



FOREST RESEARCH BRANCH

A PROBLEM ANALYSIS OF FOREST FIRE RESEARCH
IN ALBERTA

by

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ABSTRACT

This is a problem analysis of forest fire research in Alberta, based on a review of literature, discussions with officials of government and forest industry, and a field reconnaissance carried out in 1962-63. Characteristics of the forests of Alberta are described. Forest fire problems are discussed, and present knowledge of these problems in Alberta and elsewhere is indicated. Research requirements are outlined and priorities established.

A PROBLEM ANALYSIS OF FOREST FIRE RESEARCH

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A. D. Kiil

INTRODUCTION

In Alberta, forest fires burn thousands of acres of forest and range land annually, destroying forest values amounting to millions of dollars. During the 20-year period 1943 to 1962, 283 fires burned over 334,233 acres annually, with yearly suppression costs amounting to over four hundred thousand dollars. In addition to the thousands of acres of valuable forests burned, damages to soil, stream-flow, wildlife, and recreational facilities must also be considered in the final assessment of losses incurred.

Alberta's total land area is 248,800 square miles. Of this, approximately 159,064 square miles, or 63.9 per cent, is classified as being forested. Total volume of all timber four inches and over in diameter breast height is approximately 48.7 billion cubic feet. One-quarter of the forest inventory area is fully stocked; the remainder is covered by young or immature age classes, mainly the result of frequent fires. The annual net value of the forest industries is over 61 million dollars. A rapid reduction of the growing stock has taken place as a result of increased utilization, fire losses, and insect and disease damage. This depletion has been most severe in the coniferous forests that provide over 95 per cent of the total volume harvested annually.

The Alberta Department of Lands and Forests is responsible for the protection of the forest against fire. The Province has undergone a rapid expansion of protection effort, especially during the past decade. Since 1956 action has been taken on all fires constituting a threat to the forest inventory area. This policy has been facilitated by better detection methods, greater accessibility, improved communications, and new and better fire-fighting techniques and equipment.

Reduction in fire losses can be brought about by a highly effective protection organization. Administrative planning, training of fire-fighters, and development of new equipment and suppression techniques are best handled by the Alberta Forest Service. Special investigations, such as fire danger rating, weather influences, fire behaviour, and fire effects can best be carried out by the federal Department of Forestry.

The rapidly increasing protection effort during the past decade has outstripped fire research. There is a lack of factual background information to substantiate judgement and experience. Factual information is essential for policy formulation in any of the phases of fire control, particularly in presuppression activities. Fire losses can be reduced by the intelligent application of knowledge of forest fires gained by experience and scientific study. We must know what causes fires, how they behave, and how they affect the forest. The need for more intensive fire research has been recognized by the provincial and federal governments, and forest industry (Rocky Mountain Section of the Canadian Institute of Forestry, 1955, 1962).

It is the objective of this report to:

1. Report on the area and values affected by forest fires.
2. Describe the fire problems in Alberta.
3. Outline research that is needed.
4. Establish research priorities.

The problem analysis is based on a literature review, discussions with officials of the provincial government and forest industry, and a field reconnaissance carried out in 1962-63. This analysis is concerned only with problems relating to forest fire research. Although a wide range of research topics are discussed, the implementation of the program is, in the final analysis, dependent on available personnel, research facilities, and the needs of the Province and forest industry.

CHARACTERISTICS OF THE FORESTS OF ALBERTA

Alberta covers a total of 255,285 square miles. It is located between latitudes 49°00' and 60°00' north, and longitudes 110°00' and 120°00' west. It is bounded in the south by the State of Montana, in the north by the Northwest Territories, and in the east and west by the Provinces of Saskatchewan and British Columbia.

The general topography is characterized by gently rolling hills, with the exception of the Rocky Mountains and the adjacent East Slope foothills.

The altitude of the plains area ranges from 700 feet in the north to over 2000 feet near the foothills, rising to over 10,000 feet in the prominent Rocky Mountains. This mountain range is the source of the major rivers, which drain to the east and north-east.

A continental climate prevails in Alberta with strong contrast between summer and winter temperatures. Climatic summaries for a few selected stations are given in Table I.

TABLE I. CLIMATIC DATA FOR REPRESENTATIVE STATIONS IN ALBERTA

Station	Avg. Annual Mean Temp. (°F)	Mean Jan. Daily Temp.	Mean July Daily Temp.	Avg. Annual Prec.	Growing Season ¹ (days)
Lethbridge	42	18	66	15.01	180
Banff	36	12	57	19.16	160
Jasper	37	16	59	13.06	160
Edmonton	37	8	63	17.63	170
Lac La Biche	34	2	63	17.30	160
Grande Prairie	35	5	61	18.30	165
Keg River	31	0	60	14.95	145
Embarras	31	-3	64	15.42	140

¹ Taken from Atlas of Canada.
(mean daily temperature of 42°F or more).

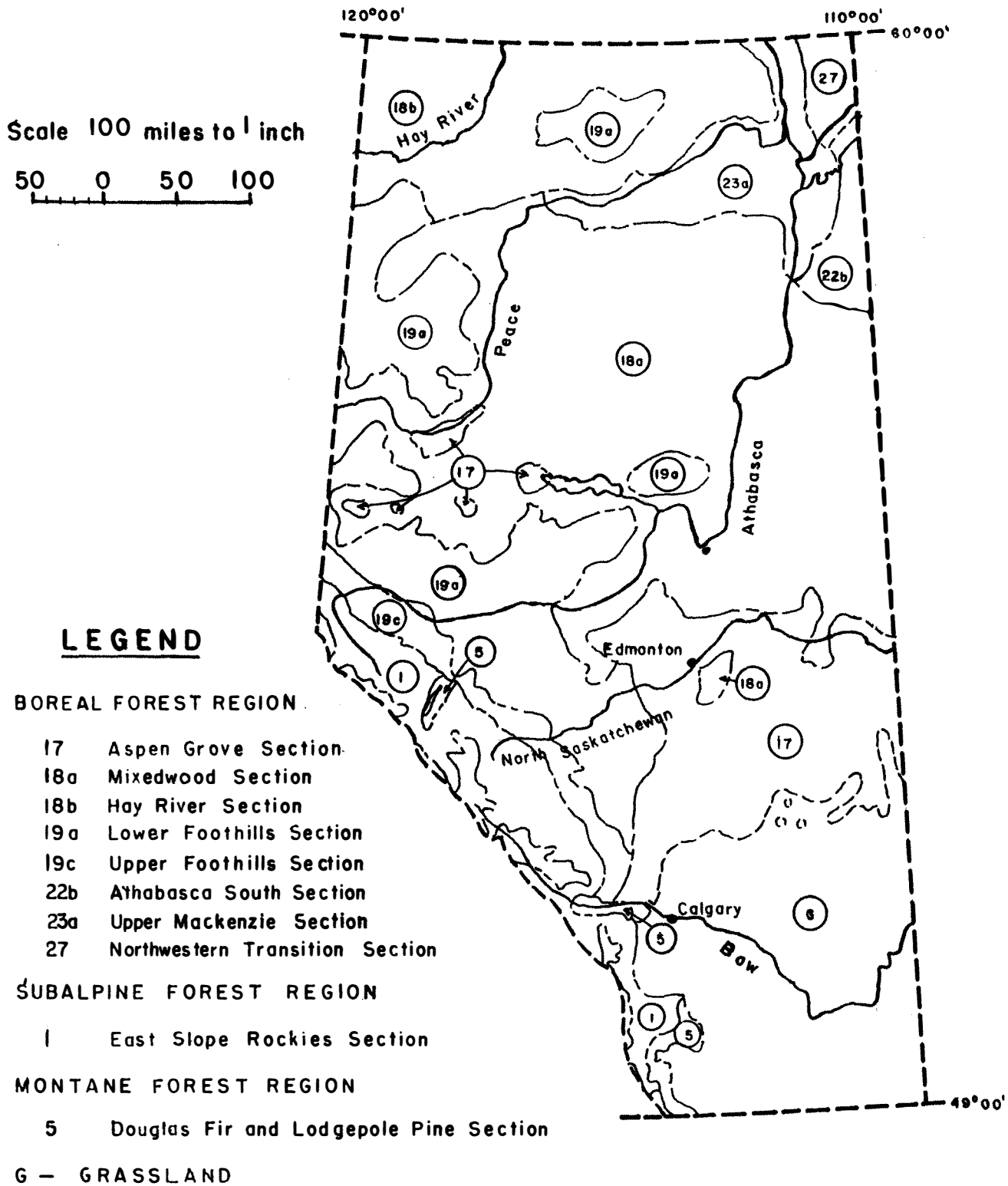
Annual precipitation ranges from 12 to 22 inches. Moderating westerly "chinook" winds, which are most obvious during the winter months occur frequently in the southern half of the Province and may occasionally extend northward.

Rowe (1959) in "Forest Regions of Canada" has classified the forest cover of Alberta into distinct Forest Regions. Each Region is further sub-divided into Forest Sections. Three Regions comprise the greater part of the forested area. The Boreal Region, biggest of the three, covers approximately three-quarters of the land area. The other two, Subalpine and Montane, cover about seven per cent of the area. The remainder of the Province is predominantly grassland (Figure I).

Approximately 159,064 square miles, or 62.3 per cent of the total area, is classified as being forested. Total productive forest land is 116,744 square miles (Canadian Forestry Statistics, 1961). Nearly 90 per cent of this is unoccupied forest land.

According to the Alberta Forest Inventory (1958), the total volume of all timber four inches and over at diameter breast height is 48.7 billion cubic feet. Deciduous species comprise 23 billion cubic feet, but their annual utilization is less than five per cent of the total. Only 24 per cent of the forested area is fully stocked, with an average volume of 1320 cubic feet per acre. The gross allowable annual cut in the Forest Divisions is 1,260 million cubic feet. Annual depletion agents include commercial timber operations, fire, insects and disease. The annual depletion by these factors is estimated as 0.65 per cent of the total growing stock, or about one-fourth of the gross allowable cut.

