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Forest Fire Research in the Canadian Forestry Service

C.E. Van Wagner

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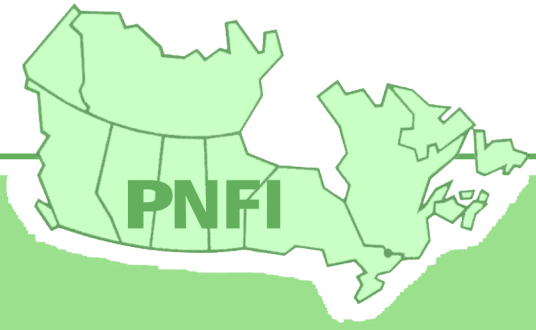
Petawawa National Forestry Institute



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PETAWAWA NATIONAL FORESTRY INSTITUTE

The Petawawa National Forestry Institute (PNFI) was formed on April 1, 1979, as the result of an amalgamation of the Petawawa Forest Experiment Station with the Ottawa-based Forest Management and Forest Fire Research Institutes. The Forestry Statistics and Systems Branch was established at PNFI in 1980.

In common with the rest of the Canadian Forestry Service, the Petawawa National Forestry Institute has as its objective the promotion of better management and wiser use of Canada's forest resource to the economic and social benefit of all Canadians. Because it is a national institute, particular emphasis is placed on problems that transcend regional boundaries or that require special expertise and expensive equipment that cannot be duplicated in CFS regional establishments. Such research is often performed in close cooperation with staff of the regional centres or provincial forest services.

Research at the Institute is in two main areas:

FIRE RESEARCH AND REMOTE SENSING. Every year in Canada large areas of productive forest are destroyed by fire. Research concentrates on studies of forest fire behaviour, the development of new methods of fire control, the evaluation of fire-fighting equipment and retardants, and the development of computerized fire management systems that are rapidly finding applications with fire-fighting agencies across the country. The environmental and economic impact of forest fires and the use of fire as a silvicultural tool for intensive forest management are also studied.

In remote sensing, investigations are made into the application of modern satellite and airborne remote sensing systems to forestry problems. In this respect, the ARIES digital image analysis system is proving invaluable.

INTENSIVE FOREST MANAGEMENT. As Canada moves into more intensive management of its forest to meet expected increases in demand for this vital resource, the role of this program will become increasingly important. An extensive reforestation program will require a steady supply of high-quality seed of the desired species. Improved growing stock, obtained through tree breeding and forest genetics research, is highly desirable. Increased emphasis is being placed on using the entire above-ground portion of the tree (biomass), but the effect on the environment of this and other forms of intensive management has to be carefully monitored. Biotechnological methods of improving yield while maintaining site productivity are being investigated.

In support of its research programs, the Institute has at its disposal a 98 km^2 area of forest in the western part of the Petawawa military reserve. Records of experiments and sample plots have been maintained since the 1920s. The forest also serves as a field laboratory for students from local schools, and a visitor centre is operated during the summer months.

The operations of PNFI also include THE FORESTRY STATISTICS AND SYSTEMS BRANCH (FSSB) which is responsible for the acquisition and publication of national information on the forests of Canada. Through the Canadian Forest Inventory Committee, which is comprised of provincial and federal forestry officials, the FSSB works in close cooperation with provincial forest agencies to improve and standardize the information available on Canada's forest resources.

Through the FORSTATS program, which involves all regional establishments of the Canadian Forestry Service, the FSSB coordinates the acquisition and publication within the CFS of national statistics on the forest of Canada.

Every five years, the FSSB publishes Canada's Forest Inventory, the official report on the location, extent, species, and condition of the forest resource. In addition, the FSSB is working closely with the provinces to expand the information available on changes to the forest from fire, harvesting, insects and disease, and from forest management activities. This information is essential to the development of sound policies for the improved management of this important and renewable natural resource.

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Foreword

This position paper is about forest fire research in the Canadian Forestry Service - its present state, something of its past, and some options and ideas about its potential future. It was commissioned by the Director-General of Research and Technical Services, and written by a single author who has been a member of the CFS fire research group for upwards of two decades. He has consulted people concerned with forest fire and research thereon in the various CFS establishments, provincial forest fire agencies, and forestry universities. He has incorporated their opinions, and differences of opinion, as objectively as he could, and the paper has been reviewed by CFS management within the Research and Technical Services Directorate. Nonetheless, the author's viewpoint as a CFS research scientist working on forest fire must be acknowledged, and the paper may be read with this in mind.

The paper consists of a Summary, which follows immediately, then 26 short sections that are arranged in logical order with respect to the paper as a whole. However, because each section stands more or less on its own, a reader may choose at will the subjects that interest him or her. In particular, some sections have been starred in the Table of Contents as being of primary interest, and may be read as a series comprising about half the length of the whole paper.

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Point Summary

I Forest Fire Statistics

a) Every year, on the average, some 9,000 forest fires occur in Canada, burning annually about 2 million ha, or about 0.5% of the national forested area.
b) About one-third of fires are ignited by lightning; however, these account for about 85% of Canada's burned area.
c) Annual costs of fire control, apart from timber losses, amount to about $250 million.

II Significance and Impact of Fire

a) Fire is a normal component of the environment of most Canadian forest types; in the natural state, these forests are renewed at random, irregular intervals by lightning fire. Most harvesting in Canada is in "post-fire" forest.
b) Fire competes with the forest industry for the annual forest increment.
c) The primary reason for fire control is thus economic rather than environmental.

III Scope of Fire Research

a) Forest fire is a phenomenon with many aspects: physical behavior, ecological impact, economic impact, suppression technology, prescribed use in forest management; many of these can be integrated into sophisticated computerized systems for use in modern fire management.

IV Potential Fire Research Agencies

a) In view of the scope of subject matter, and also the small size of forest fire science as a field of enquiry, the CFS is the only agency in Canada that could conceivably maintain a continuous, coordinated, first-class research effort on fire in Canadian forests.
b) The universities can do a limited amount of fire research, but continuity and coordination are not possible on a national scale; their logical primary role in such small fields is to train researchers.
c) The provinces are not inclined to undertake fire research themselves, and contracted consultants are, in such a small field, not the answer.

V Goals and Benefits of Fire Research

a) Appropriate goals of a CFS fire research effort are (in brief):

1) To explain the behavior, ecological role, and economic impact of forest fire for the benefit of all interested parties.
2) To develop ways of optimizing the effectiveness of fire control operations.

3) To develop the use of prescribed fire to best advantage in forest management.
4) To maintain a national pool of expertise on forest fire.

b) The economic benefits of forest fire research are not easily quantifiable. CFS expenditure on this program is less than 1% of Canadian forest fire costs and losses. It would be hard to argue that the savings resulting from this research are not many times the expense of conducting it.
c) The benefits of forest fire research encompass much more than direct economic benefit. They contribute to the long-term sound management of all vegetated areas capable of supporting fire, whether the main interest is economic or environmental.

VI Present CFS Fire Research

a) Forest fire research in the CFS currently involves 40 people and $1.5 million of direct expense.
b) Half the effort is concentrated at PNFI; the other half is distributed among PRFC, NoFRC, and GLFRC. There is no fire research at LFRC, MFRC, or NeFRC.
c) Average age of CFS fire research staff is 40 years; the average length of fire research experience is 12 years. About half of the group is professional, half technical.

VII State of CFS Fire Research

a) The basic conditions for a CFS fire research program that meets the goals outlined in V above are:

1) The full spectrum of fire-research subject matter should be maintained.
2) The joint national/regional structure of the fire research group should be retained.
3) Liaison and technology transfer servics should not be reduced.

b) In view of the scope of subject matter, plus the range of function and location to be maintained, the size of the CFS fire research group is at a critical minimum.
c) There are about half-a-dozen experienced professionals to cover the whole range of subject matter in fire research; loss of any one or more of these people could result in severe disruption of the program at any time.
d) The burdens of general administrative duties plus liaison and technology transfer services have reduced the time available for new work output to about one-third of the total person-time.
e) Completion dates for new work are difficult to schedule and the demand from client agencies considerably exceeds the rate of output.

VIII Options for CFS Fire Research

a) Reduction of the present CFS fire research effort would render untenable the basic conditions of VII a) above. The CFS would lose its position as national authority on fire in Canadian forests.
b) Given a continuation of the status quo, output of useful new work would continue at the present rate; tension between demand and output rate would probably increase.
c) An increase in fire research effort would

    1) Stabilize the pool of expertise,
    2) Increase the rate of new work output.

IX Expansion of CFS Fire Research

a) A hypothetical ideal CFS fire research effort would be about double the present one. Any increase would, of course, be useful.
b) Present ratio of about half at PNFI, half among regions should be maintained.
c) A fire research group at LFRC would be highly desirable.
d) Increased funds for more field work and freer travel about the country (PNFI especially) are needed to allow the fire research group to operate at full potential.

X Management and Coordination of fire research

a) Lines of authority within CFS run out from headquarters and downward within establishments. No single authority is possible, therefore, in a discipline like fire research that is spread among four or more establishments.
b) Central coordination, operating by stature and influence rather than through line authority, is the desirable mechanism for unifying fire research within CFS. There has, however, been no fire specialist in CFS-HQ for nearly a decade.
c) A combined fire specialist and research coordinator should be installed as soon as possible in CFS-HQ, for two reasons:

    1) The Service needs competent interpretation of forest fire in its headquarters in order to complete the front it presents to the nation.
    2) The continued success of CFS fire research and its credibility in the forest fire community requires it.

SOMMAIRE - RECOMMANDATION

I Statistiques sur les incendies de forêts

a) Chaque année, en moyenne, 9000 incendies de forêts, qui consument environ 2 millions d'hectares ou à peu près 0,5 % de la superficie forestière nationale, se déclarent au Canada.
b) La foudre cause le tiers de ces feux qui comptent cependant pour environ 85 % de la superficie brûlée au pays.
c) Les coûts annuels de la lutte, pertes de bois non comprises, s'élèvent à environ 250 millions de dollars.

II Importance et répercussions des incendies

a) Le feu est un agent normal de l'évolution de la plupart des types de forêts canadiennes; à l'état naturel, ces forêts sont renouvelées au hasard, à intervalles irréguliers, par les incendies dûs à la foudre. Au Canada, la plus grande partie de l'exploitation forestière intéresse des forêts établies à la suite d'un feu.
b) Le feu concurrence l'industrie forestière sur le plan de l'accroissement forestier annuel.
c) La principale raison pour laquelle on lutte contre les incendies est donc économique plutôt qu'écologique.

III Portée de la recherche sur les incendies

a) L'incendie de forêt est un phénomène aux nombreuses facettes : comportement physique, répercussions écologiques, répercussions économiques, techniques d'extinction, brûlage dirigé pour l'aménagement forestier; beaucoup de ces facettes peuvent être intégrées dans des systèmes informatisés perfectionnés pour servir à la lutte moderne contre le feu.

IV Organismes possibles de recherche

a) Étant donné l'objet de la recherche et aussi la petitesse du champ d'investigation, le SCF est le seul organisme canadien qui peut, de façon concevable, assurer un effort de recherche ininterrompu, coordonné et de première qualité sur les incendies des forêts du Canada.
b) Les universités peuvent s'en acquitter d'une partie limitée, mais, à l'échelle nationale, la continuité et la coordination de leur recherche sont impossibles; leur principal rôle logique, dans des domaines aussi étroits, est de former des chercheurs.
c) Les provinces n'inclinent pas à entreprendre elles-mêmes la recherche, et, dans un domaine assez restreint, les firmes de conseils ne sont pas la réponse.

V Buts et avantages de la recherche

a) Les buts pertinents de l'effort de recherche au SCF sont sommairement les suivants:

(1) Expliquer le comportement, le rôle écologique et les répercussions économiques des incendies de forêt, à tous les intéressés.
(2) Trouver des façons d'optimiser l'efficacité de la lutte contre le feu.
(3) Perfectionner le brûlage dirigé au profit de l'aménagement forestier.
(4) Assurer l'existence d'un centre national compétent dans les feux de forêt.

b) Il est difficile de mesurer les avantages économiques de la recherche. A cet égard, le SCF dépense moins de 1 % de ce que coûtent les pertes causées par les incendies de forêts au Canada. Il serait difficile de soutenir que les économies découlant de cette recherche ne sont pas plusieurs fois équivalentes aux dépenses engagées dans sa réalisation.
c) Les avantages de cette recherche dépassent largement les avantages économiques directs qu'on peut en retirer. Ils contribuent à l'aménagement avisé à long terme de toutes les superficies occupées par la végétation et capables de subir un incendie, que la perspective principale soit économique ou écologique.

