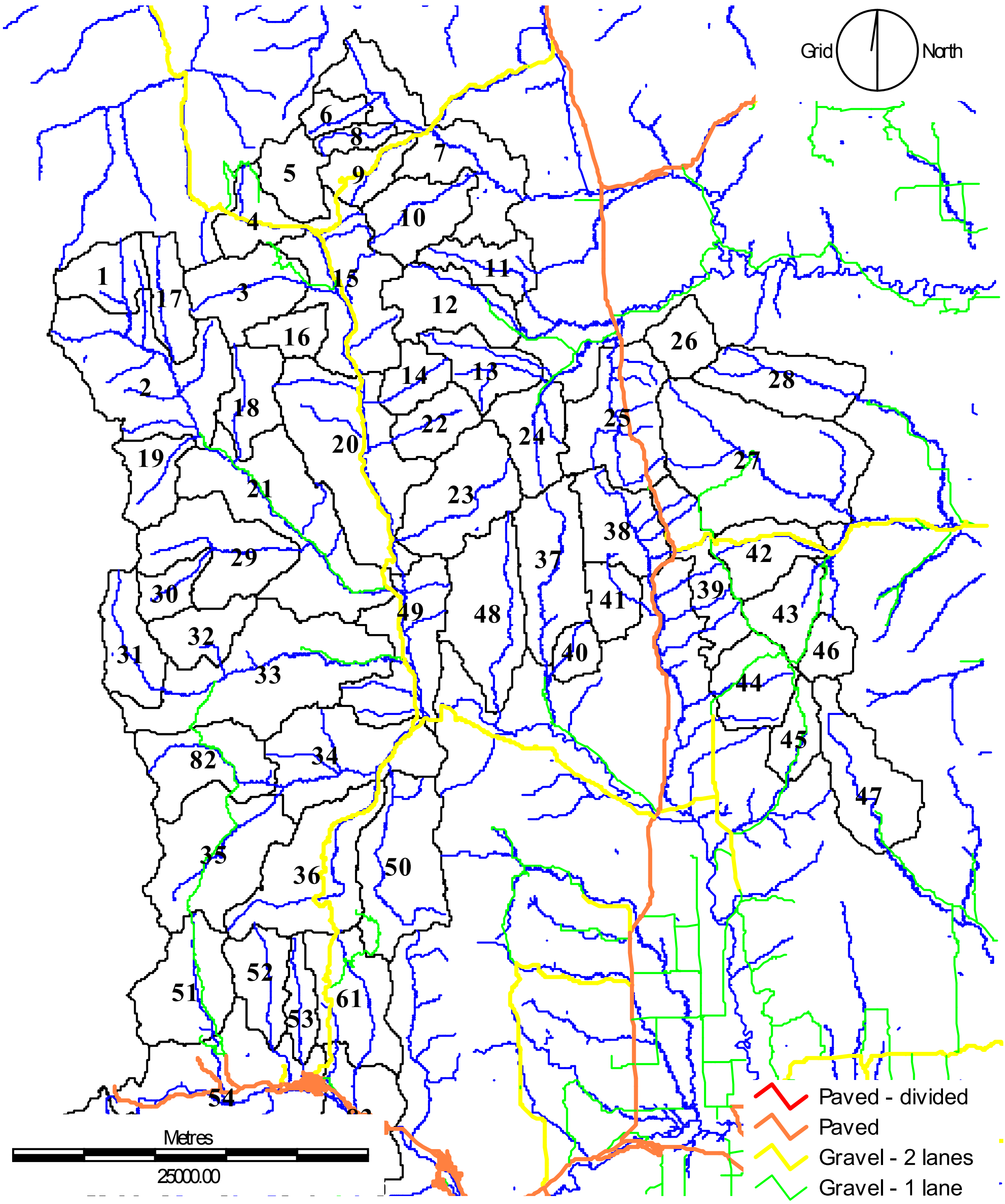

Figure 7-1a Study area used in the air photo screening process.
Portion north of Highway 3.

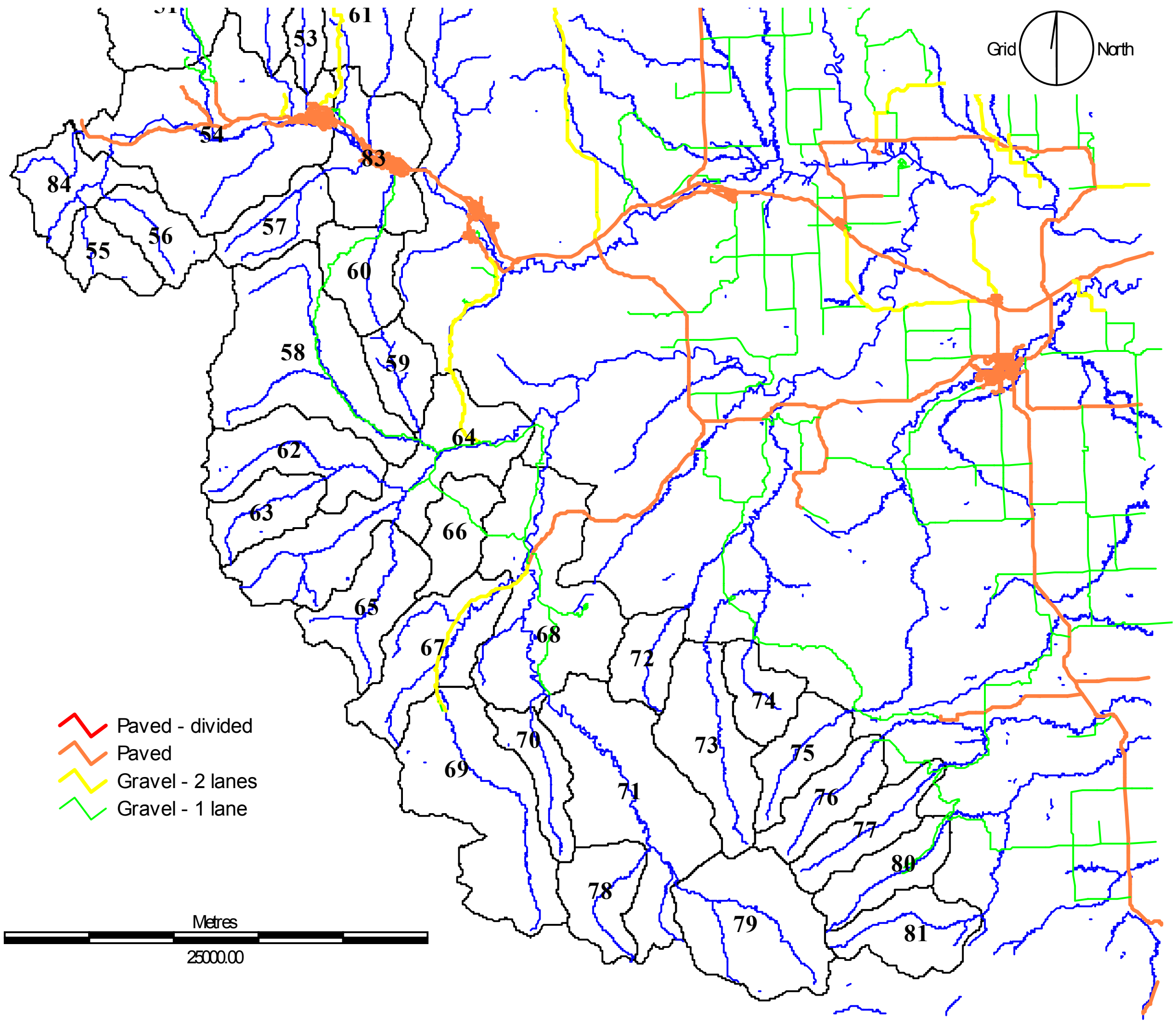

Figure 7-1b Study area used in the air photo screening process.
Portion south of Highway 3.

Table 7-1 Results of the screening process from 1950-52 aerial photography, 1:40,000.

Wtrd_ID	Valley	Watershed	Fuel continuity	V-O jctn	Complexity	# of fires	recent fires	Min age	Max age
1	Oyster	Oldman	Broken	31	Moderate	11	2	10	350
2	Head. Oldman R.	Oldman	Broken	31	Moderate	16	0	60	350
3	Savanna	Livingstone	Broken	43	High	16	2	30	350
4	Dry	Livingstone	Broken	43	Low	11	1	10	350
5	Head. Livingstone	Willow	Broken	31	Moderate	10	1	30	250
6	Corral	Willow	Continuous	21	High	9	2	10	300
7	Willow	Willow	Continuous	14	Very High	12	2	20	250
8	Iron	Willow	Continuous	21	Moderate	8	2	10	250
9	Johnson	Willow	Continuous	21	High	9	2	10	250
10	Timber	Willow	Continuous	21	Very High	12	2	10	200
11	Langford	Willow	Continuous	24	High	8	2	30	250
12	Westrup	Willow	Continuous	14	Very High	13	1	10	300
13	Hunter / Riley	Willow	Continuous	12	Very High	12	1	15	250
14	Ridge	Livingstone	Continuous	23	Moderate	9	2	15	300
15	U. Livingstone	Livingstone	Broken	3	Moderate	15	2	30	300
16	Isolation	Livingstone	Broken	43	Moderate	9	1	30	300
17	Pasque	Oldman	Broken	31	Moderate	8	0	120	350
18	Honeymoon	Oldman	Broken	31	Moderate	10	1	20	350
19	Cache	Oldman	Broken	21	Low	7	0	80	350
20	M. Livingstone	Livingstone	Continuous	3	High	23	2	10	350
21	M. Oldman	Oldman	Continuous	1	High	23	4	10	300
22	Deep	Livingstone	Continuous	23	Moderate	9	1	15	250
23	White	Livingstone	Continuous	23	High	17	1	10	250
24	Chaffen	Willow	Continuous	32	High	8	1	30	200
25	Nelson	Willow	Continuous	32	Very High	12	1	15	200
26	Squaw Coulee	Willow	Continuous	32	High	7	1	20	200
27	Trout	Willow	Continuous	14	Very High	24	3	15	200
28	Lyndon	Willow	Broken	1	Very High	9	1	15	200
29	Hidden	Oldman	Broken	41	Moderate	20	2	30	350
30	South Hidden	Oldman	Broken	21	Low	7	0	80	350
31	Head. Dutch	Oldman	Broken	14	Low	7	0	120	350
32	no name	Oldman	Broken	32	Low	9	1	10	350
33	Dutch	Oldman	Continuous	43	Moderate	21	1	10	350
34	Racehorse	Oldman	Continuous	23	High	15	2	10	350
35	South Racehorse	Oldman	Broken	24	Low	11	1	15	350
36	Vicary	Oldman	Continuous	34	High	25	2	10	350
37	Bob	Oldman	Continuous	34	Very High	11	1	20	200
38	Callum	Oldman	Continuous	1	Very High	13	2	20	150
39	Head. off Callum	Oldman	Continuous	21	Very High	10	2	20	200
40	Beaverdam	Oldman	Continuous	23	Moderate	8	1	20	200
41	Black	Oldman	Continuous	13	High	7	1	30	200
42	Burke & Mill	Willow	Continuous	12	High	9	2	20	150
43	no name	Willow	Continuous	23	High	11	1	20	150
44	Sharples & Mead	Oldman	Continuous	23	High	10	1	20	150
45	Health	Oldman	Continuous	23	High	6	1	30	200
46	no name	Willow	Continuous	23	High	7	1	40	200
47	Beaver	Willow	Continuous	1	Very High	11	2	15	200
48	Camp	Oldman	Continuous	31	High	11	3	10	250
49	L. Oldman	Oldman	Continuous	3	High	29	2	10	300
50	Daisy	Oldman	Broken	32	Very High	19	2	10	300

Wtrd_ID	Valley	Watershed	Fuel continuity	V-O jctn	Complexity	# of fires	recent fires	Min age	Max age
51	Allison	Crowsnest	Broken	34	Moderate	14	1	20	350
52	McGillivary	Crowsnest	Continuous	34	High	15	3	10	350
53	Nez Perce	Crowsnest	Continuous	34	High	10	2	10	300
54	Crownest R.	Crowsnest	Continuous	4	Very High	19	3	15	250
55	East Crowsnest	Crowsnest	Broken	12	Low	7	1	30	250
56	Ptolemy	Crowsnest	Broken	12	Moderate	8	1	30	350
57	North York	Crowsnest	Continuous	24	Low	8	1	15	300
58	Lynx	Castle	Broken	12	High	17	3	10	350
59	no name	Castle	Continuous	12	Low	7	0	80	250
60	Lyons	Crowsnest	Continuous	21	High	12	10	10	250
61	Blairmore	Crowsnest	Continuous	21	High	15	3	10	300
62	North Lost	Castle	Broken	12	Moderate	10	0	100	350
63	South Lost	Castle	Broken	21	Moderate	6	0	100	350
64	Carbondale R.	Castle	Broken	23	Very High	15	2	15	350
65	Gardiner	Castle	Broken	32	Low	7	2	15	350
66	no name	Castle	Continuous	32	High	9	2	15	250
67	L. W. Castle	Castle	Broken	23	Moderate	10	2	15	350
68	L. Castle R.	Castle	Continuous	3	Very High	14	2	15	350
69	U. W. Castle	Castle	Broken	12	Low	13	2	15	350
70	Grizzly	Castle	Broken	31	Low	10	2	15	350
71	U. Castle R.	Castle	Broken	1	Moderate	22	2	15	350
72	Gladstone	Castle	Broken	13	Low	8	0	120	350
73	Mill	Castle	Broken	34	Moderate	17	2	15	350
74	Whitney	Castle	Broken	24	Low	10	1	15	350
75	Pincher	Castle	Broken	24	Moderate	10	2	10	350
76	Drywood	Waterton	Broken	24	Moderate	11	1	20	350
77	South Drywood	Waterton	Broken	24	Low	8	1	10	350
78	Scarpe	Castle	Broken	21	Low	10	1	15	350
79	Head. Castle	Castle	Broken	41	Low	12	2	15	350
80	Spionkop	Waterton	Broken	24	Low	9	1	20	350
81	Yarrow	Waterton	Broken	43	Moderate	11	2	20	350
82	North Racehorse	Livingstone	Broken	12	Moderate	11	0	80	350
83	Crownest R.	Crowsnest	Continuous	1	High	11	1	20	250
84	Crowsnest Cr.	Crowsnest	Continuous	24	Moderate	15	2	15	250

7.5 Number of Fires & MFRI

The number of fires was estimated based on the different tones and textures of the forest cover. This means that any forest patches that looked different were counted as a different fire. Because the size of watersheds vary greatly, the number of fires estimated from photos varied accordingly. This provides a biassed perception of the fire frequency in each watershed. To correct this problem, the number of fires recorded in each watershed was normalized over an equal area of land, arbitrarily chosen to be 25 km^2, so that the number of fires could be compared across the landscape. For example, a greater number of fires are usually recorded in large watersheds than in small ones. This leads us to believe that the fire frequency would be greater in larger watersheds. But if one looks at the same information recalculated for 25 km^2 of land, we may find that the number of fires on a 25 km^2 basis could actually be similar. Figure 7-5 shows the distribution of the number of fires per watershed, while Figure 7-6 presents the same information but for a normalised watershed area of 25 km^2.

Normalizing fire occurrence data works well for watersheds that are surrounded by rocky ridges, where fires tend to be contained to one valley. However, after assessing the normalized fire occurrence data for the Montane natural subregion, especially in the Porcupine Hills, I have come to realize that this process has limitations as well. Because of the continuous fuel cover, fires tend to be larger and burn through several contiguous watersheds regardless of their size. This is what has happened in watersheds 6, 7, 8 and 9 (Corral, Willow, Iron and Johnson). The fire frequency for these watersheds is similar, but once normalized, the burning frequency is different due to the different watershed sizes. To overcome this problem, Mean-Fire-Return-Intervals (MFRI) can be used, and should be more indicative of the burning frequency. However, like fire occurrence, the MFRI also increases with the increased size of watersheds; however it will address the problem associated with large burns over continuous and extensive forest cover. The MFRI was calculated by taking the maximum forest age estimated and dividing it by the number of fires. Figure 7-7 presents the MFRI values per watershed.

The longest MFRIs are 50 to 60 years apart and are found at the headwaters of valleys that stem directly from the Continental Divide. These watersheds are Cache, South Hidden, Dutch, South Lost and, Gardiner. The shortest MFRI, which is less than 10 years, was only found in one watershed: Trout. Other short fire intervals (between 10 and 20) are found in the Oldman and lower portions of the Livingstone valleys, as well as in Vicary, Daisy, Crowsnest and the Upper Castle watersheds.

7.6 NUMBER OF RECENT FIRES

The number of “recent” fires (as of 1950) estimated to have occurred after 1900, was recorded for each watershed. This value was recorded to determine if there were regions that were more prone to fire. Because recent fires can be better detected, and there is less chance of overlap among fires, this value should be more accurate than the total number of fires from the previous section. However, it provides a much narrower view of fire occurrence, especially for regions under long fire cycles that see no or very few fires over a 50 year period. In this case, values were not normalised.

Figure 7-8 presents the number of recent fires per watershed which varied from 0 to 4. Only one watershed experienced 4 fires in 50 years and it was in the middle portion of the Oldman Valley. The majority of the study area experienced one or two fires, and only nine watersheds did not record any. Watersheds that did not record any fires are for the most part located next to the Continental Divide (North Lost, South Lost, North Racehorse, South Hidden, Dutch, Cache, Oldman and Pasque). Two other watersheds on the east end of the Castle subregion did not record any fires in the early 1900's either (no name and Gladstone watersheds). Looking at the spatial distribution of the recent fires, it does not appear that natural subregions or fuel continuity had an influence on the matter. The greater number of fires (2 or more), could be linked to the historical human use of some of these watersheds. The 1950 photos show that there was already extensive evidence of road building, mining, partial cutting and salvage logging.

7.7 Time-Since-Fire

The minimum age of the forest was visually estimated based on the most recent fire that occurred in the watershed. This exercise was carried out simply to get a feel for the time-since-fire as of 1950. Figure 7-9 shows the minimum forest age expected to be found per watershed. The watersheds that have the longest time-since-fire are, logically, the same that have the longest MFRIs. Overall, the majority of the watersheds saw a fire between 1925 and 1950 and very few of these watersheds have seen a fire since 1950. The 2003 Lost Creek fire, with over 21,000 ha of area burned, is the only recent fire that is reminiscent of the type of fire activity that took place in the late 1800's and at the turn of the 19th century.

7.8 Old Age Forest Distribution

The maximum age of fire origin was visually estimated to obtain an idea of the range of fire-return intervals per watershed. These age estimates are not intended to be used in forest management practices as they were not supported by any form of field data. Figure 7-10 shows the maximum forest age expected to be found in each watershed (at a minimum a 25 ha or 500m x 500m patch). Nearly all valleys in proximity to the Continental Divide, and that have a broken fuel cover as a result of rocky ridges, should have forests as old as 350 years. Maximum forest age shows a clear west to east gradient with forests becoming younger to the east, notably in the Porcupine Hills.

7.9 Valley Orientation

Codes were assigned to each watershed to represent their orientation. Each watershed was assigned two sets of codes because the general orientation of the valley often differs from the direction found at the intersection of two valleys (confluence). This is due to sharp curves in mountainous valleys that tend to occur near the junction of two valleys as a result of glaciation and rock strata orientation. One code was used to reflect the prevailing orientation of the valley, while the other was used to represent the orientation of the valley at the junction of two valleys. Below are the valley orientation codes and their interpretation. For example, code 12 indicates that a small valley with an orientation in a NW-SE direction, runs in a perpendicular ($\perp$) fashion to another valley that has its orientation in a NE-SW direction. Figure 7-11 presents the orientation of main valleys and of small valleys at the junction of another valley. No map was produced to represent the prevailing orientation of each watershed.

1: Main NW - SE*

2. Main NE - SW*

3. Main N - S*

4. Main E - W*

12: Small NW-SE $\perp$ NE - SW

13: Small NW - SE $\perp$ N - S

14: Small NW - SE $\perp$ E - W

21: Small NE - SW $\perp$ NW - SE

23: Small NE - SW $\perp$ N - S

24: Small NE - SW $\perp$ E - W

31: Small N - S $\perp$ NW - SE

32: Small N - S $\perp$ NE - SW

34: Small N - S $\perp$ E - W

41: Small E - W $\perp$ NW - SE

42: Small E - W $\perp$ NE - SW

43: Small E - W $\perp$ N - S

* code also used for the prevailing orientation.

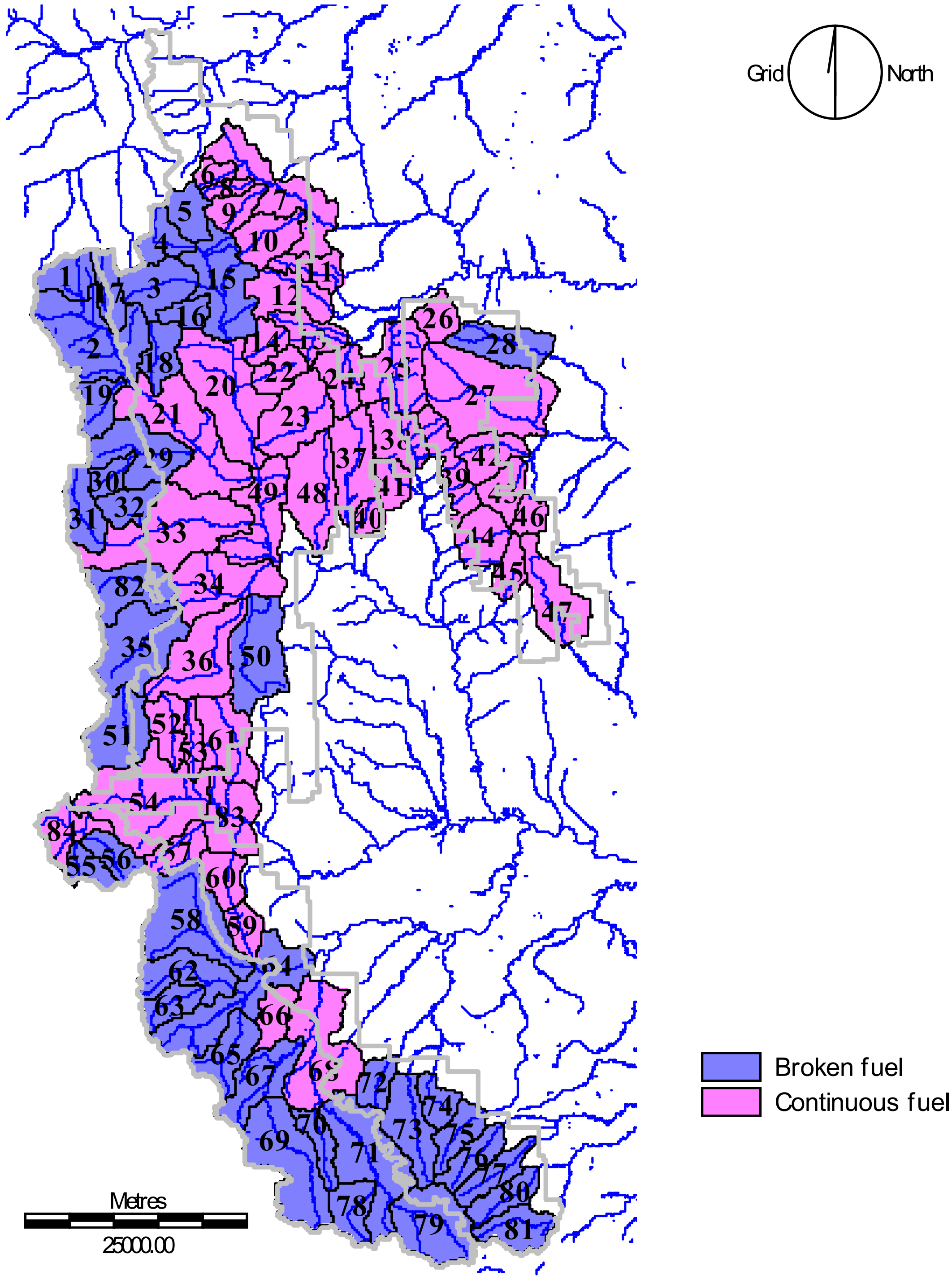

Figure 7-2 Fuel continuity representing watersheds contained by rocky ridges (broken) and those that have a continuous forest cover over rolling terrain.

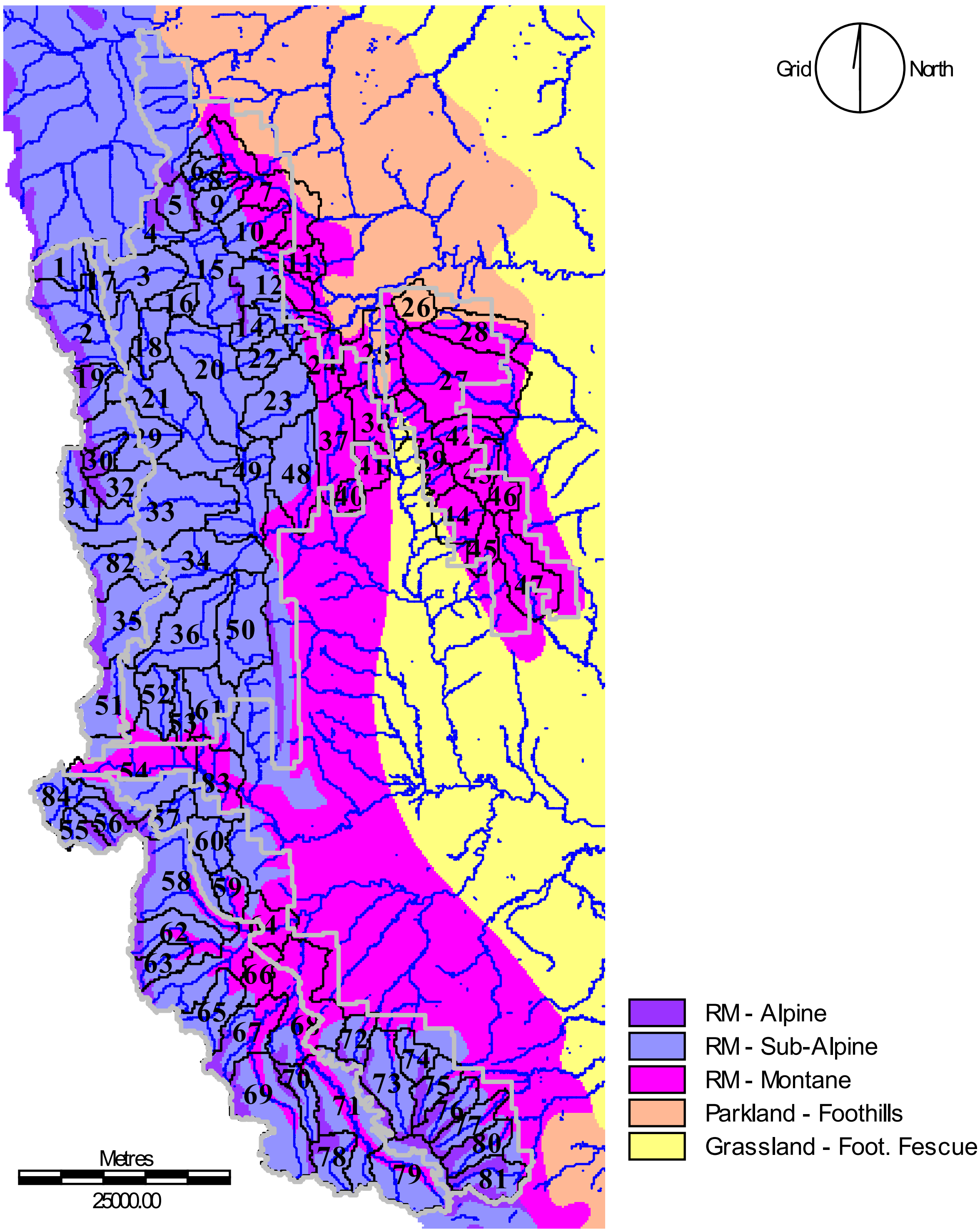

Figure 7-3 Natural subregions found within and around C5 FMU.

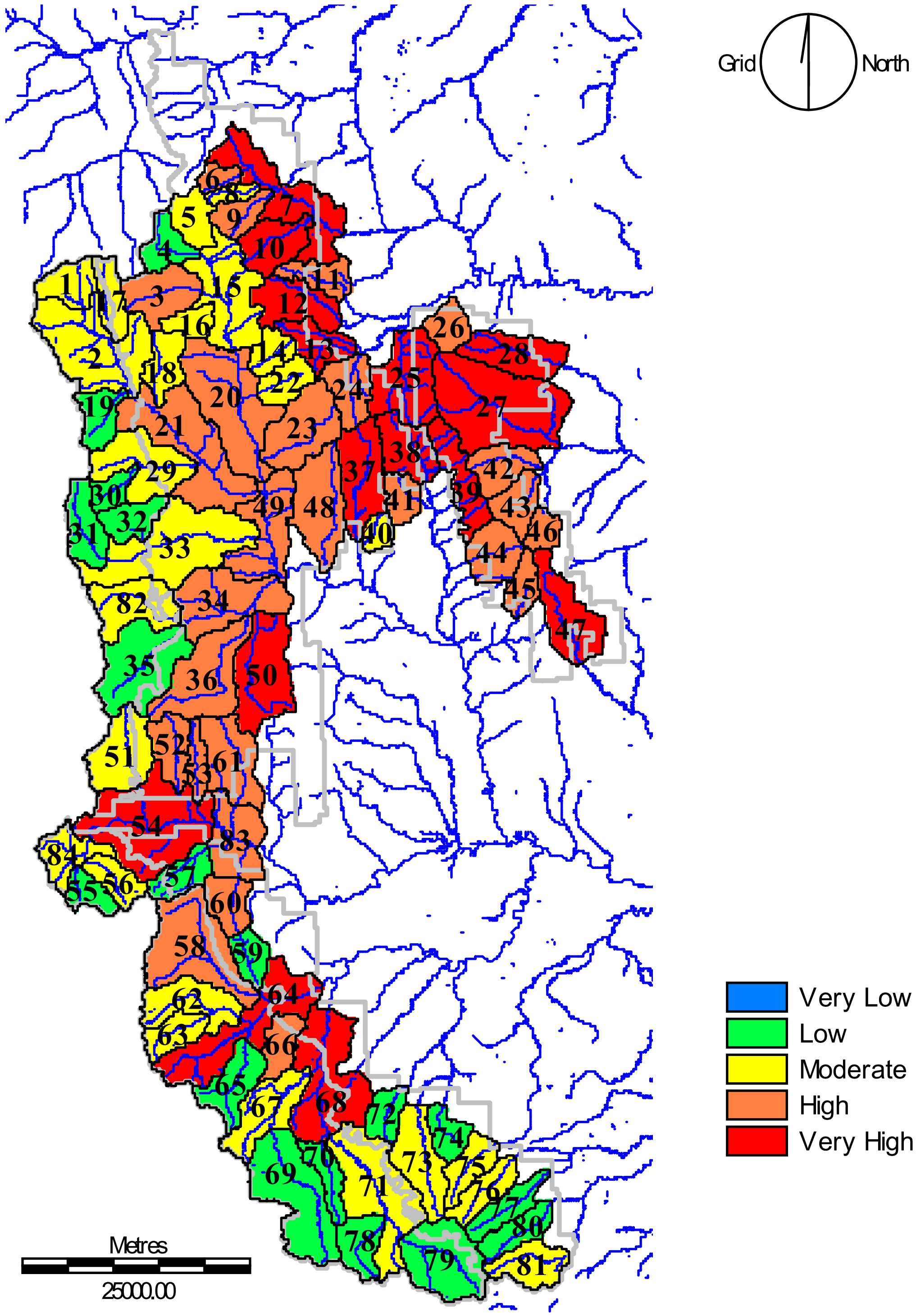

Figure 7-4 Vegetation complexity rating established from the air photo screening process.

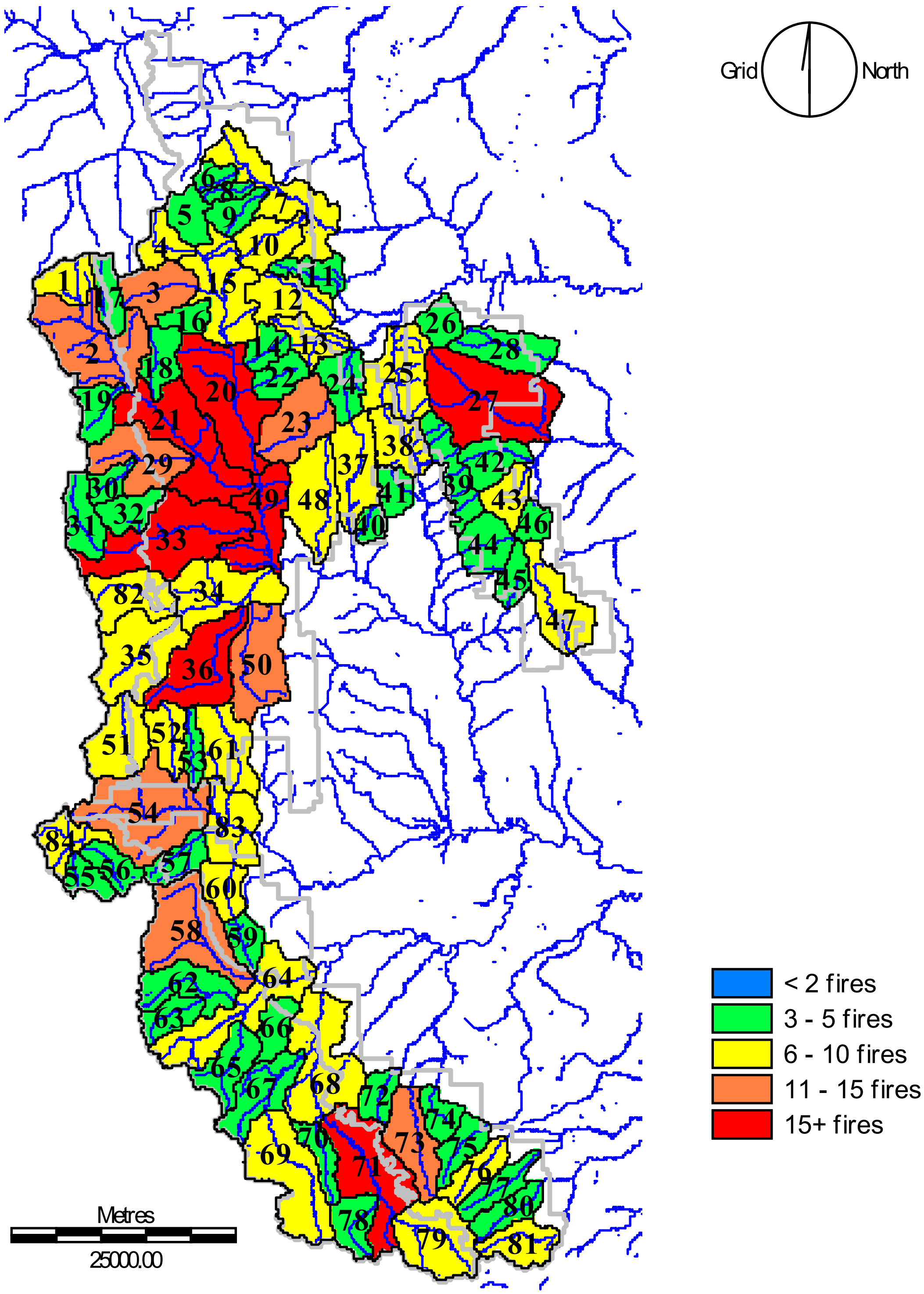

Figure 7-5 Number of fires identified from a visual screening of the air photos for an estimated period of 350 years (1600 to 1950).