FIGURE 1. PROVINCE OF ALBERTA



FOREST CLASSIFICATION OF ALBERTA

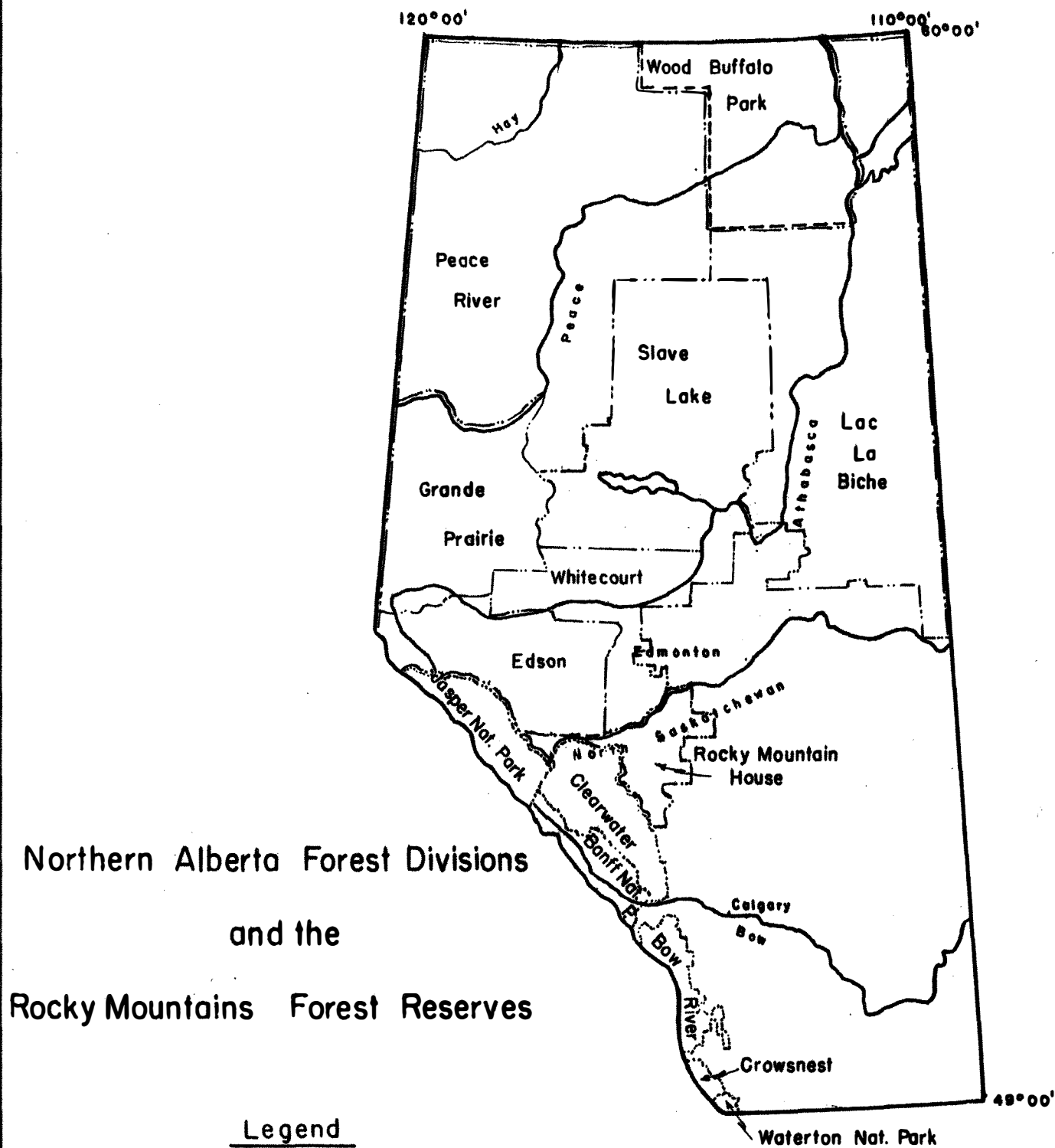
A HISTORY OF FOREST FIRES AND FOREST FIRE PROTECTION
IN ALBERTA

Forest fires in Alberta have probably occurred since time immemorial, but information about them is available only for the past sixty years. Fragmentary forest fire data is available from the annual reports of the Superintendent and Director of Forestry, Department of the Interior, and subsequent reports of the Alberta Department of Lands and Mines and Lands and Forests.

The Dominion Forest Service assumed responsibility for the protection of the forest against fire in the Rocky Mountain Forest Reserve in 1910. Commencing in 1932 the forests of Alberta were put under provincial administration. The provincial protection organization has, since assuming responsibility for protecting the forest against fire, grown by increasing the field staff, acquiring more and better equipment, and improving fire fighting methods and techniques.

Alberta's forested lands are divided into two major regions - the Rocky Mountains Forest Reserve and the Northern Alberta Forest Divisions. The Rocky Mountains Forest Reserve is administered by the Alberta Forest Service and guided by counsel of the Eastern Rockies Forest Conservation Board. The area of the reserve is 8,953 square miles, divided into three Forests. The Northern Alberta Forest Divisions total seven, covering 149,718 square miles (Figure 2).

FIGURE 2. PROVINCE OF ALBERTA.



Northern Alberta Forest Divisions
and the
Rocky Mountains Forest Reserves

Legend

- Provincial Boundary
- Forest Division Boundary
- Forest Reserve Boundary

The long-term fire statistics indicate a downward trend in the total acreage burned. This is in contrast to a general increase in the number of fires and suppression costs (Table 2). The average number of fires per year for the whole Province, during the 20-year period 1943-62, is 283. The total area burned during the past 20 years represents nearly seven per cent of the forested area, or 0.33 per cent annually. Not all of the fires are in forested areas. For example, during the twelve year period 1950 to 1961 inclusive, a total of 3,120,579 acres burned. Of this total, 995,515 acres, or 32 per cent, was non-forested land.

TABLE 2. LONG-TERM FOREST FIRE STATISTICS IN ALBERTA
(twenty-year averages)

Period	No. of Fires	Acreage Burned (M acres)	Per Cent of Area Burned	Suppression Costs (M dollars)	Suppression Costs/acre (dollars)
1943-47	254	361	0.36	49.8	0.18
1948-52	204	594	0.58	154.3	0.43
1953-57	179	275	0.27	243.7	2.26
1958-62	496	107	0.10	1,342.7	12.75
Yearly Averages	283	334	0.33	447.6	3.91

A preliminary analysis of the 1957-62 forest fire reports revealed some interesting trends and relationships. The results do not necessarily agree with those published by the Department of Lands and Forests as some reports were incomplete for purposes of this analysis.

A total of 2531 fire reports were analyzed, of which 1769 were man-caused fires and the remainder lightning-caused. During the six-year period covered, there were a total of 427,415 acres of forest and grassland burned over, or 85,483 acres annually. There were about three man-caused fires for every lightning fire. The average size of a man-caused fire was 129.4 acres; of a lightning-caused fire 330.5 acres. About 0.42 per cent of the total area under protection burned over during the period, or approximately 0.08 per cent annually.

The distribution of man-caused fires and area burned is indicated in Figures 3 and 4. In the Northern Alberta Forest Divisions most fires occur in spring, whereas in the Eastern Rockies Forest Conservation Board area fire occurrence is more evenly distributed between spring, summer and fall. In per cent area burned, the Forest Divisions experienced greatest damage in the spring, while summer and fall were more severe in the Eastern Rockies area.

Fires are classified according to size; class A ($\frac{1}{4}$ of an acre or less, class B (over $\frac{1}{4}$ acre up to 10 acres), class C (over 10 acres up to 100 acres), class D (over 100 acres up to 500 acres), and class E (over 500 acres).

FIGURE 3. FIRE OCCURRENCE BY FOREST DIVISIONS, MAN - CAUSED FIRES, 1957-62.

