ENV-P-C 2000-073

The Development of a National Fire Danger Rating System for South Africa

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July 2001

ACKNOWLEDGEMENTS

The authors would like to thank Mandla Mehlomakulu, Dineo Moshe and Will Kgame for their contributions to this report. A special thanks also to Emily Kgosana, Gill Allen and Karin Harding for their hard work in the integration and formatting of this document. Rose Clark is gratefully acknowledged for her proof-reading and editorial inputs, Bob Scholes for his formal review of the draft report, and Fred Kruger whose critical review has greatly improved the content of this report.

The authors are especially indebted to all the stakeholders who contributed to the development of the National Fire Danger Rating System and in particular to Johan Heine for his continued involvement and support throughout this process.

This project was funded by
the Department for International Development, U.K.

DFID Department for International Development

EXECUTIVE SUMMARY

INTRODUCTION

During 1998, South Africa passed the new National Veld and Forest Fire Act (Act 101 of 1998), hereafter referred to as 'the Act'. The Act provides for the prevention of veld, forest and mountain fires through the deployment of a National Fire Danger Rating System (NFDRS). Such a system does not exist at a *national* level at this stage, although localised fire danger rating systems are used in some regions. The Department of Water Affairs and Forestry (DWAF) therefore contracted the CSIR to develop a NFDRS for South Africa. The NFDRS was developed by a team of experts, in consultation with the Veld and Forest Fire Committee of the Department of Water Affairs and Forestry and several key stakeholders.

This report provides an account of the process followed in the selection of an appropriate NFDRS for South Africa and provides an overview of the main components of such a NFDRS. It briefly describes the systems used nationally and internationally, as well as a brief account of the nature of South African conditions and users, and currently available weather data. The criteria for the selection of a suitable system for South Africa are described and then applied to select the most appropriate system. The division of the country into areas of homogenous fire danger is addressed, and the use and administration of the system is discussed. The content of the main sections is summarised below.

OVERVIEW OF MODELS USED INTERNATIONALLY

A fire danger rating system, as required in the Act, will have the primary purpose of preventing and controlling wild fires. This prevention should come about through the ability to identify the conditions that would lead to dangerous fires, and then through the effective prevention of activities that would lead to the ignition of fires under such conditions. The system should consist of the following elements:

i. The capacity to monitor, on a continuous basis, the conditions that would affect fire danger (s 9 (1));

ii. The ability to delimit the regions that would be affected by high fire danger conditions (s 9 (3));

iii. The ability to take relevant factors into account, using appropriate formulae (s 9 (4)(a and b)). This will often require the use of **models** which simulate the ease of ignition and potential fire behaviour;

iv. The ability to identify high fire danger, and the listing of precautions that should be taken when the fire danger is predicted to be high (s 9 (4)(d)); and

v. The ability to communicate the fire danger ratings and necessary precautions effectively (s 10 (1) and (2)).

A total of eight systems or models currently in use nationally or internationally are identified and described briefly. These are:

i) The Swedish Angstrom Index;
ii) The USSR Ignition index;
iii) The French Fire Danger Rating System;
iv) The Canadian Forest Fire Danger Rating System;

v) The United States Fire Danger Rating System;
vi) The Australian (McArthur) Forest Fire Danger Rating System;
vii) The Australian (McArthur) Grassland Fire Danger Rating System; and
viii) The Lowveld Fire Danger Rating System.

SOUTH AFRICAN CONDITIONS, USERS AND WEATHER DATA

South Africa is divided into nine provinces, which contain a total of 367 magisterial districts. The country has a wide range of climatic conditions and vegetation types, ranging from desert to rainforest. The most widespread types are savannas, grasslands, fynbos shrublands and arid (karoo) shrublands.

The diversity of South African users of a NFDRS ranges from rural subsistence farmers to urban dwellers. Although organized and structured Fire Protection organizations/units exist in some metropolitan, urban and rural areas, the user base includes a significant proportion of remote rural communities with few to no communication capabilities.

South Africa's unique social structure has resulted in a diversity of languages, literacy levels, geographical spread and population communication abilities. Consideration has also been given to the suitability of the available supporting infrastructure and Local Government structures.

FORECASTING WEATHER AND FIRE DANGER

Weather forecasts are produced and disseminated by the South African Weather Bureau (SAWB). Extensive use is made of the ETA Numerical Weather Prediction (NWP) model for this purpose. Approximately 300 surface stations, 5 upper air stations, and AMDAR (aircraft) data are used in the model after passing quality control (Bruyere, pers. comm. 2000)[1]. These data are used to initialize the model for the twice daily simulations at 02:00 am and at 14:00 pm (Laing and du Plessis, pers. comm. 2000)[1]. The model output consists of 30 meteorological fields for a 48 hour advance period, including temperature, rainfall, humidity, wind speed and wind direction. The model is accurate with regard to wind speed and direction, but less accurate with temperature, rainfall and humidity (Laing and du Plessis, pers. comm. 2000). It is envisaged that the finer spatial resolution of the model will improve the accuracy. It is envisaged that the relevant outputs from the ETA model would be used as input to the FDR model, so that the fire danger rating could, if necessary, be calculated on a 32 to 48 km grid for present as well as forecast conditions.

CRITERIA USED TO EVALUATE THE AVAILABLE SYSTEMS

The criteria used to select a suitable model to underpin a South African NFDRS were primarily governed by the requirements specified in the Act. Based on the specific requirements of the law, a number of selection criteria were developed, after consultation with the DWAF Fire Committee, to guide the selection process. These criteria were developed with a view to ensuring that the model selected would be able to meet the needs for the implementation of the Act. They include:

i) That the model selected must be able to predict and rate fire danger both reliably and consistently;
ii) That the model must be able to predict fire danger on a daily basis, at least 24 hrs in advance;

iii) That the model must be equally applicable throughout the country;

1 SA Weather Bureau, Pretoria

iv) That the index generated by the model must be able to accommodate the full range of possible conditions that affect fire behaviour, and must not be restricted or capped in any way;

v) That the model must use data that are currently available in South Africa;

vi) That the model should have been shown to perform satisfactorily in environments like those in South Africa;

vii) That the model should not require the further development of specific fuel descriptors.

An analysis using the above criteria suggests that there are four potential candidate models that could underpin a South African National Fire Danger Rating System – the Canadian Forest Fire Danger Rating System, the United States National Fire Danger Rating System, and the McArthur Grassland and Forest Fire Danger Indices. A report on a preliminary study by Scott et al. (2001) was not able to make a clear recommendation on a suitable model. Following further discussions with DWAF, it was decided that further work would be required before a defensible recommendation of a suitable model to underpin a South African NFDRS could be made.

It is proposed that the additional work should focus on the further examination of candidate models that could potentially underpin a NFDRS, with respect to how they perform in different regions of the country (the regions chosen should span the extremes in the country). This examination should include an analysis of the sensitivity of the different models to the range of input variables. The results of this study will be used to inform a process that will deliver an objective recommendation for a preferred model to underpin the NFDRS.

In order to obtain information that will guide the examination of candidate models, we recommend the execution of a one-year experiment to test all of the short-listed models that could underpin the NFDRS. The experiment should test, on a daily basis, how the candidate models fail or succeed in predicting the conditions described in the rating system across a full range of fuel and climate. The experiment should involve the SAWB, and expert practitioners.

We also recommend the development of a proposed methodology for the delivery of (i) an agreed set of descriptions of each of the different fire danger rating categories, examples of which are given in Table 8.1; (ii) an objective recommendation for a preferred model to underpin the NFDRS, based on further work on the suitability of candidate systems, outlined above; and (iii) cut-off values for the ratings for the most important fire danger zones in the country (see section 7.2 c). The methodology should include appropriate inputs from experts and stakeholders.

SUBDIVISION OF THE COUNTRY INTO FIRE DANGER ZONES

The Act requires that the country be divided into regions that would be ‘sufficiently uniform to allow for a single rating which is meaningful for the entire region’. It is recommended that municipal boundaries be used as the basis for defining areas with forecasted high fire danger.

The process for forecasting fire danger should be carried out in a series of sequential steps:

i) Forecast the distribution of fire danger indices across the country. The forecast fire danger indices will then be plotted on a map, and isolines of fire danger indices will be drawn.

ii) Determine cut-off values above which fire danger is considered to be high, for each of the 24 regions defined by the SAWB. Current practice in Australia sets the cut-off points for McArthur’s FFDRS at <5 for low, 5 – 12 for moderate, 12 – 24 for high, 24 – 50 for very high, and > 50 for extreme. The set of actions taken in response to a given rating varies as a result of different circumstances in different regions in Australia. Our recommendation is that the cut-off values can only be finalised after further work has been done on the range of indices likely to be experienced in South Africa, and once the model to underpin the South African NFDRS has been selected.

iii) By comparing the forecast fire danger index values with the cut-off values, delineate areas where the forecast fire danger would be regarded as high.

iv) Define areas of forecast high fire danger within municipal boundaries. Any municipality that has high fire danger forecast would then be subject to any restrictions and other measures in terms of the Act. An entire municipality will be subject to the prescribed actions for high fire danger even if only part of that municipality has a forecast high fire danger. This will be done to err on the side of caution.

This process therefore proposes that the most appropriate 'regions' that can be considered '*usually sufficiently uniform to allow for a single rating which is meaningful for the entire region*' would be single municipalities. On a given day, several of these may simultaneously have a high fire danger, but as the weather changes, the aggregation of municipalities rated as high would change too.

Any municipality that had high fire danger rating forecast would then be subject to any restrictions and other measures in terms of the Act.

CATEGORIES OF FIRE DANGER RATING AND THEIR USE

The most commonly used method of depicting the fire danger rating (FDR) is through the use of colour codes. The ratings have been grouped into five categories, each represented by a colour [Blue (insignificant), Green (low), Yellow (moderate), Orange (high) and Red (extremely high)]. We provide examples of the expected fire behaviour for each category, and the measures that would be needed to ensure fire suppression in each category. These descriptions are provided merely to assist in developing an understanding of each rating and will need further refinement, in consultation with stakeholders and experts, before being incorporated into the final NFDRS. The 'recommended actions' which should be taken when the FDR is a certain 'colour' could be incorporated into regulations in terms of the Act, but are regarded as guidelines rather than regulated activities. However, for each category there is also a list of actions that should be *mandatory* and those which should be *prohibited* under certain fire danger conditions. It is these actions that should be included into the regulations of the Act to ensure legal accountability for certain actions when the fire danger is predicted to be 'high'. These, too, are provided as examples in this report, but will require further refinement and consultation before being incorporated into legislation.

COMMUNICATION OF THE NFDRS

The Act specifies that the Minister must communicate the FDR to the Fire Protection Associations (FPAs) regularly and, more specifically, when the danger is high, publish warnings to that effect. Because the SAWB already has the means of disseminating the daily weather conditions to the media, the communication of the fire danger ratings could be carried out by that institution, but this would have to be negotiated with DWAF (which has the legal responsibility to do this).

Compliance by the public to the FDRs (e.g. total fire ban) will probably be difficult to enforce. However, if the public becomes aware of the NFDRS, and perceives its purpose and its benefits in a positive way, voluntary adherence to the conditions could reduce the incidence of fires. For this reason, part of the communication strategy should address the awareness-raising aspect of the NFDRS. The communication strategy should, therefore, extend beyond the communication of the rating and also consider aspects such as awareness and training. Several mechanisms to implement this are suggested, including modules in school curricula and a national 'Fire Awareness Day'. Advanced training at tertiary institutions is also suggested for land managers.

ADMINISTRATION OF THE NFDRS

There are a number of organizations that would be involved in the implementation of a NFDRS. These include the SAWB, the FPAs and the National Disaster Management Centre (NDMC). Other organizations that would be involved would be the electronic broadcasting media and the press. The Department of Water Affairs and Forestry (DWAF) will carry overall responsibility for ensuring that the Act is implemented at a national level while the SAWB will carry out the daily calculation of fire danger indices and forecasts.

Fire Protection Agencies will be established in terms of the Act, and will have responsibility for co-ordinating activities relating to the prevention and combating of fires in their areas of jurisdiction. The NDMC should function as a repository and conduit of information pertaining to disaster management. Municipalities could be approached to fulfil the functions of FPAs, until such time as FPAs are established. It is also probable that FPAs will never be established in some areas (for example semi-desert or desert areas where fires hardly ever occur). In such cases, DWAF may legitimately decide that the relevant municipality need not participate in the NFDRS.

In terms of the Act, the communication of predicted high fire danger, through broadcasts and publication in newspapers, is compulsory.

PROPOSED AMMENDMENTS TO THE ACT

An amendment to the Act, which may increase its effectiveness, concerns the delegation of responsibilities to municipalities where FPAs do not exist. Regulations should be drawn up to prescribe the format in which to report fire statistics as well as to ensure that fire danger rating criteria are taken into account when permits are issued for burning (e.g. by Agriculture). Certain activities which are prohibited or mandatory when the fire danger is high, will also need to be included in the regulations.

A Description of the five proposed fire danger rating categories (Blue to Red), and examples of the fire behaviour, recommended control measures, actions and restrictions for each.

	BLUE	*GREEN*	*YELLOW*	*ORANGE*	*RED*
FDR RATING	Insignificant	Low	Moderate	High	Extremely high
FIRE BEHAVIOUR	Fires are not likely to start. If they start, they are likely to go out without aid from suppression forces. There is little flaming combustion. Flame lengths < 0.5 m and spread rates < 2 m/minute.	Fires will start but will spread slowly. Flame lengths typically < 1 m, and spread rates < 5 m/minute.	Fires fairly readily ignited and spread unaided, burning in the surface layers below trees. Flame lengths between 1 and 2 m, and spread rates between 5 and 25 m/minute, depending on fuel type.	Fires readily ignited and spread unaided, with local crowning and short-range spotting. Flame lengths between 2 and 5 m, and spread rates between 25 and 35 m/minute. Spotting occurs, increasing the rate of spread.	Any ignition source likely to initiate a fire. Fires will spread in the crowns of trees as well as in surface layers, and long-range spotting will occur. Spread rates can exceed 60 m/minute and flame lengths will be in the order of 5 – 15 m or more. Wide-spread spotting, greatly increases the rate of spread.
FIRE CONTROL	No control necessary.	Fires can be approached on foot. Suppression is readily achieved by direct manual attack methods.	Fires not readily approachable on foot for more than very short periods. Best forms of control should combine water tankers and backfiring from prepared lines.	Fires cannot be approached at all. Backburning, combined with aerial water-bombing are the only effective ways to combat fires. Equipment such as water tankers should concentrate efforts on the protection of houses.	Any form of fire control not likely to be effective until weather changes. Backburning dangerous and best avoided.

	BLUE	*GREEN*	*YELLOW*	*ORANGE*	*RED*
RECOMMENDED ACTIONS	None	None, other than prudent care to ensure that any open-air fires do not escape. Prescribed burning permissible.	Open-air fires should only be permitted in authorised fireplaces. Prescribed burning should be conducted with care, and any prescribed fires should be extinguished should the forecast fire danger rating turn to high.	All efforts should be made to bring any fires under control. Areas should be put on standby for evacuation should the fire danger conditions be forecast to become worse.	Dangerous areas to be evacuated. Equipment such as water tankers should concentrate efforts on the protection of houses and other structures.
PRESCRIBED ACTIONS AND RESTRICTIONS	None	None	Any unplanned fires should be extinguished.	No outdoor fires permitted.	No outdoor fires permitted.

MONITORING AND EVALUATING THE NFDRS

Fire danger indices need to be interpreted in terms of the risk of fires occurring, the number and size of fires that could be expected under certain conditions, their relative ease or difficulty of control, and the damage they could be expected to do. The fire danger indices that are recorded in any particular region could be related to the historic occurrence of fires, provided that such data are available. At present, information on fires is not recorded in most areas in South Africa, and where data are recorded, they are scattered and not in a suitable format for relating to fire danger indices.

Basic data of the type outlined above should be collected by FPAs. Data on the occurrence, size, severity, and duration of fires could be archived without mapping the fires. On the other hand, fires could be mapped and captured on a geographical information system for archival. The choice of approach will have significant implications for data collection and management, and needs to be considered carefully.

The Department for International Development (DFID) has funded a project linked to this one, in which the NFDR Information System is addressed in greater detail.

We have suggested that the responsibilities for calculating fire danger, curating the database, and collecting fire statistics will be shared between DWAF, the FPAs, the SAWB and (potentially) the NDMC.

CONCLUSION

This report has not addressed the *implementation* of the NFDRS, which was beyond our terms of reference. The implementation of the NFDRS will be a complex process, requiring substantial time and additional capacity from many different institutions in order for it to function effectively. Should the recommendations in this report be adopted, DWAF will have to address implementation through the development of a comprehensive business plan, particularly addressing the delegation of DWAF's responsibilities to the SAWB, FPAs and NDMC.

TABLE OF CONTENTS

List of Appendices

List of Figures

List of Tables

NATIONAL FIRE DANGER RATING SYSTEM

1. INTRODUCTION

During 1998, South Africa passed a new National Veld and Forest Fire Act (Act 101 of 1998), hereafter refered to as 'the Act'. The Act provides for the prevention of veld, forest and mountain fires through the deployment of a National Fire Danger Rating System (NFDRS) (Section 3 of the Act). Such a system does not exist at a *national* level at this stage, although localised fire danger rating systems are used in some regions such as the KwaZulu-Natal Midlands, Mpumalanga and the Western Cape.

A NFDRS will allow for the prediction of potentially hazardous conditions conducive to large and potentially damaging wild fires. This will allow for preventative measures to be taken to both reduce the risk of unwanted ignitions, and to increase the state of readiness for dealing with wild fires. The NFDRS should also be regarded as one of the early warning systems required by the National Disaster Management System (NDMS).

There are several international fire danger rating systems as well as a locally developed system, from which to choose. Fire is a physical process that behaves according to physical principles wherever it occurs. This suggests that models developed elsewhere should work equally well in South Africa, providing that good weather data are available for running the model(s) that underpin the systems.

The terms of reference for the development of a NFDRS for South Africa (developed by the 'Veld and Forest Fire Committee' of DWAF) state that: 'The system that is developed for South Africa needs to be simple, but effective. It should be able to produce relevant indices of fire danger from easily measured or predicted environmental parameters, and it must be able to relate these to the risk of fire occurrence (the number of fires that could be expected to occur in a given region), the potential severity of fires (the potential intensity with which they will burn, and the level of damage they are likely to cause), and the potential size of fires (the likely area that will burn under the given conditions).'

In response to this requirement for a national system, the Department of Water Affairs and Forestry (DWAF) contracted the CSIR to develop a NFDRS for South Africa. This report provides an account of the process followed in the selection of an appropriate NFDRS for South Africa and provides an overview of the main components of such a NFDRS.

The tasks which the CSIR undertook in the development of the NFDRS can be summarised from our terms of reference as follows:

Task 1 Develop a fire danger rating system and, in so doing, assess the need for additional authority, duty or responsibility in terms of the Act.

Task 2 Develop proposals for the subdivision of the country into regions which are relatively uniform within their boundaries with regard to the fire danger that would prevail for any period of time (Section 9(3) of the Act).

Task 3 Provide recommendations for the best means of communicating the ratings generated by the use of the system to and within each region as required by Section 10(1) of the Act.

Task 4 Develop a proposal (mechanisms) for a cost effective system to evaluate the performance of the NFDRS[2.]

2 This TOR is now addressed by a separate project.

The overall assignment was to be conducted with regard to:

a) the need to comply with the Act as a minimum in all cases;
b) the need for practicality and effectiveness in developing a system for rapid deployment;
c) the need for due and appropriate consultation with relevant stakeholders; and
d) regular communication and liaison with the commissioning Department (i.e. DWAF).

2. THE PROCESS TO DEVELOP THE NFDRS

The proposed NFDRS for South Africa was developed by a team of experts, in consultation with the Veld and Forest Fire Committee of DWAF and several key stakeholders.

While it was beyond the scope of this project to engage in a thorough consultation process with all interested and affected parties in terms of fire danger prediction, there were certain major role-players and users who needed to be informed of the process and who needed to contribute to the understanding of the NFDRS. These key stakeholders, identified as essential contributors to this process, are listed below, but informal discussions with various other interested parties took place throughout the duration of the project. The key stakeholders were:

- Department of Water Affairs and Forestry (DWAF) (Veld and Forest Fire Committee)
- South African National Parks (SANP)
- Provincial Parks Boards or Departments of Conservation/Environment (all nine provinces)
- National Department of Agriculture (and Agricultural Unions)
- Department of Provincial and Local Government
- Existing Forest Fire Associations (and Fire Control Committees)
- South African Weather Bureau (SAWB)
- Forest Owners Association (FOA)
- South African Timber Growers' Association (SATGA)
- South African Wattle Growers' Association (SAWGA)
- South African Emergency Services Institute

The process undertaken to select the NFDRS can be summarised as follows:

1. A working meeting to prepare a first draft of the proposed FDRS was held at the CSIR on 28 and 29 February 2000. The proceedings of the meeting and the documentation generated from it were distributed to the key stakeholders for comment in May 2000.

2. A workshop was held at Kwalata Game Ranch on 8 and 9 June 2000 to which all the key stakeholders were invited. A list of delegates who attended the workshop is attached (Appendix 1). On the first day of the workshop, the proposed outputs from the first meeting were presented and reviewed (including the preliminary criteria for evaluating the models and the choice of model for South Africa). Other aspects of the NFDRS (such as the delineation of zones, the format for presenting the fire danger rating, the activities associated with each rating and the communication strategy) were developed and refined on the second day.

3. A report based on the outputs of the Kwalata Workshop was submitted as a first draft to all key stakeholders for comment at the end of July 2000. Comments received have been incorporated into this report, wherever possible. All comments received are attached in Appendix 2[3]. This appendix also contains a summary of the major issues raised by the stakeholders and a brief description of how these issues have been addressed.

3 It is important to note that references to page numbers, paragraphs, etc in the comments refer to earlier drafts and are therefore not consistent to the content of this report.

