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USE OF ADVANCED CONCEPTS IN DISPATCHING FIRE CONTROL RESOURCES

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ABSTRACT

This paper reports on the development of the Intelligent Fire Management Information System (IFMIS), a computer program for dispatching fire suppression resources to wildfires. The program uses a number of advanced concepts to provide information to fire managers for both strategic and tactical purposes. Specifically, IFMIS integrates data bases, mathematical modeling, computer graphics, geographic information displays, and expert systems. The addition of expert knowledge bases and agency policies provides the fire manager with a greater decision support capability than that provided by traditional data processing approaches. The use of new computer programming languages, in conjunction with high-speed personal computers now makes this technology cost-effective enough to deliver to both forest and district level dispatchers.

INTRODUCTION

The dispatch of fire control resources to wildland fires is a complex process. The consequences of making the correct decision involves increasingly costly suppression resources and potential losses to valuable property and natural resources. The development of initial-attack decision support systems that employ state-of-the-art computer technologies is seen as essential to meet today's forest protection objectives. Computers have the potential to provide rapid and consistent decision support during periods of high fire loads. This paper reports on the development of a micro computer-based program for forest fire preparedness planning and initial attack dispatching. The Intelligent Fire Management Information System (IFMIS) integrates a number of advanced technologies including mathematical modeling, data base management, geographic information display, and expert systems. The goal of IFMIS is to provide a computer-based decision support system that can be used by forest fire managers for planning daily fire management activities, for real-time dispatching of fire control resources to new fires, and for training or simulation exercises.

BACKGROUND

Integrated decision support systems are not new to the Canadian forest fire management scene; the Fire Management System (FMS) developed by Kourtz (1984) at the Petawawa National Forestry Institute has been successfully implemented, either in whole or in part, in three provinces. Despite the varying success of this and other pioneering systems, the adoption of fire management information systems has generally been slow in Canada for a number of reasons. These include the high capital costs associated with the hardware platforms required for fire management systems, new continuing costs in the form of salaries for computer systems staff, the requirement to modify agency structure to meet software requirements, and the high cost associated with adapting computer software to a new location. This last point is especially true for expert systems, which tend not to be very portable from region to region.

The recent advent of powerful personal computers with their increased on-line memory and computational speed makes it possible to more-economically implement "desktop" fire management systems. So powerful are the new personal computers that they routinely outperform the pioneering systems in terms of computational speed and graphics capability. The personal computer has dramatically cut the costs for fire management systems, both in terms of capital and operating costs. There is also less need for specialized computer support staff. Advances in fire management systems have also be made possible by the availability of new programming languages, such as PROLOG and C, and by new expert system shells and data base managers.

CONCEPTUAL DESIGN

The Intelligent Fire Management Information System is a hybrid software system that integrates four advanced technologies: data base management, mathematical modeling, geographic information display, and expert systems.

Data Base Management

The development of decision support system for initial-attack dispatching demands large fire environment and fire management data bases. Consequently, data base management constitutes a considerable component of the IFMIS software. The data base management system (DBMS) is capable of handling large data volumes of varying formats. These data provide the essential inputs for the mathematical models, expert systems, and geographic display system. An example of the type and size of data bases used by IFMIS for the Alberta Forest Service's Provincial Forest Fire Centre installation in Edmonton are listed in Table 1.

Mathematical Modeling

IFMIS embodies full implementations of the two major subsystems of the Canadian Forest Fire Danger Rating System (CFFDRS) (Stocks et al. 1989), the Canadian Forest Fire Weather Index System, and the Canadian Forest Fire Behavior Prediction System. In addition, IFMIS incorporates equations to calculate course distance, bearing, and estimated time of arrival (ETA) of fire control resources to reported wildfires. These and other mathematical process models are used in a library of custom functions to conduct preparedness planning exercises and real-time or simulated dispatch recommendations.

Geographic Information Display

The ability to incorporate the display of geographic information in a computer-based preparedness and dispatching system can greatly enhance its functionality. Data inputs and outputs from the CFFDRS can be viewed spatially. A module capable of geographic information display was implemented that permits the display of user-defined maps of variable scales. The map themes that can be displayed are user-defined and represent single or multiple variables from the data-base management system.

Expert Systems

Computer programs that undertake the solution of difficult tasks by using knowledge and mimicking the solution methods of human experts are called expert systems. The knowledge embodied in an expert system may be that of one or more human experts within a given field. The experience and knowledge of a forest fire dispatcher is one example of a knowledge domain that is narrow enough to encode in an expert system. Expert systems can also be used to encode scientific information, agency policies, and other information that may be too imprecise to define in terms of mathematical models.