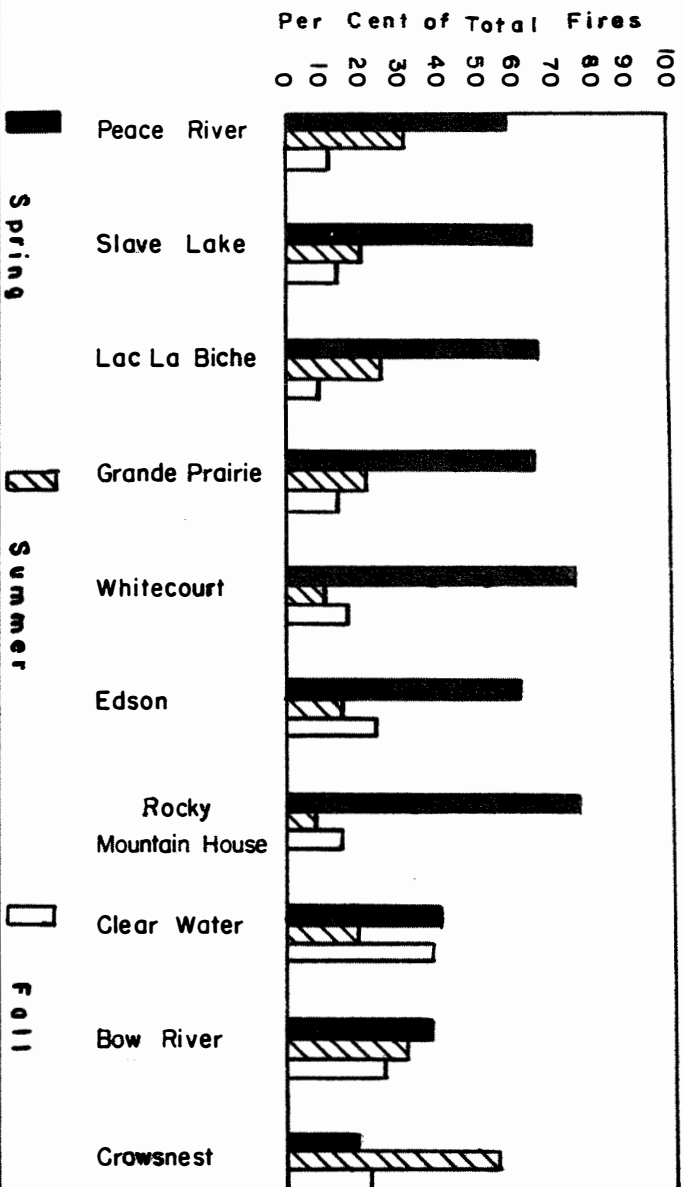
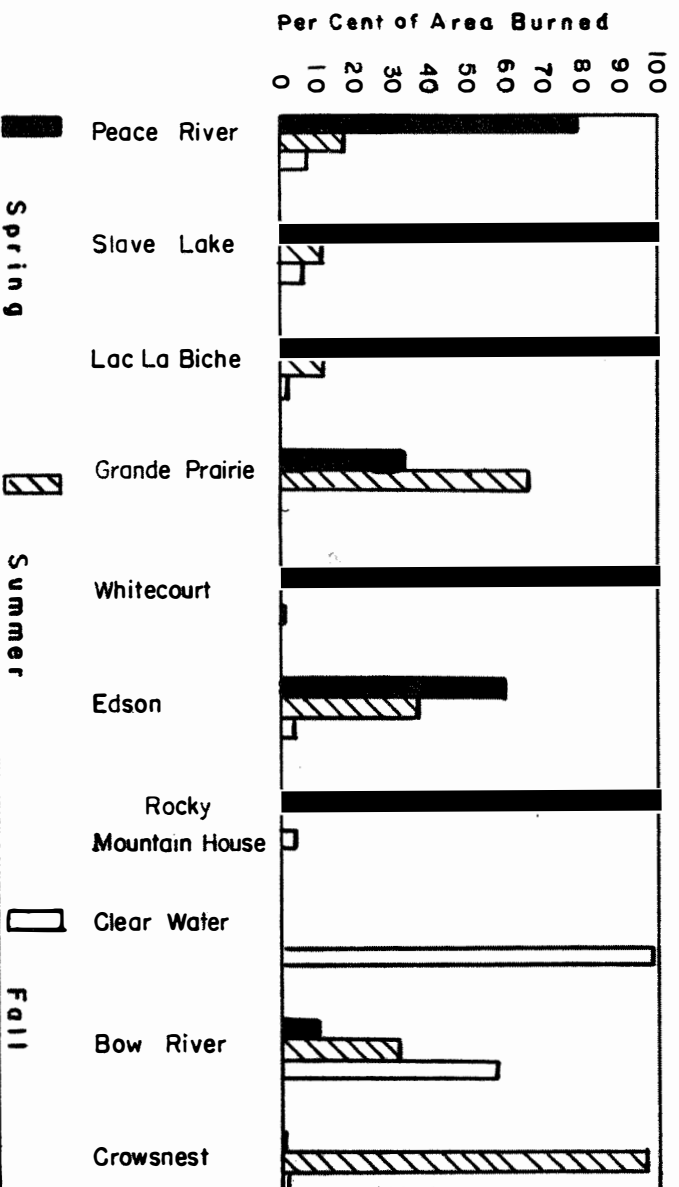


FIGURE 4. AREA BURNED, BY FOREST DIVISIONS, MAN-CAUSED FIRES, 1957-62.



Figures 5 and 6 indicate fire occurrence and area burned by D and E fires for both man-caused and lightning fires. It is apparent that the per cent of D and E fires is decreasing, but the total area burned by these fires is still substantial.

FOREST FIRE PROBLEMS IN ALBERTA

The provincial protection organization has, during the past decade, grown rapidly to a point where they are able to take suppressive action on all forest fires. This rapid expansion has created a need for immediately usable information. Subsequently, policy and legislation have, to a large extent, been based on judgement gained through experience. While many problems can be handled on this basis, others can best be solved by scientific research. This is particularly true where we are interested in knowing why certain things happen so that we can anticipate the results. Investigations of slash hazard, fire danger measurement, fire behaviour, fire effects and weather influences all fall into this category.

The fire problems are discussed under the headings of prevention, detection, presuppression, and suppression. Related literature, present knowledge of these and related problems in Alberta and elsewhere form the basis for discussion. Present and future needs and requirements for research are emphasized. Problems related to suppression activities and other control topics usually handled by the protection organization are discussed, but briefly.

**FIGURE 5. FIRE OCCURRENCE AND AREA BURNED - D & E FIRES.
MAN-CAUSED FIRES, 1957-62.**

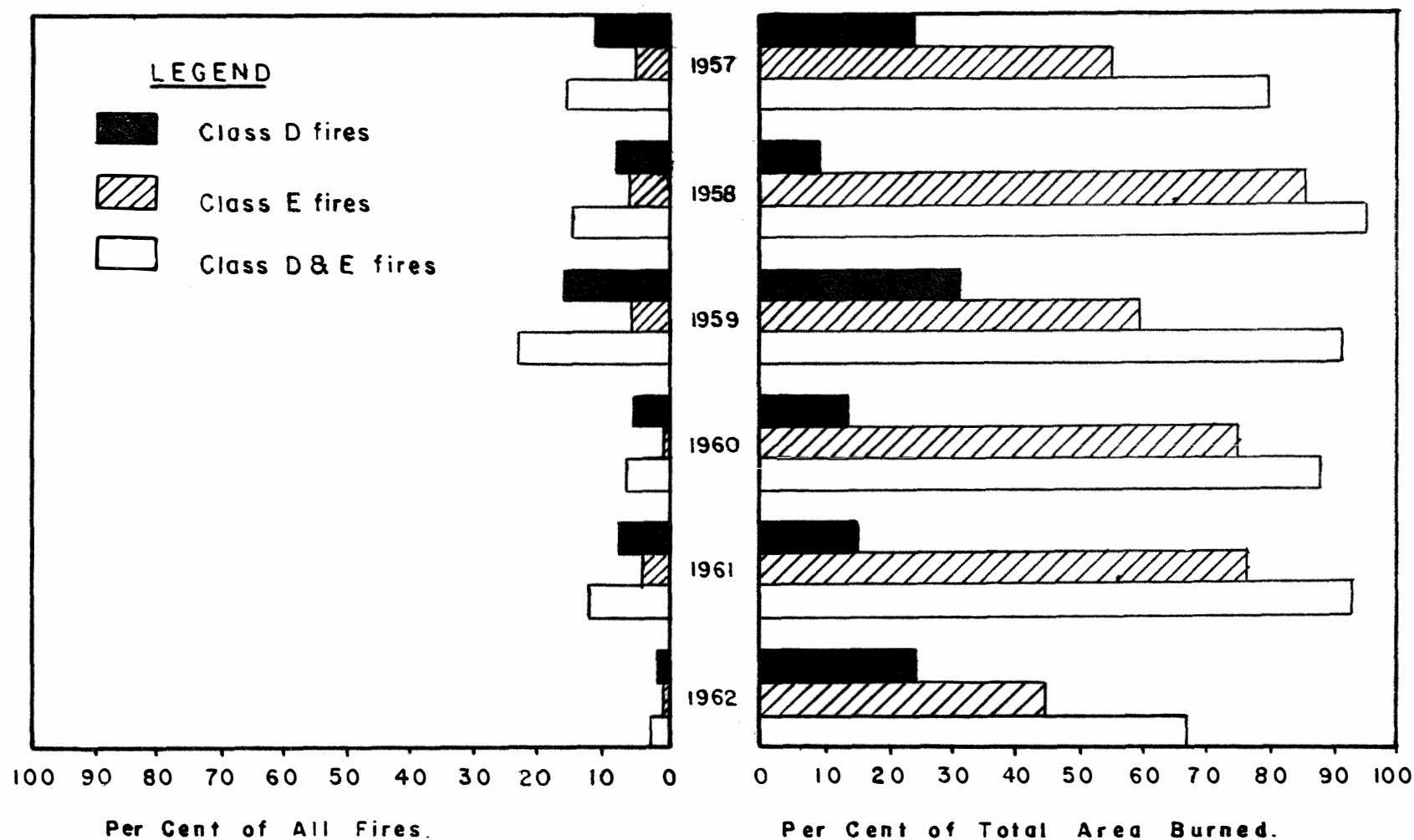
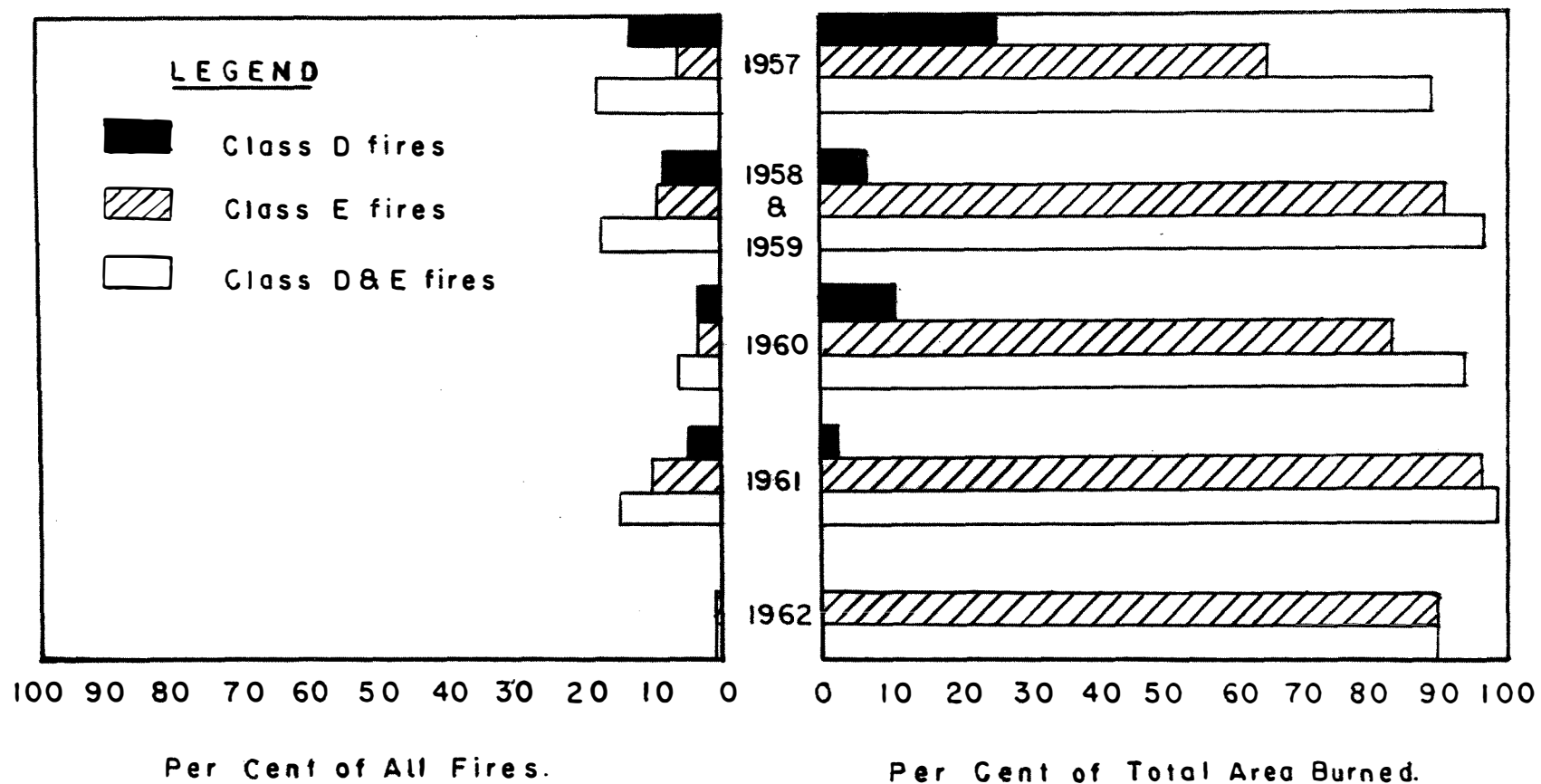