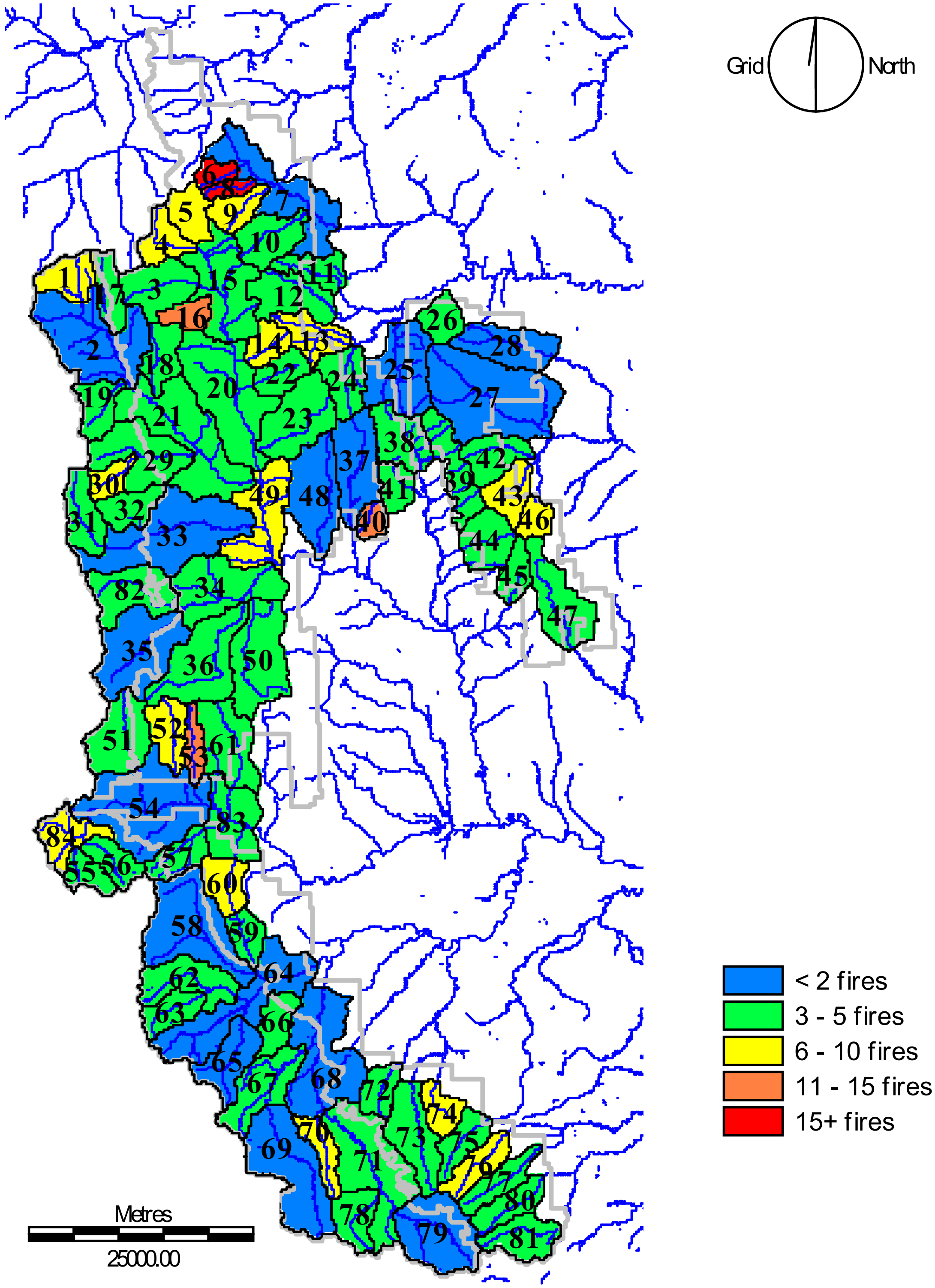

Figure 7-6 Number of fires identified from a visual screening of the air photos for an estimated period of 350 years (1600 to 1950). The total number of fires that could be detected per watershed were normalized over 25 km^2 to account for the large differences in watershed sizes.

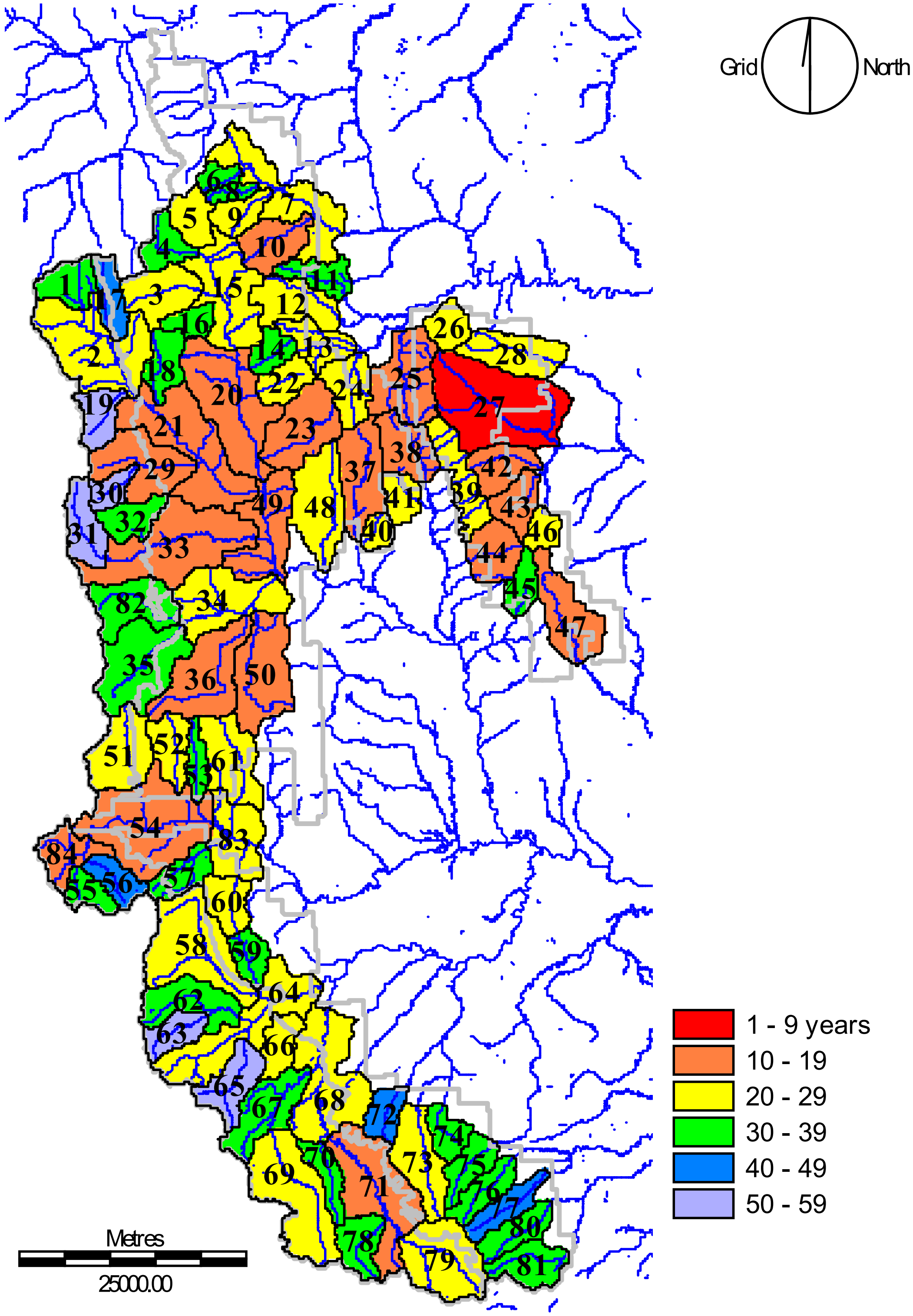

Figure 7-7 Mean-fire-return-intervals calculated from the estimated maximum forest age and number of observed fires per watershed.

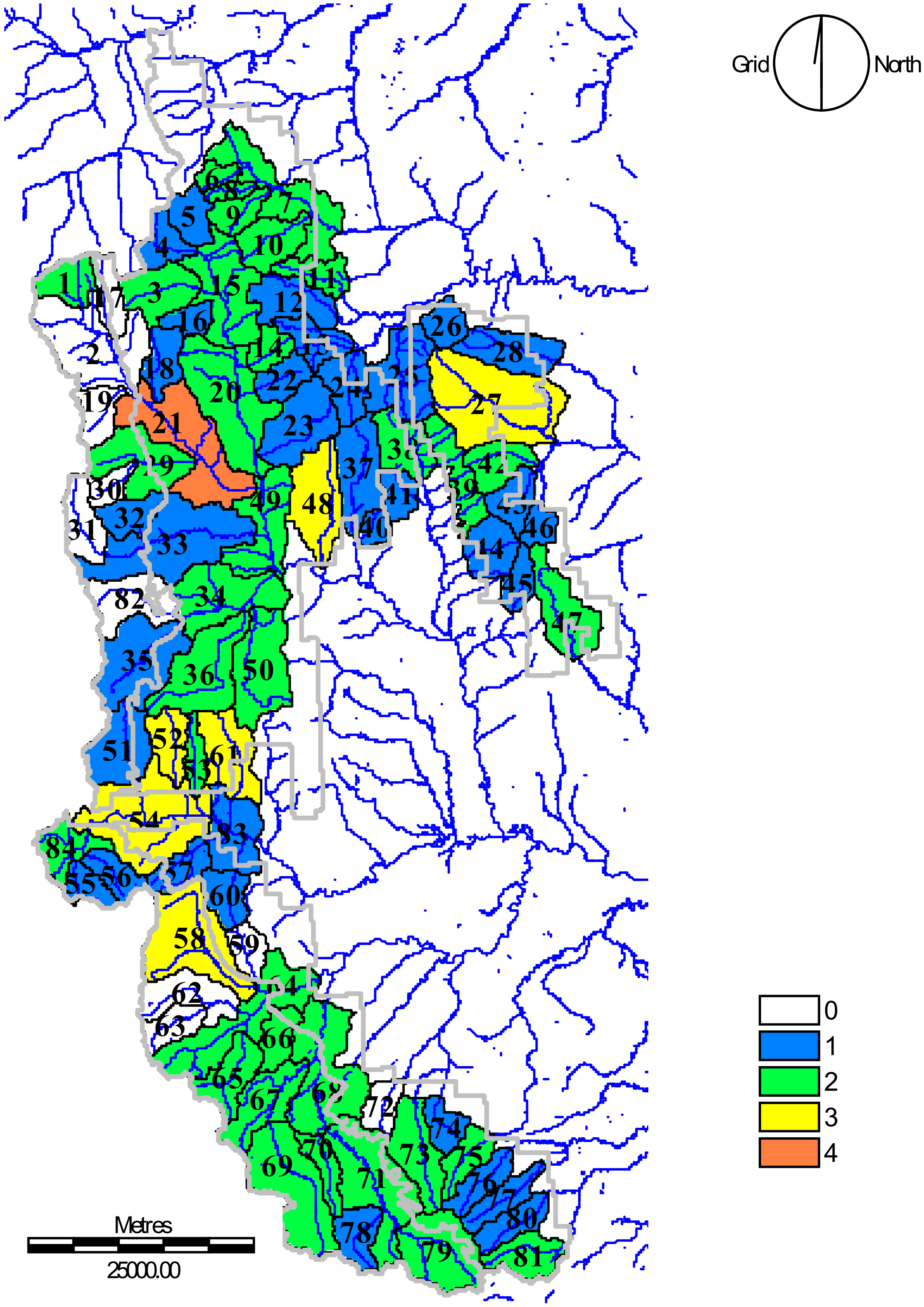

Figure 7-8 Number of recent fires (1900 to 1950) per watershed.

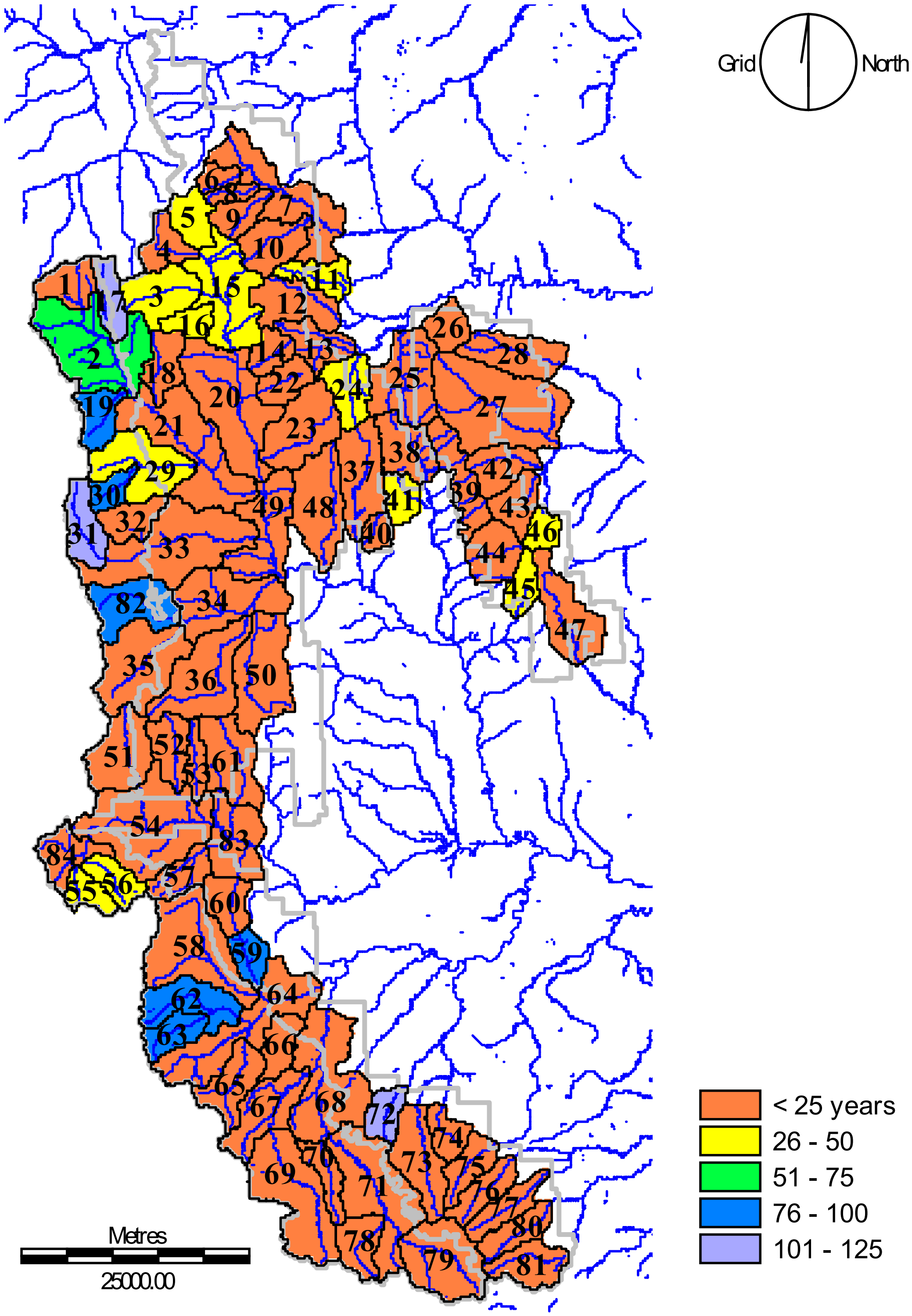

Figure 7-9 Time-since-fire (years) as of 1950. Estimated visually from the air photo screening.

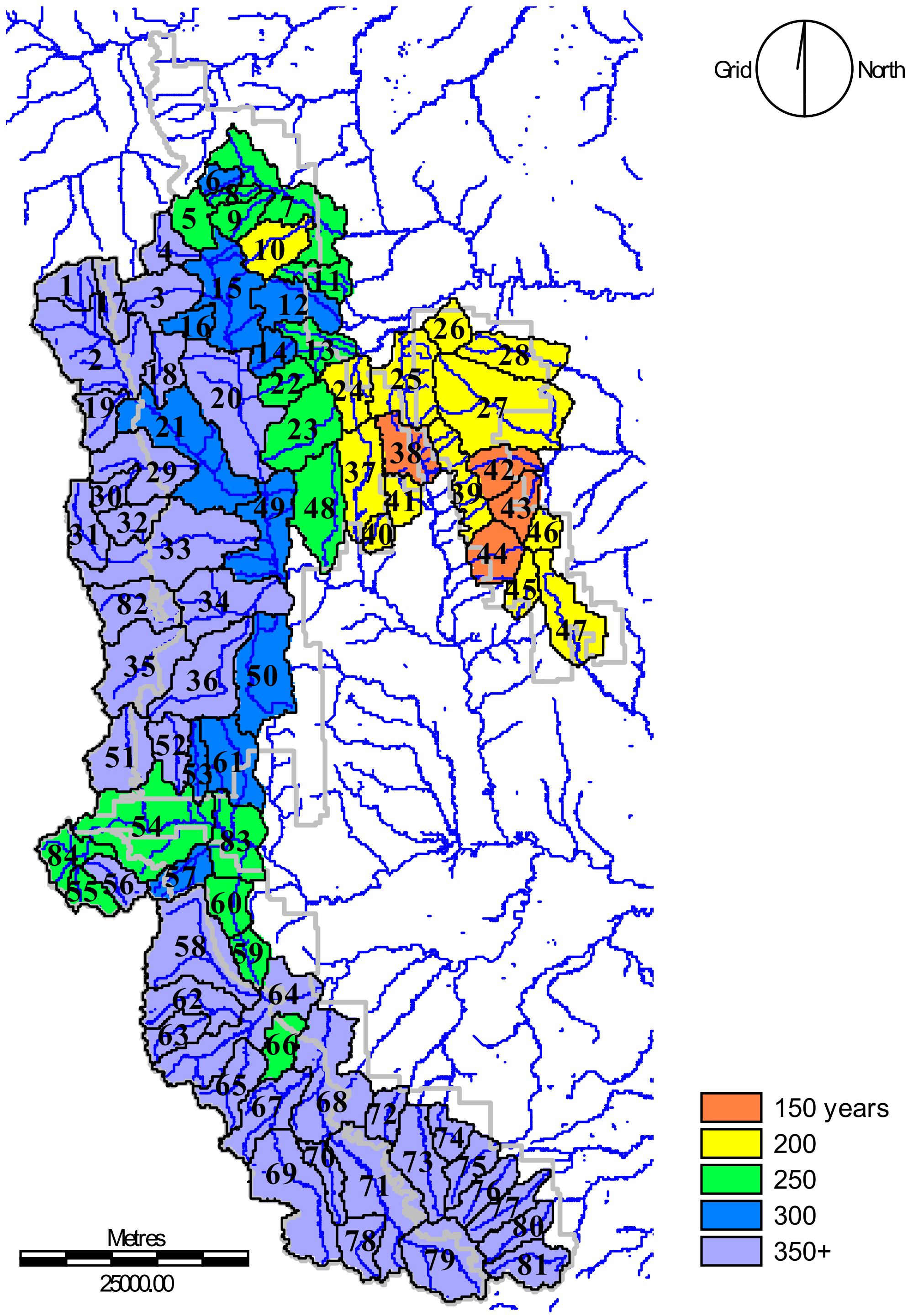

Figure 7-10 Old age forest distribution estimated visually from the air photo screening.

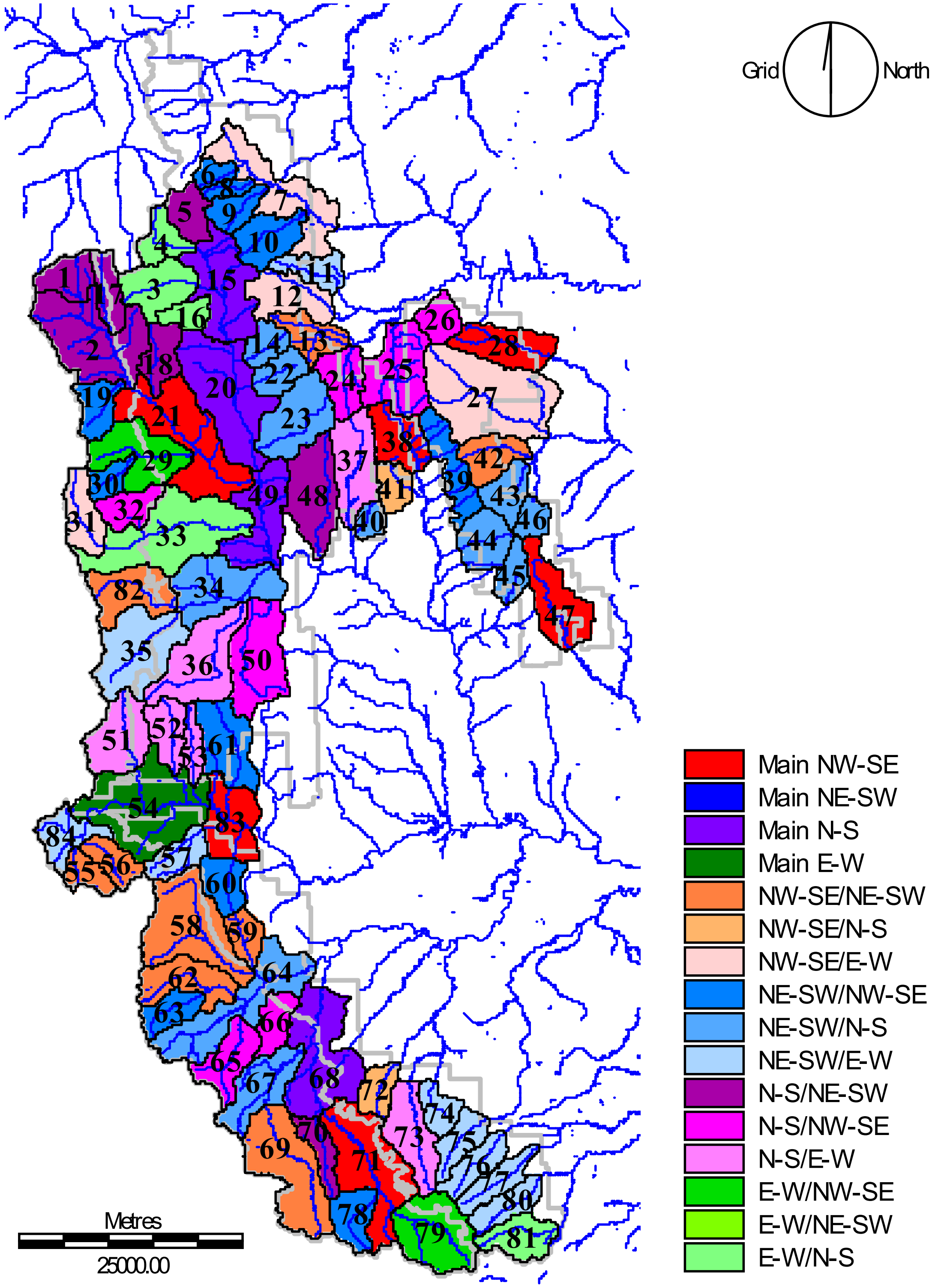

Figure 7-11 Valley orientations at the intersection of two valleys.

Cross-tabulations between the fire attribute maps and the valley orientation map were carried out. Valley orientations, having been identified as a significant topographic factor in fire distribution in the mountains (Rogeau et al. 2004), were assessed against different fire attributes from the screening process in order to see if similar deductions could be made. Table 7-2 presents the percent land cover for categories of vegetation complexity and mean-fire-return interval (MFRI) by valley orientation. The valley orientations presented are not the general valley orientation, but the orientation at the confluence of two valleys. Some valleys show strong tendencies in the kind of complexity and MFRI, but it doesn't appear that there is a direct association between these two variables. Main valleys, however, consistently have high to very high vegetation complexities with fire intervals less than 30 years.

Table 7-2 Percent land cover for classes of vegetation complexity and mean-fire-return-interval by valley orientation. Bolded numbers represent the leading variable class.

	Valley orientations													
Complexity	**1**	**3**	**4**	**12**	**13**	**14**	**21**	**23**	**24**	**31**	**32**	**34**	**41**	**43**
Low	0.00	0.00	0.00	**32.26**	**52.22**	12.14	23.95	0.00	**61.74**	7.94	23.22	0.00	**53.12**	10.76
Moderate	24.18	22.29	0.00	**29.44**	0.00	0.00	11.67	25.37	29.68	**70.39**	0.00	36.86	46.88	**70.07**
High	**39.60**	**49.03**	0.00	**30.80**	47.78	0.00	**38.28**	**53.96**	8.58	21.67	28.68	**43.35**	0.00	19.17
Very high	**36.22**	28.68	**100.00**	7.51	0.00	**87.86**	**26.11**	20.67	0.00	0.00	**48.09**	19.79	0.00	0.00
MFRI	**1**	**3**	**4**	**12**	**13**	**14**	**21**	**23**	**24**	**31**	**32**	**34**	**41**	**43**
1 to 9	0.00	0.00	0.00	0.00	0.00	**44.75**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10 to 19	**74.90**	**49.03**	**100.00**	7.99	0.00	0.00	12.65	29.02	10.65	0.00	**48.09**	**46.35**	**46.88**	**48.28**
20 to 29	25.10	**50.97**	0.00	**52.67**	47.78	**43.11**	**47.74**	**49.55**	0.00	**63.95**	28.68	**47.61**	**53.12**	19.17
30 to 39	0.00	0.00	0.00	33.47	0.00	0.00	17.11	21.43	**79.82**	27.28	9.25	6.04	0.00	32.56
40 to 49	0.00	0.00	0.00	5.86	**52.22**	0.00	0.00	0.00	9.53	8.77	0.00	0.00	0.00	0.00
50 to 59	0.00	0.00	0.00	0.00	0.00	12.14	22.50	0.00	0.00	0.00	13.97	0.00	0.00	0.00
Area (ha)	34,766	29,756	10,645	36,303	3,768	25,258	26,922	37,828	26,334	26,003	25,220	25,296	11,506	20606

7.10 Landscape Types vs Natural Regions

Landscape types refer to the fuel continuity map: rugged terrain with broken fuel cover versus rolling terrain of continuous fuel cover. The landscape type / fuel continuity map was created as part of this project because the subalpine natural subregion, which is a mountainous landscape, includes not only broken forest cover, but also extensive areas of rolling terrain of uninterrupted forest cover. The assumption is that fuel continuity affects the size of burns, as well as fire behavior and how it relates with the effect of topography. For the Kananaskis District fire regime study (Rogeau 2004), it was found that there was a stronger relationship between the landscape type and the different fire variables than with the natural subregions. As per Tables 7-3, similar observations were made for the C5 FMU. Glancing at the bolded values, there are strong differences between some of the fire variables and fuel continuity. With the exception of Time-Since-Fire and the normalized number of fires, these differences appear to be more significant than those between the Subalpine and Montane natural subregions. Cramer's V, a measure of association between two variables, actually found that the relationship between any of the fire attributes and the fuel continuity map was 38% to 44% stronger than with the natural subregion map (Table 6-4).

Table 7-3 Cross-tabulations results between fire variables and the natural subregion map and, the fuel continuity map. Values expressed in percentage of land cover.

		NSR		**FUEL CONTINUITY**	
Fire variable	**variable class**	**Subalpine**	**Montane**	**Broken**	**Continuous**
Complexity	Low	21.71	4.61	**32.76**	2.32
	Moderate	**36.78**	7.44	**47.78**	10.21
	High	**31.38**	27.26	7.79	**49.07**
	Very high	10.12	**60.68**	11.67	**38.40**
Total fires norm.	<2	27.32	**50.03**	34.14	34.87
	3 to 5	**56.64**	42.83	**55.37**	**49.58**
	6 to 10	14.14	5.61	9.57	13.03
	11 to 15	1.18	1.28	0.92	1.45
	15+	0.73	0.25	0.00	1.07
TSF	<25	**76.80**	**88.61**	**65.50**	**93.33**
	26 to 50	10.31	9.30	15.02	5.64
	51 to 75	3.70	0.00	5.52	0.00
	76 to 100	6.25	1.75	9.31	1.03
	101 to 125	2.95	0.34	4.66	0.00
MFRI	1 to 9	0.00	10.53	11.93	**52.42**
	10 to 19	**31.59**	**34.60**	**38.73**	39.35
	20 to 29	**36.52**	**44.87**	**29.60**	7.86
	30 to 39	23.37	8.55	5.26	0.00
	40 to 49	3.43	0.87	7.49	0.00
	50 to 59	5.10	0.58	7.00	0.36
Max age	150	0	11.29	0.00	6.62
	200	0.91	**44.00**	2.65	**24.65**
	250	14.57	**21.16**	2.57	**28.72**
	300	17.95	2.65	9.19	16.40
	350	**66.57**	20.90	**85.59**	23.60
Area (ha)		231,879	107,314	157,053	183,157

Table 7-4 Cramer's V measure of association values between the fire variables and fuel continuity and natural subregion classes. The measure is on a scale of 0 to 1, 1 being the strongest.

Fire Variable	NSR	Fuel Continuity
Complexity	0.49	0.86
Total fires norm.	0.43	0.71
TSF	0.43	0.75
MFRI	0.45	0.8
Max age	0.52	0.84

For the Kananaskis District fire regime study, it was recommended to pursue forest and fire management using the natural subregions despite the weaker relationships found between fire variables and natural subregions. This recommendation was based on the fact that the fuel continuity issue was only present in the Subalpine natural subregion, and that the subalpine makes up a relatively small portion of the study area. However, in the case of the C5 FMU, the Subalpine accounts to close to 70% of the management area. This means that it may not be good advice to recommend managing based solely on the natural subregion delineations. The partition of the fuel continuity map would be more appropriate to use in this instance.

As the FMU is already divided into five management zones (called subregions), two of which following closely the Continental Divide and hence their names, it would likely be better to use these divisions for fire regime restoration planning. To verify this statement, the fire variables were also cross tabulated against the management subregions. Results from Table 7-5 show that each subregion does indeed have its own set of fire regime characteristics. However, to reduce management logistics, it appears that the Castle and Continental Divide South subregions have similar enough fire regime characteristics to apply similar forest management manoeuvres.

As a side note, it would appear that Time-Since-Fire is a fire variable that is independent of fuel continuity, natural subregion or management subregion. The total number of fires calculated over normalized areas also show similar tendencies. After doing this exercise, these two variables appear to be poor indicators of fire regime variation and should not be given too much weight in the forest planning process. Vegetation complexity, MFRI and maximum estimated age are better indicators to differentiate fire regimes.

Table 7-5 Cross-tabulation results between fire variables and the management subregion map. Values expressed in percentage of land cover.

Fire variable	Variable class	P. Hills	Castle	C.D.S.	Living.	C.D.N.
Complexity	Low	0.00	**33.10**	**35.09**	3.13	36.33
	Moderate	0.00	**33.33**	**34.37**	25.48	**59.89**
	High	34.02	11.84	13.83	**49.46**	1.99
	Very high	**65.98**	21.74	16.71	21.93	1.78
Total fires norm.	<2	**41.60**	27.55	**52.33**	22.26	38.77
	3 to 5	**48.69**	**56.11**	40.33	**59.27**	**51.12**
	6 to 10	9.70	16.35	7.34	13.93	10.11
	11 to 15	0.00	0.00	0.00	3.04	0.00
	15+	0.00	0.00	0.00	1.50	0.00
TSF	<25	**91.22**	**91.06**	**84.56**	**82.11**	**44.46**
	26 to 50	8.78	0.00	5.74	14.91	8.69
	51 to 75	0.00	0.00	0.00	1.48	17.20
	76 to 100	0.00	4.40	9.71	0.37	**19.83**
	101 to 125	0.00	4.53	0.00	1.12	9.82
MFRI	1 to 9	24.89	0.00	0.00	0.00	0.00
	10 to 19	**40.12**	9.32	17.17	**48.61**	19.17
	20 to 29	**30.50**	**42.22**	**47.18**	**39.25**	**25.96**
	30 to 39	4.49	**38.01**	**23.66**	11.02	**35.33**
	40 to 49	0.00	10.45	3.23	1.12	2.06
	50 to 59	0.00	0.00	8.76	0.00	17.49
Max age	150	20.06	0.00	0.00	1.70	0.00
	200	**79.94**	0.00	0.00	9.84	0.00
	250	0.00	19.62	12.02	20.86	1.78
	300	0.00	4.23	0.85	**29.51**	1.89
	350	0.00	**76.15**	**87.12**	**38.09**	**96.32**
Area (ha)		31,872	42,392	65,799	130,628	39,086

7.11 CONCLUSIONS

Results from the 1950 aerial photography screening process, like the assessment of recent fire records, demonstrated that the historical fire regime was not homogeneous throughout the study area. Therefore, hypotheses H_{01}, H_{02} and H_{03} were rejected. The vegetation complexity rating process showed that the rating is linked to fuel continuity rather than to a west to east elevation gradient as determined for Kananaskis District. The mean-fire-return-interval was also found to be a better variable to capture burning frequencies among watersheds. The natural subregions were determined not to be good surrogates to fire regime delineation, but that the fuel continuity map was. The five management subregions map was found to be a better tool to capture the differences among fire regimes than the natural subregion map, or even the fuel continuity map, which is quite general with only two landscape type categories.

