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INTRODUCTION

This 1978 Annual Meeting of the Intermountain Fire Research Council marks the first such meeting of the council outside of the U.S.A. The idea for a Canadian locale can be traced back to 1962, when Canadian fire researchers and managers first participated in council meetings. Strong professional contacts were established between council members and Canadian delegates attending subsequent annual meetings in various intermountain states. Largely at the encouragement of Dick Sandman, representatives of the Canadian Forestry Service and the Alberta Forest Service extended a formal invitation at the 1977 annual meeting in Casper, Wyoming for the council to hold its 1978 meeting in Edmonton, Alberta.

The Steering Committee of the Intermountain Fire Research Council thanks Dr. Tom Silver, Regional Director of Forestry, Northern Forest Research Centre, and Mr. Hank Ryhanen, Director, Protection Branch, Alberta Forest Service, for their support of both the technical and social aspects of the program. Participation from seven states and five provinces signifies the keen interest in the subject matters covered in the technical sessions. The acceptance of Alberta as a full-fledged member of the Intermountain Fire Research Council will undoubtedly generate an even greater degree of involvement and cooperation to the mutual benefit of fire management on both sides of the Canada-U.S.A. border.

D. Quintilio, Chairman
Program Committee

PROTECTION ORGANIZATIONS AND RESPONSIBILITIES

L.D. Goff*

Forest protection in Canada today, as in the past, is practiced with varying degrees of vigor. Protection varies from a high degree of commitment of resources in some parts of the land to limited action or no action. Wood species, economic value, proximity to market, and commitments to industry for an assured source of raw material generally dictate protection emphasis. Only more recently, in the past 20-25 years, are effects on water, soil, recreation, wildlife, and aesthetics playing a larger role in determining protection commitments, be they financial or physical actions. As raw material demand increases and the population expands, the amount of non-protected land correspondingly decreases. Because of our weather, the need for forest protection is not very apparent for several months each year; this factor makes it more difficult to convince tenders of the public purse to increase levels of protection.

Responsibility for protection in Canada belongs to the federal government in the Northwest Territories, Yukon, and national parks and on some Indian reserves. On provincial land, provincial governments have the resource management and leadership mandate. Most provinces directly assume the forest protection role, but in some cases responsibility is delegated to second parties, such as user agencies or municipal governments.

In the past 10 years, an average of 6070 fires has occurred annually in Canada, covering an average of 2.2 million acres each year.

In the Province of Alberta, the Alberta Forest Service (AFS) provides forest protection for some 60% of the land area. The Forest Service is a division of the Department of Energy and Natural Resources, which has responsibility for administration and management of Alberta's energy, mineral, and forest resources and public lands. Through its 641 permanent employees, the Alberta Forest Service is reponsible for formulating and coordinating policies, programs, and legislation and for administering the forest resources management program. The Forest Service, headquartered in Edmonton, has five Branches: Forest Land Use, Timber Management, Reforestation and Reclamation, Program Support, and Forest Protection. The forested (green zone) area of the province is divided into 10 forest regions, called Forests, through which the forestry program is field implemented. Field staff spend approximately 20% of their time on forest protection responsibilities.

The Forest Protection Branch is responsible for protection of Alberta's forests from damage and destruction by fire, insects, or diseases; it administers The Forest and Prairie Protection Act and two sets of regulations. It also provides meteorological and communications services and statistics and analysis on forest fires.

Forest Protection objectives in Alberta involve

1. fire discovery size of 0.25 acre or less
2. actioning of all fires within 1 h of discovery
3. control of all fires at a size of 3 acres or less, and
4. remaining within an annual allowable burn of 0.1%.

While the annual allowable burn of 0.1% applies provincially within the forest protection area, certain high priority regions exist wherein no fire loss can be accepted, and protection emphasis is correspondingly increased.

* Alberta Forest Service, Edmonton, Alberta

The current annual forest protection budget in Alberta is approximately $8.9 million, for a cost of $.11 for each acre under protection. Forest protection charges are levied to certain forest industries under forest management agreements and quota and timber harvesting systems. Other forest users pay no forest protection charges but pay a timber damage assessment for each acre disturbed. Where carelessness or negligence is determined as the cause of a forest fire, an attempt usually is made to recover fire costs.

During 1971-77, an average of 677 fires occurred annually in Alberta's forest protection area. Average annual area burned has been 63 900 acres, which is well within the 0.1% allowable burn of 94 723 acres.

In the area of research, the Forest Protection Branch depends largely upon the Northern Forest Research Centre (NFRC), but does become directly involved in many joint NFRC/AFS operational research projects. The liaison and analysis section of the Forest Protection Branch performs liaison for research with the NFRC.

Involvement in the insect and disease program by the Forest Service is primarily that of detection and operational control or treatment. The insect and disease survey unit of the Canadian Forestry Service assesses the extent and severity of the infestation and recommends remedial action if required. Insect and disease problems have been minor in Alberta, so no large-scale control programs have been required to date.

Fire suppression in Alberta is enhanced by a force of over 3000 trained and dedicated native firefighters, who are recruited on an as-needed basis. Of all advances in fire suppression, the native firefighter program in Alberta has been one of the most significant.

APPENDIX

Alberta forest protection statistics

Total area of Alberta - 255 285 mi^2
- 163 382 400 acres

Total forested (green zone) area - 128 315 mi^2
- 82 121 600 acres

Total forest protection area - 148 006 mi^2
- 94 723 968 acres

Annual allowable burn (0.1%) - 94 723 acres

1971-77 FIRE STATISTICS

Average number of fires per year	677
Number of fires, 1978 to date	631
Number of fires, 1977	556
Average annual area burned	63 900 acres
Average fire size	94.4 acres
Less than 5 acres at control	75.7%
Less than 3 acres at control	24.3%
0.25 acre or less discovery size	69.9%
Over 0.25 acre discovery size	30.1%

PROVINCIAL ANNUAL ALLOWABLE CUTS

Coniferous	516.8 million ft^3
Deciduous	477.8 million ft^3

HOLDING AND PROTECTION CHARGES

Green Coniferous - CTP	$.10 per acre
- Quota	$.75/M/fbm
- FMA	formula as specified in agreement ($.03 to $.04 per acre)

FIRE RESEARCH PROGRAMS AND ISSUES IN MID-CANADA

A.D. Kiil*

INTRODUCTION

Some form of organized fire control in Canada can be traced back to the late 1800's. In the western provinces of Manitoba, Saskatchewan, Alberta, and British Columbia, a fire-ranging service was begun on Dominion forest lands in 1901. It was recognized early that eventual progress in the development of various forestry programs would depend heavily on an effective fire-fighting force. Thus, the early efforts of the federal Forestry Branch of the Department of the Interior were almost entirely limited to fire suppression.

By 1914, fire protection was provided on 93 000 km^2 (36 000 mi^2) of Forest Reserves and on an additional 531 000 km^2 (205 000 mi^2) of unreserved lands or fire-ranging districts[1]. These districts soon extended into the Mackenzie River region north of 60° latitude. Fire lookouts were in operation by 1913; they were followed by portable gasoline fire pumps in 1915. In 1920 the Forestry Branch pioneered the use of aircraft for detection, reconnaissance, and transport of suppression crews and equipment in Alberta and British Columbia.

A major change in fire control responsibility took place in 1930 with the transfer of forest resources to the provinces. As a result, fire control in Alberta, Saskatchewan, and Manitoba was handled for the first time by provincial organizations. Today these provincial agencies are responsible for providing organized fire protection to about 1 092 000 km^2 (420 000 mi^2) of forest and tundra. Only the forest resources of the Northwest Territories and national parks continue to be managed by the federal government, accounting for an additional 312 000 km^2 (120 000 mi^2) under protection in this region[2]. After the three provinces assumed full responsibility for the protection and management of forest lands, the federal Forest Service concentrated its efforts on forestry research.

My task is to discuss the development and status of the fire research program in the region encompassing Alberta, Saskatchewan, Manitoba, and the Northwest Territories. Since this is the first meeting in western Canada of the Intermountain Fire Research Council, I think it is appropriate to include a description of the historical aspects of fire activity and fire research, thereby facilitating a comparison of the nature of fire management and research programs in the two regions. Research needs and priorities are discussed in the context of regional, rather than national, fire problems and mandates, although an overview of fire research programs at other Canadian Forestry Service establishments will be provided.

A HISTORICAL PERSPECTIVE

The causes and effects of fire in the northern grasslands area of Canada and the nearby United States between 1750 and 1900 have been studied in considerable detail by Nelson and England (1978). These fires were started by lightning and by man. The native

* Northern Forest Research Centre, Canadian Forestry Service, Fisheries and Environment Canada, Edmonton, Alberta

[1] Annual Reports of the Director of Forestry, Forestry Branch, Dept. of Mines and Resources.

[2] Includes provinces of Alberta, Saskatchewan, and Manitoba, and the Northwest Territories and national parks.

peoples used fire to control wildlife movement. Settlers contributed to an increase in fire incidence in the latter part of the 1800's as new causes for fire were introduced. Some early European settlers burned the grasslands to make it easier to collect bison bones, and sparks thrown from railroad engines became a widespread fire cause in the early 1880's. Because fires were an important obstacle to the settlement of western Canada during the 1870's to 1890's, they brought about the necessary legislation and subsequent development of fire control districts, initially in grassland areas.

The movement of settlers, prospectors, lumbermen, and railway builders into the forested areas west and north of the Canadian Plains increased the incidence and frequency of forest fires. Historical literature contains references to numerous major forest fires in the late 1800's and the early decades of the 1900's, but reliable fire statistics are not available. A detailed statement of fire losses was prepared in 1910, but it wasn't until 1930 that a systematic tabulation of fire losses for all of Canada was again introduced.

A tabulation of 50 years of combined fire records for the three Prairie Provinces and the Northwest Territories illustrates the highly variable incidence and burned-area patterns of forest fires (Figure 1)[3]. Since 1950, fire incidence has more than doubled, while area burned has remained nearly constant. The reduction in average fire size was most pronounced during the 10-year period from 1950 to 1960. Total damages and actual fire-fighting costs continue to increase, with the latter having increased 30-fold during the 20-year period from 1950 to 1970.

Similar data for individual provinces and territories indicate some fairly striking differences in fire incidence and burned-area patterns (Figures 2 and 3). Since 1950, fire starts have increased at roughly the same rate in both Alberta and the Northwest Territories, whereas the latter also has recorded a substantial increase in total area burned. During the 5-year period of 1971-75, average fire size in Alberta was less than 40 ha (100 acres) compared to nearly 1200 ha (3000 acres) in the Northwest Territories[4]. Actual fire-fighting costs (exclusive of overhead) have continued to increase over the past 25 to 30 years. These data serve to illustrate within-region differences in fire activity and fire control operations, but they should not be used to draw inferences about fire control effectiveness without a careful assessment of fire management policies, burned-area objectives, and methods of operation. Nevertheless, such differences need to be recognized when identifying and defining fire research problems and priorities.

Today, just under 2000 fires annually burn nearly 5200 km^2 (2000 mi^2) or nearly 0.4% of the protected area in the region. The annual burned area is roughly equivalent to a 16-km- (10-mi-) wide highway extending from Edmonton to Calgary and reflects the total area burned by all fires, including unfought fires in northern areas. Fire incidence continues to increase, but does not often exceed a relatively low annual rate of two to four fires per 2600 km^2 (1000 mi^2). Fire protection expenditures—maintenance costs as well as direct fire-fighting costs—approach $20 million annually, or about $5 per person on a region-wide basis. Reliable data are not available for gauging fire impacts on the forest estate, but conservative estimates place such losses to tangible and intangible resource values at $20 million or higher annually.

Fire incidence, area burned, and associated fire costs and damages in the rest of Canada show similar trends, but significant differences do occur between provinces and regions. During the 10-year period from 1968 to 1977, 8664 fires burned over 11 860 km^2 (4579 mi^2) of forest and tundra in Canada. About 40 years ago, about 5000 fires burned about 8094 km^2 (3125 mi^2). Present fire management expenditures range from $50 million to $100 million annually. Tangible

[3] Forest Fire Losses in Canada (Published by the Forest Fire Research Institute, Ottawa).

[4] Reports tabled at the Annual Meetings of the Canadian Committee on Forest Fire Control.

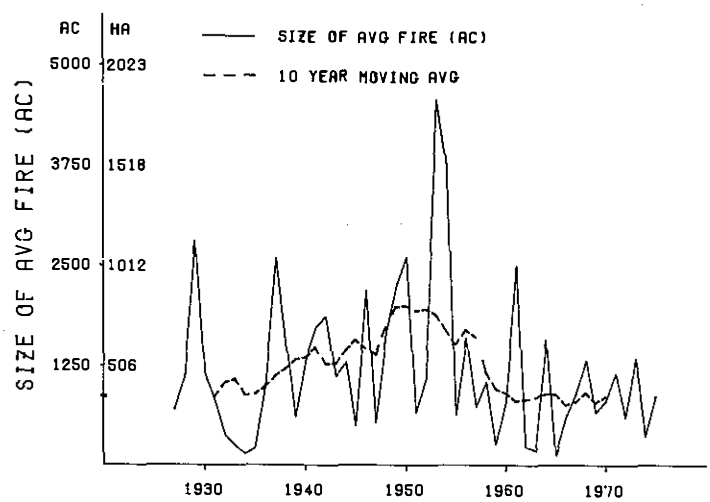
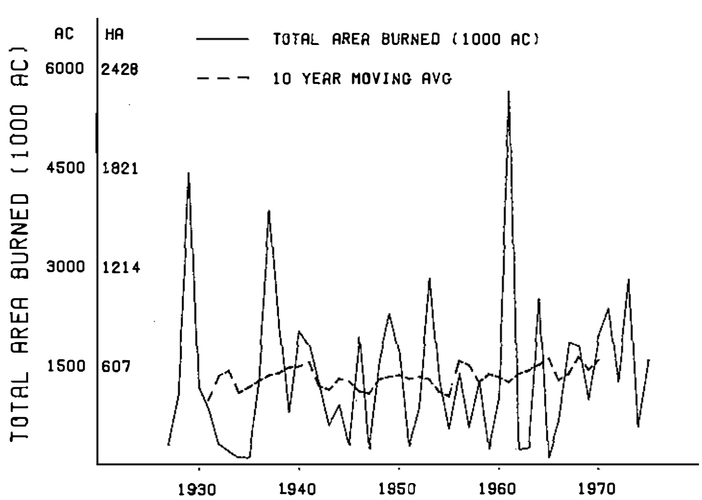
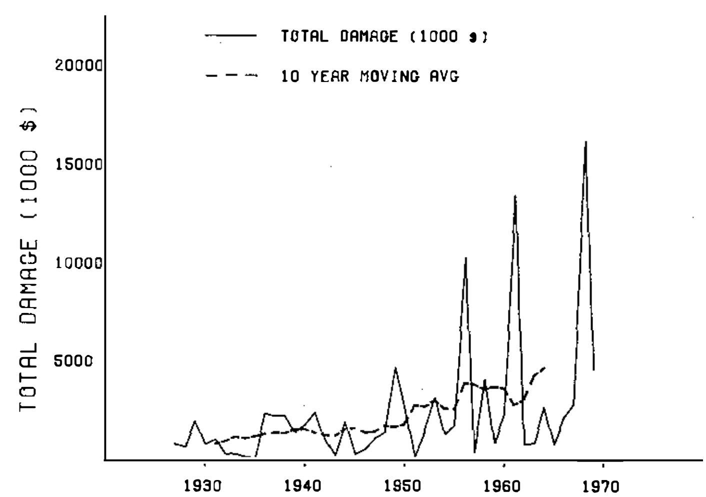
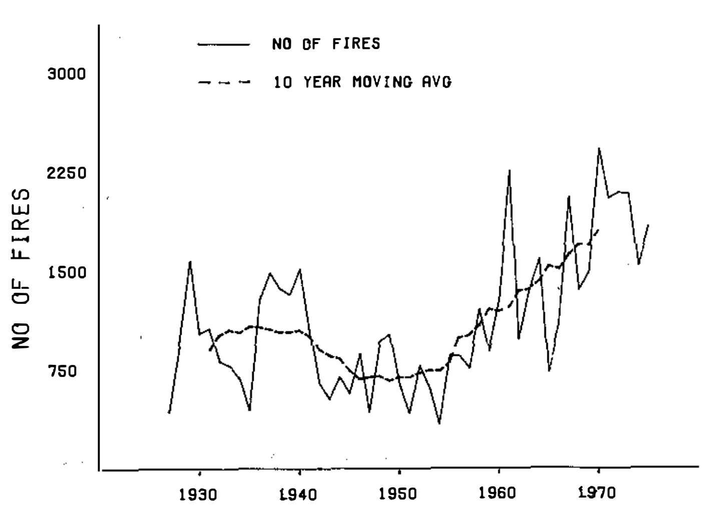
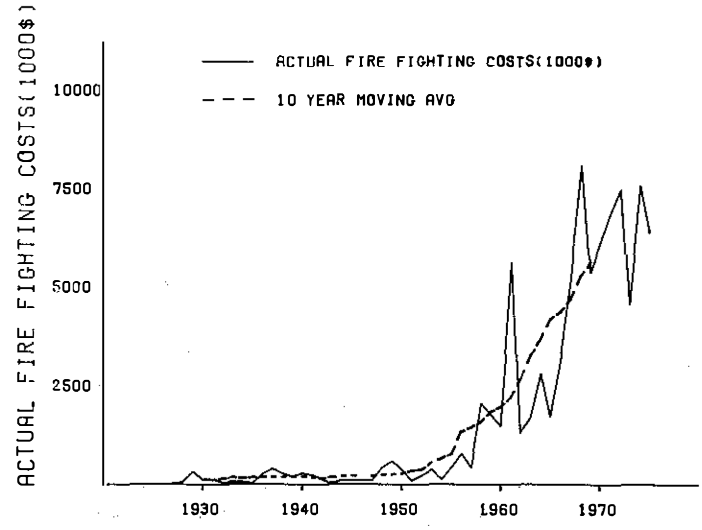


Figure 1. **Combined fire statistics for Alberta, Saskatchewan, Manitoba, and the Northwest Territories, 1927-76.**









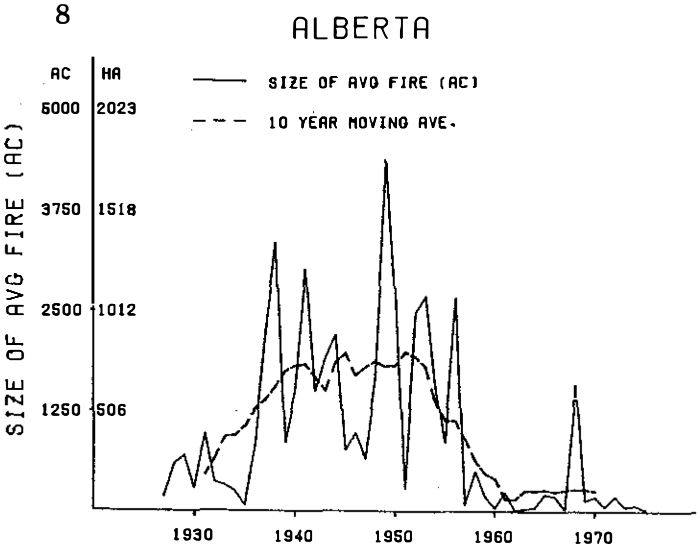
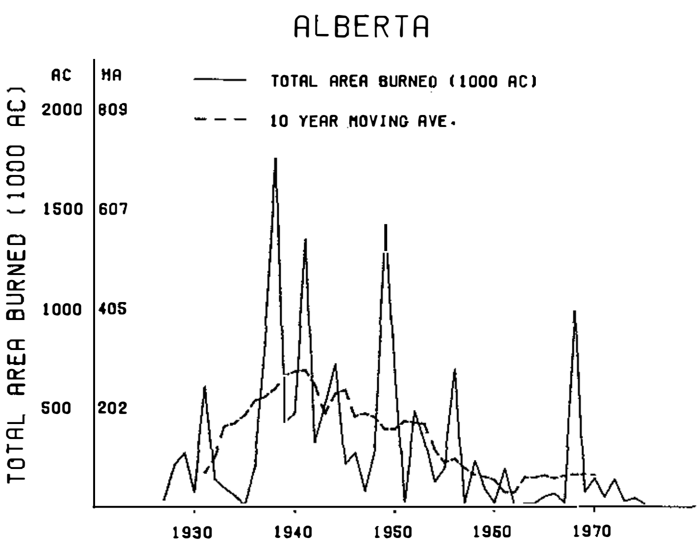
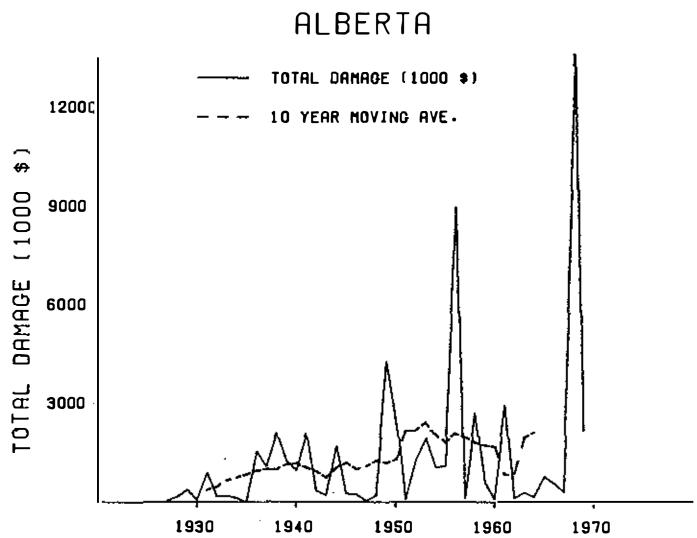
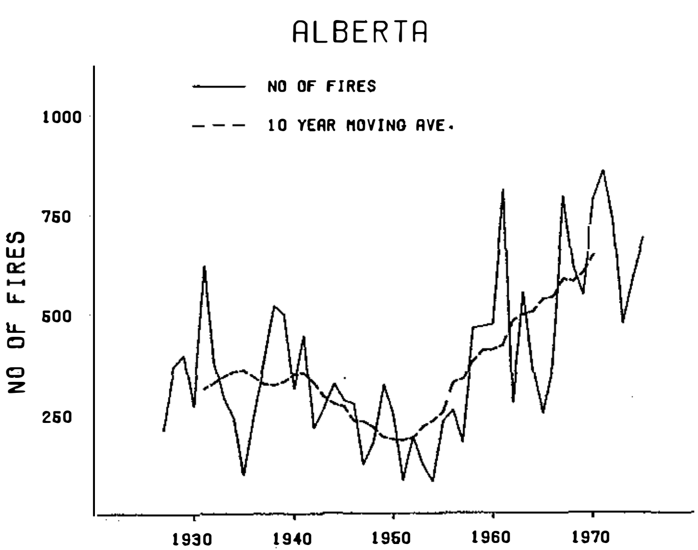


Figure 2. Fire statistics for Alberta, 1927-76.







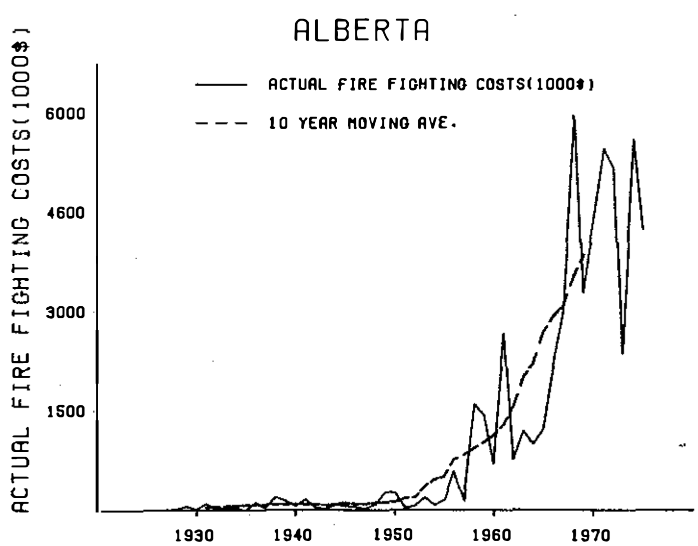
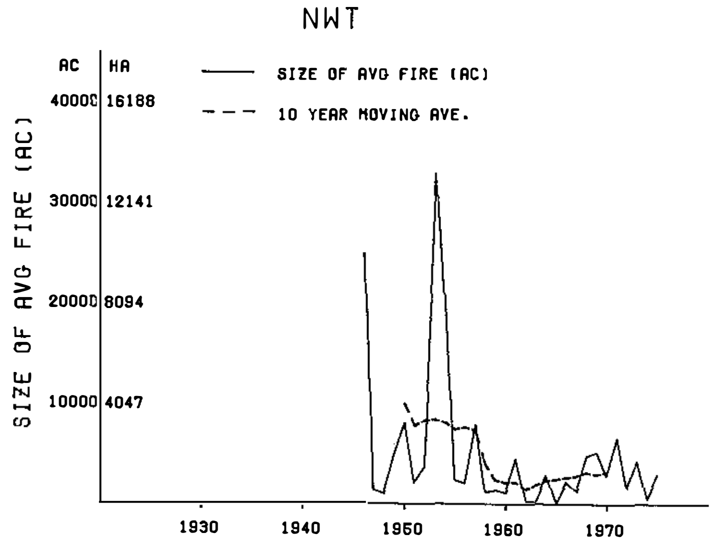
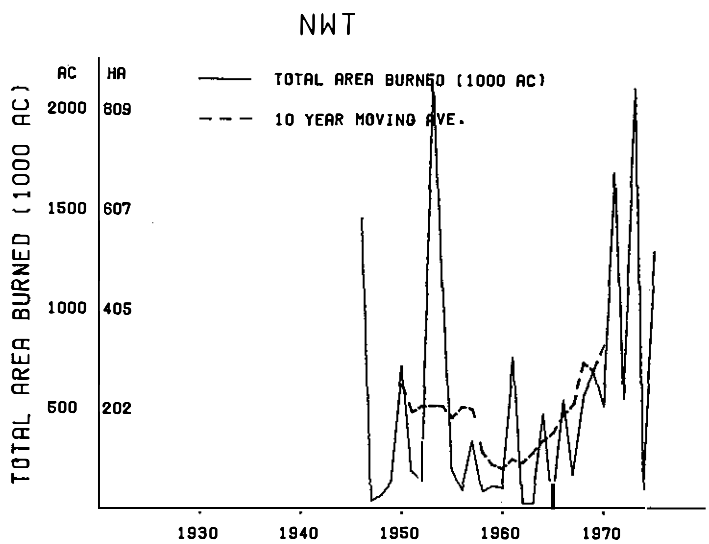
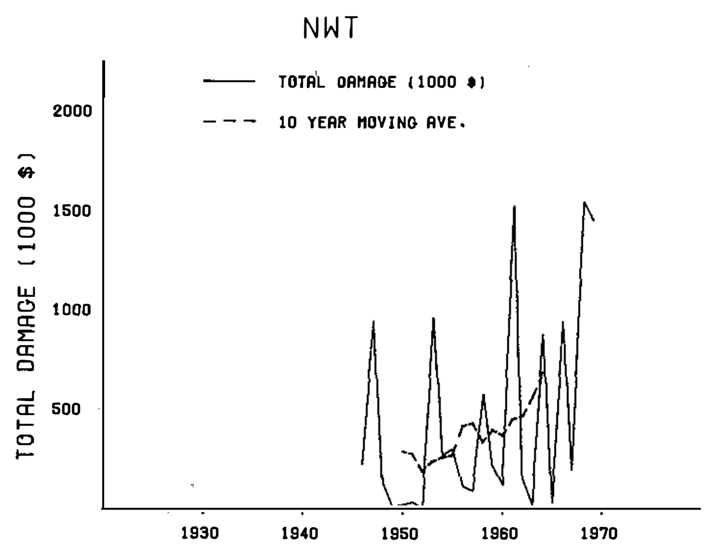
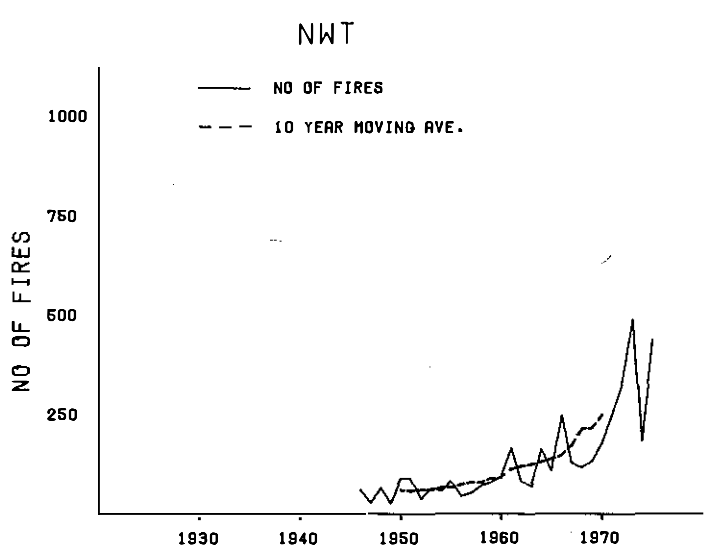


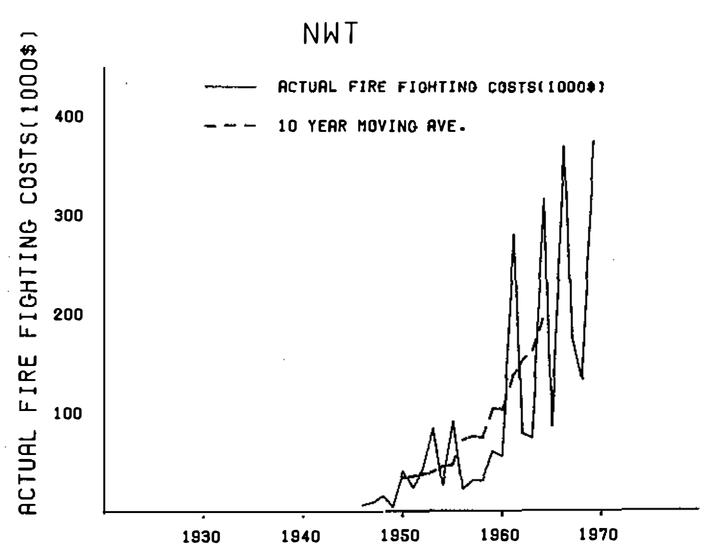
Figure 3. Fire statistics for the Northwest Territories, 1946-76.











fire damages range anywhere from $10 million to $100 million annually and are based primarily on timber stumpage rates.