FIGURE 6. FIRE OCCURRENCE AND AREA BURNED- D & E FIRES.

LIGHTNING-CAUSED FIRES, 1957-62.



Prevention

In this Province, over 80 per cent of all forest fires are caused by human agencies and theoretically preventable. The remainder of fires are caused by lightning, and for the present time at least, nothing can be done to eliminate them. Man-caused fires, on the other hand, can be reduced by implementing legislation and by educating the public regarding the danger from them. Before these measures become fully effective man must know about the fire danger in the forest, how fire affects him, and what he can do about preventing fires from starting. It is logical to assume that the agency charged with the responsibility of prevention education knows the most effective means of accomplishing this objective.

Existing classifications of forest fire causes do not provide sufficient information about fire starting agencies, nor do they provide enough information on which to base a prevention campaign. In an attempt to collect reliable statistics on which to base preventive action Doyle (1951) distributed a questionnaire to forest protection agencies in Canada. Studies of this nature provide information on what part of a region a causative agent is most active, what time of year fires are caused by the various agents, and what the extent of damage is likely to be. From a perusal of the above information the protection organization can arrive at the most effective means of educating the public regarding fires in the forest. The causative agencies in Alberta are as follows:

TABLE 3. FIRE CAUSES IN ALBERTA, 1943-61

Cause	Per Cent 1943-61	Per Cent 1957-61	Per Cent Change
Campfires	22.2	19.6	-2.6
Smokers	10.7	11.3	+0.6
Settlers	14.9	13.7	-1.2
Railways	10.8	2.5	-8.3
Lightning	11.5	24.6	+13.1
Industrial Operations	6.2	8.1	+1.9
Incendiary	9.0	12.5	+3.5
Public Works	1.2	2.1	+0.9
Unclassified	4.1	1.7	-2.4
Unknown	9.3	3.9	-5.4
Totals	100.0	100.0	

A similar approach might be taken toward lightning fires. Although lightning fires cannot be prevented, information on the conditions under which they start would be of value to fire control people.

What form of publicity is most effective to convey the fire prevention message to the public? To whom should prevention publicity be directed? What is the best way to enforce slash burning regulations? Research can help to solve these and other problems.

Detection

The system of detection and the methods used in a particular region are dependent on the total situation in relation to topography, the area under protection, the fire danger, in fact the total planning effort. Location, visibility, the observer, and equipment must be evaluated for maximum usefulness in detection. Fire detection is usually dependent on a fixed ground lookout system, airplane reconnaissance, and ground inspection. A fixed lookout system alone is seldom sufficient for 100 per cent coverage. Often an aerial patrol is carried out, especially during periods of extreme hazard, to supplement lookout coverage. The main need in detection of forest fires is to improve the efficiency of each of these methods, and to determine how best to combine them to obtain maximum coverage under all situations. The Department of Forestry has conducted a number of studies concerned with lookout tower equipment improvement and detection methods (Chorlton 1951, Wright 1953, Lockman 1962, Fraser 1962).

Presuppression

The Associate Committee on Forest Fire Protection (1963) has defined presuppression as "those fire control activities in advance of fire occurrence concerned with the organization, training and management of a fire control force and the procuring, maintenance and inspection of improvements, equipment and supplies, to ensure effective fire suppression."

Research work is vitally important in presuppression activities for it includes fire danger rating, fire seasons, fire weather, forest fuels, fire effects, prescribed burning, and fire control planning. Presuppression planning is dependent on a knowledge and understanding of the above factors. Research effort can best be applied to investigate problems that relate to presuppression activities.

Forest Fire Danger Rating

The Associate Committee on Forest Fire Protection defines fire danger as "a general term used to express an assessment of constant and variable factors for a given area which determine the difficulty of control to be expected, and also whether or not fires will start, spread, and do damage". It is the sum total of fuels, risk, values to be protected, and other factors. Fire hazard is defined as "a general term used to express an assessment of constant and variable factors for a given fuel type in a given area, which determine whether or not fires will start, spread, and do damage, and also the degree of difficulty of control to be expected."

A major contribution by the Department of Forestry^I to fire control organizations throughout Canada has been the preparation of forest fire danger tables. In Alberta, two sets of tables are used: (1) Alberta (Anon.1959)

^I Formerly Canada, Department of Northern Affairs and National Resources

and(2) Alberta East Slope (Anon.1957). A prototype forest fire danger meter, based on the Department of Forestry system of forest fire danger rating, has been developed by Paul (1962).

The tables provide for a consistent estimate of forest fire danger, based on daily measurements of rainfall, relative humidity, wind, and a drought index. In addition to the forest fire danger index, tables are provided for compilation of the slash fire hazard index, fast drying hazard index, grass fire hazard index, and correction tables for season and night relative humidity. A newly prepared Cladonia Fire Hazard Table (Mactavish 1963) has been added to the Alberta tables.

The Alberta and Alberta East Slope tables have been in use five and six years, respectively. A preliminary analysis of fire statistics has revealed certain relationships between the danger rating and some fire parameters. (Refer to Table 4).

Discussions with members of the provincial protection organization indicated that the tables fill a basic need by providing a consistent and reliable measure of the potential fire danger from day to day. In the Forest Research Branch system of fire danger measurement, the level or degree of danger is expressed on a scale of 0 to 16. The scale is divided into five classes, namely Nil, Low, Moderate, High, and Extreme. The indexes or danger classes can be averaged, compared, and related to fire occurrence, prevention publicity, closure of areas, slash burning permits, training, dispatching, prescribed burning - in effect, they can be used in most fire control activities.

TABLE 4. FIRE OCCURRENCE AND AREA BURNED, BY MAN-CAUSED FIRES
IN ALBERTA, 1957-62.

Northern Alberta Forest Divisions				Eastern Rockies Forest Conservation Board Area		
Danger Class	Number of Fires	Area Burned (acres)	Average Size of Fires	Number of Fires	Area Burned (acres)	Average Size of Fires
Spring						
Nil	6	1	0	1	0	0
Low	151	1,530	10	5	0	0
Moderate	356	36,335	102	20	14	1
High	415	92,153	222	22	20	1
Extreme	168	35,465	211	3	1	0
Totals	1,096	165,484	151	51	35	1
Summer						
Nil	1	0	0	1	0	0
Low	28	357	13	8	0	0
Moderate	85	336	4	15	4	0
High	128	5,156	40	19	55	3
Extreme	47	30,654	652	20	1,853	93
Totals	289	36,503	126	63	1,912	30
Fall						
Nil	6	1	0	2	1	0
Low	108	604	6	8	1	0
Moderate	81	3,206	40	17	43	3
High	30	1,171	39	6	65	11
Extreme	2	0	0	10	3,705	371
Totals	227	4,982	22	43	3,815	89
All Seasons Combined						
Nil	13	2	0	4	1	0
Low	287	2,491	9	21	1	0
Moderate	522	39,877	76	52	61	1
High	573	98,480	172	47	140	3
Extreme	217	66,119	305	33	5,558	168
Totals	1,612	206,969	128	157	5,761	37

One of the main criticisms of the forest fire danger tables is the relative rating between spring, summer and fall. Fire statistics indicate that, although fire occurrence is highest in spring, most damage to valuable timber occurs in the summer. The majority of spring fires burn in fine, fast-drying fuels, such as grass and brush. These fuels lose moisture rapidly, permitting hot fires to develop one or two days after a heavy rain. Coarse fuels, on the other hand, require a longer period to reach an equally flammable state.