VI Recherche actuelle au SCF

a) Actuellement, elle occupe 40 personnes et coûte directement 1,5 millions de dollars.
b) La moitié de l'effort est concentré à l'IFNP; l'autre se répartit entre le CRFP, le CRFN et le CRFGL. Il n'y a pas de recherche sur les incendies de forêt au CRFL, au CRFM et au CRFT-N.
c) L'âge moyen des chercheurs est de 40 ans; leur expérience moyenne en recherche sur les incendies est de 12 ans. La moitié du groupe est de catégorie dite professionnelle, l'autre des techniciens.

VII État de la recherche

a) Pour atteindre les buts énumérés au paragraphe V, les conditions fondamentales d'un programme de recherche sur les incendies de forêts au SCF sont :

(1) Que tout spectre possible de la recherche y soit conservé.
(2) Que la structure nationale-régionale du groupe de chercheurs soit maintenue.
(3) Que les services de liaison et d'échange de connaissances techniques ne soient pas réduits.

b) Étant donné l'objet de la recherche et la gamme des fonctions et des centres à conserver, la grosseur du noyau de recherche au SCF est au minimum critique.
c) Une demi-douzaine de professionnels expérimentés s'occupent de l'ensemble de la question de la recherche sur les incendies; il suffit d'en perdre un pour que le programme soit gravement perturbé.

d) Les responsabilités administratives courantes, la liaison et l'échange des connaissances techniques ont grugé du tiers le temps que chaque personne peut consacrer à de nouvelles réalisations.
e) Les nouveaux travaux sont difficiles à ordonnancer et la demande des organismes clients dépasse largement les possibilités de réalisations.

VIII Options

a) La réduction de l'effort actuel ferait que les conditions fondamentales énumérées au paragraphe VII a) seraient inaccessibles. Le SCF perdrait sa position de chef national de file dans le domaine.
b) Si on maintenait le statu quo, les réalisations obtenues en vertu de nouveaux travaux se poursuivraient au rythme actuel; la tension entre la demande et le travail réalisable augmenterait probablement.
c) L'augmentation de l'effort de recherche permettrait :

(1) de stabiliser le noyau des compétences;
(2) d'augmenter le rythme des nouvelles réalisations.

IX Intensification de la recherche

a) Idéalement, l'effort devrait doubler par rapport à ce qu'il est. Evidemment, toute augmentation serait utile.
b) Il faudrait conserver la répartition actuelle des chercheurs entre, d'une part, l'IFNP et, d'autre part, les régions.
c) Un groupe de recherche serait fortement souhaitable au CRFL.
d) L'augmentation du financement pour permettre plus de travaux sur le terrain et plus de déplacements au pays (notamment pour le personnel de l'IFNP) est nécessaire pour que nos chercheurs fonctionnent à plein rendement.

X Gestion et coordination de la recherche

a) Hiérarchiquement, l'autorité au SCF va de l'administration centrale jusqu'aux établissments régionaux. Il est donc impossible de chapeauter au moyen d'un seul centre d'autorité une discipline comme la recherche sur les incendies de forêts qui relève d'au moins quatre établissements.
b) Le mécanisme préférable pour l'unification de la recherche au SCF est la coordination centrale, fondée sur l'influence et la réputation plutôt que sur l'autorité. Cependant, depuis près d'une décennie, l'administration centrale du SCF ne dispose d'aucun spécialiste des incendies de forêts.
c) Un tel spécialiste, qui serait en même temps coordonnateur de la recherche, devrait être détaché le plus tôt possible à l'administration centrale du SCF, pour deux raisons:

(1) Le SCF y a besoin d'un interprète compétent des incendies de forêts afin d'étoffer l'image qu'il présente au pays.
(2) Il s'agit d'une condition fondamentale pour que la recherche au SCF continue de connaître le succès et qu'elle conserve sa crédibilité dans les milieux spécialisés.

FOREST FIRE RESEARCH IN THE CANADIAN FORESTRY SERVICE

1. Agencies Visited and Contacted

All external contacts were established through the Canadian Forestry Service (CFS) regional establishments. These visits were then made in company with the CFS fire research project leader or program director. All agencies are listed below in categories.

I CFS Establishments

1) Pacific Forest Research Centre (PFRC)
2) Northern Forest Research Centre (NoFRC)
3) Great Lakes Forest Research Centre (GLFRC)
4) Petawawa National Forestry Institute (PNFI)
5) Laurentian Forest Research Centre (LFRC)
6) Maritimes Forest Research Centre (MFRC)
7) Newfoundland Forest Research Centre (NeFRC)

At each CFS establishment separate meetings were held with management (plus project leader) and fire research staff (if any).

II Provinces and Territories

1) British Columbia, Forest Protection Branch
2) Alberta, Forest Protection Branch
3) Saskatchewan, Forest Fire Control Branch
4) Manitoba, Fire Management and Communications
5) Ontario, Aviation and Fire Management Centre
6) Québec, Service de la protection contre le feu
7) New Brunswick, Fire Protection (by phone)
8) Nova Scotia, Forest Protection
9) Newfoundland, Forest Resources and Lands
10) Northwest Territories, Fire Control Operations
11) Yukon Territory, Fire Management Operations (by phone)

III Universities (Forestry Faculties)

1) University of British Columbia
2) University of Alberta
3) Lakehead University (by phone)
4) University of Toronto
5) Université Laval
6) University of New Brunswick

IV Other Agencies

1) Parks Canada (Ottawa and Winnipeg offices)
2) Canadian Interagency Forest Fire Centre

The purposes of the consultations were, first, to inform each agency of this fire research assessment project, and, second, to gain impressions about fire research and its functions from each interested party. The discussions were informal; the author used the same agenda everywhere but with no standard list of questions to be answered. The subject matter included the nature of forest fire research, its scope and depth, the desires and needs of the agencies, and the extent to which these latter are being satisfied. Formal evaluation of CFS fire research was not a part of the exercise.

The external visits were of value in themselves as expressions of interest on the part of CFS, and as opportunities for regional CFS staff, together with a representative of the national institute (the author), to debate forest fire affairs and research thereon with the agencies concerned. All told, the author met with 75 different people during the consultations, a figure that includes all professional CFS fire research staff.

All the points made and impressions gained during so many free discussions would be impossible to list conveniently by agency, nor was it ever the intention of the author to do so. Instead, the results of the discussion should be regarded as incorporated generally throughout this position paper. However, impressions from the fire control agencies and the universities are presented in Sections 16 and 17. Other agencies are covered in Section 18 under the heading "Federal and national agencies concerned with forest fire."

2. Introduction

Fire has always had a pervasive influence on the Canadian forest and its management, yet a balanced view of it has only become fashionable during the last decade or two. There is no mystery about the bad reputation forest fires acquired in Canada's past: early logging, settlement, and fire went hand-in-hand, culminating in some terrible holocausts that incinerated whole towns and hundreds of people. And even by the 1880s the lumber interests were deploring uncontrolled fire losses in the valuable pine timber of the Ottawa River and Lake Ontario watersheds. The traditional European forestry attitude that fire is merely destructive also played its part. If a more objective Canadian (and North American) view is now developing, it is surely because the pressure of certain realities of ecology and economics has become inexorable. In other words, the effects of forest fires are not all negative, and there are limits to the expense that can be justified to control them.

Because fire has such deep and ancient roots in human history and culture, social and political reactions will always affect to some extent what is done about fire in our forest. In the author's opinion, however, the only possible basis for a successful CFS fire research program is the most rigorous, objective appreciation of the phenomenon itself, its role in nature, its economic impact, and how it fits into forestry as a whole. A general function of fire research should, therefore, be to continually develop and modify this overall view of forest fire to fit the facts as they become available.

In line with this idea, the first few sections of this paper set forth the author's best grasp of such an objective appreciation of forest fire. Following these are sections on fire research, its purposes, strategy, and components. The paper ends with sections dealing with its present status, its organization and management, and some options for the future.

One final introductory thought. Because fire pervades the whole forestry scene, a broad treatment of research on forest fire will appear to overlap into other fields of forest research. One could say that, when followed to its ultimate implications, every aspect of forestry is found to be connected to every other.

3. Forest Fire Statistics

An appreciation of forest fire in Canada begins with a few basic statistics. Some are presented below for Canada as a whole, based on ten-year averages as of 1982.

Number of fires per year - 9,200
  % caused by lightning - 33%

Area burned per year - 2,160,000 ha
  % by lightning fire - 89%

Area burned as proportion of whole forest - 0.6%

Annual cost of fire control - about $250 million

These simple statistics hide an immense amount of variation. For example:

1) The national annual burned area has varied within a range of 25 to 1. Just within the past ten years, the greatest was 5.1 million ha, the smallest 0.3 million.

2) The largest 3% of fires account for 90% of total burned area. Individual fires of over 100,000 ha occur almost ever year, yet half of all fires reported are held to less than 0.1 ha.

3) Simple national statistics obscure the regional variation. Every province and territory has its own annual trend that may not match the national average at all.

4) Although the statistics are not broken down to show it, it is obvious that the Boreal Forest Region sustains by far the greatest part of Canada's forest fire. The forest of British Columbia west of the Rocky Mountains, of the Atlantic Provinces, and of the Great Lakes - St. Lawrence Forest Region together account for a small fraction. This remark applies in the sense of proportion of area burned annually as well as to absolute area burned.

Lightning deserves special mention. Lightning-caused fires, although only half as numerous as man-caused, account for by far the greatest proportion of the national burned area. This is obviously because lightning may strike anywhere, including the most remote and inaccessible locations, and the resulting fires grow on the average to 15 times the size of man-caused fires. These latter are concentrated near roads and habitation, and are usually dealt with quickly and effectively.

The apparent trend to a greater annual burned area evident during the past few years cannot be ignored. As recently as 1977, the ten-year average national area burned was only half what it is at present. The reason is obviously climatic; that is, each recent severe fire season has been accompanied by equally severe fire weather. However, according to climatologists, it is not yet possible to judge on the basis of the past few years whether a sharp new summer weather trend is becoming established.

How much fire did Canada's forest sustain before the white man's arrival? This intriguing question has no easy answer. Clearly the 3000 annual lightning fires, burning without control, form one possible basis for estimation. One could add to this whatever fire load resulted from the activities of the native peoples. Limited ecological research suggests a fire cycle varying between 50 and 100 years throughout the boreal forest, another possible basis. A rough estimate might be that the primeval annual burned area was two to four times as much as the present average.

4. Ecological Considerations

Fire ecology has been a respectable discipline in Canada for only about two decades, although the basic facts about fire's role in nature have been known in some quarters for much longer.

Most of the Canadian forest is, in its natural state, dependent on periodic fire for its cyclic renewal and long-term stable existance. The tree species in question include nearly all the pines and spruces, Douglas-fir, the aspens, and white birch. They have apparently evolved over long ages to depend in varying degree on fire for their existence in large numbers. The Canadian forest we know may be less than 10,000 years old, but it has clearly developed to its present species composition and arrangement under the continuous influence of random periodic fire.

Within this forest there is little secondary succession. Thus, throughout the boreal forest it is difficult to find a stand in which the first trees that sprang up after the last fire are not still present. In some areas, a pioneer pine stand may give way to spruce, but this usually stagnates eventually without renewal by fire.

The periodicity of fire in the natural forest is in rough equilibrium with the fire climate and species longevity. The so-called "fire cycle" may vary from, say, 50 years in natural jack pine forest to, say, 300 years in natural Douglas- fir forest, but the forest composition in each is equally dependent on this periodic renewal.