In summary, the Porcupine Hills subregion has the most unique fire regime, followed by the Continental Divide North subregion. Both the Castle and Continental Divide South subregions can be merged together due to their slight differences in fire regime. The Livingstone subregion shares similar components with each of the other subregions, which makes it an interesting and unique region as well. The Livingstone has a tendency to have a high number of fires and a complex forest mosaic, but also contains a fair amount of old aged forest. One interesting fact is that regions of high to very high vegetation complexity, or those that have a high number of fires, do not perfectly coincide with zones of greater probabilities of lightning ignitions. As a matter of fact, many coincide with zones of low probability of lightning ignitions. This indicates that the historical fire regime had to be driven to some extent by anthropogenic sources of fire.

8.0 RECENT FIRE MAPPING

This chapter is an overview of the number and location of fires that occurred in C5 FMU between circa 1930 and 1950. The assessment is described by management subregion. Some of the fires identified were mapped, digitized and given a polygon fire_id number. Figures 8-1 and 8-2, presented at the end of this Chapter, show the location of these fires. Not all fires could be mapped as explained in the text below. Some of the fires were given dates based on original fire occurrence reports dating from 1929 to 1950 that had been provided by the Calgary Forest Protection Office. The historical fire occurrence data set was incomplete so not all fires seen on the photos could be matched to a fire occurrence report. This exercise provided an estimate of the size distribution of fires greater than 200, and it allowed for the calculation of a fire cycle for that time period. These results are presented in the last Section.

Before getting into the fire summaries, there are a few interesting comments to make with regards to the old fire occurrence reports. All reports had a map that showed the fire perimeter. For larger burns, some fire officers would mark what had been burned, such as old growth or second growth. The second growth was even dated at times, most often from 1903 to 1910, which kept the fire interval to about 30 years in most cases. All fires reported were attended rapidly by anywhere from 3 to close to 200 fire fighters. It was also reported that long fire lines were established to fight the fire from, up to 83 km in one instance. This explains some of the unusual burning patterns in the subalpine such as having fires running across slopes and not coming down into the lower elevations. Base on these reports, it is certain that fire fighting had an effect on final burn areas, which also means the fire cycle. On the other hand, most fires were man-caused due to the amount of logging, mining and exploration activity in this region in the early 1900's. These high levels of man-caused fires would supplement the source of burning area and perhaps compensate for those fires that were put out or kept smaller.

Another interesting point to make are the non-forested areas portrayed in white on the NTS 1:50,000 map sheets. The mapping of forested zones relied on photos dating from the late 1960's or the 1970's depending on the topographic map used. Photo interpreters mistakenly took recent burns for non-forested areas. Some of these white patches match perfectly the burn perimeter provided in the old fire occurrence reports. The amount of white area found on the topographic maps mislead us to believe that there are more areas above tree line and more grassy patches than there is in reality.

8.1 CONTINENTAL DIVIDE NORTH

This is the subregion that has seen the least amount of burning and as a consequence, appears to have the most older aged forest. Fire frequency was higher in the southern end of the Subregion, in the Crowsnest valley, than anywhere else in this subregion.

Fire Id 1: Small fire that occurred near treeline during the 1940's. Because of its location, it was likely caused by lightning.

Fire Id 2: This fire occurred in the 1880's at the headwaters of the Oldman and Oyster watersheds. This burn took place prior to the mining exploration. It is also the only fire prior to 1930 that could be mapped.

Fire Id 6: In the 1930's this fire came from BC over Racehorse Pass. It travelled extensively to the west and south of the Livingstone River and into Station, Vicary and Daisy watersheds. This fire is less than a few kilometres away from the Dutch Creek fire (Fire Id 4) and Camp Creek fire (Fire Id 5). It is possible that this fire is related to one of these two burns. Most of the burn patches associated with Fire Id 4, 5, 6 travelled on the ground only to become stand replacing fires on the drier slopes, with open meadows acting as a wick to connect the different burn patches. Despite it's occurrence as what would appear to be in the 1930's, no fire occurrence report was found for this burn and it was not documented by Delisle and Hall (1987) either.

In a 1938 fire occurrence report, the fire officer was reporting a fire in Alexander Creek, BC that was threatening to move into South Racehorse Creek, but didn't, unlike the 1919 fire. Fire Id 6, looks like it could be dating from 1938, and it also looks like it has burned over a fire from circa 1919. No documentation was found for the South Racehorse Creek burn, but it would be easy to put two and two together.

Fire Id 7: This fire came from BC over Deadman Pass and burned the headwaters of Allison Creek sometime in the 1930's. It was likely a human-caused fire considering the road network that already existed in 1951 and which extended into BC over that Pass. The fire stayed at higher elevations and burned with lower intensity at the very headwaters of Allison Creek. It circled around the headwaters to keep on burning only the south facing slopes of tributaries east of Allison Creek.

Fire Id 11: In the 1940's a fire from BC came across Phillipps Pass and burned the slopes below Phillipps Peak down to Crowsnest Lake. It appears that the fire spotted across Crowsnest Lake, next to Emerald Lake, and burned the lower slopes of Sentry Mountain. The portion of the burn on the south side of Crowsnest River could be from a separate source of ignition, but nonetheless both burns appear to be of a similar age.

8.2 LIVINGSTONE

The Livingstone Subregion was highly affected by man-caused fires and actually more fires were identified than those that could be mapped. Those unmapped fires were older than 1930 and had burned in such a patchy way that it was impossible to follow boundaries with certainty. It was observed that headwaters were burned more severely than at lower elevations. On steeper terrain, fires are more intense and stand replacing than in the flatter valley bottoms. Because of the higher elevations of the headwaters, post-fire regeneration can take several years longer (up to 20 and perhaps more) than at valley bottoms. On the 1950 air photos, it makes it look like a more recent fire burned the headwaters of several adjoining watersheds. This scenario is however highly unlikely as it goes against logical fire behaviour. Examples of differential forest growth rates can be found in the Johnson and Timber watersheds.

The Livingstone watershed, as well as neighbouring watersheds located east of the Livingstone Range, appear to have been affected by one large fire in the early 1900's. It is impossible to follow boundaries of this fire due to the numerous patches of remnants and discontinuity of the burn around the height of land dividing the watersheds. But, judging from the similar forest tone and texture found in all these watersheds, it is likely that forest regeneration originated from the same fire.

Another mapping hurdle associated with this Subregion, as well as the Porcupine Hills, are the grassy slopes east of the Livingstone Range, which make it difficult to connect fire boundaries together. Meadows are most often found on the drier aspects (SE, S, SW), which are also those that burn more easily. On grassy slopes, it is not uncommon to find pockets or strips of trees in the wetter creek draws. Based on this observation, it is possible that the creation or maintenance of these grassy patches are the result of frequent fire activity.

Fire Id 3: This burn occurred in the 1930's in the middle portion of the Oldman River near Hidden Creek. This fire was found to have an odd burning pattern near treeline. The fire likely started from lightning at the headwaters of a side creek and burned as a full stand replacing fire on both sides of the valley up to treeline. It also moved downslope and across in the headwaters of other side creeks, but burned with less intensity and left more remnants on the lower slopes. This is the assumed scenario, but having read the old fire occurrence reports, the spread pattern of this fire might have been affected by fire suppression, even though no occurrence report was found for this fire.

Fire Id 4: 1936 Dutch Creek Fire. This fire was documented by Delisle and Hall (1987) as a man-caused fire, but no historical fire occurrence report was found for it. This fire burned the lower portion of the NE slopes of the Oldman watershed and moved into the lower portion of Dutch Creek via Grassi Ridge. The fire mainly stayed on south facing slopes and the lower elevations of north facing slopes. Based on this information, it is likely that this was a spring or fall burn. Judging from the patches of remnants within the burn area, this fire would have overlapped a fire from the late 1890's - early 1900's.

Fire Id 5: This fire occurred in the 1940's. It could potentially be linked to the Racehorse Creek fire (Fire Id 6) or it could have stemmed from the bank of the Oldman River just east of the Livingstone River. It burned a side creek of the Oldman River entirely and moved to the north along the ridge crest to drop into headwaters of neighbouring valleys (Camp, Miles Coulee, Livingstone, Snake and Jackknife Coulee). It is highly possible that this fire fanned out over an area larger than what has been mapped. The fire boundaries to the north could not be followed with certainty to be included in the mapping.

Fire Id 6: This fire originated in the Continental Divide South. Please see description of the fire in that Subregion. However, this fire did burn more extensively in the Livingstone Subregion.

Fire Id 8: Very small fire near treeline at the headwaters of McGillivary Creek. The fire took place in the 1940's. There is a road that leads to the burn, which means that people could have been the source of ignition. The burn is too small to assume that such a long road would have been built to salvage the burnt trees, unless it was to fight the fire.

Fire Id 9: Another burn from the 1940's in the headwaters of McGillivary and Nez Percé watersheds. The fire travelled at high elevations over McGillivary Ridge and largely burned the headwaters of side tributaries. This is another odd burning pattern that was restricted to high elevations. Such burning patterns are contradictory to what has been found in Kananaskis Country and Banff National Park, which leads one to believe that fire suppression tactics had something to do with it.

Fire Id 10: Blairmore Creek fire, discovered in November 1936 (unknown start date) and thought to have been caused by a smoker. It burned as a stand replacing fire at the headwaters of Blairmore Creek, on south facing slopes. This fire burned from November 19 to 28 and was monitored but not fought due to the late season. It burned over a fire dating from 1910.

Fire Id 12: Small burn between Pelletier and Blairmore Creeks. It was started by a smoker in July 1934. If no fire occurrence had been found for this fire, it would have been associated with Fire Id 13 due to their similarity.

Fire Id 13: Small burn from the 1940's, directly north of Coleman in Nez Percé watershed.

Fire Id 14: Small burn dating from 1945 in Nez Percé watershed. It was originally thought to be part of Fire Id 13 until a fire occurrence report was found for it.

Fire Id 19: Small burn dating from September 1945, which started along Racehorse Creek near the junction of the north and south branches. It was started by a fisherman. If not for the fire occurrence report, it would have been lumped with Fire Id 6.

8.3 Porcupine Hills

No fires were mapped in this Subregion because none could be traced within the air photo coverage available. Fires that burned in this region were generally of lower intensities and as a result, fire mapping is almost impossible when not substantiated with tree age data. With short fire return intervals, differences in tone and texture on the photos are minimal and add to the mapping challenge. Because the quality of photos vary from flight line to flight line as a result of different sun angle and light exposure, regions that are subjected to frequent fires of mixed severities need to rely on stand dating if any fire mapping is to be attempted. Even with some stand dates, mapping accuracy cannot be achieved but at least a sense of the magnitude of some burns can be obtained.

The 1951 photos show that Sharples, Mead and Heath Valleys, as well as side tributaries of Callum Creek, were already extensively logged.

8.4 Continental Divide South

This subregion was affected by three large size fires in the 1930's. They all came from British-Columbia and were of human origin. Similar to the Continental Divide North Subregion, the greatest fire occurrence was found in the Crowsnest Valley.

Fire Id 15: In 1931, this fire came from Corbin, BC over Ptolemy Pass. It almost burned the entire East Crowsnest watershed, as well as the Ptolemy watershed. It also burned up Andy Good Creek and spotted into the North York watershed. The fire initially travelled on a SW facing slope at low intensity for about 2 km, then it developed into a full blown stand replacing fire on all aspects and elevations. Only small patches of remnants were left at the headwaters.

Fire Id 23: This is the 1936 Pass Creek fire that entered the Province from Saint Eloi Brook in BC, as a result of a large raging fire in the Flathead Valley. It burned down the Gardiner Valley, but stayed on the south side of Carbondale River and barely extended beyond the C5 FMU boundary. It also consumed the Syncline Brook, West Castle, Grizzly and the lower Castle watersheds. This 1936 burn slightly overlapped the 1934 Castle Fire for a few kilometres. Many areas that it burned over appear to date from the early 1900's.

Fire Id 24: The fire polygon shows the overlay of the 1936 Pass Creek fire (Id 23) over the 1934 Castle fire (Id 25). The fire overlap takes place between the Castle Fire Lookout and Castle Peak on the southwest facing slope. The 1934 fire occurrence report did not show an overlay between the two fires. However, the completely bare slope is as a result of intense burning at a short interval.

Fire Id 25: The 1934 Castle fire entered Alberta from Sage Creek BC via Scarpe Creek on August 6th. The fire was caused by a camp fire along Sage Creek. The fire was fought actively with up to 145 men and 83 km of fire lines. The fire was under control by August 30th, was patrolled until September 23rd and the fire was completely extinguished by October 15th.

8.5 CASTLE

Most recent fires that occurred between 1930 and 1950 seem to have burned over forests from the early 1900's. Fires tend to burn in similar places leaving old growth forests to perpetuate on the cooler aspects and higher elevations. The effect of topography appears to be as strong here as what was found in Banff National Park (Rogeau 2004).

Some of the large fires from the Continental Divide South Subregion spilled over into this Subregion, but did not contribute to much of the burn area. Fires dropped from high ridges into watersheds of the Castle Subregion, but did not burn a significant amount of land. Only one fire contributed to burning most of one watershed, the South Drywood.

Fire Id 15: The 1931 North York Creek fire, which spotted from Ptolemy watershed (see Continental Divide South), started burning in this valley in late August. This fire burned over a 1905 burn.

Fire Id 16, 17 & 18: Three small adjacent burns in the Star Creek watershed, and dating from the 1940's. Due to the proximity of the Town of Coleman, these burns were kept separate because each fire would have been actioned fairly rapidly by fire crews. Again, if the old fire occurrence reports had not been surveyed, these three burn patches would have been lumped as one fire event.

Fire Id 20: In November of 1936, this fire burned in Lyons watershed below Hastings Ridge. It burned over a fire from 1903.

Fire Id 21: This small fire from the late 1930's burned at the headwaters of Lyons Creek, below Willoughby Ridge. It burned over a fire dating from the early 1900's.

Fire Id 22: Small burn from the 1940's in Lynx valley. Logging was taking place in the area and could have been a source of ignition.

Fire Id 25: The fire perimeter of the 1934 Castle fire, as described in the Continental Divide South Subregion, was extended to the South Drywood watershed as it would appear that this fire crept into that valley over a high pass and then turned into a full stand replacing fire at valley bottom, which in turn consumed most of the South Drywood valley. Note that this was not documented in the fire occurrence report. In any case, the South Drywood fire also dates from the 1930's.

Fire Id 26: A fire in the 1930's burned the upper west facing slopes of the lower portion of Mill Creek. No fire occurrence report was found for this fire.

Fire Id 27: In the 1930's the lower portions of Pincher and Drywood watersheds burned. The fire was patchy and could not really be mapped at the mouth of these watersheds, just east of the FMU boundary. It would appear that a northeast wind pushed the burn into both watersheds. With the exception of the steeper slopes, it was not a high intensity burn as it left many patches and pockets of trees behind.

Fire Id 28: Also from the 1930's, this fire burned most of the Spionkop watershed. It looks like this fire could have been part of the 1934 Castle fire as well and/or the South Drywood burn (Fire Id 25). No fire occurrence report was found for that fire either.

*** Comments following helicopter reconnaissance flight***

A reconnaissance flight was taken a couple of months after conducting the recent fire mapping process. It appears that what looked like recent burns on the 1950 photos for Fire Id 27 and 28 were actually low brush and patches of dirt/rocks. No burnt snags on the ground could be seen. This affects the total burn area between 1930 and 1950 and the fire cycle calculation. Appropriate changes have been made to Table 8-1 and fire cycle value to reflect this new information.

8.6 Fire Cycle Calculation: 1930 to 1950

Table 8-1 presents the number of hectares for each fire that was digitized. With the exception of Fire Id 2, all fires are estimated to have taken place over a 20-year period between 1930 and 1950. Fire Id 2 is estimated to have occurred in the 1880's and as such, could not be included in the calculation of the fire cycle for the 1930 - 1950 period.

As per the fire summary for each subregion discussed in the previous sub-sections, and Figures 8-1 and 8-2, fires were not distributed evenly across the landscape. Many watersheds on the east and north sides of the FMU had recent fires that could not be mapped. For the fire cycle value to be representative, watersheds where fire mapping could not be achieved had to be removed from the data set. Figure 8-3 shows the land base for which a fire cycle was calculated. Also note that because many of the fires burned grassy areas, the grass fuel type was lumped with the treed fuel types.

Following are the numbers used to estimate the forested area.

Watersheds - total area: 224,573ha
Watersheds -forested only: 193,066 ha (86% of total area)

Crowsnest Corridor (outside of FMU): 10,671ha (estimated to be entirely forested or "burnable")
Total forested area: 203,737 ha

The total area burned over a 20-year period was 47,959 ha., which results in an average of 2,398 ha per year. Based on a forested area of 203,737 ha, this is equivalent to a rate of disturbance of 1.18%. To burn an amount of land equivalent to the forested area, it would take 85 years (i.e fire cycle).

Table 8-1 Area and year of fire occurrence for each fire mapped. Supporting evidence of the fire year, if found, is stated.

Fire Id	Area (ha)	Year	Historical record
1	62.82	1940's	n/a
2*	2,092.76	1880's	n/a
3	404.15	1930's	n/a
4	4,105.68	1936	Delisle & Hall (1987)
5	1,911.29	1940's	n/a
6	5,252.32	1930's	n/a
7	899.76	1930's	n/a
8	36.32	1940's	n/a
9	774.08	1940's	n/a
10	311.93	1936	fire occurrence report
11	1,163.25	1940's	n/a
12	141.46	1934	fire occurrence report
13	220.12	1940's	n/a
14	101.23	1945	fire occurrence report
15	2,970.92	1931	fire occurrence report
16	97.75	1940's	n/a
17	117.59	1940's	n/a
18	227.75	1940's	n/a
19	226.46	1945	fire occurrence report
20	252.82	1936	fire occurrence report
21	200.10	1930's	n/a
22	19.76	1940's	n/a
23	17,045.71	1936	fire occurrence report
24	1,097.29	1934,1936	fire occurrence report
25	9,947.38	1934	fire occurrence report
26	371.36	1930's	n/a
	47959.3		

* Fire Id 2 was not included in the total burn area because it dates prior to 1930.

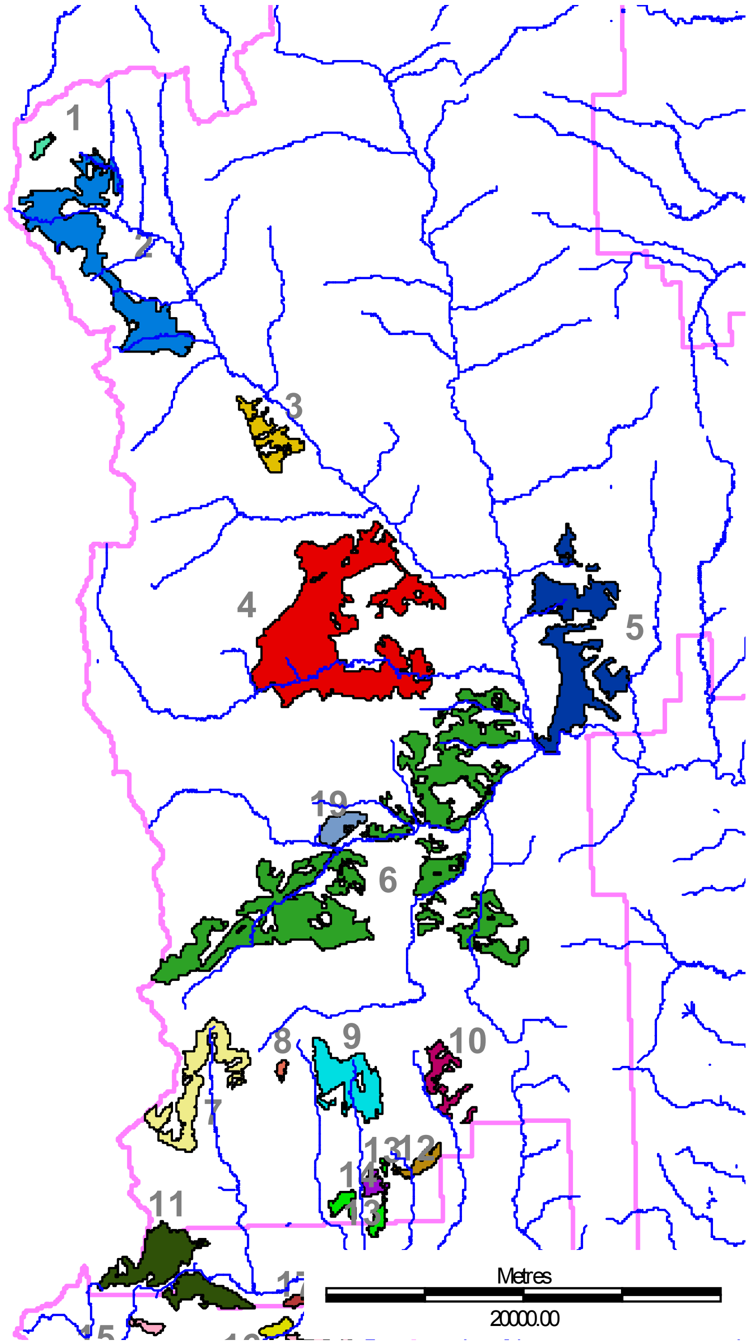

Figure 8-1 Fires dating between 1930 and 1950 for the C5 FMU, north of the Crowsnest Highway. Fire Id 2 is an exception and dates from circa 1880.

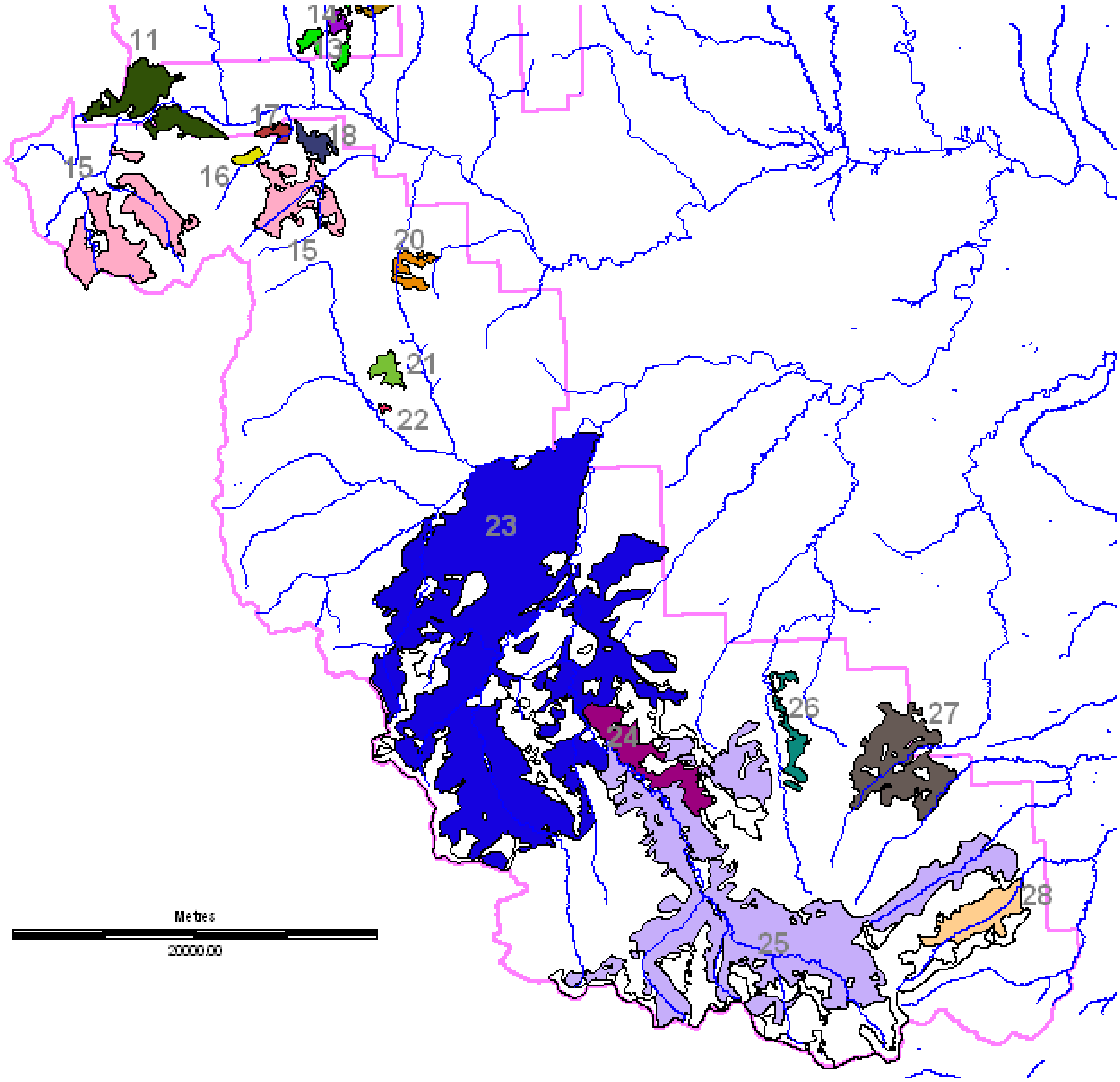

Figure 8-2 Fires dating between 1930 and 1950 for the C5 FMU, south of the Crowsnest Highway.

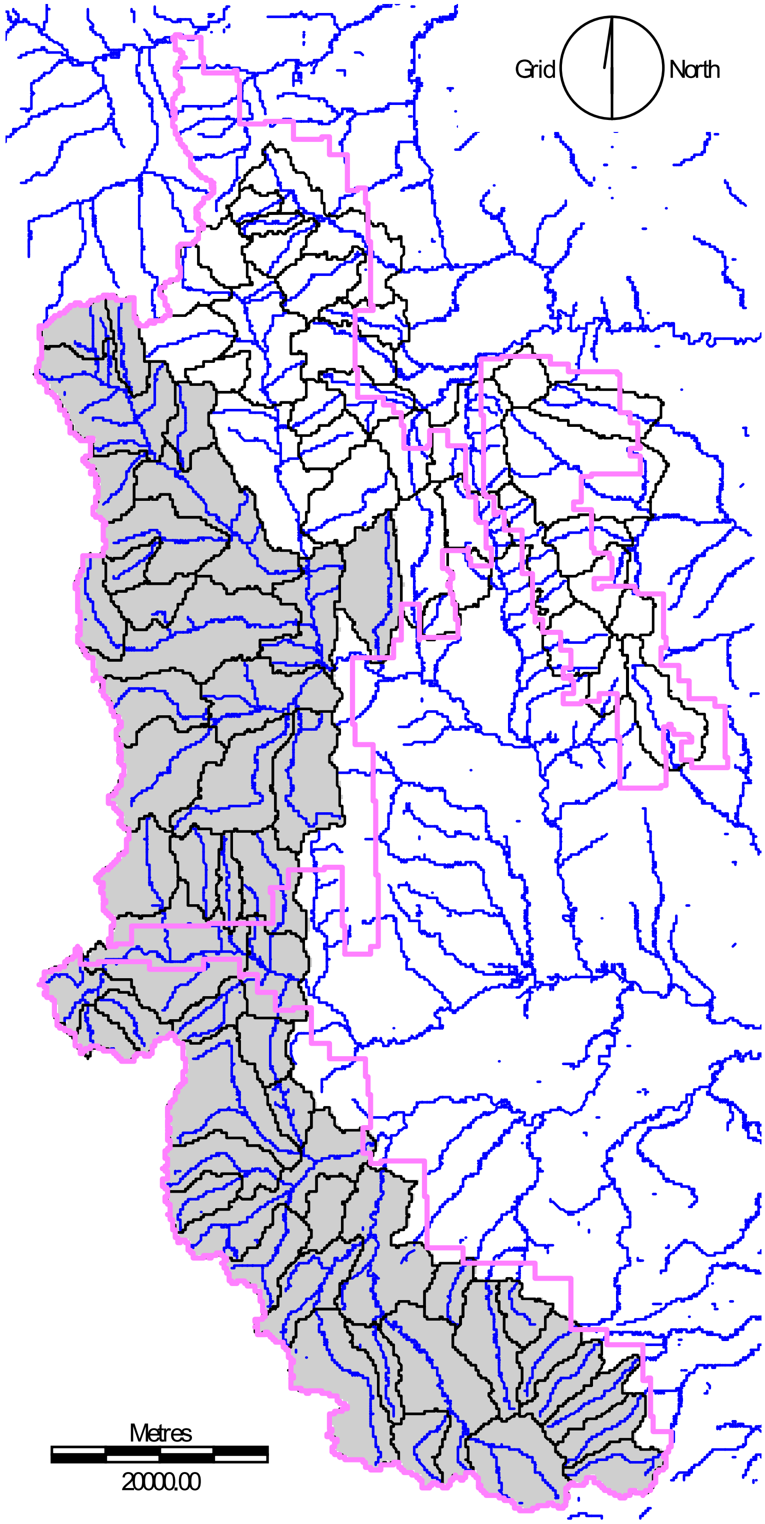

Figure 8-3 The area (shaded) used for the calculation of the fire cycle.

9.0 FIRE REGIME MODELLING

9.1 GENERAL

The stand origin modelling technique used to study fire distribution patterns over the landscape is thought to be a reasonable approach for areas with limited, or lack, of stand age information. As a general rule, fire history data has its own set of limitations which include: an insufficient amount of fire evidence due to the overlap of fires over time, life expectancy of trees sometimes being shorter than the fire return interval, poor quality of tree samples for accurate dating (rotten cores), restricted access and, the inability to sample every single stand due to the time and cost of such research. However, the greatest drawback of the stand origin mapping technique is that we are limited to a single snapshot in time, which amounts to a sample of one, of a landscape that has been shaped for thousands of years by fire. The modelling approach becomes a good complementary technique as it provides a series of stand origin maps and stand age distributions from which basic statistics (average, standard deviation, minimum and maximum) can be drawn. The strongest asset of the STANDOR model, used in this study, is its ability to keep track of the sizes of burned areas before being over-burned or partially re-burned. This feature allows managers to obtain the range of variation in fire size and to calculate the true fire cycle. Another useful feature of the model is that it allows the user to keep stand age information only for areas of interest, such as natural subregions or management subregions.

This chapter first describes how STANDOR works, the data layers used, and specific settings used for each subregion fire regime. Following is a presentation of the results and their interpretation. Simulation results are first described by natural subregion and then by management subregion.

9.2 STANDOR MODEL: HOW IT WORKS

STANDOR is a landscape disturbance model that uses real fire size and frequency statistics typical of an area in order to emulate its long term fire distribution patterns. It distributes fires over the landscape in a randomly "adjusted" fashion that accounts for the effect of fire regime on fire starts. To do so, a "likelihood of getting an ignition" map must be developed. This map is based on the knowledge of human use, density of lightning strikes and fire occurrence reports specific to the study area.

Fire growth is achieved in two ways depending on the burning season: summer or spring/fall. The first one is based on a fuel map that has no factor limiting fire growth, aside from pixels designated as non fuel which will not support fire spread. In this case, every pixel representing fuel has an equal chance of burning. This burning strategy can be used on flat landscapes, or when fire weather indices are high enough that fire will spread without regard to aspect and elevation. The other way of growing fires on the landscape is based on probability values of fire spread based on topography. In the mountains, the spread of spring and fall fires are frequently influenced by topographic components such as elevation and aspect. In early June for example, fuels located on low and southwest facing slopes in mountainous terrain are often available for burning, while there can still be a meter of snow above 1,800 meters on north and east facing slopes. This differential drying process of fuels largely controls fire spread in the mountains during the spring and fall months.

STANDOR allows the user to run up to five different fire regimes per simulation, where an unlimited number of simulations can be specified. The length of the simulation (i.e. 200, 500, 1000 years or more), size of study area and length of time periods (i.e. 5, 10, 20 years ...) are user specified. The fire regimes to be simulated, which differ by their probability of fire ignition distribution and minimum and maximum number of fires per time period, are also user specified. Fire size is governed by the fire growth module, which uses equations from the Canadian Forest Fire Behaviour Prediction System, fuel type, fuel availability, slope, number of daily burning hours and maximum number of days fires are allowed to grow. The intervals between fires or the time to the next arrival (of fire) can also be set. For example, a fire may not be allowed to re-burn an area until it has been 20 years since the last disturbance. For each simulation, the model produces a stand origin map and an age-class distribution. The model also keeps track of the number of fires per time period and the burn area associated with each fire. This feature is critical to calculating the simulated fire cycle.

Model algorithms for fire ignition, spread and extinction

1. Randomly select the number of fires for the time period. This is defined by the minimum and maximum fire frequency.

2. Verify the likelihood of a randomly selected pixel being affected by fire (using the probability of ignition map). If the random number is smaller or equal to the probability of ignition value, then a fire starts. Repeat step 2 until a pixel can support a fire.

3. Verify the fuel type. If the pixel is categorized as non-fuel, repeat step 2 and 3 until the pixel is coded as fuel.

4. Verify the lapse time since the last fire. If fuel is not yet available for burning, repeat step 2 to 4.

5. Verify in which weather zone the fire will start. Then randomly pick a start date within the appropriate weather zone from the fire weather database.

    5.1 If the date of ignition is not during the summer fire season, then the probability of burning (p_burn) map will be chosen to determine fuel availability.

        a) determine the valley orientation for initial fire spread during Day1. The fire has a 50/50 chance of spreading in either valley direction.[2]

        b) determine the probability of burning of adjacent cells by looking at their fuel type, time-since-last fire and p_burn value. If it is not available for burning,

[2] The direction of fire spread is difficult to manage due to the fact that weather stations, where the fire weather data is extracted from, can be many kilometres away from the location of burning fires. Further, in mountainous terrain there is the possibility that the wind direction may be different than that of the valley where the weather station is located. By using a valley orientation map for the first day of burning, it over-rules the wind direction input from the fire weather database and makes the spread of fire a bit more realistic.

repeat step 2 to 5. The p_burn of adjacent cells is determined by comparing their p_burn value to that of the ignition pixel. If their p_burn value is less than that of the ignition pixel, then the fire doesn't spread in that direction.
c) repeat step 5.1b) until fire weather values are too low to support a fire[3], or until the allowable burning time has expired, or until there is no fuel available to burn.

5.2 If the date of ignition chosen falls during the summer months, then no p_burn map is used, which means that there are no burning restrictions.
a) determine the valley orientation for initial fire spread during Day1. The fire has a 50/50 chance of spreading in either valley direction.

b) fire burns until fire weather values are too low to support a fire, or until the allowable burning time has expired, or until there is no fuel available to burn.