Knowledge can be represented or encoded in expert systems using a number of different approaches. The most common of these is through the use of IF-THEN rules. A fifth-generation language called PROLOG is commonly used to build expert systems (Sterling and Shapiro 1986). To encode the dispatch rules, IFMIS uses what is called a PROLOG-based expert system shell. Kourtz (1987) has used pure PROLOG to build an expert system for initial-attack dispatch for the Societe de Conservation de l'Outaouis, which is responsible for forest fire control in southwestern Quebec. Although pure PROLOG can be used to write expert systems, the use of an expert system shell specific to the initial-attack dispatch problem was considered to provide greater ease of development and long-term maintenance. This approach has been described by Lee and Pickford (1987) for a demonstration expert system for use in dispatching suppression resources to wildfires on the Okanogan National Forest of the State of Washington.

One of the main advantages of using an expert system shell is that the primary concepts of the initial-attack expert system can be formulated using a taxonomic approach. This taxonomy or structure identifies all the elements considered to be essential in the dispatch decision. Once the taxonomy has been established it can be compiled into the main body of the PROLOG code. Attached to this is a rule compiler that takes near-English syntax IF-THEN rules and translates the knowledge base into PROLOG code. What this means is that the knowledge base of the initial-attack expert system can be readily maintained by non-PROLOG programmers with very little training. By coding the rules in near-English syntax, annual updating will be a relatively easy task. This ability to easily change the knowledge base due to changes in agency policy, the addition of new knowledge, or because of

Table 1. List of the primary data bases required for the Alberta Forest Service's Provincial Fire Centre IFMIS installation in Edmonton

Data base		Number of
Name	Description	records
CELL	Forest inventory and fuel type cells (64.8 ha)	512 000
GCELL	Generalized forest inventory and fuels cells (14.5 km^2)	41 400
WXSTN	Weather stations inventory	150
FWI	Fire weather	30 000
FFWI	Forecasted fire weather	30 000
FACILITY	Facility inventory	15 000
IABASE	Initial attack base inventory	200
TANKBASE	Air tanker base and airport inventory	200
SKIMMER	Skimmer lake inventory	1 200
ACSPECS	Aircraft specifications inventory	250
CREWS	Fire crew inventory	350
TANKERS	Air tanker inventory	15

regional differences makes the expert system shell approach appropriate.

SYSTEM DESCRIPTION

The IFMIS program consists of nine modules. The module acronyms and names are listed below in the order they appear on the main system menu:

INFO	System information
DEPLOY	Resource deployment
DETECT	Fire detection assessment
FWI	Canadian Forest Fire Weather Index System
FBP	Canadian Forest Fire Behavior Prediction System
MAPS	Geographic information display
DBMS	Data-base management system
GEO	Geographic coordinate conversion and measurement
REPORTS	Report writer

A brief description follows of how each module functions.

System Information

The INFO module provides general system utilities and operating system services. The module provides a description of the functioning of the context-sensitive help facility. A setup procedure is also provided for system customization.

Resource Deployment

The DEPLOY module of IFMIS consists of two major components: a resource allocation planning tool and resource location tracking system. This module uses mathematical programming and GIS computer graphics and expert systems technology to aid the fire manager in this very important day-to-day function.

The resource allocation planning tool combines agency policy rules, the CFFDRS subsystems, and fuel-type data to assist the dispatcher determining the appropriate resource levels. These levels are determined by using a spatial analysis approach.

The resource location tracking system automates the dispatch wall map found in most fire dispatch rooms. It archives, reports, and displays the location and status of fire crews, aircraft, air tankers, ground-based vehicles, equipment caches, and other resources as defined by the user.

Fire Detection Assessment

The DETECT module is composed of two sub-modules, 1) the Detection Assessment Report and 2) the Appropriate Suppression Response Expert System

(ASRES). Both submodules of DETECT can be used either in real-time or in simulation modes. When a fire is reported, the dispatcher enters fire report information, including the fire location. After the fire report information has been entered a number of calls are made to access the data base and to spawn mathematical computations.

Selecting the Detection Assessment Report option produces the report shown in Figure 1. This report summarizes the interpolated weather and FWI system components at the geographic location of the fire. Using fuel type information from the data base, it computes the forecasted fire behavior up until midnight. The fire behavior information provided includes an hourly summary of the predicted fire area, perimeter, and forward spread distance. It also identifies the presence or absence of crowning activity. The report also provides an ordered list of available initial-attack crews and air tankers. This list includes the distance, bearing, and estimated travel time to the fire for each resource.

The Appropriate Suppression Response Expert System embodies dispatcher expertise, agency policies, and scientific information using IF-THEN rules. These rules are coded in near-English syntax to make annual updating a relatively easy task. The dispatch knowledge base is also interpreted rather than being compiled, which reduces maintenance (programming) costs.