The probability of seasonal variation of fire danger is particularly high in the northern parts of the province. The length of day varies between early spring and summer on the one hand, and summer and late fall on the other. The duration of low relative humidity is largely dependent on length of day. Subsequently, the relatively short early spring and late fall days prevent the fuels from reaching their equilibrium moisture content with the surrounding air as frequently as during periods of prolonged low humidity. Harkness (1939) reported that duff equilibrium moisture lags behind relative humidity by about two hours.

The drought index, which indicates the flammability of coarse fuels, largely determines fire persistence and difficulty of control. It is calculated from the previous day's drought index and today's total rainfall. In the absence of rainfall it increases by a factor of one daily, regardless of the time of season or type of fuel. The probability of drought conditions occurring during certain portions of the year was studied by Williams (1954).

Methods of applying soil and fuel moisture budgets to evaluate drought conditions show promise.

Wind is a "built-in" factor in the danger tables. Its importance on fire rate of spread, especially in the Nil and Low danger classes, has been questioned. Byram (1940) reports on a study of sun, wind, and fuel moisture suggesting that wind partially offsets the drying effect of sunshine. The influence of wind and fuel moisture should be studied simultaneously for it is their joint influence that determines the rate of spread. Laboratory studies, utilizing a standard fuel and a wind tunnel, appear to offer promise of success.

The danger index scale of 0 to 16 is considered a good compromise between accuracy and usefulness to the forest officer. Each danger class and index has a definite value attached to it, permitting comparison of fire season severity and related parameters within and between districts. The source of some dissatisfaction is in connection with the Extreme class (13-16). Some protection people suggest that the extreme class be extended, perhaps to 25. This would reduce the probability of obtaining exactly the same reading at two or more locations.

The application and reliability of forest fire danger and hazard indexes in Canada and the United States have been studied by a number of workers (Wright 1932, Beall 1939a, 1939b, 1941, 1950, Knorr 1942, Nelson 1961, Williams 1962). The work in Canada has been concentrated on comparing actual fire occurrence and area burned with the fire danger index.

In Alberta, reliable records are available from 1957. A comparison of the fire danger index with fire occurrence and related factors would show the reliability of the Alberta and Alberta East Slope tables.

In this Province, particularly, there are extensive areas of fast-drying fuels. The use of a general danger index in areas supporting primarily flashy, fast-drying fuels leads to a false sense of security and eventual loss of faith in the entire rating system. Education and instruction in the proper use and application of the tables, and the reasons for doing so, are considered of high priority. In general, the danger tables have a far greater potential in presuppression activities than presently utilized. Additional modifications of the forest fire danger tables should be contingent on the proper and full use of the existing ones.

The Fire Seasons

The normal forest fire season in Alberta lasts from April to November. Three periods - spring, summer, and fall - constitute the fire season. The spring period starts as soon as fires are able to run in the open and lasts until the leaves are fully developed on the aspens and birches. The summer period lasts until one-quarter of the leaves on the poplars and birches have fallen or when a definite thinning of the tree crowns first becomes noticeable. The fall season continues until the snow returns, making fire spread impossible.

The fire seasons vary in severity. The degree of variation is dependent upon a number of factors, including the fuel type, weather conditions, and the stage of vegetative development. The spring and fall seasons are characterized by grass and brush fires, while deep-burning fires are more common during the summer period. The spring period, owing to the rapid rate of spread in the typically light fuels, usually has the greatest number of fires and the largest acreage burned.

Of all the man-caused fires in the Northern Alberta Forest Divisions during the five-year period 1957 to 1961 inclusive, 68 per cent occurred in the spring, burning over 163,000 acres of forest and grassland. The fire statistics indicate that of the total number of fires in the spring and fall, 70 and 75 per cent were grass and brush fires. The corresponding figure for the summer period was only 29 per cent. Although the proportion of grass and brush fires in spring and fall was similar, the rate of fire occurrence in the spring was nearly five times as great, and the area burnt 31 times that in the fall period. Table 5 gives the number and area burned by grass fires during a five-year period.

The relative rates of fire occurrence in the Forest Divisions for spring, summer and fall were approximately 5:1:1. The corresponding ratios for the East Slope area were 1:2:1. The burned area ratios for the two regions were 4:1:0 and 0:1:2 respectively.

Weather is the principal factor controlling the flammability of forest fuels. This, along with forest cover, fuel type, and the stage of

TABLE 5. COMPARATIVE FOREST FIRE STATISTICS BY SEASONS, OF MAN-CAUSED FIRES, NORTHERN ALBERTA FOREST DIVISIONS, 1957 - 1961.

Danger Class	Total No. of all fires	Total No. of grass fires	Per cent <u>grass fires</u> all fires	Acreage burnt by all fires	Acreage burnt by grass fires	Per Cent of Area burnt by grass fires
Spring						
Nil	5	0	0	1.2	0.0	0
Low	125	91	73	1,509.7	1,263.9	84
Moderate	319	206	65	35,875.4	32,661.5	91
High	399	268	67	90,671.7	62,507.1	69
Extreme	166	106	64	35,247.9	18,113.4	51
Totals	1,014	671	66	163,485.9	114,545.9	70
Summer						
Nil	0	0	0	0.0	0.0	0
Low	23	8	35	326.3	307.9	94
Moderate	77	25	33	335.0	87.1	26
High	127	50	39	5,155.8	2,219.3	43
Extreme	47	22	47	30,645.0	7,887.4	26
Totals	274	105	38	36,471.1	10,531.7	29
Fall						
Nil	15	0	0	0.6	0.0	0
Low	95	24	25	601.1	555.2	92
Moderate	69	25	36	3,204.3	2,064.8	64
High	29	20	69	1,093.0	1,035.6	95
Extreme	2	1	50	0.0	0.0	0
Totals	210	70	33	4,899.0	3,655.6	75
All Seasons						
Nil	20	0	0	1.8	0.0	0
Low	243	123	51	2,437.1	2,127.0	88
Moderate	465	256	55	39,414.7	34,812.4	88
High	555	338	61	97,920.5	65,762.0	67
Extreme	215	129	60	66,081.9	26,000.8	39
Totals	1,498	846	57	205,856.0	129,464.2	63

vegetative development, determines whether a fire season is "good" or "bad". The duration of sunlight and the corresponding incidence of the sun's rays have a pronounced effect on the rate of hazard build-up. This is especially pronounced in the northern latitudes where the summer solstice is followed by a rapid decrease in the angle of the sun's rays reaching the earth and the duration of sunlight. It is logical to conclude that with the fuel situation kept constant, the rate of drying varies within the fire season. Beall (1934) noted that "till middle of September the number of hours of daylight is the chief seasonal factor influencing hazard variation, the tendency being towards higher hazards, under normal weather conditions, at about the time of the summer solstice". During periods of fine weather the fire hazard follows a well-defined diurnal cycle, the peak occurring between 2 and 4 o'clock in the afternoon, and the minimum between 4 and 6 o'clock in the morning.

Another reason for variation in flammability between seasons are the fuels. For example, a coniferous stand undergoes relatively minor changes in the vegetative development between fire periods compared with a hardwood stand. A hardwood stand usually supports a profuse growth of vegetation during the growing season. The high moisture retention of green vegetation inhibits the drying of the surface fuels which, in turn, prevents the build-up of extreme hazard. The profusion of green vegetation under hardwood stands affects particularly the moisture content of the heavier fuels. The feasibility of separating the summer danger tables into two - conifer and hardwood - should be investigated.

A knowledge of fire season severity gives the protection agencies a measure to equate their suppression efforts with the cost of obtaining a certain degree of success in reducing the losses from forest fires. Williams (1959) developed a method of measuring fire season severity. It is based on an evaluation of the relative severity of the various danger classes used with the fire danger rating system. The rating is based on rate of spread and difficulty of control.

The relative severity between danger classes for the main fuel types in Alberta should be determined. This would indicate the need for correcting or modifying Williams' severity rating. The use of this rating appears to have great potential in presuppression work. Fire occurrence can be related to fire weather or yearly severity ratings can be related to the number of fires and area burned. The cumulative fire severity can be charted throughout the fire season. On the basis of the severity index and past fire statistics, the expected number of fires for any season can be calculated. The effectiveness of the prevention campaign could be evaluated. In effect, the efficiency of the fire control effort can be measured.

Forest Fire Weather

Conditions under which fires will start, spread, and do damage are controlled partly by weather, partly by fuels. Both of these factors, as

pointed out in the previous section, can be highly variable within and between areas and seasons. Fine fuels, such as dead grass, may respond almost immediately to changes in relative humidity and temperature, while logs and other coarse fuels may take many months to dry out.

The relationship between weather and fire danger was recognized early. Chapman, in 1927, reported that advance information about occurrence of periods of fire weather was sought from the U. S. Weather Bureau as early as 1916. A fire hazard chart based upon the weather was begun in Alberta in 1916 (Wright 1930). It is recognized that rainfall, temperature, and wind exert an important influence on the moisture content of forest fuels. Attempts were made to weight these factors. Stickel (1934) reported that the elements in the approximate order of importance with respect to duff moisture are: evaporation rate, depression of dew-point, relative humidity, surface duff temperature, air temperature, and number of hours since last measurable precipitation. Gisborne (1936) listed the principal causes of forest fire danger as (1) character and volume of forest fuels, (2) topography, (3) lightning, (4) wind and (5) moisture content of fuels, which is determined primarily by precipitation, temperature, humidity, solar radiation, and soil moisture. An extensive study of how wind, temperature, humidity, and fuel moisture are affected by topography, water bodies, season and the fire was reported by Countryman and Schroeder (1959).

