Proposal to the FMF

Development and Application of a Wildland Fire Growth Model

April 1999

PROPOSAL TO THE FOOTHILLS MODEL FOREST

Title: Development and Application of a Wildland Fire Growth Model

Project Team: Cordy Tymstra -Team Leader (Alberta Land and Forest Service), Don Harrison (Alberta Land and Forest Service), Kelvin Hirsch and Bernie Todd (Canadian Forest Service), Gwynfor Richards (Brandon University), Software Engineers (Figure 1).

Possible Collaborators: Weldwood, other provincial fire management agencies (SK, BC, ON, QC, Parks Canada), FMF landscape disturbance team. The project team will make effort to include other collaborators once the project is initiated.

EXECUTIVE SUMMARY

Fire growth modelling involves the simulation of fire spread across landscapes with heterogeneous fuels and topography based on daily or hourly fire weather data. Using an integrated, multi-disciplinary team we propose to utilize and enhance key features from a number of existing models to create a state-of-the-art wildland fire growth model over a two year period. Its foundation will be the Canadian Forest Fire Behavior Prediction (FBP) System and the most recent wave propagation fire algorithms developed at Brandon University. The growth model will be produced as a stand alone application that will input and output data to a Geographic Information System (e.g., ArcView). The graphical user interface will be highly interactive and allow the user extensive flexibility in determining the input parameters and the output format.

It is envisioned that this fire growth model will have numerous operational and strategic applications. As part of this proposal, a pilot study will be conducted on the Foothills Model Forest to demonstrate how the wildland fire growth model can be used strategically to assess the potential threat that wildfire poses to important values-at-risk (e.g., communities, recreational facilities, primary wood supply areas, etc.) and the effectiveness of possible mitigative strategies (e.g., fuels management). The model will also provide insights about wildfire processes which can be integrated and/or linked to models of landscape disturbance, biodiversity, timber supply, and carbon loss/gain that are being developed or used within the FMF.

INTRODUCTION

Fire has been one of the primary agents of change in forest ecosystems within the Foothills Model Forest and other parts of Canada. Historically, wildfire has played a significant role in creating and maintaining landscape structure, biodiversity, and forest health. Understanding the behaviour, propagation, and effects of wildfires is essential if the approximation of natural disturbance is one of the considerations of sustainable forest management.

In this project, we propose to develop a process-based wildland fire growth model (WFGM) that will serve as the primary "engine" for numerous operational and strategic applications in fire and forest management. This includes, for example[1]:

(a) predicting the hourly or daily growth of fires that have escaped initial attack in real-time,
(b) evaluating the potential threat that wildfires could pose to important values-at-risk (e.g., communities, recreational facilities, timber management units, etc.),
(c) assessing the effectiveness of various management strategies aimed at reducing the risk of large fires, and
(d) evaluating the risk of loss due to wildfires (or burn probability) across landscapes created by different forest management strategies and practices.

The WFGM will improve public safety and forest protection, enhance the ability to conduct sustainable forest management, and increase the understanding of fire's ecological function at the stand and landscape level. It will be a valuable tool that can be integrated and/or linked to models of landscape disturbance, biodiversity, timber supply, and carbon loss/gain.