Central to the expert system is the determination of an appropriate initial response. Within the Alberta Forest Service, it is the goal of the dispatcher to ensure that the required fire control resources arrive at the new start within an appropriate time. The expert system relies heavily on the fire weather data, forest inventory data, and mathematical modeling to provide the user with an appropriate initial attack recommendation. Specifically, it uses the outputs described in the Detection Assessment Report. This factual information is imported to the expert system through the "fact pump." An example of the information provided by the expert system is shown in Figure 2. When the necessary data cannot be found in the data base, the expert system either asks the user for the missing information or infers from defaults encoded in the system. The user has the ability to ask the system why it needs the information being requested. The user can also ask the system to provide an explanation of how it determined the preferred force level.

Canadian Forest Fire Weather Index System

The FWI module is a complete implementation of the Canadian Forest Fire Weather Index (FWI) System (Van Wagner 1987). The module permits the input of morning, noon, and/or late afternoon fire weather observations and can be used to compute both actual and forecasted FWI System components. These outputs can be displayed using screen or printed graphics and in tabular reports. The graphic displays include maps, seasonal display charts, and bar charts. Figure 3 is an example of a Drought Code Season Display Chart for Berland Tower in the Whitecourt Forest. The FWI system components can also be displayed in map form (Fig. 4).

Canadian Forest Fire Behavior Prediction System

The FBP module implements the most-recent versions and modifications of the Canadian Forest Fire Behavior Prediction (FBP) System (Alexander 1985; Lawson et al. 1985; Alexander and De Groot 1988). The module provides for two methods of operation: manual and data base. The manual method functions as a calculator, querying the user for the standard FBP System inputs: FBP System fuel type, fine fuel moisture component of the FWI System, wind speed, slope, etc. The user can then elect to perform FBP System simulations that are either time, area, or distance dependent. Output can be directed to a printer as well as to the screen.

The data-base method performs FBP System projections using information from the data base. Required inputs are the date, time, and geographic location of the fire. From these inputs IFMIS will then perform FWI System and forest cover type data-base look-ups to interpret the weather, fuel, and terrain inputs. IFMIS interprets the FBP System fuel type from the cover type information. Weighted means are used when the stand contains multiple fuel types. FBP System projections can also be displayed in map form (Fig. 5) Fire intensity charts can also be displayed using the FBP module (Fig. 6).

Detection Assessment Report

Location: SW - 1 - 58 - 18 - 5   Date: JUNE 5, 1988   Ignition Time: 1615 MDT

Fire Weather/Danger Conditions:

Temp	RH	Wind	Rain	FFMC	DMC	DC	ISI	BUI	FWI	DSR
24.3	26	14.0	0.0	92.5	31.3	87	12.4	33.0	21.0	5.98

FBP System Fuel Types:

Species	FBP Fuel	% Cover
SB	C-2	65 %
SW	C-2	35 %

FBP System projections:

Elapsed (hh:mm)	Time LDT	FFMC	ISI	ROS (m/min)	Crowning potential	Dist. (km)	Area (ha)	Perim (km)
0:00	1615	92.2	11.8	13.3	No	0.0	0.0	0.0
0:15	1630	92.4	12.2	13.9	No	0.2	3.6	0.7
0:30	1645	92.6	12.5	14.5	Yes	0.4	15.1	1.4
0:45	1700	92.5	12.4	14.2	Yes	0.6	34.1	2.1
1:00	1715	92.3	12.0	13.6	No	0.8	59.3	2.8
2:00	1815	91.8	11.2	12.2	No	1.6	207.1	5.2
3:00	1915	91.1	10.1	10.5	No	2.2	404.7	7.3
4:00	2015	90.1	8.8	8.3	No	2.7	609.0	8.9
5:00	2115	89.5	8.1	7.3	No	3.1	820.6	10.3
6:00	2215	89.5	8.1	7.3	No	3.6	1063.7	11.8
7:00	2315	89.5	8.1	7.3	No	4.0	1338.2	13.2

L/B ratio: 1.35

Available crews:

ID	Base name	Resource type	Name	Status	Dist. (km)	Bear-ing	ETA (hh:mm)
W14	Grizzly	HA CREW	H-1	STANDBY	55.3	124	0:26
W32	Virginia Hills	IA CREW	I-3	STANDBY	57.4	212	0:29
W11	Tony	IA CREW	I-1	STANDBY	74.8	130	0:37
W42	Imperial	IA CREW	I-4	STANDBY	86.9	229	0:43
W21	Rat Creek	IA CREW	I-2	STANDBY	99.2	323	0:44

Available air tankers:

ID	Base name	Aircraft type	Group	Status	Dist. (km)	Bear-ing	ETA (hh:mm)
YQU	Grande Prairie	DC-6B	1	STANDBY	201.7	131	0:45
Loon	Loon River	DC-6B	3	STANDBY	362.9	195	1:21
YRM	Rocky Mountain House	SUPCANS	2	STANDBY	203.6	328	1:27

Figure 1. Detection assessment report for a simulated fire occurring at 1615 Mountain Daylight Time (MDT) on May 4, 1988, in the SW quarter of Section 1, Township 58, Range 18, west of the 5th meridian in the Whitecourt Forest of central Alberta.