4. A draft final report was submitted to DWAF for review. Subsequent meetings with the Veld and Forest Fire Committee have been held to decide on actions still required. This report incorporates the issues and concerns from DWAF and inputs from the other institutions. As part of the process to incorporate the Client's concerns, further consultation was held with representatives of the SAWB, Cape Nature Conservation, SA National Parks and SAFCOL before re-submission of the report.

3. OVERVIEW OF FIRE DANGER RATING SYSTEMS USED LOCALLY AND INTERNATIONALLY

A fire danger rating system, as required in the Act, will have the primary purpose of preventing and controlling wild fires. This prevention should come about through the ability to identify the conditions that would lead to dangerous fires, and then through the effective prevention of activities that would lead to the ignition of fires under such conditions. The system should consist of the following elements:

i) The capacity to monitor, on a continuous basis, the conditions that would affect fire danger (s 9(1));
ii) The ability to delimit the regions that would be affected by high fire danger conditions (s 9 (3));
iii) The ability to take relevant factors into account, using appropriate formulae (s 9 (4) (a) and (b)). This will often require the use of **models** which simulate the ease of ignition and potential fire behaviour;
iv) The ability to identify high fire danger, and the listing of precautions that should be taken when the fire danger is predicted to be high (s 9 (4) (d)); and
v) The ability to communicate the fire danger ratings and necessary precautions effectively (s 10 (1) and (2)).

Fire danger is the result of both relatively constant (fuel, topography) and variable (weather) factors affecting the inception, spread, difficulty of control and potential to do damage (Chandler et al. 1983). A fire danger rating system uses models which simulate those factors that combine to affect fire danger, usually producing one or more indices of fire danger. It also normally ranks these into discrete classes for the purpose of conveying public warning, implementing mitigation measures and for setting an appropriate level of readiness for suppression resources.

Many fire danger rating models only use **weather elements** in the calculation of the index and assume that the fuel, topography and ignition elements are kept constant. In this way it is possible to use weather forecasts to predict the fire danger for a period of time ahead. The weather inputs are usually taken from a specific weather station which is broadly representative, and then applied to the surrounding region.

There are several models in use that can be used to support a fire danger rating system. It is important not to confuse **fire danger** with **fire behaviour**, which describes the manner in which fuel ignites, flame develops and fire spreads. In fire behaviour prediction the important outputs are **rate of spread**, **flame height**, **fire intensity** and the **spotting potential**. Fire danger rating, on the other hand, produces a rating of the risk of a fire occurring, and of doing damage. Fire behaviour prediction is used at a finer scale than fire danger rating – for example, for predicting the behaviour of a fire in a particular field as opposed to estimating the risk of fire over a whole region or province. For this reason the fire behaviour research already carried out in South Africa (Everson et al. 1985; van Wilgen, Le Maitre and Kruger 1985; van Wilgen and Wills 1988; Trollope 1998) cannot be used for improving or testing fire danger rating models. In this section the different models are reviewed in relation to their ability to predict **fire danger**.

3.1 Swedish Angstrom Index

The simplest fire danger rating model is the Swedish index called the **Angstrom Index**. The Angstrom Index uses only temperature and relative humidity in its calculation and provides an indication of the likely number of fires on any given day. The Angstrom Index is calculated according to formula (1).

$$I = \left(\frac{R}{20}\right) + \left[\frac{(27 - T)}{10}\right] \qquad \text{.................(1)}$$

where: *I* = Angstrom Index
R = Relative humidity (%)
T = Air Temperature (°C)

Interpretation:

> 4.0	Fire occurrence unlikely
4.0 – 2.5	Fire conditions unfavourable
2.5 – 2.0	Fire conditions favourable
< 2.0	Fire occurrence very likely

The Angstrom Index is useful only as an indication of the dryness of the air. It does not cater for fuel moisture status or the important role that wind plays, as it ignores both rainfall and wind.

3.2 USSR Ignition Index

The USSR Ignition Index, developed in Russia, has a similar basis to the Angstrom Index. This index also uses temperature and relative humidity, but adds the effect of recent rainfall on the fine fuel flammability. The USSR Ignition Index recognises that if more than 3 mm of rain falls, then there will be a period of time when the fuel will not burn, so the index returns to zero. This index estimates the dryness of the fine fuel, assuming that the drying rate is related to the vapour pressure deficit and the length of the period of drying. The calculation of this index is according to formula (2).

$$P = \sum_{i=1}^{W} (t_i - D_i) * t_i \qquad \text{.................(2)}$$

Where: *P* = Ignition index
W = number of days since last rainfall > 3mm
t = temperature (°C)
D = dew point temperature (°C)

Interpretation:

0 – 300	Nil Fire Danger
301 – 1000	Moderate Fire Danger
1001 – 4000	High Fire Danger
> 4000	Extreme Fire Danger

3.3 French Fire Danger Rating

A fire danger index used in France combines the effects of a 'drought index' with wind speed as a measure of fire danger. Seasonal dryness is calculated by estimating the soil moisture capacity and adding to or subtracting from it according to the daily evapotranspiration balance. Potential evapotranspiration is calculated using a formula that includes daily rainfall, temperature and relative humidity. The effect of daily evapotranspiration for a given soil dryness provides the basis of this index of fuel dryness – a drought index (formula 3). The drought index provides a measure of ease of ignition as well as fuel availability. When this drought index is combined with wind speed, the potential rate of fire spread is also included. Thus, the fire danger index gives both a measure of ease of ignition as well as potential spread rates.

$$D = C\,e^{\left(-\Sigma E/C\right)} \qquad \text{.....................(3)}$$

where: *D* = Drought index
C = Available water capacity in the soil (mm)
E = Potential evapotranspiration (Thornthwaite, 1948)

Fire Danger = Drought Index + Windspeed

3.4 Canadian Forest Fire Danger Rating System

The model in the Canadian Forest Fire Danger Rating System (CFFDRS) has evolved and developed since the mid-1920s. The basis of this system has been extensive field experimentation and observation of fire behaviour. A wide range of vegetation types have been studied, but the most common forest types studied have been the Jack Pine and Lodgepole Pine forest which are widespread in Canada. These forests have been used as the standard fuel type in the calculation of the Fire Weather Index (FWI) and its component indices. The FWI was introduced in 1969 and is now applied nationally in Canada. The Canadian FFDRS model has been tested or adapted in New Zealand, Fiji, Alaska, Venezuela, Mexico, Chile, Argentina and Europe. The Fire Weather Index requires only daily temperature, relative humidity, rainfall, and wind speed inputs for its calculation. This is one of this system's desirable traits.

For a long time, the Canadian FFDRS has used only the FWI and its component parts as the basis for fire management. The FWI provides an indication of the ease of ignition, and should fires start, the potential spread and relative intensity of fires (Figure 3.1a). In recent years, this system has been developed further to incorporate the likely number of ignition sources and the potential fire behaviour in different fuel types, which offer a more comprehensive and specific fire danger rating system for different areas in Canada (Figure 3.1b). The advancement of the fire danger rating system beyond the Fire Weather Index has taken considerable research effort and has customised the system for application in different regions of Canada. To determine the influence of these additional factors, human and lightning ignition risks are essential inputs to the model, along with the character of the regional fuel and topography. The fire occurrence potential (FOP) and fire behaviour potential (FBP) components have made the system less transferable to other vegetation types, but the FWI is still broadly applicable to areas outside Canada.

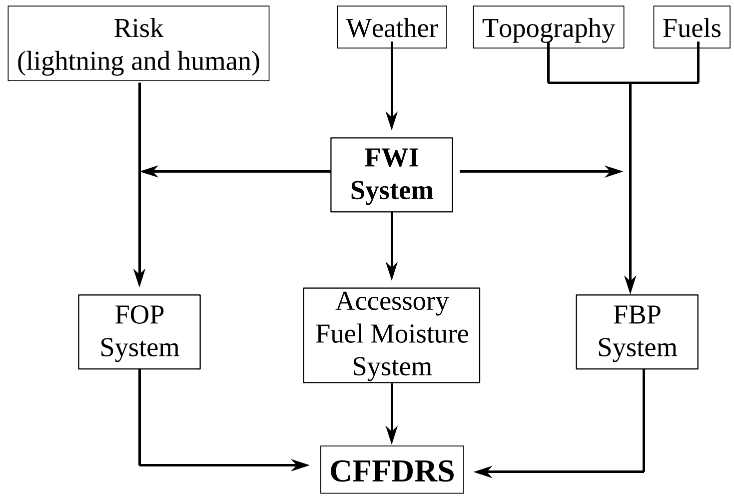


Figure 3.1a Canadian Fire Weather Index and its component parts. The terms are: FOP (Fire Occurrence Potential), FWI (Fire Weather Index), FBP (Fire behaviour prediction) and CFFDRS (Canadian Forest Fire Danger Rating System).

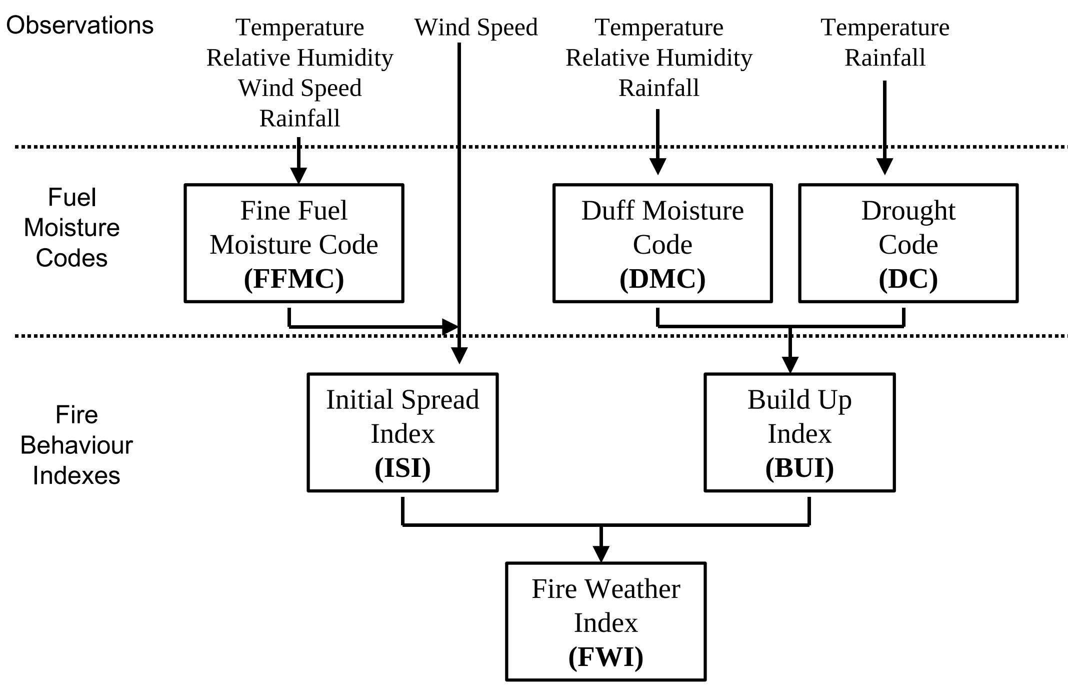


Figure 3.1b Canadian Forest Fire Danger Rating Model and its component parts.

3.5 US National Fire Danger Rating System

The simulations of fire danger in the United States National Fire Danger Rating System (US NFDRS) (Deeming *et al.* 1978) are based on Rothermel's fire behaviour model (Rothermel 1972). The US NFDRS was first introduced and applied nationally in the US in 1972. The model has been tested in South Africa, Europe, Asia and Australia.

The US NFDRS has been used across the United States and applied to a wide range of vegetation (fuel) types and climatic conditions. The system is based on a physically based fire behaviour model, which has the advantage of being based on fundamental processes. A disadvantage is the necessary increased complexity introduced when parameterising the model for new situations.

An outline of the inputs and modules of the system is shown in Figure 3.2. Unlike the models already discussed, the US NFDRS requires some data (rainfall duration and cloudiness) that are not always readily available. It is also important to use the most appropriate fuel model (a set of descriptors that characterise the dominant vegetation type in an area) to reflect the desired fire danger conditions.

The fuel models cover a wide range of fuel types, and include live fuel moisture content. Potentially, this could be very useful where canopy fuels are a significant part of the fine fuels such as in shrublands or forests subject to crown fires. The outputs from the model include a spread component (SC), an energy release component (ERC) and burning index (BI). More recent development of the system has incorporated **ignition components** for both human-caused and lightning-caused ignitions, so that the **fire load** or **fire severity index** can be estimated. The system therefore produces six indices – spread, energy release, burning, human ignition, lightning ignition and fire load indices.

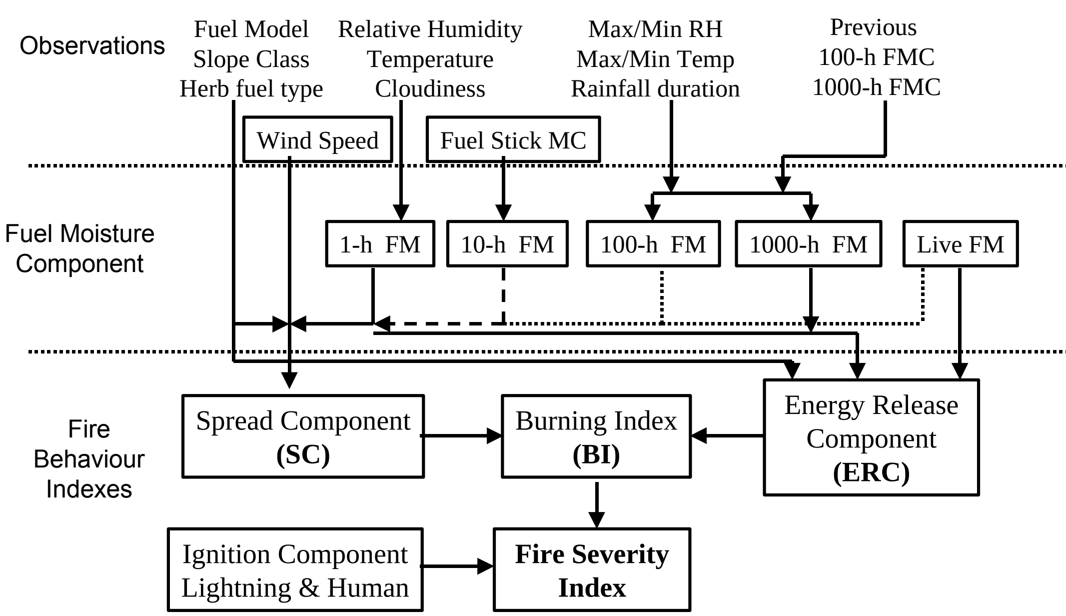


Figure 3.2 Components of the US National Fire Danger Rating System.

3.6 McArthur's Forest Fire Danger Index

Fire danger ratings were first used in Australia in 1936. Following the devastating wildfires in south-eastern Australia in 1939, a new impetus was given to improve fire management. The McArthur Forest Fire Danger Index was introduced in 1958 (McArthur 1958, 1960, 1962, 1966, 1967). This model continued to be developed, and today the Mark IV version of the index is used in south-eastern Australia. The Forest Fire Danger Index (FFDI) is subdivided into five classes rating the difficulty of suppression (Low, Moderate, High, Very High and Extreme).

The McArthur FFDI is based on an empirical model (Appendix 3.1) of fire behaviour in open forests, but the fire danger index is applied broadly to all forest types, shrublands, heathlands and mallee. Although the fire behaviour differs in these other vegetation types, most of the basic fire danger factors are common. Adaptation to vegetation types other than open forest is by means of redefining the different fire danger classes. A separate fire danger index system was developed for grasslands which included a grass curing module in place of the fuel availability module of the FFDI.

The structure of the McArthur FFDI is shown in Figure 3.3. Inputs required to run the model are air temperature, relative humidity, wind speed, rainfall, time since last rainfall, and the Keetch-Byram Drought Index (KBDI) (Keetch and Byram 1968). The KBDI itself requires the daily maximum temperature, daily rainfall, the previous day's KBDI and the average annual rainfall for the area being considered (Appendix 3.2).

The magnitude of the index is directly proportional to the rate of spread of a fire burning in an open eucalypt forest, on flat ground, and with an average surface fine fuel load of 12 t/ha. In vegetation types other than open eucalypt forest, the relationship with rate of spread may vary. The index is then subdivided into fire danger classes based on the difficulty of suppression, ranging from *Low* (where there is a low difficulty of suppression) to *Extreme* (where fire suppression is extremely difficult, if not impossible, due to the rate of spread and amount of spotting ahead of the fire front).

3.7 McArthur's Grassland Fire Danger Index

McArthur's Grassland FDI (McArthur 1960, 1966) has a similar basis to the FFDI, except that the fine fuel availability calculated using the Drought Index and Drought Factor components (Appendix 3.3) is now calculated using the degree of curing (Figure 3.4) (Griffiths 1999). Curing is defined as the proportional weight of dead grass to live grass, so a curing factor of 80% means that of the total grass biomass, 80% of the grass is dead. The moisture content of green grass is affected by physiological processes and is generally above the moisture of extinction (i.e. it is too wet to sustain combustion). However the dead grass moisture content is affected by local atmospheric conditions such as air temperature and relative humidity. The fuel moisture content is therefore determined by the combination of the degree of curing and the environmental conditions affecting the dead fuel moisture content. The fine fuel moisture content combined with the wind speed, are the main determinants of fire spread rate. The Grassland FDI is based on the predicted spread rate of a fire in lightly grazed temperate perennial grassland on flat ground. Fire spread rates would increase where the topography is generally hilly and where the grass is tall, and decrease where grasslands are heavily grazed or recently burnt. A revision was made to the Mark (Mk) IV version of the index which included a fuel loading component, but the performance of this index is no better than the Mk IV, so little use is made of the Mk V version.

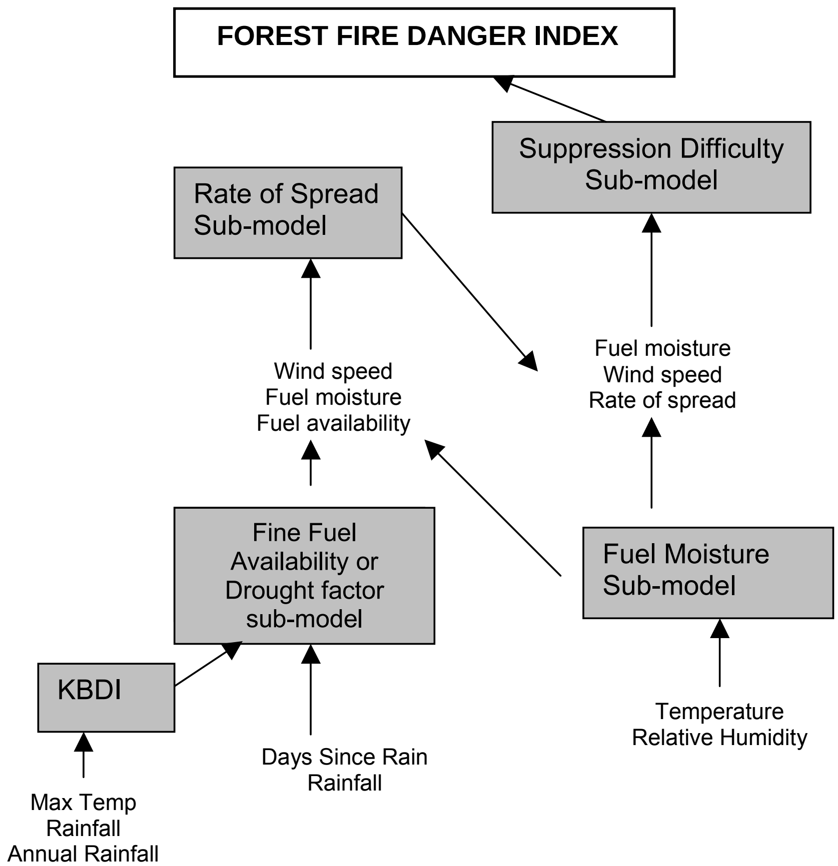


Figure 3.3 McArthur's Forest Fire Danger Index structure and inputs. KBDI is the Keech Byram Drought Index.

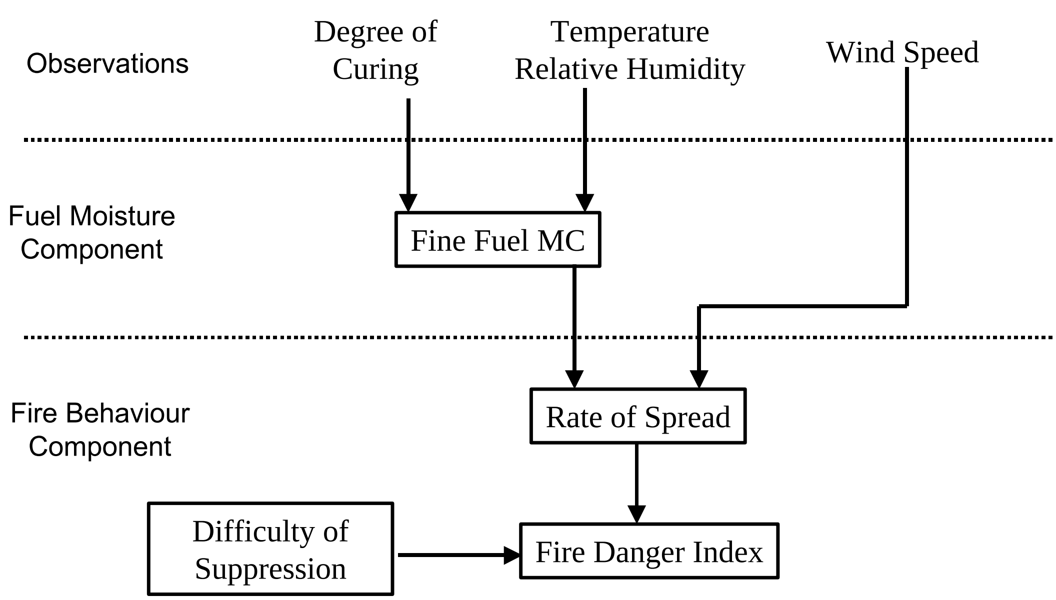


Figure 3.4 McArthur's Grassland Fire Danger Rating system (Mark IV).