6. Repeat step 2 to 5 until the number of fires chosen for the time period (step 1) is reached.

7. Before starting a new period, verify if the fire regime has changed in order to select the appropriate database for the fire frequency and probability of ignition map.

8. Repeat step 1 to 7 for the length of the simulation divided by the length of the time period.

9.3 Data Layers

A set of map layers is needed to run the model, as well as information on fire frequencies and distributions that are specific to the study area. The procedure that was used to create some of the map layers has already been described in Chapter 3, along with information on the source and format of the data used. It is recommended to refer back to this Chapter while reading this Section. Following is a description of each data layer and information on specific inputs used for each subregion modelled.

Note that all GIS raster layers that were originally created at a 20m resolution for this project were converted to 100m resolution to use with STANDOR. This had to be done to accommodate the fact that the program was written under the old MS-DOS technology and that the size of the landscape at 20m resolution contained too many rows and columns for the program to process. Despite the coarser resolution (1ha or $100m^2$), it is largely sufficient for forest management planning considering that computer modelling is not a precise science but a supplemental tool to understanding the fire regime.

[3] The rate of spread is determined by the FFMC (fine fuel moisture code) and wind speed. The minimum rate of spread is set to be of 1 m/min. Stand replacing fires are set to occur on days with BUI (build-up index) values greater than 60 or 70 depending on the region modelled.

9.3.1 Fuel type map

This map represents the type of forest fuels as described by the Canadian Forest Fire Behaviour Prediction System (CFFBS) (Forestry Canada 1992). The model uses formulas from the CFFBS to calculate the rate of fire spread based on a combination of these elements: fuel type, slope, wind speed, FFMC (Fine Fuel Moisture Code) and BUI (Build-Up Index). A total of 8 fuel type categories can be found on the C5 region (Table 9-1 and Figure 9-1).

Table 9.1 Number of hectares and (percent coverage) per fuel type category for the entire landscape and by management subregion.

FBP	PH	Castle	CDS	Living.	CDN	C5
C1: spruce/lichen woodland	233 (0.59)	3,396 (6.28)	6,601 (9.95)	6,178 (4.04)	2,938 (7.48)	19,346 (5.50)
C2: boreal spruce	1,589 (4.03)	9,948 (18.41)	25,149 (37.91)	26,770 (17.51)	17,673 (45.02)	81,129 (23.05)
C3: mature pine	4,112 (10.43)	14,981 (27.72)	12,861 (19.39)	61,650 (40.33)	6,864 (17.49)	100,468 (28.54)
C4: immature pine	561 (1.42)	582 (1.08)	828 (1.25)	855 (0.56)	2,377 (6.06)	5,203 (1.48)
C7: Douglas fir	13,674 (34.69)	1,893 (3.50)	788 (1.19)	5,811 (3.80)	365 (0.93)	22,531 (6.41)
D1: aspen	11,175 (1.03)	3,271 (6.05)	639 (0.96)	13,019 (8.52)	30 (0.08)	28,134 (8.00)
M1: mixedwood	4071.03	552 (1.02)	286 (0.43)	2,586 (1.69)	16 (0.04)	3,847 (1.09)
O1a: matted grass	7,663 (19.44)	12,959 (23.98)	12,605 (19.00)	30,356 (19.86)	2,804 (7.14)	66,387 (18.87)
Water	0 (0.00)	122 (0.23)	104 (0.16)	152 (0.10)	14 (0.04)	392 (0.11)
NF: non-forested	8 (0.02)	6,340 (11.73)	6,474 (9.76)	5,486 (3.59)	6,175 (15.73)	24,483 (6.96)
Total	39,422	54,044	66,335	152,863	39,256	351,920
Total vegetated	39,414 (99.98)	47,582 (88.04)	59,757 (90.08)	147,225 (96.31)	33,067 (84.23)	327,045 (92.93)

9.3.2 Elevation map

An unclassified 1:20,000 digital elevation model was used as part of a base layer to grow fires on (Figure 9-2). Elevation values are used by the model to determine terrain slope and calculate the appropriate rate of fire spread. Rate of spread of fires moving down hill move at the same rate as fires burning on flat terrain. The minimum rate of fire spread in the modelling exercise was set at 1m/min.

9.3.3 Valley orientation map

This map is used to determine the initial direction of burning of the fire during day 1. This feature was implemented because the fire weather data comes from weather stations that may be located in another valley that is under the influence of different valley wind directions than those where fires are actually burning. To account for valley wind, the fire will spread equally in both valley directions on day one. For example, in a valley running west to east, the fire will spread equally in both east and west directions. Burning on subsequent days will be under the influence of wind, as reported by the weather station. This map was created as part of the air photo screening process (Section 7.9, Figure 7-10).

9.3.4 Weather zone map

This map is used to outline zones of similar fire weather data. Each zone is linked to either a single or set of weather stations. This is an important feature for mountain landscapes, as higher elevations portray higher levels of humidity and cooler temperatures, hence reduced FFMC and BUI values. As a result, ignitions at higher elevations may initially not spread as fast as those from lower elevations. The exception to the rule is during the occurrence of temperature inversions, but this phenomenon is not common during the summer time on the east slopes of the Canadian Rockies.

Boundaries from natural subregions, in combination with the partition of elevation data into zones, as well as locations of weather stations, were used to create seven weather zones (Figure 9-3). Weather stations used had to have at least 10 years of fire weather data available. Three weather stations in the north section of C5 could not be used because hourly weather data had not been collected and no fire weather values had been calculated. Those were Hailstone Butte (HB), Sugarloaf (SG) and Livingstone (LV). Instead, weather from the Ironstone station (IS) was used for elevations greater than 1800m for the entire C5 FMU. Details pertaining to the weather stations are outlined further down in subsection *i) fire weather data*.

Table 9-2 Description of weather zones and their associated weather stations.

Wx zone	Description	Elevation zone	Weather stations
1	Montane under mountain influence, north of Highway 3	<1800m	Livingstone Gap (C1)
2	Subalpine and Montane, all of C5	>1800m	Ironstone (IS)

Wx zone	Description	Elevation zone	Weather stations
3	Montane under prairie influence, north of Highway 3	<1500m	Willow Creek Auto (B2)
4	Montane under prairie influence, north of Highway 3	>1500m	Porcupine (PL)
5	Montane, south of Highway 3	>1360 and <1800m	Carbondale (CB)
6	Prairies, south of Highway 3	<1360m	Castle Auto (C2)
7	watersheds in Crowsnest corridor	variable	Blairmore (BQ)

9.3.5 Initial stand age map

This is the initial stand age layer used to grow fires on. The entire study area was simply given an arbitrary age of 100 years. At the end of the 1000 year period of simulations, anything that had not burned during that time could easily be tracked down by looking for stands 1100 years of age.

9.3.6 Probability of ignition map

The probability of ignition map represents the chance a pixel has of getting an ignition. The model generates a random number from 0 to 100. If the random number is less than the p_ignition value of the pixel, then the fire starts. The probability of lightning ignition map that was created as part of the recent fire regime assessment process in Section 6.1.10 (Figure 6-3), was used as a base map to add probabilities of human ignition that are representative of historical human land use from the 1800's and early 1900's.

For this study, we are interested in the historical fire distribution before the strong influence of Europeans on the land. A certain amount of influence from anthropogenic fires must however, be included in the fire regime simulations because we know that lightning ignitions contribute to only 10% to 37% of all ignitions within the different management subregions. As many portions of the landscape appear to have been burned repeatedly according to the air photo screening process, we must assume that there were always a certain number of fires ignited by humans. First Nation People have been part of this land and the ecosystem since the retreat of the ice cap from the last glaciation, and as such they must be part of the equation when modelling the historical fire regime.

Although this project did not involve archival research on land use from the last 300 to 500 years, it is common knowledge that First Nation People used the land extensively during that time period. To incorporate the risk of ignitions from historical anthropogenic sources, only roads that are commonly and highly travelled today (2 lane roads), as well as towns and campgrounds were taken into consideration. In many cases these roads are located in the same travel corridors that were used by natives, first explorers and fur traders. Figure 9-4 shows the probability of ignition map that was created specifically to model the historical fire regime. With the combination of lightning and anthropogenic sources, probabilities of ignition ranged across the landscape from 7 to 178%. This means that a fire will always take place for cells with probability values greater than 100%.

9.3.7 Probability of burning map

In mountainous terrain, probabilities of burning vary spatially according to aspect, elevation and valley orientation. This effect is pronounced during the spring/fall season when north facing slopes and higher elevations can have snow on the ground, or a much higher fuel moisture content, which inhibits the spread of fire. Using a probability of burning model, each pixel is assigned a p_burn value on a scale from 0 to 100. Before spreading into neighbouring pixels, the p_burn value of the pixel is compared to that of the ignition pixel. If the p_burn value of the pixel is less than at ignition time, the fire will not spread in that direction.

The spring/fall season is determined in the fire weather database (subsection (i)). The length of the summer season in the C5 region varies according to elevation zones. During the summer period, all pixels are assumed to have the same probability of burning and no p_burn map is used. For all other dates, the fire spread is determined in part by the p_burn map. For example, if a spring fire starts at low elevation and on a south facing slope, that fire will not be allowed to spread higher than a certain elevation or on to north or east facing slopes. But, if that fire starts at a high elevation or on a north facing slope, it would be able to spread anywhere as other p_burn values would be greater than the p_burn value from the ignition pixel.

Probabilities of burning vary with topographic locations. An extensive study covering the east slopes of the Canadian Rockies (Banff National Park and the Spray Lakes Recreation Area of Kananaskis Country) found that valley orientation, elevation, aspect and distance from the Continental Divide play a significant role in fire distribution and spread in the mountains (Rogeau et al. 2004). Results from this study were borrowed and modified when needed to build a GIS weighing and ranking model that should reflect probabilities of burning for the C5 region. Partitioning of elevation and aspect data for the subalpine and montane subregions were taken as is. Distance from the Continental Divide was adjusted to reflect the mountain landscape width, which is narrower in this region of the Canadian Rockies. However, the valley orientation variable had to be discarded because many valleys in the C5 region did not have an orientation assigned to them, and some valley orientations found in this study area were not present in the topography study, and vice-versa. Excluding valley orientation from the probability of burning model is assumed not to have a significant effect on probabilities of burning during the spring and fall seasons. As valley orientation is spatially auto-correlated with both aspect (there can only be two prevailing aspects by valley orientation) and elevation, some of the effects of valley orientation on burning patterns are accounted for. During the spring and fall seasons, the fuel drying process and its availability for burning are largely driven by temperature and sun exposure, which are both captured by aspect and elevations.

Topographic classes were ranked on a scale of 1 to 5, 5 being the highest likelihood of burning. Each variable was also weighed by multiplying the ranked map with a percentage value in terms of its relative influence on fire distribution. Results from the grouping, ranking and weighing process are shown in Table 9-3. Each ranked and weighed map was then overlaid and subsequently divided by 5 (the number of ranks) to obtain the p_burn map. These map manipulations can be represented by the following equation:

p_burn = (0.50*[elevation_r] + 0.30*[divide_r] + 0.20*[aspect_r]) / 5
r = ranked

With this model, probabilities of burning range spatially from 20 to 92% (Figure 9-5).

Table 9-3 Ranks and weights of topographic groups used to create the probability of burning map.

Variable	Subalpine	Montane & Foothills
Elevation (50%)	5: 1400 - 1600m 4: 1600 - 1700m 3: 1700 - 1800m 2: 1800 - 2000m 1: 2000m+	5: <1600m 2: >1600m
Continental Divide (30%)	5. > 36 km 4: 26 - 35 km 3: 16 - 25 km 2: 1, 6-15 km 1: 2 - 5 km	
Aspect (20%)	4: SW, W 3: S 2: NE, E, SE 1: NW, N	3: SE, S, SW, W 2: NE, E 1: NW, N

9.3.8 Mask map

This map layer is only utilised if the user is interested in obtaining fire cycle information for a specific area. The mask has a value of one for the area of interest and a value of zero for the remainder of the landscape. For this project, masks were used to focus on natural and management subregions. Note that during the fire growth simulations, fires are distributed throughout the landscape but any information that is not of interest is then discarded.

9.3.9 Fire weather data

Before a fire is allowed to spread on the landscape, the program looks in the fire weather database (Table 9-4) to find fire weather data associated with the proper weather zone (based on the weather zone map). It then randomly picks a date and reads the fire weather values for that day. To ensure that we are modelling fire regime conditions that will sustain stand replacing fires, the database contains only the dates where BUI values are greater than 70. This value was chosen because high intensity stand replacing fires in mountain settings tend to occur on days with a BUI value greater than 70. The fire growth model will then grow fires for as long as there are consecutive days with a BUI of 70. That said, during the calibration of the fire growth model, it was found that burning fires for several days could lead to extremely large, and unrealistically big, fires that could burn the whole landscape. To regulate fire sizes, this setting was over-ruled by specifying a maximum number of burning days. Other ways to adjust fire sizes (not used for C5) can be by playing with the number of daily burning hours, which are based on the number of daylight hours, or by modifying the FFMC values.

Table 9-4 Fire weather data for the stand origin modelling sessions came from six weather stations.

Station (code)	Lat. , Long.	Elevation (m)	In operation since
Blairmore (BQ)	49.6086,-114.4514	1299	1974
Castle Automatic (C2)	49.3936,-114.3408	1360	1987
Carbondale (CB)	49.4315,-114.3579	1807	1974
Ironstone (IS)	49.5677,-114.5005	2079	1974
Livingstone Gap (C1)	49.8793,-114.3827	1417	1987
Porcupine (PL)	49.887,-114.004	1820	1974
Willow Creek Auto (B2)	50.2390,-114.3480	1478	1987

Each weather station was assigned a code to link it to its respective weather zone (Figure 9-3). All weather station data sets were appended to form a single file containing these attributes:

- year
- month
- day
- wind direction
- wind speed
- FFMC (Fine Fuel Moisture Code)
- BUI (Build-Up Index)
- summer: true or false statement
- number of day light hours (see Table 9-5)
- number of daily burning hours (1/3 of the day light hours)
- weather zone code (from the weather zone map)

Table 9-5 Number of day light hours associated with time of year.

Dates	Day light hours	Dates	Day light hours
April 1 - 13	13	Aug. 12 - 31	14
April 14 - 30	14	Sept. 1 - 11	13
May 1 - 19	15	Sept. 12 - 25	12
May 20 - July 22	16	Sept 26 - Oct. 31	11
July 23 - Aug. 11	15	Nov. - March	10

9.3.10 Fire frequency

The number of fires that will burn per period (10 years for these simulations) are chosen randomly between a given minimum and maximum fire frequency. Using the provincial fire occurrence database (1960 to 2003), the average fire frequency value was determined. Because many fires that were suppressed were not likely to ever become large, only those larger than 1 ha were considered. In the Kananaskis region, about 20% of fires become larger than 1 ha and have a chance to significantly alter the age mosaic. In the C5 region, however, this number drops to 10%. During the model calibration it was found that using only 10% of the total number of fires was unrealistic and the outcome was too long of a fire cycle, well beyond the estimated historical fire cycle values. The modelling was also attempted with 20% of the total number of fires, but 30% of the total fires presented the best approximation of fire cycle.

The number of anthropogenic fires recorded since 1960 also had to be reduced to be more representative of historical conditions. The percent reduction in people fires vary according to the subregion and its estimated historical human use (Table 9-6).

Table 9-6 Fire frequency statistics by natural subregion used for the fire regime modelling.

Sub-region	Avg. lgt fires / 10yrs	30% lgt fires / 10yrs	Avg. people fires / 10 yrs	30% people fires / 10yrs	# of fires following % reduction in people fire	Total avg. # of fires / 10yrs	Fire frequency range
Alp./Sub.	20	6	45	14	60% = 8	**14**	**4 - 24**
Montane	23	7	88	26	70% = 18	**25**	**5 - 45**
C.D.N.	2	1	7	2	60% = 1	**2**	**1 - 3**
Living.	11	3	34	10	70% = 7	**10**	**3 - 17**
C.D.S.	6	2	15	5	60% = 3	**5**	**2 - 8**
Castle	5	2	12	4	60% = 2	**4**	**1 - 7**
P. Hills	7	2	10	3	70% = 2	**4**	**1 - 7**

9.3.11 Other inputs

Other inputs required to run the model include:

- number of iterations: 5
- simulation length: 1000 years
- age class: 10 year[4]
- disturbance lapse time: variable, see Section 9.4 (this is the number of years after a fire that are necessary for the forest to be able to support a subsequent stand replacing fire)
- number of burning days: variable, see Section 9.4
- length of summer season: variable, see Section 9.4

[4]A 10-year age-class was chosen as a logical class breakdown for simulated (i.e. not real) data. Larger size age-classes are easier to handle for forest management, but it is preferable to initially collect the information in 10-year increments and reclassify to 20- or 50- year increments depending on the application.

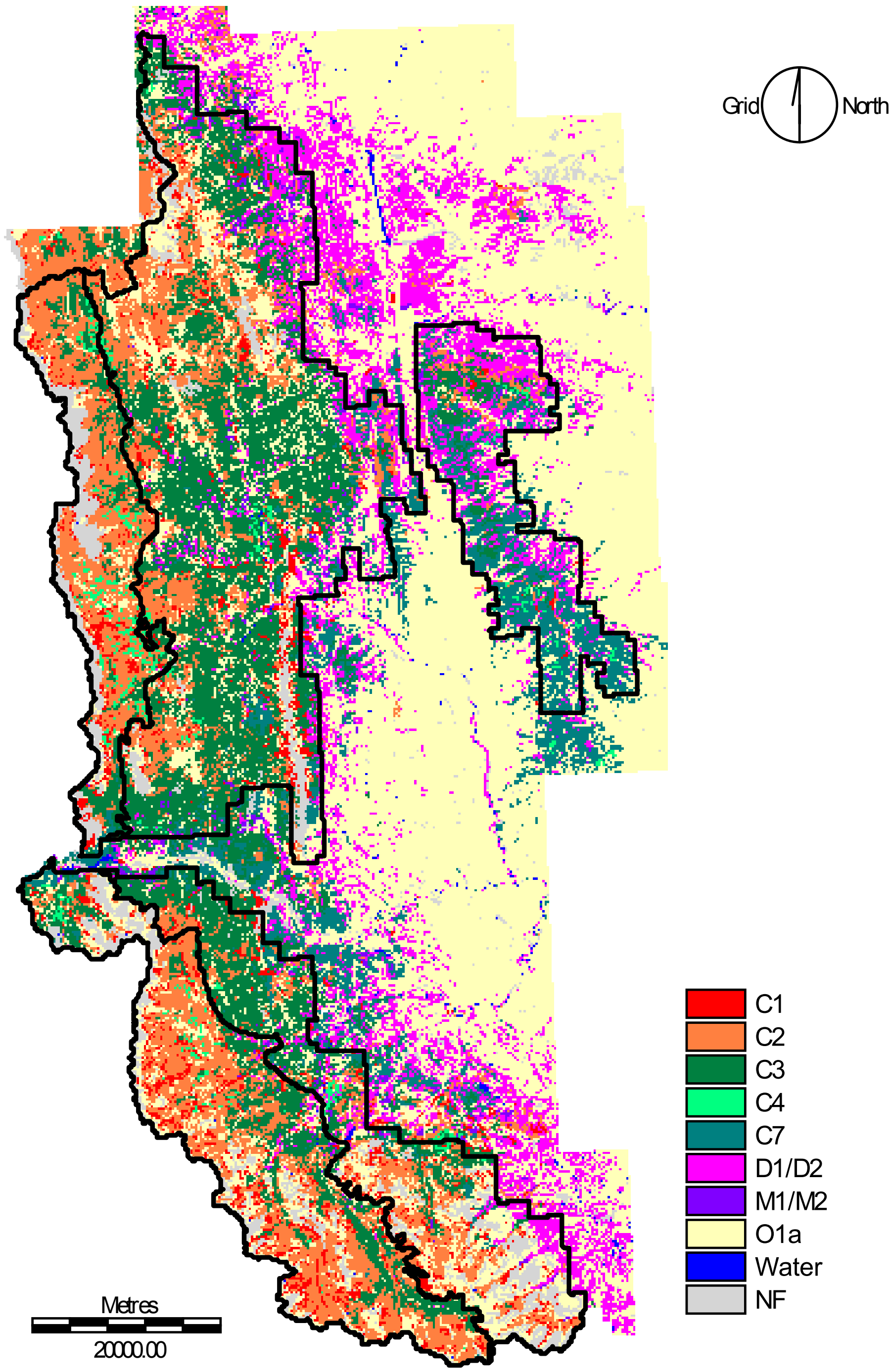

Figure 9-1 FBP fuel type map for the C5 FMU region.

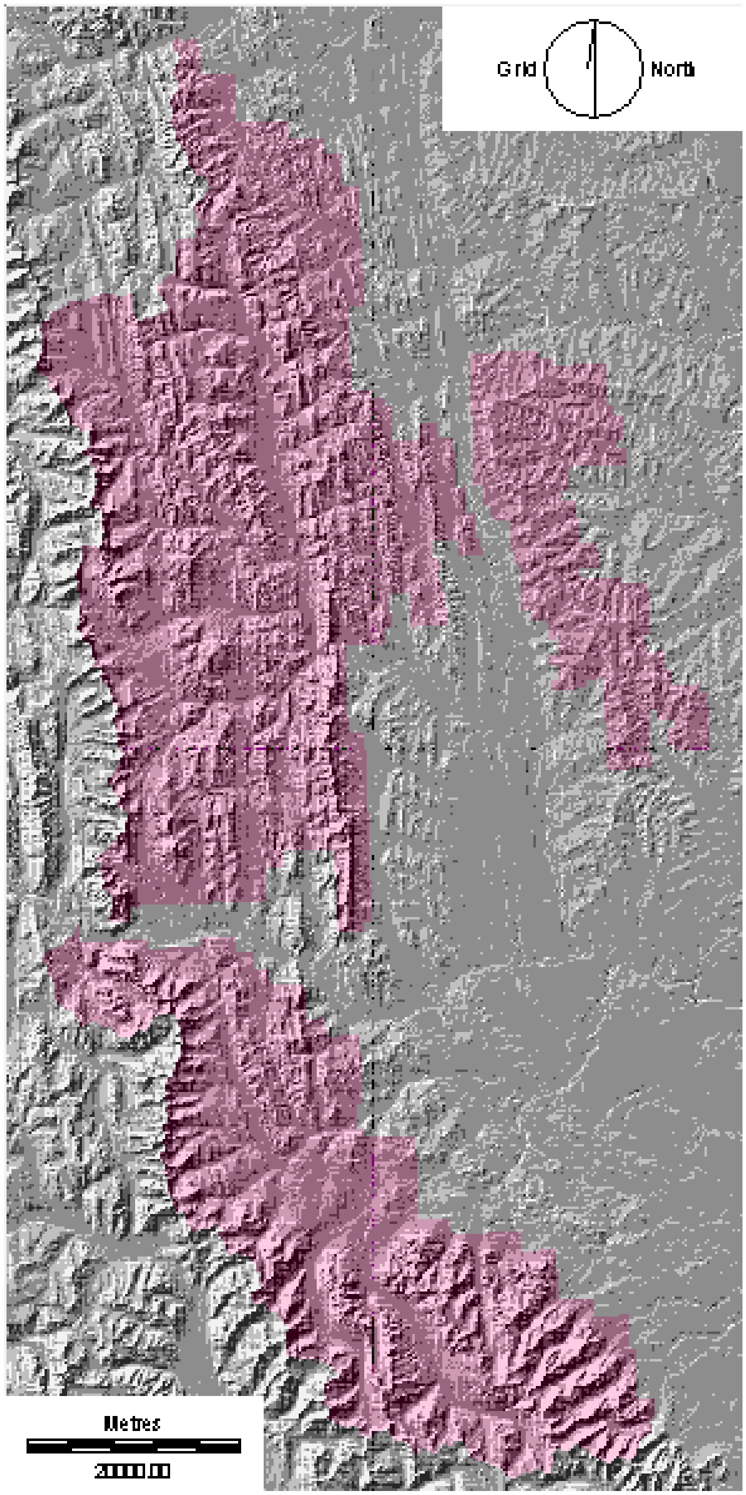

Figure 9-2 Elevation model for the C5 FMU region.

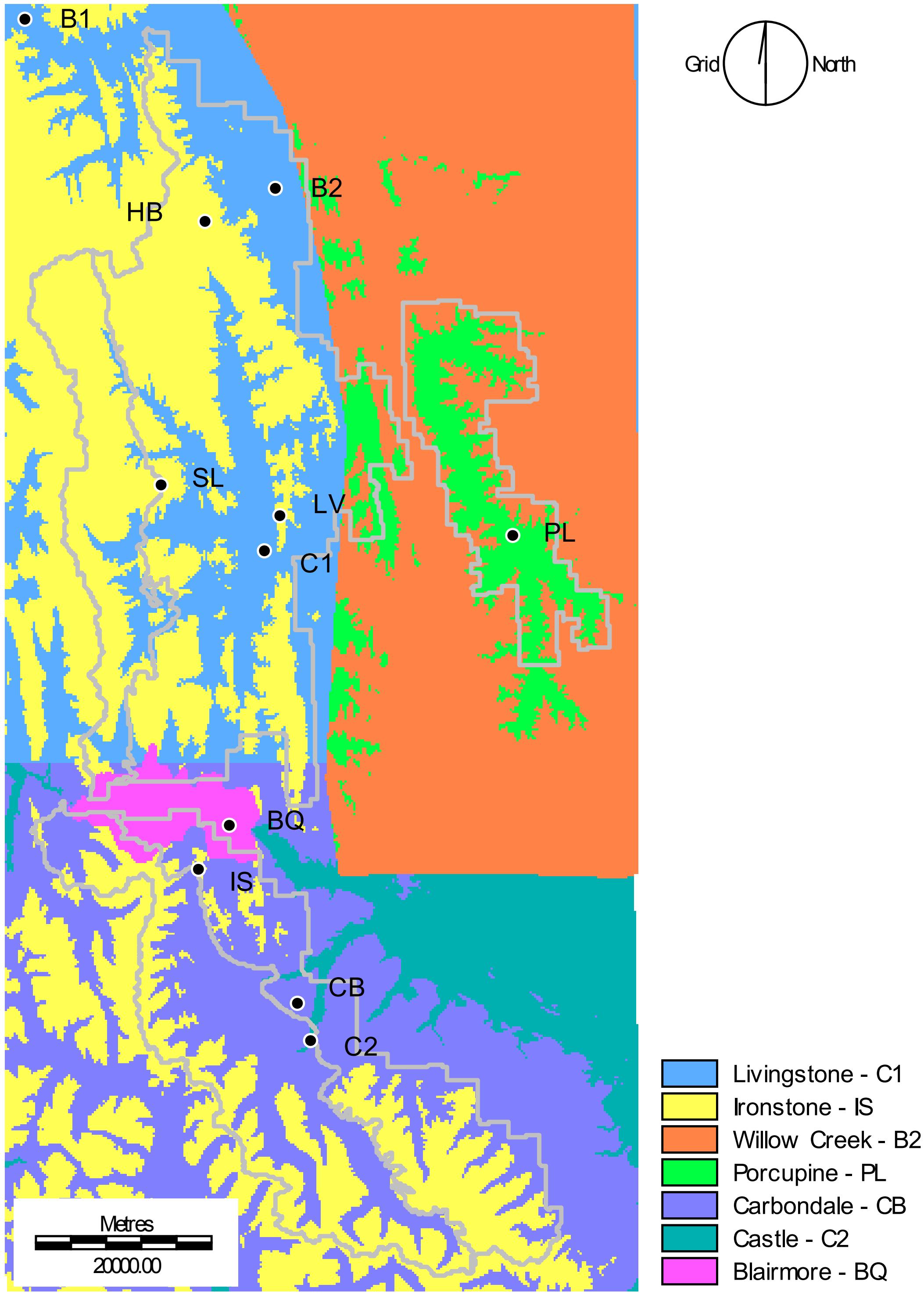

Figure 9-3 Zones of similar fire weather and location of weather stations.

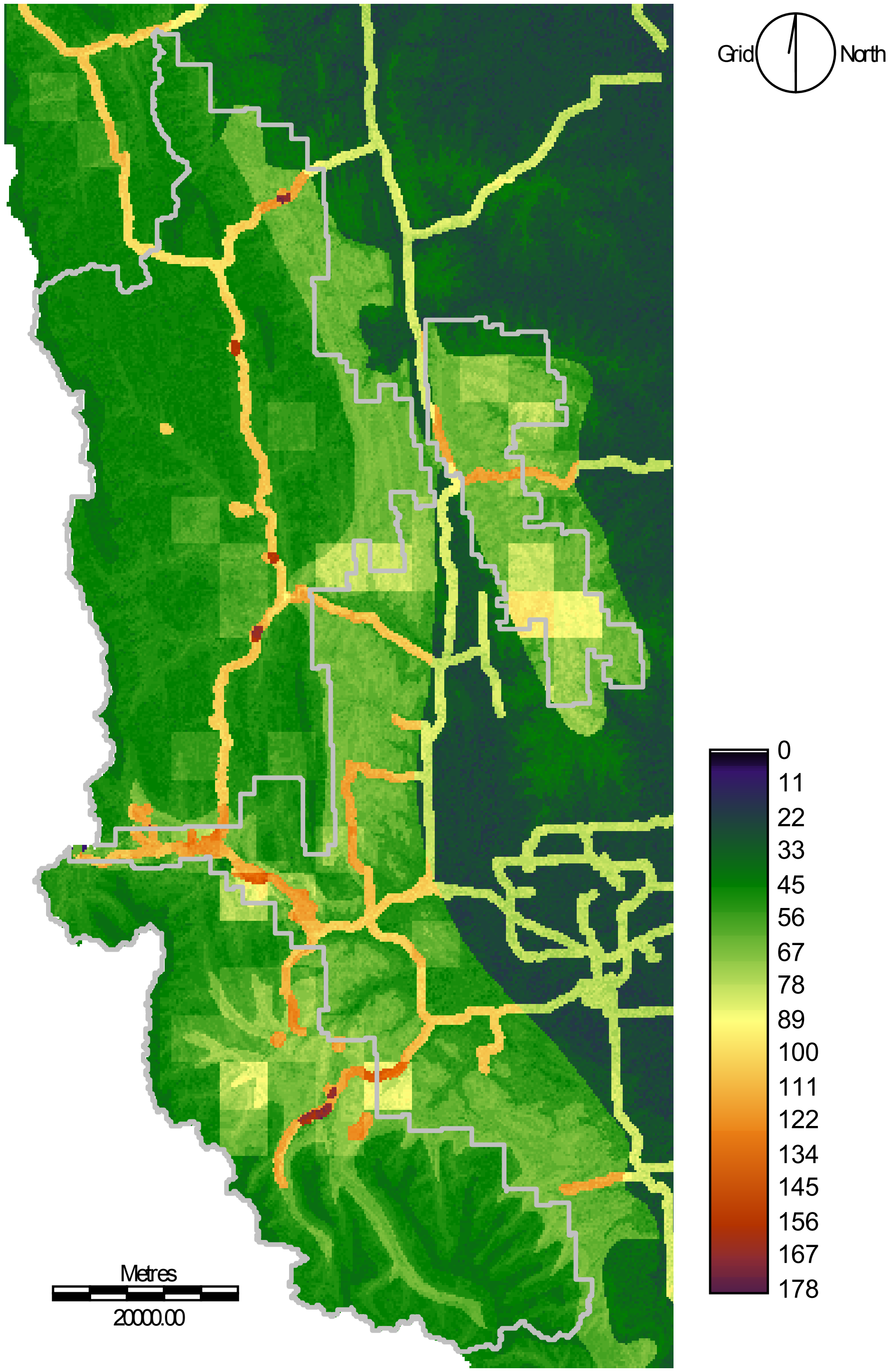

Figure 9-4 Probability of ignition model representing both lightning and anthropogenic ignitions from the turn of the century. Presented in percent probability values.

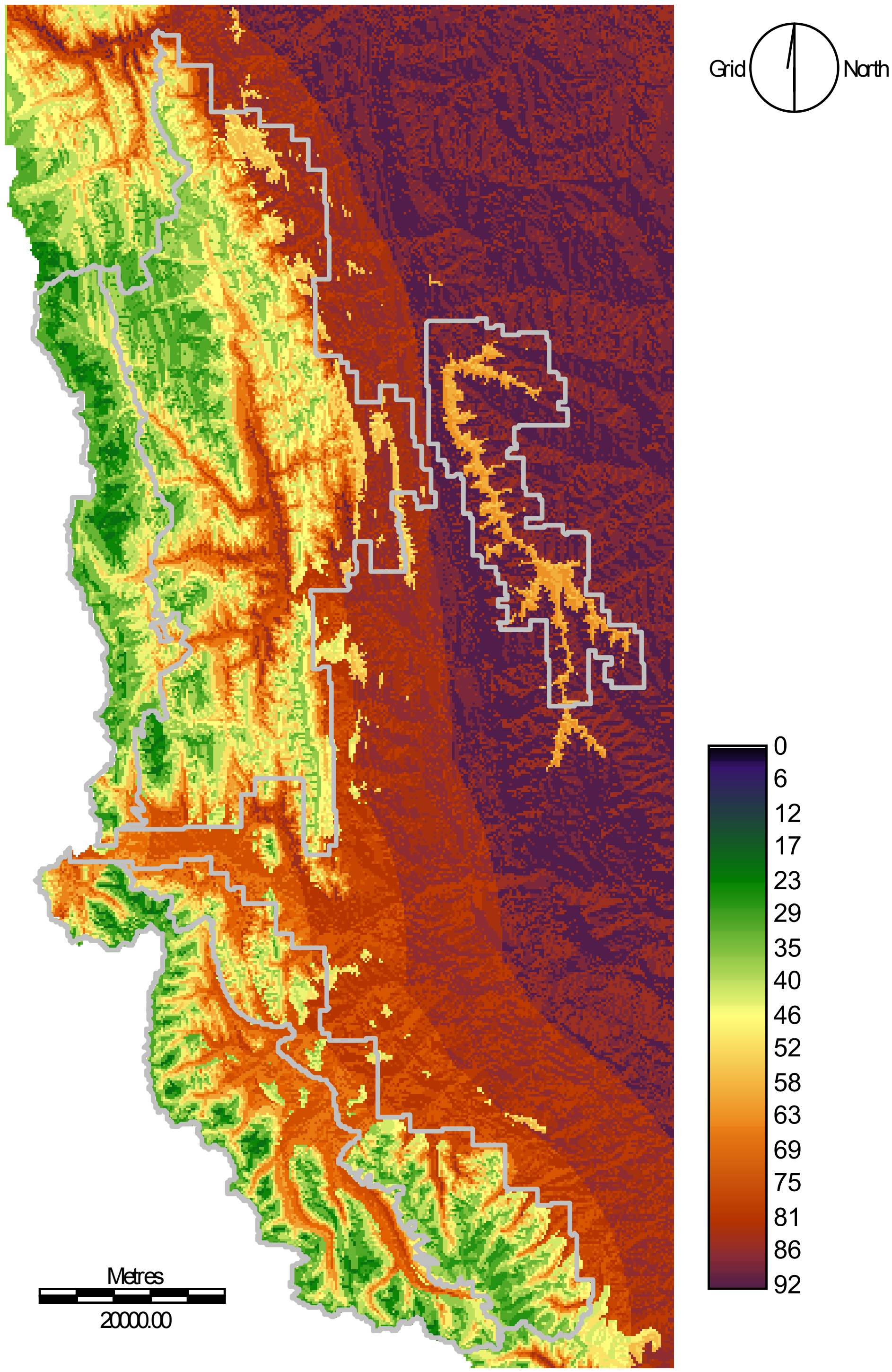

Figure 9-5 Probability of burning model based on elevation, distance from the Continental Divide, and aspect. Presented in percent probability values.