Appropriate suppression response expert system summary

Initial attack strategy: Direct and indirect attack

Fire intensity rank: 3

Low to vigorous fire behavior.
Hand prepared fire line likely to be challenged.
Heavy equipment may be required.

Special considerations:

Gas plant located at SE-13-19-58 W of 5

Recommended appropriate suppression response:

Helitack crew 1 from W14 Grizzly

Air tanker group 1 from Grande Prairie

Figure 2. Appropriate suppression response expert system summary for a hypothetical fire occurring on May 4, 1988, in the SW quarter of Section 1, Township 58, Range 18, west of the 5th meridian in the Whitecourt Forest of central Alberta.

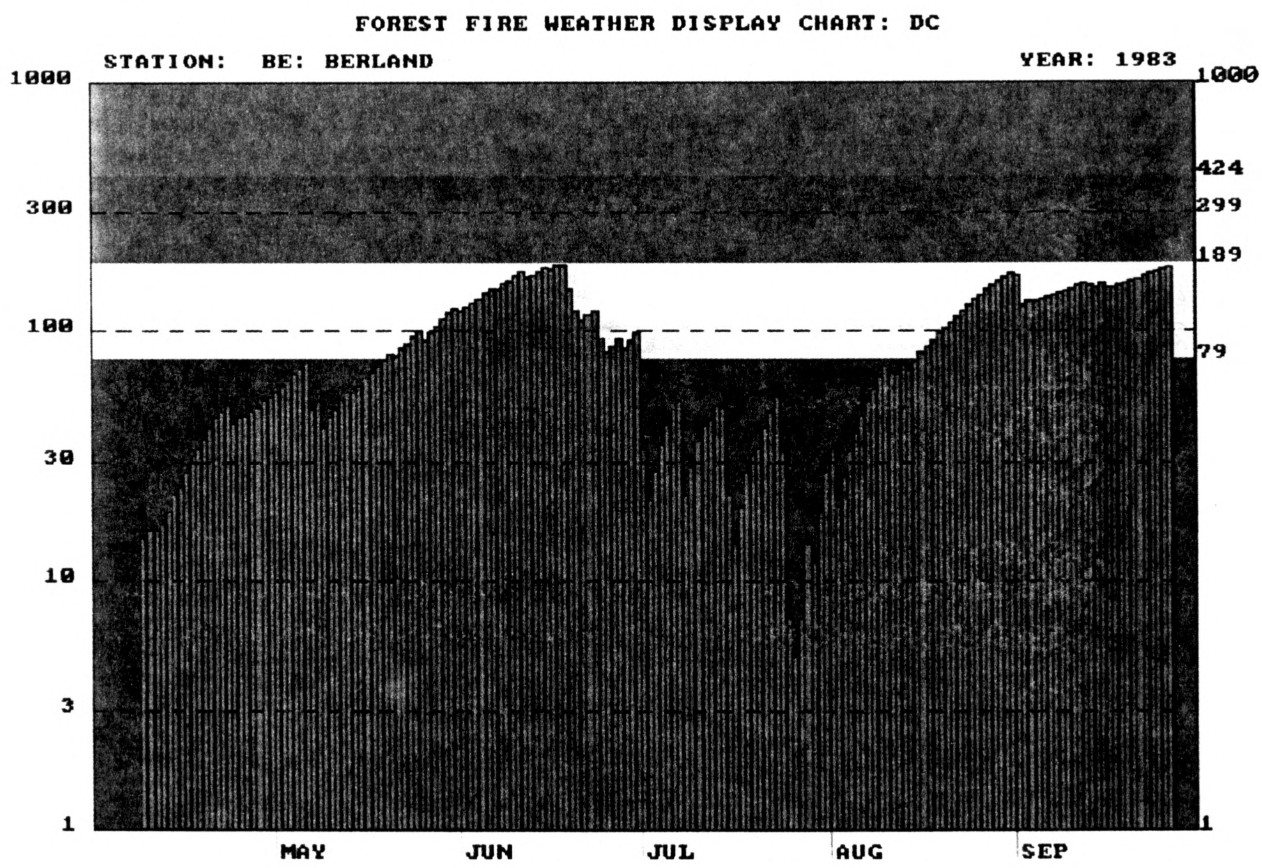

Figure 3. Seasonal display chart of 1983 Drought Code values for Berland Tower, Whitecourt Forest in central Alberta.