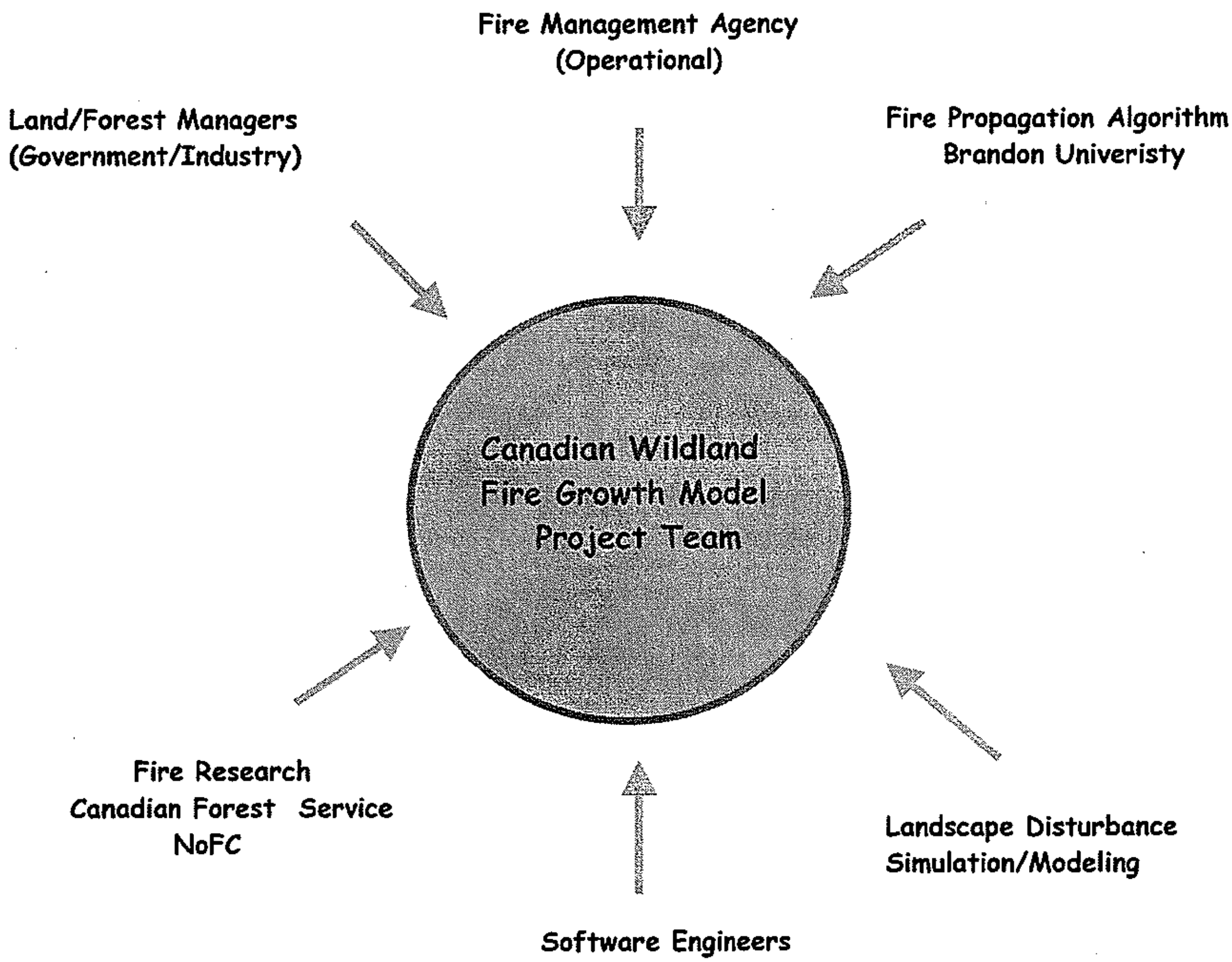
BACKGROUND

The Canadian Forest Fire Behavior Prediction (FBP) System (Forestry Canada Fire Danger Group 1992) is a complex, semi-empirical system that mathematically expresses and integrates many of the fuels, weather, and topographic factors that influence forest fire behaviour. The FBP System is used across Canada and in other parts of the world to predict fire behaviour in a quantitative and structured manner. It is based on over 500 observations of experimental fires and well-documented wildfires and produces outputs that describe the physical characteristics of a wildfire (e.g., rate of spread, fuel consumption, head fire intensity, degree of crowning). The FBP System provides the underlying fire spread models for the spatial simulation of fire propagation over a landscape.

Computerized fire propagation/growth models were first developed in the 1970s (e.g., Kourtz and O'Regan 1977), however recent advances in GIS and other computing

[1] See Appendix A for a more detailed explanation of some of the possible uses of the fire growth model.

Figure 1 Canadian Wildland Fire Growth Model Project Team



technologies, combined with the development of new fire propagation models/algorithms (e.g., Richards 1990, 1995) provide the opportunity to create an advanced, user-oriented fire growth model for use in Canada. Components of a number of currently available fire growth models (Appendix B) will be combined to produce an effective and highly efficient Canadian wildland fire growth model.

PURPOSE

The purpose of this project is to create a state-of-the-art, physically-based, deterministic fire growth model that will allow for the operational and strategic assessments of spatial fire behaviour potential on the landscape.

PROJECT OBJECTIVES

1. To utilize and enhance key features from a number of existing models in the development of a spatially-explicit, wave propagation fire growth model that will simulate fire spread over a landscape on an hourly or daily basis.

2. To demonstrate the application of the FGM in the operational, real-time prediction of fire growth of escaped wildfires.

3. To strategically apply the FGM to determine the potential threat that an individual wildfire or multiple wildfires may pose to selected values-at-risk and the effectiveness of possible mitigative strategies (e.g. fuel management).

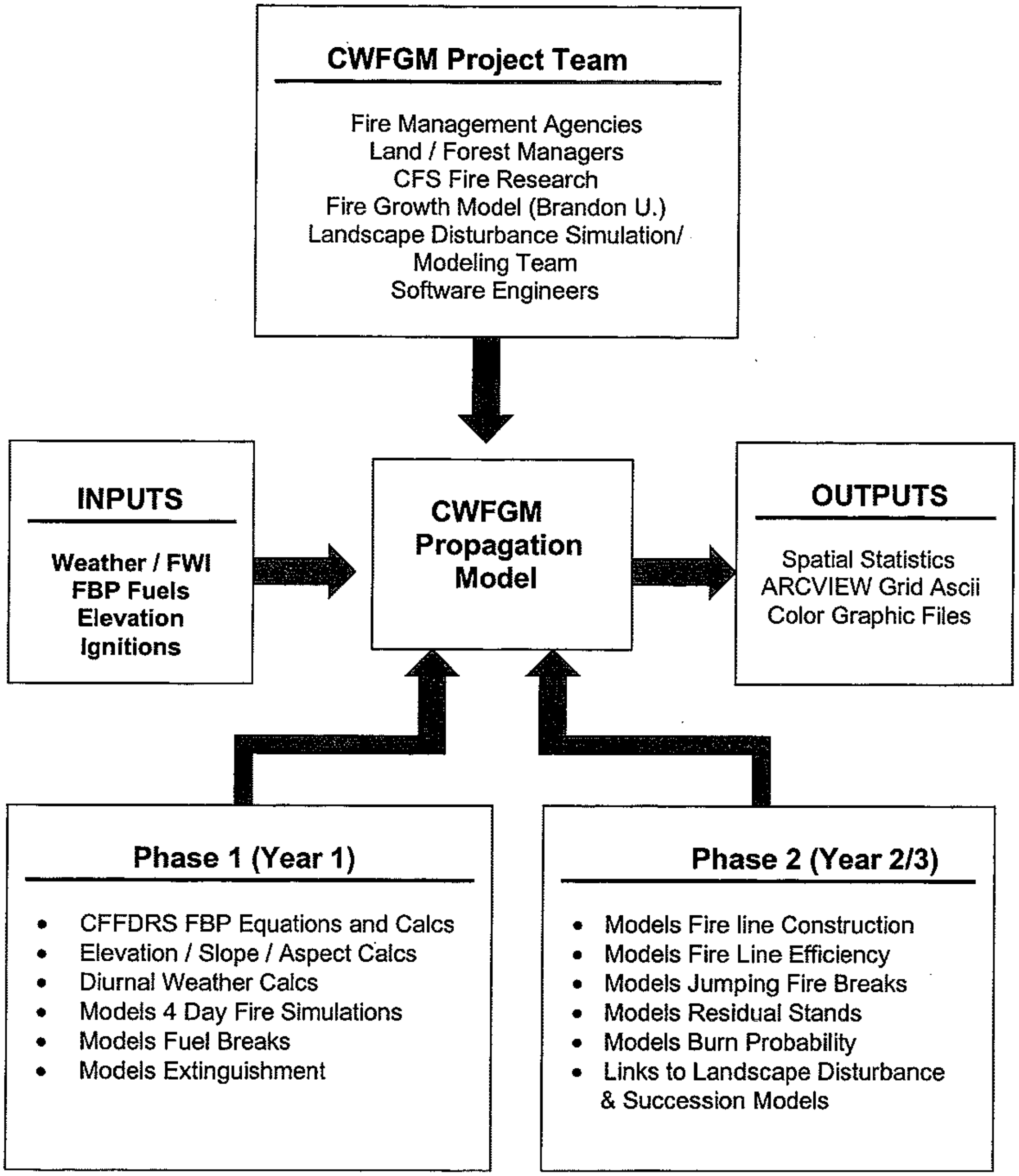
4. To ensure the FGM functions as a stand alone application that can be easily used and integrated with other applications.