While historical fire records provide essential insight into fire business, the projection of historical trends to predict future expectations must recognize ever-changing fire and resource management policies and programs. For example, fire statistics prior to 1945 are based on less than one-half of the 1 404 000 km^2 (540 000 mi^2) being protected today. Provincial and federal fire management agencies in the region continue to provide increasingly intensive fire protection coverage to both presently protected and previously unprotected areas. Even so, the level of fire protection expenditures is highly variable, ranging from less than $4/$km^2$ ($10/$mi^2$) to over $23/$km^2$ ($60/$mi^2$). In the northern fringes of the boreal forest and the tundra, many fires are unfought unless they threaten communities or other man-made installations. Early suppression of all wildfires is the primary aim of the protection agencies in relatively densely populated southern areas of high value to society.

Marked fluctuations about the long-term averages continue to dominate the fire figures, suggesting that variable climatic cycles remain an important influence on total fire activity. If we can arbitrarily define a "bad" fire year as one in which more than 1% of the protected area was burned, then 1919, 1929, 1937, 1949, 1961, and 1973 qualify. These 6 "bad" years appear to be region wide, whereas individual provinces or subregions experienced other severe fire periods locally. Losses during "good" years are considerably less, ranging from about 388 km^2 (150 mi^2) to 1942 km^2 (750 mi^2) or from 0.03% to 0.15% of the protected area. It is interesting to note that the maximum size of individual major fires has been reduced from about 10 360 km^2 (4000 mi^2) 50 years ago to about 1036 km^2 (400 mi^2) today.

Since vegetation provides thermal energy for the propagation of a fire, it is reasonable to suggest that the distribution, amount, and flammability of various fuel elements contribute to the fire potential of a particular area. For the region as a whole there is little evidence to suggest we are experiencing a widespread accumulation of highly flammable fuels. Buildup of substantial fuel accumulations is probably taking place in southern regions (e.g., East Slopes of Alberta) and some northern communities where fire protection has been most intensive, but forest harvesting, road construction, and related land-clearing activities tend to reduce the size of large tracts of flammable vegetation. In some northern areas, natural fire cycles continue to modify the forest and tundra, presumably on a scale experienced during previous millenia.

AN OVERVIEW OF FIRE RESEARCH IN CANADA

Historical

Limited studies of the relationship between weather and forest flammability were initiated at the Petawawa Forest Experiment Station and were intensified in 1929. Following transfer of the responsibility for forest resource management to the provinces in 1930, several fire hazard stations, including the Kananaskis Forest Experiment Station west of Calgary, were established in the 1930's. Subsequent work on danger rating, involving small-scale test fires, continued as the primary but by no means only federal research activity through the 1950's. Studies of fire-retardant chemicals were initiated in 1934. Other early fire research studies dealt with slash disposal through the use of prescribed burning and the development of fire control planning procedures, including burned-area objectives.

Organizationally, the most far-reaching change in federal fire research occurred in the 1960's when fire researchers were placed at regional establishments to provide continuous rather than occasional contact with fire control agencies, to conduct research, and to provide advice on programs of local significance. All of the six regional establishments—the Pacific Forest Research Centre in Victoria, B.C.; the Northern Forest Research Centre in Edmonton, Alta.; the Great Lakes Forest Research Centre in Sault Ste. Marie, Ont.; the Laurentian Forest Research Centre near Quebec City, Que.; the Maritimes Forest

Research Centre in Fredericton, N.B.; and the Newfoundland Forest Research Centre in St. John's, Nfld.—have had at least one fire researcher on staff at some time or another. The other major development in the 1960's was the establishment of the centrally located Forest Fire Research Institute in Ottawa to conduct a program of research and development which is Canada wide in scope and application. The Petawawa Forest Experiment Station has continued as an important center for work in fire danger rating and fire effects.

The presence of fire researchers at regional establishments led to the initiation of work on such diverse topics as the application of prescribed fire to reduce slash accumulations and to prepare seedbeds for planting and seeding. Work was initiated to provide operational guidelines for more effective use of the fire control dollar, particularly in the area of air tanker/retardant utilization and fire detection. New technology—satellite imagery, computers, remote sensing, aerial ignition techniques—was developed and evaluated to determine its applicability in fire control. The advent of the 1970's saw an increased emphasis being placed on the concept of "fire management", involving consideration of resource values, role of fire in the environment, the appropriate level of fire control effort and opportunities for prescribed use of fire, and fire impacts. New studies were initiated to document the historical role of fire in the forest and to determine the beneficial as well as destructive aspects of fire in the forest. The systems approach, utilizing the computational capabilities of computers, was adopted as part of the research strategy to provide guidelines and standards in support of improved fire management planning and operations.

In addition to the fire research program of the Canadian Forestry Service, several provinces conduct research and development work on field evaluation of fire control operations, cost/benefit analyses of various operational activities, and adaptation of computer technology to help solve fire problems. Work at Canadian universities is concerned primarily with basic fire chemistry and physics, thermodynamics, fire history and effects, and fire modelling.

CFS National Program Aims and Priorities

The primary aims of the CFS fire research program can be summarized as

1. to develop methods for predicting occurrence of wildfires and the behavior of wild and prescribed fire

2. to improve existing methods and techniques and to develop new ones so as to enable fire management agencies to assess and optimize the effectiveness of fire suppression operations

3. to understand the natural role of fire and fire effects on the environment and to develop concepts and procedures whereby this information can be integrated into fire management and land use plans, and

4. to monitor, develop, and standardize new fire management concepts, systems, planning aids, and information sources to maximize net social and economic benefits from fire management.

The total staff and funds available to the national program amount to about 50 research and support personnel and $1.5 million in funds, constituting about 5% of the total Canadian Forestry Service forest resources research program. Fire research staff are about equally divided between the centrally located Forest Fire Research Institute in Ottawa and regional establishments in Victoria, B.C., Edmonton, Alta., Sault Ste. Marie, Ont., and the Petawawa Forest Experiment Station in Chalk River, Ont. Recent cutbacks in federal programs have resulted in the elimination of several fire research positions at the Forest Fire Research Institute, with the remaining staff to be transferred to the Petawawa Forest Experiment Station in 1979.

Fire research in Canada has followed the empirical method, but theory has been linked with field results whenever possible. There is generally a close working relationship between researcher and user of results. Observation and measurement of wildfires and prescribed burns in standing timber and slash are usually conducted on provincial lands, implying provincial responsibility for any required suppression action. Similarly, development and testing of centralized fire management systems, utilizing modern communications, transportation, and computer technology, is done in close collaboration with operational agencies. The relatively heavy emphasis on observation and measurement of real-life situations has contributed to a generally early implementation of research results.

So much for generalities about program goals and strategies—what about examples of specific activities, and how do these contribute to help solve some of the fire problems discussed earlier? How relevant are they in relation to short- and long-term needs for integrating fire research into forest land management? A detailed discussion of all fire projects is clearly beyond the scope of this paper, but a portrayal of some program elements at each of the Canadian Forestry Service establishments actively involved in fire research should prove helpful.

Forest Fire Research Institute (FFRI)

The collection, compilation, and publishing of national forest fire statistics and related technical information has been a continuing function of the FFRI for many years. *Fire Control Abstracts* and *Annual Forest Fire Losses in Canada* are well-known examples of such activities. The Institute provides an executive secretary for the Canadian Committee on Forest Fire Control, a national committee composed of representatives from federal and provincial agencies, forest industry, and university forestry faculties. Work is under way to assess the potential of NOAA-5 VHRR Satellite data for measurement of precipitation from different types of thunderstorms. A remote weather station using satellite linkage has been designed and is being constructed. The FFRI maintains a liaison role with the Atmospheric Environment Service and the National Research Council to assess the potential of cloud seeding for rainfall inducement. A computer simulation model (AIRPRO) has been developed to determine air tanker productivity. Work has been initiated to develop standards and guidelines for appraising forest fire effects. A major program to develop, test, and apply a series of computerized information and decision-aid tools has been under way for several years and has produced numerous software packages for operational use. Other programs relate to prediction of fire occurrence, use of detonating card to produce fireguard, aerial detection, lightning counter networks, testing of fire pumps and hose, evaluation of air tankers and fire suppressants, mapping of old burns, blowdowns, and fuel distributions by using Landsat imagery, and studies of heat exchange between forest fuel layers and the atmosphere. The FFRI coordinated the development of the Canadian Forest Fire Danger Rating System involving fire researchers from various regional centres.

Petawawa Forest Experiment Station (PFES)

Fire researchers at the Petawawa Forest Experiment Station continue to play a leading role in improving the Canadian Forest Fire Danger Rating System and to clarify the role of fire in integrated resource management. Crowning potential, diurnal changes in fuel moisture content, effect of latitude on fuel flammability, and foliar moisture fluctuations are some examples of recent refinements to the danger rating system. Increased emphasis is being placed on a program to assess and predict the effect of fire on vegetation diversity and succession, tree growth, and related environmental considerations.

Great Lakes Forest Research Centre (GLFRC)

A prescribed burning program in jack pine stands continues to provide empirical data required for the development of fire behavior guides for major Ontario fuel types. Calibration and performance of the Canadian Fire Weather Index Tables is an ongoing study. Guidelines are being prepared to assist resource managers implement operational prescribed burning programs to reduce slash-fire hazards and to prepare sites for reforestation. Effects of prescribed burns and wildfires are being assessed to determine the ecological relationships between fire and vegetation in the eastern boreal forest, including the flammability of fuel complexes at different stages following spruce budworm infestations. Some of this work is carried out in cooperation with fire researchers at the PFES and the FFRI.

Pacific Forest Research Centre (PFRC)

Calibration of the Canadian Forest Fire Weather Index has been accomplished. Detailed guidelines have been prepared for predicting the behavior and impact of prescribed burning in slash fuels. Work is under way to develop techniques for use of prescribed fire for habitat and fiber management, including use of fire for dwarf mistletoe control in lodgepole pine. An automated system has been developed and is in use for the aerial ignition of forest fuels. Fire researchers at the PFRC are also developing new techniques for using wildfires and prescribed burns as significant data sources. A fire weather assessment procedure is being tested to assist in optimizing the distribution of fire weather station networks.

FIRE RESEARCH AT THE NORTHERN FOREST RESEARCH CENTRE

The objective of the regional fire research program is "to provide guidelines and standards to resource managers for operational use that will reduce at an acceptable cost the damage and losses from fire, while considering the related economic, ecological, environmental and social factors."

In the 1960's the regional program was concerned primarily with the assessment of logging-slash flammability following harvesting and the use of fire in reforestation. The need to characterize forest residues led to the development of research studies whereby 400 individual lodgepole pine, white spruce, black spruce, and alpine fir were felled, measured, and weighed. Concurrently, a field sampling program provided a basis for predicting the weight and depth of the forest floor from site and forest cover type descriptors such as moisture regime and stand age, density, and height. The results of these studies have been used to develop fire hazard rating schemes for different fuel complexes, including standing timber and logging slash. Fire researchers have participated in the development of the Canadian Forest Fire Danger Rating System, but most of the work in the area of danger rating has been concerned with calibration of the national system and acquisition of data to refine the system for regional use.

Another major work area, initiated in the 1960's, is concerned with the productivity of different fire-line construction methods such as air tanker/retardant/water combinations and bulldozers. These programs were initiated and developed in close cooperation with client agencies (federal and provincial, forest industry) and results generally have satisfied the urgent needs for information within a short time span of a few years.

By the early 1970's, resource management problems had developed that required an understanding of the historical role of fire and effects of fire on various landscapes. Field studies of plant succession/fire interactions are now under way in several national parks in this region. Work on the preparation of guidelines for fire management in Nahanni National Park is nearing completion. A wildfire detection study, initiated in 1971, is nearing completion. A highlight of this study was the operational evaluation of the AGA Thermovision 750 System and its subsequent application for detection of holdover fires.

Current work in fire danger rating is aimed at the development of fire behavior and impact guidelines for major forest and tundra vegetation types in the region. Available information on aerial and forest floor fuels, including moisture relationships, and measurement of fire behavior in natural stands are providing the required data for a more precise rating and forecasting of fire behavior and impacts in regional fuel types. Fuel moisture, fire behavior, and weather data from over 10 000 small-scale test fires conducted at various locations in the region are being reanalyzed to develop an interim calibration of Fire Weather Index components in relation to fire potential. Overwinter monitoring of the Drought Code (DC) revealed that DC values in the 300-500 range in early spring are likely to contribute to a particularly severe spring fire season.

Substantial progress has been made in measurement and evaluation of the drop characteristics and operational effectiveness of various air tanker/fire retardant/water combinations. Preliminary specifications have been prepared to guide the operational use of water-thickening compounds. Application and measurement of water and thickened water (Tenogum) directly in front of a fast-spreading crown fire in a dense black spruce stand indicate that single drops may be sufficient to extinguish or hold intense fires in this fuel type at least within 30 minutes of application. A study team of Alberta Forest Service personnel, Canadian Forestry Service researchers, and a systems analyst have recently completed a simulation model to provide a relative comparison of initial attack systems in Alberta. A second modelling effort is concerned with the allocation of air tanker groups to air bases.

FUTURE PROGRAM ISSUES AND PRIORITIES

Significant changes in forest management and land use planning are exerting greater pressures on fire control agencies to achieve new and sometimes conflicting objectives. Increased competition for the use of the same area of land—for timber harvesting, wildlife management, recreation, or strip mining—means that longer-term land use planning will become increasingly crucial in integrating the diverse needs of all types of forest-based activities. Effective fire control will undoubtedly continue as a condition of increasingly intensive resource management. At the same time, greater awareness of fire as an important natural process could allow for its use to satisfy specific resource management needs. Resource management plans could include measures for fuel management to reduce fire potential owing to fuel buildup. The far-reaching consequences of current resource management decisions lend weight to the importance of planning and operational guidelines as key ingredients of the land management process.

In this region, fire management covers an unusually wide range of activities, from simple monitoring of wildfires in the far north to relatively sophisticated planning and operations in southern areas. A recent appraisal of fire research program status and effectiveness in relation to anticipated forest land management programs and needs has led to increased emphasis on integration of research findings into a systems framework. We expect that this approach will enable us to keep abreast of and maybe ahead of operational needs. Initially, we will integrate and systematize the substantial data from earlier programs in a form that will make it more easily accessible and useful to fire managers and resource planners. Data gaps will be identified, and new studies will be initiated to obtain critical new information in support of program objectives. Operations research techniques, including simulation modelling and computer-based data systems, will be utilized to produce decision-making aids on fire behavior and effects, fire-line productivity, cost-benefit criteria and fire-related planning, and operational issues.

This added dimension to the regional fire program is geared to providing information to improve the initial response to individual fires, particularly during multiple-fire situations. The intent is to integrate research data, field experience, and modern technology to improve the efficiency of fire control and to provide essential planning data for fire management in the broader context of integrated land use.

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MUTUAL AID AND ONTARIO

R.J. Drysdale*

INTRODUCTION

Ontario has developed an effective, efficient, and highly mobile forest fire suppression force. Our fire center concept is aimed at providing fast initial attack and follow-up in all areas of the province, whenever and where-ever required. Heavy fire loads in any particular district are offset by the coordinated movement of resources from adjacent, less affected districts by the regional fire centers. Similar movements of resources from region to region are coordinated by the provincial fire center in response to identified needs. This, perhaps, is mutual aid in its most basic form.

Just as fires and heavy fire loads are no respecters of district or regional boundaries, they are no respecters of provincial or international boundaries. Fires, regardless of their points of origin along boundaries, have to be brought under prompt control. Likewise, periodic heavy fire loads in one province or part of a country may severely tax that organization's suppression resources. Aid from adjacent or distant fire organizations is essential in such cases. Ontario has always been an advocate of this type of cooperation and has been fortunate to be on the receiving end in recent years and on the providing end in previous years. We feel that the development and maintenance of this cooperation is an extremely important part of our presuppression activities.

DETAILS OF ONTARIO AGREEMENTS

Ontario has border agreements with Quebec to our east and Manitoba to our west. To the south we have an agreement with the state of Minnesota and the U.S. Forest Service (USFS) for the Superior National Forest.

Rather than dealing with the details of these agreements--they are all very similar in content—I would like to highlight a few key points concerning them:

1. Agreements take the form of either a formal document, as our agreement with Quebec, or an informal document, such as memorandums of agreement between Ontario and Manitoba and Ontario-Minnesota-USFS. Whatever the form, they both accomplish the same basic purpose for which they were intended.

2. They all identify a common zone—2 to 5 mi in width—to which the agreements pertain.

3. They all provide for prompt initial attack on fires in this area by either party and a coordinated follow-up. Procedures are outlined for reimbursing the other party for out-of-pocket costs.

4. Last, and perhaps most important, they provide for annual exchanges of information at a local level. These meetings provide an opportunity for the key fire suppression people at the local level to get together to get to know each other and to exchange information on issues such as

   - key personnel
   - means of contact
   - detection systems
   - boundaries
   - wx systems
   - technical reports
   - courses, demonstrations, etc.

One feature unique to the Ontario-Minnesota-USFS agreement is clearance for emergency border crossings by each side. This allows fire fighters and their equipment to

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cross the border into the common zone without going through the normal customs and immigration procedures.

These agreements have worked well for Ontario in the past. No major problems relating to them have been identified, and no changes are anticipated. While it is important that the written border agreement be in place, we feel that the personal contacts established and the exchanges of information at the local level really make this important type of mutual aid work.

In recent years Ontario has been in an excellent position to see mutual aid work. In 1974 and again in 1976 assistance in the form of manpower and equipment was received from many provincial agencies and from the Boise Interagency Fire Centre (BIFC). Heavy fire loads in those years had depleted our fire-fighting resources to critical levels. Outside help enabled us to carry on.

Some problems were encountered in 1974 and in 1976 in getting clearance for the BIFC equipment to come into Canada. A lot of scurrying around was required to make the necessary arrangements. Delays and inconveniences have to be minimized, since they can be so costly. This is basically what prompted the Canada/US agreement which is presently and patiently being negotiated.

In addition to the obvious short-term benefits of such mutual aid, we have identified an additional long-term benefit. The personnel accompanying the resources from outside of the province had an opportunity to observe our operations under fire. These "outsiders" were able to provide us with valuable observations of our operations and made numerous suggestions as to how we could improve. In addition, they could also relate their experiences to their own organization upon their return, to help avoid some of the pitfalls we fell into or perhaps to convey some of our successes that might help to improve their organization.

CONCLUSION

Mutual aid, although only one form of cooperation that should be promoted among organizations, is an essential part of fire management. It is a part that should be developed and maintained in the future. In Ontario, as in many other parts of the country, the demands in fire management are growing. The areas requiring protection are increasing, as are the areas of hazard and degree of fire risk. Budgets and resources available to do the job are barely holding their own. Climatic anomolies, such as the drought that affected many parts of Canada and the United States, add additional pressures. If we are to cope, it is essential that North American fire organizations continue their program of cooperation and mutual aid.

FOREST FIRE VALUE APPRAISAL

R. Paul Brady*

INTRODUCTION

In improving a system, one has to design the improvements, experiment and redesign, implement the new system, and evaluate it. I am going to discuss the concepts and constraints we encounter in designing improvements to our systems of appraising fire impact on resource values.

I want to give each and every one of you a better appreciation of the challenges we face. In so doing, those of you in fire operations who need and are asking for better information on the economic impact of forest fires will see the size and complexity of the task.

I hope that those of you in fire research will see that the task of improving value appraisal systems is multidisciplinary, because the measurement of the economic consequences of a fire rests on sound knowledge about the physical effects of fire on the forest.

Before I proceed further, I want to point out that I very seldom use the term "damage appraisal." As we all know, fire can ameliorate forest value. I refer to the measurement of the economic impact of fires that have actually occurred as fire effects appraisal and to potential fire effects as value at risk.

For the purpose of my talk, I want you to imagine yourselves to be employees of a Canadian public agency that is responsible for fire management over a large forested area. You have been asked to design improvements to the current system of value appraisal. I am going to pose some of the many questions that have to be addressed in order to improve a value appraisal system. These are not all of the questions but are some of the ones I think are more important.

Question 1. What are the values in a forested area, and which are susceptible to change by fire?

When I first started looking at value appraisal, I searched in several places for a complete and comprehensive list of the kinds of values that are affected by fire. I discovered the works of Crosby (1977) and Westman (1977), and I modified their lists of the kinds of values in a forested area to suit my own perceptions (Table 1).

In and around the forest are people, and associated with people are property and improvements and people's possessions. I call values associated with people "public liability in the forest environment." Public liability consists of public safety and the value of property and improvements, in addition to people's activities. For example, smoke pollution can disrupt the activity on a major transportation artery.

The second group of values in a forested area are what I call "forest goods." The definition of a good in the economic sense is a tangible commodity produced to satisfy societal needs and desires. In many areas of Canada, wood fiber is a very important forest good. Other kinds of forest goods are wildlife, opportunities for recreation, rangeland in some parts of Canada, and opportunities for aesthetic appreciation.

The third group of values I associate with the forest are "forest services." Because a forest is there—and with little or no effort on our part—we receive the benefit of what I call services. These services are provided to us free of charge; without them we would have to find substitutes or suffer a lower net social value. Among the services that the forest provides is the regulation of watersheds. Forests store, purify, and regulate the flow of water

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Table 1. Value categories.

I. Public liability in the forest environment
   1. Safety
   2. Improvements
   3. Activity

II. Goods from the forest
   4. Wood fiber
   5. Range
   6. Recreation opportunities
   7. Wildlife
   8. Opportunities for aesthetic appreciation

III. Services provided by the forest
   9. Watershed regulation
   10. Soil conservation
   11. Cycling of nutrients, gases and energy
   12. Microclimate regulation

over our landscapes. Forests prevent erosion, regulate microclimate, and contribute to the cycling of gases, nutrients, and solar energy.

Question 2. How do agencies in Canada conduct value appraisal?

First, I am going to give you a feeling for the general trend in systematic appraisal across Canada. By systematic appraisal I mean the kinds of appraisals done for most fires. The trend across Canada is to look at public safety, property and improvements, and wood fiber values. Usually the effect of fire on public safety is measured by counting the number of fatalities. I am happy to report that in 1977 there were no fatalities due to forest fires in Canada. When calculating the value of property and improvements, Canadian agencies use various methods, but they all pattern them after the methods used by insurance companies, which involve a combination of replacement cost and depreciation. In Canada, $5.3 million in improvements were lost in 1977.

Fire effects on wood fiber are measured by looking at the lost stumpage of mature timber. A dollar rate per unit volume or unit area is applied to the burned area. The dollar rate usually is fixed in the short run but may vary according to geographic area, whether the wood is hardwood or softwood, or changes in stumpage prices. When appraising the lost wood fiber resource in immature and regenerated stands, typically a reduced rate per unit area is applied. In Canada, $67 million of wood fiber stumpage was lost in 1977.

These statistics were generated across Canada by about 9000 fires that burned about 1.5 million hectares or 3.5 million acres during 1977.

Before continuing, I want to mention some important work being conducted in the northern territories on measuring, in a systematic fashion, the values at risk. Both the Yukon and Northwest Territories for some years have been setting priority zones for initial attack based on some measures of value at risk.

Having looked at the kinds of value appraisal that have been conducted in Canada in a systematic fashion, I would like to turn to the efforts by agencies in Canada to improve their value appraisal systems. In British Columbia, the fire report form was modified recently to include some measure of the fire impact on recreation, wildlife, and watershed, among other things. The person completing the fire report form is asked to give a subjective response as to whether the fire had positive effects, negative effects, or no effect on these resource values.

Quebec recently completed a study of protection options in the northern expansion area, simulating the cost plus loss of various options of protection. Estimates of dollar losses were based on broad average figures for recreation, wood fiber, wildlife, and watershed values, with an attempt to localize the dollar figures by taking into account regional and geographic differences.

Manitoba has tied its fire report form to its computerized forest inventory. On the report form, coded identifiers for stands that were affected by the fire tell the computer where to retrieve the volume figure for before the fire. This gives better volume estimates of wood fiber losses.

Alberta recently completed a study on air tanker location. Part of the location process involved identification of priority areas, which they based on population, wood fiber, watersheds, recreation, active oil and gas fields, and grazing areas.

Question 3. What are the requirements for resource value information?

This is the most important question one can ask when trying to improve value appraisal information systems, since many problems associated with value appraisal improvement can be avoided by being precise, clear, and realistic in the kind of value information that is requested. One must clearly identify why one is requesting information, how one is going to use that information, and how accurate that information must be. The answers to these questions help narrow down the kinds of value information techniques that will be used.

In talking to people across Canada about their requirements for value information, I often hear requests for value information that will help in public expenditure decision making. We all know that because of inflation and a lack of willingness by taxpayers to pay more for government, it is becoming increasingly competitive to get funds to carry out public activities. Most people who fight forest fires realize that the value of a forested area and the resources on it is more than what is being measured at present. They require better ways of measuring true resource value in terms of dollars. Once a given budget has been defended and is received, administrators also need help in allocating funds among different activities in fire management.

Another request is for resource management prescriptions. On a piece of land there are cooperating and conflicting land use patterns, and in many cases land use decisions are required. The fire operations people frequently make land use decisions in the process of planning, attacking, and suppressing forest fires. They often make these decisions without the benefit of guides or prescriptions regarding the kinds of land use in effect or the acceptability of fire in these areas. Sometimes fire operations people are left holding the bag after having made difficult decisions in suppression of a fire. They may be informed that the fire should have been allowed to burn or that burning-out operations should not have been allowed to take place because of the nature of the values. I see this as a need for land use decisions to be made and fire prescriptions to be given to fire management people.

The third kind of value information that is requested, and this comes right from the grass roots, is some measure of fire management benefits. Historically, after the smoke has dispersed and the fire season is over we tend to measure our effectiveness as a fire control or fire management organization in terms of the value lost. But we all know that the reason for fire management is to save values; I hear people in the grass roots of fire control organizations asking for some measures of the value saved by their efforts.

I see three kinds of requirements for value information, but I want you to notice that associated with each of these requirements is not only the problem of measuring value but an equally large problem in another area. In public expenditure decision making, for example, it is not clear that governments will stop cutting budgets, even if resource values are measured at their truer and higher levels. Similarly, the requirements for value information associated with resource management prescriptions may run into many problems because of a lack of mechanisms by which land use decisions can be made. Finally, in the measurement of fire management benefits, there are the enormous technical problems of measuring what would have burned. One takes the difference between estimates of what the fire would have done had there been no suppression and what actually was burned, and that is the value saved.

I want you to notice two things about requirements for resource value information. First, one must be precise, realistic, and clear in not only what kinds of information are required but why they are required, how they are going to be used, how often they are going to be used, who is going to use them, and how much money is available to collect this kind of information. Secondly, I want you to notice that associated with the requirements for value information are problems of equal magnitude. Finding the perfect value appraisal system may not, in fact, solve the problems at the root of the requests for better value information.

Question 4. What is meant by value?

Webster's defines value as "that quality of a thing according to which it is thought of as being useful, desirable, estimable and important." It also talks about "a fair return" for value or "market price."