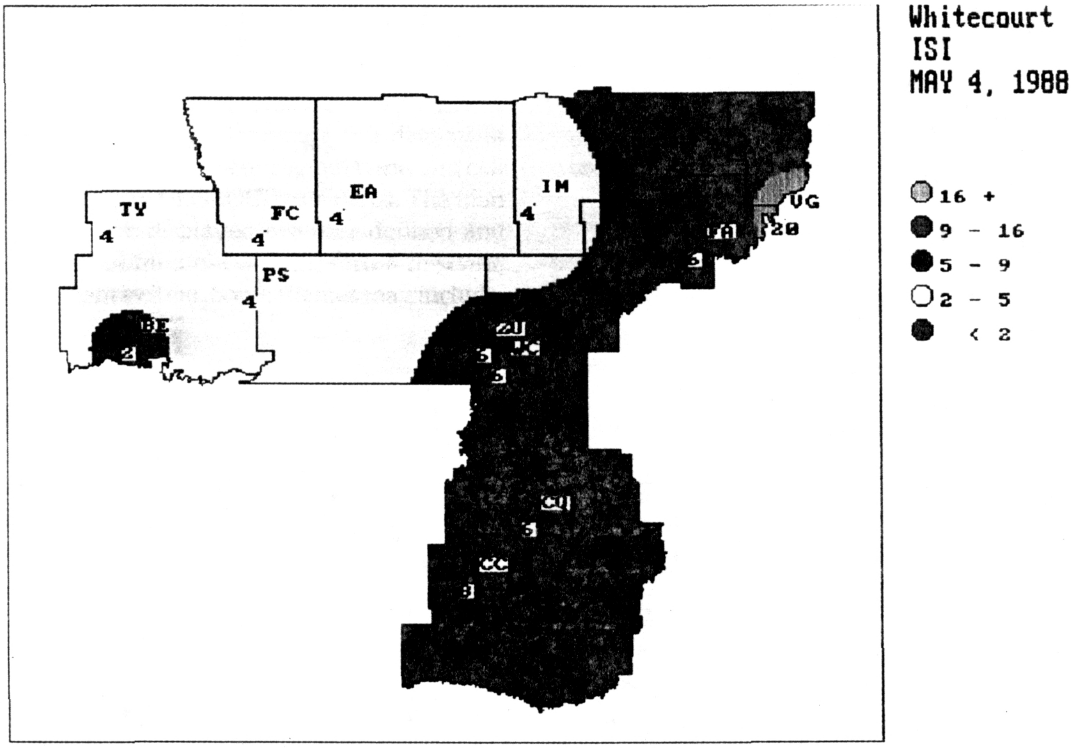

Figure 4. Initial Spread Index (ISI) map for the Whitecourt Forest of central Alberta on May 4, 1988.

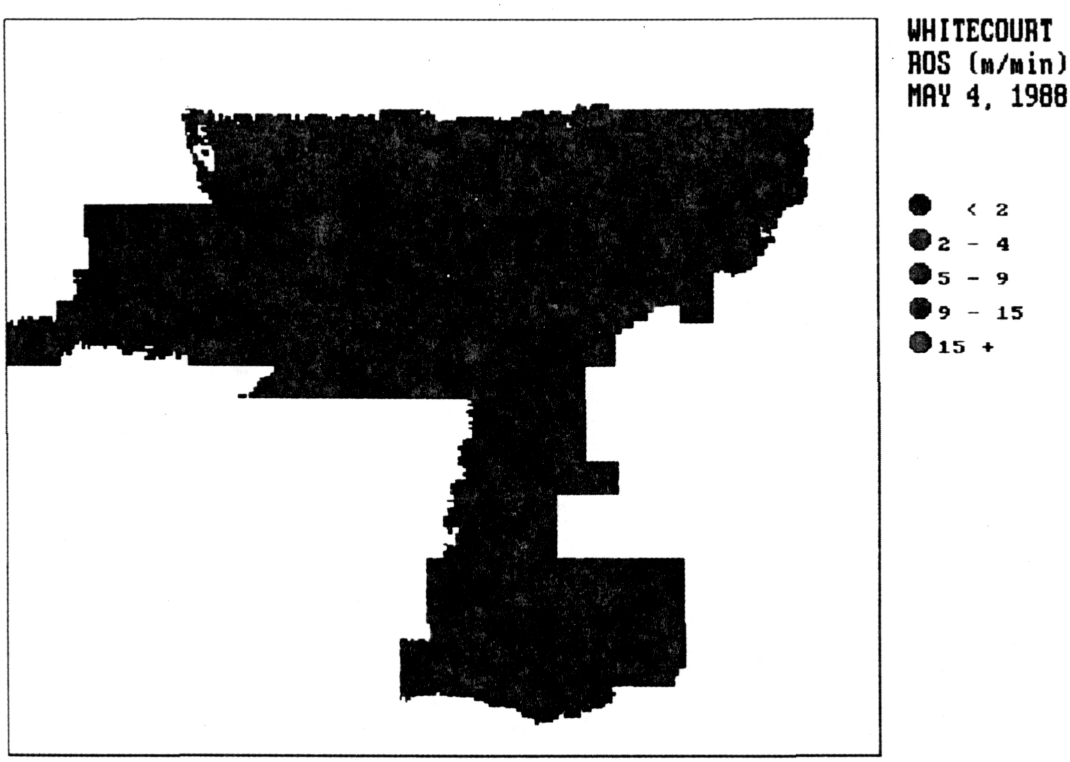

Figure 5. Predicted headfire rate of spread map for the Whitecourt Forest of central Alberta on May 4, 1988.