METHODOLOGY

The FGM will be developed through a collaborative effort involving an integrated interdisciplinary team of researchers and managers from governments, universities, and the private sector (Figure 1). Fire behaviour equations, derived from spatial fuels data, topographic data, diurnal daily/hourly fire weather information, will be combined with the most recent fire propagation algorithms in a stand alone program that inputs and outputs data to a GIS (Figure 2). The user-interface will be designed by software engineers and will be based on desirable features available in existing fire growth models such as FARSITE (Finney 1994, Finney and Ryan 1995) and WILDFIRE (Todd 1999). For example, it will allow the user to easily modify any of the input parameters (i.e., spatial fuels data, topography, diurnally-adjusted weather data) and customize the output display format.

To illustrate the strategic application of the WFGM model, a series of possible fire scenarios will be developed and analyzed for a selected area on the FMF. This "case study" will be developed through discussions with government and industry forest managers as well as landscape ecologists. This application will require creating a FBP System fuel type raster data layer from AVI data, compiling and analyzing historical fire weather data, and using the provincial digital elevation model.

Figure 2. Development of the Canadian Wildland Fire Growth Model



DELIVERABLES

1. Software and accompanying documentation of a spatially-explicit, wave propagation fire growth model.

2. A presentation and demonstration illustrating the application of the FGM in the operational, real-time prediction of fire growth of escaped wildfires.

3. A pilot project which uses the FGM to determine the potential threat that an individual wildfire or multiple wildfires may pose to selected value-at-risk and the effectiveness of possible mitigative strategies will be conducted. A report summarizing the methodology and results will also be produced.

4. A workshop/training course will be conducted to explain the components of the model and to demonstrate potential applications in the fields of forest ecosystem management and fire management.

TIMELINES

Appendix E includes a time action schedule. The objective is to provide a prototype fire growth model within one year (March 31, 2000). This will allow users to run the FGM as a deterministic model (operationally or strategically). Extended functionality and features will be completed in the second year as well as the ability to complete multiple runs (stochastically) to spatially assess burn probability.

FUNDING

Funding is required primarily to cover software engineering contract costs. Travel expenses will also be incurred to bring all the project team members together during meetings. Funding is required for a training workshop and other types of technology transfer.

An hourly rate of $70.00 is the standard rate for senior analysts on contract. Approximately 185 work days are required during the fiscal year 1999/2000. This equates to a cost of approximately $92,500.00 for the first year.

During fiscal year 2000/2001 a senior analyst is required to complete the remaining tasks as outlined in the workplan. Approximately 165 work days are required. This equates to a cost of approximately $82,500.00.

Year 1	$92,500.00	Software engineering
	$3,500.00	Travel expenses

	$96,000.00	
Year 2	$82,500.00	Software engineering
	$3,500.00	Travel expenses
	$5,000.00	Workshop

	$92,000.00	

The project team will also solicit funds from other sources. These include:

- Fire management agencies
- Forest management companies
- Other Model Forests
- Other private industry
- Research grants
    - NSERC
    - CFS (e.g. climate change adaptation fund)
    - NCE

The additional funding will be used to "fast track" the development of the prototype version and the development of enhanced features. Using the Fire Growth Model to assess the role of fire in establishing and maintaining landscape pattern and structure is considered a longer term deliverable (links to spatial timber supply and vegetation succession models are required).

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Appendix A

Potential applications of the Fire Growth Model

1. Deterministic Model Runs

1.1 Operational Use - Deterministic Model Runs

Fire management agencies will benefit by operationally using this Fire Growth Model to assist in wildland fire behaviour prediction. Suppression activities are planned based on expected fire behaviour. A Fire Behaviour Officer (FBO) will be able to use this fire growth model to run various "what if" scenarios based on the forecasted weather. Multiple fire scenarios (i.e. multiple fires in a zone) can also be evaluated to assist in assigning priorities to each fire.

The operational use of this Fire Growth Model will be the same as the strategic uses with the exception that the model will be run as a deterministic model in "real time" mode. Operational use of the model will generally involve short time periods (1 hr to 48 hr prediction).

Flexibility is an important consideration for operational use. The model will provide flexibility by allowing the end user to define the following model inputs:

- actual or forecasted weather
- single or multiple point ignition
- point or polygon input
- user defined hourly weather or daily modeled diurnal curve
- date, time and location of ignitions (point, line or polygon)
- duration of model run

The Fire Growth Model will also be a valuable tool to use during media and community briefing sessions when a large fire threatens life and property.

1.2. Strategic Planning – Deterministic Model Runs
Evaluating the Threat of Wildfire to Key Values-at-Risk

The Fire Growth Model can be used in the same manner as the operational use but in a "planning" mode rather than in a "real time" mode. The model is still run as a deterministic model, however, land and forest managers can implement the model as though they are "playing the fire game" to evaluate the threat of potential wildfires to important values-at-risk (e.g. communities, industrial facilities, recreation facilities).

This assessment can be made on current or future forest landscapes.

The end user defines the following model inputs:

- single or multiple point ignitions
- point or polygon input
- user defined hourly weather or daily modeled diurnal curve
- user defined weather
- date, time and location of ignitions (point, line or polygon)
- duration of model run

Using the model as a deterministic model in a planning mode allows end users to select the location of ignition points based on actual historic locations of fires or any location that the end user chooses to evaluate.

Running the model in a planning mode provides greater flexibility to input weather data from various sources:

- climatology (i.e. percentile FWI code and indices)
- actual historical (i.e. replicate weather from historical fires)
- worst case scenario

1.2.1 Desired Enhanced Features

- Ability to add fuel breaks
- Ability to incorporate fire line construction
- Ability to spot across (breach) fire breaks (natural and anthropogenic)

1.3 Strategic Planning – Deterministic Model Runs Evaluating Strategies to "Cool the Forest"

The Fire Growth Model can be used to assess the effectiveness of alternative forest management strategies (e.g. harvest scheduling, cutblock layout and design, silviculture) to mitigate the threat of wildfire, in particular, large, high intensity fires that will be difficult to suppress.