It follows, given this cyclic view of the fire-dependent forest, that on the average the post-fire forest is like the pre-fire forest. Otherwise it would be necessary to assume that repeated fires, no doubt more than 100 since glaciation in some places, have gradually degraded site productivity and that each generation of post-fire forest is inferior to its predecessor. A more logical hypothesis is that equilibrium has long since been reached. In other words, the small-scale pattern of species composition and stand density may shift from generation to generation, but the forest landscape remains essentially unchanged.

Out of all this flows a certain fire-oriented view of the forest and its management:

1) Fire, along with climate and soil, is one of the three major physical factors that have shaped the Canadian forest.

2) Fire in the natural forest is neither "good" nor "bad", but simply normal.

3) Modern forest management in Canada is to a large extent a process of intervening in a natural fire-cycled system, and of finding ways to match and improve on the performance of fire as the agent of forest renewal.

4) Real degradation of forest or site by fire is usually associated with human activity such as repeated logging plus burning at unnaturally short intervals.

Not all of the Canadian forest fits the above picture. Fire is of little ecological significance in areas where the climate is too wet for fire or the forest is not generally flammable. Such forests include the tolerant hardwood forest of southeastern Canada, the wetter parts of the west coast forest, some forests of the Atlantic Provinces, and, locally, extensive bogs and swamps wherever they occur.

These ecological realities may not be fully accepted without debate, but a rational policy on either fire management or fire research in Canada can no longer avoid taking them into account.

5. Economic Implications

Hand-in-hand with ecological considerations go certain realities of economics. Pressure on forestry budgets throughout Canada is increasing steadily, and most provincial forest authorities keenly desire a rational solution to the problem of forest fire's economic impact.

Traditionally, the approach to fire economics has been through the principle of "least-cost-plus-loss". Costs are easy enough to specify, but the stumbling block has been the estimation of loss. It is not easy to assign a loss value to a stand of fire-killed timber, nor to specify exactly whose bank account is depleted. It is fair to say that, even after many decades of organized fire control, the subject of fire's economic impact is still unresolved.

Perhaps the time is ripe to consider some alternate approaches, three of which are mentioned below. They may in fact be closely related, although essentially different from the traditional one.

Consider the matter of substitution. Instead of foregoing his harvest in the year in which a burned stand would have matured, does the operator log some other stand instead, perhaps less desirable? If so, how should his loss be calculated?

Consider the so-called "allowable cut effect" (ACE). This is generally taken to mean that, when funds are invested to increase forest productivity in the future, some of the returns on that investment may be realized now. If so, then does ACE operate in reverse as well? In other words, if some part of a forest is killed by fire, can the loss be diffused throughout the stream of future years instead of being completely absorbed now? Or, suppose one were to analyse the impact of fire, not on the standing forest in terms of the area burned and volume killed, but rather on the timber supply in terms of the annual harvest. In the most direct sense the forest industry depends on a steady annual harvest rather than on the standing forest per se, and analysis from these two viewpoints is not necessarily the same thing.

The common thread running through the above discussion is the question "Where should one look for a measure of the economic loss due to forest fire?" All three of the above ideas, if followed to their logical end points, yield the same picture. First, the place to seek the answer is in the forest as a whole and its timber supply, not just on the burned area with its fire-killed timber. Second, the principle behind the answer is not the traditional "least-cost-plus-loss", which treats fire control as a separate function all on its own, but rather "maximised net return", which incorporates fire control as one factor in the whole of forest management from protection to harvesting.

It is on account of all these considerations, whether accepted or not, that the earlier section on fire statistics did not include estimates of volume of timber killed by fire and its value. Not only are such estimates difficult, but the meaning of the available figures is simply not clear.

One thing certain is that a goal of total fire exclusion is physically and economically out of the question, especially throughout the boreal forest. Since a compromise with fire is therefore forced upon us, it should if possible be put on a rational basis. The terms of the compromise would obviously depend on: a) the effectiveness of fire control, and b) the size of the mean annual increment and its value as harvest.

Once a budget was cast, further improvement would then depend on:

i) increasing the efficiency of control operations (with the help of research), and/or

ii) increasing the value of the harvest (presumably through more intensive forest management).

The above discussion of fire's economic impact has been in terms of the forest as a source of timber. No doubt any other forest use or attribute that depends on age could be dealt with using similar arguments.

6. Previous Documents and Evaluations

Forest fire research, in common with other kinds of CFS research, has been examined, described, and evaluated before. A list of the main pertinent documents, for the record, is as follows:

Macleod, J.C. 1968. Forest Fire Research - a position paper. In-house paper.

Vines, R.J. 1973. Fire Research Activities in the CFS. In-house paper.

Kiil, A.D. 1975. Position Paper on Fire Research in the CFS. CFS Information Report DPC-X-5.

Kiil, A.D.; Quintilio, D. 1975. A resumé of current fire research in the CFS. Paper presented at BLM Fall Fire Review, Anchorage, Alaska.

Sinclair, W.F. et al. 1980. Forest Protection Program - preliminary report. In-house paper.

Williams, D.E. 1981. Proposal for expanding forest fire research in the CFS. In-house paper.

Van Wagner, C.E. 1981. Forest fire research in Canada - background and potential. Pages 29-42 in Thompson, K.M. ed. "An industrial assessment of forestry research in Canada" Vol. II, PPRIC.

Anon. 1981. Forest fire control in Canada - a discussion paper for the CCREM meeting, Aug. 1981. Prepared by the CCREM Task Force on Forest Fire Control.

Foster, W.T. 1983. Forest fire research in Canada - a discussion paper. Prepared for the CCREM Forestry Deputies meeting, June 1983.

Anon. 1984. Forest fire research: the need for change. A position paper on forest fire research. Prepared by the Subcommittee on Forest Fire Research of CCFFM for the attention of CCREM.

Of all these documents, only two were so-called "position papers" requested by CFS management (Macleod 1968 and Kiil 1975). The major Program Evaluation of all forest protection research carried out for the Deputy Minister (Sinclair et al. 1980) was almost a non-evaluation of fire research, for it devoted most of its attention to entomology and pathology. Several others are outlines of the fire research program (Vines 1973, Kiil and Quintilio 1974, Van Wagner 1981), and two are papers written primarily by representatives of provincial agencies promoting the need for more fire research, and directed to the attention of the Canadian Council of Resource and Environment Ministers (CCREM). Williams (1981) described the state of fire research and collected independent estimates of desired increases from the establishments, but did not have a mandate to make recommendations based on his own opinions.

The latest document (Anon. 1984) is a serious attempt by the Canadian Committee on Forest Fire Management (CCFFM) to strengthen and redirect the fire research effort within CFS. It urges an increase in manpower, better coordination, greater responsiveness to the expressed needs of the fire management agencies, and increased participation by the universities. It presses CCREM to use its authority and influence to bring all this about.

7. Short History of CFS Fire Research

Forest fire research in the CFS (or its forerunners) began about 1925 with J.G. Wright and H.W. Beall, who together or separately held centre stage until the early 1950s. The number of professional researchers, perhaps the best measure of the amount of activity, increased gradually during this period, reaching eight around 1958. This number increased during the 1960s, peaking at 28 for several years following 1969. The decline common to the entire CFS then took hold. The low point was in 1978, due in part to resignations following the consolidation of the CFS research institutes that took place in 1978-79, when there were only about 15 working fire professionals. The number has since stabilized at 20, of which several are professional support staff. The whole CFS fire research group is now just half what it was a decade ago. Of this decrease nothing more need be said except that it occurred precisely during the period when the scope and sophistication of the subject matter increased rapidly in a way that could not be ignored.

The first fire researchers were concerned mainly with forest flammability as it varies with daily weather. These studies resulted in a system of fire hazard rating issued in the early 1930s that has survived several

major metamorphoses and still forms part of the present Canadian Forest Fire Danger Rating System. The program diversified into various aspects of fire suppression and fire control planning during its first three decades, but always rested on a firm empirical basis, with widespread field data collections in various parts of Canada. The 1960s saw the increasing use of physics and laboratory studies in support of the field work, plus the development of prescribed fire and economics as fields of study. During this period the formal study of fire ecology gradually became respectable, but the CFS decline during the 1970s prevented this component from reaching a stable size. However, operations research did come of age during the 1970s, incorporating computer science and remote sensing to produce sophisticated fire information and management systems, which, as the 1980s progress, influence more and more the daily operations of the forest fire agencies.

For the first three decades, CFS fire researchers worked out of Ottawa, often spending extended field seasons in various locations from Newfoundland to British Columbia. During the early 1960s began the process of establishing fire research groups in the various CFS regions, and the Forest Fire Research Institute was set up in Ottawa in 1965 to act as the focus for the whole program. This arrangement lasted until 1979, when that Institute was disbanded and most of its program sent to the newly-organized Petawawa National Forestry Institute at Chalk River, Ontario.

The output of the CFS fire research group has taken all possible forms. Although the figures mean little by themselves, the 50-year written output includes some 200 articles in all sorts of journals, about 180 CFS Information Reports, 40 Departmental Publications, 70 miscellaneous public documents, plus a large number of mimeos and Internal Reports. The output has always been strongly oriented towards practical use, such as fire danger rating, planning aids, suppression methods, and more recently, pilot development of computerized fire management systems but, nevertheless, with a fair component of scientific literature. The Forest Fire Research Institute for many years operated regular information services to the forest fire community through:

a) annual reports on national forest fire statistics,
b) fire management publication abstracts,
c) a quasi-library of forest fire documents of all sorts and
d) an informal newsletter called "Fire and Fury".

The latter three services have lapsed since the Institute reorganization in 1979, while the first is still produced by fire research staff at PNFI in cooperation with FORSTATS.

Throughout its history, the CFS fire research group has been noted for a fair degree of cohesion among the staff in various disciplines and locations. There has been a continuous more-or-less common philosophy, and common approaches to field work and analysis. Results and experience in one category of work have been used in the other categories, producing a distinguishable whole. It has been, in fact, a national program, with substantial contributions from both regions and institutes.

8. Justification of Fire Research

Here are some conclusions that one might draw from all the foregoing background material that bear directly on the design of a research program:

1) The justification for forest fire control is mainly economic and to a lesser extent environmental:

   a) It is mainly economic because fire competes directly with industry for the forest's annual increment.
   b) It is to a lesser extent environmental, not because fire in the individual case is ecologically harmful, but because the addition of man-caused fire to the natural lightning fire load without control is more than the forest could survive in good condition especially in the more accessible areas where man-caused fire is most common.

2) It is not possible to exclude fire from forests that are normally cycled by fire, and at the same time to maintain them indefinitely with no other treatment. This condition applies to

   a) large natural parks and reserves, and
   b) remote areas not under full management.

3) Continuing great strides in the technology of computers, remote sensing, and communications present many opportunities for developing modern systems that can acquire and integrate very quickly a complex mass of information in aid of management.

4) The widespread ecological role played by fire points to various possible uses of prescribed fire in site preparation and vegetation management.

Modern forest fire management recognizes all these ideas, and that their realization depends on much detailed knowledge that can only be assembled through research. The resulting problems and opportunities, plainly apparent to the operational agencies, form both the justification and the substance of a program in forest fire research.

There are two obvious omissions from the above discussion of justification. The first is human life and safety, the second is real property and its value. Of course they are parts of the picture, and of intense concern to the fire management agencies. It is just that their priority levels and consequences defy analysis from the viewpoint of a national program of forest fire research.

9. Accomplishments

Justification of a program such as CFS fire research can also be approached from quite the opposite of need, namely through its accomplishments. The entire Canadian fire control force currently uses, whether in planning from year to year or in daily operations, information, tools, and management systems developed by the CFS fire research group over the years as the basis for decisions and allocations. Here is a short general list of subjects involved:

- fuel moisture (field methods and physics),
- fire behavior (field methods and physics),
- a national system of forest fire danger rating,
- fire detection (mapping for towers, planning for aircraft patrol),
- prediction of fire incidence on daily basis,
- prediction of fire spread rate and growth,
- tools for fire ignition from the air,
- pump and hose technology,
- fire attack planning,
- ecology of fire effects and forest cycling by fire,
- fire effect on timber supply and forest economy.