Value depends on perspective, and there are three kinds of perspectives for resource values. First, there is the owner of the resource value; for example, the owner of a timber stand values his stand according to the stumpage. There is also the user of the natural resource, who may be different from the owner. The user looks at the stand as an opportunity to generate value added, from which he can take his profits. Thirdly, there are others who are affected by change in forest value.

Look at the values associated with owners of natural resources. Owners value these natural resources according to their market price. This requires that there must be a market for this resource and a readily identifiable price. In Canada, most of the wood fiber resource on productive forest land is under provincial crown jurisdiction. In this situation the public agency finds itself in a position of relative monopoly. There are several small woodlot owners, but the stumpage rate is usually set by the crown. Stumpage is set according to procedure and rules rather than supply and demand on the marketplace. Stumpage may be based on end-product prices, management costs, or politics. Stumpage may be set higher than its true value as a tax on industry or set lower than its true value as an incentive for industry. There are similar problems with crown ownership in recreation, wildlife, and watershed management. Some areas lack markets and identifiable prices. This means that stumpage does not truly reflect the value in exchange of the wood. Although it is not perfect, stumpage is for us a surrogate price.

The second perspective from which one looks at value is that of the potential user of the forest resource. A user looks at a resource in terms of its potential for value added or consumer surplus. Value added is generated by the production of goods or services that are worth more than the sum of the costs for the inputs. From the value added, the user receives his profit. Consumer surplus is the value a consumer receives for the goods and services that is above and beyond the price he pays for those goods and services. The prices some people are willing to pay for recreation, for example, are higher than the actual prices of recreation, and they enjoy a surplus from this.

One of the concepts in identifying the value of resources to the user is that of value substitutes. That is, if there are substitutes for burned timber or recreation areas and these substitutes are available at costs equal to the original, then there is no loss in potential value added for a user. For example, with wood fiber values, if an allowable cut for an area is diminished by a forest fire but the actual cut that is made is not affected, no loss occurs from the perspective of the user. Similarly, if a recreationist finds his favorite campsite has been burned but finds a similar campsite nearby of similar quality at the same price, he has not lost an opportunity for consumer surplus. A further perplexing measurement difficulty is identifying how much consumer surplus a recreationist, for example, actually derives from an outdoor recreation experience.

Finally, the third perspective is that there are other people in society who are affected by a forest fire. For example, in many areas in Canada local and regional economies depend a great deal on the wood fiber industry and the recreation industry. These local economies receive boosts from payrolls and from tourist spending. Still others are affected by fire as a result of externalities or physical effects of the fire that are displaced from the site. An example of this is the silting up of water courses as a result of a fire upstream. Silting up can affect hydroelectric potential, for example.

We have looked at value from three different perspectives: that of the owner who looks at his resource as a marketable commodity, that of the user who looks at the resource as a potential to generate value added or consumer surplus, and that of others in society who benefit from the activities of the owner and the user or who are affected by externalities.

Question 5. How does time affect the appraisal of values?

Time is a very subtle and important aspect of value appraisal. First of all, fire effects occur over time. We must decide how long after a fire we will continue to study and measure the physical and economic effects of fire. For example, salvageable timber degenerates over time. Another example is that fire may render a site unfit for recreation. But how long is that site unfit?

Time also changes prices, and I am not speaking of inflation. What will be the price of newsprint in the year 2000? In the year 2060 what will be the price of newsprint when today's softwood seedlings mature? These are important questions to ask in measuring future values today. Time also affects technological mixes. Will we be using newsprint in the year 2000? Will we be using softwoods to produce our newsprint? Will wood be satisfying our energy needs? These are some questions which are very difficult, if at all possible, to answer.

Finally, the most important aspect of time in value appraisal measurement is that a dollar recieved today is worth more than a dollar received next year. Banks make their profits from this basic fact, because we are willing to pay a dollar plus interest next year for the privilege of borrowing a dollar today. The question is how much more is a dollar worth today than next year, and its answer depends on the choice of the discount rate. For a private firm the discount rate usually refers to the cost of capital or the borrowing rate. For a public agency the problem is very complex. There are two basic approaches. The dollars and cents approach is one that looks at the cost of government borrowing as a surrogate discount rate. This tends to make the rate high. The social approach asks, "How do we value today's lifestyles with the kinds of lifestyles we will be giving to our succeeding generations?" This tends to give discount rates that are lower, but in no case is the choice of discount rate clear.

Discount rates are very important, because in forestry, particularly in wood fiber, the harvest time takes much longer than the normal returns to capital experienced in other sectors of the economy. The effects of the discount rate are felt very sharply when the income is to be received 50, 60, or 70 years in the future. Sensitivity to the discount rate, even in differences of 1 or 2%, makes the choice of the social discount rate very difficult.

SUMMARY

I have looked at the kinds of values I perceive in a forested environment. I have described the general trends in Canadian practice for evaluating fire effects and the kinds of improvements that are being tested. We have looked at some of the requirements for value information and the importance of dealing thoroughly with this question. We have looked at the various meanings of resource values from different perspectives—from the perspective of the owner, the user, and others in society—and we have discussed the various influences of time on value appraisal. In discussing some, but not all, of the concepts and constraints in designing improvements to value appraisal systems, I have tried to give you some idea of the size and complexity of appraisal and the nature of the issues we face.

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EXPERIMENTAL BURNING IN ALASKA BLACK SPRUCE FORESTS

Rod Norum*

An estimation of values at risk for any planning unit would seem to require a double look. Of course, some means of placing value on resources is needed; however, do not overlook the other equally important question. Are the values there really at risk? First of all, will a fire ever occur there? If so, will it burn under conditions such that the desired resource will be damaged? In fact, might the very resource desired be enhanced and improved by the right fire? What things can the manager use to accurately forecast these things? On the other hand, how can he predict damage if it is going to occur?

There is a partnership between managers and researchers in solving this, no matter where it pops up. Managers must agree, by way of planning, what resource values are most important for an area. Researchers must simultaneously determine what fire does to these resources when it burns under various conditions. Here is what we are doing in Alaska to solve a part of this.

Controlled experimental burning of black spruce-feather moss forests in the interior of Alaska began in 1976. Although it was a modest beginning, those early attempts provided guidance for the work that followed.

Four small units, 0.25 acre in size, were burned under rather severe fire conditions. Three of the four fires were burned when both the surface fuels and forest floor fuels were quite dry. In the fourth fire the forest floor was moist, but surface fuels were dry.

The results of the early fires made it obvious that certain key conditions were very important for predicting the results of fire in these forests. They indicated that the intensity of the fire is not nearly as important as the condition of the forest floor, if burning away of the forest floor is a matter of concern, which it is nearly always. The moisture content of the forest floor is all important.

It is generally agreed, among both land managers and researchers, that the single most important response of an ecosystem to fire is that of the vegetation. Some parts of certain plants are killed by fire, while other parts of the same plant remain alive and ready to serve as a source for the establishment of a whole "new" plant at the same location. The levels of moisture content in the surface fuels and forest floor play a significant role. Living, above-ground parts may be burned away or killed, while subsurface parts may be insulated by a moist forest floor and not be harmed by a fire passing above.

Many plants have adapted, over time and in response to repeated fires, to respond positively to fire. Fires of different intensities affect these plants in remarkably unique ways. Some vegetation survives all but the most intense fires, although it may not appear so just after the smoke clears.

Some vegetation moves quickly into the burned area by way of seeds carried by wind. If these seeds fall on a seedbed made receptive by the particular fire treatment, the plant will germinate, become established, and grow well. The reverse is also true. If the fire burns in such a way that the forest floor is not a hospitable site for the same seeds, they will perish. However, the conditions found intolerable by one species are usually ideal for another. Consequently, the intensity of a fire and the severity of burning determine, to a considerable degree, the kind of vegetation that will first occupy a burned forest. What transpires after the establishment of the first postfire plant community depends on a com-

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plex web of occurrences we are just beginning to understand.

The forest floor is recognized by all as the most important part of the whole soil-plant system in any ecosystem. As the forest floor burns away, the composition and vigor of the future plant community changes. It should not be assumed that very mild fires are beneficial to the future plant community or that very hot fires are detrimental. Again, the strategies developed by plants to respond to fire come into play.

Some plants reproduce by sprouting from live parts hidden below the burned surface. Others create new plants only if all of the organic forest floor is burned away, exposing bare mineral soil where their seeds can germinate and root quickly. Many of the underground parts of plants that are the source of new sprouts reside in or just below the organic layer resting on top of the mineral soil. Root crowns of grasses, rhizomes of blueberries, roots of aspen, and willow root crowns are examples. Many other species fall into similar categories.

Patterns of consumption by fire of the forest floor also play a role. The burning away of the forest floor and the depth of penetration of temperatures high enough to kill plants work together to decide whether the existing plants will resprout or if new plants will come in by way of transported seeds.

If we are to accurately forecast the future plant community on a burned site, it should be obvious that we must have a sound means of predicting what the forest floor will be like following a fire. How much will be burned away? How much will be left? Using this information and what is known about plants, a reasonable prediction of the future plant community can be made.

A timely return of plants to a burned site can provide increased food for animals, stabilize the flow of water on and from the area, take up and hold nutrients in place, and make the location more pleasing to the eye. The kind of vegetation desired depends on the designated use of the area. Management plans will designate the goals and desires. Technological guidelines and instructions must provide the means to make intelligent decisions leading to the satisfaction of management goals. Such guidelines are gained only from experimental studies.

Taking guidance from the 1976 experimental fires and from work done in other places, we designed a study to determine what, if any, prefire variables can be used to predict postfire results in Alaska black spruce forests. Seven study units, ranging in size from 4.5 to 7 acres, were prepared for careful measurement and burning in 1977. All seven were burned in 1978 over a considerable range of fire conditions, giving a useful array of treatments.

Before being burned, the study units were inventoried for the presence, abundance, and distribution of a number of important items in the forest. Fuels, vegetation, topography, and soils were carefully documented. A square sampling grid of 100 points on 10 x 10 m spacings was established in the center of each unit. All sampling was referenced to it. Trees, shrubs, forbs, mosses, and lichens were located and quantified. The shrubs were given particular attention because of their known tendency to be the first vegetation to reappear following fire. Also, shrubs take up a rather large amount of nutrients for their size.

The recognized importance of the forest floor led to extensive measurements of the depth of the organic material on top of the mineral soil. Its weight was estimated from core samples taken throughout the area. Several hundred depth measurements were made on each study unit.

Although meager compared to many other forest situations, the down, dead, woody fuels were measured by way of accepted planar intersect sampling. Surface cover categories were established, and each unit was mapped along various transects and on surface area quadrats. Soil samples were collected for determining the elemental and plant nutritional content.

As the time for burning the units appeared to be approaching, the potential fuels were sampled daily in order to determine their water content. When those fuels that were expected to carry the fire were determined to be adequately dry, a small test fire was conducted: The fire behavior confirmed the measurements, and the control forces were mobilized. Spot weather forecasts were ordered.

Immediately before each unit was burned, temperature sensitive instruments were inserted into the forest floor in order to measure the depth of heat penetration. Also, large bridge spikes were driven into the forest floor so that their heads were level with the upper surface of the organic layer. These remained in place during the fires and were relocated later. The exposed portion of the spike gave a measure of the amount of organic forest floor that burned away. The depth of the remaining material was also measured. One hundred points in each unit were instrumented in this way.

Within an hour of ignition time, 10 sets of fuel moisture samples were taken on the fire site. Then each of 0-0.25 in diameter dead sticks, 0.25-1 in diameter dead sticks, the lower and upper duff, the lower and upper moss, and tree needle samples were collected. They were sealed and taken to the laboratory for gravimetric moisture content determination.

The fires were ignited in a series of progressively wider strip headfires, always starting each strip near the center line of the unit. All seven units were burned in July and August of 1978. By being burned during a slow weather change, from wet to dry, over a several-day period, different units received different fire intensities.

The first unit burned in a fairly mild fashion. Subsequent fires were more and more intense as the weather held and fuels became drier. Soon the weather changed, and rain fell; the last unit burned received the lightest fire treatment of all.

Data analysis has only begun. Our goal is to discover which things that can be measured before a fire covers an area can be used to predict a number of important things. We need to be able to estimate the impact of the fire on the forest floor. Given this and the corresponding plant responses, we can begin to predict the fate of the area, in particular, the survival or return of vegetation to the site. The expected pattern of revegetation can then lead to intelligent estimates about the watershed effects, the response of animals, and the future security of soil nutrients.

The density of local streams can be intelligently hypothesized if the soil surface condition can be predicted, the probable climatic conditions are known, and the response of the particular soil to various disturbances is known.

Sometimes fires will be beneficial and helpful to the most desired resource. At other times or at other places they will be damaging. Combining realistic management goals with the research answers about where a fire will go and what it will do gives a rational means of managing fire. It becomes management by sound choice rather than by accident or blind adherence to regulations that may not suit the particular situation.

PRIORITY ZONING AND RESOURCE VALUATION NORTH OF 60°

J.P.G. de Lestard*

ABSTRACT

In the natural lightning-fire environment of the sparsely populated Yukon and Northwest Territories, fire management policy has been expedited within a formal priority zone system since 1967. Three protected zones are based on specific criteria organized according to relative resource values. In both territories a fourth zone is unprotected and occupies approximately 70% of the area inside the northern limit of tree growth. The flexibility incorporated into the priority zone system enables fire managers to maintain fire presuppression and suppression expenditures reasonably close to allocated budgets.

Consideration is being given to developing a quantitative sliding scale of resource values for use within individual priority zones and among zones rather than continuing to apply fixed values uniformly, as in past years. Such a scheme might improve northern resource value perspectives relative to the hands-off fire suppression policy advocated recently by some Canadian university researchers, which seemingly contradicts claims by native hunters and trappers that the current level and extent of protection in relatively remote areas should be increased, not decreased. To resolve the conflicting viewpoints, research is required to ascertain the effects of wildfires on selected wildlife populations and, in particular, on hunting and trapping resource values.

INTRODUCTION

The Department of Indian Affairs and Northern Development is responsible for managing, among other programs, the nonrenewable and renewable resources within the Yukon Territory (536 325 km^2) and the Northwest Territories (3 379 686 km^2). The northern territories together comprise almost 40% of the total land and water area of Canada and contain approximately 66 000 inhabitants.

Although the Northwest Territories consists of the Districts of Franklin, Mackenzie, and Keewatin, fire management is practiced only in the District of Mackenzie and, more specifically, only inside the tree line (Figure 1). Approximately 327 man- and lightning-caused wildfires occur annually within the tree line or southwesterly two-thirds of the 1 366 194-km^2 District of Mackenzie. An average of 58% or 190 of the wildfires are fought selectively according to a priority zone system.

The Yukon Territory, located adjacent to the western boundary of the District of Mackenzie, contains an area inside the tree line of approximately 498 832 km^2 (Figure 1). Application of the same priority zone system used in the Northwest Territories results in an average of 72% or approximately 91 of 126 annual wildfires being fought selectively within the context of current fire management policy.

A natural lightning-fire environment (1, 4, 5, and 7) exists north of 60° wherein ecosystems are modified by periodic wildfires. Lightning causes approximately 45% and 63% of all fires which occur annually in the Yukon and Northwest Territories, respectively. Lightning fires are generally the cause of more than 90% of the average annual burned areas of 74 000 ha and 469 000 ha in the respective territories.

Wildfires fought north of 60° account generally for less than 28% of the average total burned area of 543 000 ha. A priority zone system is feasible particularly where the effects of wildfires on vast areas containing

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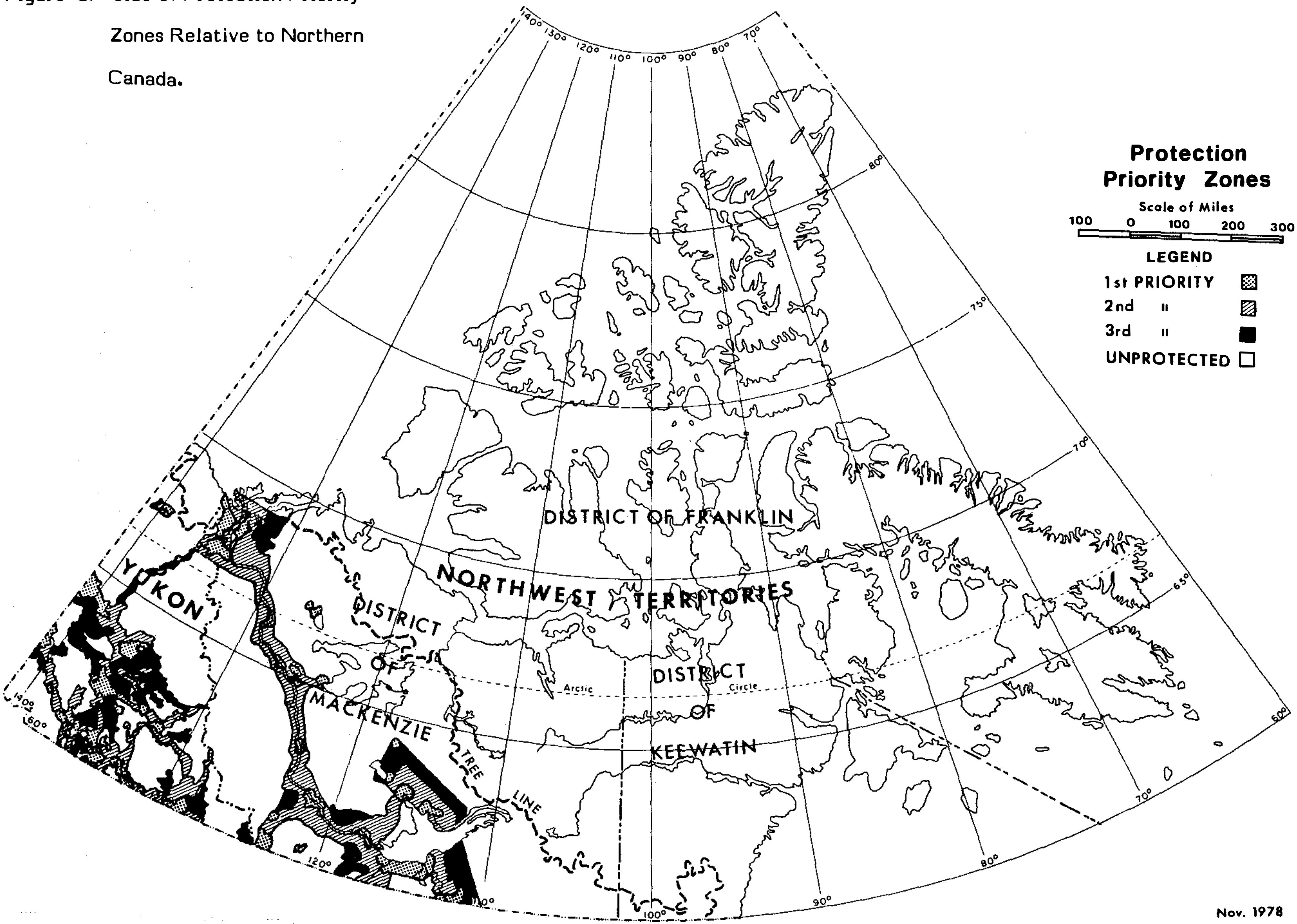
Figure 1. Size of Protection Priority Zones Relative to Northern Canada.



what are considered to be relatively low resource values do not warrant the implementation of uniformly intensive protection on a total land area basis.

NORTHERN POLICY DEVELOPMENT

Among the numerous attributes of northern Canada are its remoteness, sparseness of population, limited transportation and communications infrastructure, and widespread permafrost, the total environmental significance of which is yet to be realized. Accordingly, fire management policy prior to the 1950's dealt mainly with controlling lightning-caused fires to curtail direct threats to isolated communities. Unfortunately, the limited fire suppression capabilities north of 60° were far from adequate to overcome all threats to life and property.

In 1958 Whitehorse was threatened by a major conflagration. This wildfire activated a sudden impetus for improvements that resulted in a significant increase in fire control capabilities for the Yukon Lands and Forest Service.

By 1967 increasing populations—largely due to oil, gas, and mineral activities—were placing further demands on available fire suppression resources. Resource values had been assessed subjectively in the southern Yukon and in the Mackenzie District. Preliminary planning had confirmed that a priority zone system was the most economical and feasible approach for protecting a variety of widespread renewable resources. Accordingly, an early configuration of priority zones was delineated formally, and manpower and equipment resources were aligned to cope with anticipated fire problems.

Since 1967 periodic assessments of fire management capabilities have been made commensurate with updated resource protection requirements and the availability of man years and funds approved by the treasury board. Prompted by a disasterous fire season in 1971 that involved losses of aircraft and lives, a substantial strengthening of the Northwest Lands and Forest Service occurred in 1973. A re-evaluation of protection requirements in the Yukon Territory resulted in additional fire management capabilities being provided in 1974.

The combined 1978-79 presuppression and suppression budgets assigned to the fire management programs in the Yukon and Northwest Territories were $2.6 million and $3.9 million, respectively. Included in these budgets were salaries for 42 man years in the Yukon and 57.5 man years in the Northwest Territories. Also included were wages for extra fire fighters. Allowances are added periodically to offset monetary inflation.

The aim of fire management north of 60° is to reduce wildfire damages to a level consistent with the present and future needs of the people to ensure the continuation of their enjoyment and use of the renewable resources. Through the efficient management of periodically updated priority zones, this policy provides sufficient flexibility to meet the needs of territorial residents.

PRIORITY ZONE PRINCIPLES AND RESOURCE CRITERIA

Priority zone planning is based on the concept of having an overall protected area (zones 1, 2, and 3) and a virtually unprotected area (zone 4). Prior to 1975 the total protected area north of 60° was 486 918 km^2. However, the results of recent fire studies, primarily by Canadian university researchers (1, 2, 3, 4, and 5), has led to a gradual reduction of 119 140 km^2 of formerly protected woodland and tundra in the caribou range within the District of Mackenzie. Consequently, the current protected areas designated as priority zones 1, 2, and 3 cover 145 039 km^2 and 222 739 km^2 in the Yukon and Northwest Territories, respectively (Figure 2).

Protected Zones:

Priority zone 1

Intensive protection is provided within zone 1 to safeguard life and property in and adjacent to main communities. Occasionally only observation or limited action is

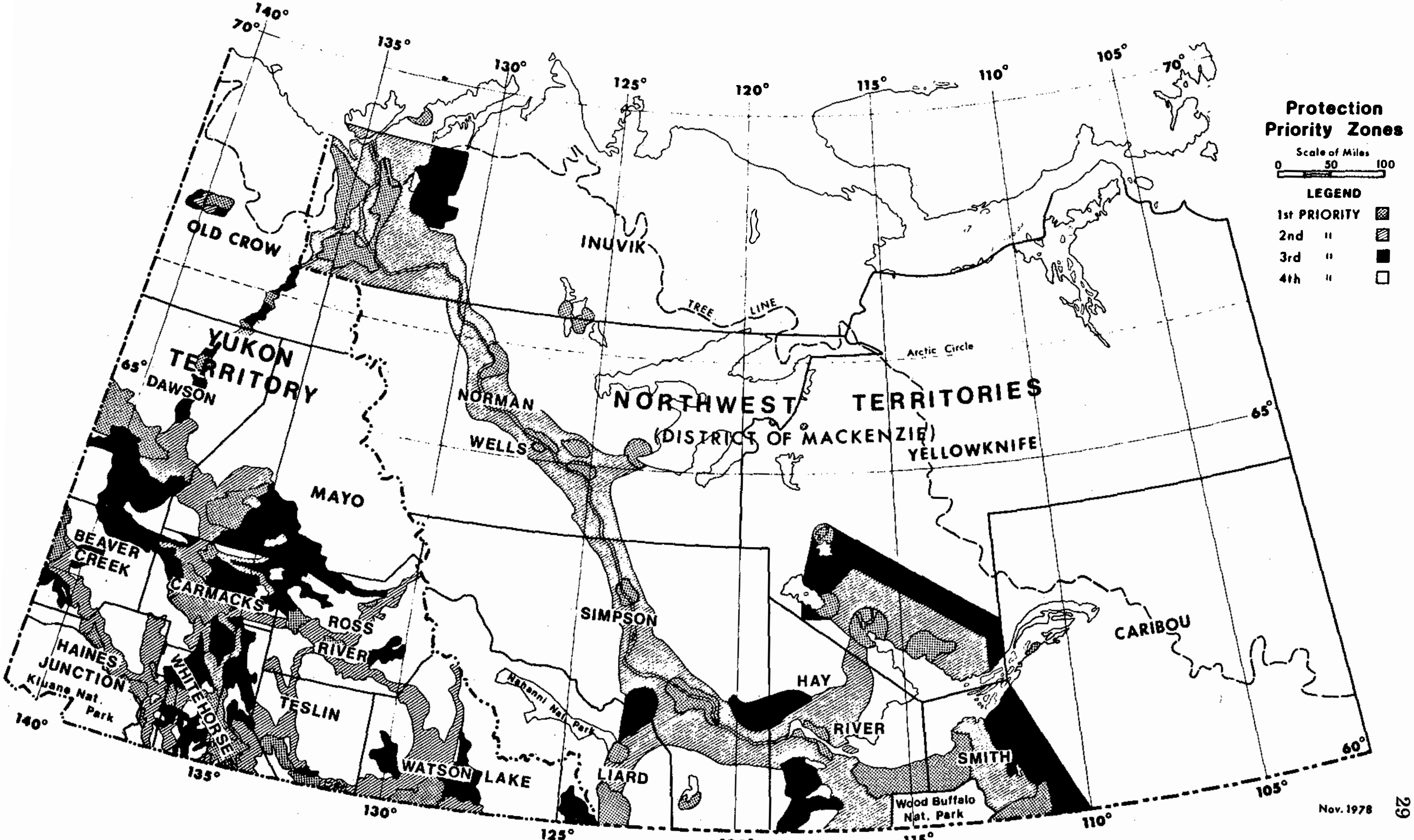


Figure 2. Detailed Protection Priority Zones North of 60°.

required for fires occurring on islands or in other relatively firesafe areas, depending on their locations and the time of year.

During periods of high and extreme burning conditions and/or simultaneous multiple fires, provision exists for withdrawal of manpower and equipment resources from lower-rated priority zones. The resources would be used to protect lives and properties in zone 1.

Zone 1 areas are either irregular or circular in shape and vary in size according to the number of local inhabitants. Total land and water areas of approximately 814 km^2 and 3255 km^2 exist around population centers with 25 to 500 inhabitants and over 500 inhabitants, respectively.

Priority zone 2

Intensive protection is applied within zone 2 to safeguard relatively high-value resources. However, depending on the location of a fire, relative resource values, and other factors, the options of partial control or no control may be exercised whenever the estimated total cost of fire suppression could detract from better alternative uses of limited presuppression and suppression funds.

Should severe burning conditions and/or simultaneous multiple fires occur in zone 2, provision exists for concentrating fire-fighting efforts on the protection of lives and properties in priority zone 1. Operations would resume in zone 2 as the situation returned to normal.

The resource criteria used to designate priority zone 2 areas include

1. an average strip width of 16 km along each side of main road systems and commercial water routes
2. an average strip width of 3 km along each side of electric-power transmission and communication lines
3. an irregular or circular area containing approximately 13 km^2 around producing mines, lodges, and settlements of fewer than 25 people, and
4. stands of merchantable timber located within 32 km of roads and navigable water routes and young forest stands on highly productive sites (normal forest inventory programs are under way north of 60°).

Kluane, Nahanni, Wood Buffalo, and future national parks are rated priority zone 2 because of their national significance and special biophysical features (Figure 2). However, the land and water areas within these parks are not included in the regular zone 2 protected area. Requests for fire suppression action originate with Parks Canada and are provided on a cost-recoverable basis.

Priority zone 3

Wildfires are fought in zone 3 particularly when zone 1 or 2 is threatened. Prior to committing in excess of predetermined expenditures on other fires in zone 3, the availability of presuppression and suppression funds is evaluated in conjunction with existing fire load, spatial distribution of fires, manpower and equipment availability, anticipated costs, operational feasibility, and values at risk.

Fire operations are scrutinized continually, especially during periods of high and extreme burning conditions and/or simultaneous multiple fires. At any time, plans may be executed to reduce fire-fighting efforts until burning conditions become less severe. Operational responses to fire management decisions must be rapid to avoid, whenever possible, annual budget over-expenditures.

Priority zone 3 resource criteria include

1. selected portions of high-value habitats or sanctuaries for wildlife, game, and furbearers
2. critical habitats for the survival of endangered wildlife species

3. important trapping areas used as a sole means of livelihood

4. areas used currently for recreational pursuits and areas exhibiting recreation potential

5. areas prone to significant slumping or erosion damage

6. high-quality sites with merchantable or potentially merchantable timber not included in zone 1 or 2, and

7. valuable watersheds or portions thereof which contribute or can be expected to contribute significantly to the flow rate, quantity, and quality of domestic water supplies.