Lightning fire research has received considerable attention in the Rocky Mountain region. Extreme concentrations of lightning fires tax the

fire control organization to such an extent that it is unable to cope with the situation (Headley 1927). The most ambitious program to study meteorological problems associated with lightning-caused fires is Project Skyfire (Colson 1957, Fuquay 1962). This project is concerned with (1) the occurrence and characteristics of lightning storms and lightning fires, and (2) techniques of weather modification. Lightning fire occurrence and behaviour in Canada were investigated by Kill and Fraser (1962).

Burrill (1927) noted that "successful fire weather work requires the active co-operation of foresters, meteorologists and those interested in the utilization of our forest resources". Some phases of fire weather and forest flammability measurements are best handled by the forester, others by the meteorologist. The main purpose of fire weather measurements is to improve fire danger prediction and fire control.

The Alberta Forest Service obtains weather data from two sources - their own fire weather stations and the Department of Transport, Meteorological Branch. The weather observations from the regular Meteorological Branch stations are of limited use in fire control since they are usually located in heavily populated areas outside the protected forest area. To supplement the Meteorological Branch network, the Forest Service has established a fire weather network consisting of over 170 stations. These stations, manned by Forest Service personnel, usually maintain Department of Transport specifications for all instruments used.

Normally, the fire weather station is erected adjacent to a Ranger Station or a forest fire lookout structure. A clearing is made available to provide the necessary circulation of air. Ideally, the weather station should be located where it is representative of typical fuel conditions of the area. This condition is seldom met, especially in mountainous terrain, where fuel and weather conditions may vary significantly over small distances. Secondly, since the fire-weather stations are near Ranger Stations and fire lookout structures, their location is dictated by circumstances.

With the present fire-weather network in the Forest Divisions and the Eastern Rockies Forest Conservation Board area each station covers, on the average, approximately 1200 and 250 square miles. Beall (1950), studying forest fires and the danger index in New Brunswick, concluded that the danger index was highly reliable within a radius of 25 miles from a weather station. The index may be useful, but not highly reliable, at distances between 25 and 100 miles from the weather station. Williams (1962) made a study of danger index reliability in British Columbia and reached similar conclusions. These distances vary from area to area, depending on local topography. For example, the network should be much denser in mountainous terrain than in relatively flat country.

The most important requirement in connection with fire danger measurement in Alberta is the need to standardize the weather instrumentation by using instruments of uniform accuracy and adjustment. The person making

the observation should be fully trained and aware of the effects of weather readings on the danger index.

The need for intensified fire danger forecasting is becoming increasingly important for foresters engaged in silviculture and fire protection. Local forecasts are particularly valuable for prescribed burning experiments, slash disposal, and burning of debris. Co-operation between the agencies interested in forest fire danger forecasting is desirable and the best way to obtain the end results.

Forest Fuels

The kind, arrangement, and continuity of fuels in the forest varies from place to place. Ground and aerial fuels are found in many associations, combining to form the fuel complex. A knowledge of fuels is essential for any fire control job. Any measure or classification of forest fuels must consider the fuel from a fire behaviour viewpoint, i.e. what kind of fire spread can be expected in a particular fuel complex.

The forest communities in Alberta have been described by Moss (1953a, 1953b, 1955) in terms of floristic composition and ecological relationships. The main associations are: white spruce, black spruce, poplar, and pine. Within these associations are other vegetation groups, consociations, and faciations or variations.

Most spruce stands support litter that is compact and poorly aerated, and exhibits good moisture holding properties. In contrast, the litter layer under a lodgepole pine stand is usually coarse, well aerated and a poor retainer of moisture. Hardwood stands, such as those composed of poplars and birches are good retainers of moisture, particularly during the summer months. Other fuels are found in these stands in varying quantities, depending on land and stand characteristics. Areas of open grassland are characterized by fine, fast-drying fuels. Grass fires in Alberta are responsible for a large proportion of the total area burned, mainly in spring and fall. During the summer months grass contains a high per cent of moisture and seldom carries a fire.

Little is known about the stand parameters that affect the fuel complex and fire behaviour. Muraro (1962), in attempting to develop a method for the evaluation of forest fuels in the southern interior of British Columbia found that height and site may be used as parameters of the fuel complex within the stand. The drying rate of a duff bed is influenced by (1) humidity (2) temperature (3) wind speed, and (4) radiation. Drying characteristics of duff were studied by Gisbourne (1923) in Idaho, who reported that the top quarter to half-inch exhibits the effects of all the weather elements as they affect dryness and flammability in the forest. Wright and Beall (1938) noted that the relationships between the moisture content and the flammability of surface leaf litter in pine and the hardwood

forest changed abruptly as soon as the autumn fall of foliage takes place".

Slash fuels on cutovers create a high hazard by increasing the quantity, continuity, and the rate of drying of the fuels. Olson (1953), Storey, Fons and Sauer (1955), Fahnestock (1960), Chandler (1960), and Fahnestock and Dieterich (1962) have all attempted to determine and evaluate slash characteristics and flammability. The measurement of tree crown characteristics has provided a good measure of slash quantity. Fahnestock found that dry weight of crown could be estimated directly from the product of length of live crown and diameter at breast height. Crown surface area is significant as a measure of combustion. Olson and Fahnestock (1955) estimated that the average pound of Douglas-fir slash has a surface area of 25 square feet, compared to the surface area of a cube of the same weight of 0.6 square foot. The variation in moisture content of Douglas-fir slash on various slopes and aspects was investigated by Williams (1962).

The classification of forest fuels has been attempted mainly on the basis of cover types. These methods are described by Shaw and Kotok (1929), Hornby (1935, 1936), and Little (1945). Studies to link flammability in various forest types with weather conditions were started by Wright (1930). Winkworth (1960) analyzed a fuel type classification questionnaire based on opinions of fire protection men on the relative hazard of 27 cover types in Ontario and Quebec and reported that age is an important factor among softwoods but season is not. The opposite is true for hardwoods, but both age and season

were significant factors among the mixedwoods except in two cases. He further noted that generally, but not always, the softwoods have a higher average rating than hardwoods. Hornby found that fuel characteristics within types exerted 3 to 15 times as much influence on initial rates of spread as forest type characteristics. Thus the factors having the greatest influence on resistance to control were listed as the amount, arrangement, size, species, and decay. These must be evaluated according to the proportion of standing timber snags, windfall, slash, brush, reproduction, grass, duff, and roots.

A usable method of fuel type classification would be valuable to the firefighter. It would enable him to plan and carry out his protection effort on the basis of past and expected fire behaviour. A better knowledge of at least the main fuel types in Alberta is essential if the protection organization is to achieve and maintain maximum efficiency. Fuel type mapping would enable the inexperienced man to size up the fuel situation as to its probable behaviour and difficulty of control.

Quantitative and qualitative methods of measuring forest fuels and fuel complexes are required, particularly for cut over areas. What are the burning potentials of fuels under a variety of forest and fuel conditions? What factors cause and control the march of moisture in forest fuels? What fuel characteristics affect flammability, and how? How does the fuel complex change as the forest stand grows? How can a measure of the fuel complex be used as a measure of predicting fire behaviour?

Fire Effects

Cooper (1961) reported that fire, along with climate, soil, topography, and arrival of life helped to shape the pattern of vegetation that covers the land. The importance of fire in Alberta's forest ecology has been established (Kennedy 1948, Bloomberg 1950, Moss 1953a, 1953b, 1955, Horton 1955, 1956, 1959, Jeffrey 1961). Aside from the above investigations of stand origin and structure due to fire some work has been carried on into the effect of fire on regeneration of lodgepole pine and white spruce. Crossley (1956) studied the cone characteristics of lodgepole pine. The baring of mineral soil by fire has also received some attention from Crossley (1952). Ackerman (1962) reported on regeneration following slash disposal in a lodgepole pine stand. Outside the Province, fire effects have been studied by Clements (1910), Larsen (1928), LeBarron (1957), Uggla (1958), Ahlgren (1959), Chrosciewicz (1960), Lutz (1960), and Lindenmuth (1960).

Clements reported on the importance of fire on lodgepole pine as early as 1910 when he stated that "it is by means of fire properly developed into a silvicultural method that the forester will be able to extend or restrict lodgepole pine reproduction and lodgepole forests at will". Fire provides the main requirements for regeneration, namely (1) seed, (2) a seedbed and (3) an absence of competing vegetation. The degree of stocking is dependent on the intensity of fire. In cut-over areas reproduction is hindered by slash accumulation and insufficient heat to open the serotinous cones.

White spruce is reported as being very susceptible to fire (Lutz 1956). It has thin bark, low branches, and is shallow rooted. Seed is borne at a late age. In the vicinity of Lesser Slave Lake it has been determined that effective maximum distance from a seed tree that good reproduction can be expected is about 4 chains to leeward, and to the windward at a distance about equal to the height of the seed tree (Blyth 1954). Reproduction is also dependent on the depth of the organic layer. The greater the exposed area of mineral soil the better is the degree of regeneration. Fire and mechanical scarification have been mentioned as the two most suitable methods of baring the mineral soil.

Fire effects are complex; variations depend on intensity and duration of fire, the composition of the stand, the character and volume of fuels consumed, and the soil. An understanding of fire effects is essential in forest management work if the best results are to be obtained. We need to know what fire intensity and duration is lethal to trees and other vegetation; how fire affects the native tree species ability to reproduce; what influence fire has on soil and minor vegetation?