Two points are worth making. One is that advances in any subject must often be made at several levels of sophistication over a long period of time, beginning in a simple relative sense, then extended to quantitative form, and eventually further developed into modern computerized systems. In this sense, the accomplishments of the past justify the assumption of continuing usefulness. Much of this material is also used as course material in university and technical forestry schools.

The other point is that from the beginning CFS fire research has built up a distinctly Canadian school of forest fire science and technology, often in contrast to the larger and more visible American one. Not only has the Canadian approach proven peculiarly suited to Canadian forests and forestry, but Canada's fire research stands equal, at least, with those of other nations wherever the phenomenon of forest fire exists.

Now is the moment to attempt a definition of the proper goals of a forest fire research program in the Canadian Forestry Service. Several versions of these are extant in various documents, all (except for Kiil, 1975) in the author's opinion falling short in some way.

10. Goals of CFS Forest Fire Research

1) To explain the phenomenon of forest fire in terms of its physical behavior, ecological role, and economic impact, for the benefit of the forestry, industrial, scientific, and educational communities.

2) To develop and/or test methods, equipment, and management systems by which the forest fire agencies can increase and optimize the effectiveness of their control operations.

3) To develop ways of using prescribed fire to best advantage in vegetation management and forest renewal.

4) To maintain within CFS a national pool of expertise on forest fire and its implications.

These goals have several properties: they fulfill the necessary mission-oriented role of all CFS research, they provide for the scientific research on which the practical output must be based, and they provide for continuous in-house expertise. They specifically do not mention the reduction of fire losses, for two reasons. First, the actual reduction of forest fire

losses in Canada is properly a function of operational agencies, not of a research group. Second, whether fire losses decrease or increase is so much dependent on weather trends and operational efficiency that a fire research group could hardly survive if seriously judged against such a goal. It may nevertheless be implied and taken for granted.

Nor do these goals refer in any way to "fire prevention." This, in the fire business, is usually taken to mean "programs of an educational or promotional nature designed to persuade the public to be more careful with fire in the forest." In that sense, the subject is social and educational rather than technical, and does not fit logically into a federal fire research program. In the sense (sometimes used) that fire prevention includes activity to render flammable areas less flammable, the subject is covered under the category of prescribed fire.

How in fact can a fire research program be judged against its goals? The rigorous determination of a cost-benefit ratio for fire research, as with most other forest research, is in the best sense impossible. This is because we are rarely able to trace the effect of some idea or system from development through its use by a fire control agency to the point where its effect on fire's economic impact can be measured. To look at the question another way, consider that the current annual cost of fire control in Canada is about $250 million, well over 100 times the annual CFS fire research budget. One would only have to argue that the entire CFS research output now in use by the fire control agencies is increasing their efficiency by a mere 1% in order to balance the annual cost of research, and the real impact is undoubtedly many times that. Add to this saving the value of any increases in timber supply made available through fire research, and the conclusion that fire research pays for itself many times over is unavoidable. Still, as with other forest research, it would be unfortunate to tie all fire research to the concept of economic benefit. Any well-balanced forest research program must contain some elements that have more to do with wise resource use and quality of environment than with economics; these would simply be stifled if justified solely against proven economic returns. The question posed at the beginning of this paragraph thus has no answer that can be entered simply in the appropriate columns of an auditor's report. The economic, environmental, and social benefits of fire research are either obvious or not on the basis of the above simple concept. They do, in any case, defy detailed rigorous analysis. The further question of the possible alternate uses of research dollars, in the larger sense, is beyond the scope of this paper.

11. Alternatives to CFS Fire Research

Why, given that research on forest fire is necessary, should the CFS have to do it? Forest fire research is well- established, for example, in the United States, Australia, and the Soviet Union, and the phenomenon of combustion in nature is the same the world over. The universities, for instance, might do fire research, or perhaps the individual provinces. Furthermore, the federal government has its well-known Make or Buy Policy to promote contract research in the private sector. There are, in fact, some good reasons why such alternatives would not work.

1) Presumably the CFS desires a complement of scientific expertise in every aspect of forestry, including forest fire. There is no way to acquire such expertise except through the conduct of research.

2) There are distinct Canadian problems and opportunities that cannot be met by simply using the fire research output of other countries. In any event, in spite of its small size, Canadian fire research makes a respectable impact on the international as well as on the national scene.

3) The forestry universities can generally afford only one forest fire person on their faculty staffs. It is difficult for these people to cover the whole fire field authoratively in the proper proportions.

4) The fire research field in Canada is relatively very small compared with research disciplines in general. Continuity of experience is hard enough to maintain within the CFS fire group itself; among private consultants it would be next to impossible.

5) If two or more provinces or territories undertook substantial fire research programs, their first and obvious problem would be coordination to avoid massive duplication of effort.

A CFS fire research program has the best chance of concentrating continuity of experience and of allocating effort efficiently among the various categories of the work. But, the small size of the whole effort in Canada is a fair guarantee that, if it were split up among various organizations, little effective work would be done. It is safe to say that, if the CFS does not do it, first-class fire research applicable to Canadian forestry will not get done.

By no means does such a conclusion restrict fruitful interaction between the CFS and any agency capable of contributing to the whole fire research output. It simply means that a viable, well-balanced CFS effort is the prerequisite. Obviously the widest possible cooperation with universities and forest management agencies plus the judicious use of supporting contracts are desirable parts of the whole.

12. Dimensions of Fire Research

A well-balanced fire research program has dimensions in a least three directions. First, there are the various functions or stages of a research program to be covered:

- conceptual innovation,
- development of research methods, or test procedures,
- collection of experimental data and information,
- data analysis and design of linking functions,
- synthesis of practical information and systems,
- liaison with clients and technology transfer.

In a small field such as fire research, any researcher or technician may combine any number of these functions, even all of them, in his work. This pattern has its advantages, since he is thus exposed continually to feed-

back from the real world; the practical output especially must be designed in full consultation with potential users. Some informal separation of these functions does take place, but true formal separation, if it were desirable, would only be possible in a somewhat larger group than the existing one. Publication may be desirable and worthwhile at any stage in this whole process.

Second, the scope of subject matter in fire research is conveniently classified into six categories and their subdivisions as follows:

1. Fire Behaviour - concerned with, a) fuel moisture physics, b) fire spread physics, c) prediction of fire behaviour by forest type, d) fire/weather interactions, e) fire danger rating systems, f) spatial weather models.

2. Fire Ecology - concerned with a) post-fire forest regeneration mechanisms, b) cyclic forest development from fire to fire, c) prediction of post-fire forest development, d) age- class distribution in fire-cycled forest.

3. Fire Suppression - concerned with a) performance rating of fire control equipment, airtankers, fire retardants and water additives, b) aerial ignition devices, c) backfiring methods, d) new suppression methods.

4. Prescribed Fire - concerned with a) tree damage and mortality, b) use of fire for hazard reduction, seedbed preparation, and vegetation control, c) design of prescriptions for proper burning conditions, d) operational techniques.

5. Fire Economics - concerned with a) economy of alternative fire control tactics, b) estimation of values-at-risk, c) effect of fire on timber supply, d) relation between fire control expense and burned area, e) ultimate impact of fire on the forest economy.

6. Fire Management Systems - concerned with a) remote sensing applications, b) computerized systems for integrating weather, fuel type, and terrain into fire spread and growth models, c) prediction of lightning and man-caused fires, d) air patrol routing, e) resource deployment, f) attack strategy, g) management of weather and fire data bases, h) information systems of various kinds.

The above classification is specifically in terms of the practical outputs of fire research as they are used by people and agencies directly concerned with forest fire. It is not meant in any sense to downgrade any activities in the fire research program that do not carry these exact labels, or to be a proposed structure for the organization of research projects. What follows below will make this clearer.

Third, consider the basic disciplines required as background in the various categories of fire research. These include:

- meteorology and climatology
- physics (moisture exchange, heat energy)
- chemistry (combustion, retardants)
- mathematics (algebra, geometry, calculus)

- statistics and data analysis
- botany and plant physiology
- plant ecology and dynamics
- soil science
- resource economics
- forest management and regulation
- computer science and technology
- remote sensing and computer graphics
- mechanical engineering

As fire management becomes more and more sophisticated in Canada, the fire research group requires professional specialists in some of these disciplines in order to provide the full benefit of current knowledge. Thus, meteorologists, computer scientists, and remote-sensing experts are already fully integrated, and other specialists may eventually be desirable.

In summary, it is apparent that research on forest fire in the fullest sense covers a great deal of ground. The range and complexity of subject matter have increased tremendously during the last 15 years, especially in the fields of biological interactions, management systems, and economic impact. Crosslinks with other kinds of forest research are also apparent.

13. Links With Other Forest Research

Fire research may appear superficially to serve, through its practical output, a rather special and separate aspect of forestry, namely the physical business of detecting and controlling forest fires. And yet it is more and more apparent that both fire control and fire research must become integral parts of the forestry scene and the research upon it. The pressure of the ecological and economic realities referred to earlier is the reason. As the scope of fire research increased, it has overlapped with other forest research in a curious manner. It is as if the traditional image of forest fire as an alien intrusion somehow prevented earlier investigation of all its aspects. Three examples are given below.

Consider fire ecology. The proper unit of study in a forest normally renewed by fire is the cycle of development from the moment one fire cools down until the next one sweeps through. Only on this basis can the life of the forest be understood and intelligent forest management undertaken. However, traditional forest ecology was often strangely silent on fire's ecological role; the fully respectable study of fire in ecology was mainly an initiative of the fire-oriented research community. Thus fire ecology filled a partial vacuum. And yet the very term is semantically awkward; there is really only forest ecology, simply expanded to take proper account of the reality of fire.

Consider prescribed fire. In view of fire's pervasive ecological role, there should be great opportunity for the use of prescribed fire to accomplish various objectives in silviculture and vegetation management. Prescribed fire use requires expertise in both the behavior and ecological effects of fire. Because these are commonly combined only in the fire research group, the subject has evolved as a category of fire research rather

than of silviculture. And yet the optimum use of fire as one of many tools of site preparation and vegetation control depends more on the initiatives of forest managers than of fire managers.

Consider fire economics. The pressure from fire management agencies trying to rationalize their budgets has resulted in a small but continuous effort in Canada and the United States to measure the impact of forest fire on the forest economy. But the problems with insects and diseases are in many ways analogous. Still further, the entire subject of forest protection economics is but an integral part of some larger field that might be called the economics of forest management, covering all aspects of forest operations from stand establishment to the delivery of wood at the mill entrance. But, because of the failure of this larger field to deal logically with fire impact as one aspect of a whole, it appears that fire economics has developed to fill another partial vacuum.

These examples raise a common problem in the classification of forest research. If one sets up a system that includes, among others,

- forest fire,
- forest ecology,
- silviculture, and
- economics,

where does one place the three examples of overlap discussed above? There is no obvious clear answer, but two practical points arise:

1) The mechanics of classifying forest research should include a two-way matrix or cross-referencing systems; a simple linear list cannot provide enough information by itself.

2) These are some obvious opportunities for fruitful collaboration among CFS research disciplines that are at present not being fully explored.

More and more, it seems, certain advances cannot be made without integration, both at the research level and in the management of the forest itself.

14. Research Strategy

As with any kind of research, the degree of success depends first of all on the strategic approach to the work. General familiarity with the forestry scene, with the implications of fire within it, and with the literature on forest fire science are all assumed starting points for effective contribution.

Consider the phenomenon of combustion in the forest: its physical behavior and biological effects. It is upon their correct interpretation that successful fire research ultimately depends, both the practical outputs directly related to these results, and the extensive operations research output that indirectly builds on them. If this basic work is not sound, then the practical output cannot be either.

The main choice is between two distinctly different research strategies, the theoretical/modelling approach on one hand, and the empirical/field approach on the other. Throughout its history, CFS fire research has opted mainly for the latter. With respect to the physical face of fire, the primary ground for this choice is that the combustion process in heterogeneous natural combustible matter is so complex as to be intractable by physical and mathematical principles alone. Therefore, rather than attempt to model forest fires in the laboratory, with the attendant nearly insoluble problems of minaturizing all physical dimensions and mass/energy processes at once according to their appropriate scaling laws, CFS fire researchers have instead obtained their basic information by observing real forest fires.