9.4 SPECIFIC DATA INPUTS BY SUBREGION

The fire growth model was tested and calibrated for each natural subregion by repeatedly running the model for a few hundred years until the average fire size was representative of the targeted fire regime. The acceptable range in fire sizes relied on the recent fire mapping exercise (see results in Chapter 8), and general knowledge of fire behaviour specific to this area. It was found that it was impossible to obtain realistic fire sizes by letting the model run its course; that is by burning as many days in a row, as long as the BUI values were greater than 70. With no burning restrictions under severe fire weather danger, and using the Fire Behavior Prediction equations, an entire natural subregion could burn. This problem was overcome by calibrating the model with a maximum number of burning days, which differed among the subregions. The number of large size fires also had to be reduced by allowing more spring/fall burns. Many summer fires were burning extensively into every headwaters along the Continental Divide, which was resulting in very short fire return intervals in regions known for their extensive areas of old growth forest. Extending the length of the spring/fall season, which allowed a more frequent use of the probability of burning map, provided more realistic burning patterns in the subalpine environment. In the end, one must keep in mind that in this fire regime simulation exercise, it is the outcome that is important and not so much how it was achieved. Fuel type coverages are generalized and weather stations are remote and not necessarily representative of the local weather pattern where fires are burning. As a result, some parameters had to be adjusted in order to compensate for fires burning too hot or not enough. The parameters used for each subregion are presented in Table 9-5.

Table 9-7 Fire growth model settings specific to each subregion.

Settings	Sub.	Montane	CDN	Living.	CDS	Castle	P. Hills
max. # of burning days	2	2	2	2	2	2	3
fire lapse time (yrs)	20	20	20	20	20	20	10
summer: (no p. of burning map used and leaf-on period)	Aug. 1-30	Aug. 1-30	Aug. 1-30	Aug. 1-30	Aug. 1-30	Aug. 1-30	Aug. 1-15
BUI breakpoint	70	70	70	70	70	70	70
fire frequency range per decade	4 to 24	5 to 45	1 to 3	3 to 17	2 to 8	1 to 7	1 to 7
targeted mean fire size (ha)	1800	2300	1800	1800	1800	1800	2700

9.5 Spatial Results

A set of five fire regime simulations were run for each natural and management subregion, for a total of 35 simulations (5 x subalpine and montane natural subregions, and 5 x CDN, Livingstone, CDS, Castle and Porcupine Hills management subregions). However, because the fire simulation outputs were eventually to be assessed by cover type, the set of fire regime simulations for each subregion modelled had to be repeated twice to account for two different percentages of coniferous content in mixedwood forests. The cover types "CD" (mixedwoods with a coniferous dominance) and "DC" (mixedwoods with a deciduous dominance) were accounted for by assigning a percent of coniferous trees equal to 65% and 35% for CD and DC, respectively. All simulations were repeated twice under these different percent of coniferous content because STANDOR can only handle one reading of % of conifer amount for mixedwood forests. In the end, a total of 10 simulation per subregion were ran for a grand total of 70 simulations.

There are two spatial outputs from STANDOR: a stand origin map and a fire count map (how many times a pixel has burned in 1000 years). The fire count map is useful to assess the mean-fire-return-interval (MFRI), and how it varies spatially. It is simply calculated by dividing 1000 by the fire count. As a general rule, the MFRI is shortest where probabilities of ignition are the greatest. Another output of STANDOR are tables that list the age-class distribution from each stand origin map, and individual fire sizes before being overlapped by subsequent burns. The fire size list is used to determine the natural range of variation in fire size and to compile burn areas until they equal the total forested land base, which is the fire cycle. Note that simulation results pertaining to fire sizes and fire cycles are presented in Chapter 10 and 11, respectively. Fire simulation outputs were also assessed by forest cover type per subregion, and these results are presented in Chapter 12.

A mean stand origin map and a mean fire count map (average based on 10 simulations) are presented for each natural subregion and management subregion. Each mean stand origin map is the outcome of a fire regime customized to each subregion. While the stand origin maps presented in the report target only the areas of interest (i.e. subregions), fire growth was taking place on a larger size landscape which allowed for external fires to burn into a subregion and vice-versa. The process consists of an unlimited number of ignitions which are distributed using the probability of ignition map. The program then keeps track of the number of ignitions within the subregion modelled, as well as fires spreading into the subregion from the outside. Burn areas are recorded only for the land within the subregion, while the age-class distribution is extracted by cropping out the stand origin map for the targeted subregion.

9.5.1 Understanding modelling limitations

While interpreting the spatial distribution of age-classes over the landscape, it is important to be aware of the data set limitations. First, no fuel type map was used from British-Columbia which means that there was no source of fire coming from the west. This would have modified the burning dynamics for valleys with treed passes along the Continental Divide. Second, STANDOR does not have a spotting function. This means that any areas of non-vegetation, as narrow as it might be, created a fire barrier that would stop fire spread in that direction. FBP fuel types, such as aspen (D1) and Douglas-fir (C7), had difficulty burning for different reasons. D1 largely burns during the spring and fall when the leaves are off. Summer fires in deciduous stands would occur only during extreme droughts. C7 assumes that a stand is fairly open and that crown fires would occur only during windy events. Very little information exists on the season of preference for stand replacing fires in the Southern Canadian Rockies. Fire scars collected in the Upper Foothills of Kananaskis District show that more trees were scarred during the spring and fall than during the summer time. A study on fire intervals around meadows in the front ranges of the Southern Rockies (from Jasper to Waterton) showed similar conclusions (White 2000). During the model calibration for the different subregion, the summer period was shortened to attempt a more realistic burning pattern and fire frequency in aspen stands. Despite this, deciduous stands still reflect much longer fire return intervals than what it should be in reality. Aspen stands from the boreal forest can have MFRI as short as 10 to 30 years. There is no reason why this should not apply here, unless the number of stems per hectare is much lower and cannot sustain a moving crown fire, but is pre-disposed to surface fire.

Despite some of the limitations described above, overall simulation results appear to reflect the different fire regimes in a satisfactory manner. The different probabilities of ignition are well represented on the fire count maps, and the range in fire frequency and targeted mean fire size prescribed for each natural subregion were well captured according to the list of fire sizes and the outcome of the age-class distributions and spatial distribution of stand ages on the landscape.

9.5.2 Subalpine and Montane subregions

Figures 9-6 and 9-7 show the mean stand origin and mean fire count maps for the natural subregions. Results from both sets of simulations: montane and subalpine, were pasted together to reduce the number of maps presented. Stand origin simulations for the natural subregions present a landscape-wide perspective of the spatial distribution of age classes and MFRI. Both the probability of ignition and probability of burning maps account for the frequency of burning of individual pixels. An elevation gradient can be observed from west to east where older aged forests tend to be located at higher elevations in closer proximity to the Continental Divide. Zones of younger aged forests are found at lower elevations but also tend to coincide with zones of higher probabilities of ignition.

The Crowsnest Corridor, which belongs to the Montane subregion, has an unusually long MFRI and older aged forests. As described above in the modelling limitations, this was attributed to the fact that there was no source of fire coming from BC, which is upwind with dominant westerly winds. Coniferous fuels are also fragmented by small patches of deciduous and mixedwood forests, as well as non-fuel patches, all of which would have limited the extent of fire spread.

Discrepancies can be expected in the spatial outputs between the natural subregions and the management subregions. For the natural subregions, fires are distributed spatially over a much larger landscape and areas with greater probabilities of ignition or more flammable fuels will see more fire activity and a greater number of large size fires. For the smaller management subregions, fire occurrence statistics were used to “force” a fixed fire frequency on each subregion. Thus, the outputs should be more reliable at the management subregion level than at the landscape-wide level. An example of a noticeable discrepancy is between the Montane and the Porcupine Hills. Because aspen and Douglas-fir could not always sustain a fire during the summer months, the Montane spatial outputs show that fires ended up burning on the prairie outskirts in the matted grass fuel type. It should be noted that the matted-grass fuel type was used for both summer and spring/fall fires, which is why fires could burn easily at all time in that fuel type. However, during model calibration for the Porcupine Hills, the number of summer days was reduced to only 15 to boost more fires in the deciduous stands.

Although the information provided at the natural subregion level is interesting for comparison purposes between the Subalpine and Montane subregions, forest and fire management planning for C5 should be done at the management subregion level. This was also suggested in both the recent and historical fire regime assessments, because each of the management subregions appear to have a unique fire regime even though similarities do exist between each of them.

9.5.3 Continental Divide North and South subregions

Figures 9-8 to 9-11 show that both subregions display similar features in terms of age-class distribution and their MFRI. Older aged forests are largely found right along the Continental Divide and at the headwaters of valleys that are dissected by rocky ridges. Forests tend to become increasingly younger further away from the Continental Divide. When comparing both subregions along the Continental Divide, the north region displays a greater extent of old aged forests. This is explained by the fact that its fire regime is characterized by a lower fire frequency than south of the Crowsnest Corridor.

The north portion of CDS (Ptolemy, Crowsnest and East Crowsnest Creeks) contains large extents of old growth forests, perhaps more than what the historical level would have been. This is explained by the modelling limitations discussed in Section 9.5.1. There was no source of fire from BC over Ptolemy Pass nor from Crowsnest Pass. The amount of Douglas fir (C7 fuel type) at Crowsnest Pass, near the mouth of these valleys, also inhibited fire spread up these valleys.

9.5.4 Livingstone subregion

As shown in Figures 9-12 and 9-13, the spatial distribution of younger aged forests seems to be found at lower elevations, as well as along the Oldman River and along Road 940. These two areas correspond to zones of higher likelihoods of ignition. Much of the old growth forests found within that subregion is the result of the modelling limitations stated in Section 9.5.1. Most notably the rocky spine of the Livingstone Range provides a good fuel break. The immediate east slopes of the range are also fragmented by deciduous and Douglas-fir patches, which do not sustain stand replacing fires as frequently as pine and spruce stands. A similar problem at the north tip of the subregion can be observed. Aside from a large number of aspen and mixedwood patches present in that area, the fuel type map ends roughly 0.5 km west of the subregion boundary. This means that chances of having a fire encroaching from the outside from that direction was much lower.

9.5.5 Castle Subregion

Most of the Castle subregion is in the path of fire burning from the west or from the east. This is well illustrated in Figures 9-14 and 9-15 by the amount of younger aged forests found in the narrower portion of the subregion. The southeast corner of the subregion (Yarrow, Spionkop, South Drywood and Drywood valleys) encompasses a large amount of old aged forests. This is due to the fact that south facing slopes are almost bare of vegetation (patches of dirt/rock and low shrubs) and that prevailing westerly winds prevent prairie grass fires to burn into these valleys. Historically, and as the model shows, most fires came from the Castle valley to the west. A close to the ground reconnaissance flight with the helicopter showed that the bare slopes were not “littered” with old burnt snags. This indicates that there hasn’t been timber on these slopes for the last couple of centuries. This was not the case in the Livingstone region where fires burned timbered south facing slopes that never grew back. These slopes are now grass covered but snag remnants on the ground are still visible. Cattle grazing may have had a role to play in this region.

9.5.6 Porcupine Hills subregion

Figures 9-16 and 9-17 show that the Porcupine Hills subregion has a large amount of old aged forests in its center and another large concentration of old growth forests to the north. Again, these are the result of aspen stands that burn as stand replacing fires only during the spring and fall seasons, and of Douglas-fir stands that are an open forest fuel type unable to sustain stand replacing fires very often.

Based on the review of the 1950 aerial photography for this region, it is not believed that the outcome from the simulations is representative of historical levels of burning. The aspen stands should have burned more frequently. The Douglas-fir stands would certainly have burned more frequently, but as intermittent crown fires and as surface fires. This fire behaviour would have maintained an open forest. The fire count map shows a long fire return interval that is often greater than 250 years for the C7 fuel type. In a fire ecology context, perhaps the simulation results for Douglas-fir forests are not far from the mark. Full stand replacing fires in open forests would in fact be less frequent. Unfortunately, there is no mean to verify this hypothesis for the Porcupine Hills. Evidence of open, mature and towering Douglas-fir trees has been removed over the years from selective logging as shown on the 1950 aerial photographs. Since then, the heavy regrowth, exacerbated by a lack of fire from fire suppression activities over the last sixty decades, has obscured what these stands historically looked liked.

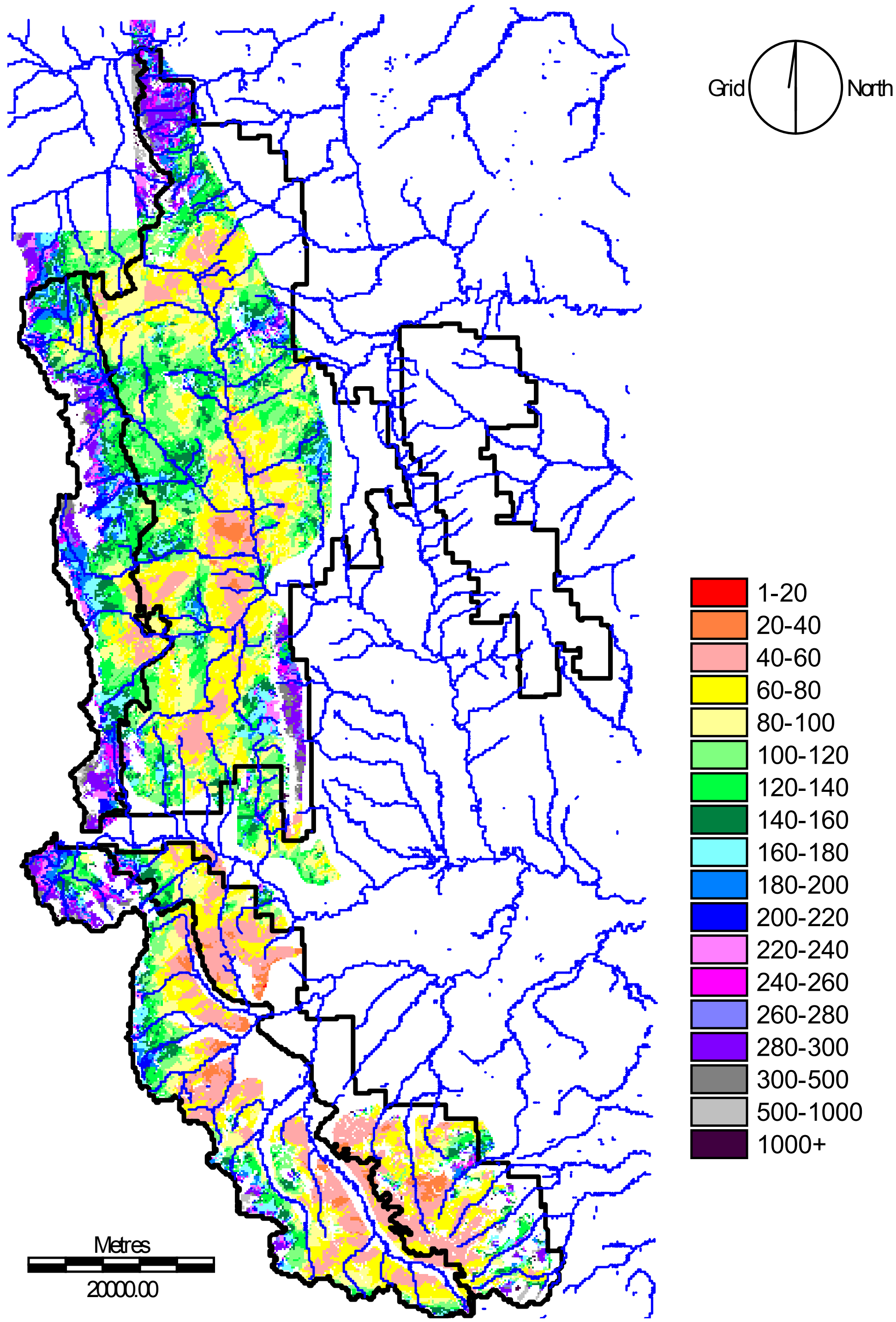

Figure 9-6 Mean stand origin map of the combined simulations results for the Subalpine and Montane natural subregions.

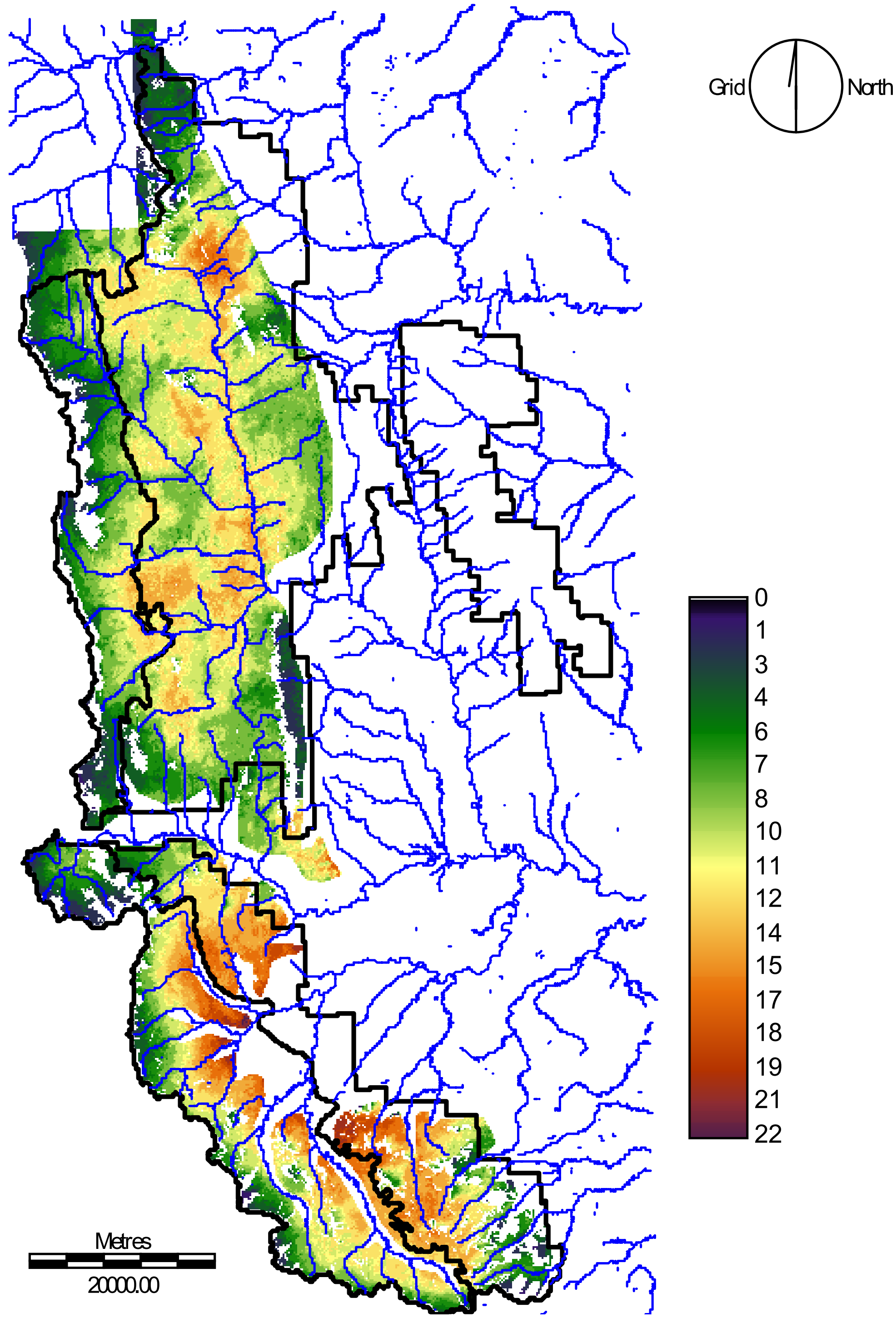

Figure 9-7 Mean fire count map of the combined simulations results for the Subalpine and Montane natural subregions.

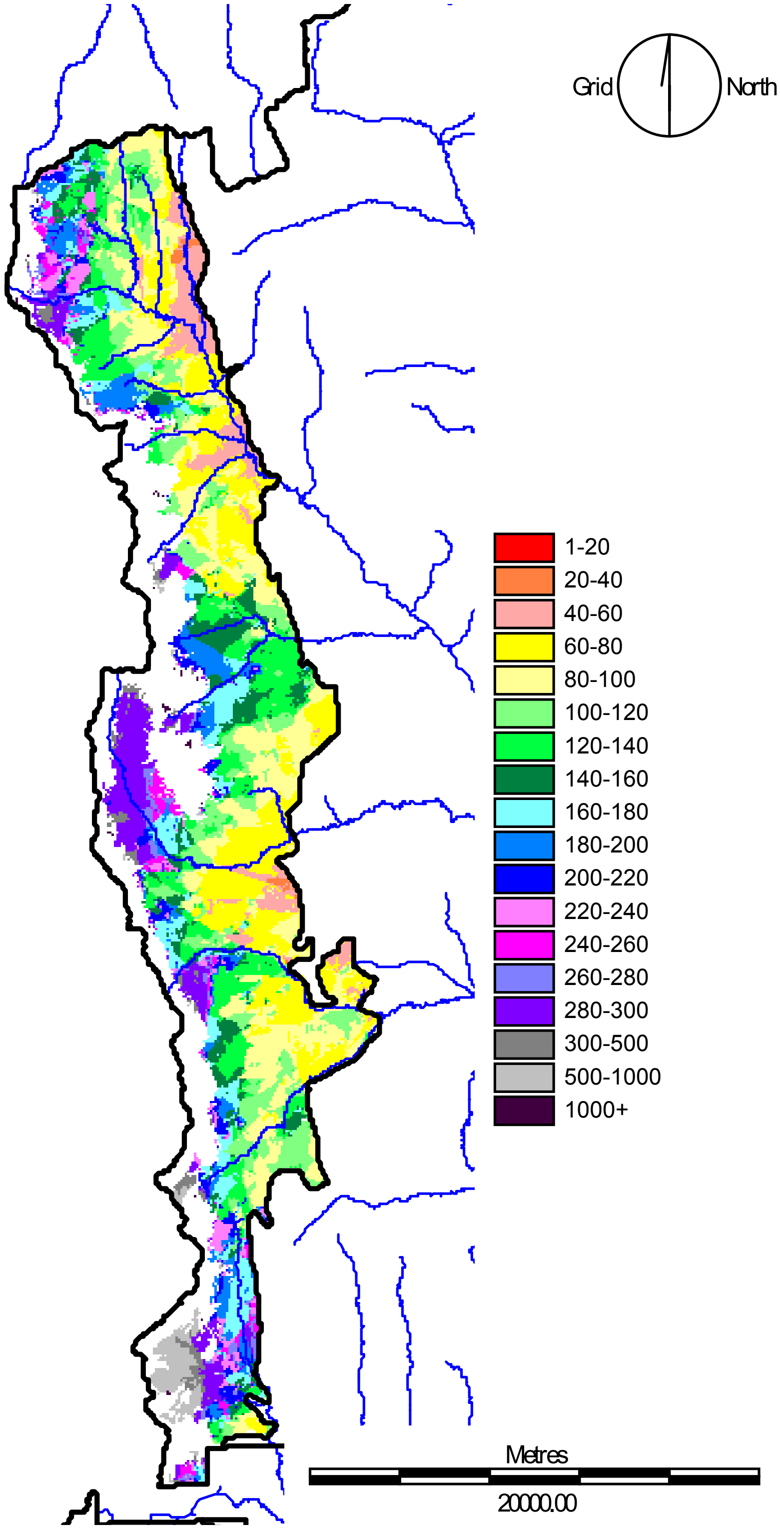

Figure 9-8 Mean stand origin map, Continental Divide North subregion.

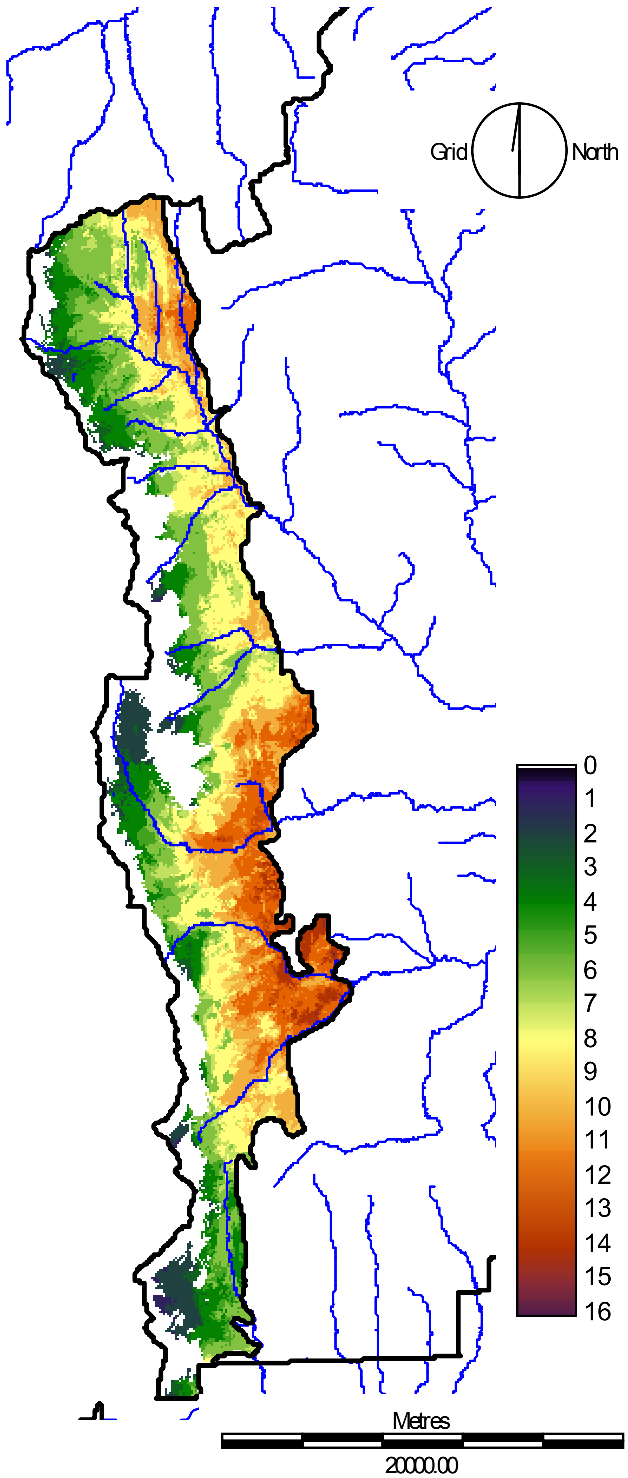

Figure 9-9 Mean fire count map, Continental Divide North subregion.

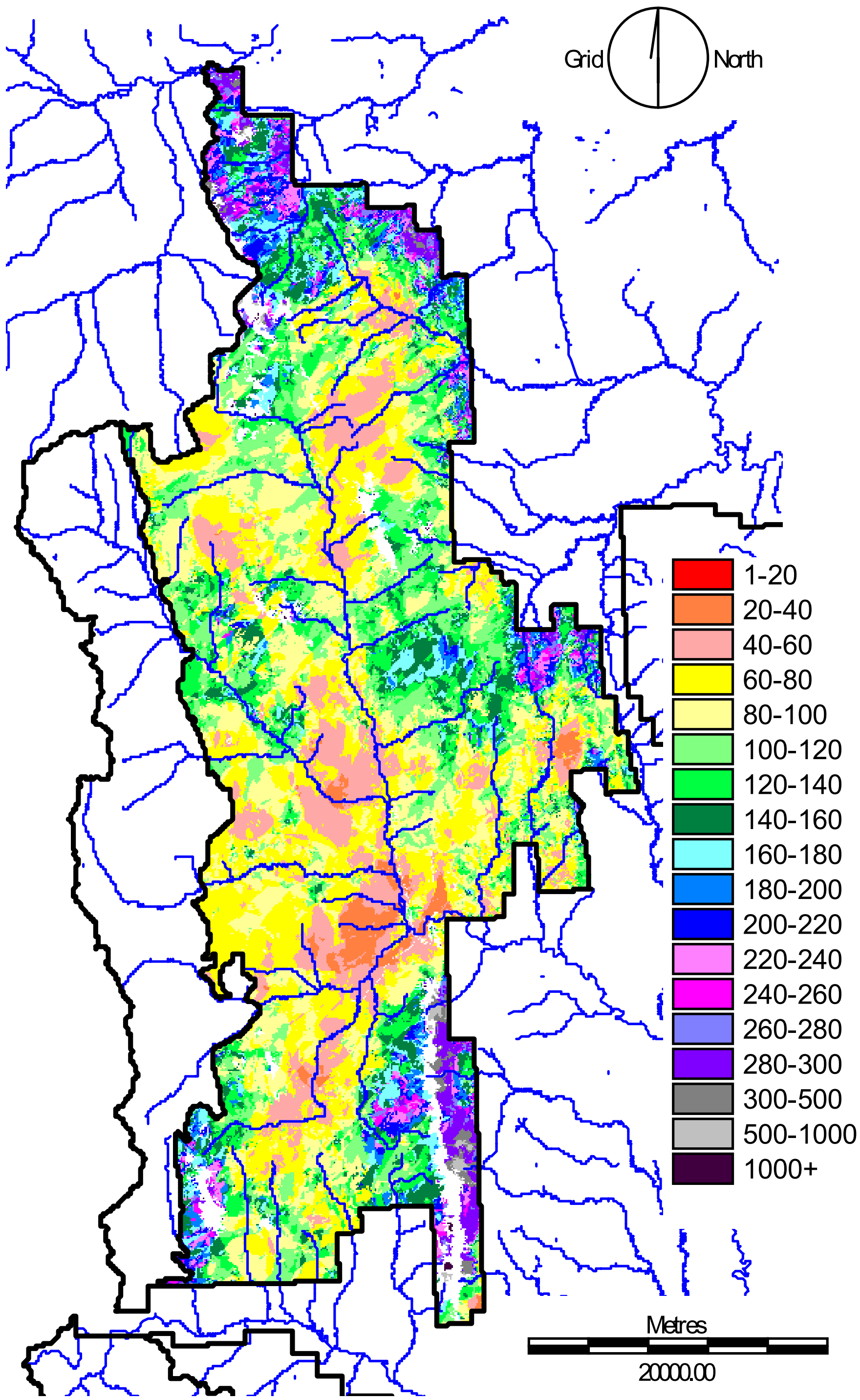

Figure 9-10 Mean stand origin map, Livingstone subregion.

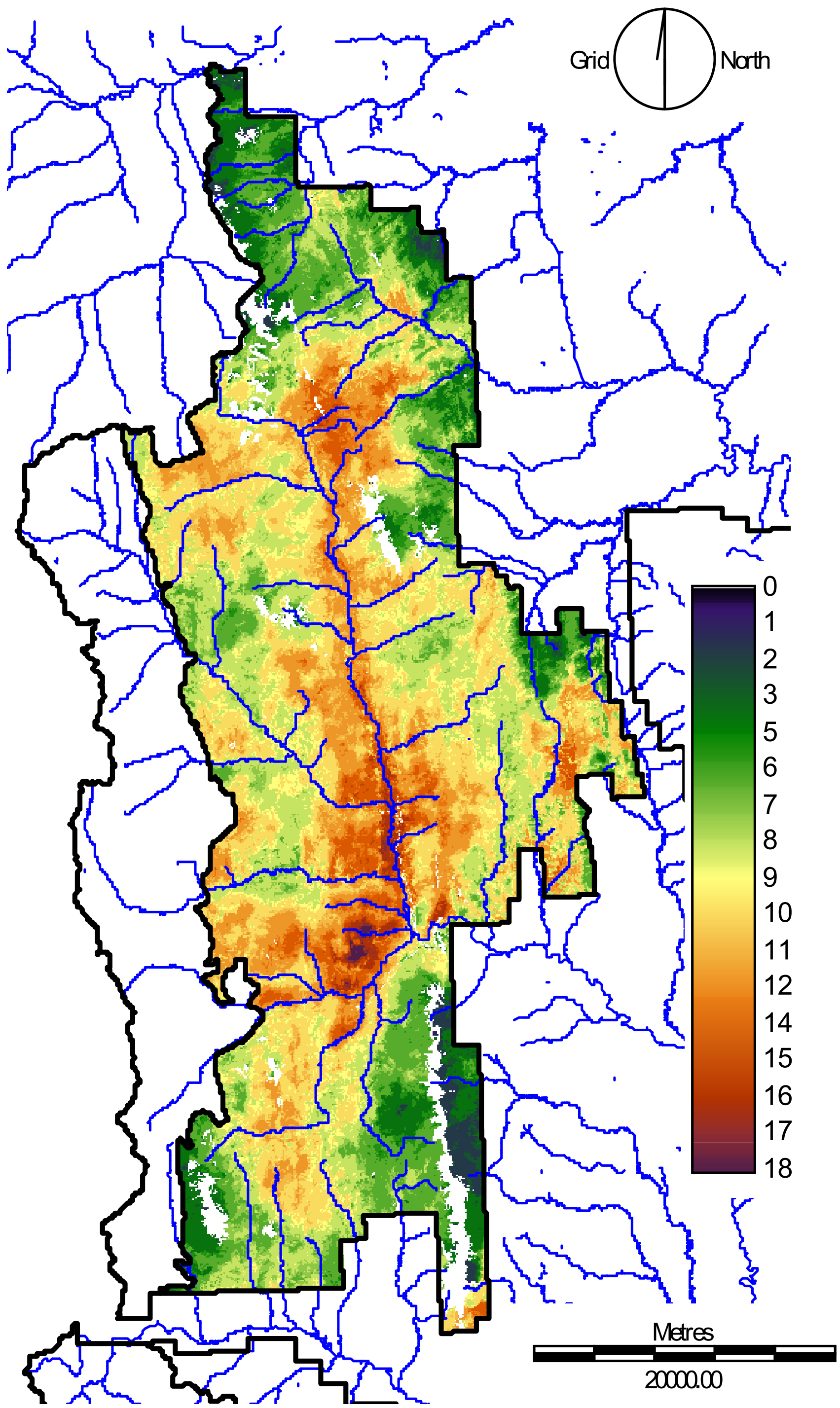

Figure 9-11 Mean fire count map, Livingstone subregion.