Unprotected Zone:

Priority zone 4

Exclusive of the three protected zones and the two national parks (Figure 2), the remaining area in the Yukon Territory and District of Mackenzie is essentially woodland and tundra. Due to recent reductions in the total size of the protected area, primarily in the caribou range of the District of Mackenzie, approximately 70% of the area inside the tree line north of 60° is currently classified as zone 4. The majority of zone 4 is considered to be inaccessible to ground transportation and subject to a low annual incidence of man-caused fires.

In addition to attempting to protect significant values at risk such as isolated tourist establishments, it is considered feasible to suppress only those fires or portions thereof which directly threaten relatively high-value resources in priority zones 1, 2, and 3.

RESOURCE VALUATION ACTIVITIES

Since 1970, accelerated regional development and rapidly rising fire management expenditures have spurred a desire to obtain relatively realistic values of renewable resources damaged by fire (Figure 3). Arbitrary fixed values have been revised periodically and recorded on individual fire report forms for years. However, consideration is being given to the development of a quantitative sliding scale of values whereby the values can be applied within and among priority zones. Values recorded to date continue to be applied uniformly throughout each zone and to all zones, which precludes consideration of such significant factors as accessibility and exploitability of resources.

In 1977 a data collection mechanism was introduced to the fire damages section of the recently computerized wildfire report form used north of 60°. A subsection was added whereby up to three types of resource damage or fire effects can be rated in order of their local significance (Figure 3). By recording local knowledge of the resource damage in each burned area, it is expected that trends will emerge which can be used to update resource delineations and values within priority zones.

Conflicts and Associated Research Need

Perhaps the most noticeable shortcoming inherent in the priority zone system north of 60° is the presence of smoke from partially fought and unfought fires. To remain as close as possible to annual fire management budgets necessitates the toleration of temporary inconveniences caused by smoke. Conversely, to obviate occasional smoke problems would necessitate the suppression of wildfires primarily in inaccessible, low-value zone 4 areas. Aircraft costs accelerate dramatically under such circumstances.

Since 1975, a back-to-the-land movement has been under way in the District of Mackenzie. Financial assistance is provided by the Government of the Northwest Territories to individual native families and multi-family groups who wish to relocate and sustain themselves on the natural resources available through fishing, hunting, and trapping.

Formal requests have been received from the native hunter and trapper associations in the District of Mackenzie to provide more intensive and additional protection for

FIRE DAMAGES

1. Forest Classification:

			Area (ha)	m^3/ha (Sol. Wd)	Total m^3	Total $ Value
Saw Timber - Swd	________	9 [10] 11				
- Hwd	________	22				
- Mwd	________	33				
Pulpwood - Swd	________	44				
- Hwd	________	55				
- Mwd	________	66				
Immature-Productive	________	9 [11] 11				
Cutover	________	19				
Unproductive	________	27				
Totals:			________		________	________

2. Property Losses (Specify)________________________________ 35

* 3. Rate the three most significant types of damage caused by this fire:

If Other, Specify________________________

____

1. ________________________ 44
2. ________________________ 45
3. ________________________ 46

* Types of resource damage include:
Property (building, vehicles etc.), recreation (aesthetics), timber, hunting, trapping, erosion potential (other than watershed), watershed (immediate or potential impairment of water quality and/or development of a serious runoff problem) and range.

Figure 3. Fire Damages Section of the 1978 Wildfire Report Form.

relatively remote areas. Ministerial replies have indicated that, without additional funds, protection cannot be increased significantly. It has been estimated conservatively that present fire management budgets would have to be increased by a minimum of $2 million annually to increase the present level of protection in zone 3 and extend protection into initially identified areas of zone 4.

To consider realistically the conflict in resource valuation which arises from being requested to protect hunting and trapping areas in a large portion of what is currently priority zone 4 will require qualifying and furthering the claims of biological, ecological, and geographical researchers (1, 2, 3, 4, 5, and 7). The researchers endorse the concept that periodic natural wildfire appears to be an essential resource or rejuvenating factor which diversifies vegetation and maintains variety within ecosystems.

Some researchers have recommended emphatically—and their point of view has gained partial acceptance—that only communities, engineering works, and resources soon to be used should be protected from wildfire (5). Other researchers (2, 3, 6, and 7) acknowledge a few beneficial attributes of wildfires but, nevertheless, question the wisdom of permitting large wildfires to burn uninhibited. They claim that significant long-term soil and microclimatic changes occur, including strong evaporative effects on unburned areas and water sources located downwind. Additional concerns are that following wildfires shrubs are slow to recover, tree seedlings require several years to become established, burned forests require many years to regain stability, and extensive site damage can occur due to the melting of permafrost after insulational vegetation has been destroyed.

The beneficial and adverse effects of wildfires on wildlife populations in specific areas remain to be documented. To be able to examine in detail the resource value implications of protecting various hunting and trapping areas necessitates obtaining suitable answers to at least two basic questions. First, what quantity, if any, of each significant wildlife species (game, furbearers, and waterfowl) is affected adversely within designated hunting and trapping areas, and to what extent and for what period of time is each species population affected? Secondly, what is the ecological significance of wildfire intensity and fire periodicity in various fuel types and in particular on the types, quantities, and qualities of vegetation suitable as food and shelter? This information, when used in conjunction with operational feasibility studies, should enable assessments to be made which reflect the major aspirations of northern native peoples.

FUTURE TREND

The future role of fire management north of 60° will involve increased sophistication at all decision-making levels in response to refinements in priority zone criteria prompted by cost-benefit considerations. Regardless of the degree of sophistication achieved, the priority zone concept is expected to remain compatible with northern fire management policy whereby wildfire damages are reduced to a level consistent with the present and future needs of the people to ensure the continuation of their enjoyment and use of the renewable resources.

SUMMARY

Within the widespread natural lightning-fire environment of the Yukon and Northwest Territories, the increasingly sophisticated system of priority zones is expected to maintain sufficient flexibility to provide adequate protection to the relatively sparse populations and extensive renewable resources.

Northern fire management practices are based on periodically updated assessments of renewable resource values and balanced with fire suppression capabilities and annual financial and man-year allotments. There is only limited flexibility for wildfires to burn freely in priority zones 1 and 2 because of their proximity to population centres and significant natural resources. Wildfires in zones 3 and 4 are managed primarily to minimize impending danger to zones 1 and 2, not withstanding temporary inconveniences arising from smoke.

The present priority zone system enables fire managers to maintain annual expenditures reasonably close to the total annual fire presuppression and suppression budgets assigned to each territory. The system is successful largely due to the continual scrutiny of fire-fighting operations within individual zones and immediate responses to fire management decisions.

Current resource valuations are subjective and applied uniformly throughout each priority zone and to all zones. Consideration is being given to the development of an acceptable valuation method whereby resources can be rated in a diminishing order of value within each zone and from zone to zone. Since 1977, regional fire managers have been recording, in order of their significance, the resource damages resulting from each wildfire. The information is recorded annually on computerized wildfire report forms as a step toward validating resource delineations and value assessments.

To justify any signifcant extensions in the current level of fire management activities in priority zones 3 and 4 will necessitate qualifying and furthering the opinions of several university researchers who have stated that, because wildfire is a natural rejuvenating force, only communities, engineering works, and resources soon to be utilized should be protected (5). This view has gained partial acceptance despite the pleas by hunters and trappers and a lack of technical knowledge to substantiate the effects of wildfires on the dynamics of animal populations and their food and shelter requirements. Ultimately, at least one major research study will be required to permit a realistic assessment of native claims for more intensive and additional protection of hunting and trapping areas within the current priority zone system.

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AIR TANKERS IN ALBERTA

C.S. McDonald*

INTRODUCTION

During autumn and winter of 1975/76, the Forest Protection Branch of the Alberta Forest Service reviewed its entire fixed-wing air tanker program. The results of this review were printed in a publication entitled *Air Tankers in Alberta,* which I am going to summarize by detailing the study objectives, briefly describing how these objectives were accomplished, and detailing some of the more important conclusions/recommendations.

The study had several specific objectives:

1. Highlight the importance of early detection and rapid initial attack.

2. Depict the resource values under protection.

3. Recommend fire suppression priority areas.

4. Define the initial attack problem in terms of fire occurrence and fire spread after ignition, under varying weather conditions, and in different fuels.

5. Establish initial attack criteria for the air tanker program in terms of maximum allowable time from report to attack and maximum allowable fire size at attack.

6. Outline the desirable characteristics for land-based and skimmer aircraft and compare selected air tankers operating in Canada to these optimum criteria.

7. Measure the operating effectiveness of selected air tankers operating in Canada.

8. Compare operating costs of selected air tankers in Canada.

9. Delineate acceptable operating zones for land-based and skimmer aircraft.

10. Provide recommendations for the air tanker program in Alberta as to

    a. objectives
    b. types and number of air tankers
    c. purchase or contracting of aircraft
    d. additional base coverage
    e. cost comparison—existing air tanker fleet versus the Canadair CL-215 option, and
    f. possible alternatives to fixed-wing air tankers.

THE FIRE PROBLEM

The importance of early detection and rapid initial attack was highlighted by briefly describing the fire problems, suppression costs, acreage/value losses, and average fire suppression costs by size class over the 14-year period 1961-74.

It is interesting to note that over this period the average annual suppression cost was $3.6 million, and the average annual value loss was $3.7 million (timber damage appraisal only). Maximums in these two areas were experienced in 1968: $8.5 million and $21 million, respectively.

Statistics for 1961-74 show that average number of fires per year and average cost per fire (1975 dollars calculated on the Consumer Price Index) varied from 305 at $463 000 for Class A to 17 at $106 000 for the Class E campaign fires.

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FIRE SUPPRESSION CONSIDERATIONS

Resource Values

To portray the land uses and values, composite maps were compiled. The maps depict the location and extent of human population centers and other resource values such as watershed, recreation, oil and gas, timber, and grazing. All land uses and values were considered on an equal basis, and no attempt was made to segregate them in monetary terms.

Priorities

A logical progression from consideration of resource values is assignment of fire suppression priorities based on the location and extent of these values. A fire suppression priorities map was formulated on the basis of threat to human life, real property, and such multiple resource values as watershed, recreation, oil and gas, timber, and grazing. In addition to an ongoing operational use, priorities mapping was used to highlight deficient coverage areas in the air tanker base network.

EVALUATION OF AIR TANKER PERFORMANCE FOR INITIAL ATTACK

Operating over certain distances and within a prescribed time frame, individual air tankers have different capabilities to deliver retardant to a fire. The evaluation technique employed in the study measured that capability against a spreading fire (containment of the head perimeter) burning in certain fuels and under certain weather conditions.

In order to carry out this evaluation technique, certain information was obtained, and assessment criteria were established.

1. Under what burning conditions were most of the fires occurring?
2. What rates of spread (in certain fuel types) could be expected per unit of time under these burning conditions?
3. Determine initial attack maximum time lapse from notification to initial attack and the size of the fire at attack.
4. Establish performance criteria for selected air tankers.
5. Calculate net effective line construction rates for selected air tankers in certain fuel types.

Fire Occurrence and Spread

Examination of Alberta's fire statistics over the 5-year period 1965-69 revealed that a high Initial Spread Index (ISI) or above occurred on 39% of the days during the fire season (April 1 to October 31). On those days when the ISI was high or above, 66% of the fires occurred.

Also, the number of fires expected per day increased significantly from 1 per day to 10 per day as the ISI increased from low to extreme. Therefore, high and very high ISI values were chosen as inputs to drive Van Wagner's (1968) Fire Growth Model to calculate the fire spread rates and head perimeter increases.

As part of the evaluation process it was necessary to select two common fuel types found in Alberta and determine their spread rates and head perimeter increases per unit of time. White and black spruce fuel types were chosen. The spread rates and perimeter increases were determined using the Fire Growth Model over the full range of ISI classes and for three time increments: 0.5 h, 1 h, and 1.5 h.

Initial Attack Criteria

The maximum time from report to containment of the head perimeter spread was set at 1 h. Fire spread rates in black spruce under high and very high ISI are such that 1 h was the maximum permissible. Over that the fire size and head perimeter are beyond the one-strike capabilities of a

1. Douglas B-26 group (3 air tankers)
2. Douglas DC-6B group (1 air tanker)
3. PBY-5A Canso group (2 air tankers), and
4. Canadair CL-215 group (2 air tankers)

The maximum fire size at initial attack was established at 3 acres. The same reasoning used for the time maximum was applied to the maximum size allowable.

Operational Performance Criteria

In attempting to establish accurate specifications and performance data for the selected air tankers—Douglas DC-6B, Douglas B-26, PBY-5A Canso, Grumman S2F Tracker, and the Canadair CL-215—it was found that much of the published information was inaccurate or conflicting. Consequently, to obtain most of the required information it was necessary to go directly to individual operators who had these aircraft in their fleet complements. The specifications and performance detailed in the report represents the results of the information compiled from these sources.

Net Effective Line Construction Rates

Utilizing the total load capacity of each aircraft and string-dropping the load door by door, the total length of the pattern on the ground was considered for long-term retardant, short-term retardant, and water. To arrive at the net effective line constructed by each air tanker, the total pattern length for each type of retardant or water was reduced to compensate for such factors as door overlap—20%, ground overlap—15%, and penetration loss factor—5% to 25%, depending upon fuel type and retardant used. The short-term retardant and water line was further reduced by a factor of 1.75 to compensate for less retarding effect on the fire.

On-fire Effectiveness

The basic procedure used to measure the effectiveness of each selected air tanker was to determine the maximum distance it could travel within 1 h to a fire and still deliver sufficient net effective line in lineal feet to equal the fire's head perimeter spread. When the head perimeter is encircled, the fire is considered contained, and it is assumed that the net effective line (long-term retardant at the 0.04 level or short-term retardant at the 0.07 level) will prevent any further progress.

The maximum radius of action calculations considered land-based and skimmer aircraft; two different fuel types, white and black spruce; and two burning conditions, high and very high ISI. The aircraft's loaded airspeed; time penalties for warm-up, loading, taxi, and takeoff; maneuvering/dropping; and an airspeed deduction to compensate for climb-out and descent were all taken into account.

Land-based Aircraft Utilizing Long-term Retardant

The effective comparisons for the selected tankers—Douglas DC-6B, Douglas B-26, Canadair CL-215, and the Grumman S2F Tracker—showed these results:

1. The Douglas DC-6B and B-26 air tankers are significantly superior performers to the Grumman S2F Tracker and the Canadair CL-215. Greater airspeed and larger loads (Douglas DC-6B) are the determining factors.

2. Three Douglas B-26's are roughly equivalent to one Douglas DC-6B.

3. Multiple air tankers within a group are very necessary (except the Douglas DC-6B) if the spread rates in white spruce (very high ISI) and black spruce (high and very high ISI) are to be coped with over longer initial attack distances within the 1-h initial attack time maximum.

Skimmer Aircraft Utilizing Long- and Short-term Retardants

The skimmer's capabilities were expressed in the maximum distance it could be from its water pickup source after travelling 60 mi to a fire with a load of long-term retardant. The first load is long-term retardant, and required loads thereafter are short-term retardant utilizing the nearest water pickup source.

The effective comparisons for the skimmer air tankers (PBY-5A Canso and Canadair CL-215) showed the following:

1. The Canadair CL-215 is significantly superior to the PBY-5A Canso in performance. Again, higher airspeed and a larger load are the contributing factors.

2. Multiple air tankers within a group are very necessary if the spread rates in black spruce (high and very high ISI) are to be equalled over the 60-mi average expected travel distance and within the 1-h initial attack time maximum.

3. Fires escaping initial attack within the 1-h time frame (1 Canso, black spruce, high ISI; 2 Canso's, black spruce, very high ISI; and 2 CL-215's, black spruce, very high ISI) are contained within the next 0.5 h. This fact demonstrates the value of skimmer over land-based aircraft. The skimmers are able to pick up off the nearest water source (usually a short distance), while the land-based aircraft are forced to return to their land base over longer distances. However, it should be pointed out that while the skimmers are spending the extra 0.5 h containing the fire in question, they are unavailable for reassignment.

Cost Comparison

Owned and operated costs where possible, were obtained directly from commercial air tanker operators in Canada. Exceptions were the Canadair CL-215 and the Grumman S2F Tracker. These aircraft were being operated at the time by government agencies, and information was either not available or insufficient. Contract costs were compiled from 1976 agreements or negotiations. Exceptions were again the CL-215 and the Tracker, as neither was owned/operated at that time by commercial companies.

Table 1 was compiled for comparison purposes only and is for a period of 10 years for one aircraft of each type. The total costs for each aircraft type were detailed at 1976 costs and "owned/operated" is contrasted with "contracted". Annual utilizations quoted are the last 5-year averages in Alberta for land-based (67 h per aircraft per season) and skimmer (135 h per aircraft per season) aircraft.

Table 1. Cost comparisons of selected air tankers.

Air tanker	Type	Owned vs. contract	Annual utilization	Ten-year total (1976 costs for comparison only)
Douglas DC-6B	Land	Owned	67 h	$ 3,012,310.00
Douglas DC-6B	Land	Contract	67 h	1,615,980.00
Douglas B-26	Land	Owned	67 h	1,233,420.00
Douglas B-26	Land	Owned	67 h	1,082,850.00
Douglas B-26	Land	Contract	67 h	842,885.00
PBY-5A Canso	Land & Skimmer	Owned	135 h	954,600.00
PBY-5A Canso	Land & Skimmer	Contract	135 h	1,102,500.00
Canadair CL-215	Land & Skimmer	Owned	135 h	11,174,329.20

Land-based and Skimmer Zones

A significant portion of the area under protection in Alberta contains lakes of sufficient length and depth to support skimmer operations. Development of skimmer operations to their fullest, within the overall context of an air tanker fleet, is quite important for several reasons: skimmer aircraft do not require costly bases or long runways, they utilize a cheaper retardant, and they have the capability to deliver a greater quantity per unit of time than land-based aircraft.

In considering the land-based and skimmer aspects of the air tanker fleet as a whole, it became obvious that those parts of the forest protection area where it was more advantageous to use skimmers would have to be precisely defined. Defining land-based and skimmer operational zones has several advantages: it defines operating areas, gives an indication of desired land-based/skimmer aircraft mix, highlights areas not adequately covered, and is a useful tool for preattack planning and to dispatchers during a developing fire situation.

In delineation of operational zones for land-based and skimmer aircraft, two important factors must be determined: average expected travel distance to the fire and the maximum effective radius of action for each air tanker type (distance from base for land types and distance from a suitable water pickup source for skimmers).

The average expected travel distance for skimmers was determined to be 60 mi (1972-75 BDO Drop Reports), and the maximum effective radius of action from the nearest suitable water pickup source was established at 10 mi. Average expected travel distance to a fire for land-based aircraft and the maximum effective radius of action (MERA) were found to be very similar, 69 mi and 67 mi, respectively. The MERA was set at 70 mi.

The skimmer zone was established using the effective radius of action from the nearest suitable water source of 10 mi. The land-based zone is all of the remaining forest protection area after the skimmer zone has been outlined.

PROPOSED AIR TANKER PROGRAM FOR ALBERTA

Some of the more significant recommendations were as follows:

Objectives

1. Provide sufficient air tankers of suitable type to contain all inaccessible (by road and vehicle) and/or all high spread potential fires within the 1-h initial attack maximum and at 3 acres or less in size. The emphasis in this objective is on containment, not extinguishment. The role of air tankers should be to contain the spread of fire until effective follow-up support arrives to provide final control, mop-up, and extinguishment.

2. Provide a network of airports/airstrips and bases in the land-based zone which when combined with the operational areas within the skimmer zone will give overall coverage of the forest protection area.

Air Tankers

1. At least three more land-based air tankers/helicopters are a necessity to cope with multiple fire situations in any great numbers over several forests.

2. Specifying total air tanker requirements by number is difficult at this time due to a lack of basic data. Research is presently being carried out to provide the necessary information in the two major areas of need.

   a. At least 10 years of fire statistics are being related to fire weather information, i.e., fire danger classifications. Completion of this project, currently being worked on by the Canadian Forestry Service, will give an accurate idea of fire loading (number of fires, expected spread rates, etc.) by fire danger/fire spread class. This information, along with fire occurrence/location plots is very vital to any calculations regarding total suppression resource requirements, whatever the tactic employed.

b. A co-operative research project being carried out by the Alberta Forest Service/Canadian Forestry Service will provide necessary and more accurate data on fire retardant effectiveness on going wildfires, the other area of information that is important in determining total air tanker requirements.

3. Maintain a ratio of land-based versus skimmer aircraft of roughly 0.66 to 0.33.

4. In the immediate future, retain the Douglas B-26 for land-based operations and the PBY-5A Canso for skimmer duties.

5. The Forest Service in Alberta should not become involved in ownership and operation of air tankers.

Air Tanker Bases

1. In addition to the bases currently under construction at Pincher Creek and Whitecourt, construct three additional bases at Westview, Loon River, and Manning-Rainbow.

Costs

1. Cost/benefit is defined strictly in terms of least cost for the most effective fixed-wing air tanker (land-based or skimmer).

   a. The Douglas B-26 is the most suitable fixed-wing air tanker for operation in the land-based zone.

   b. Of the skimmer aircraft available, the Canadair CL-215 is the most effective air tanker; however, this advantage over the Canso PBY-5A is offset completely by the tremendous difference in total hourly costs: $8277/h versus $707/h, an 11-fold difference. Clearly, the Canso PBY-5A is the most effective skimmer for the least cost.

Alternatives

1. Study the possibilities of using medium and large helicopters in the helitanker role. This recommendation was followed up in 1977 by a detailed study. In 1978 a helitack operation was implemented in the Westview area.

THE DETECTION OF HOLDOVER FIRES IN ALBERTA

J. Niederleitner*

Holdover or sleeper fires are a major problem in Alberta. Basically we are dealing with three categories of sleepers:

1. Holdover fires caused by industrial or agricultural debris disposal projects on forest land comprise the first category.

   There are some 120 000 km of cleared lines (pipelines, power lines, seismic lines, and road allowances) on Alberta forest lands. In excess of 12 000 km of new lines are added each year. Mainly because of economic restraints, the debris resulting from these land clearing projects is burned in situ during the off-season. Frequently, sleeper fires started by these burning projects survive until spring, when they surface with the arrival of warm weather. Spreading rapidly in the cured grass that is found in most boreal forest stands, they reach unacceptable sizes by the time suppression crews arrive.

2. The second class of holdover fires is the remnants of wildfires or prescribed fires.

   In our deep duff area, pockets of hidden sleepers at times pose a major problem. They slow down mop-up work, and there is always the possibility that a hot spot is overlooked by the mop-up crews. Some of Alberta's major forest fires were the result of missed hot spots on fires considered extinguished.

3. Dormant lightning strikes form the third category of problem sleeper fires.

   It has happened repeatedly that lightning strikes and the resulting flare-ups were observed and reported by lookouts, but by the time the suppression crews arrived, there was not sufficient smoke to find it. Later the fire became active and burned out of control before the crews could be brought back.

Since the industrial and wildfire-related holdover fires appeared to offer the best opportunity for a successful solution, and since they were by far the most abundant problem, we began working on them first.

Starting in 1970, in cooperation with the Canadian Forestry Service's Northern Forest Research Centre (NFRC), we looked at available technology and equipment in the search for a suitable solution. Initially we followed the conventional path and tried approaches described in literature. We borrowed several instruments, a Barnes Airborne Fire Spotter(R) was purchased by the NFRC, but nothing seemed to work right. However, through this work, we became aware that sleepers of the type we wanted to detect were not as hot at the surface as the customary charcoal targets, meaning we needed a much more sensitive and more reliable scanner than the Barnes, for instance.

Any method we adopted had to involve an airborne detector in order to cover the large target areas (the Alberta forest protection areas measure over 400 000 km^2) and had to be fully portable, because no dedicated aircraft would be available. Aircraft in Alberta are often chartered on a local basis for individual jobs.

By 1975 we had arrived at a workable solution using an AGA Thermovision 750(R), hand held in a helicopter. In a series of semi-operational tests, we could find more hot spots from the air than the crews on the ground could by cold trailing. Our method of using the instrument as it came from the manufacturer and in any available helicopter

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blended well into the operational procedures used in the field.

The Thermovision 750$^{(R)}$ is a lightweight, precision, nitrogen-cooled scanner with interchangeable lenses.

The indium antimonide detector has a temperature resolution of 0.2°C and, with the 20° lens, a spatial resolution of 3.6 mrad. A full set of controls allows the operator to choose the temperature scanning range, the temperature level to be scanned, black cold or white cold mode, automatic scanning level adjustment, and isotherm display. The 750 is not affected by radio transmission, lightning strikes, or other interferences.

The most successful scanning method was simply to point the camera at the area of interest from a helicopter flying usually 100 m from the target. By using two observers—the camera operator (usually a ranger) pointing the camera and doing the visual observations and the second observer watching and adjusting the infrared display—an effective visual-infrared inspection could be accomplished.

When found, targets were marked with paper rolls for future location by the suppression crews.

In 1976 the Alberta Forest Service purchased a Thermovision 750 and put it into operational use. A second 750 was purchased in 1977. Both machines are used regularly, flying some 100 h of inspection each year in spring, which amounts to about 800 km of right-of-way burning, mill sites, and timber landings. Each year over 100 hot spots are detected during these inspection flights. The number of wildfires scanned increases each year. Four fires were scanned in 1976, and in 1978 we scanned 15 fires.

Difficult fires required several scans. One fire was scanned five times before the last sleeper was found. There was no instance of a flare-up after the final scan.

Regular training sessions are held each year to maintain and improve the skill of the operators.

Work is going on to adapt the 750 for lightning-caused sleeper detection. By using an oscillating scanning mirror adapter and a recorder, we managed to search larger areas of up to 100 km^2 using a fixed-wing aircraft. Each time, the test targets, small piles of glowing charcoal (12 egg briquettes), were detected. The only guidance given the air crew as to the target's location was a bearing from a lookout tower and a rough distance estimate.

It is hoped that for the 1979 fire season a scan mirror adapter for helicopter and fixed-wing use will be available on an operational basis. However, only after some time of operational use will we be in a position to tell whether the 750 and the scan mirror are an effective tool for the detection of lightning-caused fires. We think it is.

A CRITICAL LOOK AT MESOSCALE AUTOMATED TELEMETRY SYSTEMS

B. Janz*

ABSTRACT

Technological advances during the past decade have made reliable automated data acquisition from remote areas a reality. Any organization considering the purchase of automated telemetry equipment must analyze its data requirements, and management has a responsibility to make certain basic decisions that will vitally affect the design. Automated telemetry systems are reviewed critically with the aim of illustrating for managers how their basic decisions will determine design of the system.

INTRODUCTION

We are currently seeing significant advances in data acquisition by automated telemetry systems. Although much of the work to date has been developmental, several large-scale systems, primarily related to hydrometeorological and air quality applications, are nearing the operational stage.

Because of the highly technical nature of automated data acquisition systems, mid- and higher-level managers of services or organizations considering the use of such systems often limit their main responsibility to negotiating a suitable price. This is a fundamental misconception thay may, in part, be responsible for the confusion and misunderstandings about the automation of data acquisition systems.

Another misconception often encountered is that, once operational, an "automated" system works with little or no attention. Not so; just like conventional systems, automated systems require varying degrees of servicing and maintenance. Some managers seem to have the notion that data acquisition by automated methods should be cheaper than by conventional means. Depending on the specific circumstances, this may or may not be realistic. The essential point to remember is that automated systems can provide data at a time and from a place not practical by conventional means.

The term "management" as used in this paper refers to management of the user organization. Mesoscale refers to areas 100-150 km across.

ROLE OF MANAGEMENT

The essential components of a fire-weather telemetry system collecting data from remote sites are shown in Figure 1.

Efficient design requires certain definite decisions by user management in several areas: definition of data requirements, operating environment, and servicing philosophy.

Definition of Data Requirements

Any organization considering the automation of data acquisition, whether for fire-weather or any other purpose, must first define very clearly the purpose of such a system and indeed the expected results. Management should be able at the outset to define clearly how the data will be analyzed, achieved, and used. A fundamental fact is often overlooked, namely, that a data bank in itself does not add to scientific knowledge. Only when the data are analyzed, interpreted, and applied do they further scientific progress.