This does not mean that theory has been ignored. A good deal of theory has been adopted or developed, and then used to design and analyse field experiments. The general approach has been decidedly deductive rather than inductive. It does mean that physics and maths have been used to complement the essential field observations but never to supplant them.

An analogous position exists in ecological research. First, the chosen unit of study is the cycle of development from one fire to the next. Then, rather than trying to work out basic processes in soil chemistry and plant biology, the CFS group has instead concentrated on the vegetation, its development and patterns. The forest itself is used as the empirical integrator of all fire effects, both short-term or long-term. Of course, as the program progresses, basic processes such as soil nutrient status and its effect on tree growth should receive more attention; but they should be used to explain the evidence of the vegetation itself rather than to replace it.

An empirical/field approach has two drawbacks compared with the theoretical/modelling route. The independent variables are less controllable, and the results of a particular study less widely applicable. The answer to the first is proper statistical design, and to the second is a combination of simple theory and judgement. It would, of course, be presumptuous to maintain such a strategy with a closed mind. Research on fire modelling, especially strong in the United States, must be monitored continuously, and the CFS fire research group should maintain at least the expertise required to evaluate progress, if not to engage in such work itself.

Sound interpretation of fire's behavior and ecological role clears the way for a wide range of practical fire research outputs. These include fire danger systems, prescribed fire procedures, computerized management systems of any kind that depends on estimates of flammability or fire spread rate, evaluation of suppression methods, and even, to some extent, economic impact.

15. The Six Categories of Forest Fire Research

Here are notes on the previously listed six categories of fire research in the CFS.

1) Fire Behavior. This is the only truly independent line of work in forest fire research. It has practical output of its own, namely the Canadian Forest Fire Danger Rating System, and in addition forms the basis of the

other five categories. It deals with the links between weather, fuel moisture, and fuel arrangement on one hand, and the physics of fire spread on the other. Its aim is to describe, explain, and predict fire behavior in any kind of forest or fuel under any weather conditions. Meteorology, physics, chemistry, and mathematics all enter strongly into this work. Because of the scientific complexity of spreading combustion, a high professional level is required in order to evaluate potential research strategies, select the best meteorological variables for correlation with fire behavior, and to work out the variation in fire behavior with forest type. Even when a primarily empirical approach is chosen, it must be based on a clear appreciation of the alternative theoretical/modelling work carried on elsewhere. Research on fire behavior must be done well, and it must command the confidence of those engaged in the other categories of fire research.

Because of the special importance of meteorology to this work, the fire research group includes two professional meteorologists. Their first main concern is the better description of current weather in terms of area rather than as a set of point measurements. This involves modelling the distribution of wind, temperature, and humidity over the landscape for interpolation purposes, plus the development and evaluation of weather radar for measuring rain. Their second main concern is the definition and choice of weather variables for the optimum explanation of fire behavior. For example, does the prediction of extreme fire intensity require parameters of atmospheric structure in addition to the standard surface weather variables used at present?

The chief practical job facing fire behavior research at present is to raise the prediction of fire behavior from its current relative form, as embodied in the Fire Danger Rating System, to a quantitative form in terms of rate-of- spread and fuel consumption. This information is instantly taken up as it is produced, both directly by the fire control agencies and as the basis of computerized management systems.

2) Fire Ecology. This line of work is really forest ecology, simply taking full account of the role of fire in a manner not previously well covered. This means approaching ecosystem life history as a series of cycles of varying duration from fire to fire. Its business is the explanation and prediction of forest regeneration and development following fire under any conditions in any kind of forest. Because fire behavior is a variable, not a constant, research in fire ecology calls for a good background in fire behavior and its use in the prediction of fire effect. Apart from scientific value, fire ecology research has at least four practical functions:

(i) It must settle whether, or to what extent, the forest needs protection from fire for environmental reasons as well as economic.
(ii) It contributes to the integration of concern for fire into forest management as a whole. For example, as ecology expands to the landscape scale, there is a clear continuous line from the study of fire intervals and cycles through age-class distribution and its form to the impact of fire on timber supply in managed forests.
(iii) Information on fire in ecology is the first need of the large national and provincial parks in resolving their dilemma of how to

perpetuate natural forest ecosystems that include fire as a factor of their environment.

(iv) Finally, ecological information is the required basis for the evaluation of prescribed fire as a tool of site preparation and vegetation management.

3) Fire Suppression. Work on fire suppression includes performance rating of fire control equipment and materials, evaluation of air tanker productivity and efficiency, and development of ground and aerial fire control systems of all sorts. The results form a link between manufacturers and fire control agencies, and also provide organized information on the effectiveness of alternative suppression methods and aerial attack systems. Two aerial ignition devices for prescribed fire and burnout attack on wildfires have been developed by CFS fire researchers and are in widespread use both within and outside Canada. The fire research group provides a regular newsletter on suppression equipment and systems to the fire control community.

The propriety of this work has been questioned repeatedly during the past two decades. Is it appropriate for a federal agency? Should the equipment industry or the provinces be doing it instead? Should it be contracted out? The answer is fairly clear: either the CFS does it or it will not be well done. The reasons are as follows:

a) The manufacturers are dealing with a small, uncertain market and cannot afford to perform this function adequately, even if their objectivity were not in question.
b) The provinces are operationally-oriented and could not individually do as much as the CFS. Coordination among themselves would be difficult.
c) A contract group would be lacking the desirable close contact with CFS fire research, especially on fire behavior, and its continuity would always be in doubt.

Certainly, the work of the fire suppression group is in constant demand by the provincial and territorial agencies, and is welcomed equally by the aircraft and equipment industries and contractors. Its results are important linkages in fire management systems and fire attack models. It would be desirable to place a stamp of policy approval on this line of work once and for all.

4) Prescribed Fire. The use of prescribed fire is dependent on knowledge of both the behavior and ecological effects of fire, in roughly equal amounts. Inevitably, because of the variety of fuel complexes and the resultant fire behavior and effects, the use of prescribed fire is to some extent an art as well as a science. The task of research is to provide the best possible technical basis for the practice, thus minimising the need for detailed personal experience. Any potential use of fire must account for the following points:

a) effectiveness for purpose desired,
b) safe, dependable procedure,
c) lack of deleterious side-effects,
d) economy in comparison with alternate treatments,

e) enough weather opportunities for practicality.

So far, research in Canada has dealt mainly with the burning of clear-cut areas as preparation for regeneration and as hazard reduction. Secondary study fields have been a) burning under standing forest as preparation for regeneration after partial cutting, and b) maintenance of wildlife range. The work involves the observation and specification of the desired effects plus the prescription of the appropriate burning conditions for operational fire use. Impetus for the work depends mainly on the interest and open-mindedness of forest management people; the CFS fire research group can study and propose, but must have this interest as justification for the work. Because of the nearly universal ecological presence of fire, its use in site preparation may be preferable in many cases to mechanical or chemical treatments. Also, its special nature as a treatment that maintains its own momentum once it has been applied at selected locations affords an obvious economy of scale. There undoubtedly exists a great opportunity for the increased use of prescribed fire in forest renewal and vegetation management.

5) Fire Economics. This line of work is carried on in direct response to the continuing strong interest of the fire control agencies. It includes the study of alternate tactics of fire detection and control as well as the larger question of economic impact. Nevertheless, the subject is delicate, since strict adherence to economic analysis could conceivably lead to substantial reallocations within provincial forestry budgets. The function of CFS fire economics studies should probably be to shed light on general principles and methods rather than to conduct formal regional quantitative analyses. Some problems at issue are:

a) burned-area-only or whole forest as basis for the assessment of fire's impact on values-at-risk,
b) relation between fire control expense and average annual burned area,
c) the appropriate value of a unit volume of standing timber for protection purposes,
d) fire's effect on non-consumptive forest uses (such as recreation), and
e) fire's effect on natural forest benefits (such as wildlife).

6) Fire Management Systems. This line of work is an example of a successful research program resulting first from an opportunity rather than an expressed need. The advent of three developments in advanced technology, namely the computer, modern remote sensing, and modern management science, have led to the development of sophisticated computerized fire management systems that offer the chance of revolutionizing fire control operations. The amount of data that can now be either stored ready for use or acquired quickly is almost unlimited; selected data can then be processed and integrated on demand through complex math procedures. This means that many kinds of information previously unavailable or beyond reach in reasonable time can now be provided almost instantly for current operational use.

Such systems depend first on well-designed data bases of historical fire weather and occurrence, and of digitized information on terrain and forest type. They then use and integrate all the output of studies on

fire weather, fire behavior, and fire suppression that exists in quantitative form. The main advances have been in:

a) the use of remote sensing for identifying fuel types, burned areas, etc.,
b) the integration of lightning detectors into communication and information systems for fire detection planning,
c) the daily prediction of the numbers and likely locations of lightning and man-caused fires,
d) the planning of fire detection flights,
e) the inventory and deployment of men and equipment,
f) fire growth models, and
g) the evaluation of ground and air attack strategies.

Conceivably the field could be expanded to incorporate models of ecological and economic impact, thus utilizing the outputs of practically all the rest of the CFS fire research group.

Such research is best carried on in close cooperation with certain chosen fire management operations, so that development, pilot trial, and full-scale operation form a continuous stream. The installation at the Societé de conservation de l'Outaouais in Maniwaki, Quebec, is the best example. Implementation throughout the country depends very much on two concurrent processes: 1) greater centralization of control at the provincial or regional level, and 2) an increase in the professional level of fire operations staff. The desire and need for computerized management systems then goes hand-in-hand with these developments. The expectation of increased efficiency and consequent overall savings is the justification.

This line of work by its very nature requires a large capital investment in computers and peripheral hardware. Once well established, this equipment will have to be updated or renewed from time to time in order to keep the research program abreast of current technology as it advances. It is important that this point be recognized. The results of this category of fire research are already the subject of great interest throughout Canada, and any faltering in the support for it would have an immediate negative impact on the operational agencies.

16. Impressions from the Fire Management Agencies

Here are some points on which the fire management agencies contacted were either in general or majority agreement:

- CFS fire research is well-regarded and useful.
- The CFS should maintain the full spectrum of its fire research subject matter; to drop some categories would be a distinct step backwards.
- Priority among fire research categories varies from agency to agency.
- All agencies agree on the importance of research on fire behavior, fire suppression, and prescribed fire.
- Most but not all agencies desire information on ecology and economics, and on the use of computerized management systems.

- Liaison with the CFS fire research group and technology transfer are intensely important.
- These latter services are not at present evenly available across Canada. Deficiencies exist in the three eastern regions where no fire research exists, and also with respect to the PNFI fire management systems work at the ends of the country most distant from Chalk River.
- The agencies agree that they must raise the professional level of their staffs in order to take advantage of the increasingly sophisticated outputs of fire research.
- The historical fire occurrence and fire weather data bases must be modernized, as the required background for many advances in fire management.
- Modern attitudes to forest fire are evident everywhere; ecological and economic realities are widely recognized.
- In consequence, fire management is seen more and more as an integral part of forest management, not as an end in itself.
- The required new integrated policies must therefore come from a higher level; nevertheless, the initiative, it seems, continues to rest with the fire management staff.
- The CFS is looked upon as the sole agency capable of mounting a continuous, stable forest fire research effort.
- CFS fire research is seen to be stretched very thinly; technology transfer and liaison must be maintained, which means a slow rate of new output.

The general impression is one of great interest in CFS fire research on the part of all provincial and territorial fire management agencies. Research output of a practical nature is taken up quickly, and the CFS fire research group currently operates considerably behind the demand. No province is seriously considering a fire research effort of its own. The fire management agency managers and staff are generally more enlightened with respect to forest fire and its impacts than the higher levels of their forestry departments.