1.3.1 Desired Enhanced Features

- Use historical, climatology or user defined weather (e.g. worst case scenario)
- Ability to link to spatial timber supply models
- Ability to link to landscape fire behaviour potential analysis models (SFMS)

2. Probabilistic Model Runs

2.1 Strategic Planning - Probabilistic Model Runs Evaluate Burn Probabilities across the Landscape

This application is identical to the use of the Fire Growth Model as a strategic planning deterministic model, with the exception that instead of using individual deterministic runs, multiple runs are completed to spatially assess burn probability. To derive a statistically valid burn probability map, an estimated minimum of 100 runs should be completed.

The Fire Growth Model can be run repetitively to evaluate the burn probability of current and future forest landscapes.

This application inputs point ignitions. The date, time and location of these ignitions can be randomly selected. True random or weighted random locations can be used. The weighted random location is a random location that is weighted by area and historical occurrence (e.g. Working Circle A, Compartment A or Landscape Management Unit A have 60% of all fires based on fire origin location in the historical database). A true random location is a location randomly generated by a program.

End users may also want to select the actual historic fire origins to "re-play" the incidence of lightning fires (natural disturbance) and person caused fires. This may be useful because most fires are suppressed when they are small.

The ability to use projected (expected) fire incidence is another extension of using the fire growth model to evaluate burn probabilities using different scenarios of fire incidence.

2.1.1 Desired Enhanced Features

- Ability to link to spatial timber supply models
- Ability to link to values at risk to produce quantitative threat assessment

2.2 Strategic Planning - Probabilistic Model Runs
Evaluate the Function of Fire as a Landscape Disturbance Process

The Fire Growth Model can be used to assess the role of fire in establishing and maintaining landscape patterns. This requires succession models for vegetation succession.

2.2.1 Desired Enhanced Features

- Requires succession models
- Ability to link to landscape disturbance models

Appendix B

Evaluation of Fire Growth Models
Abstracts

Cellular (Point) Propagation Models

The most common technique to model fire growth is the cellular model. This model uses regular grids (raster) both as data input layers and as the template for propagating the fire. Each cell is modeled as a point source that potentially spreads to neighbouring cells.

Various templates are applied to cellular models to approximate the elliptical shape of fire and to emulate the application of Huygen's principle. Basic cellular propagation models underestimate fire size and shape. This error can be minimized by increasing the number of spread vectors to extend the template. Increasing the number of spread vectors in the direction of fire spread results in an asymmetric template. Asymmetric templates increase the accuracy of fire area and perimeter.

Cellular propagation models are technically not as complex to develop and program (code). Richards (1995) suggests that these models are compromised by a phenomenon referred to as coordinate ghosting. This phenomenon is based on a dependency of the modeled output to the grid characteristics (raster coordinate arrangement).

Wave (Vector, Curve) Propagation Models

Some fire growth models use a use a vector or wave propagation technique to produce vector fire perimeters at selected time intervals. The fire growth models, FIREBRAND (Richards 1995) and FARSITE (Fire Area Simulator, Finney 1994) for example, implement the Huygens' principle for modeling surface fire growth using the method developed by Gywn Richards at Brandon University (Richards 1988, 1990, 1993, 1995, Richards and Bryce 1995). The simple ellipse is used as the underlying model of diffusion and shape (Van Wagner 1969). Huygens' principle of wave propagation is applied by using the vertices of the fire perimeter as propagation points to begin new elliptical growth. This creates an elliptical wave front. Richards (1990, 1995) calculated orthogonal spread rate differentials for each vertex.

The wave propagation technique avoids some of the problems encountered with cellular models (e.g. geometric distortion, under estimation of size and perimeter location). Though more validation and comparison studies are required, the vector output is considered to be more representative of the behaviour and final imprint (i.e. shape, size, location) of fire on the landscape. French (1992) compared cellular and wave propagation model outputs against actual data and found that the wave propagation model outputs were more accurate. Computation speeds were also faster.

WILDFIRE

Bernie Todd - Canadian Forest Service

Wildfire is an eight-point elliptical fire growth model that incorporates GIS data, FBP System calculations and diurnal weather calculations to estimate patterns of hourly fire perimeters. The user supplies basic fire ignition information (date, start time and location in latitude and longitude coordinates), the current day's weather data (relative humidity (RH), wind speed, wind direction), three of the current day's Canadian Forest Fire Weather Index (FWI) System values (Fine Fuel Moisture (FFMC), Duff Moisture Code (DMC), and Drought Code (DC)) and the average daily minimum and maximum values for temperature and wind speed. The user also must supply raster-based fuel and elevation data.

The model then uses the geographic location to calculate times of sunrise and sunset and the associated diurnal hourly weather values for the next several days (Beck, 1989). These values include hourly estimates for temperature, RH, wind speed, wind direction and the corresponding value of FFMC. The calculation of hourly weather data is then applied to the calculation of rate of spread across cells as based on the CFFDRS. The accumulation of rate of spread values provides estimates of fire perimeters and fire areas. Outputs include ARCView compatible Grid ASCII text files and Graphical Color Files for the hourly time since ignition, the actual FBP System calculations (ROS, HFI, SFC, TFC and CFB) for inside the fire area, as well as, for outside the fire area.

Prescribed Fire Analysis System (PFAS)

Kerry Anderson - Canadian Forest Service

The Prescribed Fire Analysis System is a long range fire growth model intended to predict probable fire spread and extinction over the course of weeks to months. Beyond the range of normal weather forecasting, PFAS is a probabilistic model based on climatology. Probable fire extents are estimated by first estimating the probability of a fire reaching a certain point within a certain time. The probability of a fire extinction event is then estimated. This is the probability of a fire stopping event occurring prior to the fire reaching the point of concern. The probabilities are calculated from climatological records. The PFAS model combines the spread and extinction probabilities and spatially produces a probable fire extents map.

Medium Range Fire Growth Model (MRFGM)
Kerry Anderson - Canadian Forest Service

The Medium Range Fire Growth Model calculates fire growth on the scale of hours to days. Using the FBP system, the rate of spread is calculated to propagate the fire across the landscape and maps of ignition time, fire intensity, and fuel consumption are calculated. Diurnal trends are captured using J.A. Beck's diurnal equations for temperature, humidity and wind speed. The MRFGM predictions can be passed to PFAS to add more current knowledge to the long term fire growth. The MRFGM is currently under development and features will be added to it in the near future.