3.8 The Lowveld Fire Danger System

The current fire danger rating model used in parts of South Africa is an adaptation of a Fire Hazard Index developed by Michael Laing in Zimbabwe (then Rhodesia) in 1968 (Laing 1978). The basic model uses the same inputs as the McArthur models, which are scaled to produce a simple model that can calculate numbers easily without needing any complex calculations. (McArthur 1958, 1967). It is often referred to as the 'Lowveld Fire Danger System' since this is where it has been most widely used. However, the process by which the system was developed, and the assumptions that were made, were never documented (M. Laing, pers. comm.).

The calculation of the Burning index (BI) uses a simple nomogram (Figure 3.5) using temperature and relative humidity or computer programs. Once the burning index has been obtained it is then adjusted for wind by adding a value according to the prevailing wind conditions at 14h00. For example, if the windspeed is between 3 and 8 km/h then a value of 5 is added to the burning index. The fine fuel availability is accounted for by using a, 'rainfall correction factor' that uses the antecedent rainfall conditions to adjust the burning index (Table 3.1).

A recent modification to the calculation of the Lowveld FDI has been to the Rainfall Correction Factor. This adjustment applies if the temperature exceeds 23^{o}C, the relative humidity is less than 50% and the wind speed is greater than 20 km/h. When this occurs, the latest rainfall event is moved back one day for every hour these conditions persist. This adjustment recognises that fine fuels will be drying quicker than usual under these conditions and hence the probability of fires starting and the rate of fire spread, should one start, will be greater. Other recent adjustments to make the model more suitable for local conditions include changes to make the temperature scale more sensitive to higher temperatures, a smother wind correction factor and a forecasting model using barometric pressure, historical data and weather forecasting information (Heine, pers. comm.)[4].

3.9 Summary

The three main Fire Danger Rating Systems used internationally are the US NFDRS, the Canadian FFDRS and the McArthur FDIs. Some of the features of these systems are summarised and compared in Table 3.2. The models vary in the degree of sophistication and requirement for data input.

4 Mr Johan Heine, Forest Fire Association (Lowveld)

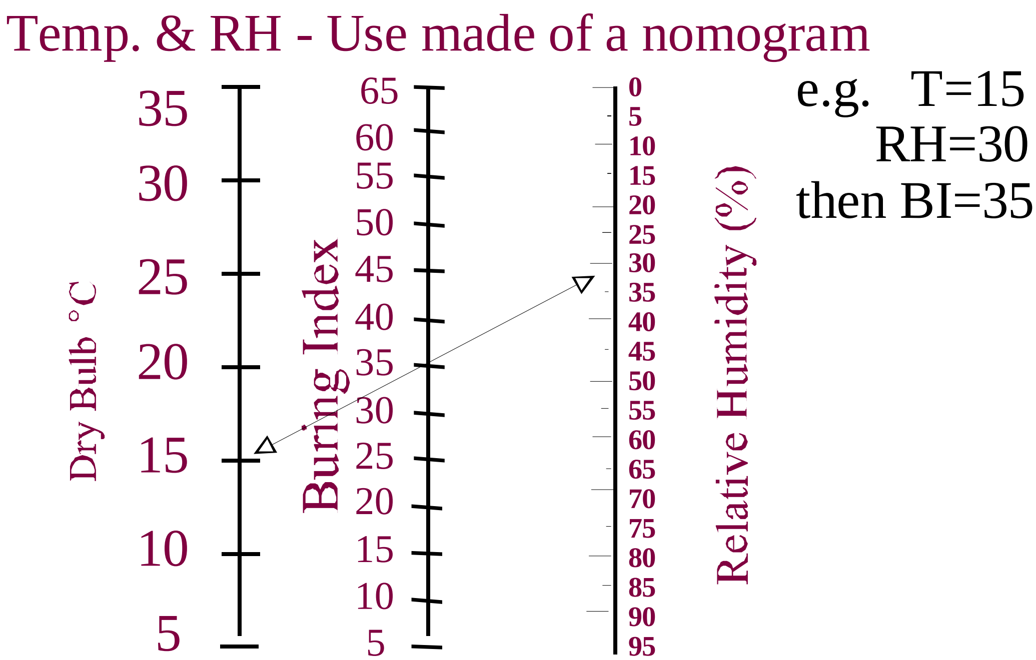


Figure 3.5 **The Lowveld Burning Index look-up table. The nomogram is used to estimate the Burning Index from temperature and relative humidity.**

Table 3.1 **The table of rainfall correction factors (RCF) used to adjust the burning Index for antecedent moisture conditions.**

FDI = (BI + Wind Factor) x RCF

Rainfall	*Number of days since rain last fell*									
mm	1	2	3	4	5	6	7-8	9-10	11-12	13-15	16-20
0.1-2.6	0.7	0.9	1.0								
2.7-5.2	0.6	0.8	0.9	1.0							
5.3-7.6	0.5	0.7	0.9	0.9	1.0						
7.7-10.2	0.4	0.6	0.8	0.9	0.9	1.0					
10.3-12.3	0.4	0.6	0.7	0.8	0.9	0.9	1.0				
12.9-15.3	0.3	0.5	0.7	0.8	0.8	0.9	1.0				
15.4-20.5	0.2	0.5	0.6	0.7	0.8	0.8	0.9	1.0			
20.6-25.5	0.2	0.4	0.5	0.7	0.7	0.8	0.9	1.0			
25.6-33.4	0.1	0.3	0.4	0.6	0.6	0.7	0.8	0.9	1.0		
38.5-51.1		0.2	0.4	0.5	0.5	0.6	0.7	0.8	0.9	1.0	
51.2-63.3		0.2	0.3	0.4	0.5	0.6	0.7	0.7	0.8	0.9	1.0
63.9-76.5		0.1	0.2	0.3	0.4	.0.5	0.6	0.7	0.8	0.9	1.0

Table 3.2 Comparison between the three main Fire Danger Rating models used internationally.

SYSTEM	US NFDRS	Canadian FWI	McArthur's FDI
INPUTS	Temperature Relative Humidity Wind speed Cloudiness Rainfall duration Fuel model Slope class Climate class	Temperature Relative Humidity Wind speed Rainfall amount	Temperature Relative Humidity Wind speed Rainfall amount
OUTPUTS	Spread Component-SC Energy Release Component-ERC Burning Index -BI Ignition risk (two indices) Fire Severity Index -FSI	Initial Spread Index-ISI Build Up Index -BUI Fire Weather Index-FWI	Fire Danger Index-FDI Drought Factor-DF
AREA OF VALIDITY	Open conditions on exposed slopes	Under closed forest	Open conditions on flat ground
BASIS OF MODEL	Physical models	Empirical with some physical models	Empirical models

4. NATURE OF SOUTH AFRICAN CONDITIONS AND USERS

This section provides a broad overview of the general background information considered important for investigating and developing an appropriate Fire Danger Rating System suited to South African conditions and users.

The Republic of South Africa (RSA) covers a total surface area of 1 219 080 km^2 and has an extensive coastline of approximately 3 200 km constituting the western, southern and eastern boundaries of the country. South Africa is divided into nine provinces, each comprising groupings of smaller administrative units called magisterial districts which together total 367. While some of the provincial boundaries follow rivers and other geographical features, the provincial and magisterial boundaries have been determined more by socio-economic than by biophysical considerations.

4.1 The biophysical conditions of South Africa

Conditions for consideration essentially relate to the broad biophysical aspects that characterise the South African environment. These include climatic conditions, geographical variation and vegetation diversity

Climatic variation

South Africa generally has a temperate climate, although weather patterns and rainfall statistics vary widely. While the Western Cape experiences Mediterranean-type winter rains, and the other coastal areas a rainfall spread throughout the year, 80% of the country's rain falls during the summer months of October to March, much of it accompanied by hail and thunderstorms.

South Africa is a dry country with an average annual rainfall of only 464 mm against the world average of 857mm. Approximately 65% of the country has an annual rainfall of less than 500 mm, while some of the higher mountains receive an annual rainfall of over 2000 mm. The general trend for annual rainfall patterns is for an increase in total amounts from west to east. Together with the rest of sub-Saharan Africa, the country is periodically afflicted by prolonged and severe drought, although flooding rains and wet spells do occur.

Mean annual temperature is highly negatively correlated with height above sea level with the coldest parts being the Drakensberg Mountains. Temperatures get warmer as one descends off the Great Escarpment, and reach a mean daily average of more than 20°C in the low-lying coastal and lowveld areas of the north eastern parts of the country. Summers are generally warm to hot; winters dry and sunny, interspersed with occasional spells of intense cold and heavy frosts in the interior and snowfalls on the highest mountains.

Coastal lows and Berg winds usually occur together and do much to determine the characteristic features of coastal and adjacent inland climates (Preston-Whyte and Tyson 1988). Coastal lows usually originate on the west coast of South Africa when air moves westward off the high interior plateau. All coastal lows produce offshore airflow ahead of the system, with adiabatic warming occurring as the air descends from the interior plateau giving rise to Berg winds. These winds may blow for several days or only for a few hours and are most common in late winter and early spring (Preston-Whyte and Tyson 1988). As the coastal low migrates along the coast, cool onshore flow replaces the Berg wind and temperatures drop, with cloud and drizzle commonly occurring.

Geographical variation

South Africa may be broadly divided into two main regions: an interior plateau separated from a narrow coastal plain on three sides by an escarpment of mountains and hills.

The two prominent ranges that make up the bulk of the escarpment are the Cape Fold Mountains in the south west and the Great Escarpment. The Cape Fold Mountains, represented by the Langeberg, Swartberg, Outeniqua and Cedarberg, are a prominent topographical feature stretching from Port Elizabeth in the east to the northerly extreme of the Cedarberg at Van Rhynsdorp. The Great Escarpment stretches from Springbok in the north-west, south to Sutherland and then eastwards and northwards to the Soutpansberg in the north. The Great Escarpment is most visible in the Drakensberg range stretching from Lesotho into Mpumalanga and the Northern Province.

South Africa’s terrain is particularly diverse, encompassing plains, lowlands, hills, mountains, escarpments and table-lands, each with a variety of elevational differences.

Vegetation diversity

South Africa’s natural vegetation is broadly classified into seven biomes, namely: Forest; Thicket; Savanna; Grassland; Nama Karoo; Succulent Karoo and; Fynbos. The biomes are derived from the life form dominance and climatic characterization of natural ecosystems. Each biome comprises a number of vegetation types with a total of 68 different vegetation types identified for the country (Low and Rebelo 1996). A broad similarity exists between the boundaries of terrain morphological units and vegetation types. In terms of natural vegetation land cover, forests and woodlands cover approximately 5.75%, shrubland and low Fynbos 34.05%, thicket and bushland 17.56% and unimproved grassland 21.28% of South Africa’s surface area (Fairbanks *et al*. 2000). National agricultural land cover includes 12.11% of cultivation and 1.47% of forest plantations, while urban land cover accounts for some 1.14% of the country’s surface area (Fairbanks *et al*. 2000).

This section details South Africa’s major vegetation types, their dominant fire regimes and their respective fuel properties.

Forests

The forest biome comprises coastal, afromontane and sand forests of mostly evergreen trees. Forests are restricted to frost-free areas with mean annual rainfall of more than 525mm in the winter rainfall region and more than 725mm in the summer rainfall region.

The fuel structure of afromontane forests has been studied in detail in the Western Cape. Here it is restricted to densely packed litter layers with sparse tree canopies consisting of live material (van Wilgen *et al*. 1990). The fuel component of the above-ground biomass is around 3500 g/m^2. Fires in these vegetation types are rare and restricted to occasional crown fires of high intensities (>100 000 kW/m) and canopy fires under extreme weather conditions. Surface fires are associated with dry/deciduous forests and range from low (if only litter is consumed) to very high fire intensity where stemwood ignites (van Wilgen and Scholes 1997).

Thicket

The thicket biome comprises dune, valley and succulent thicket vegetation types, which are considered to be transitional vegetation between savanna and forest. Thickets comprise closed shrubland to low forest dominated by evergreen, sclerophyllous or succulent trees, shrubs and vines. Although no fire-related literature exists for thickets in South Africa, as part of the forest/savanna mosiac, their particular fire regimes and fuel properties would be dependant on whether the vegetation physiognomy was more representative of savanna or of forest vegetation.

Savanna

The savanna biome is the largest biome in South Africa, occupying over one third of its surface area. The biomass of savannas is shared by trees and grass. The environmental factors delimiting the savanna biome are complex with broad altitudinal and rainfall ranges. Almost every major geological and soil type occurs in the biome.

The fuel structure of South African savannas is composed of erect grass swards sometimes with patchy distribution providing fine fuel to support fires. Total above-ground biomass varies between 500 – 6000 g/m^2, of which up to 4000 g/m^2 can be woody vegetation. Trees are unimportant in carrying fire but provide woody material for smouldering combustion. Fire frequency ranges between one and six years with fires occurring mainly in the dry winter periods where grasses are cured or relatively dormant (van Wilgen *et al*. 1997). Fire intensities range from <100 to 4000 kW/m. Fires are generally surface fires with tree canopies being scorched but not contributing to combustion.

Grassland

The grassland biome occurs mainly on the high central plateau of South Africa and the inland areas of KwaZulu-Natal and the Eastern Cape in areas which are cooler, especially in winter, than the savannas (Everson *et al*. 1985). The topography is mainly flat and rolling, but includes the escarpment itself. The South African grasslands are divided into 'sweet' (warm and dry, on fertile soils, seldom burned) and 'sour' (cool, wet and infertile, frequently burned) grasslands. Fire formerly played a major role in keeping southern African grasslands treeless, and the trees were historically confined to fire-protected habitats within them.

The fuel structure of grasslands comprises erect grass swards with continuous distribution providing fine fuel to support fires. Fire frequencies average between two and four years nationally and one in two years in the Natal Drakensberg with fuel loads of around 600 g/m^2 and fire intensities of 1000 – 3000 kW/m. Fires occur as surface fires, mainly in the dry winter periods and fuel consumption is efficient with 70 – 80% of biomass being consumed.

Nama Karoo

The Nama Karoo biome is the second largest biome and occurs on the central plateau of the western half of South Africa at altitudes between 500 and 2000 m (Low and Rebelo 1996). The distribution of the biome is determined primarily by rainfall and the dominant vegetation is a grassy dwarf shrubland. The vegetation includes open karroid shrublands where fuels are often not sufficient or continuous enough to support fires (van Wilgen and Scholes 1997).

Succulent Karoo

The succulent Karoo biome covers a flat to gently undulating plain with some hilly veld, mostly situated to the west and south of the escarpment, and north of the Cape Fold Belt. The biome is dominated by dwarf succulent shrubs and is primarily determined by the presence of low winter rainfall and extreme summer aridity. The amount and nature of the fuel load is insufficient to carry fires, which are rare events.

Fynbos
Fynbos refers to the sclerophyllous shrubland vegetation of the Western and Eastern Cape provinces. These shrublands dominate on nutrient-poor soils in areas of Mediterranean-type climate (wet winters and warm, dry summers), and fires tend to occur in the dry summer months but can occur at other times under suitable weather conditions. Fynbos fuels are complex, comprising mixtures of restioid and ericoid elements, forming a continuous fuel bed below a stratum of broad-leaved screlophyllous proteoid shrubs (van Wilgen and van Hensbergen 1992). Fuel loads are largely dependant on post-fire age and the intervals between fires range from once in ten to thirty years. *Fynbos* fires are regarded as canopy fires with fire intensities ranging between <500 and >20 000 kW/m (van Wilgen and Scholes 1997). Because of the longer intervals between fires, fuel loads are much higher than those associated with grasslands or savanna. Typical fuels range from 1000 to 3000 g/m^2 at 15 years post fire with maximum fuel loads of >7000 g/m^2 in 40 year post-fire stands (van Wilgen and Scholes 1997).

Plantations
Plantations have been included in the vegetation overview as a result of their importance when considering the vegetation components relevant to the NFDRS. South African plantations are predominantly comprised of non-indigenous tree species including *Pinus* and *Eucalyptus*. The plantations are actively defended against fire, with varying degrees of success. An average of 6430 ha (0,5% of the planted area of 1,3 million hectares) per annum was burned in South Africa over the period 1986-1993. In some plantations, slash resulting from pruning or felling operations is intentionally burned (De Ronde *et al*. 1990).

The fuel structure of plantations comprises evergreen trees with moderate moisture contents and compact, often substantial, litter layers. Above-ground biomass is substantial (18000 – 25000 g/m^2 in mature pine stands) with needle litter biomass able to exceed 15000 g/m^2 (van Wilgen and Scholes 1997) Plantation fires are mostly accidental and occur typically in the dry season as surface fires for prescribed burns and crown fires for wildfires. Prescribed burn fire intensities have been measured at between 250 and 700 kW/m (De Ronde *et al.* 1990).

4.2 South African Users of Fire Danger Rating

The diversity of South African users of a NFDRS ranges from developed to developing world conditions. Although organized and structured Fire Protection organizations/units exist in some metropolitan, urban and rural areas, the user base includes a significant proportion of remote rural communities with limited access to telephones, radio and television.

Fire Protection Associations
Fire Danger Rating Systems are of particular importance to the commercial forestry industry in KwaZulu-Natal and Mpumalanga. Their concerns in this regard have been driven by their substantial economic interests in commercial forests.

Fire Protection Associations currently exist in only two of the nine provinces, namely KwaZulu-Natal and Mpumalanga. These were established prior to the promulgation of the Act and, therefore, do not necessarily comply with the requirements of the current legislation. KwaZulu-Natal has a Fire Protection Association (FPA) in the Midlands and two FPAs in Zululand (one inland and the other coastal), while Mpumalanga has a single Forest Fire Association (FFA).

Both SAFCOL and Cape Nature Consevation currently use FDR forecasts supplied by the Cape Town Weather Office. The FDR system used is the Lowveld System.

Fire Protection Associations will be able to use the FDRS as a decision-making tool for fulfilling their role of supporting the forestry sector as well as the surrounding farming community and the general public.

Farmers

The NFDRS would apply to the farming community when making decisions regarding the burning of firebreaks and other agricultural management burns. As for all users, the NFDRS is relevant for fire prevention purposes.

Conservation Agencies

Provincial conservation agencies exist in all of the nine provinces and, together with the national conservation agency, are responsible primarily for protected area management. The KwaZulu-Natal Nature Conservation Service and the Western Cape Nature Conservation body provide a fire protection function for the areas under their jurisdiction and contribute towards fire protection in the immediate surrounding areas.

A concern raised by conservation agencies is that in some instances, conservation areas may need to be burned under fairly extreme or high fire risk conditions, where extremely hot fires are required for ecological reasons. This may be a problem where a ban on fires might be proposed using the NFDRS.

The Public

The NFDRS is relevant to the general public for fire prevention purposes. However, communicating the NFDRS ratings to the South African public presents a substantial challenge, given that more than 95% of the population speak one or more of 11 different languages with Zulu, Xhosa, Afrikaans, Pedi and English being the five most common languages. In terms of population distribution, there is an approximate equal split between the number of rural and metropolitan inhabitants.

National adult literacy levels exceed 70% and more than 85% of all South African households own radios, while only 50% of African households (mostly restricted to the metropolitan areas) own television sets (Central Statistics 1999). Some 40% of all South Africans do not have access to any form of telecommunication and the majority of major urban daily newspapers are printed in English and Afrikaans, with minor circulations of Xhosa and Zulu language dailys.

National Disaster Management Centre

A National Disaster Management Centre (NDMC) as proposed by National Government will coordinate disaster management at various levels and promote and assist the implementation of cross-sectoral disaster management activities. The NFDR system would enable the NDMC to track, monitor and disseminate information on the potential for fire-related disaster events (Department of Constitutional Development 1999).The role of the NDMC is discussed in sections 10 and 11.

Local Government

Local Government, in the form of municipalities, is responsible for providing fire protection services to the citizens residing in their areas of jurisdiction (refer to section 10). Most metropolitan areas have resident fire brigades to fulfil this role.

Municipalities and the Urban/Rural Interface

The NFDRS is particularly relevant to municipalities with an urban/rural interface with fire-prone ecosystems, for example: Cape Town, Port Elizabeth and Hermanus. These areas are faced with creeping urban development pressures on the surrounding *fynbos* ecosystems.

South African National Defence Force
The South African National Defence Force (SANDF), particularly the Air Force, fulfils a vital role in disaster management at a provincial and national level. National Defence budget constraints have forced the SANDF to charge for their fire combating services.

5. AN OVERVIEW OF THE SOUTH AFRICAN CLIMATIC CONDITIONS AND CURRENTLY AVAILABLE WEATHER DATA

5.1 Introduction

The weather of South Africa is influenced by its position relative to the mean circulation of the atmosphere: southern Africa lies within the semi-permanent high pressure belt of the Southern Hemisphere. Consequently, the South Indian anticyclone, South Atlantic anticyclone and the continental anticyclone largely determine South Africa’s climate and weather (Preston-Whyte and Tyson 1988; Lindesay 1992). The South Indian and Atlantic anticyclones vary significantly in position throughout the year, with a 6º northward shift in winter (Preston-Whyte and Tyson 1988). Furthermore, the South Indian anticyclone displays a longitudinal movement of 24º westward between summer and winter, and the South Atlantic anticyclone a 13º eastward movement between summer and winter (McGee and Hastenrath 1966; Tyson 1986).

The intra-annual displacement of these anticyclones has important effects on the summer and winter conditions of South Africa. During winter, when both anticyclones are at their northern-most position, travelling westerly disturbances (such as cold fronts and their associated troughs) affect the south-western and southern Cape region, resulting in rainfall during that season. By contrast, the establishment of the continental anticyclone over the north-eastern interior results in dry conditions over the central and eastern parts of the country. During summer, the southward (and eastward) displacement of the anticyclones allows for a tropical control of the weather over the northern parts of South Africa (Preston-Whyte and Tyson 1988). This is manifest by tropical easterly flow and the occurrence of easterly waves and low pressure systems. Rainfall occurs in conjunction with these systems over much of the central, northern and eastern parts of the country. The South Atlantic anticyclone affects the south-western Cape during this season, resulting in clear, dry conditions. The South Atlantic anticyclone may also ridge south of the country, causing rainfall along the south and east coasts.