In specifying the data requirements, management must be realistic and be aware of what is technically possible. Specifications of data requirements include

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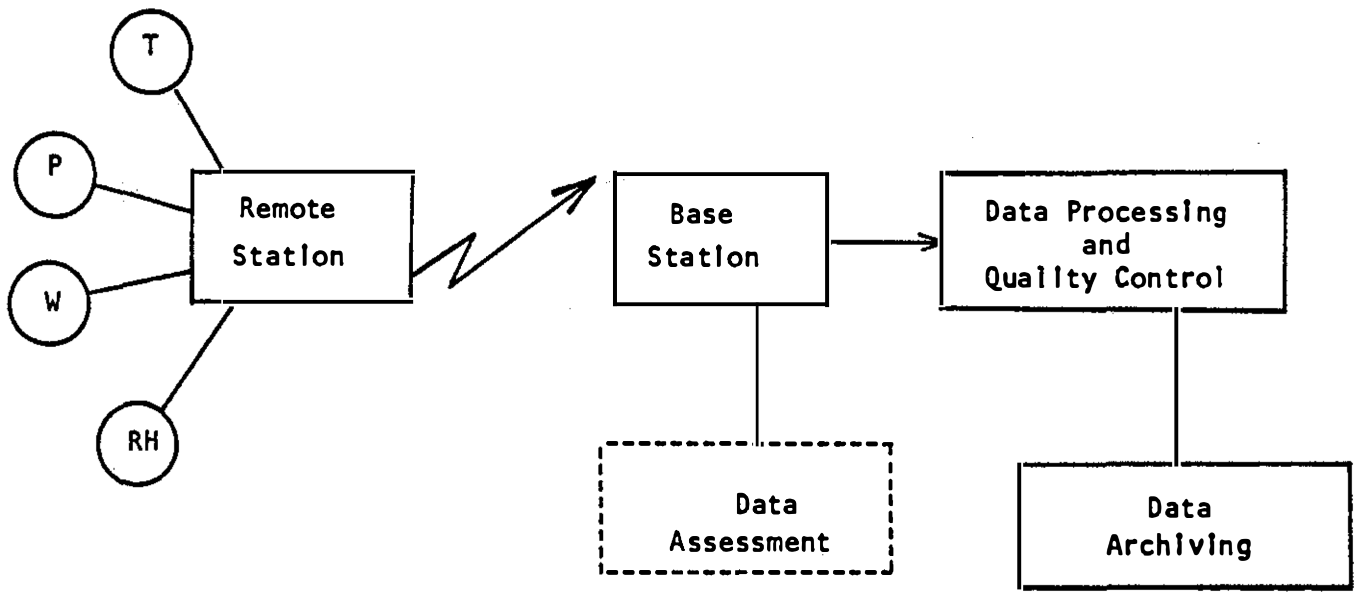

Figure 1. Schematic for a typical fire weather data acquisition system using telemetry from remote stations.

1. parameters to be measured
2. accuracy or precision of required data
3. size and location of network
4. frequency of measurements (i.e., daily, hourly, etc.), and
5. delivery format of data.

For fire-weather purposes, the parameters are likely to be wind speed and direction, temperature, precipitation, humidity, and fuel moisture. Frequency of measurement might normally be once daily, but occasionally hourly observations might be required. The format of delivery is important in that data should be immediately intelligible when received. This permits early assessment of data quality and possible equipment malfunctions. This will be further discussed in a later section.

Operating Environment

The size and location of the network more or less define the environment in which the remote station must function. The various components must be chosen, designed, and installed to cope with whatever weather, wildlife, or vegetation conditions affect it. Thus, a station designed for data acquisition in severe winter weather will differ from a fire-weather station designed to work only during the summer months.

Servicing Philosophy

Many managers feel that decisions about servicing and maintenance can be made after the system has been acquired. Although details can be worked out at this later stage, management has the responsibility to give the technical designer a good idea whether servicing is to be done when required, weekly, or whatever. The manager must also decide whether repairs are to be done in the field by highly qualified personnel or whether the station configuration should be such as to permit quick and easy replacement of modules or circuit boards by less expert personnel.

Obviously, the planner has a wide choice, and the final decision depends on the size of the network and the remoteness of the stations. For a network in which aircraft must be used for access, it is probably best to opt for a high degree of modularization, in which individual modules can be replaced by spares. The modules can then be returned to a shop for overhall and calibration. Sensors should be chosen for easy replacement in the field in all anticipated weather conditions.

At this point, it is also wise to consider the requirements for spare parts for the system. A good rule of thumb is to purchase an extra 20% of the main sensor and electronic components for spares.

Servicing and maintenance can be done by means of a service contract or in-house. Service contracts in which sensor, electronic, and communications servicing are each awarded to different firms should be avoided. Such arrangements can lead to accusations and bickering over where the problem lies when a remote station malfunctions. In other words, whether servicing is done in-house or by contract, the responsibility for ensuring proper operation of the system should not be divided.

For a seasonal fire-weather system the question of overwintering of the equipment should be considered in design. Particular attention should be paid to the ease and speed with which a remote station can be prepared for overwintering.

The impact of management decisions on system design can be seen in the schematic in Figure 2, which shows the complexity of the interrelationships and clearly indicates how management decisions affect the technical decisions.

TECHNICAL DECISIONS

In most remote telemetry systems in existence today, the first decision probably has been a technical one. If one were to go to different firms and ask for the design of an automated telemetry system, one would undoubtedly find different approaches. Some designers would begin with the communication mode, such as meteor burst or satellite. Other firms might begin with the electronics

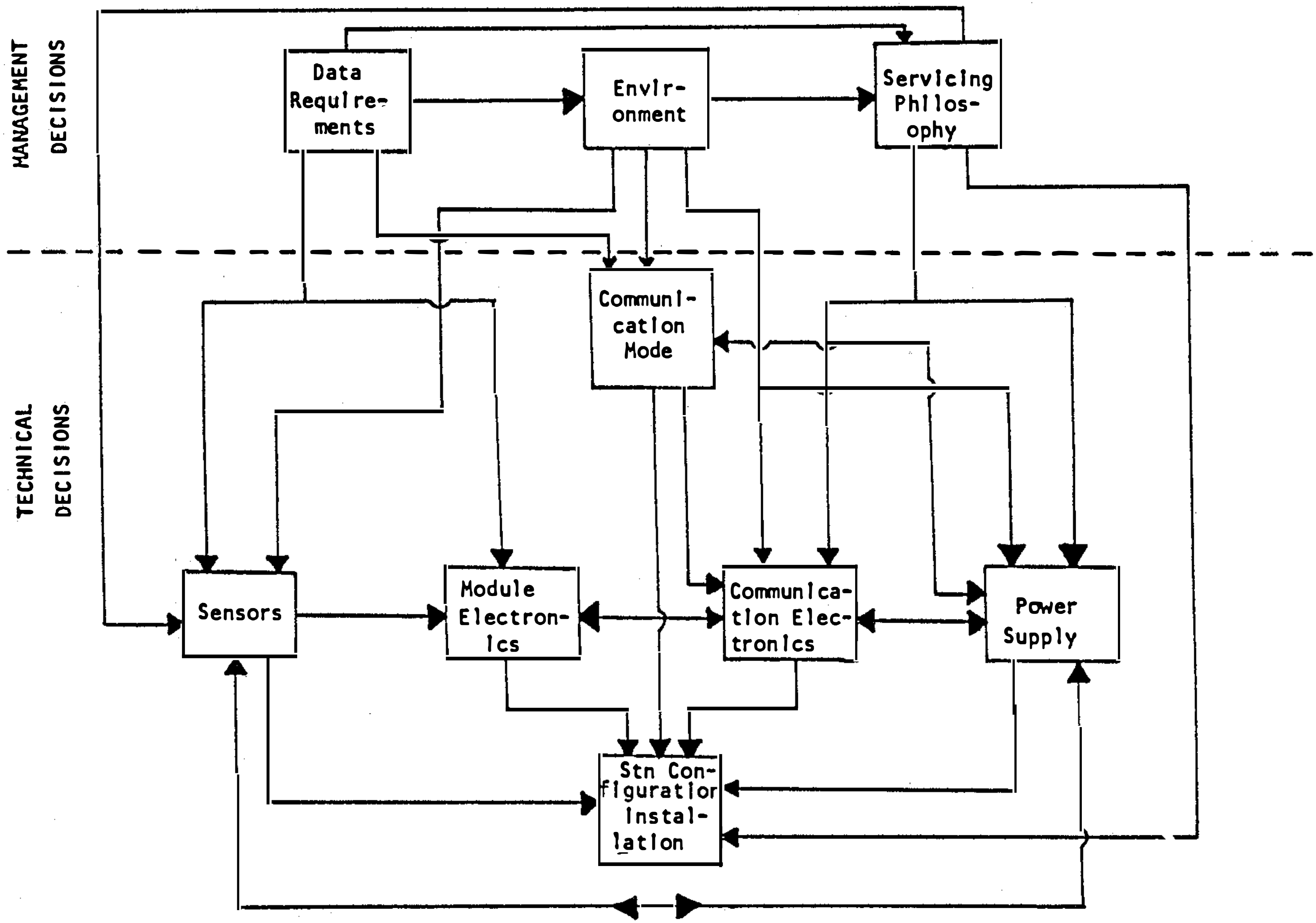

Figure 2. Remote station planning. Schematic of major decisions.

package; another might begin with the sensors. It all depends on their major sales item. All too frequently, the blocks designated as management decisions in Figure 2 are ignored at the outset. However, failures and problems eventually lead to redesign and modifications meant to overcome the weaknesses introduced, because these fundamental decisions were not made at the proper time. Data quality, the real purpose of the system, suffers the most in such a back-door approach.

Communications Mode

Once management has specified the basic data requirement, working environment, and general servicing philosophy, the communication mode can be chosen in consultation with technical advisers. There are, of course, a number of choices: landline, VHR, satellite, meteor burst, etc. Each mode has its own particular advantages but also disadvantages, and at this stage some compromise as to data requirements may have to be made in order to accommodate the communication mode.

For mesoscale networks, VHR offers advantages, versatility, and independence not available with other modes. VHR would be quite suitable for a fire-weather network covering an area of about 250 x 250 km if antennas could be sited appropriately. With one or more VHF repeaters the network can be expanded to cover larger or mountainous areas.

Use of a satellite as a communication mode is likely satisfactory for fire-weather purposes, both technically and costwise. However, it presents limitations as far as interrogation of a remote site is concerned.

Sensors

In sensor choice, all the interrelationships shown in Figure 2 should be taken into account. Sensors must be durable enough to withstand the environment in which they will function. They must deliver the data with the required accuracy. They must be compatible with the available power and certainly must be chosen with servicing and maintenance in mind.

Thought must be given to the integration interval of the sensors. For instance, would an instantaneous reading (1 s) of wind speed and direction be satisfactory, or should the reading be taken over a longer time interval (such as 1 min or 10 min)? This specification is basically a management decision.

For fire-weather purposes, the appropriate wind, temperature, and precipitation sensors are available. Sensor quality varies widely, and cheap sensors should be avoided, because in the long run they will not provide the durability required in remote installations. Unfortunately, the state of the art is such that an entirely satisfactory humidity sensor (for fire-weather purposes) is not available. Either the accuracy is unacceptable in dry periods or the instrument does not retain its calibration throughout the fire season (McKay 1978).

Electronics Packages

Modern advances in electronics are responsible for the feasibility of remote data acquisition systems. The state of the art is such that data requirements and sensor requirements present little or no difficulty to the electronic design. The problem is the configuration and packaging of the electronics in order to meet the environmental and servicing requirements.

Power Supply

The effect of the power supply on the other facets of remote station operation is often poorly appreciated by management. Again, there is a wide choice of hardware. One can opt for dry cells that require replacing every few weeks (more frequently in very cold weather) or, at the other end of the spectrum, solar cells charging lead batteries that provide reliable long-term power requiring a minimum of servicing or maintenance. The drastic drop in energy suffered by the cells during cold weather is not fully appreciated by many managers and design engineers. The design of a power supply for most fire-weather purposes presents no technical problem. A system giving good service throughout the fire season should be available at a modest cost. It should be noted, however, that if power is not generated on site, a station service interval is clearly defined. If the station is at a site where transportation costs are high, the payback time on a high capital cost power supply may be surprisingly short.

Station Configuration

As can be seen from Figure 2, the remote station configuration is the culmination of many decisions, both managerial and technical. Two extremes in station configuration are shown in Figures 3 and 5. The station shown in Figure 3 was designed by Bristol Aerospace to operate in the Arctic Ocean under the most severe winter conditions. Note that all electronic components are placed in submerged silos to keep them warm. Power is supplied by a wind turbine.

A very high degree of modularization, shown in Figure 4, is used by Bristol Aerospace in its MAPS(R) (Modular Acquisition and Processing System). Every sensor has its own interface module, and thus a station used for fire-weather purposes would have about six or seven individual modules. With appropriate test equipment, malfunctions in any particular module can be identified and the defective module replaced by a spare in a matter of minutes.

The station shown in Figure 5 is the BLM fire-weather station developed jointly by LaBarge Inc. and the Bureau of Land Management. This station obviously has been designed for a different purpose and is much less rugged than the former. Note that there is no need for protection against severe arctic conditions. The electronics are housed in two canisters such as the one shown in Figure 6 and are placed in the rectangular Hammond box located about a metre above ground. In the event of an electronics failure, the entire canister is replaced by a spare.

BASE STATION

Base station design is essentially a technical matter; however, there are several facets that should be considered by management. First, data retrieval should be such that, if required, processing and archiving can be done by or easily adapted to computer methods.

Secondly, the incoming data should be formatted in such a way as to permit easy and rapid assessment of quality and reliability. Assessment should be done in real or near real time. Such monitoring can give an experienced operator clues as to possible reasons for malfunctions and thus enable corrective action to be taken at the earliest possible time. The person or unit charged with such data assessment should be given the authority to direct the repair or servicing of any system component that is malfunctioning.

Thirdly, if the communication mode permits, consideration should be given to permitting interrogation of any or all remote sites from the base station. Also, the selection of sampling interval might be a very useful feature.

Fourthly, management must consider the whole question of how the data will be presented, because this affects base station design.

DATA PROCESSING

Many data users prefer to have the data from remote stations put directly into computer facilities where data are massaged and processed for display. This has the advantage of immediacy and is fine as long as all components of the system are functioning well. However, in the event of a malfunction, it may be much more difficult to ascertain the problem. There is a distinct advantage in having the incoming data printed on hard copy parallel to the computer input.

COSTS

It is not within the purview of this paper to discuss costs of a telemetry system. Suffice it to say that the approach in which management goes to a designer and asks, "What can I get for $x?" is not a good one. It is preferable to discuss costs on the basis of the requirements outlined in this paper. The

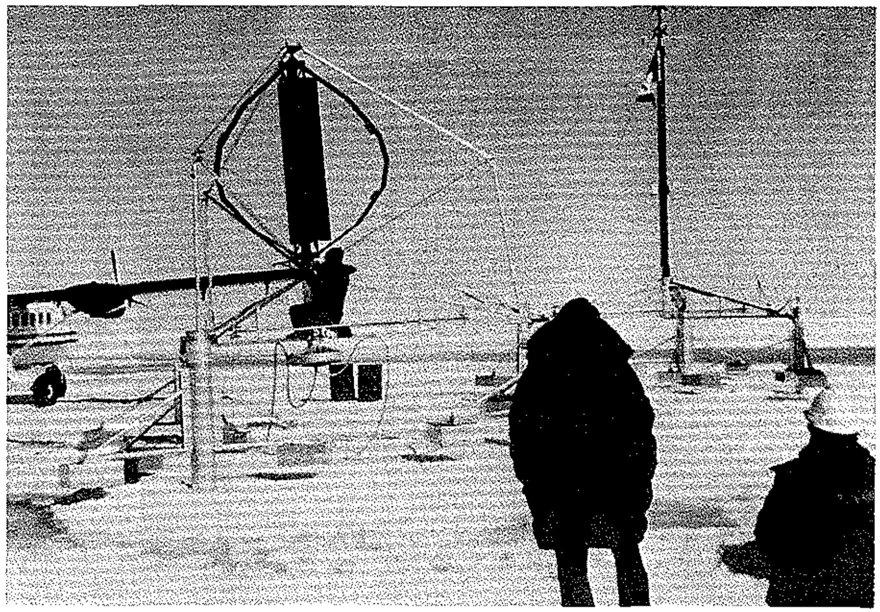

Photo courtesy Bristol Aerospace

Figure 3. Remote station designed for operation on ice floes in Arctic Ocean. Note wind turbine for power generation, communication via GOES.

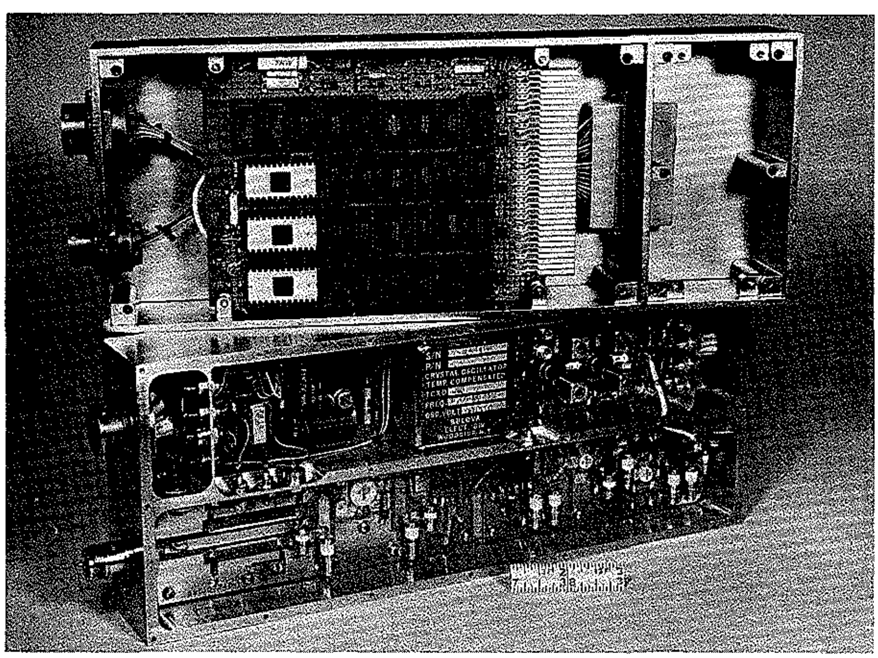

Photo courtesy Bristol Aerospace

Figure 4. Modules used in highly modularized approach to design (such as Bristol's MAPS(R)).

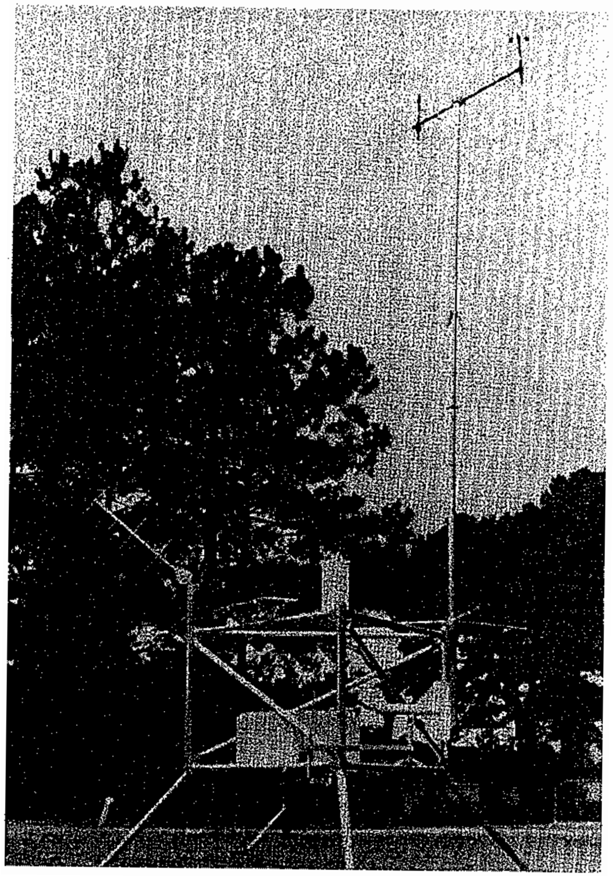

Photo courtesy Dale Vance

Figure 5. Fire-weather station developed by LaBarge Inc. and Bureau of Land Management.

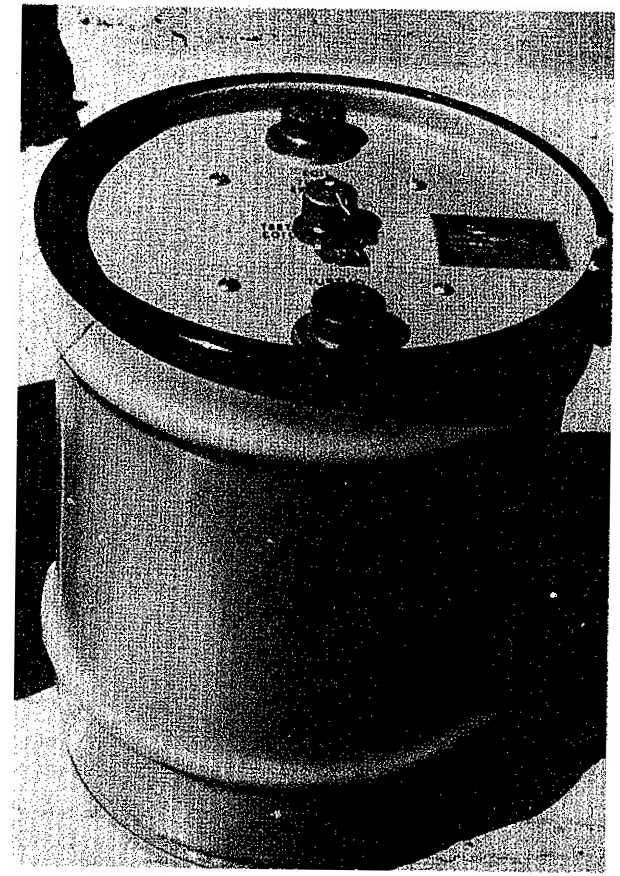

Photo courtesy Dale Vance

Figure 6. Partial modularization as used in BLM fire-weather station at left.

relatively high costs may be a disappointment to many potential users. On the other hand, it is most encouraging that recent developments in the electronics field suggest that costs in certain areas are coming down and quality is improving. On the other hand, because there is very little incentive to develop appropriate sensors, sensor costs continue to rise without a corresponding improvement in performance.

CONCLUSION

An attempt has been made to present a general, but comprehensive, view of remote data telemetry from a management point of view. Although remote data telemetry is certainly feasible and several mesoscale systems are operating successfully, there is a certain amount of confusion and uncertainty about the technology. Undoubtedly, this can be attributed to the rather piecemeal approach taken by different designers and developers in this expanding field. To date, most of the development has been by technical designers, with relatively little input from management.

Because of summer-only operation, telemetry systems for forestry purposes by and large should present fewer technical design problems than all-year systems. However, it should be remembered that sensors and other hardware must very likely be protected or stored indoors for the winter months.

The other essential point that must be borne in mind by management is that good data do not come cheaply. Telemetry is not the avenue to cheaper data but the means of getting data that otherwise would be very costly or difficult to obtain.

A "shopping list" is provided in the Appendix as a guide to managers who are considering an automated data acquisition system. No claim is made for the completeness of this list, but it should enable the manager to ask some of the appropriate questions when discussing equipment requirements with manufacturers or suppliers.

ACKNOWLEDGMENTS

The author wishes to thank Gavin Thomson of the Atmospheric Environment Service, Robert Grauman of Alberta Research Council, and Bernie Wiebe of Bristol Aerospace for their criticisms and helpful suggestions concerning this paper.

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APPENDIX

"Shopping list" for a fire-weather telemetry network

1. Will the system give you the data you require?

2. Are the data available in real time?

3. Are the data compatible with data from other agencies (e.g., 10-m wind vs. 10-ft wind)?

4. Are the incoming data immediately intelligible, or must the user go through a complicated decoding process?

5. What are the characteristics of the humidity sensor? How durable is it? What is its accuracy? Do not accept unsubstantiated claims.

6. How durable are the other sensors (wind, precipitation, temperature)?

7. What must be done regarding overwintering of equipment? Has dismantling and reinstallation been considered in the design? How long will it take?

8. What are the power requirements of individual sensors and electronics at remote sites? Does the power supply demand a fixed service interval?

9. Is the remote station designed to require one or more service trips during the fire season, or is maintenance on an as-required basis?

10. Has the user any choice as to frequency of data transmission?

11. What corrective action can be taken if data are of unacceptable quality?

12. Is the remote station prone to vandalism? What about bears, squirrels, etc.?

13. What is the philosophy of field maintenance: replacement of boards (or modules) or individual components? Will field servicing be done by electronic engineers or field technicians?

14. Will maintenance be done in-house or by contract?

    a. If in-house, what special training is required by technical staff? Are test sets available? What is the degree of modularization of remote sites?

    b. If by service contract, will servicing of the entire system be done by one firm? Are separate contracts required for different phases of the operation?

15. What is the installation procedure? What is the installation cost, e.g., transportation and time? Remember, this is one of the most important phases of the entire exercise. Lack of attention to detail can doom the system to failure.

16. Do not accept the manufacturer's or salesman's word that the system will operate satisfactorily unless he can give you documented proof that a similar system has operated for at least 1 year under conditions (environment, power source, communication mode, etc.) that you will impose on it.

POSSIBLE ROLE OF SATELLITES IN FIRE PLANNING

Robert E. Burgan*

It is interesting how society's problems—such as our current energy shortage or, more in our area of interest, various environmental dilemmas—continually tax our technological capabilities and force us to improve them. The Forest Service's revision of its national forest fire management policy is no exception. It has placed fire managers in the position of having to use current technology to its fullest extent to cope with the decisions demanded of them.

It is no longer prudent to attempt extinguishment of every fire by 10 a.m. the next day. Budgeting constraints are beginning to require more cost effective fire fighting. Also, in areas where natural resource conditions can be improved by prescribed fire, and where plans have been approved for the purpose, suppression action may be modified to meet resource management objectives. Unless one takes an extremely conservative approach, determining whether a particular fire will likely benefit or damage the resource is not an easy task. The fire manager is required not only to make rapid and accurate assessments of each new fire situation, but also to monitor ongoing natural fires. In short, the fire manager needs all the help he can get to do an effective job. One source of information that could provide increasing help in future years is satellite data.

Satellite imagery is available for the entire U.S. from the Earth Resources Observations Systems (EROS) Data Center in Sioux Falls, South Dakota. 1:1 000 000-scale color prints can be purchased for about $12. In addition, high altitude U-2 photography has been flown for portions of the U.S. These can also be obtained from EROS at about the same cost. If you have not already done so, it would be well worth your time to familiarize yourself with these products by ordering a photo or two for an area of interest. The ordering information can be obtained by writing to EROS Data Centre, U.S. Geological Survey, Sioux Falls, S.D. 57198.

The Forest Service itself also has a nationwide forestry applications program of remote sensing in cooperation with NASA/Johnson Space Center in Houston, Texas. Their charter is to work on a joint program to determine the feasibility of using satellite remote sensing for large-area forest and range inventories. They are primarily involved in development and evaluation of techniques, not in large-scale mapping projects; that type of work is delegated to private contractors. However, the forestery applications group will provide expertise and assistance in developing a contract or will cooperate on small demonstration projects.

While U-2 and satellite photographs are interesting to look at, satellite imagery is just a pictorial representation of the primary digital data. This information is much more useful in digital form. Some of the advantages of digital processing include

1. data in digital format
2. enhanced contrast between features
3. enhanced edges between features
4. digital enlargements to 1:24 000
5. efficient monitoring of change
6. rapid, consistent classification decisions
7. cost effectiveness for large areas
8. efficient input to inventory systems
9. efficient registration to map base, and
10. compatibility with information systems.

The last item, "compatibility with information systems," leads directly into the type of technology that may greatly aid fire managers in their efforts to implement the revised fire management policy.

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It is easy to find examples of vegetation mapping using satellite data, but that in itself is not enough. We need to put this information to use to improve fire management capabilities.

Look a moment at the basic information needed. It is all alluded to in the fire triangle (Figure 1). Notice the reference to fire modelling in the center of the triangle. This is basically the synthesizer of the fuel, weather, and topography information.

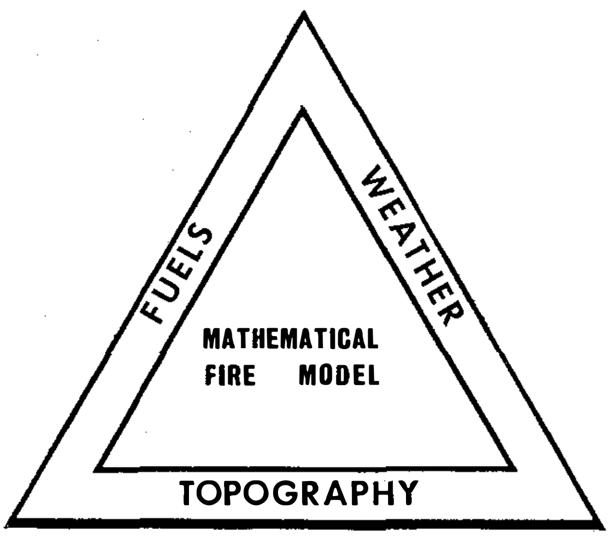

Figure 1. Fire triangle.