Prescribed Burning

Fire is, without a doubt, the primary historic factor determining the forest composition and succession of the three most important species

in Alberta. But despite this overwhelming evidence pointing to the importance and beneficial effects of fire, little effort has been expended in this Province trying to find out more about the use of fire as a tool of forest management.

Prescribed burning is defined by the Associate Committee on Forest Fire Protection (1963) as "the burning of forest fuels on a predetermined area to fulfill silvicultural, wildlife management, sanitary or hazard-reduction requirements". Prescribed burning requires planning. Planning is best done on the basis of previous experience and results. Although fire has been used extensively in some areas, there is a general lack of guides or prescriptions for carrying out burning experiments. This dearth of information is partly responsible for the reluctance to experiment with fire.

During the past few years interest in the use of prescribed fire has increased, particularly in eastern Canada. Bickerstaff (1958), reporting on the use of prescribed fire in the pine types of New Jersey and the Carolinas, recognized certain Canadian conditions where fire could have definite possibilities, both in silviculture and protection. In fire protection work it could be used to reduce the flammable fuels in both uncut and cut stands. From a silvicultural viewpoint prescribed burning might be applied to the following situations: (1) preparation of seedbed and release of seed in jack pine and lodgepole pine types, (2) large-scale site preparation for planting or artificial seeding on cut-over areas, (3) reduction of hardwood

and shrub competition, and (4) improvement of humus and soil conditions where there is a rapid build-up of raw humus.

Williams (1955, 1958) reported on the application of fire for slash hazard reduction purposes. Crosciewicz (1959, 1960) and Beaufait (1962) have studied the use of fire to obtain jack pine regeneration. VanWagner (1963) carried out prescribed burning experiments in red and white pine stands near Petawawa.

The use of prescribed fire must be judged objectively. Prescribed burning procedures have been and are being developed for a wide range of conditions. Knowledge and experience gained in other areas should form the basis for experimentation in Alberta. The basic need in Alberta is to develop prescriptions for a variety of fuel and weather conditions. Once a certain degree of confidence and efficiency in the use of fire has been achieved, specific studies can be undertaken with a minimum of risk.

Slash Hazard Reduction

Logging slash, by increasing the accumulation of woody material on the forest floor, creates a high forest fire hazard. Slash fires are considered difficult to control, owing to fuel quantity, arrangement, distribution, size, age, and the increased desiccating influence of climatic factors. The scale and importance of the slash fire hazard varies within areas, depending on forest cover, logging operation, the degree of utilization, and weather influences.

The problem of slash hazard has received considerable attention and study by a number of investigators (Hafner 1927, Lyman 1947, Olson 1953, Steele 1960). In spite of the effort expended on slash hazard reduction there is considerable controversy regarding the best treatment for a particular area. Some investigators report that slash treatment and disposal is essential for effective fire protection (Mitchell 1921, Munger and Matthews 1941, McCulloch 1944), while others contend that slash is not an extreme hazard type (Cheyney 1939). The controversy concerned with slash as a fuel type stems from the large number of variables influencing flammability. Owing to its heterogenous nature, slash cannot be easily broken down into the various components that determine the fire hazard.

Work in Canada has been of a limited and sporadic nature. Wright, in 1939, reported on preliminary fire-hazard studies on cut-over lands of eastern Canada and developed slash hazard tables for use in balsam fir and spruce slash. Williams, in 1955, completed a study at the Sandilands Forest Reserve in Manitoba to determine experimentally (1) the comparative fire hazard in jack pine slash in similar areas where different slash treatments had been employed and (2) the variations in hazard which occur as slash ages. He found that burning of jack pine slash reduces the fire hazard to a level comparable to that of unburned forest and to about one-third of that of unburned slash. The same investigator carried out two other burns on the KVP Company limits and found that the severe slash hazard was eliminated and sufficient heat was developed to open the cones in the seed trees.

In the United States, extensive studies of particular interest to Alberta were reported on by Fahnestock (1960) and Fahnestock and Dieterich (1962). This work reveals that all kinds of conifer slash are similar chemically and physical characteristics determine its burning potential. The quantity of slash can best be determined from measurements of standing trees. Quantity is the main factor affecting the rate of spread during the year of cutting, while species becomes most important during subsequent years.

Aside from the work done by Loman (1959), studies of slash characteristics and hazard in Alberta have been subjective and of limited application. Existing slash treatment legislation requires that slash be lopped and scattered, or treated in a manner deemed satisfactory to reduce the hazard to within safe limits. This policy is universal throughout the Province, regardless of the type of forest cover, method of logging, the degree of utilization, or prevailing weather conditions. It is based on the theory that when tree tops are brought into contact with the ground they can absorb moisture more readily, thereby increasing the rate of decay and deterioration. While this theory is generally accepted, there is an urgent need to investigate the effect of other factors such as quantity, arrangement, and condition of slash. It is possible that one or all of these have a greater effect on total slash hazard than proximity to the surface moisture. The important question to be answered is this: does lopping and scattering, or any other slash treatment, reduce the fire hazard sufficiently to warrant the work necessary? If so, which treatment does the best job for

the least cost, and what factors influence the desired end result of reduced slash hazard?

The physical characteristics of slash provide a basis for appraisal of flammability. Fine fuel components, by having a high ratio of surface area to volume, have the greatest influence on fire spread and intensity. These characteristics can best be identified and studied while the tree is standing. Certain tree crown characteristics are easily noticeable to the naked eye. Others can only be found after extensive measurements and analysis. Length, width, and density of crown affect the total amount of solids in the tree crown.

Immediately following logging, the tree crown and branches start to lose moisture. The rate of moisture loss varies with species, size of slash, degree of cutting, and weather factors. The fine material dries fastest, thereby increasing the hazard. Slash is most hazardous while the needles are drying on the branches and twigs. After the needles have dropped to the ground the hazard is reduced considerably. The rate of foliage loss varies among species. Loman, in discussing the effect of moisture content on the rate of decay found that ground-contact slash had a consistently higher moisture content than suspended slash but the differences were not great. This is an important consideration as moisture content, along with air and heat, controls the rate of decay. This was discussed by Childs (1939) who suggested that during much of the summer, parts of the debris are fully exposed to sunlight and in the absence of substantial amounts of rain may

be too dry to decay. Therefore, the retention of bark and the development of shade may be favourable to the decay of slash, particularly in clearcut areas.

A study of various slash characteristics and flammability would provide a basis for examining the need for slash treatment and the effectiveness of such treatment. The application of a particular treatment to slash without gauging its effectiveness is of limited value. It is paramount that a particular treatment be applied where it will be most effective. The appraisal of slash hazard on the basis of judgement and experience is not always reliable. An objective evaluation of slash characteristics and flammability, based on sound scientific measurements, is urgently required. What slash characteristics determine flammability? What effect does slash size have on the potential rate of fire spread? How important is continuity, depth and density in relation to other fuel characteristics? What climatic factors influence the march of moisture and the incidence of decay? How can flammability and fire intensity be best evaluated? The use of prescribed fire, along with a study of physical slash characteristics, offers the best chance of success.

Seedbed Preparation

Clearcutting is used extensively in the Province, particularly on pulpwood operations. The result is a heavy accumulation of slash and

debris and sometimes an undisturbed organic layer. Under such conditions natural regeneration of most conifers is poor or completely absent. Before satisfactory natural regeneration is achieved the surface layer or organic material must be removed to expose the mineral soil. This can be accomplished in a number of ways, including scarification and fire. Scarification is relatively expensive, while the use of fire merits further investigation. Ackerman (1962), in studying regeneration following strip clear cutting, scarification and slash disposal in a lodgepole pine stand reported that seedbed treatment is necessary to obtain adequate regeneration of lodgepole pine.

Crossley, in 1952, recognized that fire may be the natural method of reproduction and should not be ignored. That coniferous regeneration on logged and burned areas is superior in quantity and quality to the regeneration on areas that are logged only was reported by Blyth (1954). Considerable work has been done with scarification, but practically nil in connection with the use of fire as a means of seedbed preparation. There is sufficient evidence from other regions that fire can be used to bare a mineral seedbed. It is therefore recommended that prescribed burning procedures and the use of fire in seedbed preparation be investigated in clearcut areas of lodgepole pine and white spruce.

Forest Fire Protection Planning

The effectiveness of a fire protection organization is judged on

the basis of its ability to keep fire losses to a minimum. This evaluation can be carried out only if the fire losses are known, the fire season severity has been determined, and the total suppression costs accounted for. The need for protection planning increases with the protection activities of the organization. Objectives must be determined and goals set. How much protection is needed for a particular area and how much is justified on economic grounds? For this we require reliable data of past fire occurrence, fire damage, fuel types, weather influences, and detection efficiency.

Beall (1949) developed a basic system of forest fire protection standards for Canada. He defined primary objectives in terms of acceptable burned area and described a method by which secondary objectives may be calculated. The burned area objectives take into account both values requiring protection and factors which affect the difficulty of protection. Secondary objectives of elapsed time to meet the burned area standards can be obtained from analysis of past fire records.

Suppression

Suppression activities must allow for flexibility to cope with the ever-changing fire situation. The provincial protection organization is responsible for all suppression activities within the provincial boundaries. New fire-fighting techniques have been developed, and major advances made in fire-fighting equipment and communications.

Investigations relating to suppression activities have been carried out by the federal Forestry Branch from time to time. Some of the publications are listed below:

The designing of a forestry-hose folder (Macleod 1955).

A study of soil sterilants and herbicides in forest fire control (Fraser 1958).

An investigation of slip-on tankers for forest fire suppression (Mactavish 1960).

Characteristics of back-pack pumps in forest fire suppression (Mactavish 1960).

A survey of equipment available for forest fire protection in Canada (Fraser 1961).