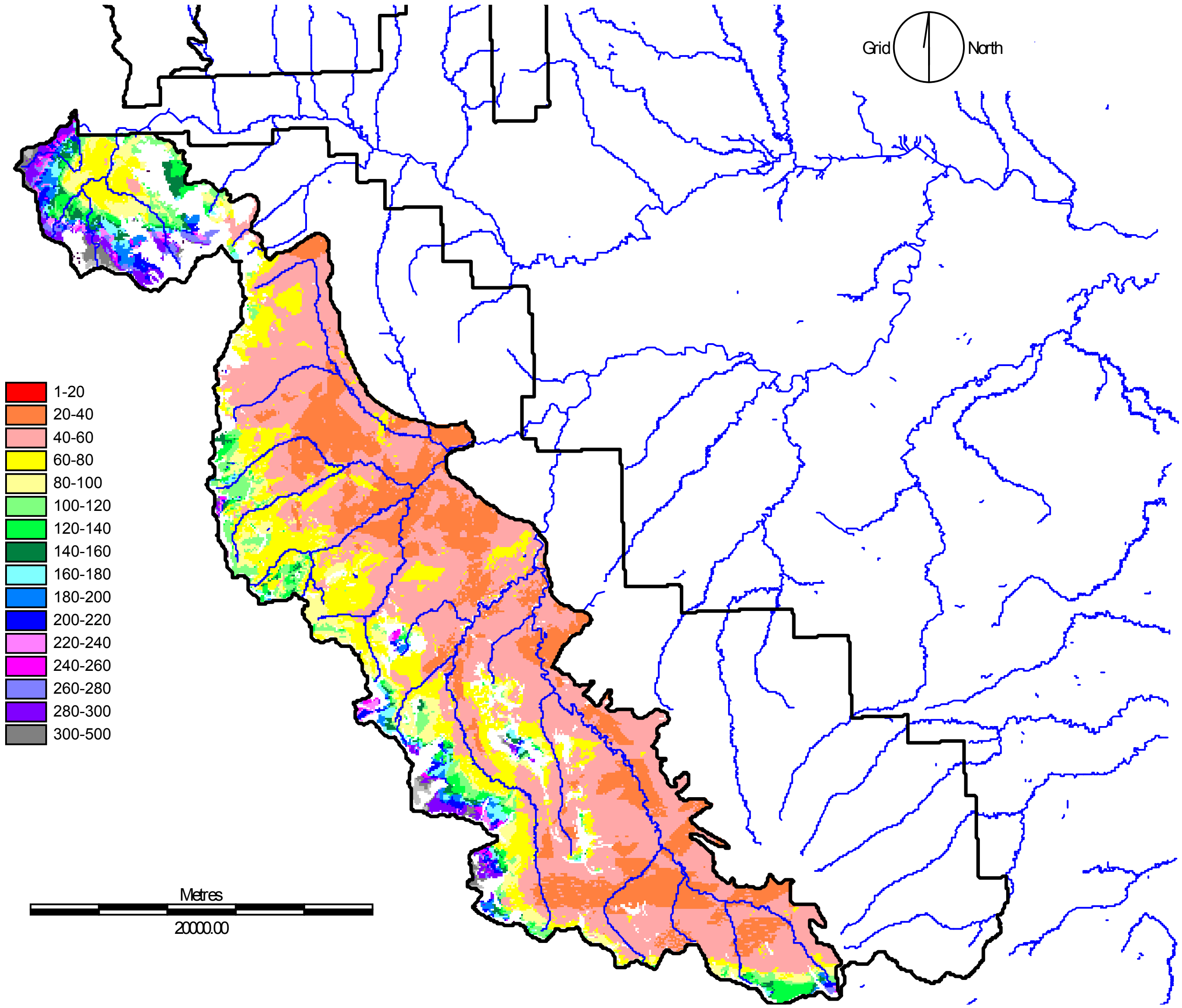

Figure 9-12 Mean stand origin map, Continental Divide South subregion.

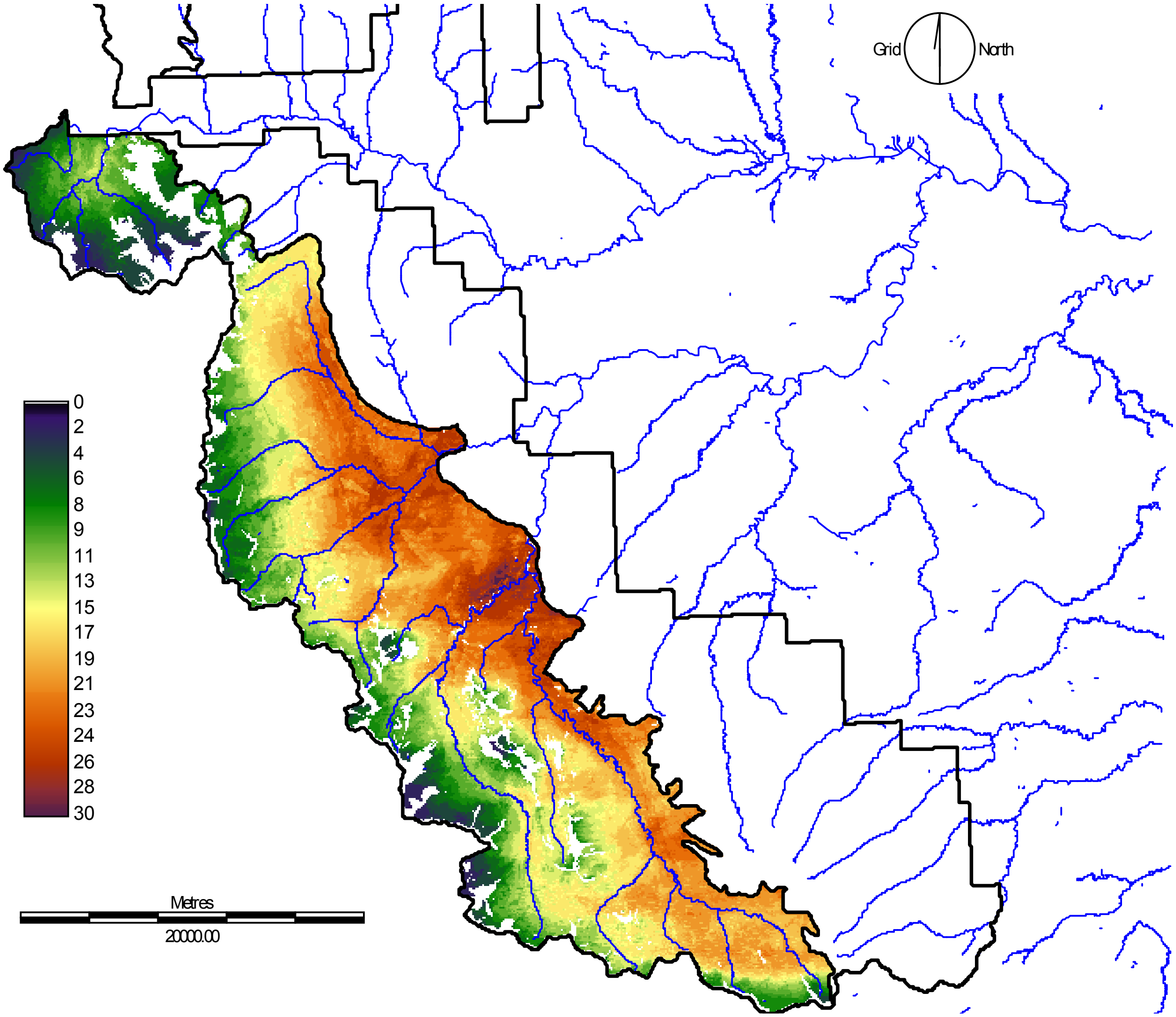

Figure 9-13 Mean fire count map, Continental Divide South subregion.

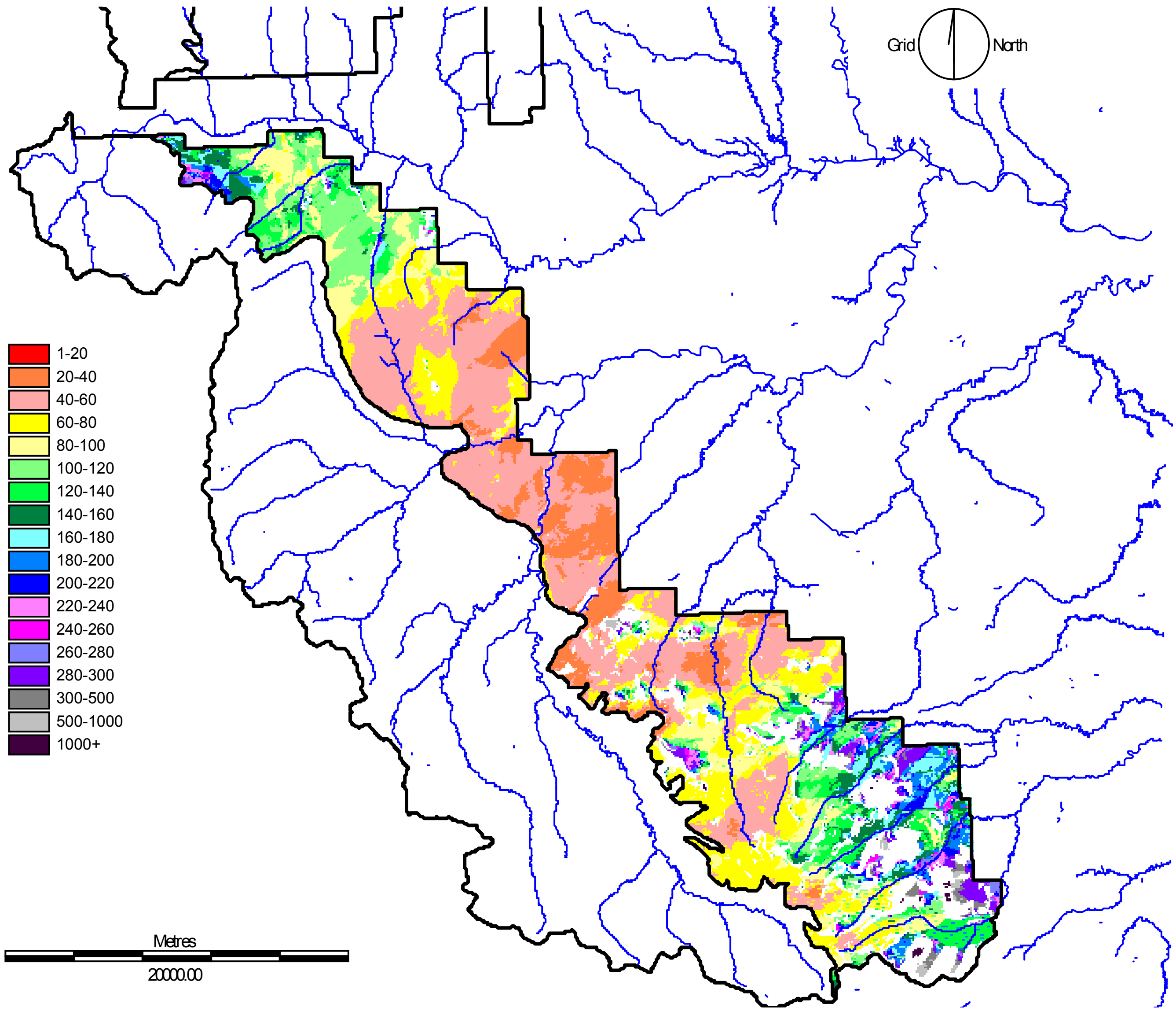

Figure 9-14 Mean stand origin map, Castle subregion.

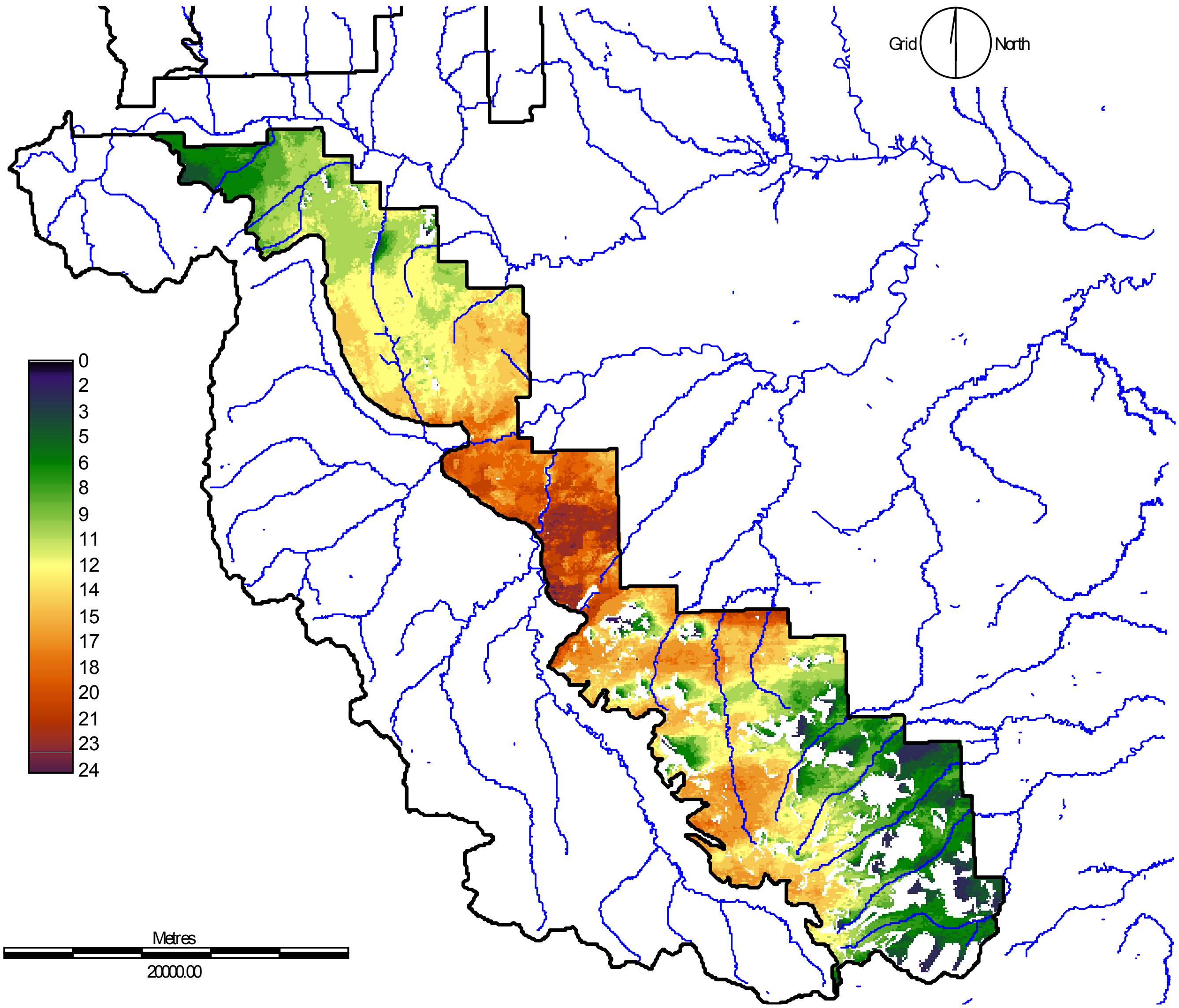

Figure 9-15 Mean fire count map, Castle subregion.

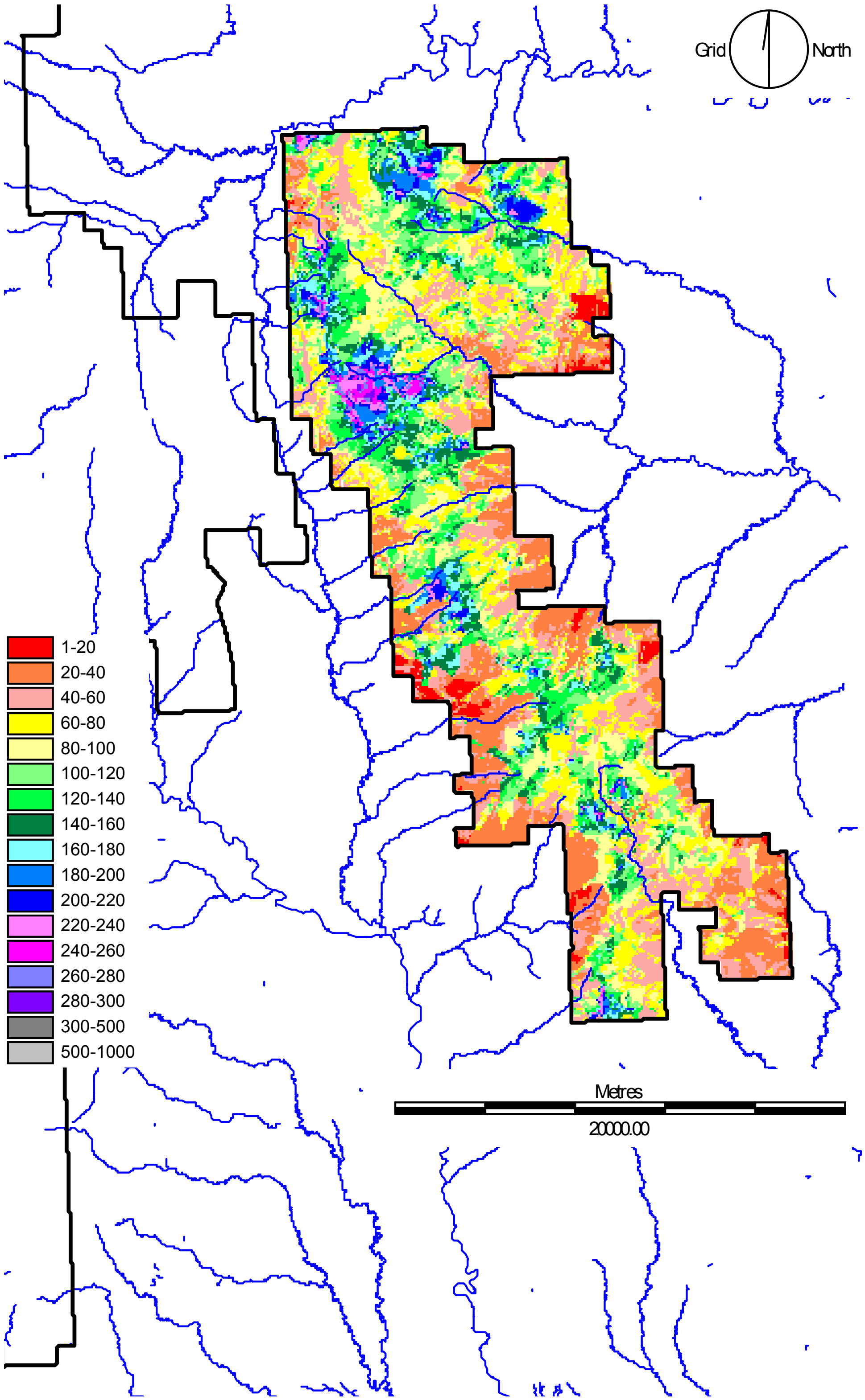

Figure 9-16 Mean stand origin map, Porcupine Hills subregion.

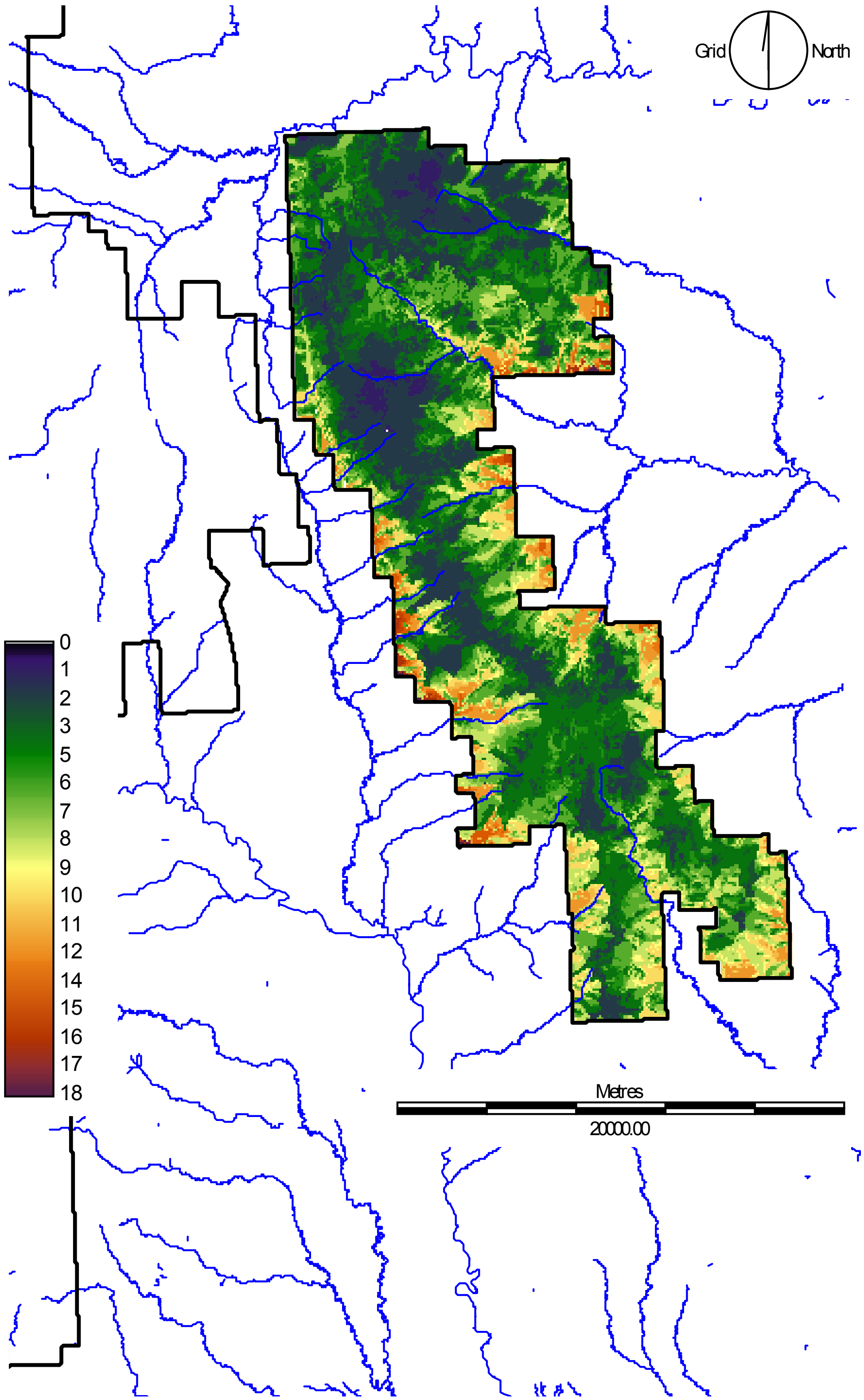

Figure 9-17 Mean fire count map, Porcupine Hills subregion.

9.6 AGE-CLASS DISTRIBUTION RESULTS

Mean age-class distributions as a percent of vegetated land base (forest + grass), with their natural range of variation (i.e. standard deviation around the mean) are shown in Tables 9-6 and 9-7 for the natural subregions and management subregions, respectively. Despite the visual differences in age patterns among the different landscapes, the question is: are the age-class distributions statistically different when compared non-spatially? When comparing population (i.e. age-classes) means between the natural or management subregions, it was found that for the most part the age-class distributions were not statistically different. An analysis of variance (one-way ANOVA) was conducted for the natural subregions and the management subregions to compare the variance between population means. The F test statistic was used to verify the variance per age-class between each subregion. The percent area per age-class obtained from the 10 simulations run were used as data entry. For the management subregions, Fisher's Least Significant Difference test was also used on the age-classes showing significant differences to establish which pairs of subregions are statistically different (Table 9-8).

Statistical test results showed that there is very little difference between the age-class distribution from the Subalpine and Montane subregions. Only age-classes 20, 270 and 280 were statistically different (df_1= 1, df_2=18, $F_{\alpha 0.05}$ = 4.41). Similar results were obtained for the management subregions where these age-classes were found to be statistically different (df_1=4, df_2=45, $F_{\alpha 0.05}$ = 2.59): 20, 30, 50, 80, 230, 290 and 350+. The largest differences in area per age-class reside in the young and old-age tails, and these can easily be spatially identified by using the mean stand origin maps or the fire count maps. The subregion that appears to be the most different is the Porcupine Hills as per Fisher's test. Even though the overall percent area per age-class is relatively similar between the subregions, both Tables 9-6 and 9-7 show that within a subregion, there can be a wide range in burn areas per age-class as noted by the standard deviation values (i.e. NRV or natural range of variation). This demonstrates the point that forest management should not rely on a unique stand origin map, which is only a sample of one and amounts to a narrow vision of the fire regimes that disregards the natural, temporal fluctuations in fire frequency and burn area distribution.

Table 9-8 Mean percent of age-class distribution and natural range of variation (standard deviation around the mean) presented by natural subregion. "*" = statistically different ($F_{\alpha 0.05} = 4.41$)

	Subalpine		Montane	
Age class	**Mean**	**NRV**	**Mean**	**NRV**
10	11.25	7.80	13.51	5.93
20*	7.74	3.36	14.92	6.45
30	5.78	5.73	6.88	4.25
40	7.81	3.28	6.95	4.02
50	7.30	5.11	5.08	1.79
60	6.20	4.38	5.21	3.82
70	5.66	4.18	6.16	3.66
80	3.23	2.27	4.82	3.45
90	3.45	3.16	2.56	1.65
100	2.83	1.73	3.68	2.62
110	2.99	2.52	2.95	2.14
120	2.74	1.97	3.42	2.27
130	2.38	2.03	2.39	1.57
140	2.28	2.01	1.98	1.20
150	1.72	1.35	1.11	1.00
160	2.75	2.71	1.28	0.69
170	1.14	0.68	1.35	0.98
180	2.07	1.84	1.24	0.57
190	1.56	1.26	1.04	0.47
200	1.96	2.50	1.33	0.67
210	1.14	1.02	1.14	1.24
220	1.62	1.10	0.89	0.75
230	1.07	0.65	0.98	0.88
240	0.97	0.83	0.46	0.43
250	0.65	0.95	0.60	0.43
260	0.77	0.67	0.53	0.25
270*	0.83	0.49	0.37	0.26
280*	0.65	0.35	0.24	0.26
290	0.51	0.57	0.24	0.25
300	0.59	0.37	0.34	0.26
350+	8.37	1.79	6.34	2.31

Table 9-9 Mean percent of age-class distribution and natural range of variation (standard deviation around the mean) presented by management subregion.
"*" = statistically different ($F_{\alpha 0.05} = 2.59$)

	CDN		Livingstone		CDS		Castle		P. Hills	
Age class	**Mean**	**NRV**	**Mean**	**NRV**	**Mean**	**NRV**	**Mean**	**NRV**	**Mean**	**NRV**
10	8.16	6.79	8.37	7.03	12.89	12.14	11.62	7.92	10.28	5.50
20*	6.88	6.97	8.95	4.81	16.44	13.22	16.34	16.77	3.76	4.10
30*	2.70	3.21	10.39	6.13	9.41	6.15	11.04	9.11	5.99	6.47
40	9.41	10.55	8.05	6.36	11.74	8.26	7.13	7.27	5.33	4.01
50*	6.78	7.18	5.61	2.84	12.20	7.60	2.62	2.52	4.13	4.50
60	9.70	9.74	5.80	5.23	4.86	3.71	4.92	5.83	4.44	4.01
70	5.14	5.40	4.94	2.75	4.10	3.91	6.74	5.39	3.08	2.71
80*	1.60	1.22	6.33	4.15	2.81	3.80	1.91	2.52	1.82	1.54
90	3.05	5.19	3.50	2.17	2.40	2.83	4.21	3.49	1.08	1.33
100	2.37	3.40	2.70	1.94	4.92	7.76	3.27	3.46	2.40	1.80
110	4.49	5.18	3.06	2.97	2.51	1.80	1.10	1.37	2.39	1.96
120	1.48	2.74	3.04	1.86	1.40	1.60	3.86	4.20	1.89	2.48
130	3.70	5.08	1.90	1.18	2.28	2.83	3.59	3.05	3.43	3.50
140	1.71	1.85	1.24	1.15	1.55	2.23	1.67	2.08	2.39	2.30
150	0.76	1.69	1.34	1.03	0.81	0.77	1.29	1.71	0.92	0.73
160	2.35	2.32	2.43	2.10	0.87	1.07	1.53	2.77	0.84	1.07
170	2.07	1.76	2.03	1.68	0.37	0.44	2.00	2.50	3.92	4.55
180	1.83	2.43	1.47	1.25	0.44	0.47	0.97	1.45	1.55	2.37
190	2.34	3.28	2.31	2.02	0.34	0.71	0.88	1.14	2.15	2.11
200	1.37	1.27	1.02	0.74	1.39	2.08	1.12	1.42	0.48	0.38
210	0.80	1.05	1.68	1.83	0.46	0.66	2.06	2.03	0.65	0.81
220	1.19	1.95	1.01	1.25	0.44	0.54	0.61	1.39	2.56	2.86
230*	0.81	1.04	1.10	0.77	0.44	1.10	0.62	0.96	2.42	2.06
240	1.54	2.68	0.58	0.48	0.34	0.52	0.85	1.45	0.91	0.92
250	1.82	3.16	0.78	0.75	0.39	0.67	1.15	1.60	1.40	2.18
260	1.74	2.88	0.70	0.58	0.30	0.40	1.15	1.55	2.96	3.87
270	1.14	1.40	0.92	0.79	0.17	0.27	0.14	0.22	0.86	1.14
280	0.25	0.45	0.23	0.20	0.10	0.16	0.83	1.40	2.90	5.32
290*	0.13	0.25	0.57	0.50	0.19	0.20	0.18	0.34	1.35	1.75
300	0.77	1.16	0.50	0.59	0.09	0.18	0.45	1.01	0.31	0.48
350+*	11.94	4.61	7.45	2.42	3.35	1.32	4.16	2.48	21.43	6.24

Table 9-10 Fisher's LSD test pairwise comparison of age-class means by subregion found to be significantly different (α=0.05).

Significantly different age-class	Significantly different pairs of subregions
20	P. Hills & Castle, CDS
30	CDN & Livingstone, CDS, Castle
80	Livingstone & all other subregions
230	P. Hills & all other subregions
290	P. Hills & CDN, CDS, Castle
350+	P. Hills & all other subregions CDN & Livingstone, CDS, Castle Livingstone & CDS

9.7 Conclusions

Simulation results show that fire regimes are visually distinct, notably by the amount and distribution of young and old aged forests. Emulating natural disturbance patterns should thus focus on this element while trying to maintain similar proportions of forests in each age-class as described in Table 9-7. The yearly rate of disturbance (ha/yr), established from the fire cycle value (see Chapter 11), must be used in conjunction with Table 9-7. Lastly, remember that values from Table 9-7 are expressed in <u>percent</u> values of <u>vegetated area</u> (forest + grass). The fire growth model kept track of burn areas which included both forest and grass fuel types. All subregions have about a 20% grass cover with the exception of the Continental Divide North that has a 7% grass cover. The ecosystem restoration aspect of the forest management program for the C5 FMU should consider grassland burning, as well as forests. For management purposes, it is also recommended that age-classes be lumped into 20, 40 or 50 year classes to simplify the harvest and disturbance planning process. The seral stage categories established by cover type is a good approach.

Note that the selection of age-classes to harvest each year, and by how much, must rely on adequate stand origin data. The reliability of this data will dictate the lumping process of age-classes for forest harvest planning. Given the short-comings of AVI age data in terms of its ability to date fires, it is recommended a field stand age validation process be undertaken for those areas that lack fire history information such as the Livingstone and the Porcupine Hills subregions. During the recent fire mapping process, very few to no fires could be identified and mapped in these subregions (for reasons detailed in Chapter 8).

Emulating fire patterns to maintain the ecological integrity will imply that the oldest forests are no longer pursued and that younger aged forests will need to be revisited more frequently for harvesting. Alternative forest management programs to increase timber volume over shorter periods of time, such as thinning of newly reforested areas and focussing on managing forests in productive areas, will need to be considered.

10.0 NATURAL VARIATION IN FIRE SIZE

In order to emulate natural disturbances on the landscape, it is important to identify the range of patch sizes created from fire. Although we recognize the existence of other patch creating sources such as avalanche, blow-down, insects and diseases, fire remains the prevailing source of forest stand replacement with the greatest variability in disturbance sizes. Fire also has the ability to burn over blow-down and diseased areas, making it the prevailing or outstanding factor in shaping the forest mosaic. Fire is also the easiest source of disturbance to replicate on the land by using prescribed burning or harvesting methods.

In this Chapter, three methods were used to determine the range of variation in fire size distribution. The first method consisted of using the provincial fire records from 1961 to 2003, while the second method, referred to as "recent fire mapping", consisted of mapping fires that occurred between circa 1920 and 1950 and that had not been overlapped by subsequent ones. The last method used outputs from stand origin modelling simulations. As reliable stand origin information is limited, it is important to use as many tools that are available to address the research objectives as thoroughly as possible.