5.2 Climatic Regions

The meteorological factors summarised above result in a diversity of climatic conditions in South Africa. These can be subdivided on the basis of climate, as well as uniformity of weather and season associated with fire risk, into the following zones:

- South-western Cape and adjacent interior
- Southern Cape coast
- South-eastern and eastern coast and adjacent interior
- North-eastern escarpment
- Eastern interior
- Central interior
- Western interior

The meteorological conditions conducive to desiccation and possible fire conditions will be outlined for each relevant zone.

South-western Cape

This region extends from Saldanha Bay in the northwest to Cape Agulhas in the southeast. Rainfall occurs during the winter months (~48% of annual total) (Table 5.1). Summer is the driest time of the year, with approximately 10% of the annual rainfall occurring during that season.

Desiccation during summer is the result of the South Atlantic anticyclone ridging over the area bringing clear, hot weather over the region for extended periods (Preston-Whyte and Tyson 1988). Severe heat waves, with temperatures 10ºc higher than average, may occur for periods of two to five days (Schulze 1984). Strong south-easterly winds often occur over the south-western Cape in conjunction with this circulation system. These strong winds have important ramifications for wild fires over the region. Ridging anticyclones occur mainly between October to May, with a maximum frequency during December and February (Taljaard 1982).

Southern Cape

This region extends roughly from Cape Agulhas in the west to Port Elizabeth in the east. Rainfall is evenly distributed throughout the year, with a relative minimum during summer (~22% of annual total) (Table 5.1).

Hot, dry weather over this region is associated with offshore north-westerly to north-easterly airflow, in conjunction with an anticyclone over the interior and ahead of a coastal low pressure system. This shallow system usually forms on the west coast and migrates along the coast to KwaZulu-Natal (Preston-Whyte and Tyson 1988). All coastal lows produce warm off-shore flow ahead of the system and cool on-shore flow behind. Adiabatic warming as the air descends the escarpment may even result in warming on the inland plateau.

Berg winds may blow for up to several days. The winds are most common in late winter or early spring (Preston-Whyte and Tyson 1988).

South-eastern and eastern regions

This region extends roughly from Port Elizabeth to the Mozambique border in the northeast, and includes the adjacent interior. Rainfall is characterised by a summer maximum (~40% of annual total) and a winter minimum (Table 5.1).

As in the previous zone, hot, dry weather is associated with an anticyclone over the interior and/or the passage of a coastal low along the coast. Strong north-westerly to northerly winds may occur, which exacerbate the fire risk.

These systems occur in late winter/early spring when the vegetation is extremely dry after the winter drought.

North-eastern escarpment

This region extends roughly from Swaziland to the Zimbabwe border in the north, and includes the lowveld. Rainfall is characterised by a summer maximum (~50% of annual total) and a winter minimum (Table 5.1).

Hot, dry conditions conducive to forest and veld fires occur in conjunction with anticyclones over the northern interior of the country, resulting in north-westerly, descending air along the escarpment. Pre-frontal north-westerly flow ahead of a westerly wave in late winter and spring may also cause hot, dry conditions conducive to fires.

Eastern interior

This region occurs eastward of a line drawn roughly from Mafikeng to southern Lesotho and encompasses most of the highveld. Annual average rainfall varies from about 650mm in the west to 900mm in the east (Schulze 1984). The rainfall is characterised by a spring to summer maximum (30-50% of annual total) and a winter minimum (Table 5.1).

Conditions conducive to runaway veld and forest fires generally occur with strong, north-westerly flow ahead of an approaching cold front. These conditions occur mainly during the winter and early spring.

Central interior
This zone borders the previous zone on the west. It encompasses the western parts of Northwest Province, the central and western parts of the Free State and the Cape Midlands. This is a semi-arid region receiving about 250mm in the west to 500mm in the east (Schulze 1984). The rainfall is characterised by a summer to autumn maximum (26-45 % of the annual total) and a winter minimum (Table 5.1).

Conditions conducive to runaway veld fires generally occur with strong, north-westerly flow ahead of an approaching cold front. In addition, strong northerly flow around the continental anticyclone may also create conditions conducive to veld fires in the south of the region.

Western interior
This region includes most of the Northern Cape Province. The rainfall is low, amounting to about 250mm per annum in the interior and decreasing to approximately 50mm towards the coast (Schulze 1984). The rainfall in the interior is mainly in the form of thundershowers in summer and autumn (33-41% of the annual total), with some frontal precipitation occurring in winter in the southern parts of this zone (Table 5.1).

Runaway veld fires are unlikely in this zone, owing to the sparse vegetation. However, hot easterly flow when the anticyclone is established over the interior may create conditions conducive to fires.

Table 5.1 Average rainfall per season in millimetres (percentage of annual in parenthesis) for two sites in each region.

		Summer (Dec, Jan, Feb)	Autumn (Mar,Apr, May)	Winter (Jun, Jul, Aug)	Spring (Sep, Oct, Nov)
SW Cape	Jonkershoek	114 (10%)	278 (26%)	483 (45%)	203(19%)
	Paarl	84 (9%)	226 (25%)	442 (49%)	160 (17%)
S Cape	Diepwalle	264 (23%)	283 (24%)	265 (23%)	347 (30%)
	Tsitsikamma	207 (22%)	247 (26%)	264 (28%)	227 (24%)
SE & Eastern Regions	Dohne	284 (37%)	196 (25%)	80 (11%)	211 (27%)
	Cedara	363 (42%)	181 (21%)	64 (7%)	253 (30%)
NE Escarpment	Nelspruit	366 (48%)	156 (20%)	29 (4%)	216 (28%)
	Tzaneen	458 (50%)	180 (20%)	47 (5%)	225 (25%)
Eastern Interior	Bethlehem	259 (38%)	161 (24%)	46 (7%)	214 (31%)
	Belfast	423 (48%)	152 (17%)	21 (2%)	282 (33%)
Central Interior	Bloemfontein	254 (45%)	145 (27%)	35 (6%)	125 (22%)
	Cradock	117 (37%)	95 (30%)	30 (9%)	75 (24%)
Western Interior	Upington	74 (41%)	68 (37%)	9 (5%)	31 (17%)
	Calvinia	35 (15%)	75 (34%)	81 (35%)	37 (16%)

5.3 New climate regions

The SAWB has recently developed a new map, which is a revision of an older map of climatic regions (Schulze 1965). It has been developed by Andries Pretorius of the SAWB, with input from external sources. The map, and the additional information, will shortly be included in a new publication of the SAWB (probably entitled Climatic Regions in South Africa), but this is still in a planning phase. This map has been used as a basis for the development of homogenous fire danger regions (see Section 7 of this report, and Figure 7.2).

5.4 Forecasting weather and fire danger

Weather forecasts are produced and disseminated by the South African Weather Bureau (SAWB). Extensive use is made of the ETA Numerical Weather Prediction (NWP) model for this purpose.

The ETA model is a global hydrostatic model with a horizontal grid spacing of approximately 48 km and with 50 vertical levels, with layer depths that range from 20 m in the planetary boundary layer to 2 km at 50 hPa. It is envisaged that the horizontal resolution of the model is to be brought down to a finer spatial resolution of 32 km. This means that there will be forecast meteorological parameters every 32 km over South Africa.

Approximately 300 surface stations, 5 upper air stations, and AMDAR (aircraft) data are used in the model after passing quality control (Bruyere, pers. comm. 2000). These data are used to initialize the model for the twice daily simulation at 02:00 am and at 14:00 pm (Laing and du Plessis, pers. comm. 2000). The model output consists of 30 meteorological fields for a 48 hour advance period, including temperature, rainfall, humidity, wind speed and wind direction. The model is accurate in terms of wind speed and direction, but less accurate with temperature, rainfall and humidity (Laing and du Plessis, pers. comm. 2000). It is envisaged that the finer spatial resolution of the model will improve the accuracy.

It is envisaged that the relevant outputs from the ETA model would be used as input to the FDR model, so that the fire danger rating could, if necessary, be calculated on a 32 to 48 km grid for present as well as forecast conditions.

6. EVALUATION OF THE AVAILABLE MODELS

6.1 Development of criteria to evaluate the models

In terms of the National Forest and Fire Laws Amendment Bill (B-99), a fire danger rating system for South Africa will have to:

- Take into account the relevant peculiarities of each region where reasonably possible, including:
    - the topography;
    - the type of vegetation in the area;
    - the seasonal climatic cycle;
    - typical weather conditions;
    - recent weather conditions;
    - current weather conditions;
    - forecasted weather conditions, and
    - any other relevant matter.

- Incorporate the formula or formulae needed to:
    - take into account all factors affecting the fire danger for each region;
    - calculate the indicators needed to rate the fire danger, and
    - rate the fire danger in each region for an appropriate period or periods.

- Show the rating in a clear format.

- Identify:
    - what activities are dangerous and what precautions should be taken for each rating, and
    - when the fire danger is rated as high.

Based on the specific requirements of the law, a number of selection criteria were developed, after consultation with the DWAF Fire Committee, to guide the selection process. These criteria were developed with a view to ensuring that the model selected would be able to meet the needs for the implementation of the Act. They include:

- **That the model selected must be able to predict and ate fire danger both reliably and consistently**

  The index generated by the model should be able to allow users to predict, with confidence, the likely number of fires, the likely degree of difficulty of suppression, and the likely degree of difficulty of containment. These features of fire behaviour are dependent on a limited number of important "drivers". Suppression and containment are related to flame lengths, which can be predicted from a combination of fuel amount and arrangement, wind speed, and fuel moisture (in turn influenced by temperature, relative humidity, and rainfall). The likely number of fires is also strongly linked to these factors (which affect "ease of ignition"), combined with an assessment of ignition risk. A reliable FDRS should therefore consider, at least, all of these factors.

- **That the model must be able to predict fire danger on a daily basis, at least 24 hrs in advance**

  This implies that the all of the input variables for the model should be such that they can be forecast at least 24 hours in advance.

- **That the model must be equally applicable throughout the country**

  This criterion implies that the model should be developed from basic physical principles, and should not have been empirically derived for a single area only. In cases where models have been empirically derived, the models should be robust enough to accommodate expected conditions outside of the area where they have been developed.

- **That the index generated by the model must be able to accommodate the full range of possible conditions that affect fire behaviour, and must not be restricted or capped in any way**

  The restriction of an index to a given range may mean that it could perform adequately in some environments, but not in others where the conditions affecting fire danger go beyond the range from time to time. This would have to be tested by means of examining severe conditions to check if the range can accommodate them.

- **That the model must use data that are currently available in South Africa**

  The input data should be available in a form that can serve as inputs to the model at sufficient resolution of scale to make the model applicable over the whole country.

- **That the model should have been shown to perform satisfactorily in environments like those in South Africa**

  In cases where the model has not been specifically tested in South Africa, it should have been shown to perform in environments like those in South Africa, where similar conditions of fuel (vegetation), climate and weather occur.

- **That the model should not require the further development of specific fuel descriptors**

  Some fire danger rating systems require that specific fuel descriptors be used as inputs, and these fuel descriptors need to be developed for particular vegetation types. In cases where South African vegetation differs from the available fuel models, it would take time to develop these and this could delay the implementation of the system.

6.2 Application of the criteria for the selection of a suitable system

The above criteria were applied to the available systems described in section 3 of this report.

The need to deal explicitly with fuel types and their geographical arrangement was not considered important enough to disqualify any of the candidate models. The resason for this being that it should be possible to scale fire danger rating indices, when applied to a particular region, to reflect the fuel conditions in that region. For example, a certain set of weather inputs would produce the same index in any region regardless of the fuel, but the actual fire *behaviour* (such as flame lengths) would differ in regions with different fuel types. So, for example, under the same set of weather conditions, flame lengths would be smaller in regions dominated by short grassy fuels than in regions dominated by tall, dense fynbos. As flame lengths are related to the difficulty of containment, a given index could therefore indicate large flame lengths (and therefore high fire danger) in fynbos areas, and small flame lengths (and therefore lower relative fire danger) in grassland areas, for the same index value. This can be accommodated by scaling the index values to produce different cut-off values for high fire danger according to the region.

Secondly, the issue of ignition risk is a separate factor that is not explicitly accommodated in any of the basic models that rate fire danger. The Canadian and US systems do have separate models that rate the risk of ignition, but these do not influence the indices that simulate fire behaviour potential. The ignition models were developed outside of South Africa and are probably not applicable here. For that reason, the inability of a model to take ignition risk into account was not considered important enough to disqualify it as a potential candidate for south Africa.

6.2.1 The Swedish Angstrom Index

This index is based on relative humidity and temperature alone. As such, it does not take all of the relevant factors that affect fire danger (such as rainfall, wind and fuel) into account , and will probably not be able to predict or rate fire danger reliably or consistently as a result (Table 6.1). For this reason, it was deemed unsuitable, and the remaining criteria (Table 6.2) were not applied to this model.

6.2.2 The USSR Ignition Index

This index is similar to the Angstrom Index, but also considers the length of time since the last significant rainfall. It does therefore account for long-term drying of fuels, albeit in a simplistic way, but as in the case of the Swedish Angstrom Index, does not take into account all the relevant factors that affect fire danger, such as wind and fuel (Table 6.1). For this reason, it was also deemed unsuitable, and the remaining criteria (Table 6.2) were not applied to this model.

6.2.3 The French Fire Danger Rating Index

This index is based on a drought index (a surrogate measure for the ease of ignition) and wind speed (a driver of fire spread). As such, it represents a better option than the two models above (because of the inclusion of wind, Table 6.1). However, the system has not been shown to perform in environments such as those in South Africa (Table 6.2), and as there are better options available, this system should not be selected as a candidate to underpin a South African NFDRS.

6.2.4 The Canadian Forest Fire Danger Rating System

The Canadian Forest Fire Danger Rating System, and especially the Fire Weather Index (FWI), is considered to be a reliable and consistent predictor of fire danger (see Table 6.1). However, the system has been specifically developed for boreal forest ecosystems, and contains elements that are designed to simulate processes in boreal forests. For example, the index relies partially on a duff moisture code. Duff (the thick litter layers that build up in boreal forests) is a particularly important fuel type in Canada, but does not occur in South Africa. As the Canadian system has never been fully tested in South Africa, or in environments similar to those in South Africa (Table 6.2), it is not possible to make a judgement on its suitability without further testing. It is, however, a more rigourous model than the three models discussed above and may well function effectively in South Africa. A separate report by Scott *et al*. (2001) concluded that there were no compelling reasons for excluding the Canadian FFDRS from consideration for use in South Africa at this stage, and it would appear that further testing of a shortlist of candidate models will need to be carried out before a final recommendation on a suitable model can be made (see section 6.3).

6.2.5 The US National Fire Danger Rating System

The US National Fire Danger Rating System is considered to be a reliable and consistent predictor of fire danger (see Table 6.1). It takes all of the important drivers of fire behaviour into account. It has also been tested in South Africa (in fynbos and montane grassland areas), and shown to perform well under a range of conditions. However, it may fail to qualify as a suitable basis for a South African NFDRS on two grounds (Table 6.2). Firstly, the input data required to run the system (rainfall duration, and estimates of cloudiness) are not readily available in South Africa. Secondly, local vegetation descriptors are not available to meet the requirement for specific fuel models for each region, and would have to be developed. These drawbacks are not considered sufficient to exclude the system from further consideration. Scott *et al*. (2001) were able to run the system using basic weather inputs (see page 27 of Scott *et al*. 2001). This does violate the assumptions of the model by converting inputs using fixed conversion factors, but the impact of this is not fully understood. In addition, the standard fuel models in the system may well meet the requirements for South African conditions, therefore eliminating the need to develop new ones. However, further testing of this model will need to be carried out before a final recommendation on a suitable model can be made (see section 6.3).

6.2.6 McArthur's Grassland Fire Danger Rating Index

The McArthur Grassland Fire Danger Rating Index was developed for use in grassland systems in Australia. As grassland fuel complexes are not characterised by coarse dead fuels that take several days to reach equilibrium moisture contents, the simulation of moisture content relies only on temperature and relative humidity (Table 6.1). It will therefore not be applicable over the whole of South Africa (Table 6.2), but only in grassy areas where coarse dead fuels are not present. Scott *et al.* (2001) did not consider this as one of the three models that were best suited to South African conditions, but it should be considered as a potential candidate until further testing has been done (see section 6.3).

6.2.7 McArthur's Forest Fire Danger Rating Index

The McArthur Forest Fire Danger Rating Index is considered to be a reliable and consistent predictor of fire danger (see Table 6.1). It takes all of the important drivers of fire behaviour into account. It also meets all of the additional criteria for selection as suitable for underpinning a South African Fire Danger Rating System (Table 6.2). The index is not capped, but was designed to work on a scale from 0 to 100, as it was not expected that a value of 100 would ever be reached. However, several values of over 100 have been experienced in Australia since the meter was introduced in 1966, but this does not limit the applicability of the system in South Africa. In a separate study (Scott *et al*. 2001) the McArthur FFDRI did not exceed values of 60 in 30 years of weather records at two stations in South Africa. The McArthur FFDRI therefore appears to meet all of the criteria and will need to be included as a candidate system when further testing is carried out (see section 6.3).

6.2.8 The Lowveld Fire Danger Rating System

The Lowveld Fire Danger Rating System takes most of the important drivers of fire danger into account, and is considered to be a reliable predictor of fire danger (Table 6.1). However, it has been developed and calibrated specifically for use in the Mpumalanga and KwaZulu/Natal areas, and will not be applicable over the whole of South Africa (Table 6.2). For example, wind speeds in the Western Cape, and along the coast of the Eastern Cape, are much higher that in the areas where the model was calibrated, and this would lead to abnormally high indices being generated. A major drawback is the fact that its development (and the assumptions that were made in the development) has never been documented. There is therefore no basis on which to judge the validity of the system, and, given that other suitable and well documented systems are available, we do not recommend that this system be selected to underpin a South African NFDRS.

6.3 Conclusions

The above analysis suggests that there are four potential candidate models that could underpin a South African National Fire Danger Rating System – the Canadian Forest Fire Danger Rating System, the United States National Fire Danger Rating System, and the McArthur Grassland and Forest Fire Danger Indices. A report on a preliminary study by Scott *et al*. (2001) was not able to make a clear recommendation on a suitable model. Following further discussions with DWAF, it was decided that further work would be required before a defensible recommendation of a suitable model to underpin a South African NFDRS could be made.

The proposed work should focus on the further examination of candidate models that could potentially underpin a NFDRS, with respect to how they perform in different regions of the country (the regions chosen should span the extremes in the country). This examination should include an analysis of the sensitivity of the different models to the range of input variables. The results of this study will be used to inform a process that will deliver an objective recommendation for a preferred model to underpin the NFDRS.

In order to obtain information that will guide the examination of candidate models, it is recommended that the execution of a one-year experiment be carried out to test all of the short-listed models that could underpin the NFDRS. The experiment should test, on a daily basis, how the candidate models fail or succeed in predicting the conditions described in the rating system, across a full range of fuels and climate. The experiment should involve the SAWB and expert practitioners.

The development of a proposed methodology is recommended for the delivery of (i) an agreed set of descriptions of each of the different fire danger rating categories. While examples of these are given in Table 9.1, further consultation with stakeholders and experts will be required to finalise these before they can be incorporated into the NFDRS and into legislation; (ii) an objective recommendation for a preferred model to underpin the NFDRS, based on further work on the suitability of candidate systems, outlined above; and (iii) cut-off values for the ratings for the most important fire danger zones in the country (see section 7.2 c). The methodology should include appropriate inputs from experts and stakeholders.

Table 6.1 Comparison of eight Fire Danger Rating Systems with regard to meeting the criterion of being able to able to predict and rate fire danger both reliably and consistently.

Fire Danger Rating System	Wind	Moisture			Fuel	Ignition risk
		Relative Humidity	Temp.	Rainfall		
Swedish Angstrom Index	No	Yes	Yes	No	No	No
USSR Ignition Index	No	No	Yes	Yes	No	No
French FDRS	Yes	Yes	Yes	Yes	No	No
Canadian FFDRS	Yes	Yes	Yes	Yes	Yes, but not in FWI	Yes, but not in FWI
United States NFDRS	Yes	Yes	Yes	Yes	Yes, explicit in fuel models	Yes, but not in fire indices
McArthur FFDI	Yes	Yes	Yes	Yes	Based on Eucalypt fires	No
McArthur Grassland FDI	Yes	Yes	Yes	No	Based on grass fires, takes curing into account	No
Lowveld FDRS	Yes	Yes	Yes	Yes	No	No

Table 6.2 Comparison of eight Fire Danger Rating Systems with regard to meeting a range of criteria.

Fire danger rating system	Able to predict on a daily basis	Applicable all over South Africa	Caters for full range of conditions	Uses currently available data	Performs in environments like those in South Africa	Does not require further fuel model development
Swedish Angstrom Index	Not considered further					
USSR Ignition Index	Not considered further					
French FDRS	Yes	Yes	Yes	Yes	No?	Yes
Canadian FFDRS	Yes	Yes	Yes	Yes	No?	Yes (if only FWI considered)
United States NFDRS	Yes	Yes	Yes	No	Yes	No
McArthur FFDI	Yes	Yes	Yes	Yes	Yes	Yes
McArthur Grassland FDI	Yes	No	Yes	Yes	Yes	Yes
Lowveld FDRS	Yes	No	Yes	Yes	Yes	Yes

7. HOMOGENOUS FIRE DANGER REGIONS

7.1 Introduction

The Act requires that the country be divided into regions that would be 'sufficiently uniform to allow for a single rating which is meaningful for the entire region'. The South African Weather Bureau currently forecasts weather on a provincial basis, but this will not be suitable for the purposes of the Act, as provinces are too large and varied to represent sufficiently uniform areas. The South African Weather Bureau has, however, defined 24 regions that take both climatic and vegetation factors into account. This new map is a revision of the map of climatic regions in the SAWB WB28 publication (Schulze1965) and will shortly be included in a new publication of the SAWB. We have used this map (Figure 7.2) as a basis for the delineation of homogenous fire danger regions, in the process described below. The areas in Figure 7.2, although an improvement on provincial boundaries, are still too large and varied for the purposes of forecasting fire danger. There are two main reasons that the SAWB's new regions cannot be adopted as fire danger regions.