It seems possible that digital satellite data could be merged with terrain data to describe the fuels and topography of an area. Then the addition of either measured or assumed weather inputs could provide all the information needed by the fire model to estimate probable fire characteristics over relatively large areas. Let us look at this process in more detail.

We know digital data from Landsat can be processed with the aid of a computer to produce a vegetation-type map with area statistics. Although it was not possible to include the vegetation-type map in this paper, the resulting area statistics are shown in Figure 2.

If vegetation data such as this can be interpreted to produce a fuel-type map, then

AREA SUMMARY

VEGETATION TYPE	COLOR CODE	LANDSAT ACRES
DOUGLAS-FIR	RED	7891
LARCH	BLUE	6319
LODGEPOLE	YELLOW	4686
HARVEST	MAGENTA	5904
OPEN	CYAN	3204
AREA NOT CLASSIFIED	–	3922

Figure 2. Acreages of vegetation types classified from digital satellite data.

we suddenly have the ability to describe, in a rather detailed way, the fuel mosaic over relatively large areas. The theoretical resolution would be about 1 acre; however, practical resolution may be about 4 or 5 acres.

Dr. Jim Brown at the Northern Forest Fire Laboratory is working to develop a method for inferring fuel models from cover type, percentage cover, stand age and height, and degree of grazing. Perhaps some of these variables can be obtained from satellite data; others require on-the-ground verification.

While one side of the fire triangle represents fuels information, terrain information is represented by the base.

Digital topographic data from the Defense Mapping Agency terrain tapes can be used to obtain slope, aspect, and elevation. The computer graphic in Figure 3 is a pictorial representation of data obtained from these tapes.

Finally, merging the fuels and topography data in a geometrically correct coordinate system places it in a format usable by the fire model. Imposition of weather conditions is the final step required to "game" what a fire would do if allowed to burn under a given set of fuels, weather, and topography conditions for a specified period of time. The conceptual illustration shown in Figure 4 ties the procedure together.

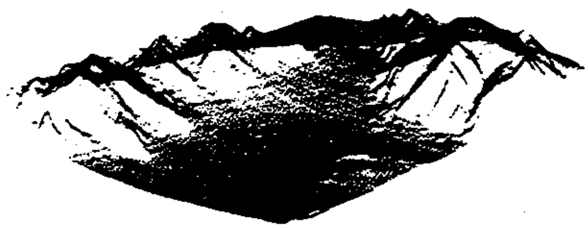

Figure 3. Computer graphics representation of digital terrain data.

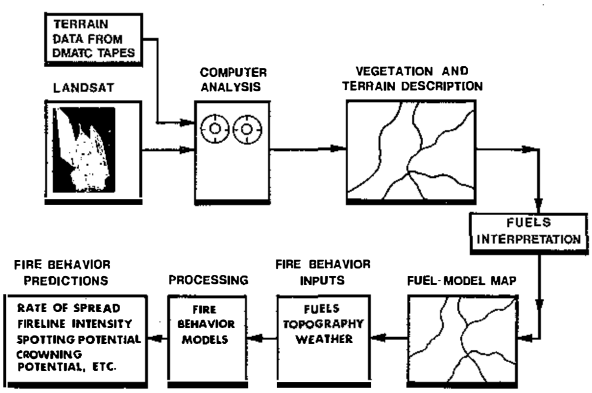

Figure 4. Conceptual illustration of process to obtain wide area fire behavior estimates.

Bill Frandsen and Pat Andrews of the Northern Forest Fire Laboratory have provided an example of the form the output could take. They simulated a fuel arrangement constructed of two fuel types, sagebrush and grass. In this case flat topography was assumed; however, slope, aspect, and elevation data could also be superimposed. Then, by "igniting" the fuel array at the bottom, a fire was simulated by allowing it to "burn" under given wind and moisture conditions. Figure 5 shows the fire pattern that developed at the end of 10 minutes. The black area indicates where the fire has burned out, the lined area is still burning, while the white area is unburned fuel.

In addition, it is possible to describe the fire in statistical terms. We know that a fire does not burn at a single rate of spread.

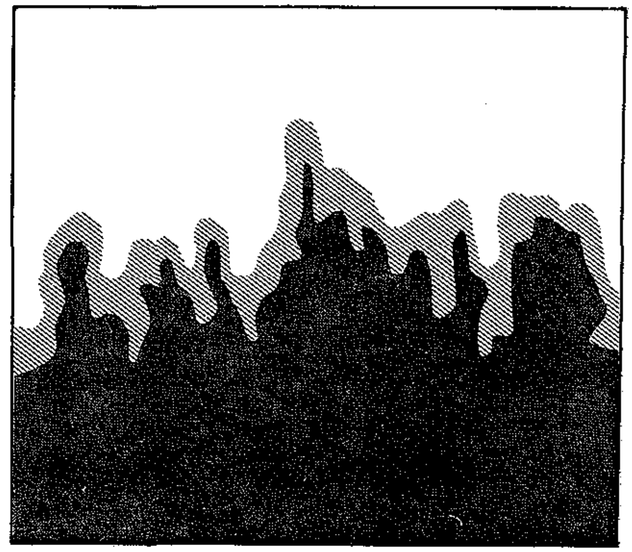

Figure 5. Simulated fire front in sagebrush/grass fuel type after 10 minutes burning time.

Various portions of the fire front move at different speeds. Figure 6 illustrates the distribution of spread rates, which varied from 20 to 44 ft/min with the majority of cell rows burning at 33 ft/min. This provides the fire manager with much more information than he can get from an average rate of spread.

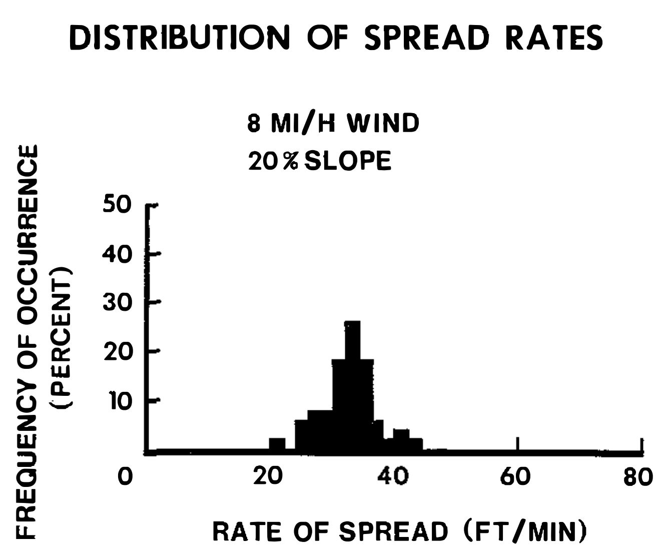

Figure 6. Distribution of spread rate for simulated fire.

A similar distribution can be obtained for fire-line intensity (Figure 7). In this case, about 20% of the fire is burning at an intensity low enough for men with hand tools to control, but about 8% is at an intensity too great for control by any means.

DISTRIBUTION OF FIRELINE INTENSITY

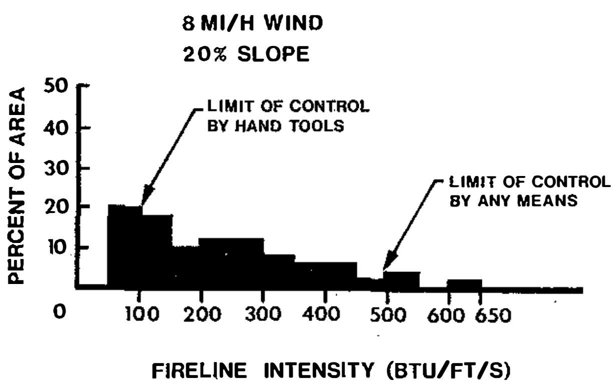

Figure 7. Distribution of fire-line intensities for simulated fire.

This analysis tool seems most applicable to fire planning for rather large areas. It may have potential for real time fire behavior predictions, but that would require rapid transmission of data between a computer facility and the fire site—a task that could be very difficult. Since I was sure you were familiar with currently operational systems such as AFFIRMS, FIRDAT, FBO techniques, and perhaps FIRECAST, I have described instead a possible next step to improve the fire manager's planning capabilities by putting together various technology that is either available or under development with a reasonable chance of success.

THE ESTIMATION OF LOGGING RESIDUES USING LARGE-SCALE AERIAL PHOTOGRAPHS

C.L. Kirby and R.J. Hall*

INTRODUCTION

Large-scale photo (LSP) sampling systems have been developed to provide an adequate data base for forest management. The operational application of LSP sampling techniques has been made possible through the use of minicomputers and new and improved radar altimeters, which provide information on height of the aircraft above ground. Minicomputers with developed software can easily perform the many calculations associated with analytical photogrammetry. In addition, minicomputers can provide useful summaries of information for management.

The purpose of this paper is to show how LSP may be applied to the estimation of logging residues using the line-intersect sampling technique. The measurement of logging residues is of interest to

1. fire management personnel, for fuel loading and rates of accumulation
2. silviculturists, for site preparation for forest regeneration, and
3. individuals concerned with the utilization of forest residues as an energy source.

LINE-INTERSECT METHOD

Line-intersect sampling for estimating volume, weight, and number of pieces per unit area is well tested and ready for operational application. The method was first proposed by two New Zealanders (Warren and Olsen) in 1964 and was further developed by Van Wagner (1968). Since that time, the line-intersect method has been tested by a number of Canadians and Americans, including Muraro (1970), Morris (1970), and Martin (1976), to name a few.

In application, the method requires only the length of the sample line, the diameter of pieces intersecting the line, and the use of a simple formula. Tallying rules can be found by referring to Van Wagner (1965, 1968). If the slash is oriented in a nonrandom fashion, potential bias can be avoided by multiple random starts and random orientation.

Simply stated, the formula for volume in cubic metres per hectare is

$$V = \frac{\pi^2 \Sigma d^2}{8L}$$

where: d = piece diameter (cm)
L = length sample line (m)
V = volume (m^3/ha).

Multiplying the above formula by the specific gravity of the wood and the appropriate conversion factors can result in weight with units of tonnes per hectare.

LARGE-SCALE PHOTO SAMPLING SYSTEM

The Northern Forest Research Centre has developed an aerial camera and interpretation system (Kirby 1978) for large-scale photo sampling. The camera system consists of a Honeywell radar altimeter, two 70-mm Vinten aerial cameras, and an intervalometer (van Eck and Bihuniak 1978). The interpretation system consists of a Hewlett-Packard 9825A minicomputer interfaced to a Carl Zeiss-Jena Interpretoskop, with parallax measuring device and digitizer.

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The camera system has been used on fixed-wing aircraft (twin-engine Aztek) and on Jet Ranger (Bell 206B) helicopters. Figure 1 is a photograph of the aerial equipment under the 206B.

The intervalometer permits the cameras to be operating at different cycling rates. This, in combination with aerial camera lenses of different focal lengths, results in simultaneous localized and broader views of the terrain. Digital height information on light-emitting diodes is displayed through the secondary optics on one of the Vinten cameras. This results in the height above ground and exposure time to 1/100 s being recorded on the lower corners of each aerial photograph. Figure 2 is an aerial photograph with the digital information displayed.

The versatility of the sytem is its capability to provide two scales of photography with different films at the same time. With a multistage sampling approach, sample area stratification, plots, and sample lines are often located and delineated on photographs obtained with a wide-angle lens (77.45 mm) and Kodak color infrared (2443) film. Larger scale photographs are then obtained with a telephoto lens (281.9 mm) and Kodak aero color negative (2445) film for measurements. The sampling option can be used to obtain bursts of several color photographs for stereo viewing and actual measuring of plots and sample lines.

METHOD AND RESULTS

A test was conducted on an intensively studied area in Hinton, Alberta, to indicate the use of large-scale color aerial photographs and line-intersect sampling. Color photographs at a scale of 1:220 were taken in a helicopter on May 19, 1978. The flying height was 60 m (200 ft) above ground. The area was photographed in the spring when the grass was dead and still down from the winter.

Fieldwork was done in the fall of 1978 in an area that was logged during 1966-67. The slash was approximately 11 years old at the time the photographs were obtained. Two 10-m sample lines were located on the ground and on the photos.

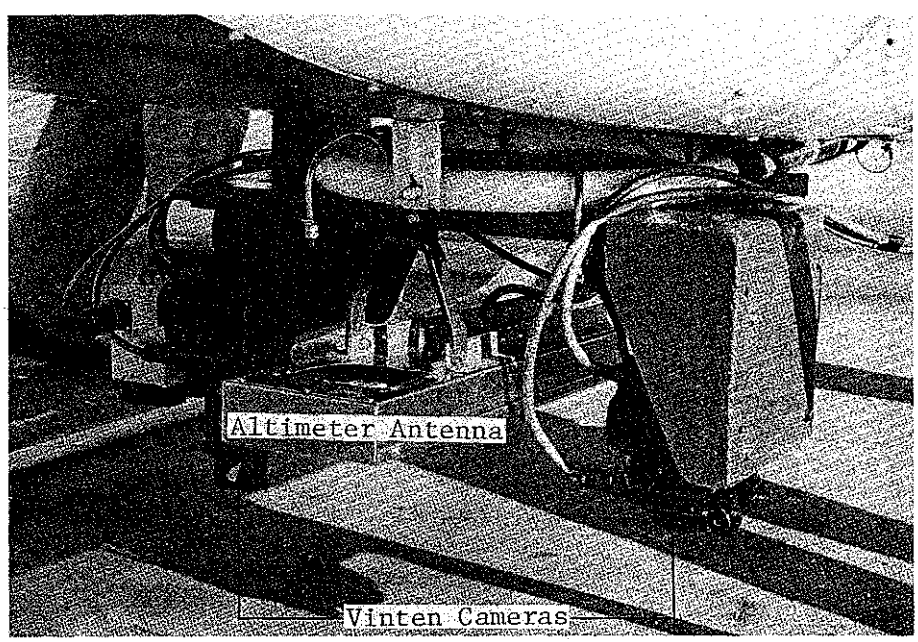

Figure 1. Cameras under the 206B helicopter.

Figure 2. Black-and-white aerial photograph from aero color negative. Lower left corner: exposure time (min/s/1/100 s). Lower right corner: height above ground (ft).

As can be seen in Table 1, the volume estimates of residue calculated for the two sample lines from the photos and ground were found to be remarkably close. Sample lines 1 and 2 showed a volume difference between photo and ground of only +1% and -7%, respectively.

The mean percentage missed for pieces tallied on photos to those on the ground was 14. This difference occurred from partial coverage by regeneration and slash, which affected detection and measurement. These factors will be mentioned in greater detail later.

The piece diameter range for both sample lines was 2.5-15 cm on the ground and 2.5-17 cm on the photo. A simple linear regression was performed to determine the relationship between piece diameters from the photo estimating and the ground diameters (Figure 3). The results showed mean ground and photo diameters of 6 cm (SD ±3) and 6.1 cm (SD ±2.6), respectively. The data showed a high correlation of 87.6%, and at two standard errors the ground diameter could be estimated from the photos to ±2.5 cm.

An important fact to note is the bunching of data at several common photo diameters for a range of ground diameters, which can be seen from the plotted regression line in Figure 3. This bunching occurred because of the limitations in measuring photo diameters. The smallest distance detectable on the contact prints was 0.1 mm, which at the scale of the photos was to the closest 2.2 cm. Ground measurements, on the other hand, could be taken to the closest millimetre (±1 mm) with a metric diameter tape.

Problems

There were three problems which affected this particular study:

1. Slash on the ground may have been partially covered by grass, soil, or other slash.

2. Slash may have been partially or entirely hidden on the photos by forest regeneration or its shadow.

Table 1. Results of the line-intersect method in sampling logging residues.

Plot No.	Volume of residue Ground	Volume of residue Photo	Percentage diff. with ground	Ground diameter range	No. pieces measured Ground	No. pieces measured Photo	Percentage missed on photo[1]
1	1568.3 109.7	1584.3 ft^3/ac 110.8 m^3/ha	+1	1.1- 5.9 in. 2.8-15.0 cm	25	21	16
2	1964.7 137.5	1822.4 ft^3/ac 127.5 m^3/ha	-7.2	1.0- 5.0 in. 2.5-12.7 cm	25	22	12

[1] $\overline{X} = 14$

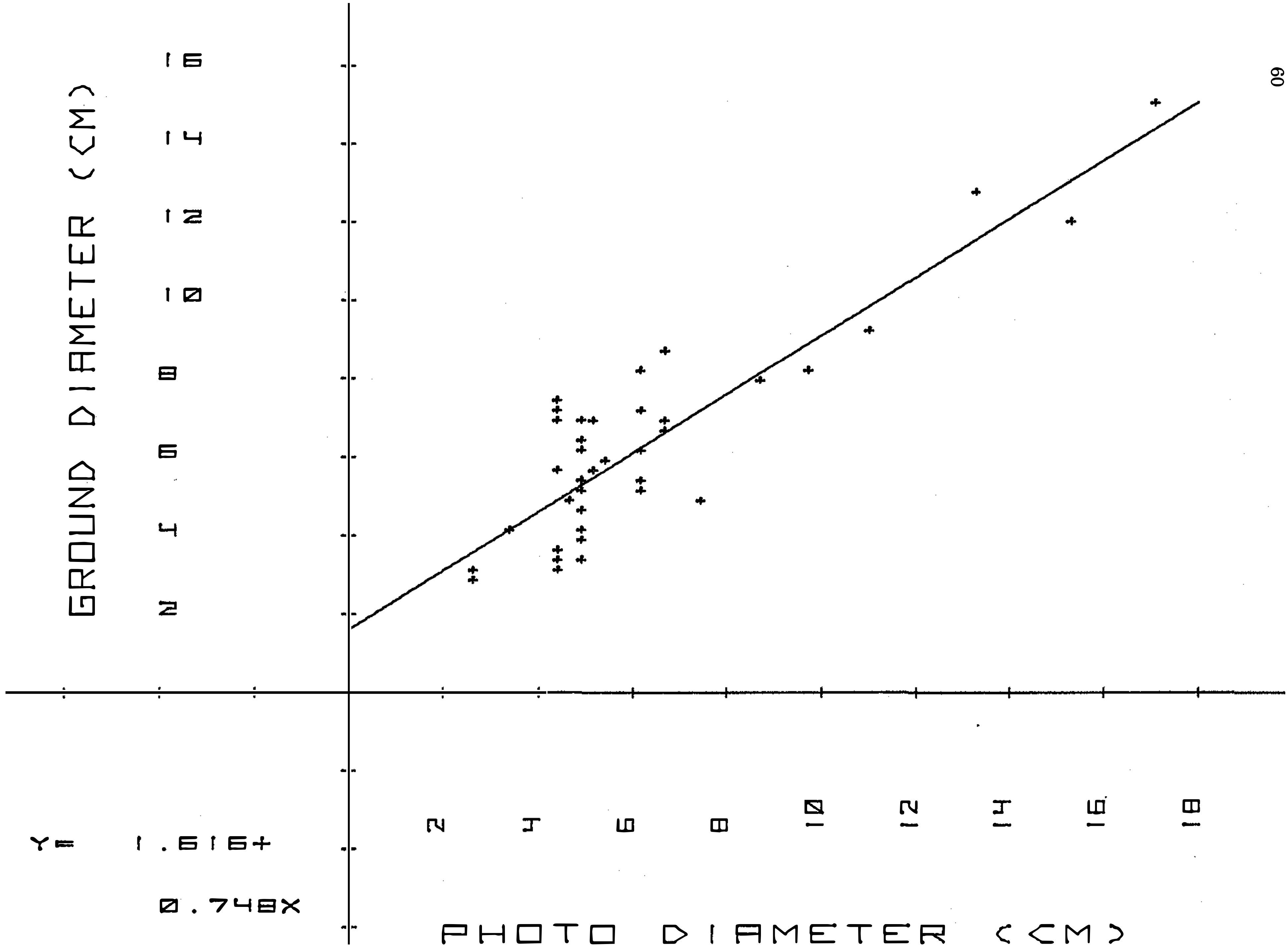

Figure 3. Photo-ground results (r^2 = 0.767, SE = 1.25, N = 43).

3. A slight loss in image sharpness occurred from the photos being slightly out of focus due to the low altitude from which the photos were being taken.

These problems affected the resultant piece count and the ability to obtain accurate photo measurements. Other possible problems were variations in photo scale due to steeply sloping ground (>40%) or large tips and tilts.

DISCUSSION AND CONCLUSIONS

From our studies of different scales and aerial films, we have concluded that using aero color negative film (with its high film speed and wide exposure latitude) in the spring before tree leafout and under high overcast conditions is most satisfactory at a scale of 1:500, with 1:2000 color infrared being obtained simultaneously. With a multistage sampling design, the smaller scale (1:2000) would be used for stratifying sampling units and for sample location. The larger scale (1:500) would then be used as the secondary sampling medium in actual sampling at the prescribed intervals.

Grass and tall regeneration (up to 1.5 m) were problems in that some measurements were hampered. Slight image fuzziness was also a problem that could have been rectified by flying at a higher elevation to obtain slightly smaller scale photographs (i.e., 1:500 instead of 1:220). Another solution would be to refocus the lenses for altitudes lower than 100 m.

Aircraft ferrying, the amount of area to be flown, the sampling plan, and the precision desired will greatly affect the cost of photography. At Hinton, Alberta, where no ferrying was required, the estimated cost of photography (including air time, aerial films, film processing, equipment charge, and wages plus expenses) would be approximately $36/line km for 50 line km (30 line mi)[1]. This cost was based on a flying altitude of 150 m above ground with sampling groups of four photos at 200-m intervals. With sampling groups representing photo plots, the cost of photography alone would be approximately $9/photo plot[1].

A hypothetical example showed the photo measurement rate for a photogrammetrist to be approximately 51 m/h[1]. Based on contract field work, production was calculated to be roughly 36 m/h[1,2]. Note that consideration must be given to fuel type, fuel loading, and the number of pieces to be tallied, since these will affect the production figure. As such, these figures must be taken only as estimates. The figures do seem to indicate, however, that large-scale photo sampling could be an efficient alternative to ground sampling.

The results have shown potential in wood volume estimation using low-level aerial photographs. Further testing and application are warranted and will be carried out in the near future.

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[2] Personal communication. D. Quintilio, Fire Research Section, Northern Forest Research Centre, Canadian Forestry Service, Edmonton.

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FUEL MANIPULATION IN RESOURCE MANAGEMENT

G.R. Fahnestock*

First, let's get away from the term "fuel management," which suggests that managing fuels is an end in itself. Actually, we manipulate fuels both as a result of and as a means of managing resources. I am indebted to Lou Egging, an industrial engineer at the Northern Forest Fire Laboratory (NFFL) in Missoula, for pointing this out. Secondly, I am not going to review studies at this point. Such a review presumably will be available in print from the Northern Forest Research Centre (NFRC) in Edmonton some time next year. I hope you will find it useful. Instead, I shall deal rather briefly with the kind of knowledge we have relevant to fuel manipulation and how we use it to enhance resource management.

Recognizing that fuel manipulation is an integral part of resource management puts one in the planning business right away. Principles and procedures of planning are well understood and extensively documented; at last year's Intermountain Fire Research Council meeting, Dick Barney (1977) ably explained the process of integrating fire into land use management. Bill Fischer (1977a, b) at NFFL has written a problem analysis and work plan for developing fuel management planning guidelines. I will not repeat what has been written already except to use the steps in planning as a framework on which to hang my own ideas.

The first step in planning is to identify issues, the second is to establish program requirements. For resource management on public lands, these steps are political: through some political process, or combination of processes, the public decides in general for what purpose a given land area shall be managed and, in more detail, what mix of products will be expected from it. "The Word" comes down to land managers in the form of laws, administrative regulations, quotas, etc. On private land the process is essentially similar but may be simplified by the owner's interest in a single output (e.g., timber) and complicated by conflict between the owner's goals and public constraints.

It would appear from the above that basic issues are defined and performance requirements established well in advance of any consideration of fuel manipulation. However, a concurrent stage of planning conditions the basic decisions. This is physical/biological situation assessment, or what can you realistically expect to accomplish in a given natural situation? Here we start to use what knowledge is available and to develop what is not. The information gathered for integrating fire into land use management provides much of the background for planning fuel manipulation, but there is a need to particularize and/or expand on the situation analysis, whose standard components are fire history, fire weather, fuels, and fire effects. Unfortunately, the treatment of these factors too often is more mere documentation than analysis. An array of facts and figures sanctifies certain conclusions but does not necessarily support them. Lots of knowledge is available; often it simply is not used right.

Fuel measurement and appraisal are obvious components of the situation analysis basic to fuel manipulation. We have a lot of information on these subjects. We especially possess good capability for estimating the weights of tree crown and hence of predicting the quantities of fine fuels created by cutting trees of all sizes. For this we are indebted to many people, including recently Jim Brown and associates (1977), John Muraro (1971), Dave Kiil (1968), John Walker and Bryan Stocks (1975), Paul Woodard (1974), and Dick Barney and Keith Van Cleve (1973). We

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know what fire behavior to expect in slash having various characteristics. I had the privilege of starting some of this line of work (Fahnestock 1960); Hal Anderson *et al.* (1966), Dick Rothermel (1972), and Frank Albini (1976) have refined it; but we have a much poorer understanding of crown fires that involve the same fuels arrayed differently.

We also now have a good capability for measuring dead woody surface fuels, for which we can thank mainly Charlie Van Wagner (1968) and Jim Brown (1974). Techniques for measuring herbage and brush are less standardized, but we can get at them. What about prediction of these natural fuels? Forget it for the immediate future. Ecologists and foresters somehow have embraced unquestioningly the premise that fuel builds up throughout the life of a stand and so fire hazard increases with stand age. This is one of the most erroneous generalizations that I know of. How do you square it with the low-low fuel-type rating (U.S. Forest Service 1968) long assigned to many types of old growth or with the huge accumulation of dead fuel that follows a single burn in most Rocky Mountain timber types and gradually becomes less hazardous with age (Wellner 1970)? The plain fact is that stand history is much more indicative of the fuel to expect than is stand age, although the two must be considered jointly. A further difficulty with respect to natural fuels is that deterministic means of assessing fire behavior (e.g., fuel and rate-of-spread models) do not work very well. The fuel beds and the weather surrounding them are simply too variable in space and time.

Even if we do measure or predict fuels and fire behavior accurately, how do we determine what to expect in the way of fire problems on a given piece of land? The all-too-common approach is to view with alarm, to assume that future fire experience will be a direct function of the predicted fuel hazard. But will it? Here is where study of fire history comes into the picture. During recent years I have found cause to consider that fire history, carefully compiled and rigorously interpreted, is the backbone of the situation analysis. Tremendous volumes of information are available, mainly from individual fire reports, covering enough years to support rather dependable statements of long-term expectations. A few brave souls, Jack Barrows (1951) in U.S. Forest Service Region I and Bob Miyagawa (1974a,b) in Alberta, have published regional analyses of fire statistics. Although monumental, these treatises are only a start toward the particularized analyses needed to support intelligent planning.

I know of little particularization of fire history with respect to fuels and fuel manipulation, but even this small amount leads to troublesome questions. More than 20 years ago Bill Morris (1955) reported that accidental fires in untreated logging slash in Oregon and Washington, except fires started by logging, averaged no larger than accidental fires in all other fuels. Last year I found that escaped slash fires accounted, on average, for more than half of the area burned on state and private land in western Washington. Is it possible that manipulation, in this case disposal, of slash fuel really accomplishes nothing or, worse, that manipulation by means of fire actually has a harmful effect? To date, foresters have not been willing to contemplate these possibilities; ultimately they must, or discredit themselves in the ever-more-probing public eye.

One may question whether history provides an adequate basis for predicting the future. I would reply that it can go a long way if we ask the right questions and really seek out the complex relationships of fire to fuels as modified by weather, topography, etc. The usual broad-brush fire history, though essential, is only a beginning.

The preceding may sound as if I am preparing to go on record against fuel manipulation. Not so; I merely insist that we must look much more critically and searchingly at the need for manipulation from purely the fire standpoint than most people have done heretofore. This is only a start, for fuel manipulation is potentially as important a tool for resource management as it is a protection measure. Unfortunately, resource managers are at the least as ignorant as protectionists of what they gain (or lose) through fuel manipulation. In the first place, they tend either to not recognize the change in fuels that resource management inevitably brings about or to shift responsibility for the consequences to fire management people. They know, for example, that complete cleanup of logging slash greatly speeds up planting, increases survival, and the like, but I don't think many can tell you their minimum requirements or put good numbers on the benefits. So when you get a handle on fire-fuel relations, you still have to work with resource managers to determine resource-fuel relations. Having done so, you are ready to formulate management objectives and strategies, evaluate the consequences thereof, and select the best alternative.