17. Impressions from the Universities

Here are some points on which the university people contacted were either in complete or majority agreement:

- The universities' first priority is to teach; research, inspite of pressure on faculty staff to publish, must come second.
- The university fire professors use and value CFS fire research output in their teaching program.
- The forestry faculties are generally able to provide one staff member only with full-time responsibility for forest fire.
- It is therefore impossible for any one university to maintain first-rank expertise in the whole range of forest fire science. Although it cannot be planned deliberately, the Canadian fire professors do at present cover the whole range fairly well among themselves.
- Fire research at the universities will usually be done by postgraduate students under the professor's guidance. It is therefore very difficult for the universities to maintain continuity of experience.
- Thus the primary function of university fire research is to train researchers rather than to do definitive work in the long term.

- A stable, continuing CFS fire research program is therefore required as the backdrop for university fire research.
- Full, easy cooperation with the CFS fire group, with participation on post-graduate committees and occasional lecturing, is desired.
- At present, funding for university fire research is less a problem than finding the people and time to do the work.
- The basic problem is the lack of employment opportunities for trained fire postgraduates. The CFS hires only rarely, and the fire management agencies are upgrading their professional level very slowly if at all.
- It would be desirable for the CFS to be willing to wait up to a year for a promising fire postgraduate student, or at least to hire at the bachelor level and provide further training.
- Otherwise, if the CFS desires an experienced fire researcher immediately and hires a non-Canadian, the negative cycle with respect to fire science within Canadian forestry faculties merely repeats itself.
- Staffing efficiency for CFS positions, whether for summer students or permanent professionals, is seen to be at a very low ebb.
- Student programs increase steadily in complexity, and approval dates are later year by year. This makes it difficult to secure the best students with an aptitude for a particular line of research, especially in a small field like fire. And yet, in the past a number of successful CFS fire researchers had their first taste of fire research as summer students.
- As for recent graduates, it is difficult to move the ponderous federal staffing process fast enough to secure easily the few eligible Canadian candidates before they are forced to seek employment elsewhere.

All these impressions back up the view that the main role of the universities with respect to the CFS fire research program is to train researchers rather than to attempt continuous definitive research themelves. At the same time the university fire professors need close contact with CFS fire research to the mutual advantage of both parties. It is desirable for ultimate health of forest fire science in Canada that the universities' stature in this small field be raised; otherwise the larger role of university science, namely to be a brains trust at the forefront of advancing knowledge, taking full advantage of its academic freedom, cannot be realized with respect to forest fire.

18. Federal and National Agencies Concerned with Forest Fire

The primary clients of CFS forest fire research are naturally the provincial government agencies that deal with forest fire on Canadian crown lands, plus the analogous federal agencies in the territories. Within the remainder of the general audience of groups and individual people concerned with fire, there are several specific federal or national agencies that either use fire research results or interact with the CFS fire research group. Six such agencies are listed and discussed below.

1) Atmospheric Environment Service (AES)
Part of AES's program is the regional provision of fire weather services to the fire control agencies. These include the daily dissemination of current and forecast indexes of the Canadian Forest Fire Danger Rating System, which was developed over the years by the CFS fire research group.

Relations between AES and CFS on this account are regulated by a formal policy signed in 1975 by the respective Assistant Deputy Ministers. By its terms, the CFS retained all responsibility for research and development of the fire danger system and its official form, relegating all or any federal operational activity to the AES. The obligations of CFS fire research with respect to this relationship are two: 1) to communicate effectively to AES all new developments in research on fire weather and fire danger rating for use in their daily service, and 2) to take part in the regional fire weather committees that bring together AES, CFS, and operational fire personnel for regular discussions of fire weather services. This relationship is currently being reviewed by the two services. The AES of course retains its reponsibility for basic research on meteorology and weather forecasting.

2) Parks Canada (PC)

The policy of the national parks calls clearly for the preservation of natural ecosystems for posterity. These ecosystems are as often as not forests that depend on random periodic fire for cycling and renewal. The traditional practise of fire control to the point of exclusion (if possible) is, in the long run, incompatible with this policy. Parks Canada is currently striving to formulate a new attitude to fire and to devise the necessary operations that go with it. Its first need is adequate information on ecology, followed closely by a need for better knowledge of fire behavior to back up its operations.

As of 1971, it has been the habit of Parks Canada to buy its research and scientific surveys, not to build up its in-house staff for these purposes. It has used university and consultant people, always with the problems of continuity and concentration of experience. The CFS is a logical source of these services, and has in the past carried out survey work and ecological fire research in the parks. Parks Canada's needs are clearly more than the present CFS fire research group can provide; some studies, already paid for by PC, are badly delayed and new work is difficult to schedule.

There does exist an informal CFS/PC understanding of CFS support for PC objectives, but with no obligation on the part of either service. Parks Canada does command mandatory support from the Canadian Wildlife Service (CWS), but this arises out of the special history of the CWS's origin. Any formal agreement of this sort between PC and the CFS would presumably require the creation of dedicated P/Y's, a scarce commodity to say the least.

Parks Canada, it is hoped, will benefit incidentally from any useful research results in ecology and fire behavior produced by the CFS fire group. As well, free and easy consultation channels are in place at all CFS establishments. Beyond this, there is no solution in sight for increased support of PC's objectives.

3) Canadian Committee on Forest Fire Management (CCFFM)

This committee (formerly the Canadian Committee on Forest Fire Control) comprises the senior fire management people from all provinces and territories, plus representatives of universities, technical schools, and the CFS. It is the country's main regular forum for the discussion of

forest fire affairs. For many years it has been pressing for more fire research by CFS. Being an associate committee of the National Research Council, it has used that channel to make representations, as well as through resolutions forwarded directly to DOE or CFS. These requests have so far had no effect other than to maintain the visibility of CCFFM's concern. To increase the fire research effort in a time of scarce resources would of course require a reallocation from some other kind of forest research, something the CFS is presumably very reluctant to do. In May 1984 the CCFFM transmitted a strong new position paper on the need for increased fire research to CCREM (see Section 7).

4) Canadian Interagency Forest Fire Centre (CIFFC)
The CIFFC is new on the forest fire scene, having been set up in 1982 in Winnipeg under the auspices of CCREM. Its purposes are to collect and disseminate daily information on forest fire activity and equipment availability across Canada, and to be a national focus for contacts with its American counterpart. Ultimately, it will concern itself with training and with the allocation of the national air tanker fleet and other equipment. Relations with the CFS fire research group are already intimate, and will deal especially with data collection, storage, and the current situation during the fire season. There is no suggestion that CIFFC should engage in or sponsor research, nor would this be appropriate. CIFFC does, however, join with CCFFM in pressing for a larger fire research effort, by the CFS if possible.

5) Canadian Council of Resource and Environment Ministers (CCREM)
As part of its concern with forestry, CCREM maintains a task force on forest fire, composed of people who are, in addition, members of CCFFM or CIFFC. This task force has secured agreement in principle for a) increased federal support for forest fire control (viz. the CL-215 program), b) a common national training program for fire-fighters, and c) more fire research.

6) Canadian Forestry Association (CFA)
The Canadian Forestry Association is a non-profit educational and promotional agency, funded by voluntary contributions of all sorts. It works mainly through its associated provincial forestry associations. Its original main concern, and still important, is forest fire. Among other activities it sponsors the Smokey Bear fire prevention program in Canada. The CFA has always maintained good informal contact with the CFS fire research group, especially important during a period of changing attitudes to forest fire. Ecological realities and the use of prescribed fire have complicated Smokey Bear's original message that "fire is all bad", and such contact will help to keep fire prevention programs in tune with these realities. Along with other organizations, the CFA advocates much increased forest research in general and fire research in particular.

19. Present Profile of CFS Fire Research and Staff

As of 1983 fire research occupied the following position within the CFS as a whole:

	Staff	Budget
Size of fire research effort	39 P/Y	$ 1.5 million
% of total establishments	4.2%	4.0%
% of total forest research	7.1%	7.5%
% of Improved Forest Mgt. Program	8.0%	8.5%
% of Forest Protection Program	12.8%	14.1%

The position differs little in 1984.

The present staff is physically distributed as follows:

Petawawa National Forestry Institute	(PNFI)	19
Great Lakes Forest Research Centre	(GLFRC)	6
Northern Forest Research Centre	(NoFRC)	9
Pacific Forest Research Centre	(PFRC)	4
TOTAL		38

This total includes the Program Director at PNFI, because his experience and concern are mainly with forest fire, and there is one vacancy, namely at NoFRC. Also, two liaison fire positions are planned within the Forestry Development Program for the Northern Region; it is not yet clear whether they will devote full-time to direct enhancement of the fire research program. There are no fire research positions at the three easternmost regional establishments, namely LFRC, MFRC, and NeFRC. The CFS fire research effort thus comprises 36 active research staff, 1 manager, and 1 vacancy for a total of 38; the two planned liaison positions, if applicable, would raise this to 40.

Here is a brief profile of the CFS fire research group, in terms of age, classification, education, and experience. Totals do not include vacancies.

Age - Average age of whole group - 40 years. By age class, the proportions are as follows:

20 - 29	5
30 - 39	16
40 - 49	9
50 - 59	6
60 + ...	1
	37

Classification - The old sharp distinction between professionals and technicians has become less and less distinct. By job classification, the present group comprises:

Senior Manager (SM)	- 1
Research Scientists (RES)	- 5
Forestry Officers (FO)	- 14
Physical Science (PC)	- 1
Computer Science (CS)	- 1
Technical Support (EG-ESS)	- 15
	37

Education - The fire research group holds degrees or training in the following proportions:

Doctorate	- 3
Master's	- 12
Bachelor's	- 7
No Degree	- 15
	37

Most of the last class have two years of technical training beyond high school.

Experience - The whole group has spent an average of 12 years in CFS fire research, broken down by experience class as follows:

0 - 5 yrs	10
6 - 10 yrs	8
11 - 15 yrs	7
15 - 20 yrs	6
21 - 25 yrs	5
26 + yrs	1
	37

The fire research work is divided into seven parts: five research projects at PNFI and three regional units at GLFRC, NoFRC, and PFRC. The Project Leaders and Unit Heads constitute a special group of senior researchers; their average age is 46 and they have worked an average of 15 years in fire research. Their functions differ with the nature of the work; however, they all report to their respective Program Directors and may be considered equal in status from the viewpoint of the CFS fire research program.

The general picture is one of a fairly mature group with a great deal of experience. The proportion of Ph.D holders is probably less than for most other CFS research groups, but the high proportion of Forestry Officers is in line with the practical orientation of much of the work and the great need for effective liaison with the forest fire community.

The proportions by which the research effort is distributed among the six categories of fire research are best considered in terms of numbers of staff involved. However, this is not easy for two reasons. One is that the dividing lines between research categories are not all clearcut. The other is that some individuals have broad experience and operate in two or more categories of research. The following table is partly according to the author's judgement, and the proportions therein are best interpreted as amount of effort rather than as discrete individuals.

	P/Y	%
Fire behavior	13	36
Fire ecology	4	11
Fire suppression	8	22

Prescribed fire	3½	10
Fire economics	1	3
Fire management systems	6½	18
Total	36	100

It can be seen that about one-third of the effort is fire behavior research, about a fifth each in fire suppression and fire management systems, with various smaller proportions in the three other categories.

20. Organization and Coordination of CFS Fire Research

Four separate aspects of the CFS fire research program and its operation are discussed here:

- the question of centralization vs. regionalization,
- the problem of coordination,
- links with other kinds of research, and
- direct management.

1) The first question concerns the extent of centralization as opposed to regionalization. On the one hand, the nature of fire is universal, which suggests centralization. On the other hand, the size of the nation and its diversity of forest argue for regionalization. From the compelling nature of both of these considerations, the answer is clear: The fire research program must have the best of both worlds. Most opinions gathered, as well as the author's own, agree that CFS fire research needs both a set of lead projects, presumably at PNFI, and strong regional units as well. The success of the whole program depends on this combination. The lead projects must produce output and common approaches that are acceptable to all or most regions, but, being protected from direct regional pressures, are able to devote more time to innovation and continuity. Let it be emphasized that the role of the regional groups in such an arrangement is in no way subservient and is in some ways more demanding. As well as special regional work, they must cover regional adaptation of national output, and perform the essential roles of liaison and technology transfer. An essential qualification is necessary here. While the lead projects would normally be based at PNFI, there is no rule that this must be so. This is because innovation cannot be ordained, but must rather be recognized and encouraged wherever it arises. At the same time, the PNFI group may engage in some liaison and technology transfer, but it is understood that, for proper service and efficiency, these functions must operate mainly within the regional groups on the agencies' home ground.