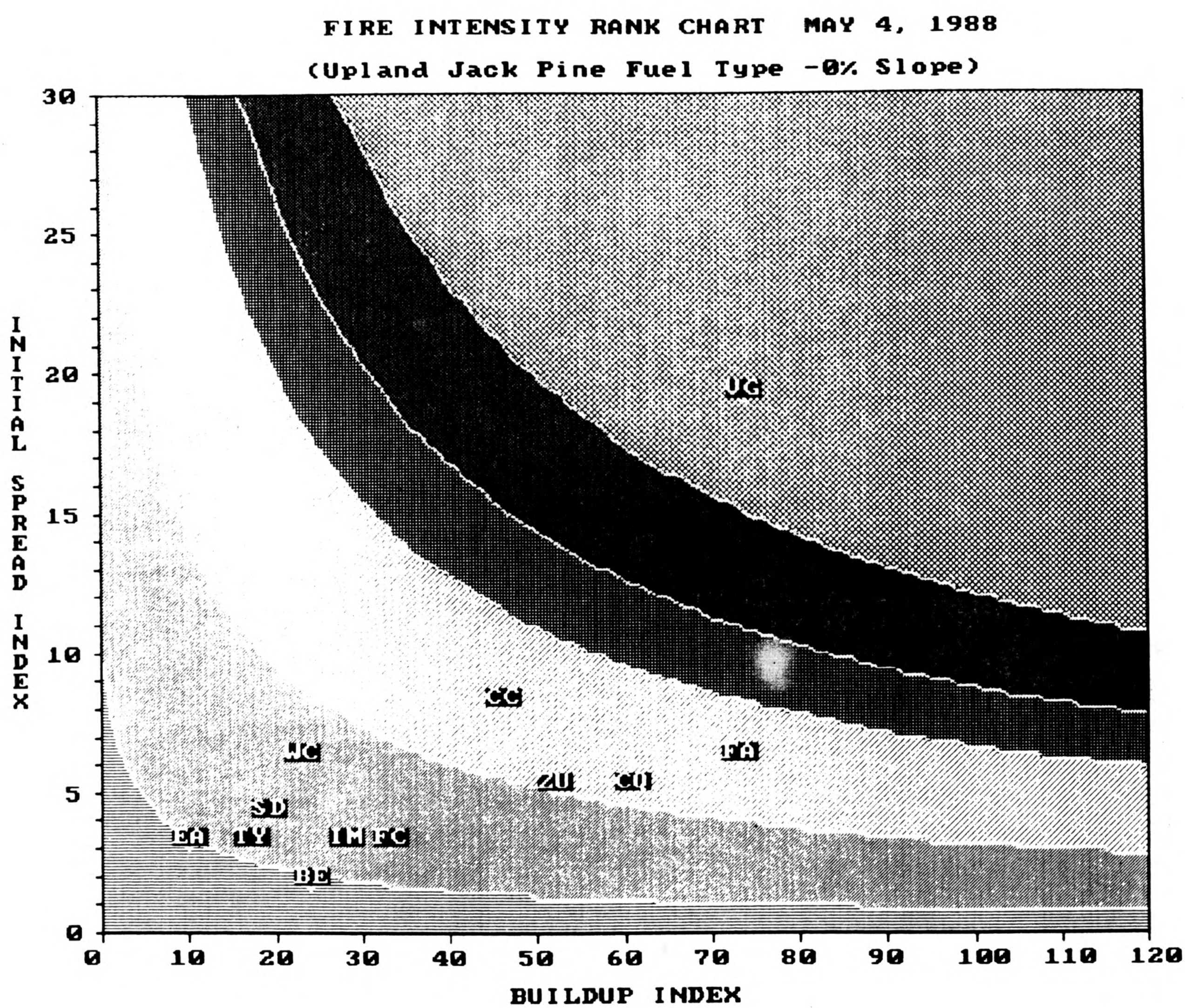

Figure 6. Fire intensity rank chart display for all fire weather stations in the Whitecourt Forest of central Alberta on May 4, 1988.

Geographic Information Display

The MAPS module implements a geographic information display system that permits the display of provincial or territory, forest or region, park, and cell (e.g., township, UTM, GEOLOC) scale maps. The map themes that can be displayed are user defined and represent single or multiple variables from the database management system. Some themes may include:

- Forest inventory
- Districts
- Protection priorities
- Resource values
- FWI System components
- FBP System components
- Suppression resources
- Road networks

An example map of FBP System fuel types for the Whitecourt Forest is presented in Figure 7.