FARSITE
Mark Finney - Systems for Environmental Management

FARSITE (Fire Area Simulator) is a vector propagation fire growth model that integrates models of surface fire spread, crown fire spread, spotting, fire acceleration and fuel moisture. Vector fire perimeters are produced at specified time intervals. FARSITE uses Huygen's principle for modeling fire growth. The methodology and algorithms developed by Richards (1990, 1995) are incorporated in FARSITE.

Spatial data (GIS raster databases) of fuels and topography are required. The weather and winds are inputted as streams of data.

FARSITE is the primary fire growth model used by fire management agencies throughout United States. The vector fire perimeter output represents an integration of the 5 models, using a fire phase approach. Although some of the theoretical models (crown fire spread, spotting and acceleration) may apply in Canada, FARSITE is not used in Canada because BEHAVE is the main fire spread model used in the simulator. The Fuel Moisture Model (NFDRS) and the surface spread model (BEHAVE) are fire behaviour models specific to United States. As well, the approach to fire behaviour modeling in Canada is significantly different than the approach used in the United States.

Firebrand
Gwynfor Richards - Brandon University

Firebrand is the fire growth model developed by Gwynfor Richards at Brandon University. The algorithms first published by Richards were incorporated in FARSITE. Since then, Richards has improved the algorithms and has included an approach for integrating topography.

Firebrand was developed primarily as a research application. It has not been used operationally in Canada because customization of the program is required.
This fire growth model is the most advanced, state-of-the-art vector propagation model available.

FireNB
Ugo Feunekes - Remsoft Inc.

FireNB is a raster propagation fire growth model. FireNB uses an 8-12-8 asymmetric template for fire growth. This template applies additional spread vectors in the effective spread direction, thereby reducing errors in estimating fire area and perimeter. This model assigns "paths" from source to target based on spread azimuth. The path is used to approximate relative percentages of fuels and slope effects.

Since FireNB was developed for the Province of New Brunswick to address a specific need, it is a customized application. In particular, specific inputs and outputs are required.

Operational use of FireNB by fire management agencies, requires significant customization. This company has also shown a preference to develop generic products that can be used nationally or internationally, rather than developing many different customized versions of the same model.

Prescribed Burn Management System (PBMS)
Tom Grims - Evergreen

Parks Canada contracted the development of a fire growth model called PBMS. PBMS is a variable point elliptical fire growth model. This model was not included in the evaluation because of the lack of time and information available.

Note: The following evaluation of existing fire growth models is a quick assessment or "skate across the pond". It does not represent a thorough review and detailed assessment of the models. Ideally, evaluation criteria should be weighted. The most important component of a fire growth model is the "engine" - the spread propagation algorithm used. The intent of the evaluation is to assess the existing functionality available with the existing models and to identify the strengths and weaknesses of each model.

Optimal Model
Canadian Wildland Fire Growth Model
Canadian Wildland Fire Growth Model Project Team

The optimal fire growth model is the wave propagation fire spread model proposed in this proposal. It incorporates and builds on many of the features and functionality of existing fire growth models. This model will be easy to use and interactive. It will also input and output to GIS. Appendix B identifies the features and functionality of this model.

	Wildfire	PFAS

Modeling Principles

General Specifications

Type of Model	8 pt Symmetrical Raster	8 pt Symmetrical Raster
Type of Model Output	Time Units	Probability Units
Search Mechanism	Hash-link Chain	Matrix - Pointer
Length of Simulation Period	0 to 48 hrs	Infinite
Speed of Model	Fast	Moderate
Metric Compatible	Yes	Yes
ARCView compatible	Yes	Yes
Any validation completed	No	In Progress

Programming Language

Model and Interface Separate	Yes	Yes
FGM	Microsoft C	Microsoft C
Interface	Visual Basic	Visual Basic

Operational Use

Hardware Requirements	PC	PC
Operating System	Windows 95 / NT	Windows 95 / NT
Software Requirements	None	None
Ease of Integrating FBP Data	Easy	Easy
Overall Ease of Use	Easy	Moderate

Modeling Specifications

Uses Latest CFFDRS FBP Eqns	Yes	Yes
Uses FBP Slope / Wind Eqns	Yes	Yes
Uses CFFDRS FWI Eqns	Yes	Yes
Method of Incorporating Elevation	Grids	Grids
Models Diurnal Weather Trends	Yes	Yes
Type of Diurnal Modeling	Beck and Trevitt 1989	Beck and Trevitt 1989
Models Fuel Breaks	Yes	No
Models Jumping Fire Breaks	No	No
Type of Model	None	No
Models Extinguishment	Yes	Yes
Type of Extinguishment	DMC / ROS	DMC
Models Residual Stands	Yes (ROS / CFB / HFI)	No
Sophistication of Residual Modeling	Low	No
Models Fire Line Construction	No	No
Type of Fire Line Modeling	No	No
Types of Fire Lines Allowed	No	No
FBP-FireLine Efficiency Criteria	No	No
Ignition Type (point / line / polygon)	Point	Point / Polygon (Grid)
Number of Ignitions Allowed	3	1
Ease of Parameter Changes	Moderate	Moderate
Conversion Cost for Canadian Apps	None	None

Special Model Requirements

Model Requirements	None	- 30 yrs of Climatological Data - Binary Weather Database - Climatological Data Input Grids - Lambert Projections on Grids - Yearly Climatological Records
Comments	- Good user manual (documentation) Provided	

	Wildfire	PFAS

Model Inputs

General

Handles Grid Data	Yes	Yes
Format of Data	ARCView GridAscii	ARCView GridAscii
Maximum Size of Input Area	Yes	Infinite
Handles Variable Cell Size	Yes	Yes

Fuel / Elevation Data

Uses FBP Fuels	Yes	Yes
Uses FBP Lookup Table	Yes	Yes
Uses FBP Grid Input File	Yes	Yes
Uses Elevation Grid Input	Yes	No
Uses Slope Grid Input	No	Yes
Uses Aspect Grid Input	No	Yes