Performance test for portable fire pumps (Macleod 1961).

A report on tests of water-dropping characteristics of the Martin Mars air tanker (Williams 1962).

RESEARCH

Neither the Alberta Forest Service nor forest industry are directly involved in basic forest fire research. The responsibility for research lies with the federal Department of Forestry. At present, one forest fire research officer is engaged in the program. It is his

responsibility, in consultation with provincial and industrial fire protection agencies, to initiate, plan and carry out the research work in Alberta.

The need for a forest fire research program has been established. Past research has been inadequate in view of the values involved and advances made in forest fire protection activities. The reserve of known facts is small. Subsequently, provincial forest fire protection policy is based primarily on experience and prevailing opinion; and only limited scientific fact. The primary objective of the research program is to expand on the reserve of known facts, thereby providing the protection organization with a basis for policy formulation.

This report has attempted to evaluate and describe existing conditions and problems. The proposed research program is based on the fact-finding survey. The immediate and long-term needs are recognized, but their implementation will depend on the capabilities, available personnel, facilities, and equipment. The program has been aligned with the needs and requests of the protection organization and forest industry. The active participation of all interested parties is essential to keep up with the rapidly increasing protection requirements. This will ensure that all problems peculiar to each agency are recognized and acted on with a minimum of duplication and a maximum amount of useful knowledge becoming available.

Basic forest fire research in other areas should not be ignored. There is much to be gained by an interchange of ideas and information. Too often the attitude prevails that if research is not done where the results are to be utilized, it is of little or no use. In many cases,

only pilot trials would be necessary to evaluate the usefulness and applicability of research carried out in other areas.

Past Research Work

Some forest fire research in the Province has been expended in the preparation of forest fire danger tables for Alberta East Slope (1957) and Alberta (1959). Field work for these was carried out at Kananaskis and Whitecourt. Macleod (1948) studied the effect of night temperature inversions on the forest fire danger index. MacHattie has made studies of fire weather near Kananaskis. The deterioration by decay of lodgepole pine slash near Strachan was investigated by Loman (1959).

Current Program

The current program, consisting of three projects, is based on requests and recommendations made by government and forest industry. These are concerned primarily with measuring slash fuels and evaluating flammability. A short outline of each project follows:

1. Title. Tables for predicting quantities of slash following clearcutting of lodgepole pine and white spruce in west-central Alberta.

Objectives. To prepare a table(s) by which the quantity of slash fuels expected following a logging operation could be predicted. A knowledge of slash quantity expected on a particular area will provide a means of predicting the potential fire hazard and help to determine the best method for slash treatment.

Status. Initiated during the 1963 field season. A preliminary compilation and analysis of one year's data is in progress. The project will be completed during the 1964 field season and slash quantity tables prepared for publication the following winter.

2. Title. A preliminary study of the physical characteristics and moisture content of lodgepole pine and white spruce slash in Alberta.

Objectives. This study has been requested by the Alberta Department of Lands and Forests. It is undertaken to study the physical characteristics and moisture content of lodgepole pine and white spruce slash of various ages and treatments with a view to determining which treatment best provides the desired reduction in hazard; to compare moisture content changes in lopped and unlopped slash; to evaluate the effect of species, age, moisture content and slash treatment on fire hazard. It will also provide an opportunity to observe and assess the development of minor vegetation on cutovers, and its influence on moisture content and rate of decay.

Status. Field work was initiated in 1963. An extensive fuel sampling routine was carried out until the end of the field season. A progress report is being prepared. This project will continue for at least three more years.

3. Title. A study of slash hazard and flammability on cutovers in Alberta.

Objectives. The principle objective is to assess the relative slash hazard and flammability of lopped and unlopped slash on lodgepole pine and white spruce cutovers. It will provide an opportunity to observe and assess forest fuels, weather effects, and fire behaviour under controlled conditions. The results may also be applied to evaluate the effectiveness of fire as a method of slash disposal; to determine if effort is being directed against hazards in proportion to their severity; to develop procedures for prescribed burning experiments; and to study the effect of fire on regeneration silviculture.

Status. Two burning sites have been located. A 12½% timber cruise of the stands has been completed and it is expected that the timber will be cut in the winter 1963. Burning will be carried out in 1964 and 1965.

Proposed Program

Following is a proposed forest fire research program for the next ten year period. The order of priorities has been established by keeping in mind requests for research by the provincial government and forest industry. Many of the proposed studies require close co-operation between the various agencies involved. The priorities may be changed annually, depending on personnel, progress made and the need for specific studies from time to time.

1. Title. Forest fires and fire danger in Alberta.

Objectives. To determine the accuracy of the Alberta and Alberta East Slope forest fire danger tables. An attempt will be made to correlate the danger and hazard indices with fire occurrence, fire size, fire season, and other related parameters.

Justification. Past fire records indicate the relationship between fire danger and the fire parameters listed above. A compilation and analysis of fire statistics would provide a basis for evaluating the accuracy of the forest fire danger tables. The need for modifying the existing forest fire danger tables would be indicated. It would also provide the protection organization information about fire occurrence, fire size and damage, enabling them to concentrate their prevention and presuppression efforts where needed most.

2. Title. Studies in prescribed burning.

Objectives. To develop guidelines for prescribed burning under a variety of fuel and weather conditions; and to investigate methods of evaluating fire behaviour.

Justification. Fire is the most important historic factor determining the forest composition and succession of the three most important species in Alberta. Despite this evidence pointing to the importance and beneficial effects of fire, little effort has been expended in this Province trying to find out more about the use of fire as a tool in forest management. To judge prescribed fire objectively, procedures must be developed for a wide range of conditions. Once a certain degree of confidence and efficiency in the use of fire has been achieved, specific studies can be undertaken with a minimum of risk.

3. Title. Modification of forest fire danger tables.

Objectives. To modify the current forest fire danger tables on the basis of forest associations or cover types.

Justification. The need for modifying the tables will be established by the compilation and analysis of past fire records.

4. Title. Studies to appraise and improve forest-fire weather instrumentation and measurement.

Objectives. To aid the provincial government, as requested, in standardizing fire weather instrumentation and measurement, and location of fire-weather stations.

Justification. The fire danger tables are based on the relationship between fire weather readings and test fire behaviour. The accuracy of the tables depends, to a large extent, on equally accurate fire-weather readings.

5. Title. Forecasting forest fire danger.

Objective. To investigate and develop forest fire danger forecasting needs and procedures in Alberta.

Justification. The need for intensified fire danger forecasting is becoming increasingly important to foresters in silviculture and fire protection. Local forecasts are valuable for prescribed burning experiments, slash disposal, and burning of debris.

6. Title Rating of fire season severity in Alberta.

Objectives. To determine the relative severity between danger classes for the common fuel types found in the Province. This would indicate the need for modifying Williams' severity rating.

Justification. The use of a reliable severity rating appears to have great potential in presuppression work. It would give the protection agency a measure to equate suppression efforts with the cost of obtaining a certain degree of success in reducing fire losses. The rating could also be applied to record the cumulative severity throughout the fire season to forewarn of impending critical conditions.

7. Title. The short and long-term effects of fire on the forest environment.

Objectives. To study fire effects on native tree species' ability to regenerate; to evaluate the effect of fire on minor vegetation; and to determine what fire intensity and duration is lethal to trees and other vegetation.

Justification. Knowledge of fire effects on the forest environment is limited. Variations in fire effects depend on intensity and duration of fire, the composition of the stand, the character and volume of the fuels consumed, and the soil. A better knowledge of these factors would aid the forest manager in formulating effective forest policies.

8. Title. The effect of fuel size on rate of combustion.

Objectives. To determine the effect of an increase in fuel surface area on the rate of burning. This project could be best carried out under controlled laboratory conditions.

Justification. Forest fuels vary in size and arrangement. Weighing of tree crowns indicates that size distribution can be predicted with good results. The effect on rate of burning of the various size groups is not known. Fuel size and arrangement are particularly important in the initial stages of a forest fire. A better knowledge of fuel size would be beneficial in understanding and predicting fire behaviour.

9. Title. Rate of combustion of sound and decayed forest fuels.

Objectives. To measure the calorific value of sound and decayed wood for a range of moisture conditions.

Justification. Does volume of sound wood, with other factors equal, give off the same amount of heat as an equal volume of decayed wood? The answer will permit evaluation of the relative rate of hazard change in forest fuels from year to year. It would prove particularly useful in the evaluation of slash hazard on cut overs.

SUMMARY

This is a problem analysis of forest fire research in Alberta, based on a literature review, discussions with officials of the provincial government and forest industry, and a field reconnaissance carried out in 1962-63. The purpose of this report has been to report on the area and values affected by forest fires, to describe the fire problem in Alberta, and to outline research that is needed.

The first part of the report deals with Alberta's land area and forests. Brief mention is made of the climate, forest classification, the volume and value of forest production, growth, and depletion. A history of forest fires and fire protection is reviewed and supported by references to tables and graphs.

The second part of the problem analysis is concerned with fire problems in the Province. These are discussed under four main headings, namely prevention, detection, presuppression and suppression. Present knowledge of these problems is indicated, and approaches toward their solution suggested. Emphasis is placed on discussion of presuppression topics, including fire danger rating, the fire seasons, forest fire weather, forest fuels, fire effects, prescribed burning, and fire protection planning.

The last part of the paper deals with past, current, and future fire research. Responsibility for protecting the forest against fire lies

with the provincial protection organization. The federal Department of Forestry is responsible for carrying out research, based on needs and priorities set by the protection organization and forest industry.

The reserve of known facts is small. Subsequently, provincial forest fire protection policy is based primarily on experience and prevailing opinion. Progress depends largely on close co-operation between the various agencies, particularly in the field of prescribed burning. Current and future research projects are discussed briefly.

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