Data Base Management System

The DBMS module of IFMIS spawns the data-base manager, which is used for general data base maintenance of system files.

Geographic Coordinate Conversion and Measurement

The GEO module of IFMIS provides the user with a number of geographic utilities for converting between various coordinate systems and for calculating the distance, bearing, and time to travel between two geographic locations.

Report Writer

A REPORTS module provides a facility for reporting on selected IFMIS data bases using predefined

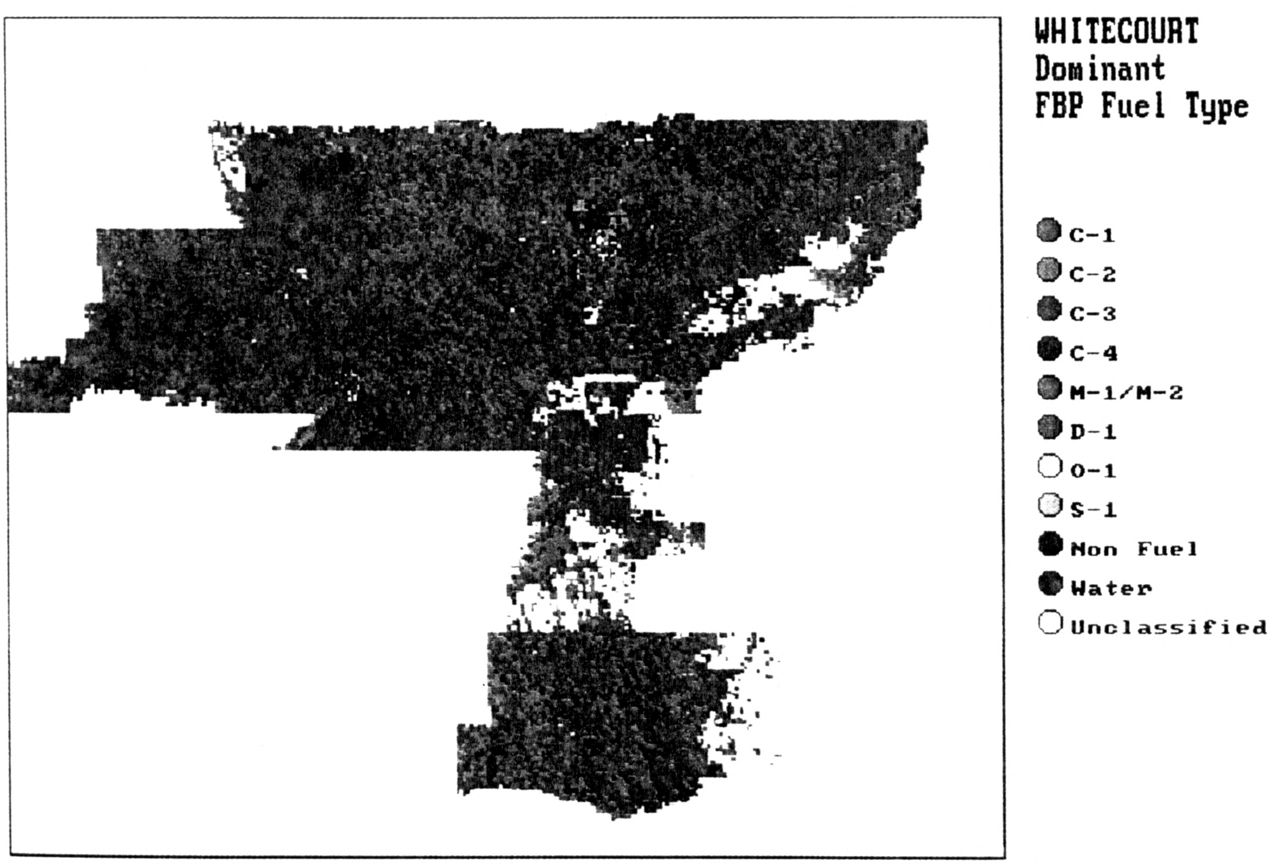

Figure 7. FBP System fuel types for the Whitecourt Forest in central Alberta.

queries. These queries can be directed to the screen, a printer, or a file.

IFMIS IMPLEMENTATION

Operational prototypes of IFMIS will be installed at three locations in Alberta and one location in Saskatchewan for the 1989 fire season (Fig. 8). By the 1990 fire season, IFMIS will be operational in all provincial and most regional forest fire centers of Alberta, Saskatchewan, and Manitoba.