Weather Data

Uses Weather Grid Input	No	No
Number of Weather Stations Used	1	Multiple
Interpolates Weather	No	Yes
Weather Values Required	Temp, RH, WS, WD, Rain	Historic Temp, RH, WS, WD, Rain
FWI Values Required	FFMC, DMC, DC	Historic FFMC, DMC, DC Today's DMC
Generates Diurnal Trends	Yes	Yes
Diurnal Weather Vales Required	Max-Min Temp and WS	Monthly Max Min – Temp, WS
Allows On-Screen Changes	Yes	No
Ease of Use / Entry	Easy	Real-time : Mod – Startup : Low

Ignition Points

Uses Latitude / Longitude	No	Yes
Allows On-Screen Input	Yes (DialogBox + Cursor)	Yes (Diallogbox)

Fuel Break Construction

Allows On-Screen Input	Yes	No
Ease of Use / Entry	Easy	No

Fire Line Construction

Allows On-Screen Input	No	No
Ease of Use / Entry	None	No

Colors

Uses FBP Fuel RGB Lookup Table	Yes	No
Uses FBP Class RGB Lookup Table	Yes	No
Uses Fire Hour RGB Lookup Table	Yes	No
Ease of Use / Change	Easy	Poor

Model Outputs

Format of Output	ARCView GridAscii	ARCView GridAscii
Table Summary of Spatial Statistics	Yes	Yes
Summary of Fire Hours	ARCView GridAscii	ARCView GridAscii
Summary of FBP Values Inside Fire	ARCView GridAscii	No - NA
Summary of FBP Values Whole Area	ARCView GridAscii	No - NA
Number of FBP Outputs	10	No - NA
Graphical File Outputs	Yes	Yes
Number of GIF Outputs	15	3
ARCView Compatible	Yes	Yes

MRFGM

Modeling Principles

General Specifications

Type of Model	8 pt Symmetrical Raster	
Type of Model Output	Time Units	
Search Mechanism	Matrix – Stack Pointers	
Length of Simulation Period	3 – 10 days	
Speed of Model	Fast	
Metric Compatible	Yes	
ARCView compatible	Yes	
Any validation completed	No	

Programming Language

Model and Interface Separate	Yes	
FGM	Microsoft C	
Interface	Visual Basic	

Operational Use

Hardware Requirements	PC	
Operating System	Windows 95 / NT	
Software Requirements	None	
Ease of Integrating FBP Data	Easy	
Overall Ease of Use	Moderate	

Modeling Specifications

Uses Latest CFFDRS FBP Eqns	Yes	
Uses FBP Slope / Wind Eqns	Yes	
Uses CFFDRS FWI Eqns	Yes	
Method of Incorporating Elevation	Grids	
Models Diurnal Weather Trends	Yes	
Type of Diurnal Modeling	Beck and Trevitt 1989	
Models Fuel Breaks	No	
Models Jumping Fire Breaks	No	
Type of Model	None	
Models Extinguishment	No	
Type of Extinguishment	No	
Models Residual Stands	No	
Sophistication of Residual Modeling	No	
Models Fire Line Construction	No	
Type of Fire Line Modeling	No	
Types of Fire Lines Allowed	No	
FBP-FireLine Efficiency Criteria	No	
Ignition Type (point / line / polygon)	Point	
Number of Ignitions Allowed	1	
Ease of Parameter Changes	Moderate	
Conversion Cost for Canadian Apps	None	

Special Model Requirements

Model Requirements	Accesses Climatological records to Define Max-Min Ranges for Diurnal Calculation.	
Comments	Under Development – Similar to the Wildfire Model in concept. Development has been temporarily postponed. Interface needs work.	

MRFGM

Model Inputs

General

Handles Grid Data	Yes	
Format of Data	ARCView GridAscii	
Maximum Size of Input Area	Yes	
Handles Variable Cell Size	Yes	

Fuel / Elevation Data

Uses FBP Fuels	Yes	
Uses FBP Lookup Table	Yes	
Uses FBP Grid Input File	Yes	
Uses Elevation Grid Input	No	
Uses Slope Grid Input	Yes	
Uses Aspect Grid Input	Yes	

Weather Data

Uses Weather Grid Input	No	
Number of Weather Stations Used	1	
Interpolates Weather	No	
Weather Values Required	Temp, RH, WS, WD, Rain	
FWI Values Required	FFMC, DMC, DC	
Generates Diurnal Trends	Yes	
Diurnal Weather Vales Required	Max-Min Temp and WS	
Allows On-Screen Changes	Yes	
Ease of Use / Entry	Moderate	

Ignition Points

Uses Latitude / Longitude	Yes	
Allows On-Screen Input	Yes (DialogBox)	

Fuel Break Construction

Allows On-Screen Input	No	
Ease of Use / Entry	No	

Fire Line Construction

Allows On-Screen Input	No	
Ease of Use / Entry	No	

Colors

Uses FBP Fuel RGB Lookup Table	No	
Uses FBP Class RGB Lookup Table	No	
Uses Fire Hour RGB Lookup Table	No	
Ease of Use / Change	Poor	

Model Outputs

Format of Output	ARCView GridAscii	
Table Summary of Spatial Statistics	No	
Summary of Fire Hours	ARCView GridAscii – Time Hrs	
Summary of FBP Values Inside Fire	GridAscii – HFI-CFB-SFC-TFC	
Summary of FBP Values Whole Area	No	
Number of FBP Outputs	4	
Graphical File Outputs	Yes – HFI-CFB-SFC-TFC	
Number of GIF Outputs	4	
ARCView Compatible	Yes	

	FARSITE	Firebrand

Modeling Principles

General Specifications

Type of Model	Vector	Vector
Type of Model Output	Time Units	Time units
Search Mechanism	N/A	N/A
Length of Simulation Period	Data dependent	Data dependent
Speed of Model	Fast	Fast
Metric Compatible	Yes	Yes
ARCView compatible	Yes	No
Any validation completed	Yes	Yes

Programming Language

Model and Interface Separate	?	No
FGM	C++	C
Interface	?	C

Operational Use

Hardware Requirements	PC	PC
Operating System	Windows 95 / NT	Windows 95 / NT
Software Requirements	None	None
Ease of Integrating FBP Data	Easy	Moderate
Overall Ease of Use	Moderate	Moderate