I am not a planner, but I perceive that a lot of interaction goes on between these stages of planning. Here is where consideration of that *ole debbil*, economics, comes in. I have been very disappointed that the forest residues research program at the Pacific Northwest Forest and Range Experiment Station has never seen fit to analyze the physical and economic impacts of residues and residue disposal. The residue manipulator is pretty much on his own in a field where hobby-riding, with respect to techniques, appears to be a virtue (at least, as regards favorable attention from one's superiors). It is the old fallacy that doing something, even though it be stupid and expensive, is better than doing nothing. Perhaps my printed review will contain something substantive in economics. For now, I will just counsel the use of a little common sense, such as, maybe you shouldn't spend X dollars on slash disposal if you could buy a slash-free parcel of equivalent land for less than X dollars.

The final outcome of planning is implementation, which provides feedback for updating and improving plans. I suppose it is unnecessary to say that planning is a continuing process. You seldom really start from square one, and you never reach a static destination. I have tried to indicate the kinds of knowledge you need in planning for fuel manipulation as an integral part of resource management, to point out some sources of information and how to use it, and to warn of gaps in knowledge and pitfalls in analysis. In retrospect, the effort doesn't look particularly brilliant, but I hope it stimulates a little thought.

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FUEL VARIATION IN THE NATURAL FIRE-CYCLED BOREAL FOREST

C.E. Van Wagner*

The material presented in this paper is drawn from one of the fire research studies at the Petawawa, Ontario, Forest Experiment Station; namely, an ecological study of fire in our boreal forest. The purpose of this work, in the official language of project statements, is "to provide a predictive fire effects input into forest management planning and fire management decision-making." In plain English, we want to find out what happens after the forest burns. This work has been going on for four years, and within another year or so my colleague Dr. Ian Methven and I expect to publish some of this information and our conclusions. I should also mention a piece of philosophy that is behind this work. We believe that fire behavior and fire effects work go hand in hand, each dependent on the other, so that by the time a study like this is complete, the degree of overlap is also nearly complete. The principal information coming out of such a study is about forest and vegetation development. For present purposes, consider the forest as fuel and how it affects fire behavior.

The key word here is "cycle." Our example is the central and eastern Canadian boreal forest, found in various phases from about the longitude of Edmonton, Alberta, east to the Atlantic Ocean. The two most prominent species are black spruce and jack pine, with attendant white spruce, balsam fir, tamarack, trembling aspen, and white birch. By and large, this forest exists as a patchwork quilt of different age classes and species, all dependent on periodic fire for disturbance and renewal. In most of this forest, the first generation of trees that arose after the last fire is still present at the time of the next one, so that true secondary succession is not common. Many fires do not kill all trees in the stand, but the general process involves wide-spread intense fire that kills all existing trees and sets the stage for a complete new single-age stand. Four of the major species—black spruce, jack pine, trembling aspen, and white birch—are ecologically equipped to spring back even after complete mortality over a wide area.

There are three major determinants of the fuel complex. The first of these is age-class distribution. In the natural state such a forest would tend to a negative exponential age-class distribution (Van Wagner 1978), with bulk of the area being of young and moderate age. Given effective protection for many decades, a bell-shaped distribution should result, with mature ages predominating. Once the forest is brought under management, the ultimate goal would be a rectangular distribution in which all ages up to specified rotation age would be equally represented. The age-class distribution is of interest to the fire control officer because it tells him the relative probability of fire in various ages of forest. Age is one of the three main determinants of fuel type and consequently of fire behavior.

The second major factor is site quality or habitat type. Most of the boreal tree species can be found on a wide range of sites, the forest floor and understory vegetation being quite different from one another. Even jack pine, with much less ecological amplitude than, say, black spruce, has many different characters, each representing, in a sense, a distinct fuel complex.

The third major factor is stand density. Especially in the conifer types of the natural boreal forest, the stocking of trees will depend on three things: the prefire forest; the moisture content and depth of duff at the

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time of the fire, which determines seedbed quality; and the postfire weather, which determines the rate of seedling survival. Not only is the crown structure of the resulting stand affected (by stand density, that is), but the surface vegetation also responds greatly to the degree of stand opening. Such variation is somewhat independent of site quality, so that any given forest generation between fires in a given place may be well or poorly stocked. Stand density, then, is the third major determinant of fuel complex and fire behavior.

What about the behavior of the fire itself? From our work on crown fires at Petawawa (Van Wagner 1977) we found that the crown structure of conifer stands can be used to judge how easily the stand will crown; young stands crown much more readily than old ones. Also, the intensity of the surface fire required to support a crown fire can be specified. The prediction of surface fire behavior is, in fact, probably more difficult than the prediction of crowning potential, because of the multiplicity of possible forest floor and understory fuel complexes. The problem of interacting fuel layers would be a major feature of complete fire prediction, the three main layers being forest floor, shrub-level vegetation, and the tree crowns themselves.

Two general conclusions may be drawn from these observations. First, fire behavior in this forest is not a simple function that rises with age since last fire. Fire behavior depends mainly on the quantity and arrangement of fine fuels; thus, the optimum condition appears rather early in the cycle, then falls off somewhat with age, increasing again as the stand breaks up. Secondly, this means that fuel buildup in the sense of straight fuel loading is something of a red herring in the fire-cycled forest. True, duff and large downed wood do increase greatly with stand age, but they are largely unavailable as fuels for the main fire front. This is not to say that they do not burn--indeed, they may smoulder away for some time—but they do not contribute strongly to fire intensity and area burned.

In fact, the complete comsumption of the duff layer is often a desirable feature of fire in this forest, both releasing mineral nutrients and providing a good conifer seedbed. According to our observations, the average stand density in much of the boreal conifer forest is a direct function of the proportion of duff removed during fire. One might say that, from an ecological point of view, the drier the better when the forest burns, which may be a paradoxical idea to some fire control people.

To sum up, we may say that on any given spot the fuel complex in this boreal conifer forest cycles from fire to fire, starting from an essentially fire-proof state, passing through one high hazard peak in early life, falling to a reasonably steady state in the mature forest, and rising again as the tree stand deteriorates. The full cycle may be cut short at any time by random fire and may differ considerably from generation to generation, depending on species and stand density. Fire behavior will vary accordingly. Figure 1 is a diagram of this proposed concept.

It is all very well to describe this whole process in a qualitative sense, but the real scientific challenge is to put it on a quantitative basis. This implies a model; however, the list of separate subprocesses is long, each with its independent and dependent variables and the functions linking them. We are not at all certain that a comprehensive model will be the final grand result of this and similar studies. If we can put logic and numbers to a few key features of what fire does in the boreal forest, that may be a sufficient goal for the present.

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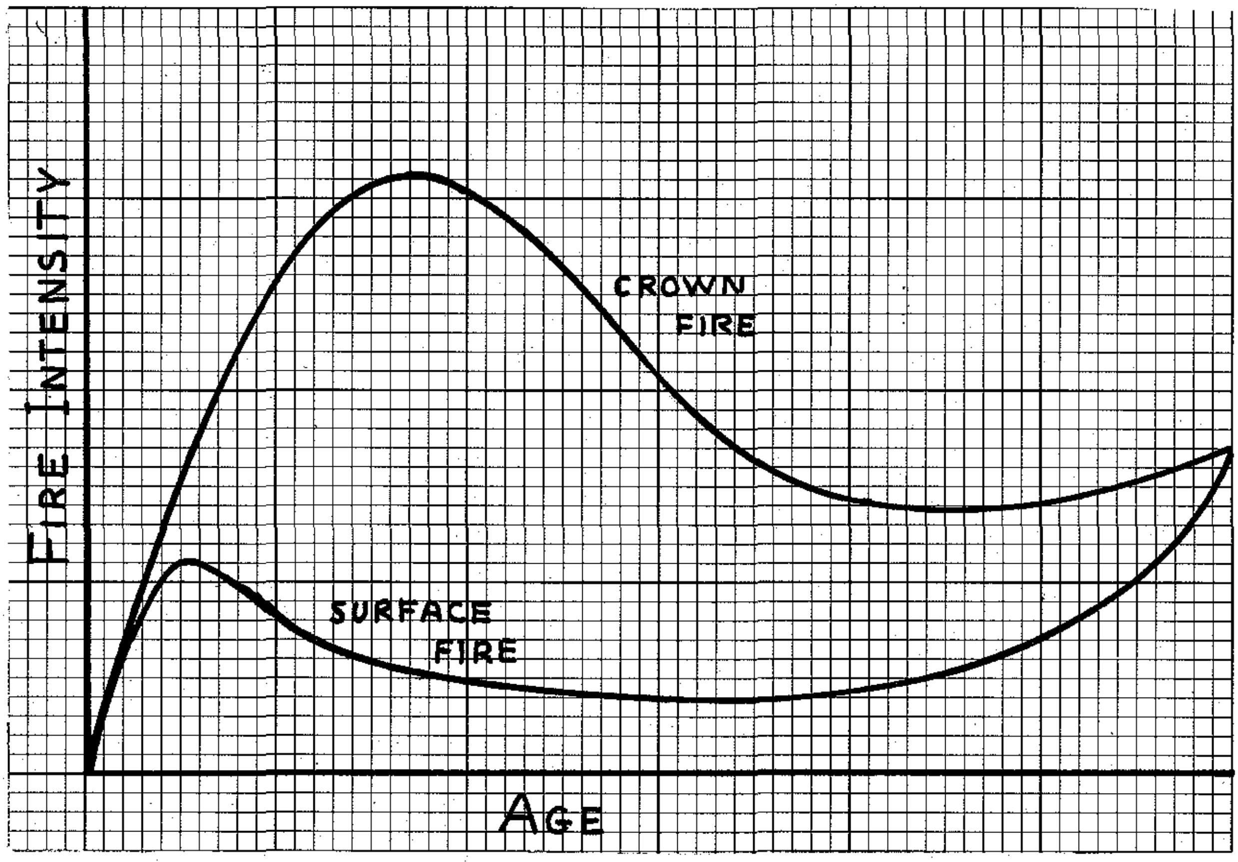

Figure 1. General scheme of fire behavior cycle in one generation of boreal conifer forest.

FIRE DANGER RATING APPLICATION TO INTEGRATED LAND USE PLANNING

H.W. Gray*

INTRODUCTION AND BACKGROUND

During 1976-77, the Slave Lake Forest prepared a Management Issues Report that outlined, in order of priority, all areas requiring integrated resource management planning. The Big Bend area was designated as the priority area for fire danger rating application to integrated land use planning in the Slave Lake Forest (Figure 1).

In late 1977 a planning proposal for the Big Bend study area was drafted. The proposal outlined the major problems, concerns, and aims of the planning process; designated the planning group; and identified the lead and data input agencies. The Forest Protection Branch was contacted in the initial stages to determine possible fire management inputs.

As the Big Bend study was the first concentrated effort at formulating an integrated resource management plan, little previous experience existed, especially with regard to fire inputs. Operational constraints and lack of clear guidelines for such an undertaking left the fire control section short of answers on how to approach the subject.

In September 1977 the planning section of the Forest Protection Branch became involved in investigating possible inputs. By December 1977 a simple guide was devised to provide the evaluation of potential fire danger represented by the various management options in Big Bend.

SYSTEM VALUE

The final danger rating system is considered to be a broad, stage one planning guide. The guide identifies potential danger and/or need for specific stage two planning. Such a system is not designed to be used in determining the uses of particular lands but is a guide to the wise development of integrated uses.

The guide has two primary values:

1. It aids initial planning by identifying specific fire problem areas when high-risk uses are contemplated in high-hazard fuel types. Where options exist, the guide would help in selecting alternatives.

2. The guide provides the operational protection group with a quick evaluation of areas where fire danger will result from a particular management decision. Such a flagging of potential trouble spots allows for advanced operational planning.

For low and moderate danger, slight adjustments to existing organizational procedures may be adequate. In cases of high to extreme danger, specific stage two operational plans (e.g., prevention, preattack, etc.) may have to be developed.

SYSTEM DEVELOPMENT

A system was required to provide the resource management planners with fire management information. The system had to provide a simple procedure for evaluating the interaction between the risk created by a specific land use and the existing fuel hazard in the study area.

The following steps were taken in developing a final fire danger chart:

1. All man-caused fire data from the four southern Slave Lake Districts for 1971-76

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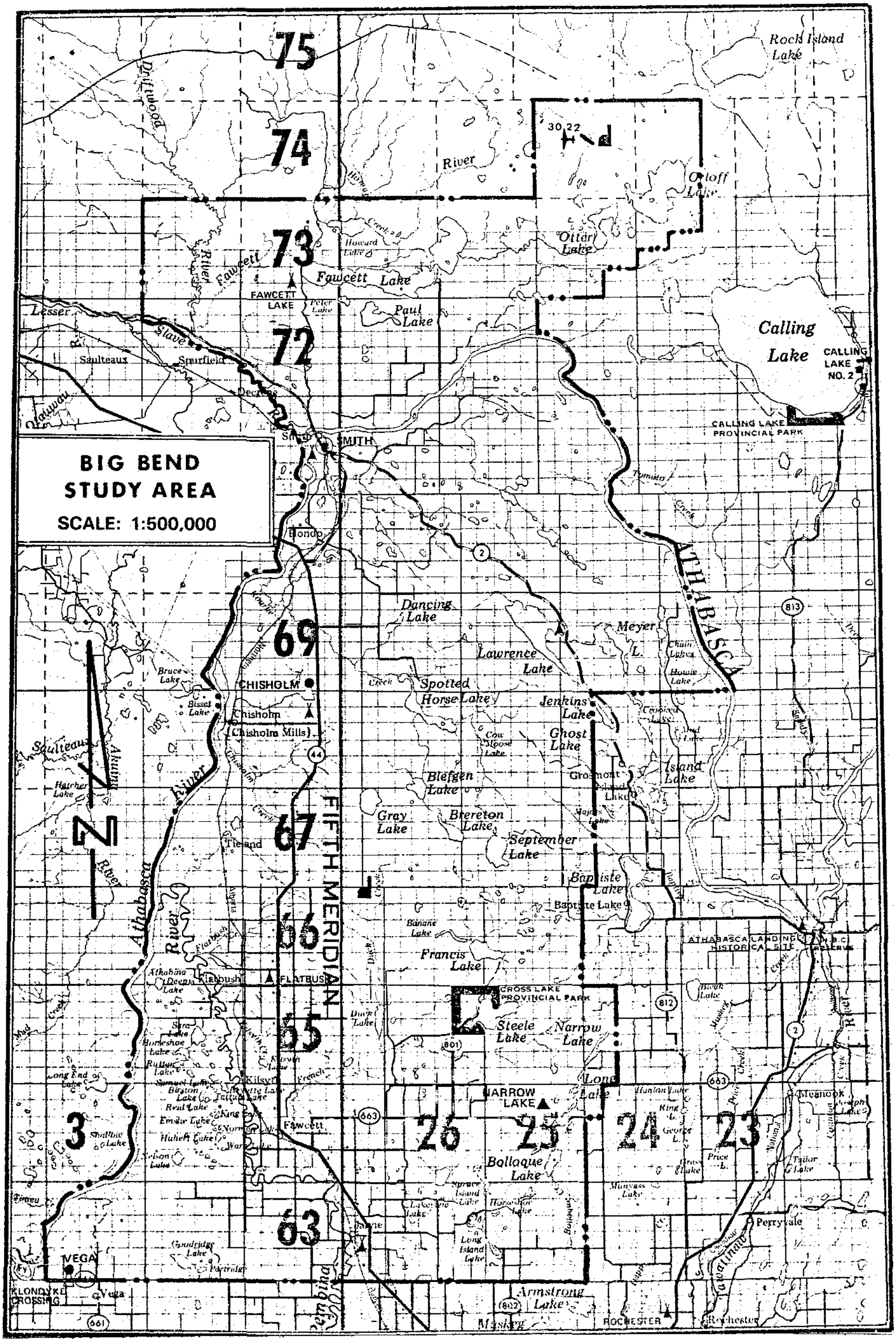

Figure 1. Slave Lake Forest priority planning area.

was gathered and classified by cause. All fire causes were subjectively related to specific potential land uses in the Big Bend area (Table 1).

2. All man-caused fire data from the four north central forests (Lac La Biche, Slave Lake, Whitecourt, and Peace River) for 1971-76 was gathered and classified. This data was compared with that in step 1 to determine if local incidence trends were following the larger pattern or if they were unique (Table 2).

3. Slave Lake data proved to be consistent with provincial trends and was selected as the basis for establishing a risk rating. The risk classes were based on the percentage of fires caused by a particular activity. For example, an extreme risk was assigned any use which caused more than 9.1% of man-caused fires in Slave Lake (Table 3).

4. A point rating of 0-100 was used for the risk-rating component (Tables 4 and 5).

5. A timber-type map at a scale of 1 inch = 1 mile was color coded based on a subjective estimate of the fire hazard represented by various types.

6. Five broad fuel complexes were recognized in the Big Bend area:

   a. Black spruce—slow growth types.
   b. Coniferous—SW.
   c. Mixedwood.
   d. Brush, grassland, sparsely treed muskeg.
   e. Deciduous.

7. A point rating system of 1-16 was used for the hazard-rating component (Table 6).

8. The fuel hazard was assessed based on a standard summer high-hazard day due to our extreme spring hazard conditions. During spring (May 1-June 15) all types are considered high-extreme.

9. The fuel hazard and risk components were then combined into a fire danger chart. With known use (risks) and existing fuel type in the study area, the fire danger can be determined quickly by either the resource management planners or fire operation staff (Table 7).

CONCLUSION

This guide was a first attempt in Alberta to have fire management input in an integrated land use plan. Although designed specifically for the Big Bend project, because of short notice it lacks detail and several desirable components.

Such a simplified system will require a great deal of refinement to become a more comprehensive fire management input to integrated use planning; however, this system serves as a good starting point.

Table 1. Man-caused fire data summary sheet for Slave Lake Forest (DS1-4), 1971-76.

	No. of fires	Percentage of total
Settlement agriculture		
Land clearing	11	5.7
Grazing pasture land	10	5.2
Grazing reserves	3	1.6
Grazing leases	7	3.7
Residence-country	3	1.6
Established farms (maintenance)	3	1.6
Towns, hamlets, settlements	60	31.4
Woods industry		
Developmental clearing	1	0.5
Mill operations	5	2.6
Woods operations	6	3.1
Transportation & related access		
Railroad	2	1.0
Highway & related access construction	10	5.2
Highways, maintenance, repairs & access related	8	4.2
Power lines	14	7.3
Recreation		
Day use	8	4.2
Overnight camping & hiking	24	12.6
Fishing	3	1.6
Hunting	3	1.6
Back country use	1	0.5
Group camping	2	1.0
Lodges	1	0.5
Oil & gas industrial		
Oil, gas, geophysical, pipeline clearing	4	2.1
Oil & gas well, pipeline operation & maintenance	2	1.0
Trapping	0	0
TOTAL	191	99.8

Table 2. Man-caused fire data summary for four settlement (northern) forests—Whitecourt, Slave Lake, Lac La Biche, Peace River, 1971-76.

	No. of fires	Percentage of total
Settlement/agriculture		
Grazing pasture land	78	7.1
Land clearing	147	13.4
Grazing reserves	35	3.2
Grazing leases	45	4.1
Country residences	20	1.8
Established farms (maintenance)	36	3.3
Towns, hamlets, settlements	146	13.3
Woods industry		
Developmental clearing	13	1.2
Mill operations	29	2.6
Woods operations	23	2.1
Transportation & related access		
Railroads operation & maintenance	31	2.8
Highways & related access construction	48	4.4
Highways maintenance & access related	30	2.7
Power lines	47	4.3
Recreation		
Day use	71	6.5
Overnight camping & hiking	116	10.6
Fishing	30	2.7
Hunting	35	3.2
Back country use	10	0.9
Lodges	12	1.1
Oil & gas industrial		
Oil, gas, geophysical, pipeline clearing	27	2.5
Oil & gas well, pipeline operation & maintenance	13	1.2
Trapping	6	0.5
TOTAL	1073	98

Table 3. Point & class assignment for the uses (risks).

An extreme risk is any use that caused more than 9.1% of the total man-caused fires occurring in the Slave Lake Forest.

Very High	6.1-9%
High	3.1-6%
Moderate	2.1-3%
Low	1.1-2%
Very Low	0-1%

Table 4. Risk rating system.

Extreme	81-100
Very High	61- 80
High	41- 60
Moderate	21- 40
Low	11- 20
Very Low	1- 10

Table 5. Summary of fire causes by descending incidence for Slave Lake (DS1-4) and risk rating factor.

Risk		Risk factor
Extreme	1. Towns, settlement related	95
Extreme	2. Overnight camping and hiking	81
Very High	3. Power lines	70
High	4. Land clearing	60
High	5. Other graying Pri land	55
	Highways and related access construction	55
High	6. Highways maintenance and related access problems	50
High	7. Grazing leases	45
High	8. Woods operations	41
Moderate	9. Mill operations	35
Moderate	10. Oil, gas, geophysical, pipeline clearing	30
Low	11. Grazing reserves	15
	Country residences	15
	Established farms (maintenance)	20
	Fishing	12
	Hunting	12
Very Low	12. Railroads operation and maintenance	10
	Group camping	8
	Oil and gas well, pipeline operation and maintenance	8
Very Low	13. Lodges	2
	Back country use	2
	Developmental clearing woods industries	2

Table 6. Fuel hazard rating system.[1]

Extreme	16	Black spruce—slow growth
Very High	8	Coniferous
High	4	Mixedwood
Moderate	2	Brush, grassland, treed muskeg
Low	1	Deciduous

[1] Based on premise that each increase in hazard level doubles the potential; e.g., black spruce is 16 times as hazardous as the deciduous species.

Table 7. Fire danger rating Big Bend area, Slave Lake.

Fuel	Fire risk index					
hazard	1-10	11-20	21-40	41-60	61-80	81-100
1	VL	L	L	M	M	M
2	VL	L	M	H	H	H
4	L	L	M	H	VH	VH
8	L	M	H	VH	VH	E
16	M	H	VH	VH	E	E

E = extreme. M = moderate.
VH = very high. L = low.
H = high. VL = very low.

FIRE MANAGEMENT IN NATIONAL PARKS

Dennis E. Dubé*

The role and impact of fire in national parks are receiving considerable attention by researchers and managers engaged in the development of overall resource management plans for individual parks.

Parks Canada and the Canadian Forestry Service are actively involved in fire-related studies in several national parks. The underlying rationale for these studies is based on the general recognition that fire has significantly influenced the development and maintenance of most vegetated landscapes within the parks. In many instances, the natural fire cycle has been obscured by man's intervention. Fire exclusion due to successful control practices or, conversely, an increase in fire occurrence because of human carelessness in time will alter dramatically plant and wildlife communities to something quite different from those which would occur under a natural fire regime. In any event, the present vegetation complex reflects the past fire regime.

Observations of the gross vegetation mosaic, stand age structure analysis, and fire scar work along with an examination of written fire records all aid in deciphering the fire history of a particular park.

Knowledge of the natural and historic role of fire provides park managers with needed background and perspective. However, an understanding of fire behavior is also required in making sound fire management decisions.

A major parameter influencing fire behavior is the amount of available fuel, including its size-class distribution and horizontal and vertical arrangement within a forest stand. A quantitative assessment of fuels in different vegetation types varying in age and structure, when considered in conjunction with weather variables and physiographic influences, will provide information required in developing management guidelines and prescriptions for both naturally occurring and prescribed fires.

Fire history and fuel information is currently being gathered in Nahanni and Wood Buffalo national parks. At the same time, biophysical land classifications are nearing completion for each park. These data will serve as the basis for developing operational fire management plans that should be effectively tailored to complement and support other aspects of overall park planning.

Although data is still being analyzed, preliminary findings indicate that fire has long been an influential factor in Nahanni Park. Several observations indicate that fire frequency and area burned are highest on the south- and west-facing slopes, although the north- and east-facing slopes also show common evidence of fire occurrence. Larger fires have occurred in the broad glacier-scoured valleys of the Flat River and South Nahanni River above Virginia Falls. Below the Flat/S. Nahanni confluence the rugged topography breaks up fuel continuity, resulting in fires smaller in size though much in evidence. Although some fire scars are still being confirmed, 70-75 different fire years have been documented for 1813 to 1977, indicating a forest fire somewhere within the park approximately once every 2 years.

Stand origin data will provide additional fire years that will increase past fire frequency estimates throughout the park. It should also be noted that time spent in the park (20 days) was relatively short and that

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many areas of past fire were observed from the helicopter but unfortunately were inaccessible. Also, large intense fires in the past would eliminate evidence of earlier fires, and light surface fires may not leave any obvious evidence. These considerations suggest that fire has occurred much more frequently in the past than the data indicate.

In 1978, dead, surface, woody fuel was measured in 20 stands using the line-intersect method. Density, frequency, and basal area were determined for the living stand by the point-centered quarter method. Stand origin and depth of duff were also recorded. The weight of dead, surface, woody material ranged from 0.12 t/ha in a 198-year-old white spruce stand to 47.3 t/ha in a 33-year-old lodgepole pine stand. Generally, stands of an intermediate age, (25-60 years) contained the most down and dead, surface, woody material. These stands originated after fire, and the fuel now on the ground represents the fire-killed stems of the prefire stand uprooting and falling to the ground. In younger stands this has not occurred yet, while in much older stands fallen stems have since decayed or are covered with a moss or lichen carpet. Fire hazard is likely greatest in intermediate-aged stands due to the heavy surface fuel loading.

Fuels and fire history data, when considered with climatic and topographic variables, will provide the park manager with some tools required to determine fire hazard, fire danger, and fire effects within the parks and should aid in the development of overall resource management plans.

FIRE HISTORY AND FUEL APPRAISAL OF KANANASKIS PROVINCIAL PARK PART I

Brad C. Hawkes*

INTRODUCTION

Peter J. Murphy and I were contracted by Alberta Provincial Parks to do a fire history and fuel appraisal study of Kananaskis Provincial Park. Our proposal to Provincial Parks emphasized that detailed knowledge of fire history, fuel loading, and flammability are essential in preparing a fire management plan.

The objectives of this study were to

1. document the fire history
2. determine fuel loading, flammability, and resistance to control using hand tools for selected fuel types, and
3. provide recommendations for fuels and forest fire management in Kananaskis Provincial Park.

LOCATION OF STUDY AREA

The research area is 141 km (76 mi) southwest of Calgary. Kananaskis Provincial Park includes the main valley around the Lower and Upper Kananaskis Lakes up to the Opal Range on the east, the Upper Kananaskis River and Three Isle Creek drainages, the Smith-Dorrien Creek drainage, and the area around Burstall Lakes (Figure 1).

The Park encompasses 508 km^2 (196 mi^2), and there are approximately 236 km^2 (92 mi^2) of forest in the study area.

FIRE HISTORY

The fire history of Kananaskis Provincial Park is not as complex as that of lower-elevation montane forests in the Rocky Mountains. The area east of Lower Kananaskis Lake (facility zone) is covered by extensive tracts of even-age lodgepole pine regeneration as a result of fires in 1920, 1890, and 1858 (Figures 2, 3, and 4). Most fires in Kananaskis Provincial Park were large (+1000 ha) and of medium to high relative fire intensity (derived from height of fire scars, type of stand replacement, and more recent fire reports). The park has a catastrophic fire regime where "natural" fires are usually conflagrations, killing the overstory and understory of the forest. Low-intensity surface fires usually have occurred on the edges and backing sections of large fires.

The results indicate that the park has had 11 major fires since 1712, with an average of 21 years between fires. A total of 17 fires occurred from 1712 to 1920, with a mean fire return interval (MFRI) of 14 years and a range of 3-38 years. The last major fire was in 1920.

The total number of fires since 1712 and the MFRI's for four areas of Kananaskis Provincial Park are listed in Table 1. The lower Kananaskis Valley has had over twice the number of fires as the other areas. This area is where all the park facilities are being built.

Burn direction of major fires in the lower Kananaskis seems to be related to the prevailing wind patterns (Figure 5). Most fires have burned through the area east of the Lower Kananaskis Lake. Fire reports of more recent large fires in the Kananaskis Valley indicate that spotting can occur up to 5 km (3 mi) ahead of the fire. This kind of fire behavior expected from large fires in Kananaskis must be reckoned with by resource planners in developing the valley.