IMPLICATIONS FOR FOREST FIRE MANAGEMENT

The integration of the four technologies described above will, when completely operational, provide the forest-fire dispatcher with a wide range of usable information in a form that is easy to use and understand. The application of forecasted and actual weather using a spatial interpolation approach will provide better estimates of fire weather and fire behavior potential. The integration of geographical information displays of forest cover type, FBP System fuel type, and terrain data will provide more accurate and reliable fire intelligence data on which to base potentially costly decisions. The presuppression planning capabilities of IFMIS will result in better allocation of initial-attack crews and air tankers. The operational use of the computer-based fire detection assessment (smoke) reports that analyze the interpolated weather conditions, predicted fire behavior, and nearest available resources to assist the dispatcher in ensuring that the most appropriate resources are allocated to fire will no doubt become common place and routine in the near future.

CONCLUSIONS

The forest-fire dispatcher will be required to incorporate increasingly more information into daily decision-making to reduce suppression costs and damages to values-at-risk. Without the application of advanced computer technology such as that described in this paper, it will not be possible to incorporate this increase in information into the decision-making process. Decision support systems designed for initial-attack dispatching, such as IFMIS, will be able to compensate for these increased demands by successfully implementing expert systems to act as assistants to the forest-fire dispatcher. The operational use of expert systems will not occur overnight but will take many years of research, development, and testing. The demystification of computers and new technologies such as artificial intelligence, expert systems, and geographic information systems will no doubt yield even greater benefits for fire management practitioners in the near future.

ACKNOWLEDGMENTS

This work has been supported in part by the Canada-Alberta, Canada-Saskatchewan, and Canada-Manitoba forest renewal and development agreements.

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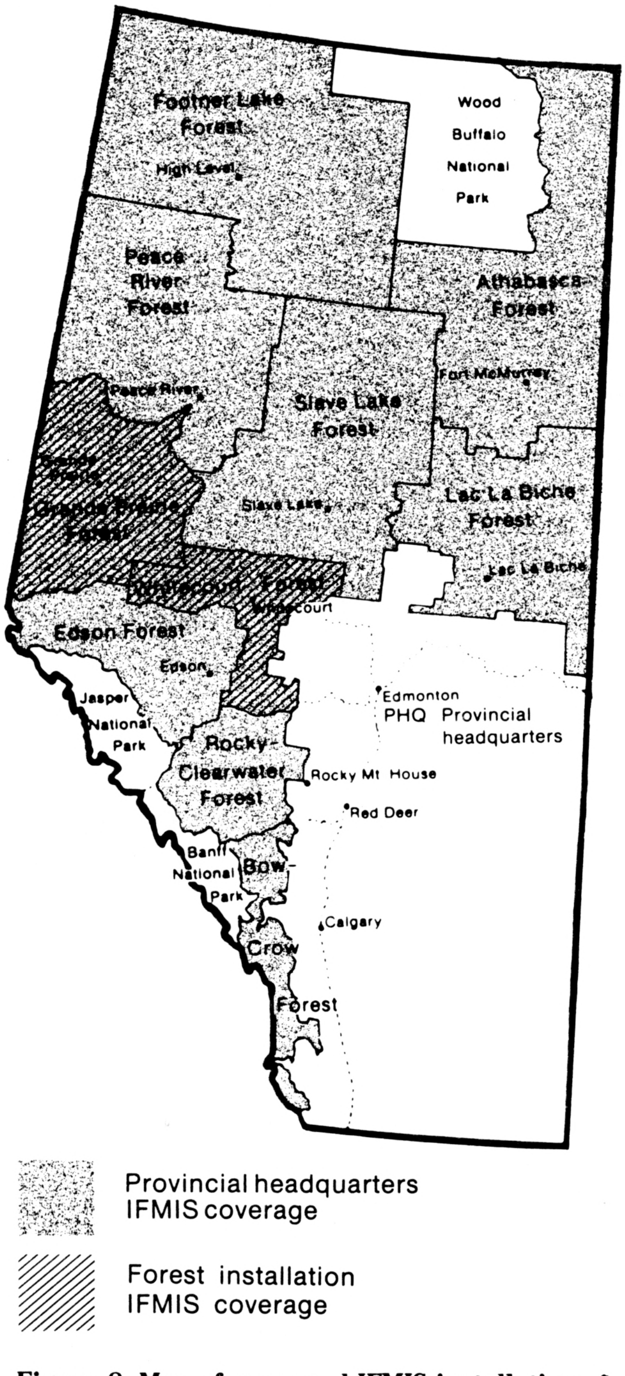

Figure 8. Map of proposed IFMIS installations for the 1989 fire season in Alberta.

THE ART AND SCIENCE OF FIRE MANAGEMENT

Proceedings of the
First Interior West Fire Council Annual Meeting and Workshop
Kananaskis Village, Alberta,
October 24-27, 1988

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INFORMATION REPORT NOR-X-309

FORESTRY CANADA
NORTHWEST REGION
NORTHERN FORESTRY CENTRE
1990

This publication was printed with funds provided by the
Government of the Northwest Territories
and Alberta Forestry, Lands and Wildlife.

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