10.1 FIRE OCCURRENCE RECORDS METHOD

The Provincial fire occurrence records from 1961 to 2003 were used to determine the distribution of fire sizes for those fires larger than 12 ha. This size was chosen as we are mainly interested in stand replacing fires that are sufficiently large enough to have an impact on the yearly rate of forest disturbance. Table 10-1 presents the size class distribution for fires that occurred within the C5 FMU. Because very few fires larger than 12 ha occurred in the FMU, the information could not be subdivided by natural regions or management subregions. To obtain a better understanding of fire size distribution between the natural subregions, the entire Provincial fire occurrence data set was also used (Table 10-2). Table 10-2 was borrowed from the Kananaskis Fire Regime Study (Rogeau 2004) which includes only fires between 1961 and 2002 and do not include the large 2003 fires from C5 (but they are in Table 10-1).

We must remember that the burn areas (fire sizes) from this data set have been affected by fire suppression to different degrees. It is particularly obvious in the Montane subregion where the mean fire size is 51 ha. The large majority of montane zones in Alberta are populated or contain highly used transportation corridors. The Montane in Jasper National Park (Athabasca Valley) has a highway and a railroad, the Montane of the North-Saskatchewan River Valley also contains a highway, the Montane of Banff National Park and adjacent provincial land (Bow Valley) contains a highway and a railroad, as does the Crowsnest Valley. This would explain why the proportion of anthropogenic fires in the Montane can be as high as 90% (Kananaskis District fire occurrence data). It can also explain why fire sizes are so small due to its easily accessible terrain and to the fact that the fire response in these valleys is prompt. Based on historical photographs, fires in the Montane can be as large as those in the Foothills.

Table 10-1 Fire size and burn area distributions for the C5 FMU.

Size class	Count	% occ	Burn area (ha)	% area
< 1 ha	704	91.67	72.40	0.25
1 - 10 ha	38	4.95	143.85	0.49
11 - 100 ha	16	2.08	673.53	2.32
101 - 200 ha	4	0.52	656.41	2.26
201 - 500 ha	2	0.26	652.49	2.24
501 - 1000 ha	0	0.00	0.00	0.00
1001 - 5000 ha	3	0.39	5,705.00	19.63
> 5000 ha	1	0.13	21,163.00	72.81
	768	100	29,066.68	100

Table 10-2 Percent fire occurrence by size class and natural subregion. Provincial land base, 1961 to 2002. This data set does not include fires that occurred in National Parks.

	Natural Subregions			
Fire Size (ha)	Alpine/Subalpine		Montane	
	Count	% Count	Count	% Count
12 to 40	16	35.56	25	73.53
41 to 100	10	22.22	5	14.71
101 to 200	4	8.89	3	8.82
201 to 500	6	13.33	1	2.94
501 to 1000	3	6.67	0	0.00
1001 to 2000	4	8.89	0	0.00
2001 to 5000	1	2.22	0	0.00
5001 to 10000	1	2.22	0	0.00
> 10,000	0	0	0	0.00
Total	45	100	34	100
Maximum	9,214		348	
Mean size	537		51	
Std error	1,441		67	

10.2 Recent Fire Mapping Method

This method makes use of stand replacing fires that occurred between circa 1930 to 1950. This is a period when fires can still be easily identified on the 1950 aerial photography. Fires from this period are also less likely to have been overlapped by subsequent burns. This period should provide more realistic fire sizes that have not been affected as severely by fire suppression tactics. Unfortunately not enough fires have been identified to be able to address the fire size distribution by natural region or by management subregion. This time period includes one of the most severe fire seasons (1936) where many large size fires occurred throughout the Province. Fire weather and burning conditions in 1936 were equivalent to what has been seen during the 2003 fire season, and as such, it provides a very good spectrum of fire size distribution.

Table 10-3 presents the recent fire mapping results as presented in Chapter 8. Table 10-4 shows the percent of fires recorded in each size class, as well as the percent forested area it corresponds to.

Table 10-3 Area and year of fire occurrence for each fire mapped. Supporting evidence of the fire year, if found, is stated.

Fire Id	Area (ha)	Year	Historical record
1	62.82	1940's	n/a
2*	2,092.76	1880's	n/a
3	404.15	1930's	n/a
4	4,105.68	1936	Delisle & Hall (1987)
5	1,911.29	1940's	n/a
6	5,252.32	1930's	n/a
7	899.76	1930's	n/a
8	36.32	1940's	n/a
9	774.08	1940's	n/a
10	311.93	1936	fire occurrence report
11	1,163.25	1940's	n/a
12	141.46	1934	fire occurrence report
13	220.12	1940's	n/a
14	101.23	1945	fire occurrence report
15	2,970.92	1931	fire occurrence report
16	97.75	1940's	n/a
17	117.59	1940's	n/a
18	227.75	1940's	n/a
19	226.46	1945	fire occurrence report
20	252.82	1936	fire occurrence report
21	200.10	1930's	n/a
22	19.76	1940's	n/a
23	17,045.71	1936	fire occurrence report
24	1,097.29	1934,1936	fire occurrence report
25	9,947.38	1934	fire occurrence report
26	371.36	1930's	n/a
	47959.3		

* Fire Id 2 was not included in the total burn area because it dates prior to 1930.

Table 10-4 Percent of fire recorded in each size class and percent of forested area burned by size class. Forested area estimated at 203,737 ha. (See Chapter 8 for details)

Fire size (ha)	Count	% occ	Total area (ha)	% of forested area
<100	4	16	216.65	0.11
100 to 500	11	44	2,574.97	1.26
500 to 1000	2	8	1,673.84	0.82
1000 to 2000	3	12	4,171.83	2.05
2000 to 5000	2	8	7,076.60	3.47
5000 to 10000	2	8	15,199.70	7.48
>10000	1	4	17,045.71	8.37
	25	100		

10.3 Fire Regime Modelling Method

Stand origin simulations were run for each natural and management subregion, and actual fire sizes (not overlapped by other fires) were recorded for 10 simulations of 1,000 years. As detailed in Section 9.5, five simulations were done with a coniferous content of 35% for mixedwood stands and another five simulations were run to represent a greater coniferous content of 65%. In total this is 10,000 years of fire size data, which provides an excellent range of variation. Table 10-5 presents the fire size distribution, minimum, maximum and average fire size recorded for each subregion, while Table 10-6 shows percentages of disturbance area by fire size class.

Table 10-5 Percentage of fire by fire size class and other descriptive statistics extracted from stand origin simulations.

Fire size (ha)	Sub. % fires	Montane % fires	CDN % fires	Living. % fires	CDS % fires	Castle % fires	P.Hills % fires
1 to 10ha	8.89	8.95	6.66	10.69	8.43	10.69	9.71
11 to 100	21.27	22.63	19.56	24.62	15.81	21.13	29.35
101 to 250	12.68	14.83	13.41	14.18	11.26	12.54	19.82
251 to 500	11.18	13.29	12.55	11.56	10.15	11.10	15.42
501 to 1,000	12.08	13.32	14.38	11.45	12.12	11.54	12.22
1,001 to 2,000	11.45	12.26	13.47	10.24	13.53	11.42	7.77
2,001 to 5,000	12.64	11.31	16.01	10.09	17.32	13.71	4.92
5,001 to 10,000	6.57	2.75	3.66	5.12	8.83	6.66	0.65
10,001 to 15,000	2.06	0.48	0.30	1.26	1.89	0.98	0.10
15,001 to 20,000	0.77	0.09	0.00	0.52	0.52	0.24	0.00
> 20,000	0.42	0.09	0.00	0.27	0.14	0.00	0.05
<100	30.15	31.57	26.22	35.31	24.24	31.81	39.06
<250	42.83	46.41	39.63	49.49	35.50	44.35	58.88
N fires	13,919	24,767	1,968	9,931	4,983	4,099	4,027
Avg. fire size	1,670	985	1,170	1,296	1,876	1,385	503
Std. Dev.	3,205	1,894	1,698	2,746	2,921	2,332	1,013
Min. size	1	1	1	1	1	1	1
Max. size	43,458	46,149	11,165	38,161	32,667	19,971	21,440

Table 10-6 Percentage of total burn area by fire size class extracted from stand origin simulations.

Fire size (ha)	Sub	Mont	CDN	Living	CDS	Castle	PH
	% burn	% burn	% burn	% burn	% burn	% burn	% burn
1 to 10ha	0.02	0.04	0.03	0.04	0.02	0.04	0.09
11 to 100	0.57	1.05	0.76	0.83	0.39	0.68	2.73
101 to 250	1.26	2.52	1.93	1.81	1.01	1.52	6.48
251 to 500	2.43	4.89	3.98	3.23	1.98	2.95	11.15
501 to 1,000	5.18	9.75	8.84	6.33	4.70	6.01	17.11
1,001 to 2,000	9.80	17.81	17.01	11.38	10.52	11.95	21.71
2,001 to 5,000	24.37	35.11	43.92	24.89	29.59	31.99	28.67
5,001 to 10,000	27.53	18.67	20.76	27.41	33.03	33.39	7.86
10,001 to 15,000	14.72	5.95	2.77	11.87	12.05	8.36	2.15
15,001 to 20,000	7.75	1.55		6.94	4.78	3.12	2.05
> 20,000	6.35	2.66		5.27	1.92		
<100	0.59	1.09	0.79	0.87	0.41	0.72	2.82
<250	1.85	3.61	2.72	2.68	1.42	2.24	9.3

Before interpreting the data in the above tables, it is important to know that fire sizes were cropped if they extended beyond a subregion. This was done during the modelling session so that the exact burn area per subregion would be known for calculating the fire cycle. The smaller a subregion is, the greater the possibility of seeing more small size fires. Results from both natural subregions are likely more realistic because they have the largest land base. But fires from the montane moving uphill into the subalpine were cropped at the subalpine boundary. The subalpine has the largest land base and also contains the most fires greater than 10,000 ha. It likely has the most realistic array of fire sizes expected to be found in this region.

Table 10-5 shows that on average about 30% of fires are less than 100 ha, and depending on the subregion, close to half of the fires are less than 250 ha. Harvesting disturbances at this time are all less than 250 ha. While there is a greater number of small size disturbances in the mountains than in the Foothills (Kananaskis Fire Regime Study - Rogeau 2004), most of the age mosaic is driven by large size disturbances. In actual fact, the % of total burn area from fires less than 250 ha is less than 4%. The Porcupine Hills output at this point are not trustworthy due to modelling difficulties and shorter than normal mean-fire-return-intervals obtained. The age mosaic is largely driven by disturbances ranging between 2,000 and 10,000 ha in size, as they account for about 52% to 65% of the total burn area.

When considering that cut block sizes are less than 250 ha in size in the Southern Rockies, it is a large bridge to gap in terms of emulating natural disturbances. While it would be inconceivable to harvest the forest in patches as large as fires, measures call for a different way of harvesting to allow for larger size disturbances to take place. Larger size disturbances actually allow forest planners to be more creative with the harvesting process in a way that can consider other fire regime characteristics such as intermittent harvesting that leaves a number of trees and island remnants within a harvest block. Such an approach is also more in line with the landscape visual appeal (than the square and bare blocks) and insures a form of wildlife corridor preservation at the same time.

10.4 CONCLUSIONS

In summary, the harvest patch size distribution, as recommended by the Alberta Timber Harvest Planning and Operating Ground Rules (ASRD 1994), falls within the natural range of variation of fire size (i.e patch sizes), BUT is not representative of the natural range of variation because all harvest blocks are found at the bottom end of the spectrum. Thus, both null hypotheses H_{07} and H_{08} are rejected (Section 2.1). Fire size results were produced from three independent data sets, none of which were highly similar, although disturbance area results from the recent fire mapping and simulation methods were comparable. The most trusted outcome would be from the recent mapping process, although like the other methods, it has its limitations. The recent mapping has a shortage of data for the Montane natural subregion and it is not clear what the natural array of fire sizes should be. Considering that the Montane landscape is less dissected by natural fuel breaks such as rocky ridges, fires could get much larger than in the subalpine, but perhaps not as large as what is seen in the Foothills. The fire occurrence data set has been highly affected by fire suppression so this method does not offer representative proportions of fire size classes. As for the fire growth modelling, simulations grew a great number of large size fires based on assumptions made about the historical fire regime. Simulations offer the largest fire size data set with natural of variation. Some of the modelling assumptions may need to be verified over time using fire history data collected in the field. I would like to stress again that the simulation outcome for the Porcupine Hills subregion is not quite in line with what the historical fire regime suggests (from the air photo screening analysis). Fire history data collection for this region is highly recommended in order to shed some light on frequency and size of past fires.

In light of these results, there is a strong concern that harvesting practices, which follow guidelines from the Alberta Timber Harvest Planning and Operating Ground Rules (ASRD 1994), are not reflective of natural disturbance size and area, but only representative of a small number of natural disturbances and their effect typically found in the Southern Canadian Rockies. From simulations, patches less than 250 ha account for only between 1.42% and 3.61% of the total burn area in a subregion (P. Hills results not included). Fires greater than 500 ha in size on the other hand, account for about 92% to 97% of the area burned. For this to happen, the simulation data sets suggest that 39% to 54% of fires must be greater than 500 ha. These statistics are not representative of Canadian fire statistics which stipulate that on average, 95% of the area is burned by only 3 to 5% of the total fires (Harrington 1982, Johnson and Wowchuk 1993). These numbers were developed from recent fire databases that have been affected by fire suppression of various degrees. In summary, we can see that even though there can be a large number of small disturbances on the landscape, their impact in terms of disturbed area remains minimal. However, this does not imply that small size disturbances should be discounted or ignored as part of forest management practices, as they are highly beneficial in maintaining biodiversity and a healthy ecosystem.

11.0 NATURAL VARIATION IN FIRE CYCLE

The fire cycle is the number of years it takes to burn an area equal in size to the study area. During a cycle, some areas may burn more than once, while others may not burn at all (NRC 1987). The fire cycle allows managers to calculate the yearly disturbance rate of the forest. This is therefore an important parameter for harvesting guidelines. In this case, there are three complementing methods that can be used to predict fire cycles and they are presented below. The fire size and frequency statistics method is the most simple and requires very little effort, but offers only a general fire cycle value for the entire area. The fire statistic method uses fire records from 1961 to 2002, and as such, the fire cycle will be representative of the fire suppression era. The second method, which uses results from mapping fires between 1930 and 1950, offers a fire cycle value that has not been as severely impacted by fire suppression efforts. Lastly, the fire regime modelling procedure is instrumental to test the natural variation in fire cycle, as the multiple simulations will provide a large array of fire cycle values. Fire cycles obtained from the different methods will be converted into yearly % of forest disturbance rate. These numbers can be used by forest planners to compare their yearly forest disturbance rate created from harvesting to the natural rates.

As part of this project, no testing has been done to determine the effect of topography on fire distribution and hence, fire cycles. It is likely affected in a similarly way as what was found in Banff National Park, the Spray Lake Recreation Area and the Whitegoat and Siffleur Wilderness areas (Rogeau et al 2004, Rogeau 1999). Topography strongly influences fire distribution and fire spread, which results in spatial variation in the fire cycle at the microscale level. Valley orientation, elevation, proximity to the Continental Divide and aspect combined, contribute to the spatial variation of the fire cycle over the landscape. Values given in this report provide the temporal range of variation per subregion, but not the spatial variation. In mountain landscapes, the natural range of variation is as important spatially as it is temporally.

11.1 FIRE SIZE AND FREQUENCY STATISTIC METHOD

As shown in the equation, by taking the average fire size and the yearly average fire frequency, one can estimate how many years it would take to burn an area equivalent in size to the study area.

Fire cycle = [study area (ha)] / {[avg. fire size (ha)] x [avg fire frequency (N/yr)]}

Using fire occurrence information from the recent fire regime profile and mean fire size statistics from the fire size distribution table (Table 10-1), the following values were entered into the equation:

C5 FMU (forested): 327,063 ha

mean fire size: 1,670 ± 3,200 ha (approximated from modelling results for the Subalpine subregion)

estimated historical avg of fires >12 ha/yr: 2.5 (min: 1, max: 4)

By using a constant mean fire size of 1,670 ha and by varying the yearly fire occurrence value from 1 fire/year (minimum) to 2.5 fire/year (mean) and 4 fire/year (maximum), we have an historical fire cycle that varies from 196 years to 49 years, with a mean fire cycle of 78 years. Any variation in the mean fire size could significantly change these fire cycle values. By doubling the mean fire size under similar fire frequencies, the fire cycle is cut in half. Based on the numbers provided above, the yearly rate of disturbance, which is the inverse of the fire cycle, would vary from 0.51% to 2.04% with a mean disturbance rate of 1.28% of the forested area.

11.2 Recent Fire Mapping Method

This method made use of the burn areas obtained from the 25 fires mapped from the 1950 aerial photography. Only those fires that had not been overlapped were used, which restricted the period covered from circa 1930 to 1950. None of these fires have been field dated, the period was simply estimated by judging the amount and height of forest coverage since the fire event. Some historical fire reports found do support the date of fire occurrence as being between 1930 and 1950. A few other fires from that same period were also visible, but they were not mapped for reasons detailed in Chapter 8. Below is a repetition of the fire cycle information already presented in that Chapter.

For the fire cycle value to be representative, watersheds where fire mapping could not be achieved had to be removed from the data set. Figure 8-3 shows the land base for which a fire cycle was calculated. Also note that because many of the fires burned grassy areas, the grass fuel type was lumped with the treed fuel types.

Following are the numbers used to estimate the forested area.

Watersheds - total area: 224,573ha
Watersheds -forested only: 193,066 ha (86% of total area)
Crowsnest Corridor (outside of FMU): 10,671ha (estimated to be entirely forested or "burnable")
Total forested area: 203,737 ha

The total area burned over a 20-year period was 47,959 ha., which results in an average of 2,398 ha per year. Based on a forested area of 203,737 ha, this is equivalent to a rate of disturbance of 1.18%. To burn an amount of land equivalent to the forested area, it would take 85 years (i.e fire cycle).

11.3 Fire Regime Modelling Method

The best reason for using the STANDOR landscape disturbance model resides in its abilities for calculating true fire cycles - something that cannot be accurately calculated using a real stand origin map. As all fire sizes prior to being overlapped by other burns are recorded over time, these sizes can be tabulated to obtain the number of years it takes to burn an area equal in size to the study area. The model uses masks, which allows for the extraction of fire size information only for that area of focus (the mask). In this case, masks were used to retain information for the natural and management subregions being modelled.

For each subregion, output from ten simulations of 1,000 years was used. To calculate the fire cycle, the forested area of each subregion was computed using the FBP fuel type map issued by ASRD. Next, the burn area was tabulated until an area equal in size to the forested area was reached. The number of decades (the model's output was done in 10 year increments) it took to reach that value was then counted. Depending on the subregion modelled, 4 to 16 cycles could be counted over a 1,000 year period. The output from all ten simulations were merged together to obtain the magnitude of variation in fire cycles, which is presented in Table 11-1.

An important advantage of the fire cycle is its ability to provide managers with the annual area disturbed (ha/yr) and percent rate of disturbance (% area/yr). This is simply done by dividing the forested area by the fire cycle value or by taking the inverse of the fire cycle. These results are also presented in Table 11-1.

Table 11-1 Fire cycle and yearly rate of disturbance values by natural subregion. FC = fire cycle, NRV = natural range of variation.

	Sub	Montane	CDN	Living.	CDS	Castle	P.Hills
Avg FC	116	92	145	115	64	84	197
Std Dev	23	16	38	22	16	25	40
NRV FC	93-139	76-108	107-183	93-137	48-80	59-109	157-237
Shortest FC	70	60	80	70	40	40	110
Longest FC	190	150	270	170	110	160	310
Forested area	269,425	222,959	33,067	147,225	59,758	47,582	39,414
Annual area (ha/yr)	2,320	2,433	229	1,280	935	564	200
Avg dist. rate (%/yr)	0.86	1.09	0.69	0.87	1.56	1.19	0.51
NRV dist rate (ha)	1,938-2,827	2,064-2,937	181-309	1,075-1,583	747-1,245	437-807	166-251
Min dist. rate (ha)	1,418	1,486	123	866	543	297	127
Max dist. rate (ha)	3,849	3,716	413	2,103	1,494	1,190	358

The fire cycle values calculated for each subregion clearly show the spatial variation of fire cycles over the landscape. This is the result of slightly different fire regime characteristics such as: fire frequency, mean fire size and probabilities of ignition. The Subalpine fire cycle obtained from the simulations is longer than the one calculated from the recent fire mapping (85 years). This can be explained by the fact that the fire frequency for the simulations was reduced by 40% to be more representative of the fire regime of the turn of the century. Fires mapped for the period between 1930 and 1950 were largely man-caused fires as a result of the important commercial activity that was taking place in the forests (mining exploration and logging). The fires mapped in the 1930's were also under the influence of a serious drought (1934, 1936), which accounted for a number of very large size fires that would have contributed to a shorter fire cycle for that period. This is a reminder that temporal variation is as important as the spatial variation. The NRV in fire cycle provided in Table 11-1 are temporal variations over a 1,000 year period. Again, the values provided for the Porcupine Hills are not representative of what they should be. This long fire cycle is directly attributed to the C7 (Douglas-fir) and D1 (aspen) fuel types that could not sustain large size fires using the FBP fire spread equations. Perhaps the Porcupine Hills are largely under a spring/fall fire regime, which would allow deciduous and mixedwood stands to burn.

11.4 Conclusions

All three methods used to calculate the fire cycle had their limitations and generated different results. Both the fire occurrence and simulation methods were attempting to emulate a historical fire regime. Despite that, the fire cycle value for all of C5 is about 30 years shorter when using fire occurrence data. The fire cycle value from the recent fire mapping method is in between the two other methods. Its limitations are that it focussed on a narrow temporal scale, it could not cover the full range of magnitude in fire size variation and, it had a limited number of fires by subregion that prevented the calculation of a fire cycle by subregion. Overall, because of the natural variation provided by the simulated fire cycles, the stand origin model remains the best tool to predict the variation in the yearly rate of forest disturbance, and specifically for different subregions within the landscape. These simulated historical fire cycle values can be used as benchmarks for harvesting practices with a fairly high level of confidence.

12.0 VEGETATION COVER TYPES AND FIRE

This Chapter presents the results from the stand origin simulation outputs when assessed by vegetation cover type. Note that the creation of the cover type map has been described in Section 3.9. The cover type map was used to extract the area and patch size distributions for each cover type's seral stages. The mean-fire-return-interval distribution by cover type was also analyzed. A description of the cover types' seral stages is presented in Table 12-1, as provided by ASRD. Please make note of the revised age-classes for the Fa/La cover type that better reflect the seral stages of this vegetation community in relation to fire. All analyses were repeated for the five subregions and two natural subregions found within the C5 FMU.

Table 12-1 C5 Forest Management Plan vegetation cover types and seral stages.

		Seral Stage				
Cover Type	**Description**	**Regen-eration**	**Young**	**Mature**	**Early Old Growth**	**Late Old Growth**
C-Fa/La	Forested areas with > 80% conifer species composition in the overstory layer with Alpine Fir or Alpine Larch as the leading species.	0-40	41-100	101-200	201-250	> 250
C-Fd	Forested areas with > 80% conifer species composition in the overstory layer with Douglas-fir as the leading species.	0-30	31-90	91-200	200-250	> 250
C-Px	Forested areas with > 80% conifer species composition in the overstory layer with Lodgepole, Whitebark or Limber Pine as the leading species.	0-25	26-80	81-150	151-200	> 200
C-Sx	Forested areas with > 80% conifer species composition in the overstory layer with either White Spruce or Engelmann Spruce as the leading species.	0-30	31-90	91-180	181-230	> 230
CD	Forested areas with 50% up to 80% conifer species composition in the overstory layer.	0-25	26-80	81-150	151-200	> 200
DC	Forested areas with 30% up to 40% conifer species composition in the overstory layer.	0-25	26-80	81-150	151-200	> 200
D	Forested areas with 20% or less conifer species composition in the overstory layer.	0-30	30-70	71-130	131-180	> 180

12.1 AGE-CLASS DISTRIBUTION

The age-class distributions by cover type, presented in Tables 12-2 to 12-5, were obtained from the simulated mean stand origin map produced for each subregion. Please refer back to Section 9.5 for more details on this process. Values presented in the tables below are expressed in percent of land base by seral stage. The seral stage's age-class values are found in Table 12-1. The weighted mean age by cover type is presented as well and was calculated from unclassified ages (i.e. before forming broad seral stage classes). The tables' legend for seral stages is as follow: R = Regeneration, Y = Young, M = Mature, EOG = Early Old Growth and, LOG = Late Old Growth.

Table 12-2 Percent area by seral stage and vegetation cover type for the Montane and Subalpine natural subregions of C5 FMU.

	Montane						Subalpine					
Cover type	**R**	**Y**	**M**	**EOG**	**LOG**	**Wgt mean age**	**R**	**Y**	**M**	**EOG**	**LOG**	**Wgt mean age**
Fa/la	3.69	56.72	17.00	9.51	13.08	117	2.17	47.31	25.02	8.64	16.86	132
Fd	0.10	37.14	46.47	7.57	8.71	135	0.19	27.01	51.69	9.63	11.47	151
Px	0.11	53.14	30.54	8.52	7.69	101	0.03	32.56	48.04	10.11	9.28	109
Sx	1.33	71.60	24.16	1.94	0.97	81	0.07	43.64	42.33	6.97	6.98	109
CD	1.81	46.81	34.43	6.62	10.33	107	1.14	33.21	35.79	12.65	17.21	110
DC	1.23	51.34	26.96	9.03	11.44	108	0.00	22.87	43.35	15.05	18.73	144
D	0.53	23.42	36.64	17.04	22.37	136	0.23	10.04	34.91	22.11	32.72	167

Table 12-3 Percent area by seral stage and vegetation cover type for the Continental Divide North and Livingstone subregions of C5 FMU.

	CDN						Livingstone					
Cover type	**R**	**Y**	**M**	**EOG**	**LOG**	**Wgt mean age**	**R**	**Y**	**M**	**EOG**	**LOG**	**Wgt mean age**
Fa/la	0.00	14.13	32.39	18.26	35.22	195	0.08	48.42	26.43	10.75	14.31	127
Fd	0.00	3.88	46.98	23.28	25.86	210	0.67	26.58	51.43	9.13	12.19	149
Px	0.00	25.86	46.67	11.93	15.55	137	0.00	33.74	49.89	9.74	6.63	114
Sx	0.00	34.98	47.28	8.10	9.63	137	0.45	49.44	42.38	4.21	3.53	109
CD	0.00	0.00	0.00	86.67	13.33	n/a*	4.60	30.90	36.93	13.07	14.50	123
DC	0.00	66.67	11.11	22.22	0.00	n/a*	0.00	30.19	40.94	12.31	16.56	135
D	0.00	40.00	26.67	0.00	33.33	n/a*	0.31	16.08	37.09	16.37	30.16	153

* unrepresentative land base with less than 30 ha.

Table 12-4 Percent area by seral stage and vegetation cover type for the Continental Divide South and Castle subregions of C5 FMU.

	CDS						Castle					
Cover type	**R**	**Y**	**M**	**EOG**	**LOG**	**Wgt mean age**	**R**	**Y**	**M**	**EOG**	**LOG**	**Wgt mean age**
Fa/la	6.09	69.80	13.34	3.81	6.96	94	4.34	60.21	23.18	4.67	7.60	106
Fd	1.74	19.77	34.88	14.53	29.07	198	0.06	68.61	27.87	2.25	1.21	88
Px	0.01	87.21	6.35	1.96	4.47	69	0.15	60.33	33.28	4.47	1.77	84
Sx	1.17	90.55	6.30	1.10	0.87	63	0.49	72.13	25.32	1.21	0.86	78
CD	1.93	82.04	14.92	0.28	0.83	54	0.81	74.14	18.99	5.45	0.61	65
DC	0.00	91.93	0.00	4.97	3.11	63	0.00	57.29	24.35	13.17	5.19	99
D	1.57	87.98	7.49	0.70	2.26	62	0.00	30.34	9.46	25.43	34.78	149

Table 12-5 Percent area by seral stage and vegetation cover type for the Porcupine Hills subregion of C5 FMU.

	Porcupine Hills					
Cover type	**R**	**Y**	**M**	**EOG**	**LOG**	**Wgt mean age**
Fa/la	n/a	n/a	n/a	n/a	n/a	n/a
Fd	8.11	52.28	36.39	2.62	0.60	91
Px	0.39	23.80	55.74	14.75	5.31	120
Sx	0.59	59.29	39.58	0.48	0.05	90
CD	0.00	32.27	38.34	10.22	19.17	143
DC	0.93	11.12	37.91	16.98	33.07	182
D	4.06	24.24	40.63	19.63	11.45	112

Data comparisons show that differences in the fire regime among subregions have been captured by the seral stage distributions. For example, the weighted mean age of each Montane cover type is younger than those for the Subalpine. Within a subregion, differences in area distribution of seral stages and weighted mean ages among cover types are largely driven by the fire behaviour prediction equations that are used in the fire growth model (based on the FBP fuel types). The Douglas fir fuel type is a good example. This fuel is described as being an open forest with sparse ground fuel. As a result it is more difficult for this fuel to support stand replacing fires at the same frequency as pine or spruce forests. Note that the seral stage distribution and weigted mean age of Douglas fir for the CDS subregion is unreliable. It mainly represents one large patch of forest along the BC boundary and the Crowsnest corridor where sources of ignitions were much less due to the fact that no fires were coming from the BC side.

An interesting factor observed is the influence of fuel types on their neighboring fuels. For example, in the Castle subregion, the Douglas fir cover type was found to be of an age similar to the pine cover type. The spatial distribution of this cover type in this area consists of scattered narrow patches of Douglas fir forests that are surrounded by pine and spruce. Similar observations were made with the mixedwood cover types and with the pure deciduous fuel type. When those cover types have similar seral distribution tendencies and weighted mean ages as coniferous fuels, it is due to the level of fragmentation and dispersion of these deciduous patches on the landscape. Narrow and small patches of deciduous forests are largely influenced by their coniferous surroundings. On the other hand, large continuous extents of deciduous forests cannot sustain stand replacing fires as frequently as coniferous stands due to the green leaf period during the summer time. In order for deciduous forests to have shorter fire cycles, their fire regime needs to be driven by spring and fall burning. This is an element that needs to be verified in the field by dating fire scars and identifying if scared tissue is located in the early-early wood, middle-early wood, late-early wood, late wood, or during the dormant season. Interestingly, small patches of conifers that are surrounded by large extents of deciduous forests tend to be older. This is the case in the Porcupine Hills where pine forests are surrounded by aspen forests. The Douglas fir weighted mean age in the Porcupine Hills is similar to that of the spruce because most of the Douglas fir forests is not as fragmented in this region and it is largely surrounded by grass. During the fire modelling session, more spring and fall fires had to be set for the Porcupine Hills otherwise the fire return interval for this subregion was simply too long and unrealistic (greater than 300 and 500 years).

The similarities in seral age distribution and weighted mean age between the pine and spruce cover types are also questionable. From a strict fire behaviour point of view, both fuel types are equally flammable during high fire weather severity, which was modeled for. However, in reality, spruce stands are often older than pine, especially in a mountain environment. Spruce stands tend to grow in mesic to moist soil conditions in creek draws, land depressions, cooler aspects and higher elevations that see more precipitation. The fire growth model used does not incorporate soil drainage conditions and does not have a built-in forest succession module. The model does a respectable job at emulating regional fire regimes and fire spread patterns, but making observations at the cover type level revealed the limitations of the model in that regard.

12.2 Mean-Fire-Return-Interval

The MFRI distribution by cover type, presented in Tables 12-6 and 12-7, was obtained from the simulated mean fire count map produced for each subregion. Please refer back to Section 9.5 for more details on this process. The mean fire count map showed the number of times (frequency) a cell burned over a 1,000-year period. The MFRI was simply obtained by dividing 1000 by the fire frequency value. MFRI values were grouped into seven classes and a weighted MFRI value was also calculated prior to classifying the information. The weighted MFRI should be a good approximation of the fire cycle on the landscape. The MFRI evaluated on a cell by cell basis is actually equal to the fire cycle. But since it varies spatially over the landscape, the weighted value is a better representation for a regional fire cycle value.

The evaluation of MFRI (of fire cycle) values by subregion and cover type share similar conclusions to the seral stage distribution data presented in the above section. The weighted mean age values are often within less than twenty years apart from the MFRI. While the weighted mean age is not an exact representation of the fire cycle, it can be used as a guideline. The reason for the differences in value is that the weighted mean age relies on the last landscape snapshot after 1,000 year of fire emulations, while the MFRI map captured the frequency each cell burned during 1,000 years. It is obvious when the data is compared in this manner, that the fire growth model had difficulties emulating a stable fire regime for the Porcupine Hills subregion. The most recent snapshot of the landscape actually represented fairly young ages. When the data is evaluated using the MFRI data, the fire cycle is much longer; three times longer in the case of the pine cover type. This is another indication that the model outputs for the Porcupine Hills are unreliable and should not be used in forest management planning.

Table 12-6 Percent area by MFRI class and vegetation cover type for the natural subregions of C5 FMU.

MFRI	Fa/La	Fd	Px	Sx	CD	DC	D
				Montane			
41-50	0.00	0.20	2.68	1.46	2.31	0.52	0.53
51-67	7.26	2.29	15.30	20.18	9.69	5.42	3.42
68-100	56.07	30.81	38.62	48.25	36.46	38.99	28.33
101-200	18.33	36.27	29.16	24.89	39.02	35.66	36.50
201-500	18.10	30.18	14.20	5.21	12.52	19.25	30.97
>500	0.24	0.25	0.04	0.00	0.00	0.17	0.25
land base (ha)	840	31,952	27,350	14,915	3,593	4,240	45,196
Wgt MFRI	114	143	110	91	112	125	147
				Subalpine			
41-50	0.04	0.00	0.11	0.29	0.36	0.97	0.21
51-67	3.09	1.11	1.55	3.42	0.00	1.42	0.62
68-100	42.22	23.54	44.77	50.67	38.37	29.72	23.89
101-200	26.19	47.10	40.18	28.38	39.45	48.39	39.20
201-500	26.05	27.63	12.77	16.52	21.82	18.80	35.53
>500	2.40	0.61	0.62	0.72	0.00	0.71	0.55
land base (ha)	16,134	5,212	87,533	69,762	1,668	1,548	5,291
Wgt MFRI	150	152	125	123	137	139	170

Table 12-7 Percent area by MFRI class and vegetation cover type for the management subregions of C5 FMU.