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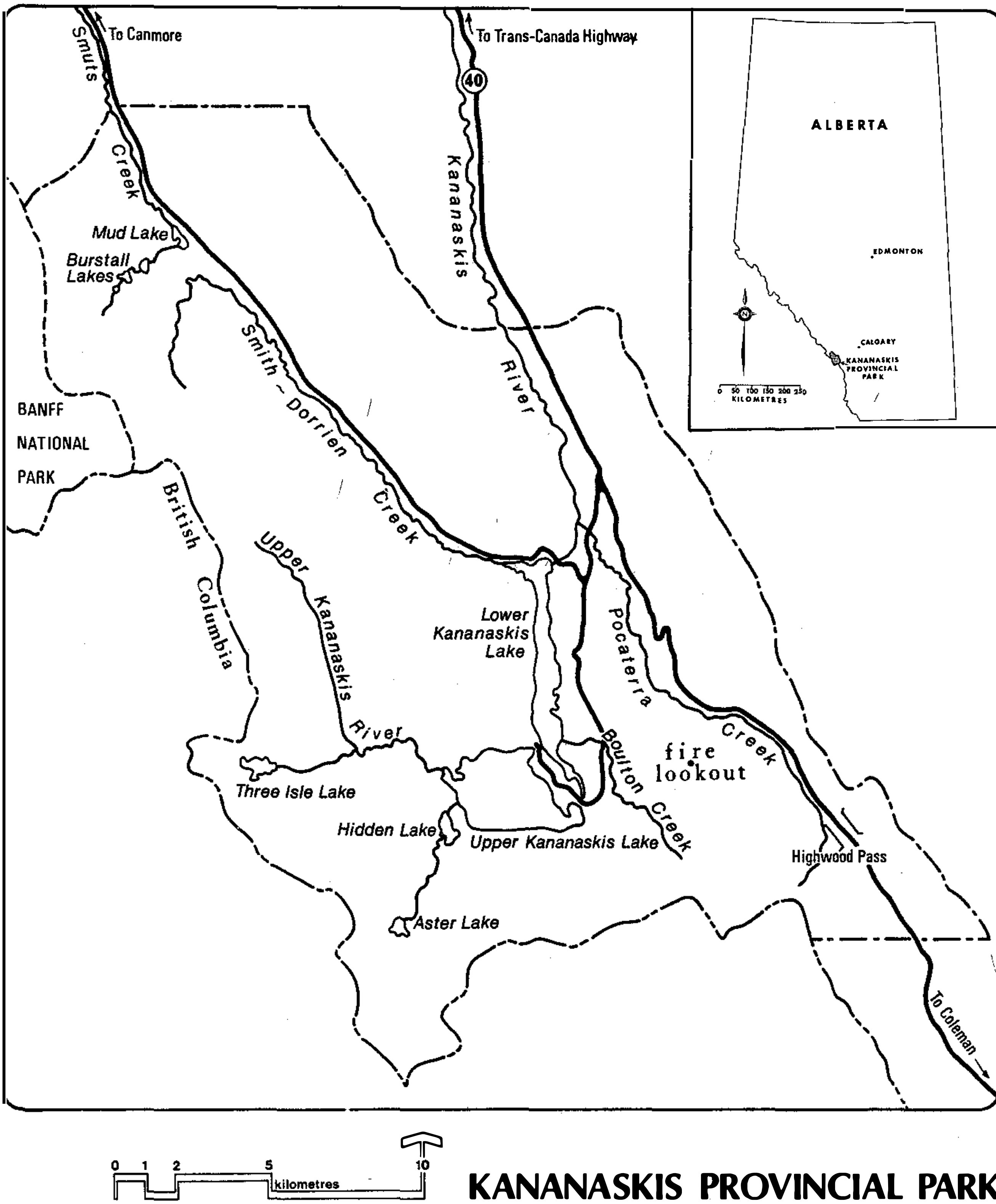

Figure 1. Location of study area.

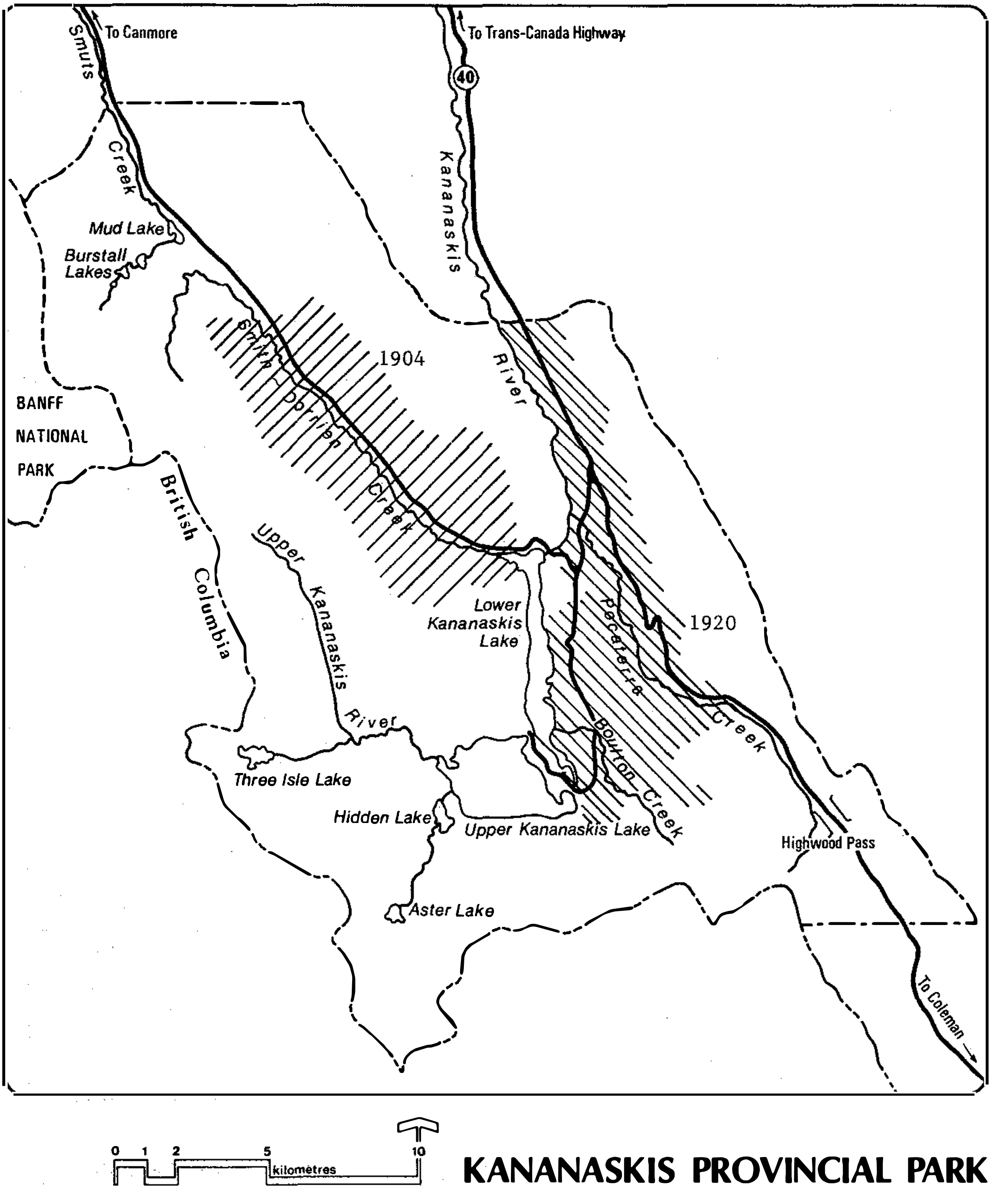

Figure 2. Areal extent of the fires between 1891 and 1920 in Kananaskis Provincial Park.

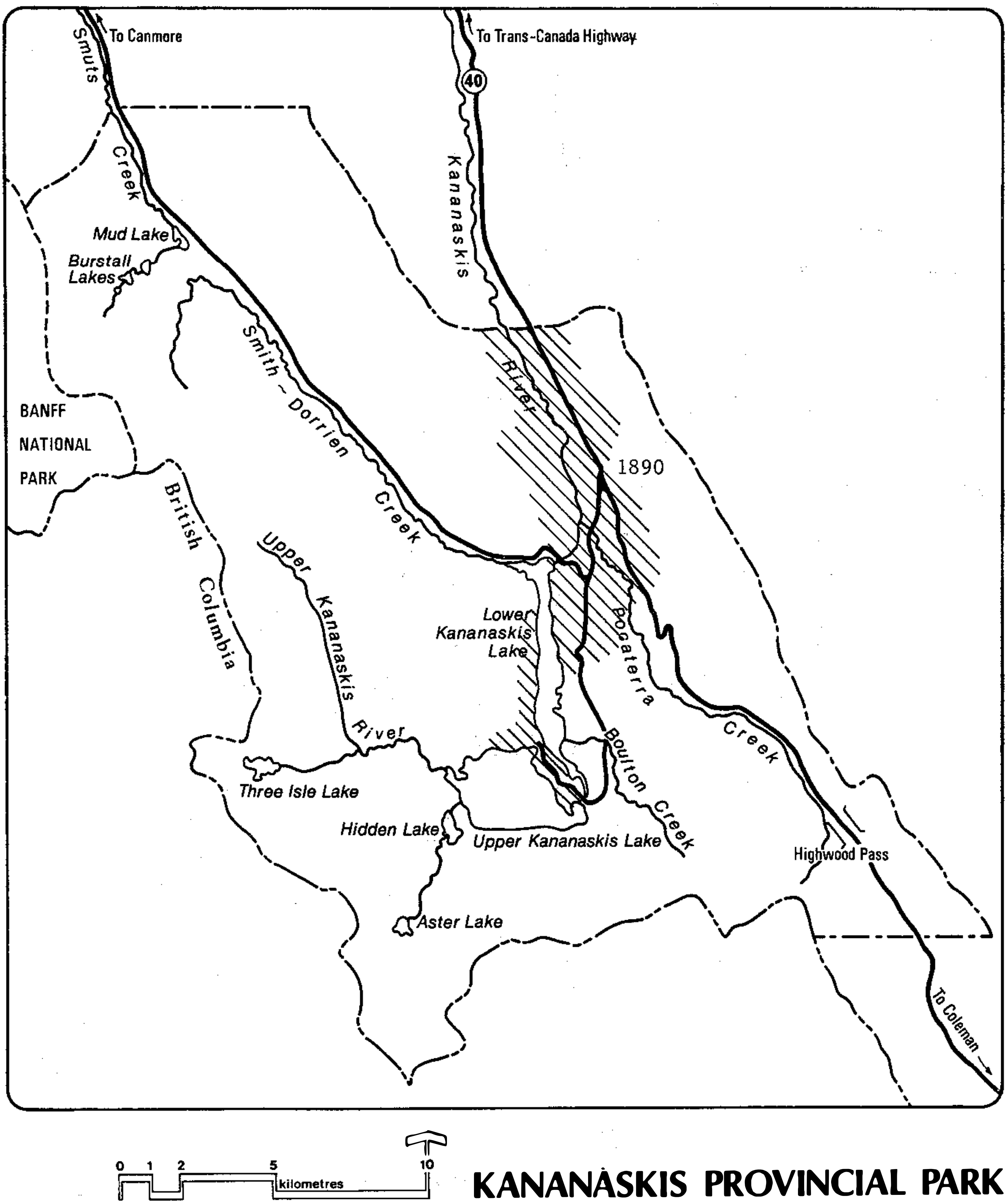

Figure 3. Areal extent of the 1890 fire in Kananaskis Provincial Park.

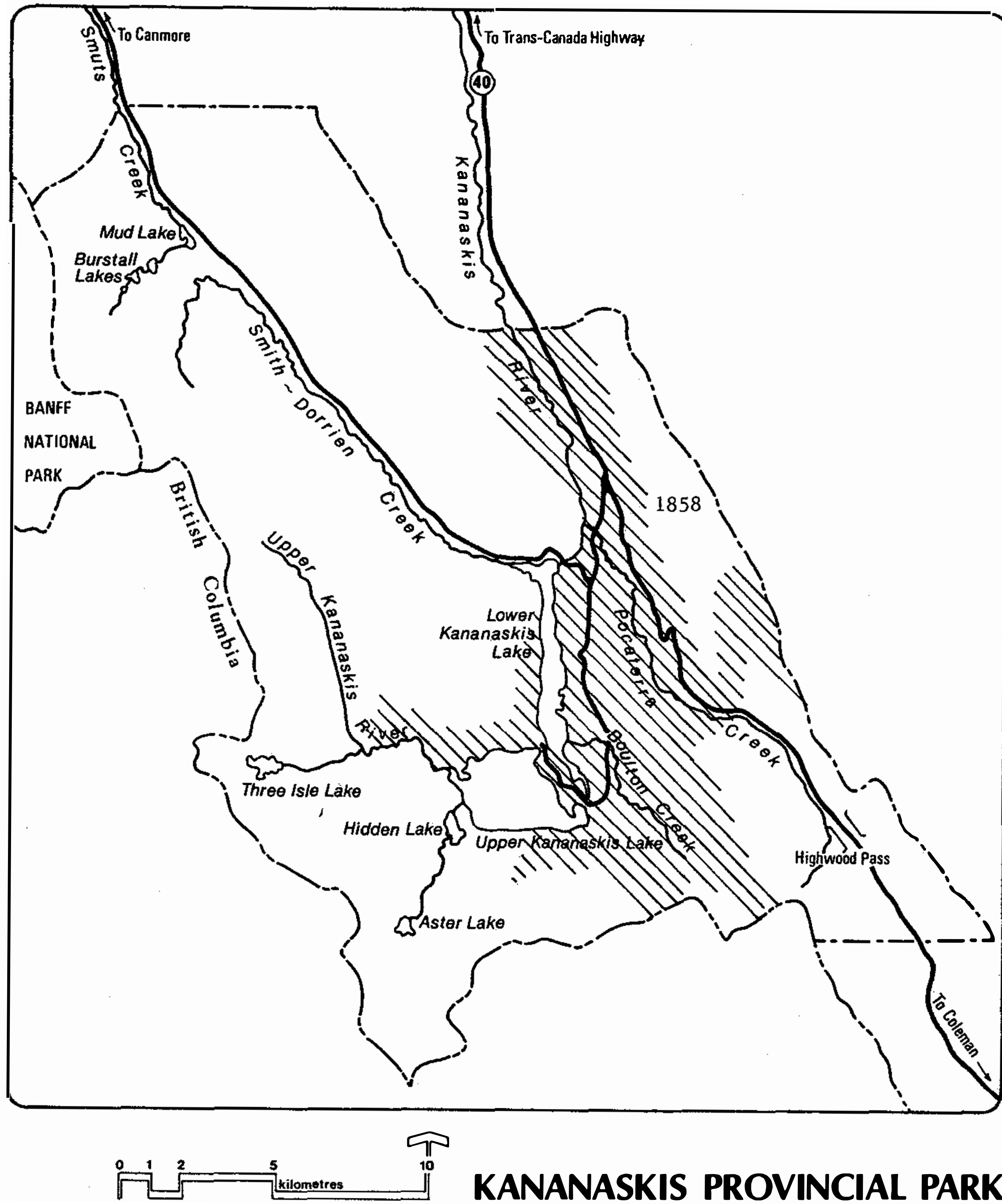

Figure 4. Areal extent of the 1858 fire in Kananaskis Provincial Park.

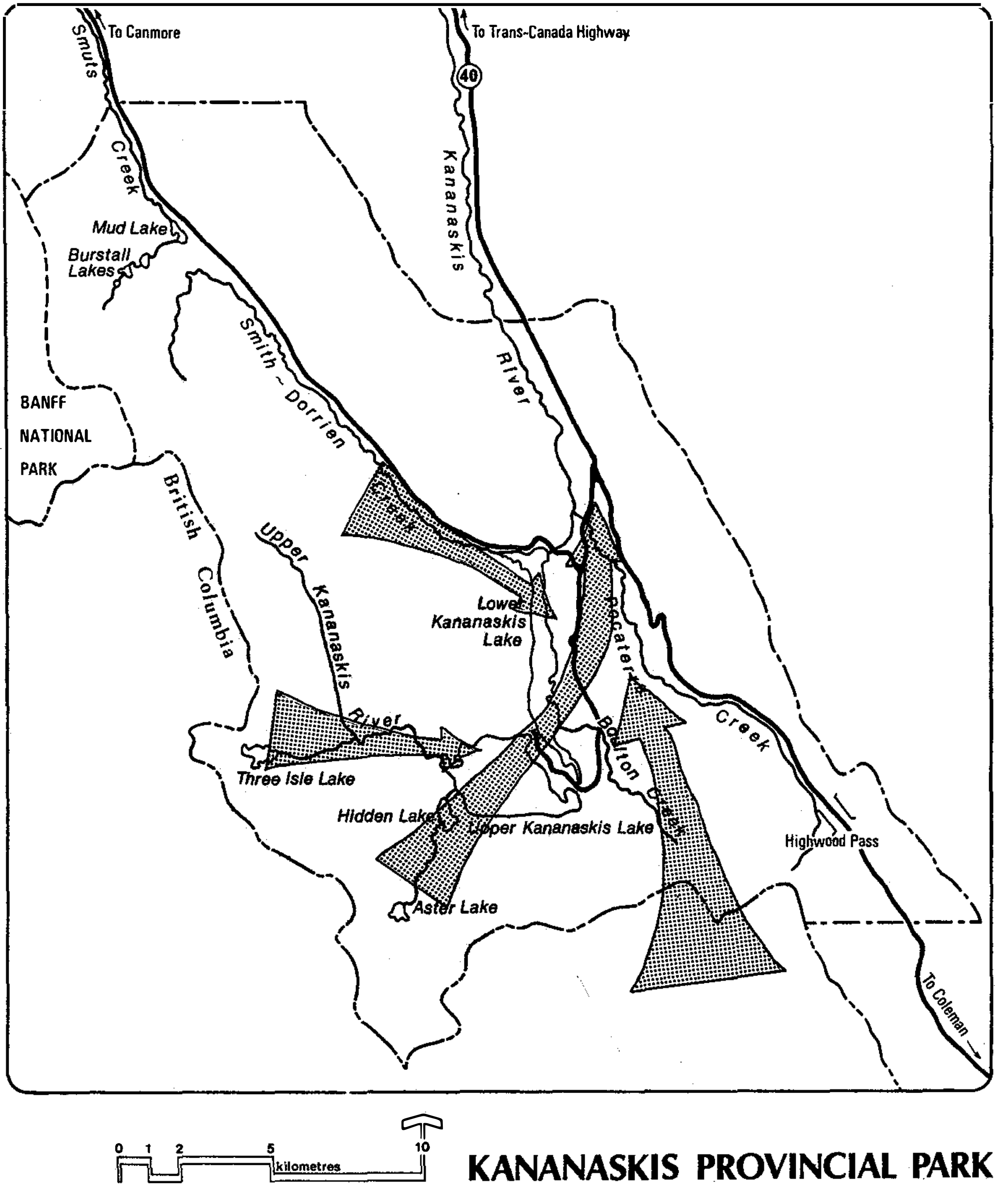

Figure 5. Prevailing wind patterns for July and August in Kananaskis Provincial Park (from Kananaskis Lookout records, 1966-71).

Table 1. Total number of fires since 1712 and mean fire return intervals for four areas of Kananaskis Provincial Park.

	Smith-Dorrien	Upper Kananaskis	Pocaterra	Lower Kananaskis
Number of fires since 1712	6	6	6	14
Mean fire return interval (years)	52	48	42	17

FUEL APPRAISAL

Thirteen fuel types were identified in Kananaskis Provincial Park. Fuel types were stratified on the basis of differences in stand tree density, age, plant species composition, amount of dead and down material, presence of ladder fuels between the ground fuels and the tree crowns, and development of the shrub layer.

Three fuel types cover most of the development area east of Lower Kananaskis Lake (Figure 6). They all resulted from the 1920 fire but vary in fuel loadings, fire hazard, and fire history.

Type 1 is located at the north end of the facility zone. It has an open appearance with little dead and down material and a well-developed shrub layer. I have rated this fuel type low in terms of initial rate of spread, crowning potential, and resistance to control. This area has experienced three fires in the past 120 years.

Type 2 is the most widespread over the lower Kananaskis Valley. It includes 1920- and 1890-origin lodgepole pine with a dense appearance, medium amount of dead and down fuel, and a poorly developed shrub layer. It has a moderate crowning potential but high initial rate of spread and resistance to control. This area has experienced two fires in the past 120 years. There are some localized areas of blowdown occurring, which will need some attention.

Type 1A occurs in localized areas such as the new Elkwood campground area. This fuel type has a low crowning potential, similar to type 1, but when the heavy loadings of dead and down fuels are considered, crowning potential would increase under extreme fire hazard. It has a high resistance to control and initial rate of spread. This area has experienced only one fire in the past 300 years.

Under extreme fire weather conditions, many of the differences in the amount and arrangement of fuels between fuel types might be considered academic. They do provide a relative scale which under low to high fire weather conditions will help in fire management planning and its incorporation into the overall resource management plan.

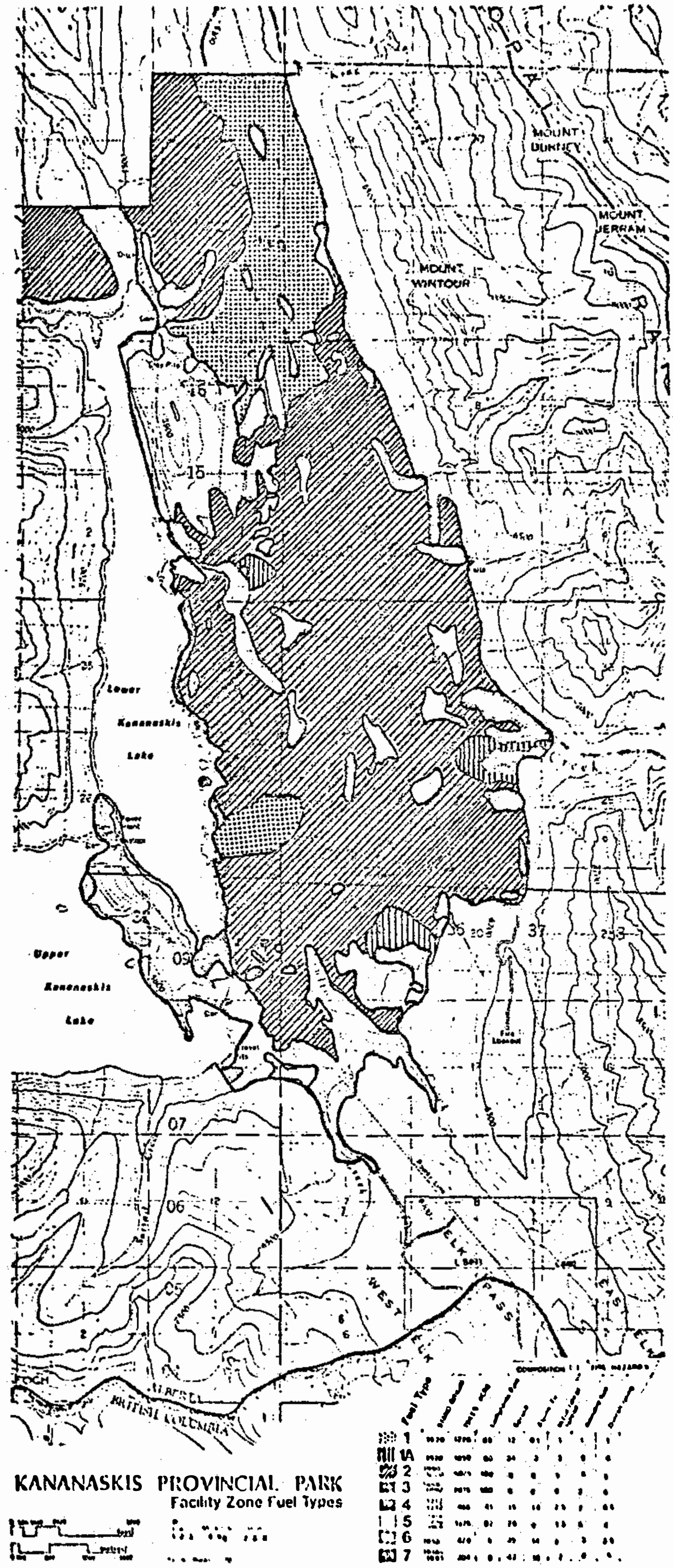

Figure 6. Areal extent of fuel types 1, 1A, and 2 in the facility zone of Kananaskis Provincial Park.

FIRE HISTORY AND FUEL APPRAISAL OF KANANASKIS PROVINCIAL PARK PART II

Melanie Miller*

The fire history and fuels data certainly have implications for resource management and park planning in the Kananaskis Park. In the long run, we would like to let ecosystems run themselves, and that can mean allowing wildfires to burn in areas where they will be contained by topography and will not threaten other park values. Natural fire planning will require the collection of several years of weather data in remote areas of the park. The range and variation in fire hazard can then be related to the fire history and fuels information.

Prompt initial attack will remain the rule in the area east of the Kananaskis Lakes, the part of the park in which visitor use and facility development will be concentrated. This relatively flat land has the highest fire incidence and largest fire size, and fires have usually killed much of the stand. Much of the area now has a moderate to high rating for initial rate of fire spread, moderate dead and down woody fuel loadings, and some potential for crown-fire development. Crowning potential will increase dramatically with high wind speeds.

Two major campgrounds will be located east of the lakes, along with several day-use areas, group camps, and a special user facility for handicapped people. Wooden buildings with cedar shake roofs are the standard for Kananaskis Park. Man-caused risk will drastically increase because of the influx of park visitors. We thus have a classical conflict in that Parks administrators will be putting people and facilities into a fire-prone forest and hoping that it does not burn down.

An initial attack crew is stationed at present in the Kananaskis Valley, and fire equipment is available in the park. Some park staff have had some fire training. However, protection alone is not adequate, considering the high-hazard situation and the values at risk. Much more in the way of fire management planning is necessary. We must be better prepared for that inevitable day when a fire will start after a long, hot, dry spell in August.

A preattack plan will increase the probability that a fire will be controlled when small. Such a plan would locate natural barriers to fire spread; optimum sites for control lines, such as existing roads and trails that can be used as bases for burnout operations; water sources; and other fire control facilities. Prefire planning should make provision for additional training of park fire crews and detail an evacuation plan for park visitors. Parks should develop an administrative mechanism to speed the implementation of restrictions on open fires or park closure in the event of extreme fire hazard, with decisions pegged to values of the Fire Weather Index. Parks interpretation personnel should plan programs to increase visitor awareness of fire hazard.

Fuels management in Kananaskis can do much to reduce the danger to park visitors and facilities in developed areas of the park. However, it is not feasible to manage fuels throughout the entire facility zone. Prescribed burning for fuel reduction would be the cheapest method but would likely kill much of the lodgepole pine overstory. Mechanical treatment would be very expensive. Fuel breaks would have to be extremely wide to prevent crown-fire spread through the forest, with their effectiveness limited by the potential for spotting as much as 5 km (3 mi) ahead of the fire front.

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We should modify fuels in the vicinity of heavily used areas with two objectives in mind: to reduce human-caused risk, and to lessen the hazard to facilities from crown fires moving in from the adjacent forest. Hazard from the human element can be reduced by removing fine fuels, thereby limiting the potential for ignition by tossed cigarettes or other carelessness and increasing the probability that a fire can be controlled once started. Park visitors will use fine fuels for kindling and rapidly clean out the understory in certain intensively used areas. However, fine fuels along roadways, major trails, and other facilities should also be removed. Construction debris from major roads and access roads to recreational facilities should also be removed or chipped.

Crown-fire potential can be reduced in stands adjacent to facilities by thinning, limbing all dead and some lower tree branches, removing ladder fuels and dead branchwood, and thinning any thick stands of brush. A thinned stand would grow more quickly, be more aesthetic, and likely have greater wildlife values.

We should remember the forest fire hazard when locating and designing facilities. Steep slopes and other areas with potential for extreme fire behaviour should be avoided. Facilities should be sited in vegetation types with relatively low fire hazard and resistance to control. Separate entrance and exit roads should be constructed at campground, day-use, and administrative areas to increase the speed of evacuation. Building construction should reflect the forest fire environment, with fire-resistant roofing materials as a minimum. It is a lot more difficult to get a slate-covered roof to burn than it is to ignite cedar shakes.

We must consider these things now. Prefire planning and fuels management should be an integral part of resource and development planning for every park and recreation area within a wildland forest. People who prefer the ostrich approach to fire hazard should remember California, where in the fall of 1978 millions of dollars of poorly sited houses within a highly flammable fuel type went up in smoke. People have said that it cannot happen here, and I agree that chaparral is different from lodgepole pine, but consider a subdivision just outside Missoula, Montana, which illustrates my point.

A fire started in grassland on a hot, windy July afternoon and raced up a hill into a Douglas-fir, western larch, and ponderosa pine forest. Initial attack was unsuccessful because the fire moved too quickly. The raging crown fire burned 1200 acres of forest and grassland in several hours and could only be controlled after cool, rainy weather set in the next day. Some houses survived the fire, probably because they were located in forest clearings or because understory vegetation or stands of coniferous reproduction were absent. However, six houses worth about $300 000 were burned. Miraculously, no one was hurt.

The government of Alberta is spending $40 million on recreational development in Kananaskis Park and the adjacent 2880 km^2 (1800 mi^2) of Kananaskis Country. I hope my example reminds us of the risks involved and makes us more aware of the prefire planning that is needed.