Firstly, the regions must, in practice, be small enough to have a uniform rating on a given day, as high fire danger would potentially exist over relatively small areas. Fire bans in large areas when the fire danger only exists in a small area will impact on the effectiveness and credibility of the system.

Secondly, there is a need for the boundaries to be clear for legal purposes. For example, if fire bans are imposed, landowners need to know exactly which areas are affected. For these reasons, we recommend that municipal boundaries[6] be used as the basis for defining areas with forecasted high fire danger.

The process whereby fire danger forecasts will be made for municipal areas is outlined in the section below.

7.2 The process to determine uniform fire regions for South Africa

The process for forecasting fire danger should be done in a series of steps, described below.

(a) The first step in the process is to **forecast the range of fire danger indices across the country**. This will be done by forecasting the input variables for the chosen model (e.g. windspeed, rainfall over 24 hours, minimum RH and maximum temperature). The variables are, in turn, generated by standard forecasting models (on a 4 x 4 km grid) used by the SAWB. The forecast fire danger indices will then be plotted on a map, and isolines of fire danger indices will be drawn (Figure 7.1 provides a hypothetical example of these isolines). Actual values will also be collected from a range of weather stations around the country in order to calculate the actual fire danger (see section 5).

(b) The predetermined value of a fire danger index, above which fire danger is considered to be high, is critical for the implementation of the system. When the forecast fire danger is equal to or greater than this value (the "cut-off" value), then fire danger will be considered to be high, and certain prescribed actions will come into force in the area concerned. **The actual cut-off value**, which will differ for each of the 24 regions defined by the SAWB (Figure 7.2), **needs to be established**. The reason for this is that each of the regions will have a different dominant fuel type. In an area dominated by short grasses, for example, an index of 45 could lead to flame lengths of (for argument's sake) one meter. The same weather conditions (and index) in an area dominated by tall fynbos and pine plantations may result in flame lengths of 4 meters – which presents a quite different fire danger scenario. The value of the cut-off points for each of the 24 regions in the country has not yet been set.

Proposed cut-off points for the different fire danger rating categories for three fire danger ratings are given by Scott *et al*. (2001) – see Table 5 on page 27 of Scott *et al*. (2001). Current practice in Australia sets the cut-off points for McArthur's FFDRS at <5 for low, 5 – 12 for moderate, 12 – 24 for high, 24 – 50 for very high, and > 50 for extreme danger ratings. The set of actions taken in response to a given rating varies as a result of different circumstances in different regions in Australia. It is recommended that the cut-off values can only be finalised after further work has been done on the range of indices likely to be experienced in South Africa, and once the model to underpin the South African NFDRS has been selected (see section 6.3).

(d) By **comparing the forecast fire danger index values** (Figure 7.1) **with the cut-off values** (Figure 7.2), it is possible to delineate areas where the forecast fire danger would be regarded as high (Figure 7.3).

(e) In order to be able to define legally valid boundaries to the areas of forecast high fire danger, the final step of the process would be to **overlay the map of forecast high fire danger areas** (fig. 7.3) **with a map of municipal boundaries**. Any municipality that has high fire danger forecast (Fig. 7.4) will then be subject to any restrictions and other measures in terms of the Act. An entire municipality will be subject to the prescribed

6 . The municipal boundaries portrayed in Fig. 7.4 include all municipal boundaries, namely types A, B, CBLC and DMA. The map includes 6 unicities (A's), 223 "B" municipalities, 8 CBLC's (which straddle more than one province) and 25 DMA's.

actions for high fire danger even if only part of that municipality has a forecast high fire danger. This will be done to err on the side of caution.

This process therefore proposes that the only regions that can be considered '*usually sufficiently uniform to allow for a single rating which is meaningful for the entire region*' would be single municipalities.

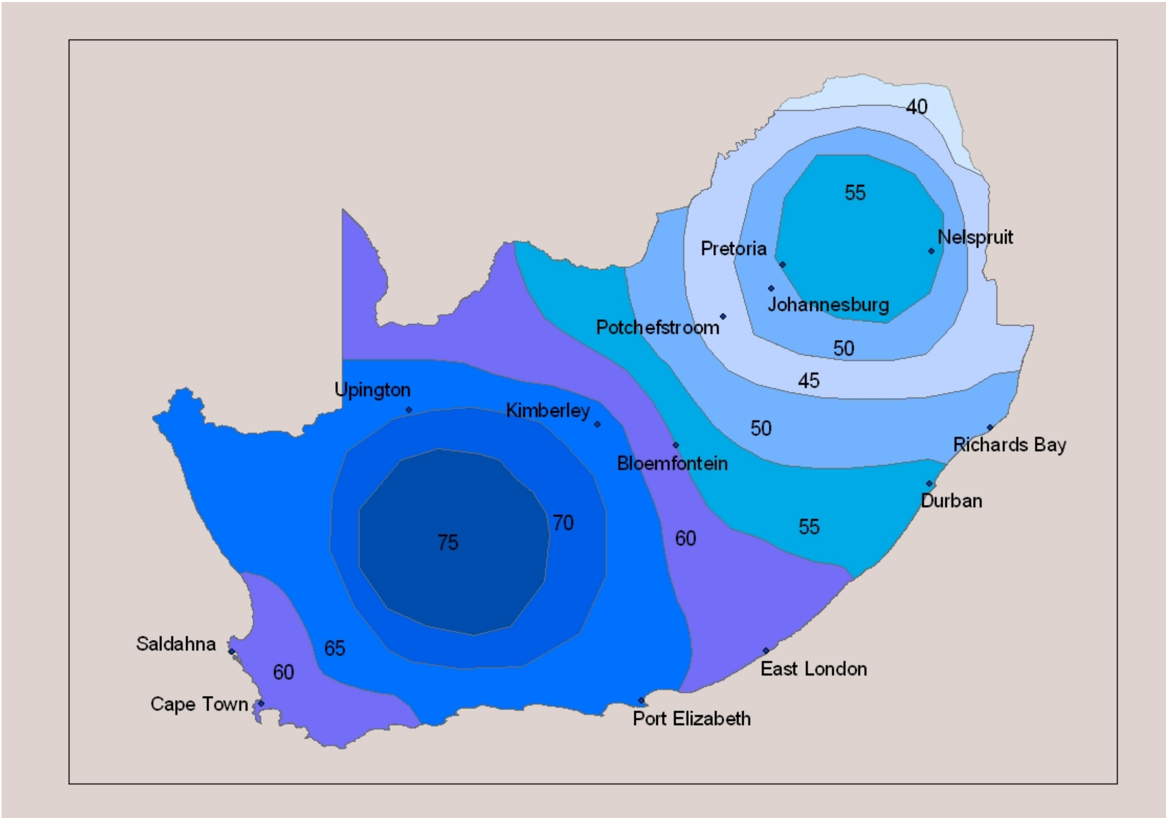


Figure 7.1 **Map of South Africa depicting hypothetical isolines demarcating different fire danger indices. These indices would be calculated by running a fire danger rating model, using forecast climatic data inputs such as temperature, rainfall and wind speed.**

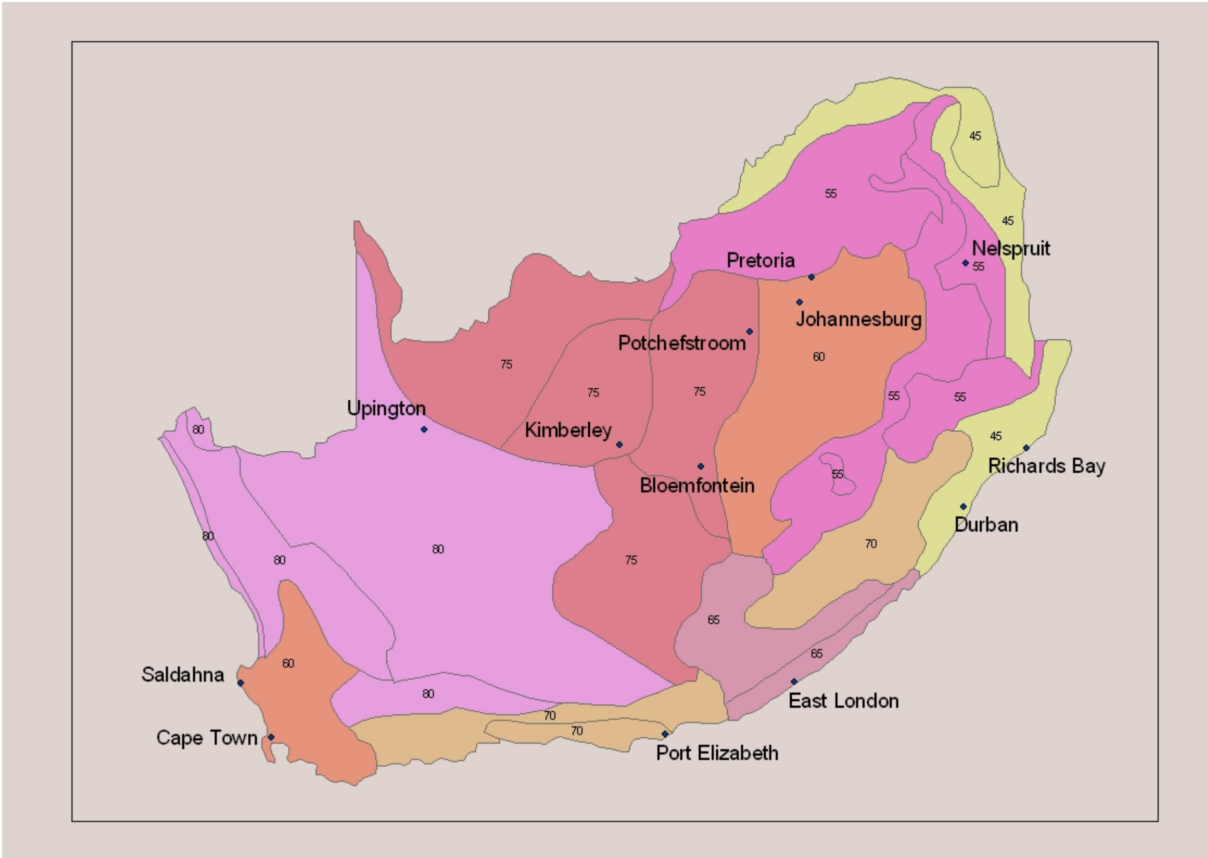


Figure 7.2 **Map of South Africa's climatic regions, as developed by the SAWB, depicting FDIs above which the fire danger would be considered to be high in the region concerned. (note – at this stage the values are hypothetical).**

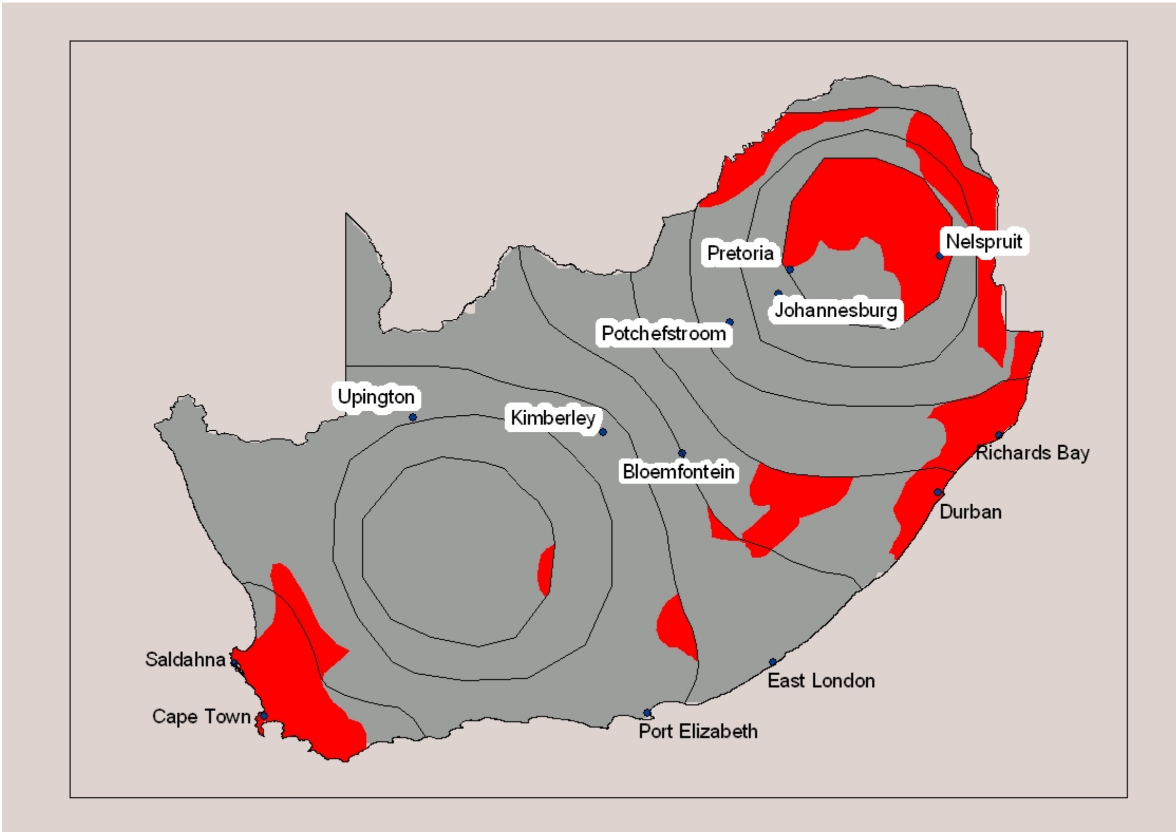


Figure 7.3 By comparing the daily predicted fire danger indices (Fig. 7.1) with cut-off values for different parts of the country (Fig. 7.2), areas of high fire danger are identified (in red on the map).

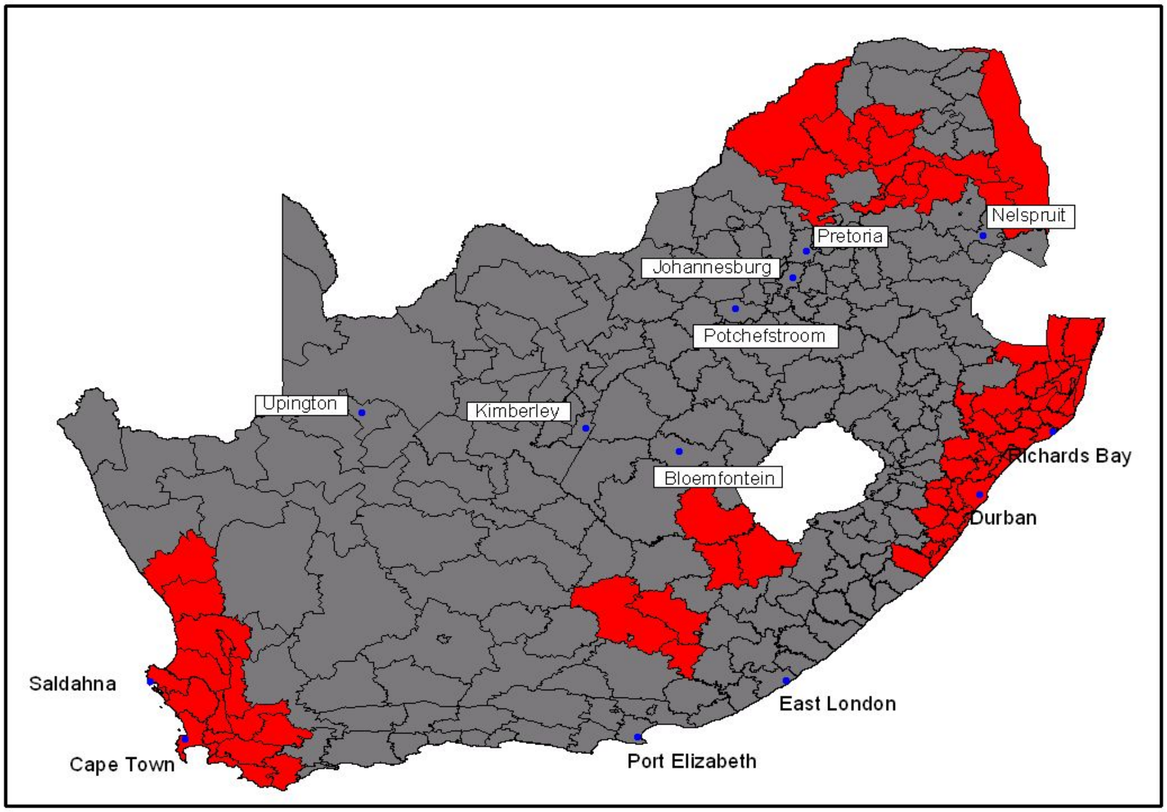


Figure 7.4 **The areas of high fire danger on any given day are overlaid with municipal boundaries (categories A, B, C and D) to ensure clear demarcation of areas where total fire bans will be prescribed. Any municipality in which all or part of the area is estimated to have a high fire danger rating will be included in the fire ban.**

8. CATEGORIES OF FIRE DANGER RATING AND THEIR USE

The most commonly used and preferred method of depicting the fire danger rating is through the use of colour codes. The ratings have been grouped into five categories, each represented by a colour. A description these categories is presented in Table 8.1 as well as brief descriptions of fire behaviour, recommended actions to be taken and prohibited activities for each category. These are provided as examples, merely as a basis for further consultation after which final descriptions will be incorporated into the NFDRS.

Sections 9(4)(d) (ii) and 10(1)(b) of the Act mention use the word 'high' to refer to a certain level of fire danger which would require certain legal interventions. Current practice in South Africa is to use the descriptive wording for each colour code, namely *low* (blue), *moderate* (green), *high* (yellow), *very high* (orange) and *extremely high* (red). Yet the legal implications of using the word 'high' for a rating which will not require legal intervention (i.e. 'yellow' days) makes this terminology unacceptable.

Two options to address this issue can therefore be considered:

i) to change the wording of the Act so that the 'total fire ban' would only apply when the fire danger was 'very high' or 'extremely high'; or
ii) to change the wording used to describe the various fire danger rating categories so that the word 'high' is only used for 'orange' or 'red' days, thus making the Act, as it now stands, acceptable.

It is proposed that the latter be adopted for the following reasons:

- The categories need to be the best for the entire country and the forestry industry will easily adapt to new wording provided the *colour coding* remains unchanged.

- It is not sensible to call the fire danger on a 'yellow' day 'high' but still allow all burning activities to take place (this would confuse the general public).

The proposed wording in Table 8.1 to describe the various categories therefore reflects this recommendation. In terms of the interpretation of the Act therefore, ***any*** category including the word 'high' would be read as "high" in terms of the Act. In other words, both the 'orange' and the 'red' categories (see Table 8.1 below) would be considered as high by current legislation because both include the word 'high'.

Table 8.1 contains examples of the expected fire behaviour for each FDR category and examples of the expected measures which would be required to ensure suppression of fire in each category. These descriptions are provided merely to assist in developing an understanding of each rating and will be developed further in consultation with stakeholders and experts. Table 8.1 also contains a row describing examples of the recommended actions which should be taken when the FDR is a certain 'colour'. Actions such as these could be incorporated into legislation but are considered preferable as guidelines rather than regulated activities. Finally, Table 8.1 has examples of actions which should be *mandatory* or which should be *prohibited* under certain fire danger conditions. It is actions such as these which should be included into the regulations of the Act to ensure legal accountability for certain actions when the fire danger is predicted to be 'high' (i.e. orange or red days).

Table 8.1 A description of the five proposed fire danger rating categories (Blue to Red), and examples of the fire behaviour, recommended control measures, actions and restrictions for each.

	BLUE	***GREEN***	***YELLOW***	***ORANGE***	***RED***
FDR RATING	Insignificant	Low	Moderate	High	Extremely high
FIRE BEHAVIOUR	Fires are not likely to start. If they start, they are likely to go out without aid from suppression forces. There is little flaming combustion. Flame lengths < 0.5 m and spread rates < 2 m/minute.	Fires will start but will spread slowly. Flame lengths typically < 1 m, and spread rates < 5 m/minute.	Fires fairly readily ignited and spread unaided, burning in the surface layers below trees. Flame lengths between 1 and 2 m, and spread rates between 5 and 25 m/minute, depending on fuel type.	Fires readily ignited and spread unaided, with local crowning and short-range spotting. Flame lengths between 2 and 5 m, and spread rates between 25 and 35 m/minute. Spotting occurs, increasing the rate of spread.	Any ignition source likely to initiate a fire. Fires will spread in the crowns of trees as well as in surface layers, and long-range spotting will occur. Spread rates can exceed 60 m/minute and flame lengths will be in the order of 5 – 15 m or more. Wide spread spotting, greatly increasing rate of spread
FIRE CONTROL	No control necessary.	Fires can be approached on foot. Suppression is readily achieved by direct manual attack methods.	Fires not readily approachable on foot for more than very short periods. Best forms of control should combine water tankers and backfiring from prepared lines.	Fires cannot be approached at all. Backburning, combined with aerial water-bombing are the only effective ways to combat fires. Equipment such as water tankers should concentrate efforts on the protection of houses.	Any form of fire control not likely to be effective until weather changes. Backburning dangerous and best avoided.

	BLUE	***GREEN***	***YELLOW***	***ORANGE***	***RED***
RECOMMENDED ACTIONS	None	None, other than prudent care to ensure that any open-air fires do not escape. Prescribed burning permissible.	Open-air fires should only be permitted in authorised fireplaces. Prescribed burning should be conducted with care, and any prescribed fires should be extinguished should the forecast fire danger rating turn to high.	All efforts should be made to bring any fires under control. Areas should be put on standby for evacuation should the fire danger conditions be forecast to become worse.	Dangerous areas to be evacuated. Equipment such as water tankers should concentrate efforts on the protection of houses and other structures.
PRESCRIBED ACTIONS AND RESTRICTIONS	None	None	Any unplanned fires should be extinguished.	No outdoor fires permitted.	No outdoor fires permitted.