2) The second question concerns the coordination of fire research in such an arrangement. Lines of authority in CFS run out from Ottawa headquarters at the regional directors' level, and downward within regions; it is therefore not possible to place a whole program like fire research under a single authority. There are two possibilities:

   a) a strong central coordinator with the stature to persuade all elements of the group into a cohesive whole, or

b) grass-roots coordination carried on among the researchers themselves.

This latter process has been working with fair success for the past two decades, during the second of which there has been no fire research coordination from headquarters. A visible example of successful cooperation is the Fire Danger Group, a committee of researchers from the four fire research establishments formed in the early 1970s. The development and production of the modern Canadian Forest Fire Danger Rating System through four editions are due to their efforts. As need develops and people become available, similar committees to handle a) ecology plus prescribed fire, and b) fire management systems, would be desirable.

But, as fire research becomes more and more diverse and sophisticated, and the establishments become more independent, the grassroots process becomes less and less adequate. Clearly the time has arrived for permanent strong representation of forest fire in CFS-HQ. The Service itself needs competent interpretation of fire in its Headquarters just to present a credible picture of forestry to the nation. The fire research group needs an unbiased focus for its activities, able to represent its interests to CFS management, and carry out what coordination is possible within the HQ mandate.

A word about coordination, a function with several possible interpretations. The ideal coordinator, in the author's view, would certainly be well versed in most aspects of forest fire affairs, be familiar with the whole fire research program, and see to it that all researchers knew what the others were about. He would visit all establishments regularly and actively bring the research staff together at frequent intervals in small working groups or as a whole. (Frequent meetings and field trips are most important to the cohesion of the widely-scattered CFS fire research group and are, historically, a prime reason for its past successes.) The coordinator would, further, seek to maintain an overall strategy for the research group as a whole, and to develop the essential integrated view of forest fire as it fits into forestry in general. He would have to operate from a position of stature and influence rather than by line authority. He would deal formally with the establishment Program Directors, but his main contacts would be the senior researchers. Since fire research in the CFS has been without central coordination for nearly a decade, the benefits of such a function, well carried out, could be very great. The fire research effort could eventually fragment without it.

3) The third question concerns the relationship between fire research and all other forest research within CFS. Fire behavior, fire suppression, and fire management systems are subjects clearly quite specific to the physical problems of detecting and controlling forest fires. But, just as clearly (see Section 14), fire ecology, fire economics, and prescribed fire overlap strongly with other kinds of forest research. Integrating concepts are called for that are not yet in place. These are important not only for the researchers themselves, who must interact to make sensible progress on a broad front; they are also important to the CFS as a whole, and to the view it presents to the national forestry community.

4) Finally, consider the management of the fire research group itself. As with most forest research this is a delicate enough matter. The senior

fire researchers tend to serve for long periods, say 15 years and upwards, and may become very experienced and knowledgable. Management staff tend to turn over at much shorter intervals. In fire research especially, however, the project leaders usually find themselves (except at PNFI) reporting to a program director with little or no direct experience in their subject. Ideally this should make no difference; but it is possible to doubt that fire research always receives its full share of attention on this account.

It is true that fire research in the CFS throughout its history has been almost entirely conceived and developed by the researchers themselves. There has, in fact, been little that management could do to assist this process, except to offer consultation, support, and make hard decisions when necessary. If management can be supplemented by a coordinating presence in CFS-HQ, the results should be entirely positive.

21. Liaison with Fire Management Agencies

By liaison is meant here the whole range of contact with the agencies who detect, control, and use fire in a forestry context; namely the fire management agencies throughout Canada. This contact includes:

- consultation on agency problems and the kind of research to be done,
- provision of practical information on a regular basis,
- provision of solicited advice on request, and
- helping to put the results of research into practice, i.e., technology transfer.

As to the first of these, there is much concern among the agencies that the CFS fire research group is too overloaded and uncoordinated to pay proper attention to pressing practical problems. One response to this concern is the plan voiced by the Canadian Committee on Forest Fire Management (CCFFM) to have more direct influence on choice of subjects to be studied. This interest is commendable and healthy as long as the need to base useful practical advances on sound science is acknowledged by all. The actual research program must therefore always be a compromise between the agencies' practical concerns and the need to investigate the nature of fire and its effects on the forest and forestry in the best scientific sense.

Information services by the fire research group includes or included at various times, the following items, all but one of which were started by the former Forest Fire Research Institute (FFRI) in Ottawa and produced there for some years before 1979:

1) Annual reports of national forest fire statistics. Still produced at PNFI, these are comparative tabulations and syntheses of data obtained from all jurisdictions by specific request. This information is the necessary base for any opinion or policy about forest fire in Canada and is not available without great difficulty by any other means.

2) Periodic issues of "Forest Fire Control Abstracts". These were collections of short notes on articles and publications of all sorts pertinent to the Canadian forest fire scene, designed especially with non-research

people in mind. They were published three or four times a year from 1950 to 1978, but ceased after the demise of FFRI and the staff reductions attending the establishment of PNFI in 1979.

3) A "Technical Information Centre" and enquiry service. This Centre is, in effect, a collection of some 5,000 publications and documents, arranged for computerized access, that pertain to forest fire and research thereon in Canada. It is not just a conventional library, since many of its items are data collections, unpublished reports, and special correspondence relating to the activities of the CFS fire research group. It was developed at FFRI and operated as an enquiry and loan service to all interested parties. Although still in existence at PNFI, additions to the collection have slowed to a fraction of the former active level, and the accompanying service is no longer advertised.

4) Two bibliographies of CFS fire research output. These were arranged by author and by publication type respectively. They were issued in loose-leaf format, and annual page changes and additions were issued to all registered holders. The items were simply listed; annotations would appear in Forest Fire Control Abstracts. This service lapsed in 1978 as well.

5) An informal newsletter called "Fire and Fury". This began as an internal communication to keep regional fire researchers aware of the activities of other CFS fire research staff including FFRI. It was the special creation of D.G. Fraser of FFRI who issued it several times annually from 1965 to 1976. As its distribution increased (internally and externally) by popular demand, items on fire control techniques and equipment were added. It ceased with the retirement of its founder, and, because his talent was unique, there was no attempt to continue its publication.

6) A newsletter on fire suppression methods and equipment called "Smoke Signals". This is a new effort begun in 1982, that resumes that part at least of the function of the defunct "Fire and Fury". Produced by the fire suppression project at PNFI with contributions from regional projects as well, it is intended as a regular serial for the foreseeable future.

In the author's opinion, the publication of national forest fire statistics must be continued, possibly transferred with care to the Forestry Systems and Statistics Branch at PNFI. "Forest Fire Control Abstracts" deserves greatly to be reinstated, as do the two research bibliographies. "Smoke Signals" performs an already-valued service. The Technical Information Centre would be difficult to update fully, but deserves consideration for modification or blending with a library. In general, these services filled and would still fill a need for which no easy substitutes exist, performed by the only group in Canada that could, namely the CFS fire research staff. Consultations with all forest fire agencies confirm that even after the passage of five years, these services are sorely missed.

The third type of liaison service, namely the provision of solicited advice and expertise is perhaps the most informal and difficult to define. CFS fire research staff, by virtue of their lines of work and length of experience, are usually the best-informed people available on the scientific and technical aspects of forest fire. Especially in the regions they are there-

fore in demand for informal opinion and advice by people at many levels in the fire management agencies. This function must be regarded as both necessary and legitimate from the CFS viewpoint, but the amount of time consumed may seem proportionally too great. The problem of how to regulate this activity without destroying its value is not easy.

Technology transfer, by which is understood the putting of worthy new ideas and research results into practise, deserves a short special treatment with respect to CFS fire research. On reflection, it is clear that technology transfer is a system with three components:

1) an agent within the research organization charged with maintaining positive contact with potential users of research results,

2) an effective means of contact and communication, and

3) a technically competent receiver at the user's end.

If any of these components is lacking, then the process cannot go to completion.

The requirements for effective communication demand that, to do the job properly, the liaison agents must be on the user's home ground. A particular problem arises with respect to fire management systems, for which most of the expertise is at PNFI. The rate of technology transfer in this field would be distinctly speeded by developing the necessary expertise among the regional staffs. At the same time, to fulfill their national mission, PNFI projects must be provided with sufficient travel funds that British Columbia and Newfoundland can be visited as easily as Ontario and Quebec.

As the products of fire research become more sophisticated, their potential can only be realized if the management agencies have the professional capacity to use them. In other words, technology transfer works best when certain key people in the user agencies have the required credentials and keep in close touch with CFS staff. Ideally, new technology should have to be transferred only once; training systems and communication within the management agency should do the rest. In fact, CFS staff must be available for agency seminars and to help establish training courses. It is the obligation of repeating the same message year after year or in different locations that CFS staff must somehow minimise.

What about the concept of special liaison groups within CFS establishments, to whom the fire research projects would turn over their results for transfer to the user? However well this may work for other kinds of forest research, all experience with fire research argues against it. Intimate contact with all external parties concerned with fire is essential throughout the development work; the final "technology transfer" is then an integral part of the whole research process that cannot be logically separated out. The effort that would be required to inform some specially-designated in-house liaison group would be better spent with the users' representatives themselves, with whom the CFS research staff must maintain contact in any event.

This whole range of liaison services is regarded by all parties concerned with forest fire as of crucial importance to the success of the CFS fire research program. Among the regional units, the time spent on all such services may be very high, as much as 60% or so of available working effort. But liaison in all its forms must be well done and seen to be well done, no matter how great the load.

22. CFS Fire Research in Eastern Canada

At present one-half the CFS fire research strength is at PNFI, the other half spread among the three regions from Ontario west. What of the three eastern regions, who at present have no fire research component? The three establishments in question are LFRC, MFRC, and NeFRC.

As for Quebec, the time to consider a fire research unit at LFRC has clearly arrived. The provincial forest fire agencies desire it, the university forestry faculty supports it, and the regional CFS authorities would welcome it. The advantages are several:

a) An additional large part of forested Canada would receive direct attention from the CFS fire research group.
b) CFS fire research would have a French component, a decided improvement from the national viewpoint.
c) Direct pressure on PNFI from the Quebec Region would be partially relieved.

With the present overall proportions of the fire research effort in mind, such a unit should include, initially at least, three professionals plus technical support. They should cover regional studies of fire behavior and the biological aspects of fire, and work closely with PNFI on the further implementation of fire management systems throughout Quebec.

Next, consider the Maritime Provinces. It is not just that New Brunswick, Nova Scotia, and Prince Edward Island together account for, on the average, only 0.5% of the nation's burned area. The proportion of their forested land that burns annually is also, at 0.06%, only one-tenth that of Canada as a whole. It is hard to avoid the conclusion that forest fire is not a serious problem in the Maritimes. The fire control agencies are geared to a smaller scene, and accountable annual fire costs total some $3.5 million, a small fraction of total forestry expenses and industrial value in the Maritimes. The provinces and the MFRC management agree that a CFS fire research unit would not be justified in the Maritimes.

At the same time, proper provision should be made through MFRC for freely-available research service from PNFI and other CFS fire research units. A liaison officer qualified in fire affairs, and in close touch with CFS fire research staff and the provincial agencies would be a possible solution. The potential use of prescribed fire following harvest is an aspect of special interest.

The situation in Newfoundland is to some extent intermediate between that of the other two eastern regions. The proportion of forest land burning annualy is about 0.3%; while only half the national average, this is still

high enough that fire rates as a substantial problem in Newfoundland forest management. However, including Labrador, Newfoundland accounts for only 2.5% of the average national burned area. Thus, the absolute dimension of the problem makes it difficult to recommend a full-scale CFS fire research effort in Newfoundland. In fact, the NeFRC authorities and the provincial forest service, together with the author, are in general agreement on this point.