MFRI	Fa/La	Fd	Px	Sx	CD	DC	D
				CDN			
68-100	9.37	0.86	24.23	24.01	0.00	66.67	13.33
101-200	27.30	11.59	46.59	47.37	70.00	33.33	53.33
201-500	58.69	84.55	25.09	28.12	30.00	0.00	33.33
>500	4.64	3.00	4.09	0.50	0.00	0.00	0.00
land base (ha)	2,370	233	7,430	15,610	30	9	15
Wgt MFRI	227	241	158	151	*	*	*
	* not enough land to be representative (<30ha)						
				Livingstone			
51-67	0.00	0.00	0.29	0.59	0.39	0.77	0.35
68-100	41.07	18.86	34.11	45.84	24.77	21.79	19.77
101-200	28.46	47.06	52.41	40.65	51.74	47.10	39.46
201-500	30.48	33.15	13.00	12.67	23.03	29.68	39.91

MFRI	Fa/La	Fd	Px	Sx	CD	DC	D
>500	0.00	0.92	0.19	0.25	0.08	0.66	0.51
land base (ha)	1,237	5,191	63,730	26,830	2,584	2,584	11,457
Wgt MFRI	134	166	128	123	140	151	171
CDS							
<40	0.12	0.19	3.14	1.11	11.88	9.94	14.29
41-50	4.80	3.49	47.07	32.30	70.44	62.73	67.60
51-67	17.12	1.74	22.67	21.51	2.21	7.45	9.06
68-100	42.83	19.19	15.52	35.63	9.94	6.21	3.48
101-200	23.90	37.60	5.04	7.15	3.59	5.59	2.61
201-500	10.25	37.21	6.34	2.25	1.93	5.59	2.96
>500	0.97	0.58	0.22	0.06	0.00	2.48	0.00
land base (ha)	8,108	516	14,811	21,670	362	161	574
Wgt MFRI	106	176	72	68	54	83	55
Castle							
41-50	0.03	1.04	4.18	5.50	10.91	5.39	5.51
51-67	4.98	15.29	12.86	21.22	41.62	27.54	12.76
68-100	59.61	46.39	59.99	56.25	31.31	33.33	15.90
101-200	23.85	32.03	16.45	12.69	11.31	17.17	21.95
201-500	10.42	5.14	6.50	4.29	4.85	16.57	41.00
>500	1.11	0.12	0.03	0.06	0.00	0.00	2.87
land base (ha)	3,954	1,733	14,952	8,624	495	501	2,993
Wgt MFRI	113	96	91	83	76	102	167
P. Hills							
51-67	n/a	0.21	0.00	0.00	0.00	0.51	0.26
68-100	n/a	3.97	0.27	0.27	3.19	5.91	2.81
101-200	n/a	35.10	12.22	27.88	62.30	34.45	21.54
201-500	n/a	43.47	48.71	59.08	26.20	46.02	40.64
>500	n/a	17.24	38.80	12.77	8.31	13.11	34.74
land base (ha)	0	13,674	4,067	1,872	313	389	10,944
Wgt MFRI	0	256	356	261	202	235	330

12.3 Patch Size Distribution

The original intent of this exercise was to provide a patch size distribution by seral stage for each cover type. However, it was observed that due to the spatial fragmentation of some cover types, it was the fragmentation of the fuel type itself that was driving the patch size distribution and not the break down in seral stage groups. Figure 12-1 provides an example of such vegetation fragmentation for the Douglas fir fuel type. The worst cases of landscape fragmentation are for the CD and DC fuel types, followed by the Fa/La and Fd. Due to this data limitation, it was decided that it was better to group the fuel types into two main categories: coniferous (Fa/La, Fd, Px, Sx and CD) and deciduous (D and DC) to obtain a less fragmented forest cover. These two main cover types were classified into different age-classes so as to represent all possible combinations of seral stages associated with each cover type. Results are presented in Tables 12-11 to 12-17 and are expressed in percent of occurrence. The [All] field represents the patch size distribution for all of the coniferous fuel types and for all of the deciduous fuel type. These values are indicators of the level of fragmentation of the forest without considering seral stages.

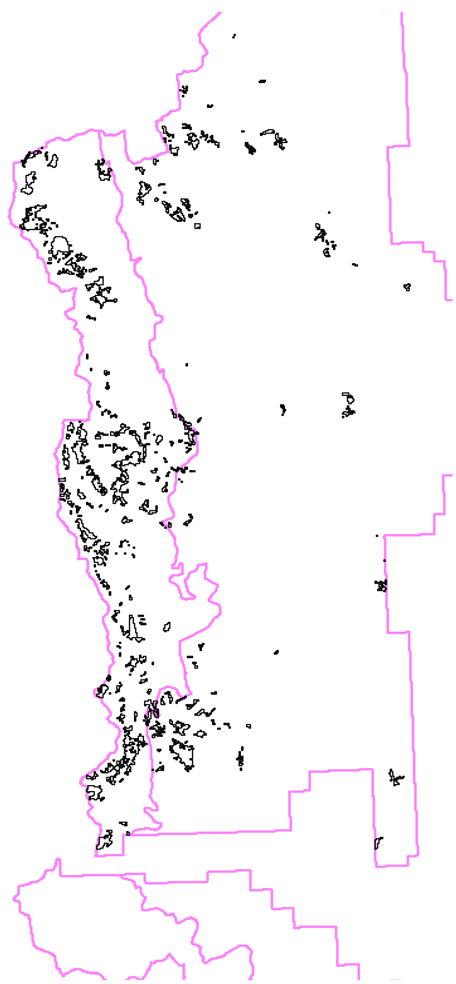

Figure 12-1 Example of forest fragmentation for the Douglas fir (Fd) cover type in the Continental Divide North and Livingstone subregions.

Table 12-8 Patch size distribution by seral stage for the Montane natural subregion. Values are expressed in percent of occurrence.

Patch size	R	Y	M	EOG	LOG	All
Fa/La						
6	77.89	78.35	80.56	85.39	85.02	76.15
40	16.83	16.49	15.18	12.68	12.21	18.18
80	2.54	2.41	2.02	1.69	1.38	2.53
250	2.15	1.72	1.33	0.24	0.69	1.62
500	0.20	0.73	0.48	0.00	0.23	0.48
500+	0.39	0.30	0.43	0.00	0.46	1.05
Fd						
6	86.54	77.76	80.48	85.39	85.02	
40	9.62	17.52	14.87	12.68	12.21	
80	3.85	2.38	2.38	1.69	1.38	
250	0.00	1.31	1.42	0.24	0.69	
500	0.00	0.49	0.35	0.00	0.23	
500+	0.00	0.54	0.51	0.00	0.46	
Px						
6	86.67	79.14	81.23	84.92	84.73	
40	13.33	16.29	14.29	13.25	11.83	
80	0.00	2.23	1.79	1.33	1.93	
250	0.00	1.47	1.89	0.42	0.83	
500	0.00	0.44	0.33	0.00	0.28	
500+	0.00	0.44	0.47	0.07	0.41	
Sx						
6	86.54	77.76	81.82	85.11	85.09	
40	9.62	17.52	13.55	13.41	12.05	
80	3.85	2.38	2.36	0.93	1.34	
250	0.00	1.31	1.58	0.56	0.96	
500	0.00	0.49	0.25	0.00	0.19	
500+	0.00	0.54	0.44	0.00	0.38	
D						
6	91.03	86.74	84.72	88.70	81.04	75.13
40	7.69	12.47	13.65	10.51	15.14	20.68
80	1.28	0.55	1.22	0.62	2.13	2.10
250	0.00	0.20	0.41	0.18	1.19	1.54
500	0.00	0.03	0.00	0.00	0.43	0.41
500+	0.00	0.00	0.00	0.00	0.09	0.14

Table 12-9 Patch size distribution by seral stage for the Subalpine natural subregion. Values are expressed in percent of occurrence.

Patch size	R	Y	M	EOG	LOG	All
Fa/La						
6	70.83	84.12	80.89	82.75	84.30	87.95
40	19.27	10.84	14.21	13.04	10.60	8.88
80	4.69	2.14	1.17	1.68	1.88	1.33
250	4.69	1.51	1.86	2.10	2.15	0.61
500	0.52	0.58	0.59	0.42	0.40	0.41
500+	0.00	0.81	1.28	0.00	0.67	0.82
Fd						
6	70.83	82.89	81.76	82.75	84.30	
40	25.00	11.70	13.63	13.04	10.60	
80	0.00	2.04	1.62	1.68	1.88	
250	4.17	1.59	1.15	2.10	2.15	
500	0.00	0.83	0.68	0.42	0.40	
500+	0.00	0.95	1.15	0.00	0.67	
Px						
6	87.50	82.05	82.32	78.35	83.45	
40	12.50	12.48	12.42	16.79	11.55	
80	0.00	2.17	2.16	1.92	1.64	
250	0.00	1.68	1.32	2.17	2.21	
500	0.00	0.28	0.79	0.38	0.38	
500+	0.00	1.33	1.00	0.38	0.77	
Sx						
6	70.83	82.89	82.50	82.75	84.11	
40	25.00	11.70	12.66	13.24	11.58	
80	0.00	2.04	1.65	1.39	1.36	
250	4.17	1.59	1.28	2.00	1.82	
500	0.00	0.83	0.85	0.44	0.34	
500+	0.00	0.95	1.06	0.17	0.79	
D						
6	100.00	86.45	88.27	87.17	84.81	79.91
40	0.00	13.55	11.60	12.63	11.88	17.75
80	0.00	0.00	0.14	0.20	2.21	1.44
250	0.00	0.00	0.00	0.00	1.10	0.90
500	0.00	0.00	0.00	0.00	0.00	0.00
500+	0.00	0.00	0.00	0.00	0.00	0.00

Table 12-10 Patch size distribution by seral stage for the Continental Divide North subregion. Values are expressed in percent of occurrence.

Patch size	R	Y	M	EOG	LOG	All
Fa/La						
6	78.57	78.46	81.28	77.90	83.33	90.26
40	21.43	14.62	10.84	15.47	12.18	7.14
80	0.00	0.77	0.99	6.08	1.92	1.30
250	0.00	2.31	3.94	0.55	1.28	0.65
500	0.00	0.77	0.99	0.00	0.00	0.00
500+	0.00	3.08	1.97	0.00	1.28	0.65
Fd						
6	n/a	75.40	83.33	77.90	83.33	
40		12.70	11.84	15.47	12.18	
80		3.17	0.44	6.08	1.92	
250		4.76	2.19	0.55	1.28	
500		2.38	0.88	0.00	0.00	
500+		1.59	1.32	0.00	1.28	
Px						
6	n/a	68.94	82.14	79.91	80.79	
40		22.73	10.20	13.84	12.81	
80		1.52	3.06	1.79	4.43	
250		4.55	2.04	3.13	0.00	
500		0.00	0.51	0.89	0.49	
500+		2.27	2.04	0.45	1.48	
Sx						
6	n/a	75.40	81.40	78.26	83.60	
40		12.70	12.56	11.96	11.11	
80		3.17	0.47	5.43	2.65	
250		4.76	2.33	4.35	1.06	
500		2.38	1.40	0.00	0.53	
500+		1.59	1.86	0.00	1.06	
D						
6	n/a	100.00	100.00	n/a	100.00	100.00
40		0.00	0.00		0.00	0.00
80		0.00	0.00		0.00	0.00
250		0.00	0.00		0.00	0.00
500		0.00	0.00		0.00	0.00
500+		0.00	0.00		0.00	0.00

Table 12-11 Patch size distribution by seral stage for the Livingstone subregion. Values are expressed in percent of occurrence.

Patch size	R	Y	M	EOG	LOG	All
Fa/La						
6	73.68	82.21	83.73	84.38	84.13	84.87
40	16.84	13.26	12.33	12.85	12.70	12.18
80	5.26	2.40	1.04	2.04	2.12	1.05
250	3.16	1.03	1.75	0.73	0.79	1.05
500	0.00	0.48	0.44	0.00	0.00	0.42
500+	1.05	0.62	0.71	0.00	0.26	0.42
Fd						
6	75.00	81.23	84.24	84.38	84.13	
40	21.88	14.34	11.75	12.85	12.70	
80	3.13	2.00	1.14	2.04	2.12	
250	0.00	1.18	1.41	0.73	0.79	
500	0.00	0.52	0.87	0.00	0.00	
500+	0.00	0.74	0.60	0.00	0.26	
Px						
6	n/a	80.91	84.13	82.71	81.11	
40	n/a	14.16	11.86	13.57	14.24	
80	n/a	2.02	1.19	2.34	2.32	
250	n/a	1.54	1.63	1.13	1.86	
500	n/a	0.73	0.49	0.16	0.15	
500+	n/a	0.65	0.70	0.08	0.31	
Sx						
6	75.00	81.23	83.73	83.91	80.59	
40	21.88	14.34	12.09	13.25	15.58	
80	3.13	2.00	1.19	1.78	2.48	
250	0.00	1.18	1.68	1.07	0.90	
500	0.00	0.52	0.65	0.00	0.23	
500+	0.00	0.74	0.65	0.00	0.23	
D						
6	58.33	86.91	85.31	89.64	82.12	79.68
40	41.67	12.60	13.58	9.76	14.13	17.35
80	0.00	0.49	0.51	0.44	2.21	1.69
250	0.00	0.00	0.51	0.15	1.32	0.88
500	0.00	0.00	0.08	0.00	0.00	0.20
500+	0.00	0.00	0.00	0.00	0.22	0.20

Table 12-12 Patch size distribution by seral stage for the Continental Divide South subregion. Values are expressed in percent of occurrence.

Patch size	R	Y	M	EOG	LOG	All
Fa/La						
6	72.87	87.92	78.71	75.23	78.64	88.86
40	17.41	9.90	15.21	24.77	14.56	9.51
80	2.83	0.67	2.28	0.00	4.85	0.93
250	3.24	0.67	3.04	0.00	1.94	0.23
500	2.02	0.34	0.38	0.00	0.00	0.00
500+	1.62	0.50	0.38	0.00	0.00	0.46
Fd						
6	72.97	90.11	78.81	75.23	78.64	
40	16.22	8.47	14.57	24.77	14.56	
80	8.11	0.85	2.98	0.00	4.85	
250	2.70	0.00	2.65	0.00	1.94	
500	0.00	0.00	0.33	0.00	0.00	
500+	0.00	0.56	0.66	0.00	0.00	
Px						
6	100.00	89.71	78.61	80.95	77.78	
40	0.00	9.12	14.74	13.61	14.53	
80	0.00	0.59	2.02	5.44	4.27	
250	0.00	0.00	3.18	0.00	1.71	
500	0.00	0.00	1.45	0.00	1.71	
500+	0.00	0.59	0.00	0.00	0.00	
Sx						
6	72.97	90.11	78.72	79.51	78.45	
40	16.22	8.47	14.53	18.03	14.66	
80	8.11	0.85	3.04	1.64	5.17	
250	2.70	0.00	3.04	0.82	0.86	
500	0.00	0.00	0.68	0.00	0.86	
500+	0.00	0.56	0.00	0.00	0.00	
D						
6	100.00	82.39	91.30	100.00	88.89	83.78
40	0.00	17.61	8.70	0.00	11.11	15.68
80	0.00	0.00	0.00	0.00	0.00	0.54
250	0.00	0.00	0.00	0.00	0.00	0.00
500	0.00	0.00	0.00	0.00	0.00	0.00
500+	0.00	0.00	0.00	0.00	0.00	0.00

Table 12-13 Patch size distribution by seral stage for the Castle subregion. Values are expressed in percent of occurrence.

Patch size	R	Y	M	EOG	LOG	All
Fa/La						
6	77.98	81.49	85.89	86.67	88.00	84.73
40	17.43	11.07	8.78	11.11	10.67	10.55
80	0.92	2.41	2.19	1.11	1.33	1.64
250	1.83	3.02	2.51	1.11	0.00	1.64
500	1.83	0.60	0.31	0.00	0.00	0.36
500+	0.00	1.41	0.31	0.00	0.00	1.09
Fd						
6	80.00	82.07	85.40	86.67	88.00	
40	15.00	11.72	10.16	11.11	10.67	
80	5.00	1.38	1.59	1.11	1.33	
250	0.00	3.45	1.59	1.11	0.00	
500	0.00	0.23	0.63	0.00	0.00	
500+	0.00	1.15	0.63	0.00	0.00	
Px						
6	66.67	81.75	83.02	89.86	86.09	
40	16.67	10.90	10.69	8.21	11.30	
80	16.67	2.84	3.14	0.48	0.87	
250	0.00	3.32	1.89	0.97	1.74	
500	0.00	0.00	0.31	0.48	0.00	
500+	0.00	1.18	0.94	0.00	0.00	
Sx						
6	80.00	82.07	86.09	88.67	86.05	
40	15.00	11.72	9.27	10.00	10.47	
80	5.00	1.38	1.32	0.00	2.33	
250	0.00	3.45	1.99	1.33	1.16	
500	0.00	0.23	0.66	0.00	0.00	
500+	0.00	1.15	0.66	0.00	0.00	
D						
6	n/a	84.40	83.33	80.53	75.36	79.43
40	n/a	13.60	16.67	15.93	15.94	17.41
80	n/a	2.00	0.00	2.65	4.35	1.58
250	n/a	0.00	0.00	0.88	2.90	0.95
500	n/a	0.00	0.00	0.00	1.45	0.32
500+	n/a	0.00	0.00	0.00	0.00	0.32

Table 12-14 Patch size distribution by seral stage for the Porcupine Hills subregion. Values are expressed in percent of occurrence.

Patch size	R	Y	M	EOG	LOG	All
Fa/La	Does not occur in this subregion					
Fd						
6	81.25	73.88	83.65	84.76	87.88	73.55
40	17.86	19.77	11.70	12.38	12.12	21.16
80	0.45	3.61	1.55	2.86	0.00	2.77
250	0.45	1.73	1.72	0.00	0.00	1.51
500	0.00	0.72	0.69	0.00	0.00	0.00
500+	0.00	0.29	0.69	0.00	0.00	1.01
Px						
6	85.33	74.93	83.58	87.03	84.38	
40	14.67	19.48	11.38	9.81	13.54	
80	0.00	2.72	1.79	2.22	1.04	
250	0.00	2.15	1.79	0.95	0.00	
500	0.00	0.57	0.81	0.00	1.04	
500+	0.00	0.14	0.65	0.00	0.00	
Sx						
6	81.25	73.88	84.25	82.80	90.00	
40	17.86	19.77	10.79	15.29	8.00	
80	0.45	3.61	1.88	1.27	0.00	
250	0.45	1.73	1.71	0.64	2.00	
500	0.00	0.72	0.86	0.00	0.00	
500+	0.00	0.29	0.51	0.00	0.00	
D						
6	92.23	89.93	84.29	84.83	82.27	69.72
40	7.77	9.95	13.85	13.10	12.77	25.22
80	0.00	0.11	1.21	1.15	3.55	1.98
250	0.00	0.00	0.66	0.92	0.71	2.60
500	0.00	0.00	0.00	0.00	0.71	0.37
500+	0.00	0.00	0.00	0.00	0.00	0.12

Despite lumping all coniferous fuel types together to reduce the amount of fragmentation in the forest cover, it is obvious from the results found in the [All] column of each table that it is the fragmentation of the forest cover that drives the distribution of patch sizes by seral stages. Similar conclusions apply to the deciduous cover type as well. In all cases, over 70% of the patches are less than 6 ha. This was found true for all seral stages, all cover types and within all subregions. It would be improper to use these results for forest management planning considering how unrealistic this level of fragmentation is (large number of patch sizes less than 6 ha) for a vegetation mosaic created from overlapping fires.

What is actually dissecting the forest cover into a great number of small patches are the interspersed patches of grass, mixedwood and deciduous forests. The cover type used contained roads that had to be represented as grass so that the fire growth model could burn through linear non-fuel features. These roads contributed to the increase in patchiness of the forest cover. Unfortunately, this fragmentation of the forest cover does not allow us to understand what the patch size distribution, as a result of centuries of burning, should be.

12. 4 CONCLUSIONS

The analyses performed between the vegetation cover types and the fire simulation outputs did not prove to be reliable for forest management planning. As discussed in the previous sections, the fire growth equations used by the model prevented some fuels from burning on a more frequent basis. These fuel types are the Douglas-fir (C7), the mixedwoods (M1/M2) and the pure deciduous fuel types (D1/D2). Based on the length of the fire return interval in these fuels, it is likely that the fire regime may be driven by a much higher number of spring and fall fires. This would be especially true for the Montane natural subregion. This is a factor that needs to be verified in the field by dating fire scars and identifying if scared tissue is located in the early-early wood, middle-early wood, late-early wood, late wood, or during the dormant season.

The similarities in seral age distribution, weighted mean age and weighted MFRI between the pine and spruce cover types are also questionable. From a strict fire behaviour point of view, both fuel types are equally flammable during high fire weather severity, which was modeled for. However, in reality, spruce stands are often older than pine, especially in a mountain environment. Spruce stands tend to grow in mesic to moist soil conditions in creek draws, land depressions, cooler aspects and higher elevations that see more precipitation. The fire growth model used does not incorporate soil drainage conditions and does not have a built-in forest succession module. The model does a respectable job at emulating regional fire regimes and fire spread patterns, but making observations at the cover type level revealed the limitations of the model in that regard.

The high level of fragmentation of the forest cover also prevented the formation of any sound conclusions about the patch size distribution by seral stages.

13.0 CONCLUSION

13.1 GENERAL

Patch size distribution from harvest blocks, as described in the Alberta Timber Harvest Planning and Operating Ground Rules, was found not to be suggestive of natural disturbances. Unsurprisingly, cutblock sizes are found at the lower end of the spectrum of the fire size distribution. This was true for all natural subregions. Although the patch size distribution and disturbance area do not mimic fire, it may be that the yearly rate of disturbance from harvesting approximates that of fire disturbances. This is something that Alberta Forest Protection needs to verify for each management subregion.

Before proceeding with the emulation process of natural disturbances, fundamental questions must be answered a priori. Can the forest sustain harvesting pressure at the same rate as fire? From a different perspective, can the emulation of natural disturbances sustain the logging industry? In an attempt to emulate fires, larger size cutblocks may result, as well as an increase in the yearly rate of forest disturbance. But, to truly emulate fire disturbance, the harvesting industry would also have to change the spatial distribution of cutblocks. Using the information from the effect of topography, more cutblocks would have to be distributed in areas of shorter fire cycles (where fire activity has naturally been higher), while areas of longer fire cycles would see a reduced number of harvesting disturbances. This is an opposite logic to current harvesting practices where older patches of forests are pursued for practical and economical reasons. In this emulation process, there would have to be a greater percentage of cutblocks in younger aged forests. Perhaps, at this time it is still feasible for a change in process since we are still playing catch up with the effect of prolonged fire suppression, which has created a shift towards an older age-class distribution in the forest.

To conclude, a number of recommendations are presented with respect to future potential studies and, data gap issues. As well, for the reader's interest, a short summary of the "take home" messages from the Natural Disturbance Symposium held in Edmonton in March 2001 is provided.

13.2 RECOMMENDATIONS

Based on the results obtained and information available to date, a number of recommendations have been listed below.

13.2.1 Data Gap - effect of topography

Due to the small number of fires that could be mapped and the narrow period of time represented (Chapter 8), it is recommended to borrow fire cycle information from other fire history studies. Banff National Park (Rogeau and Gilbride 1994), the Whitegoat and Siffleur Wilderness Areas (Rogeau 1999), Spray Lakes Recreation Area (Rogeau 1994), Kananaskis Valley (Johnson and Fryer 1987) and Peter Lougheed Provincial Park (Hawkes 1980), all have a complete stand origin map that was produced from fire history data collection. From this large data set, the effect of topography on fire patterns was evaluated and a series of fire cycle values that vary spatially according to the ecoregions (montane versus subalpine) and topography have been determined

(Rogeau et al 2004). These results should be implemented for the "rugged" part of the Rocky Mountain natural region that contains fuel breaks from rocky ridges and abrupt changes in valley orientations, but not for areas of continuous forest cover.

13.2.2 Data Gap - Montane & Porcupine Hills

The Montane natural subregion has always been a challenge when it comes to understanding its historical fire regime. Because of its long-term, intensive and extensive use by man, especially at the turn of the century, many fires of different burning intensities occurred at short intervals, which created a complex vegetation and age mosaic. For these reasons, fire mapping has always been difficult for this natural subregion. The Porcupine Hills is a good example with regards to these issues. This fire regime study, even after using several tools and methods to understand and define its fire regime, is lacking some important elements. Notably, fire size, mean-fire-return-interval and fire cycle. The recent fire mapping process (Chapter 8) was unable to trace any complete fires from the montane. This includes portions of the Livingstone and the Porcupine Hills. The fire simulation model was also unable to replicate burning patterns for the Porcupine Hills. The FBP equations of fire spread for C7 (Douglas fir) and D1 (aspen) could not sustain large stand replacing fires on a relatively frequent basis. The number of spring burning days was increased to encourage larger burns in aspen forests but it was not successful in bringing down the fire return interval to reasonable levels expected to be 30 to 50 years. Instead, the fire interval was above 200 years. As for the C7 fuel type, it is too open to sustain a moving crown fire so this fuel type would burn only during extreme windy events.

In light of these findings, it is strongly recommended that fire history field data collection take place in the Montane natural subregion. The Porcupine Hills being the subregion with the greatest data gap should be prioritized, followed by the Montane portion of the Livingstone subregion.

13.2.3 Testing for the Distribution and Size of Fire Refugia

Fire refugia is another important element for emulating natural disturbances. Fire refugia means those patches of forest, or individual trees, that escape burning. Some fire refugia can be quite extensive and will escape fire many times. This is usually where extensive areas of old growth forests are found. This aspect of fire refugia can be addressed as part of a full stand origin mapping process or as part of an old growth distribution study. However, those small patches of forest found within burn areas are just as important as those large undisturbed patches of forest. This is especially true if the logging industry is heading towards larger size cutblocks. With large size cutblocks, patches of forest left uncut will be necessary to emulate natural disturbance patterns and most importantly, to ensure connectivity for wildlife corridors, lower soil erosion and, reducing the visual impact for the public eye.

These islands of remnants differ in number and size according to the size of the wildfire. It can range from individual or pockets of trees, notably during passive crown fire activity, to significant size patches of remnant forest due to a drop in fire intensity or topographic barriers such as rock outcrops, rivers, lakes, bogs. Recording the distribution of these patches is mostly a detailed mapping exercise with large scale photos. Different analyses of patch distances and shape can then be performed with a GIS, as well as different correlation analysis with topographic features. As each fire is unique due to a combination of elements that involve fire burning indices, local weather, fuel type, topography and suppression efforts (for recent fires), it may be difficult to find trends in the island remnant distribution. The Foothills Model Forest and Alberta-Pacific Industries have both undertaken such work and I would recommend borrowing some of their findings.

13.2.4 Landscape Fragmentation Study

Based on the comparison of disturbance size distributions between historical fires and cutblocks, it was found that percentage wise, the cutblock distribution was significantly different than that of historical fires. We already know that fire distribution on the landscape is related to probabilities of ignition and that fire patterns are largely driven by topography. Cutblock distribution on the other hand, are currently based on different guidelines that do not emulate fire distribution. Therefore, the next logical step, would be to evaluate the impacts that cutblock patch size, configuration and spatial distribution have on the landscape.

The need to study the effect of cutblock mosaic on the landscape stems from the fact that the spatial configuration of cutblocks could have an equal or greater impact on the ecosystem than their annual rate of disturbance. In summary, although the annual rate of harvest is different than the natural rate of fire disturbance, understanding and measuring the landscape fragmentation to learn about the impacts of a harvest mosaic in comparison to a fire mosaic, might be of benefit in identifying the negative, neutral and positive effects of harvesting on biodiversity and the overall ecosystem.

13.2.5 Monitoring the Annual Rate of Disturbance

If fire based disturbances are to be emulated, benchmarks must be set within each fire regime identified (i.e. management subregions) to monitor the disturbance deficits or over-achievements. This can be done by subregion, and even at a finer scale by using watersheds or management units. Every year the area disturbed by harvesting and fire must be recorded spatially and verified against a mean disturbance rate benchmark. This method is currently used in Banff National Park to monitor their rate of prescribed burns in order to recover the historical rate of burning. The same principle can be applied to harvesting practices.

13.2.6 Thoughts on the future of natural disturbance replication

A three-day Natural Disturbance Symposium sponsored by the Foothills Model Forest and the Sustainable Forest Management Network, held in Edmonton in March of 2001, addressed some of the concerns raised as part of this study, and also discussed direct implementation of natural disturbance studies results in the field. This is why it is thought appropriate that some of the take home messages be listed as part of the concluding remarks of this phase of the project.

1. Natural disturbance emulation in the field of forest management is not a process that can be fully mimicked. However, by attempting to replicate some of the fire effects, it is believed that

biodiversity endemic to the area will be maintained. Biodiversity should be monitored as it is an indicator of forest health.

2. The full extent of the natural range of patch sizes cannot be fully emulated but larger size cutblocks are needed to approximate fire effects:

- move away from the 2 to 3 passes method of harvesting
- concentrate patches in one area of the valley as this leaves a larger area of undisturbed forest
- every year the cutblock just gets bigger, instead of distributing blocks all over
- larger size cutblocks allow to "play" with the number of residuals within the block
- concentrating blocks on one side of the valley means less road construction and less stream crossings

3. Fire refugia should include single trees, clumps, and patches of different sizes, which will vary in function of the size of the cutblock. Residuals should include merchantable timber, not just the unmerchantable trees, as well as snags.

4. The logging contractors must be brought on board as they are the key people that will implement the form or structure of the harvest block. Landscape architects are not hired to design a priori the amount and configuration of residuals. Contractors take advantage of the land (streams, slope steepness, wet areas) to decide where residuals will be left. Air photos and GPS are then used to evaluate how much area was actually left.

14.0 LITERATURE CITED

Andison, D.W. 1997. Landscape fire behaviour patterns in the Foothills Model Forest. Foothills Model Forest, Hinton, Alberta. 63 p.

ASRD, 1994. Alberta Harvest Planning and Operating Ground Rules. Pub. No 71. Information Centre, Alberta Environmental Protection, Edmonton, AB. 57p.

Delisle, G.P. and R.J. Hall. 1987. Forest fire history maps of Alberta, 1931 to 1983. Canadian Forestry Service, Northern Forestry Centre, Edmonton, Alberta. 55p.

Feunekes U. and C.E. Van Wagner. 1995. A century of fire and weather in Banff National Park. Internal report, Banff National Park, P. O. Box 900, Banff, AB, T1L 1K2.

Harrington, J.B. 1982. A statistical study of area burned by wildfire in Canada 1953-1980. Information Report PI-X-16. Petawawa National Forestry Institute, Canadian Forestry Service.

Hawkes, B.C. 1980. Fire history of Kananaskis Provincial Park - Mean fire return intervals. *In* Proceedings of the fire history workshop. Oct. 20-24. Tucson, Arizona. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-81. pp. 42-45.

Heinselman, M.L. 1973. Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota. Quaternary Research 3: 329-382.

Houston, D.B. 1973. Wildfires in Northern Yellowstone National Park. Ecology 54(5):1111-1117.

Johnson, E.A., and D.R. Wowchuk. 1993. Wildfires in the southern Canadian Rocky Mountains and their relationship to mid-tropospheric anomalies. Canadian Journal of Forest Research 23: 1213-1222.

Johnson, E.A. and G.I. Fryer. 1987. Historical vegetation change in the Kananaskis Valley, Canadian Rockies. Canadian Journal of Botany 65: 853-858.

Johnson, E.A. and C.E. Van Wagner 1985. The theory and use of two fire history models. Canadian Journal of Forest Research 15: 214-220.

National Research Council of Canada. 1987. Glossary of forest fire management terms. Fourth edition. Canadian Committee on Forest Fire Management, Ottawa, Ontario. Publication NRCC No. 26516.

Nimchuk, N. 1989. Ground-truthing of LLP lightning location data in Alberta. *In* Proceedings of the 10th Conference on Fire and Forest Meteorology, April 17-21, Ottawa, Canada. pp 33-40.

Rogeau, M-P. 2001. Comparing Two Methods of Fire/Stand Age Mapping: AVI vs Stand Origin. Prepared for Alberta Land and Forest Service, Forest Protection Division. 22p.

Rogeau, M-P. 1999. Fire history study of the Central Rockies Ecosystem Inter-agency North-Saskatchewan Unit. Parks Canada, Banff National Park, Box 900, Banff, AB. T0L 0C0. 61 p.

Rogeau, M-P. 1996. Understanding age-class distributions in the Southern Canadian Rockies. M.Sc. Thesis, Dept. of Renewable Resources, University of Alberta, Edmonton, Alberta. 139 p.

Rogeau, M-P. 1994. Fire History Study of the Spray Lakes Area, Alberta. Central Rockies Ecosystem Inter-agency Liaison Group, Operation Branch, Kananaskis Country. 12 p. + one map sheet.

Rogeau, M-P. and D. Gilbride 1994. Stand Origin Mapping of Banff National Park. Resource Conservation Branch, Banff National Park, Alberta. 70 p. + 8 map sheets.

Rogeau, M-P., I. Pengelly, and M-J.Fortin. 2004. Using topography to model and monitor fire cycles in Banff National Park. Pages 55-69 *in* R.T. Engstrom and W.J. de Groot, (eds.). Proceedings of the 22nd Tall Timbers Fire Ecology Conference: Fire in Temperate, Boreal, and Montane Ecosystems. Tall Timbers Research Station, Tallahassee, FL.

Tande, G.F. 1979. Fire history and vegetation patterns of coniferous forests in Jasper National Park, Alberta. Canadian Journal of Botany 57: 1912-1931.

Watson, E. and B.H. Luckman. 2001. Dendroclimatic reconstruction of precipitation for sites in the southern Canadian Rockies. The Holocene 11 (2): 203-213.

Wierzchowski, J.L., Heathcott, M. and Flannigan, M.D. 2002. Lightning and Lightning Fire, Central Cordillera, Canada. International Journal of Wildland Fire. 11: 41-51.

Appendix A: Overview of computer fire models

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 fores 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 pre-determined 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 pre-determined.	Real-time fire growth as it does not use detailed fire weather data, and size of fires are pre-determined.	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 language Operating 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 PC	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 man-caused fires on the landscape modelled.
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 don't 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 represent 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.

	FEENIX[1]	TARDIS[2]	LANDIS[3]	LANDMINE[4]	STANDOR[5]
Fire extinction	Random, with a landscape-specific maximum fire size.	Pre-determined 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.
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 behavior model	Does not use Fire Behavior Prediction (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

	FEENIX[1]	TARDIS[2]	LANDIS[3]	LANDMINE[4]	STANDOR[5]
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. (Cumming 2000b)

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

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

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