9. COMMUNICATION STRATEGY

The Act specifies that the Minister must communicate the FDR to the FPAs ‘regularly’ and, more specifically, when the danger is high, warnings must be published to that effect. The communication strategy should, however, extend beyond merely the communication of the rating and also consider aspects such as awareness raising and training.

9.1 Communicating the FDR

The South African Weather Bureau should be responsible for forecasting the weather and running the model to obtain the fire danger ratings. The obligation to communicate the ratings lies with the Minister (Section 10(1) of the Act), yet the Act also allows for delegation of any of his or her duties in terms of this section to the SAWB (or any organisation with the necessary expertise). Since the SAWB has daily access to the inputs required to run the model, it would be the most logical organisation to forecast the FDR by running the model. The communication of the fire danger ratings (extrapolated from the indices) can then be communicated to the media in the same way that weather reports are disseminated, but this would have to be negotiated between DWAF and the SAWB. Regional radio stations and newspapers will only present those ratings relevant to their region. The specific duties and responsibilities of the various institutions, in terms of the communication of FDR, are addressed in section 10.

The FDR needs to be communicated daily, forecasting the daily ratings 48 hours in advance. It is imperative that the forecast for each 48 hour period be made available by noon preceding the 48 hour period to ensure that land managers and other institutions such as fire brigades, have ample time to take any required action in preparation for a red day (e.g. putting staff on standby, cancelling certain activities, etc.).

A website should be developed on which the FDR is kept up to date on an approximately 6-hourly basis (the time frame by which the SAWB updates its weather data). This will give managers the opportunity to obtain up-to-date information by which to manage their activities. However, if a ‘high’ day is forecast for the next day by the SAWB for a specific region, this should be binding for the purposes of a total fire ban, irrespective of whether or not the forecast turns out to be correct. The use of cellular phones to access the FDR is already being practised in South Africa and this could be expanded to a national scale. This would allow people without access to computers or the Internet to have access to the current FDR.

The SAWB will communicate the actual and forecast FDRs to DWAF. The Department may negotiate with the SAWB to communicate the rating to the media, the FPAs and the NDMC, or DWAF may develop its own system to address this requirement.

9.2 Awareness raising

Compliance by the public to the FDRs (e.g. total fire ban) will be difficult to enforce. However, if the public becomes aware of the NFDRS, its purpose and its benefits, in a positive way, voluntary adherence to the conditions could reduce the incidence of fires occurring. Also the communication of the FDR to formally structured institutions (e.g. FPA’s) does not address the vast rural population of South Africa. This sector may well have access to the media (radio and newspapers) but will need to be adequately informed about the new NFDRS. For this reason, part of the communication strategy should address the awareness-raising aspect of the NFDRS. Several mechanisms to implement this are suggested below:

- Radio, TV and newspaper broadcasts explaining the NFDRS.
- A short module in the biology/environmental curriculum of primary, secondary and tertiary institutions. This could also provide the pupils with some materials to take home to their families, such as a chart depicting the different ratings and the associated activities.

- A NFDRS 'kit' with a pamphlet explaining the ratings, and the activities associated with each rating. The kit could also contain a 'cut-and-assemble' nomogram (fire danger meter) or a computer diskette with the software to be loaded onto a computer instead of a nomogram.

- Local fire-fighters, NGOs environmental officers, volunteer fire-fighters presenting lectures at nursery schools, scout groups, etc. as well as hosting activities in shopping centres and malls (possibly including competitions).

- A national 'Fire Awareness Day'.

- A website catering for all ages, including games for children, down-loadable software (including the FD model and how it should be used).

9.3 Training

Land managers such as those managing plantations, agricultural land and conservation areas, will require a deeper understanding of the system than the general public. Formal training should be made available through tertiary institutions as part of current courses dealing with environmental management, or as a short 'stand-alone' course for current managers to attend. The course content should be standardized and controlled to ensure that anyone obtaining a NFDRS certificate has an acceptable level of understanding. The training would include aspects such as:

- The explanation of the model being used and the data used to populate the model
- The interpretation of the FDIs into FDRs (as described in section 7)
- The legal requirements in terms of the Act.

10. THE ADMINISTRATION OF THE NFDRS

10.1 Duties, authorities and responsibilities

There are a number of organizations that would be involved in the implementation of a NFDRS. These include the SAWB, the FPAs, and the NDMC. The responsibilities for calculating fire danger, curating the database, and collecting fire statistics will be shared between DWAF, the FPAs, the SAWB and (potentially) the NDMC. The proposed relationship between these organisations is governed in part by the requirements of the Act, and conceptualised in Figure 10.1.

Currently, no FPAs have yet been formed (under the new Act), and until such time as they have been formed, some of their functions could be performed by municipalities. Other organizations that would be involved would be the electronic broadcasting media, and the press. The duties and responsibilities of each of these organizations are outlined below.

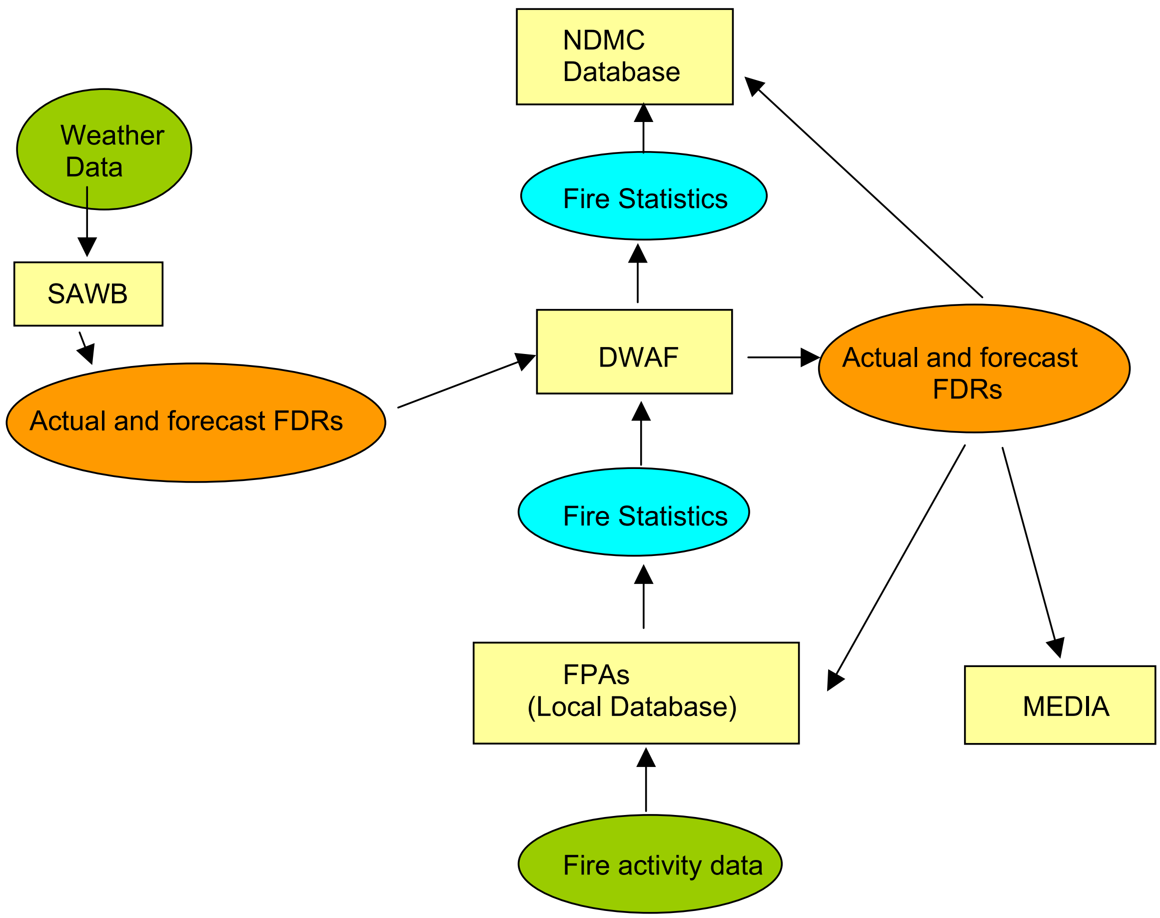


Figure 10.1 The proposed relationships between participating organisations with respect to the collection of data, the calculation of fire danger indices, and the curation of databases.

The Department of Water Affairs and Forestry (DWAF): DWAF will carry overall responsibility for ensuring that the Act is implemented at a national level. DWAF's responsibilities will include:

1. assessing areas where fires are important, but where no FPAs have been established. In such cases, and where there is an obvious need to establish FPAs, DWAF may choose to enforce the Act to initiate the establishment of a FPA. Where no FPAs exist, DWAF could approach municipalities to collect the relevant data;

2. ensuring that FPAs (or, in their absence, municipalities) collect relevant information on fire activity in their areas of jurisdiction, and that they report annually as required in the Act;

3. making available to the SAWB the formulae and compatible software for the calculation of fire danger indices, the cut-off points for categories, and the boundaries of the fire danger regions;

4. communicating the FDR to the FPAs, the NDMC and the media by email, fax, Internet and phone lines;

5. maintaining a list of radio and TV stations, and newspapers that would need to be contacted in the event of high fire danger being forecast;

6. ensuring that copies of radio broadcasts and newspaper notices are stored, as required by the Act;

7. education, awareness and ongoing research to meet the needs of implementing the NFDRS;

8. receiving fire statistics in an agreed format from the FPAs around the country on an annual basis. This presents two options: Either DWAF could act as custodian of the national database, or it could delegate this responsibility to the NDMC. In the latter scenario, DWAF would be responsible for submitting the fire statistics to the NDMC for curation; and

9. ensuring that the cut-off values for categories of fire danger are updated regularly, using the latest fire statistics, and that these updated cut-off points are communicated to the SAWB.

The SA Weather Bureau (SAWB): The SAWB may carry out the daily calculation of fire danger indices and forecasts. Their responsibilities would include:

1. collecting actual and forecast weather data on a daily basis. The SAWB would calculate two indices daily – a forecast, which will be based on forecast weather data, and used for warnings to the public; and an actual index, based on actual weather data; and

2. communicating the actual and forecast fire danger indices to DWAF through a suitable means, for example by email, fax and Internet, on a daily basis.

The Fire Protection Associations (FPAs): FPAs will be established in terms of the Act, and they will have responsibility for co-ordinating all activities relating to the prevention and combating of fires in their areas of jurisdiction. In terms of the NFDRS, their responsibilities would include:

1. collecting information on the occurrence, duration, area, and severity of all fires within their area of jurisdiction, along with other relevant information, in the required format (see section 11);

2. making these statistics available to DWAF annually, as required by the Act;

3. Agreeing on the conditions to be placed on members when the fire danger index reaches certain predetermined levels, and ensure that these conditions are made explicit and adhered to.

4. Keeping a local database of fire activity and related fire danger indices for the area under their jurisdiction, for their own use.

The National Disaster Management Centre (NDMC): The White Paper on Disaster Management (Dept. of Constitutional Development 1999) contains a description of the functions of the NDMC in detail. These include information management and co-ordination and support during disaster and emergency situations. For the purposes of the administration of the NFDRS, this centre should function as a coordinating structure that is a repository and conduit of information pertaining to disaster management. As such, it should strengthen existing capacity for tracking, monitoring and dissemination of information on phenomena and activities that trigger disaster events.

The NDMC could act as the curator of a national database on fires and of fire danger indices. There are several advantages to this model, including the fact that the NDMC would have direct access to statistics on fires and the damage they cause, and could use these in disaster management planning on a national scale. The NDMC would receive its information from DWAF and from the SAWB as indicated in Figure 10.1.

The municipalities: Municipalities (e.g. local fire brigades) could be approached to fulfil the functions of FPAs, until such time as FPAs are established. It is also probable that FPAs will never be established in some areas (for example semi-desert or desert areas where fires hardly ever occur). In such cases, DWAF may legitimately decide that the relevant municipality need not participate in the NFDRS.

The electronic media and the press: In terms of the Act, the Minister must ensure the communication of a predicted *high* fire danger rating, through electronic and radio broadcasts and publication in newspapers.

10.2 Necessary amendments to the Act

An amendment to the Act, which may increase its effectiveness, concerns the delegation of responsibilities to municipalities where FPAs do not exist. Sections 5(1) (i) and 5 (2): Fire Protection Associations (FPAs) are required to supply the Minister, at least once every 12 months, with statistics about veldfires in its area. As the establishment of FPAs will take time, the Act could be amended to require municipalities to perform this duty until such time as FPAs are established. Alternately, municipalities could be deemed to be FPAs until FPAs are formed, which may not require an amendment. The Act could further empower the Minister to exempt certain municipalities from this requirement (for example, those that cover non fire-prone areas).

Regulations should also be drawn up to prescribe the format in which to report fire statistics. These would support Section 5 (1) (i) of the Act, and are described in section 11 of this report. They are addressed in more detail in the report on the DFID-funded project on an information system to support fire danger rating (Luger *et al*. 2001).

11. PROPOSED SYSTEM TO EVALUATE THE PERFORMANCE OF THE MODEL

11.1 Data requirements

In order to evaluate the performance of the model, fire danger indices should be stored on a central database, together with the various weather inputs used to calculate the fire danger. In addition to this, data will also be needed on the levels of fire activity.

Fire danger indices need to be interpreted in terms of the risk of fires occurring, the number and size of fires that could be expected under certain conditions, their relative ease or difficulty of control, and the damage they could be expected to do. The fire danger indices that are recorded in any particular region could be related to the historic occurrence of fires, provided that such data are available. At present, information on fires is not recorded in most areas in South Africa, and where data are recorded, they are scattered and not in a suitable format for relating to fire danger indices. Examples of the type of questions that would be asked by those charged with the responsibility of interpretating the fire danger indices, and the data needed to answer the questions, are given in Table 11.1 below.

Table 11.1 Typical questions asked by fire managers, the nature of answers required, and the data needed to support the answers.

Typical questions asked by fire managers	***Type of Answer needed***	***Data needed to derive answer***	***Significance for fire management***
What levels of fire activity could I expect for any particular level of fire danger index?	The number of fires and their size (area burnt).	The number and size of fires that occurred in the area. The dates of fire.	Level of preparedness.
At what fire danger index level can I expect that fires will become difficult to control?	Cut-off levels of fire danger where fires: will not occur, will occur but can be easily controlled, will be difficult to control, and will become a major problem.	The number and size of fires that occurred in the area, and an estimate of their ease or difficulty of control. The dates of fire.	Level of preparedness, and implementation of measures to reduce risk (e.g. a ban on open-air fires).
Under these fire danger conditions, what are the most likely sources of ignition that will cause fires?	The relative contribution of different sources of ignition to fires in the past.	Cause of each fire on record.	Planning to reduce the risk associated with certain types of ignition.
What levels of damage have been associated with fires that occurred under similar FDR conditions in the past?	The types of damage, the extent of the damage, and the cost.	Damage to structures and crops, and estimates of losses suffered (in Rands).	Motivation for expenditure on prevention measures.
Under current conditions, which vegetation types are most likely to burn?	The relative areas of different vegetation types burnt in fires in the past under similar conditions.	Areas (in ha) of vegetation types burnt in each fire.	Preparedness.
How easy or difficult will it be to control a fire if one was to break out now, and what levels of resources would I need to combat the fire?	Estimates of the manpower and equipment that will be needed, and their likely effectiveness in containing the fire.	Numbers of staff deployed for each fire. Equipment deployed for each fire. The success rates of each approach in containing or extinguishing the fire.	Decisions on when to deploy certain approaches.
If a fire should break out now, how much would it cost to control?	The average cost of fires, and the range.	Costs of manpower, equipment hire, and running costs for each fire. Costs of overheads (equipment purchase, training).	Budgetting.

Typical questions asked by fire managers	***Type of Answer needed***	***Data needed to derive answer***	***Significance for fire management***
At what levels of fire danger would prescribed burns be expected to go out of control?	Cut off levels of fire danger when prescribed burns have been known to escape.	Dates of instances where prescribed burns escaped out of control.	Decisions on whether or not to allow prescribed burns.

11.2 Approach for collecting data

Basic data of the type outlined above should be collected by FPAs. It is suggested that they should be the designated institutions to collect such data, as they have the mandate, and it will be in their direct interests to do so.

Important decisions need to be made with respect to the types of data archived. For example, data on the occurrence, size, severity, and duration of fires could be archived without mapping the fires. On the other hand, fires could be mapped and captured on a geographical information system for archival. The mapping itself could be done manually, by means of aerial photography, or by means of satellite imagery. A cost benefit analysis (beyond the scope of this report) will be required to guide the final approach adopted. However data on fire occurrence and area, without being explicitly mapped, would provide a sound basis for the refinement of categories of fire danger indices in a given area.

Satellites can detect and map fires over large regions. There is considerable experience in this field of work in South Africa. Landsat and SPOT images provide very high resolution (20m) maps, but would be expensive to apply nationally. This precision is not required nationally, but may be useful in some local regions. The AVHRR sensor on the NOAA weather satellite can detect active fires. Data from this satellite are provided at no cost, so the costs would only be for the processing of the data and would amount to substantially less than those described above. The resolution is 1 – 2 km.

The new MODIS instrument on TERRA has been specially designed for fire mapping. The resolution is 250 m and the coverage is daily. The data would be provided at no additional cost, and a fire product is standard. This is the recommended choice for the future, but is still undergoing testing. The CSIR is currently involved in its validation.

The database could be housed with DWAF or the NDMC. This debate is addressed in greater detail in the report pertaining to the NDFR Information System (Luger *et al.* 2001). However, consideration should be given to the purpose of maintaining the database. While the NDMC may only require information on fires at a large enough scale to classify as ‘national disasters’, DWAF will require information on a finer scale in order to use the data for reporting purposes, as well as for refining the NFDRS on an ongoing basis.

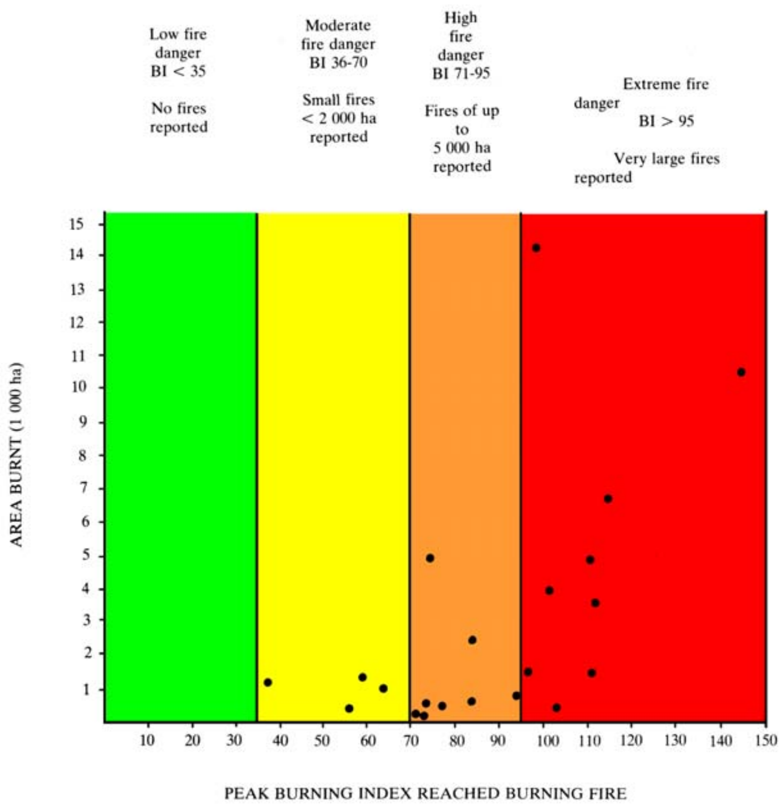
11.3 Approach for analysis and interpretation of data

Fire danger indices are divided into five colour categories for the purposes of making management decisions (see section 8 for a detailed account of the interpretation). The range of fire danger indices that constitute the different categories will vary from one region to another. For example, high fire danger may fall between FDR indices of 50 and 75 in one region, but between 40 and 60 in another. The actual placing of the cut-off values for each of the categories should be determined from the historical occurrence of fires and fire weather in any one region.

The most meaningful parameter for the initial determination of cut-off points would be the total area burnt in the fire. Using the number of fires that are associated with a particular fire danger index value would be less meaningful, as the fires could be very small. For example, it is possible to get 20 fires that burn an area of only (for argument's sake) 20 ha, but a single fire could burn 20 000 ha, a far more dangerous condition. The total cost of a fire is another measure that should be related to levels of fire danger. Examples of the use of this approach are shown in Figure 11.1.

11.4 Approach for feedback loops and improvement

The refinement of the cut-off points for categories of fire danger will be an ongoing process, as more data on fire occurrence and severity become available. The cut-off points can be adjusted accordingly. This should be carried out on a regular basis, coinciding with the reporting activities of the FPAs as required by the Act. The most important criteria for adjusting the cut-off points will be the total area burnt, and the total cost associated with the fire, but further refinements could be made based on the severity of fires, their difficulty of control and the damage incurred.