Nevertheless, as with the Maritimes, there is considerable interest in the potential application of prescribed fire following clear-cutting or spruce budworm mortality. This interest is strong enough that all parties desire some regional effort. It should be possible to set up a study to be operated by one professional (plus technical support) provided he was a) qualified in the fields of silviculture and site preparation, b) an integral part of a larger project working on these matters, and c) in close touch with CFS fire researchers at PNFI and GLFRC for advice on the fire behavior aspect of the study. Prescribed fire is one aspect of fire research that lends itself to integration with another field of forest research. Such a course could be justified provided there was no need for solid long-term continuity in fire research at NeFRC.

23. Size of CFS Fire Research

It would be easy just to say that the CFS fire research group is obviously too small for its job, and should be enlarged. The external forest fire community, especially those agencies that can articulate needs and opinions, is certainly agreed on this point; some have exerted pressure for an increased fire research effort for years. There are, however, some objective measures that might be applied. Consider three criteria: scope of work, rate of output, and stability, each taken in turn.

The scope of modern forest fire research is very broad, as made abundantly clear in Sections 12 and 15. It may be argued that it would be better for the CFS to concentrate its limited fire research effort on some part of this range, presumably just the forest protection aspect, and to drop the rest. This would, in the author's opinion, be a serious backward step. The CFS, to fulfill its mandate in forestry leadership, needs voices of authority on all aspects of forest fire and its implications. The research group itself, to maintain its internal sense of proportion, must be engaged in all categories of fire research. Could some other research agencies perhaps handle the ecological and forest management aspects of fire? Immediately, though, all the difficulties of contract or university research in such a small field raise their heads, as outlined in Section 11. The recent increase in the scope of fire research cannot be reversed without a price, namely the loss of CFS credibility on the subject of forest fire in general.

By stability is meant the ability to maintain a continuous level of expertise and output, more or less independent of the turnover of staff. In a small field like fire research, where much of the experience resides among the current researchers themselves, it takes about five years before a new professional at, say, the Master's level can make a full, steady contribution. It takes 10 to 15 years before the senior researchers are recognized authorities in their lines of work.

There is also the need for the creativity and innovation on which the excellence of the scientific and practical outputs ultimately depends. With its present size, some 20 professionals, the CFS fire research groups has hardly one experienced authority per subject category. Given further the range of location and function, continuity of creativity and expertise cannot be taken for granted. The CFS fire research effort is liable to severe disruption at any time through the loss of one or more of its senior people. Stability is, therefore, not one of its attributes.

As for rate of output, it is the production of new knowledge and information systems on which the CFS fire research group ultimately stands or falls. The key point here is the necessity of maintaining the crucial liaison services, already argued strongly. As the whole group gradually shrank during the 1970s, this need exerted obvious leverage on the available time for new work. The regional fire research projects especially are all heavily occupied in liaison, leaving little time for research. Most PNFI fire projects are also unavoidably much occupied with it as well. When one accounts for the inevitable administrative load that all CFS research projects must bear, as well as its liaison functions, the whole CFS fire research group has, as a rough estimate, hardly one-third of its time available for research. Certainly, the impression gained by the author is that the rate of demand everywhere exceeds the rate of output. In this atmosphere, committed deadlines for the completion of new work are very difficult to specify. The clientele for the practical outputs are generally patient and agreeable, but this understanding may be increasingly hard to maintain.

At any moment, there are always three obvious options: reduce, maintain, or increase the present effort. Consider first a reduction of, say, 10 percent or more. Probably one regional or PNFI project would be lost for every ten points of reduction. Furthermore, any concentration of the remainder would then reduce the efficiency of the liaison function, and new output would have to be concentrated in some particular lines of work to the exclusion of others. Credibility would suffer and the CFS would abdicate its position as the national authority on all aspects of fire in the Canadian forest.

Second, suppose the fire research group were to be held more or less constant for the foreseeable future. Certainly, useful new work would continue, but so would the present problems with stability and rate of output. Serious disruption of the program would be possible at any time, in which case the major clients might seek elsewhere for solutions to some of their problems.

Third, consider an increase in fire research staff. The main aims of such a course would be to:

a) relieve pressure on the regional groups to permit a reasonable output rate of new work,
b) achieve stability in the pool of scientific expertise, especially at PNFI,
c) establish a regional fire project at LFRC, and
d) reinstate the centralized information services such as "Forest Fire Control Abstracts" and the bibliographies.

How much increase would in fact be desirable? The most elementary objective yardstick is the maintenance of a corps of experienced researchers. Suppose that all professionals worked exactly 15 years in fire research, then resigned. In its steady state, a group of 20 would then contain 7 people with 10 or more years service. Given the required scope of subject matter, location, and function, such a group, even with perfect management, could hardly provide continuous across-the-board excellence of the sort desired in a modern CFS fire research program. Given further a reasonable attrition rate and normal variation in aptitude, a doubled professional staff of 40 is probably needed to guarantee a continuous corps of six or eight first-class experienced researchers. With a parallel doubling of technical staff, the result would be a total fire research staff of 80. This figure represents the author's objective estimate of the force required to meet the continuing legitimate needs of all parties.

The above estimate of optimum size obviously bears no relation to the current climate of restraint in CFS research manpower. Nor is there any suggestion here that increases in fire research should be made at the expense of some other discipline. Simply on the grounds listed throughout this paper, CFS fire research does need and warrant some substantial increase in manpower for its own continuing health and that of the CFS as well.

With respect to funding, it is understood that proper expenses for field work, travel for contacts and conferences, and high-technology equipment would accompany any increase in staff. Funding levels for the current program are currently reasonable among the regional establishments, but distinctly inadequate at PNFI. To fulfill its national mandate, Petawawa staff must be able to travel and work as easily at the ends as in the middle of the country, as well as to acquire the sometimes expensive equipment needed for modern research.

The rate of increase in staff, in the event of a substantial addition, should allow for both proper integration of new people and the limited rate at which Canadian universities can turn out trained graduates. Hiring of experienced professionals from outside Canada, if deemed necessary, would only perpetuate the cycle of difficulties in raising the profile of fire science in Canadian forestry faculties. About 15% a year would be a reasonable rate.

The question of priorities in the event of occasional modest increases in manpower is not dealt with here. Current pressures and opportunities at such a time would undoubtedly rule. Conversely, the author bypasses the question of what to cut first in the event of a forced reduction; a general negative impact on the whole group would be the principal effect of such an event. Even if no increase is forthcoming, the continued dedication of the present CFS fire research group may be taken for granted.

24. Dispositon of an Ideal CFS Fire Research Group

If CFS fire research were to be substantially increased, where and how should it be disposed? Each CFS establishment deserves some special consideration:

PFRC - British Columbia has nearly half the nation's timber volume to protect; its forests and topography are unique within Canada. There is intense

interest in modernizing fire management, in the practice and effects of ment, in the practice and effects of prescribed burning, and in the ecological and economic impacts of forest fire.

NoFRC - This fire research unit deals with a huge area of boreal forest that sustains more than half of Canada's annual burned area on the average. The Northern Region contains, in addition, the bulk of the area of Canada's National Parks. With these plus three provinces and NWT to service, its liaison load is the greatest of any region's.

GLFRC - This unit currently operates the largest field program in experimental fire behavior of any CFS establishment, with implications for a much wider area than Ontario alone. Ontario itself is greatly concerned with improvements in fire management, prescribed fire use, and integration of its fire control effort into overall forest management.

LFRC - Establishment of a fire research group here would open up opportunities for addressing the special needs of Quebec. Because climate becomes generally moister as one proceeds eastward in Canada, Quebec poses some particular problems in fire behavior and ecological effect. Its unique organization of seven separate fire control agencies requires special attention with respect to technology transfer.

MFRC and NeFRC - The two eastern CFS establishments have needs with respect to technology transfer in general, and prescribed fire use in particular.

PNFI - The particular needs at the national institute are to stabilize the pool of scientific expertise, to raise the rate of output, and to reinstate some or all of the centralized information services.

The disposition of a doubled fire research group should in the author's opinion, continue to reflect the complementary demands of scientific excellence, practical output, and liaison. The best chance of achieving this is a continuing roughly equal division between national institute and regions, always with the proviso that neither has a monopoly on any particular function. Addition of a unit at LFRC might drop the PNFI share to somewhat less than half. Taking all factors into judgement, here is the author's picture of the disposition of a doubled CFS fire research group compared with present strength.

Establishment	Present P/Y	Doubled Total
PFRC	4	12
NoFRC	9	12
GLFRC	6	10
LFRC	-	8
MFRC	-	1
NeFRC	-	1
PNFI	19	35
CFS/HQ	-	1
	38	80

25. Distribution of Effort among Research Categories

An estimated breakdown of fire research effort among the six categories described elsewhere (Section 15) was tabulated in Section 19. Using judgement based on the various arguments so far laid out, here is the author's picture of an optimum hypothetical doubled fire research program.

Research Category	Present Program		Doubled Program	
	P/Y[1]	%	P/Y	%
Fire behavior	13	36	20	25
Fire ecology	4	11	12	15
Fire suppression	8	22	12	15
Prescribed fire	3½	10	12	15
Fire economics	1	3	4	5
Fire management systems	6½	18	20	25
	36	100	80	100

[1]Minus 1 manager, 1 vacancy.

The principal suggestions are a) a partial shift of emphasis from fire behavior to fire management systems, b) increased emphasis on the biological aspects of fire, namely ecology and its practical offshoot prescribed fire. Note that, with doubled total staff, even those categories projected at lower percentage of total would still receive an absolute increase. Management (at PNFI at least), liaison, and the inevitable administrative load are assumed to be distributed as necessary throughout the above ideal fire research program.

Here are notes on the suggested disposition of strength within each category of fire research:

Fire behavior - Central effort at PNFI oriented to meteorology and physics, with strong regional efforts oriented to field studies and wildfire.

Fire ecology - Central effort at PNFI oriented to process studies and eastern boreal ecology. Strong regional efforts at PFRC and NoFRC at least.

Fire suppression - Main effort at PNFI, with other strength at NoFRC at least.

Fire suppression - Main effort at PNFI, with other strength at NoFRC at least.

Prescribed fire - Strong regional efforts at PFRC and GLFRC especially with representation at all establishments, including MFRC and NeFRC. PNFI to study burning under standing forest.

Fire economics - Concentrated at PNFI.

Fire Management Systems - Strong central effort at PNFI, with regional efforts at PFRC, NoFRC, GLFRC, and LFRC oriented to special regional problems and adaptation.

Understood of course is the generally greater liaison content of all regional efforts as compared with PNFI's. Understood also is the cooperative nature of the research effort within each category, with progress on a national front from which all establishments and their regional clients benefit. No attempt is made here to detail the distribution of P/Y's by both research category and location, or the priorities by which modest increases should be allotted.

26. Conclusion - The Job to be Done

It is easy to write out a long list of individual subjects worthy of study in fire research. The author accumulated dozens during his consultations; over 30 are listed (see Section 6) in Van Wagner (1981). The problems with such lists are:

a) how to arrange subjects in order of equivalent scope and difficulty,
b) how to judge what level of complexity and confidence is feasible or necessary for each study and its result, and
c) how to account for innovation.

Section 15 (The six categories of forest fire research) outlines the concerns and opportunities in each subject area; information or working systems do certainly already exist in all areas. How, then, can one decide when the job is done?

The answer is that the job is never done, for three basic reasons. The first is that any research result or practical output comes under immediate pressure for continuous improvement as soon as it is made public, from either the scientific community or the practitioners and users. The greater the success, the greater the pressure. The second is that a pool of expertise cannot be maintained in any other way than by conducting research. The third is that research, by its very nature, implies a succession of breakthroughs that cannot be foretold. These may at any time confound the most careful planning and change the course of the research into new, more fruitful directions.

The ultimate justification for conducting research on forest fire is a) that it is a complex natural phenomenon with both physical and biological dimensions, b) that it can only be described and understood through scientific investigation, c) that it profoundly affects an immensely important natural resource, and d) that useful information systems of increasing sophistication can be produced that assist appreciably in its management. It has been hardly two decades since increasing enlightenment about the nature of forest fire has prompted the free investigation of all its aspects. The job will be complete when forest science itself has fulfilled its potential.