Modeling Specifications

Uses Latest CFFDRS FBP Eqns	No	Yes
Uses FBP Slope / Wind Eqns	No	Yes
Uses CFFDRS FWI Eqns	No	Yes
Method of Incorporating Elevation	Grids	Grids
Models Diurnal Weather Trends	No	Yes
Type of Diurnal Modeling	Beck and Trevitt 1989	Standard Curve
Models Fuel Breaks	Yes	Yes
Models Jumping Fire Breaks	No	No
Type of Model		
Models Extinguishment	No	Yes
Type of Extinguishment	No	?
Models Residual Stands	Yes	Yes
Sophistication of Residual Modeling		High
Models Fire Line Construction	No	No
Type of Fire Line Modeling	No	No
Types of Fire Lines Allowed	No	No
FBP-FireLine Efficiency Criteria	No	No
Ignition Type (point / line / polygon)	Point/line/polygon	Point/line/polygon
Number of Ignitions Allowed	Multiple	Multiple
Ease of Parameter Changes	Moderate	Moderate
Conversion Cost for Canadian Apps	$30 - 50K U.S.	None

Special Model Requirements

Model Requirements		
Comments	- FARSITE courses held in the U. S. - Developer resides in Missoula, MT	

	FARSITE	Firebrand

Model Inputs

General

Handles Grid Data	Yes	Yes
Format of Data	ArcInfo ASCII Grid	ASCII Grids
Maximum Size of Input Area	?	None
Handles Variable Cell Size	No	No

Fuel / Elevation Data

Uses FBP Fuels	No	Yes
Uses FBP Lookup Table	No	No
Uses FBP Grid Input File	No	Yes
Uses Elevation Grid Input	Yes	Yes
Uses Slope Grid Input	Yes	Yes
Uses Aspect Grid Input	Yes	Yes

Weather Data

Uses Weather Grid Input	No	No
Number of Weather Stations Used	1	1
Interpolates Weather	No	No
Weather Values Required	Max-Min Temp, RH, Rain, WS, WD, elevation	Temp, RH, WS, WD, Rain
FWI Values Required	No	Yes
Generates Diurnal Trends	Yes	Yes
Diurnal Weather Vales Required	Max-Min Temp and WS	None
Allows On-Screen Changes	Yes	No
Ease of Use / Entry	Moderate	Easy - Moderate

Ignition Points

Uses Latitude / Longitude	Yes	Yes
Allows On-Screen Input	Yes	Yes

Fuel Break Construction

Allows On-Screen Input	Yes	Yes
Ease of Use / Entry	Easy	Easy

Fire Line Construction

Allows On-Screen Input	No	No
Ease of Use / Entry	No	No

Colors

Uses FBP Fuel RGB Lookup Table	No	No
Uses FBP Class RGB Lookup Table	No	No
Uses Fire Hour RGB Lookup Table	No	No
Ease of Use / Change	Poor	Poor

Model Outputs

Format of Output	Ascii Grid	Grids
Table Summary of Spatial Statistics	Yes	?
Summary of Fire Hours	Yes	?
Summary of FBP Values Inside Fire	No	?
Summary of FBP Values Whole Area	No	?
Number of FBP Outputs	No	?
Graphical File Outputs	No	No
Number of GIF Outputs		
ARCView Compatible	Yes	No

Optimal (Proposed)

	Modeling Principles	Year

General Specifications

Type of Model	Vector	1
Type of Model Output	Time Units	1
Search Mechanism	N/A	
Length of Simulation Period	3 – 10 days	1
Speed of Model	Fast	1
Metric Compatible	Yes	1
ARCView compatible	Yes	1
Any validation completed	No (but Firebrand validated)	

Programming Language

Model and Interface Separate	Yes	1
FGM	Microsoft C	1
Interface	Visual Basic	1

Operational Use

Hardware Requirements	PC	1
Operating System	Windows 95 / NT	1
Software Requirements	None	1
Ease of Integrating FBP Data	Easy	1
Overall Ease of Use	Moderate	1

Modeling Specifications

Uses Latest CFFDRS FBP Eqns	Yes	1
Uses FBP Slope / Wind Eqns	Yes	1
Uses CFFDRS FWI Eqns	Yes	1
Method of Incorporating Elevation	ASCII Grids	1
Models Diurnal Weather Trends	Yes	1
Type of Diurnal Modeling	Beck and Trevitt 1989	1
Models Fuel Breaks	Yes	1
Models Jumping Fire Breaks	Yes	2
Type of Model	Albini	2
Models Extinguishment	Yes	1
Type of Extinguishment	DMC, ROS	1
Models Residual Stands	Yes	1
Sophistication of Residual Modeling	High	1
Models Fire Line Construction	Yes	2/3
Type of Fire Line Modeling	Variable	2/3
Types of Fire Lines Allowed	Variable	2/3
FBP-FireLine Efficiency Criteria	Yes	2/3
Ignition Type (point / line / polygon)	Point/Line/Polygon	1
Number of Ignitions Allowed	Multiple	1
Ease of Parameter Changes	Easy	1
Conversion Cost for Canadian Apps	N/A	

Special Model Requirements

Model Requirements		
Comments		

Optimal (Proposed)

Model Inputs — Year

General

Handles Grid Data	Yes	1
Format of Data	ARCView GridAscii	1
Maximum Size of Input Area	Min. 1000 X 1000	1
Handles Variable Cell Size	Yes	1

Fuel / Elevation Data

Uses FBP Fuels	Yes	1
Uses FBP Lookup Table	Yes	1
Uses FBP Grid Input File	Yes	1
Uses Elevation Grid Input	Yes	1
Uses Slope Grid Input	Yes	1
Uses Aspect Grid Input	Yes	1

Weather Data

Uses Weather Grid Input	Yes	2
Number of Weather Stations Used	1	1
Interpolates Weather	No	
Weather Values Required	Temp, RH, WS, WD, Rain	1
FWI Values Required	FFMC, DMC, DC	1
Generates Diurnal Trends	Yes	1
Diurnal Weather Vales Required	Max-Min Temp and WS	1
Allows On-Screen Changes	Yes	1
Ease of Use / Entry	Easy	1