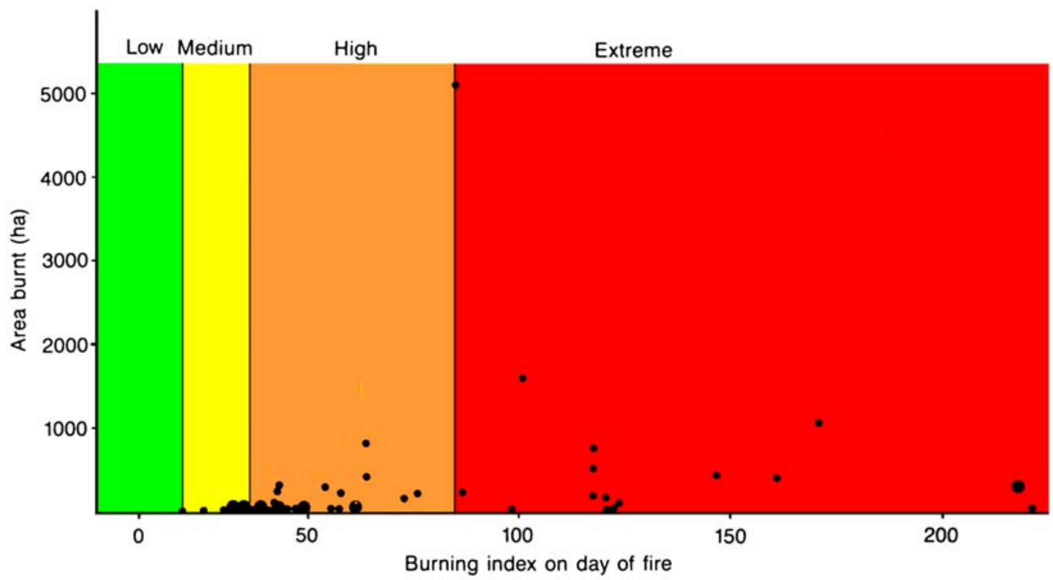


Figure 11.1 Examples of the relationship between the highest burning index (BI, as calculated during the fire by the US NFDRS) and the size of fires, used to determine the cut-off points between different categories of fire danger (from van Wilgen and Burgan 1984 and Everson *et al.* 1988).

12. CONCLUSION

The strategies and recommendations for the implementation of the NFDRS have been intentionally designed to be as simple, effective and affordable as possible. Wherever possible, these have taken into consideration already existing institutions, systems and processes to prevent unnecessary duplication of effort and resources. The format of the danger ratings is a simple colour coding which has been implemented successfully internationally and locally.

An amendment to the Act has been suggested in order to improve its effectiveness with regard to the implementation of the NFDRS and to bring it in line with existing fire management practices in some parts of the country.

Many South African ecosystems are fire-prone and fire-dependant, and fire is necessary for the conservation and wise use of this country's unique and substantial biodiversity. Therefore, not all fires are considered to have a negative impact, in fact, in some cases intense fires are essential for the preservation of our ecosystems. These issues need to be considered in the implementation of the Act.

The implementation of the NFDRS will be a complex process, requiring further research, and additional capacity from many different institutions, in order for it to function effectively. This report has not addressed the implementation of the NFDRS, which is beyond the terms of reference. Should the recommendations in this report be adopted, the Department will have to address the implications of implementation through the preparation of a comprehensive business plan, including delegation of responsibilities and infrastructural requirements.

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APPENDIX 1: Participants of the NFDRS workshop held at Kwalata Game Ranch on 8 & 9 June 2000

Mr Fanie Bekker	W. Cape Nature Conservation Board
Mr Pierre Bekker	SAFIRE (Insurance)
Mr Bruce Brockett	North West Parks and Tourism Board
Dr Peter D'Abreton	CSIR
Mr D Dobson	S.A. Wattle Growers' Union
Dr Colin Everson	CSIR
Mr Gavin Fleming	CSIR
Mr Johan Heine	Forest Fire Association (Lowveld)
Mr George Kilian	Dept. of Provincial and Local Government
Dr Fred Kruger	DWAF Veld and Forest Fire Committee
Mr Albert Mabunda	Gauteng Dept. of Agriculture, Environment and Land Affairs
Mr Marcel Meso	Dept. of Agriculture & Environment (N. Province)
Ms Dineo Moshe	CSIR
Mr Graham Munro	Mpumalanga Parks Board
Mr Reuben Ngwenya	Mpumalanga Parks Board
Mr Mark Roods	Mpumalanga Parks Board
Ms Ida Setshwane-Mathe	North West Parks and Tourism Board
Dr Kevin Tolhurst	University of Melbourne, Australia
Mr Cornelius van der Berg	Dept. of Agriculture & Environment (N. Province)
Mr Theo van der Merwe	DWAF Veld and Forest Fire Committee
Dr Brian van Wilgen	CSIR
Ms Carla Willis	CSIR

APPENDIX 2: Comments report

2.1: Written and verbal comments from the stakeholders prior to, and during the workshop at Kwalata Game Ranch

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1. WRITTEN COMMENTS

Written comments were received from Mr Jake Oosthuizen (KZN-FPA) and Ms E. Powell (Northern Cape Nature Conservation). Ms Willis had a telephonic follow-up with Ms Powell to address her concerns to her satisfaction. Ms Willis mentioned that the entire report would be available for comment by mid-July and this was well received. The response from Ms Willis to Mr Jake Oosthuizen served merely to thank him for his e-mail.

JAKE OOSTHUIZEN KZN-FPA

Due to unforeseen circumstances it has become impossible for me to attend the NFDRS workshop on the 8th and 9th June. I have read Report 1 and agree with the direction that the system is going.

I have been in contact with Mr J.Heine from FFA and have given him the authority to act on behalf of this Association. I would however request that the prior to the establishment of the Regions, we are given opportunity to comment.

Thank you for all the hard work to date.

E POWELL ACTING DIRECTOR NORTHERN CAPE NATURE CONSERVATION SERVICE

The **National Fire Danger Rating System** document received, dated 28 May 2000, has reference:

1. It is clear that various points still need to be incorporated into the document.
2. In general there are a few grammar and sentence construction mistakes, but I assume these will receive attention later.
3. With regard to the System to be used, the Northern Cape Nature Conservation Service (NCNCS) has a few questions:
   a. How would this Fire Danger Rating System be incorporated if it does not comply to the requirements of the National Veld and Forest Fire Act (No. 101 of 1998)?
   b. How frequently would this system be reviewed and updated?
   c. Although veld fires are very rare in some parts of the Northern Cape (e.g. Succulent Karoo), it still needs to be addressed in your document (the LFDRS was just developed for forests).
4. NCNCS would like to comment on the document emanating from the workshop in June 2000.

2. VERBAL COMMENTS

The verbal comments summarized below are those which were made at the workshop held at Kwalata Game Ranch on the 8th and 9th June 2000. The responses to the comments, where relevant, are also included in italics.

i) **Concern was expressed at the choice of the McArthur model and the process used to arrive at this choice. The particular concern revolved around the selection of the McArthur model as opposed to the US model.**

Several hours were spent debating this issue, evaluating the criteria to assess the models and discussing local previous experiences in the use of the models. The option of testing the models was debated but the participants concluded that testing has already taken place in South Africa and that it was beyond the scope of this project to undertake new research to test the models. Participants such as Graham Munro, Colin Everson, Brian van Wilgen and Johan Heine, all confirmed that local testing of the two models had resulted in the McArthur model being preferred for two main reasons:

(a) No difference in the rating using either model (i.e. the US did not produce better results)
(b) The simplicity (without reduced accuracy) of the McArthur model made it the preferred choice in all instances.

It was, however, discovered later that this logic was erroneous as the US model was never tested against the McArthur system, but rather against the Lowveld system. Nevertheless, the various models considered, the criteria used to evaluate the models and the recommendations for further testing of four models are included in greater detail in the report.

ii) **The concern was raised that the McArthur system was developed for forest biomes and whether it was suitable for the other biomes of South Africa.**

The response to this concern was that because the model is based on climatic data, the indices can be applied to any biome.

iii) **A suggestion was made that 'Given the pros and cons of each proposed model couldn't we develop our own model for South Africa? '**

This was not considered a feasible option. Many years of research and resources have gone into developing these models elsewhere and it would be a case of 're-inventing the wheel' unnecessarily.

iv) **The issue of 'total fire bans' was discussed extensively. The concern was that certain land managers need to burn on hot days when the fuel load is high as part of their management objectives.**

General agreement was reached that the total fire ban on 'red days' is essential as a means of attempting to prevent large, out-of-control fires which are often classified as national disasters. 'Orange' days should provide the necessary conditions for these prescribed burns. Permits would help control burning on these 'dangerous' days. Further consultation with DWAF, however, has resulted in the recommendations of the report including both 'orange' and 'red' days in the total fire ban.

NOTE: The details pertaining to the activities which may / may not be undertaken within each of the fire danger categories are described in detail in the report. These were developed at the workshop with the participation of those delegates present, but later

vii) **Concern was raised around the absence of FPAs in most parts of the country and the fact that the Act cannot enforce the formation of FPAs. This leaves a gap in terms of certain aspects of the administration of the NFDRS.**

General agreement was reached that the municipalities should be the institutions which take responsibility for certain activities in the absence of FPAs.

NOTE: A description of the duties and responsibilities of the NFDRS is presented in greater detail in the report. These were developed at the workshop with the participation of those delegates present.

vi) **The question was raised as to whether or not the Act should be amended to ensure the review of the NFDRS every three/five years.**

The general agreement within the group was that this was not appropriate. It should not be legislated because (a) it should be an ongoing process and (b) the review should happen as-and-when-appropriate (i.e. the time frame should not be prescribed by legislation).

v) **The division of the country into homogenous zones was unclear at the presentation made at the workshop.**

Several hours were spent on the second day of the workshop jointly defining the zones. It was agreed that overlaying the existing municipal boundaries, climatic regions and broadly defined vegetation types would provide a good basis for the regions. This was carried out during the workshop, making use of the expertise of participants from all parts of the country. However, further discussions with the SAWB resulted in a totally different approach and the final proposal on the division of the country into regions is based on these discussions.

2.2: Comments received on the draft final report (August 2000)

M. W. PRETORIUS CHAIRMAN: TECHNICAL COMMITTEE SOUTHERN AFRICAN EMERGENCY SERVICES INSTITUTE

Comments regarding the document are as follows:

- We have no problem with the content of the document and the process as described.
- We feel that this program is a first for South Africa and must be tested in the field to prove its effectiveness.

Our concerns, however, are the following;

- How long will it take to implement the system?
- Will it be cost effective?
- Public education should be incorported in the program.

If more details are needed please make contact with the Technical Committee of SAESI.

T. VAN DER MERWE VELD AND FOREST FIRE COMMITTEE DWAF

Thank you for the documents and the electronic versions for the NFDRS development.
I have very little comment and found it to be a good proceedings of what happened at the workshop.

The following comments:
Editorial: Page 33 second last line 'too' should read 'to'.

Table 8.1. Certainly it was agreed that 'high' equals 'orange' not 'yellow'. It was agreed that the 'Yellow' category should be tagged ' Dangerous' (I think we said). All through the document you refer to 'orange' being the entry point for category 'high' which agrees with my argument.

Appendix 1: Change George Kilner to Kilian.

A. SOUTHWOOD
ENVIRONMENTAL SCIENTIST
DEPARTMENT OF ECONOMIC AFFAIRS, ENVIRONMENT AND TOURISM

I have read the document. It is very comprehensive and covers all applicable topics. I have a few general comments.

If a few of the larger cities and towns were depicted on Figures 8.1, 8.3 and 8.5 (now fig 7.1 to 7.4) it would be easier to orientate oneself.

Is the choice of the nodal weather stations (Page 29) the best? Would, for example, Knysna and Queenstown, be able to provide appropriate weather data for input into the McArthur model?

I agree with the content of Paragraphs 10.1 and 10.2. A short module should also be presented at secondary and tertiary institutions. Children love computer games: what about developing one that incorporates the basics of the NFDRS - something that can be down-loaded off a website?

I agree with the contents of Paragraph 11.2.

The question of the issue of permits to allow any kind of burning (including prescribed burning) outdoors must be carefully considered. Permits should only be issued by one body after carefully consideration of the fire danger and all factors relevant to a particular application. Perhaps the FPAs or Municipalities/District Councils should be given this responsibility. After all they are the ones who often have to extinguish fires. Government Departments (such as SADF and conservation authorities) should not be exempt from obtaining permits. The FPA will have the obligation to cancel any permit right up to the time the fire would be ignited if changing circumstances dictate this.

Do you perhaps know whether one is obliged by law (Conservation of Agricultural Resources Act) to apply to Agriculture for a permit to burn on private land? We have enquiries from the S A Police in this regard.

Paragraph 11.2. All fire data should be stored in a GIS.

J. HEINE
LOWVELD FFA

Congratulations, I think it is an excellent report and hope we can get the funding to start with the implementation. The only comment I have so far is on Annexure 5, where I think we should try to stick to the existing National Report Form as far as possible, as a lot of work was done to get it where it is now.

The other thing that I did not see mentioned is the cost involved in making the adaptations. I really enjoyed working with you and hope we will do so in future again.

W. BOND
BOTANY DEPARTMENT, UNIVERSITY OF CAPE TOWN

Firstly I think this is a good job and am pleased that the authors have taken a pragmatic approach to the problem. I particularly endorse the recommendation that the proposed system is tested against fire data for the regions to fine-tune the indices for particular areas and conditions.

The report does not make it clear why two Fire Indices were developed in Australia, the forest and grassland indices. Presumably a separate grass index was developed because the Forest index did not work effectively for grass fuels. If this was the case, why are we not using the appropriate index for the appropriate fuel? If it really does make a significant difference which index you use for which fuel type than we should use both. What is the Australian experience?

I am also a bit uneasy about the extrapolation of Eucalypt woodland models to shrubland fuels characteristic of the south-western Cape. How well has the McArthur system worked in south-western Australia which is most similar to the south-western Cape? Why not cite appropriate references, if they exist, for use of the Forest Index in SW Australia?

The most extensive data on fire intensity (ROS etc) collected in South Africa is that of Professor Winston Trollope from the University of Fort Hare for grassland and savanna fuels (200 monitored fires). His work is published in an internal report (Trollope 1998. Effect and Use of Fire in the Savanna Areas of Southern Africa. Dept of Livestock and Pasture Science, Faculty of Agriculture, University of Fort Hare, Alice, South Africa). It would make sense to test his equations for fire intensity against the proposed system to see how well they correlate? This would give users greater confidence that the system is appropriate for at least this type of South African condition. As an example, he developed a multiple regression equation for predicting fire intensity as follows:

Q = 2729 + 0.8684G - 530(M)^.5 - .907 H^2 - 596/W

Where Q = fire intensity kJ/s/m, G = grass biomass kg/ha, M is fuel moisture (%) H is relative humidity (%) and W is wind speed (m/s).(Equation 8 in Higgins, Bond, Trollope, 2000, J. Ecol 88:213-229). He may also have equations for ROS for more direct comparisons. His e-mail address is winston@ufhcc.ufh.ac.za.

There are still one or two minor spelling/editing errors (e.g. gamut for gambit).

J.H.L. JOUBERT
RISK MANAGER
MONDI (LOWVELD AND KOMATI REGIONS)

Great job done within a very short time frame!

Observation: In the body of the Draft on p 13 pr 4.1 Climatic variation in the 3rd paragraph's second line the following statement appears 'Temperatures get cooler as one descends.......' That should read warmer.

On page 28 reference is made to considering replacing the KBDI with the SDI (pr 4). This substitution to the SDI must be the preferred objective. Low soil moisture is one of the big contributors to damage by fire to the subsurface roots on shallow soil leading to extensive erosion with the first rains.

S. MEIKLE
SAPPI

Thank you for the opportunity to comment on the proposed Fire Danger Rating System. As I was the person who previously introduced the system currently used into South Africa from Zimbabwe in 1983, and having been the Chairman of the LFPA and FFA for the first years of their existence, I have some concerns over the current proposals – some of which may already have been voiced. I am pleased to see that the simplicity and reliability of the existing method have been vindicated over complicated overseas models.

Executive Summary

1. What is the objective of the proposal? The current Forestry users are happy, but there is a desire to apply it to the whole country? Why has it been accepted by the Forestry users? - because there was something in it for them (better management – less hazards, manage costs , insurance requirements etc)
2. Does anyone else see a need for a system to embrace the whole country? – one must ask this question, because if no-one sees a need for it, we are all wasting our time.
3. One of the problems with the legislation in terms of the old Forest Act was that, apart from the larger Forestry companies, no-one applied it. What has changed? The Police never acted then in cases of contravention, what hope now with rampant crime in many areas?
4. I think the existing prohibition areas and regulations should stay, and awareness campaigns should be instituted with suitable structures (maybe municipalities?) in all danger areas.
5. I can't comment on the role of current FPA's in the 'areas of jurisdiction' – my experience is that these things only work where the majority of landowners buy in to the scheme and have a financial interest in their success. The new municipal areas have a much larger population with many varied interests and concerns, to many veld fire will be the least of their worries (until threatened by one), so will have zero buy-in. My concern is that forcing other people in may weaken existing organisations that are performing well. Having seen what is done as regards rural fire-fighting in Italy, France, Spain and Portugal in 1996, and previously in Canada, all I can say is that the costs will be so high, even for a volunteer–based organisation, and that it will never be high on the list of priorities for this country – nor should it be.
6. I really fail to see the purpose of collecting all the data on fires. For forestry companies, yes – but most of the landowners (in terms of hectares owned) are farmers who in any case burn the veld for grazing, both in the formal, commercial sector and the informal. As a taxpayer I object to the capturing of information for no purpose, except to provide data for someone to do a research project on, the results of which no-one wants. Has the farming sector ever asked for this information?
7. The last line of the Executive Summary says it all ' Implementation will be a complex process, requiring substantial time and additional capacity from many different institutions in order for it

to function effectively!' Involved as I am with the CMA process, I have to give this zero chance of success – mainly because no-one wants it , and there are other ways to deal with the very real problems of veld fire (Land Bank, Farm Insurance, etc.) rather than legislation. The good parts are the FDRS, which exists already, and increasing the awareness – the rest I see as nice-to-have.

Introduction
Para 2 – An effective NFDRS will allow the detection of ………fuel build up?? Who knows the fuel condition? The Weather Bureau – this is nonsense. The efficient landowner knows already – the unaware will still be unaware! No ' Preventative measures' can be taken, except by the landowner – that is where awareness comes in.

Process to develop the NFDRS
I have no problem with this process – it does seem to have been quite a long winded process to vindicate something which was already working well.

NDMC and Municipalities
I am concerned at a possible duplication here. We have (or had) a Civil Defence organisation, covering at least part of the area. As I understand this was largely voluntary. The municipalities facilitated the role of Civil defence. The municipalities are unlikely to be heavily involved in fire fighting in veld fires (trying to close the stable door while the horses are escaping) – but there is a role for Civil Defence in assisting afterwards in any type of disaster and in helping to prevent fires. (awareness). As stated the urban/rural interface is where the municipalities can and must have a role to play, to protect the urban dwellers. The rural area is a different ball game.

Page 36
All these are very well in a structured area with large forestry companies – maybe even a commercial farming area – many fires are lit by passers-by, picnickers, passengers in broken down vehicles, etc. Overseas experience is that with urbanisation comes an increasingly fire-ignorant population, even people who resent the fact that, from being peasant farmers with an appreciation of the uses/hazards of fire, they are now landless factory workers (Italy). You will not see applications for permits from these people, nor from peasant farmers on communally-owned land. On a Red day, one has such a small time frame for successful reaction (say 30 mins), it is questionable whether it is not more dangerous to put resources in, even if they are suitable. The use of helicopters etc in the Cape fynbos areas may be justified as the urban/rural interface is more scattered – but I wonder how long they will continue to provide this?

Page 37
Awareness raising is one of the very few effective tools – but would have to be done thoroughly and properly (see comment re urbanisation above).

Page 41
I have a problem with this. We already know the answers to this in general terms. On a Red day the fire is going to burn until it runs out of fuel, or the weather changes, or usually both. What is the database for? So:-

- Q.1. – Answered
- Q.2. – Chicken/egg question: the longer it takes people to get there, the more difficult to control. Too many variables
- Weather.distance/equipment.training/leadership/terrain/access/fuel type etc etc
- Q.3. – See above – does anyone care how long? What are the dangers/topography/fuel/weather? Effective breaks anywhere? What is an effective break anyway? In general terms, a fire can burn until it hits the sea or the rains come!
- Q.4.- Having kept fire records for Sappi Mpumalanga since 1983 , I think I can safely say that anything can cause a fire on a red/orange day – and usually does, and they all start at the same time. Fire risk identification is important, but we know the answers already.

- Q.5 – Depends what is in the way of the fire. A major problem is the costing of damage. How do you value grazing land? Buildings, Plantations? Human lives, injuries?, Job losses? – Replacement value, Cost to date? Do you update each year by CPI? I don't think this helps – we all know what damage fire can cause.
- Q,6. – Practical value? It all depends on the weather – especially local weather, so unless you are measuring weather at the fire front, you aren't comparing apples.
- Q.7 – More important is the Fire Control – I have seen large numbers of people useless at a fire, on the other hand a few highly motivated and equipped people, working wonders.
- Q.8 – This is a really stupid question. There are too many variables, including the equipment available. I have on record instances of very large fires on red days costing less than R1000 to control, or smaller fires costing over R 100000 to control on a yellow day.
- Q.9 – We think that we know the answer to that, but some very experienced fire managers will dispute that, so I would not put my head on a block.

Page 43
I have a problem on data collection, apart from what it will be used for. Farmers by and large are unlikely to submit forms (why should they? what is in it for them?) – so we come back to the Forestry associations – who should capture the data themselves, to analyse what is going on at any time they want, in the way they need. Now this information will be sent to NDMC, for what? Forestry Associations will not be interested (they already have the data)

In my experience too (17 years of collecting fire data) I can say that even with processing information from people in the same company, trained in the same way, the data has to be verified by someone with experience, or it is useless. If the data is being processed by a clerk somewhere, the results will not be credible. One has to ensure all fire data is recorded, otherwise conclusions are relevant only to the info submitted and correctly recorded (and not lost in the post, or never submitted!) In FFA we use Fire Report forms serially numbered in books, to ensure all information is received – the serial numbers are frequently used to track down missing information – are we going to do that with farmers? If the farmers don't report the fire, who will?

Our previous experience with Dept of Forestry recording of data was terrible. The information was wrong – it was years out of date, analysed for things no-one was interested in, and stopped when there was not a budget for it anymore. I see absolutely no reason for the state to collect this data. Farmer's Unions can collect data, if the member's see a need, as can Municipalities.