Ignition Points

Uses Latitude / Longitude	Yes	1
Allows On-Screen Input	Yes (DialogBox)	1

Fuel Break Construction

Allows On-Screen Input	Yes	1
Ease of Use / Entry	Easy	1

Fire Line Construction

Allows On-Screen Input	Yes	2
Ease of Use / Entry	Easy	2

Colors

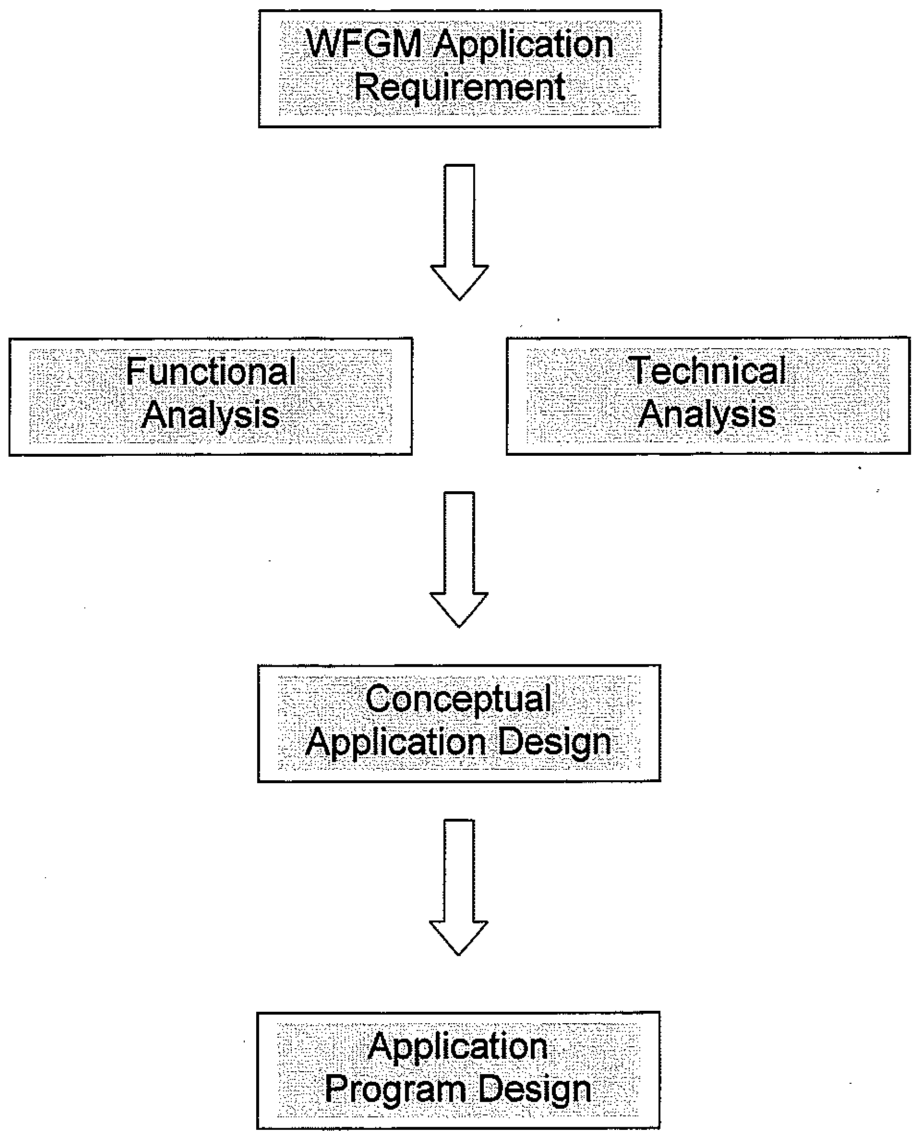
Uses FBP Fuel RGB Lookup Table	Yes	1
Uses FBP Class RGB Lookup Table	Yes	1
Uses Fire Hour RGB Lookup Table	Yes	1
Ease of Use / Change	Easy	1

Model Outputs

Format of Output	ARCView GridAscii	1
Table Summary of Spatial Statistics	Yes	1
Summary of Fire Hours	ARCView GridAscii – Time Hrs	1
Summary of FBP Values Inside Fire	GridAscii – HFI-CFB-SFC-TFC	1
Summary of FBP Values Whole Area	Yes	1
Number of FBP Outputs	All	1
Graphical File Outputs	All	1
Number of GIF Outputs	4	1

Appendix C

Wildland Fire Growth Model (WFGM) Application Design Process



Appendix D

Definitions

Fire Behaviour

Fire behaviour refers to how fuel ignites, flames develop and fire spreads and exhibits other related phenomenon. Fuel, weather and topography influence fire behaviour.

Fire Hazard

Fire hazard is a general term used to describe the potential fire behaviour associated with physical fuel characteristics (i.e. fuel loading, arrangement, fuel load, occurrence of ladder fuels).

Fire Risk

Fire risk refers to the probability or chance of fire starting from natural and person caused sources (lightning and person caused ignitions).

Fire Intensity

Fire intensity is the rate of heat energy released by the fire measured in kilowatts per metre (kW/m) of fire front. Fire intensity is one of the primary outputs of the FBP system. It is a good indicator of the relative success of suppression activities.

Ladder Fuels

Ladder fuels are all fuels that provide vertical continuity between the surface fuels and the crown fuels.

Risk of Loss Due to Fire

In the context of risk theory and management principles, risk is defined as the exposure to a chance of loss (i.e. damage) due to fire. In this context, risk refers to loss (potential damage) and uncertainty (potential ignitions).

Wildfire Threat

Wildfire threat is a contemporary, systematic and integrated approach to assess fire danger. It is based on fire risk, values-at-risk, suppression capability and fire behaviour.

Appendix E

Work Plan – Time Action Schedule

Project Tasks	1999												2000															
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Complete evaluation of fire growth models				15																								
Complete functional analysis of optimal model				15																								
Workshop - Design criteria					14																							
Application design of WFGM						30																						
Re-write Firebrand code Incorporate 1. new algorithms 2. topography												31																
Build prototype interface															31													
Incorporate 1. extinguishment 2. fuel breaks 3. diurnal trends															31													
Apply prototype model to a selected area in the FMF																		30										
Incorporate 1. spotting 2. stochastic modeling (burn probability)																						31						
Build final version of model																										28		