Fire Report Form
The contents are fairly similar to the forms used by FFA, and suit a Plantation forestry context. I really cannot see a farmer filling these in, perhaps not even a small grower. The following points in particular:

- Fire intensity – what does that mean, in a veld fire?
- Rate of spread? Varies all the time. Are we looking for numbers, or words?
- Grid references – How many people can give grid references and get them right?
- Map of burn scar – Really !
- Cause of fire – Own operations (not building). Where does a neighbour burning breaks fit in? Does he also put in a form? How does the inputting clerk know not to put in the same fire twice – your report & neighbours?
- Weather conditions –. How many farmers can give this information? If the information is incomplete, what does that do to your database? Are their weather instruments calibrated accurately or situated properly? Remember – rubbish in, rubbish out.
- Size of area burnt. Many veld fires cover several farms, communal areas, over several days – picture the typical E. Cape veld fires, the farmers filling in the fire reports, the clerk trying to sort out:-
    - Are they all the same fire, or several
    - Hectares burnt, losses – all, or only the respondee

    - Start time, finish time, duration, mopping up completed – on one farm, several farms or all farms.
    - What about spot fires, or re-ignition from the original fire – who or how does that get reported?
- For Forestry, damage is not replanting cost – it is normally establishment plus maintenance at least until utilisable – so Forestry will have a different loss figure to DWAF for a start.

Conclusion
If you have read this far, you may be wondering whether to throw this submission away. I may never know what happened to it, but I do believe I have some valid points which should be addressed now rather than have to face up to something that does not work later.

- It appears that the consultants knew very little about the realities out there, though I see there have been submissions from some organisations (was this only on the FDRS or the whole process.)
- Again with the CMA experience, I can see the need to ensure that the information gathered will be valid, will be needed by land managers, not just a job creation exercise for consultants. What info does who need to manage what? What is the most cost efficient way of getting it? The farmers in particular are relatively negative to DWAF, as I see it, and I don't see this as producing anything worthwhile, even if it is Law.
- DWAF has a major exercise on its' hands on the Water Act and licensing. Resources should be allocated to getting that right before embarking on a nice to have like this.
- What happened to the 'Criteria And Indicators' exercise the Industry badly needs for Certification purposes? We had a meeting in March 1997 – then nothing !!

W. J. OOSTHUIZEN
KWAZULU-NATAL FPA

1. I agree that the Mc Arthur system is the correct system for South Africa.

2. With regards to the Regions; I agree with the nine regions of homogenous fire but would like to point out that the KwaZulu Natal region has extreme variations in Fire weather. We are effected by the coastal pressure systems, our topography varies from sea level to 11000 feet in 80 nautical miles, the hot coastal areas of Maputoland have fires all year round and the Eastern slopes of the Drakensberg mountains result in some of the severest fire weather conditions in the world.

We have historically divided the Region into 5 areas and will probably continue to do so, on a local basis.

1. At present the Fire Protection Associations, being KZNFPA, ZFPA and ZIFPA, accumulate weather information from 16 automatic weather stations spread throughout the areas. All costs related to these stations have been carried by the members. The actual weather information is e-mailed to the Weather Bureau in Durban twice a day at 10:00am and 14:00pm. The Weather Bureau then calculates the FDR Forecasts and makes this information available to us.

2. The forecast FDR is broadcast on East Coast Radio at 06:45am every morning and up dated during the day as required. The Associations distribute the forecasts via e-mail to all interested parties and via SMS to all it's members, twice a day. The SAWB place the information on their website and on recorded messages on a cellular number.

3. In KwaZulu Natal, the KZNFPA could become the Umbrella Association as per the Act and could continue to perform this service. For each FPA to set up it's own weather stations and communicate with the Weather Bureau, would cause unnecessary duplication. The umbrella Associations (KZNFPA, FFA and other umbrella association's still to be formed)

are managed by people who are qualified in Meteorology and are able to communicate with the SAWB.

4. As the new FPA's will increase the administrative costs of the Umbrella Associations, it will be necessary for these Umbrella Associations to recover a portion of their costs from the FPA's.

5. The KZNFPA has spent large amounts of money on the development of software to calculate FDR's and keep record of weather information. Will the new software be provided by DWAF and will there be any costs involved?

6. APPENDIX 5. There is a standard fire report, printed in a book form, which is being used by the present Associations. With some minor changes, this report could be used by all FPA's. (Copy of report faxed to you).

7. The Fire Associations in KwaZulu Natal have an existing fire database in place. This Database has been developed over the past eight years and should, with minor changes, be more than adequate for National Statistics. Let's not re-invent the wheel when it comes to this one! (I have faxed copies of some of the reports produced by this Database for your information).

8. Point 7.3. I designed the modification to the Rainfall Correction Factor in 1996 and applied it in the Zululand area. This was done after consultation with the weather bureau and Mr. Mike Lange. The system was recommended to the KZNFPA and FFA but was not applied by them. The modification was applied for the first time by the KZNFPA is 1998.

F. KRUGER
VELD AND FOREST FIRE COMMITTEE
DWAF

These comments are on behalf of the Veld and Forest Fire Committee of the Department of Water Affairs and Forestry. *(Author's Note: According to DWAF, these are F. Kruger's personal comments and do not necessarily reflect those of the Veld and Forest Fire Committee).*

The report outlines a number of analyses of options that are essential prerequisites to a decision on the NFDRS. In this respect it yields important progress on this issue. However, a number of aspects of its contents need attention before we can close the case.

Since the readers of this report will include people who are not experts in all its aspects, this evaluation focuses as much on issues of clarity and comprehension, as on substance.

Comments address all aspects and follow serially, according to the contents of the report. Obviously, however, certain aspects are more important than others are.

1. Title: the document needs a more appropriate title, e.g. 'Evaluation of optional systems for national fire danger rating ….'
2. Do not use the passive voice ('was seen as potentially useful'); use the active voice so that the reader can know who made the finding, or had the opinion, or whatever.
3. P 1, paragraph 1, line 2: quote Section 2 of the Act.
4. P 1, paragraph 2: defines what is meant by 'effective': how did Environmentek derive this definition? Is it appropriate and relevant to the users? For example, it is more important in the context of this project, to predict rather than to detect. Also, we should regard a NFDRS as one of the early warning systems required by the National Disaster Management System.

5. Somewhere here or soon after you need to define terms, such as fire danger, fire danger rating, system, and so on. The report uses the terms ‘model’ and ‘system’ inconsistently throughout, which confuses the reader and, it seems the authors. Refer to system when you mean the whole system and to model when you meant the (mathematical) indexation model.
6. P 1, paragraph 3: Is there only one local system? Managers in the Western Cape also use a system; consult the CEO of the Cape Nature Conservation Board.
7. P 1, paragraph 4. This paragraph sets out the requirements for the system, but does not tell us how Environmentek derived these requirements. Further, one requirement is that the system must be ‘simple’. It is not clear what is meant by ‘simple’. It refers to ‘risk’ and defines risk as a likelihood, rather than as it is normally defined; refer to risk management literature.
8. P 1, paragraph 5: quote the contractual terms of reference, or paraphrase them and include the TOR in full as an appendix. Was Environmentek required to ‘develop a NFDRS’? Check the use of the word ‘develop’ throughout.
9. P 2, paragraph 3: you need to consult with the Veld and Forest Fire Committee, as the report claims.
10. P 2, paragraph 4: how did you identify key stakeholders? Why were landowners not included? Who represented the stakeholder groupings?
11. P 3, paragraph 1, item 2: ‘This report comprises the main output of the workshop’. This statement is confusing. Does it imply that the report consists of workshop findings? Was no expert analysis done? What of proper consultation?
12. P 3, paragraph 1, item 3: ‘within two weeks’ of which date? Why so short a period? Representatives of their constituencies cannot possibly comment in so short a period.
13. P 4, section 3 in general: Draw a proper distinction between rating system and model (the section refers to models, but discusses systems). Define the purpose of the FDRS as stated in the Act; quote and interpret this. It is not for the purpose of managing a given fire, e.g. for on-site prediction of fire behaviour; make this distinction clear (see for example p. 26). Distinguish also between model and system, and define both. Use more precise language. What does ‘constrained in detail’ mean? What does it mean to say, ‘All the indices incorporate a fine fuel moisture component.’? Do you mean that all models include formulas to calculate fine-fuel moisture content, and that the final output, i.e. the index, is a product of other calculated variables and this moisture content? If so, where is this formula in the Angstrom Index? If as you say earlier the systems (models?) only use weather elements what does it mean if they incorporate a fine fuel moisture component?
14. Also in general, the section does not cogently argue for and against the choice of a given model for the system. This is important; when we read section 7 later, and learn about all the limitations to the McArthur index, we begin to wonder why you recommend this at all. This is because you do not evaluate the strengths and weaknesses of the different models properly, neither in section 3 nor in section 6. It is no good to argue that the workshop reached a certain conclusion; a group of expert scientists has been contracted to do this work and expert science is needed. This does not mean new research, but it does mean proper use of scientifically valid information and the proper use of scientific logic.
15. Quote sources when referring to the performance of models.
16. P 4, section 3.1: neither here nor in section 6 can the reader understand why the Angstrom Index is to be rejected. It is ‘simple’. What does ‘not scientifically credible’ mean, or ‘considered to be oversimplified’? Does it mean that it lacks important elements of fire danger rating, and therefore consistently yields erroneous predictions? If so, what empirical or logical evidence is there for this? Why is it important to ‘consider fuel load’ if all models assume that fuel is kept constant (p. 4)? Why is the fact that it does not consider ignition risk as a disqualifier, if the McArthur index also omits this, but nonetheless is recommended?
17. Section 3.2 and 3.3: as in 15 above.
18. Section 3.4: ‘The FWI provides an indication of the ease of ignition.. of fires should they start (Fig. 3.1a)’ – (a) why indicate ease of ignition only once fires start and (b) the figure does not support the statement; it identifies the ISI and the BUI as contributors to the FWI,

and these terms do not apparently relate to the variables mentioned in your statement. Explain FOP etc in Figure 3.1b. Again, neither here nor in section 6 do we have a convincing rationale as to why the Canadian model should be rejected.

19. Section 3.5. What does the word 'sophisticated' mean? Clarify the phrase 'can still be problems with trying to adequately parameterise new fuel types'. What are the implications of this apparent shortcoming? If we can assume a constant fuel model for McArthur, why not for this one? Quote sources. Although the model requires certain data that are not readily available, we do know that this has been solved by using simplifying assumptions. What is the problem with such a solution? You use the word 'gambit' – do you mean 'gamut'? 'As with previous models, the outputs from the model include a spread component.. etc'. Which previous models? None of them refers to these terms. Why is the problem of requiring a programmable calculator or computer an issue, if we are looking for a national FDRS, i.e. not a model for calculating local fire behaviour? Explain. The concluding paragraph is too vague; summarise the scientific findings. Figure 3.3 shows three indices (or four?), but on page 22 you mention six – what is correct?
20. In this section (3.6) you confuse the phrases 'Fire Danger Index' and 'Fire Danger Rating'. In the legend to Figure 3.3, in the body of Figure 3.4, and in Table 3.1 you stipulate the output of the model as being a Fire Danger Index, but refer elsewhere to a Fire Danger Rating. I assume that the models put out an index.
21. Section 3.7: 'the Drought Index and Drought Factor components are replaced by the degree of curing (Figure 3.4).' Unclear. Do you mean that Fuel Availability is a function of Degree of Curing? The relationships between the models would be easier to understand if Fig. 3.4 were set out in the same format as 3.3. Finally, since we have such large areas of grassland, it is difficult to understand from the report why we should not use the GFDR.
22. Section 3.8. This summary seems not to be entirely correct. For example, is it true that all have ease of ignition and fire spread components? In addition the language is vague and confusing. For example, what do the following phrases mean: strong weather component; in a seasonal context; fire intensity component (fuel availability, rate of combustion); growth rate; fire activity level component?
23. Table 3 does not summarise the inputs required by each model correctly. For example, it does not list all the variables named in Fig. 3.3. It refers to DF, which is nowhere defined. It says that McArthur applies to 'open conditions' whereas it refers to eucalyptus forest.
24. P. 12. 3rd paragraph. What is the South African Fire Danger Rating System?
25. Section 4.1: the country also gets flooding rains and wet spells, not only prolonged and severe droughts. Specify the temperatures mentioned: mean daily?
26. P. 14, forests. Ground fires also occur in forests.
27. P. 14, thickets. If there is no literature, what does this mean? That fire does not occur there?
28. P. 14, savanna. 'shrubveld where the woody component occurs near the ground'. Perhaps you want to say that savanna has got trees in it. Is it true that 'fires are restricted to the dry winter periods'? Fires certainly occur in spring and autumn, perhaps even in summer.
29. P. 14, grassland. The first sentence probably requires the word 'and'. Is Ellery et al (1989) a good reference on grassland, when the paper refers to a peat fire in the Okavango?
30. P. 15, Nama Karoo. The report is not clear about the boundary of this biome. It probably includes the mountains between Graaf Reinet and Middelburg, where fires are often problematic, and not 'rare events'.
31. P. 15, fynbos. Is it true that fynbos fires are canopy fires? Unlikely.
32. Section 4.2. It is not appropriate to contrast first world and third world type conditions. Be clear about what the issue is. What is meant by 'communication capabilities'? Also revise the second paragraph. You should also refer to the Act and the responsibilities it places on the landowner.
33. Section 4.2, Fire Protection Associations. It is untrue to say that the commercial forestry industry is the only sector to have taken FDRS seriously in SA; please correct.
34. Section 4.2, farmers. The first paragraph is contradictory. What in any event does it purport to say? That farmers who graze (or manage for wildlife?) must practise fire management?

35. Section 4.2, Conservation Agencies. Is it correct that in Natal and the Cape (?), these agencies protect immediate surrounding areas?
36. Section 4.2, The Public: update this from the latest October Household Survey.
37. P. 17, section 4.2, NDMC. Correct this by drawing upon the White Paper on Disaster Management.
38. P. 17, section 4.2, Local Government. What is meant by 'in the absence of Fire Brigades'? The Constitution requires that Local Government provide fire services.
39. P. 19, section 6.1. Quote the requirements in the Act. How did you derive the criteria listed? Must the model be presentable in a clear format, or the predictions in the system? Should the model be able to forecast (none can)? Further, generally, these criteria need more explanation.
40. P. 20, evaluation of the models. First paragraph unclear. See also comments in 13 above.
41. P. 20, Criterion 2: seems to contradict the finding in Criterion 1 (two disqualified instead of three). Also, the McArthur FFDRS is designed for eucalypt forests only, so why not disqualify it?
42. P. 20, Criterion 3: explain why a complex model is not simple to use. Discuss data requirements when discussing criterion 5.
43. P. 21, Criterion 4: Later you point out that a NFDRS based on McArthur will involve lots of training; will it (the NFDRS based on McArthur) really be more affordable than others? It seems that this criterion is not a disqualifier.
44. P. 21, Criterion 6: it seems from the earlier descriptions that fuel loads are in any event set constant: what does this imply?
45. P. 21, Criterion 7: the argument is weak.
46. Table 6.1: provide references and summarise relevant scientific findings in the text, e.g. when referring to 'tested in SA before and rejected'. What does 'oversimplified' mean? Is McArthur not scientifically sound?
47. Section 6.2: you refer to systems but mean models. You also misquote the Act; it does not require that fuel factors or ignition risk should be taken into account. Overall, however, the rationale for the choice is very poor, and must be improved. It requires proper logic, as well as summaries of supporting scientific evidence (the discussion at the bottom of page 22 is not enough – show the results and findings).
48. Section 7.1 – 2nd sentence: check practise in the Cape.
49. P. 24, 3rd paragraph, 1st sentence' what does 'general insensitivity to the accuracy of the input data' mean? It could imply that the model itself is inaccurate.
50. P. 28, rescaling of the McArthur FDI. This proposal needs stronger motivation. We expect all users across the country to adopt the FDI, not only FFA members. It may be that one should use the two scales in consulting users who are accustomed to the Lowveld Index, especially when consulting about Fire Danger Rating Classes, but then revert to the McArthur scale for the sake of some kind of global standard.
51. P. 28, replacing the KBDI with the Mount Soil Dryness Index (Mount 1972): this also needs stronger motivation. Hydrologists may offer a better index than Mount, which is apparently based upon unrealistic hydrological assumptions – these may or may not be appropriate to our current requirements. Alternatively, we may use Mount on the understanding that better alternatives will need investigation, if the motivation is convincing.
52. P. 29: we need a firm recommendation on Griffiths.
53. P. 29: similarly, we need more information the required documentation and training: at least a list of recommended, specified items.
54. P. 29: Table 7.1: the proposed nodal weather stations need to be reviewed in the light of comments and consultation; for example, there are probably better ones to use than Hoedspruit and Worcester.
55. P. 30. section 8.1: quote the Act, rather than paraphrase it.
56. P. 30, section 8.2, 3rd sentence: 'several climatic variables which are no longer in use'. It is difficult to imagine which variables are in disuse; please explain; what new variables are used instead to define the boundaries; the next phrase is also unclear – how do the variables affect whether the boundaries are meaningful or not?

57. P. 30, section 8.2: the rest of the section is also unclear. Why use climatic variables (rainfall, temperature) in a classification which already includes climate (i.e. the SAWB classes); why use elevation, which is correlated with rainfall and temperature (see your earlier section on climate)? – these decisions all seem to violate the principle of orthogonality in choosing variables for classification. How were the biomes ranked by relative fire danger (and what scale was used)? Explain the meaning of the different classification techniques. But the classifications do not in any event seem to be meaningful, given the methods followed, and apparently need not be reported upon.
58. P. 31, section 8.1: explain how the boundaries of the SAWB regions were adjusted on the basis of topography, and vegetation type. The map in Figure 8.5 does not reflect any apparent consistency in this respect; for example, the Southern Coast obviously includes a very wide range of vegetation types and topographies: what is there to suggest that as defined the region will have a relatively uniform fire danger? Why not use the SAWB boundaries and simply adjust them for District boundaries (not Provinces: using administrative boundaries is a convenience for administrative and evidential purposes, and provincial boundaries are not essential in this respect; you have in any event not followed the boundaries of provinces).
59. P. 31, section 8.3: explain how you determined that each region 'is internally homogenous with respect to the fire danger rating' (note that the Act requires that the fire danger should be sufficiently uniform, not the rating).
60. It seems that the regions need to be defined by better methods than offered in this study. As a fallback, we might have to be satisfied with the SAWB regions. In any case, the descriptions offered in section 8.3 need improvement, both with regard to the precision of language (e.g. what does 'the north side of the Soutpansberg' mean?) and the information offered (describe the climate and fire regimes, for example).
61. P. 33, section 9, 1st paragraph. Rewrite for clarity and consistency. Refer to the output of the model as an index (see comment no. 20 above). The danger rating is established by classifying the index values in five categories, etc.
62. P. 33, section 9.3. You say that the rating is high when the category is orange or red, but in Table 9.1 the rating is described as 'high' when it is in the yellow category. Given Section 10(2) of the Act, and the proscriptions you propose in Table 9.1, it seems that only the category red should be rated as high. The whole of Table 9.1 needs revision.
63. P. 37, section 10, 1st paragraph, 2nd sentence. What do you mean when you say that 'the fire danger rating will be developed … by that institution' – predicted? See page 39 in this connection.
64. P. 37, section 10.1, 1st sentence: 'SAWB will be responsible for gathering the weather data' – do you mean 'predicting the weather'?
65. P. 37, section 10.1, 3rd sentence: you misinterpret the Act; Section 10(1)(a) requires the Minister to communicate to each region regularly. Revise this section after studying the Act.
66. P. 37, section 10.2, what do you mean by 'It will not be possible to enforce a 'total fire ban' on a 'red day'? Why should the legislation be used to prosecute only when fires get out of control? Do you propose that Section 10(2) should be amended? If so, why?
67. P. 39, line 14. When you say 'on a daily basis' do you mean every day?
68. P. 39, line 14, line 29. Which burning permits do you refer to here (see also page 40)?
69. P. 40, on the National Disaster Management Centre: set out the relevant functions of the Centre as stipulated in the White Paper on Disaster Management and the Disaster Management Bill.
70. P. 40, 6th paragraph: confusion between 'model', 'system', 'index' and 'rating. What does the sentence 'While a combination of the McArthur ratings and actual fire statistics …' mean?
71. P. 45, Figure 12.1. The legend to the figure refers to the Burning Index, presumably as calculated from the US NFDRS. Explain.
72. P. 46, Figure 12.2. Complete the Figure by showing that the DWAF supplies the NFDRS to the SAWB. Does weather data flow to the SAWB, or does the SAWB predict the weather?
73. P. 47, section 13, 2nd paragraph. From section 9 it is clear that the format for the NFDRS is not 'a simple colour coding' – please specify your recommendation fully.

D.A.G. DOBSON
DIRECTOR
SAWGU

Thanks for the copy of the workshop proceedings. I do not have anything further to add.

A. KÜHN
VELD AND FOREST FIRE COMMITTEE
DWAF

1. Proof reading
There are a number of typographical and other errors relating to proof reading which I have given to Carla Willis over the phone for the sake of efficiency.

2. Models of Fire Danger Rating Systems
Throughout the report you make reference to the Lowveld system (eg piii, p20), yet you do not adequately explain it in your models from p4 to p12. You obliquely refer to it being part of the McArthur system, which I don't think is sufficient, given that you explicitly use it in your comparison exercise on p20 to p23.

3. Use of terminology

3.1 'third' and 'first' world
Please consider whether this is the best terminology. Generally today the terms 'developing' and 'developed' are used respectively. See p15 and p21 in the table.

3.2 FPA
Your use of the acronym FPA on p16 to indicate a Fire Protection Agency is confusing, given that the commonly used acronym for Fire Protection Associations as set out in the Act is FPA. My suggestion is that you do not need an acronym, use the term in full for Fire Protection Agencies.

4. Legal interpretations of the National Veld and Forest Fire Act
In certain instances, your interpretation of what the Act says is flawed.

4.1 Factors to be taken into account for the NFDRS
On p22, you state, 'The Act requires that the system should take fuel factors into account' and 'The Act also requires that the system should take ignition risk into account.' Neither of these two statements is true and could lead one to believe that the authors of the report have not read the Act.

S9(4)(a) of the Act states:

The fire danger rating system must –
(a) take into account the relevant peculiarities of each region, including –
- (i) the topography;
- (ii) the type of vegetation in the area;
- (iii) the seasonal climatic cycle;
- (iv) typical weather conditions;
- (v) recent weather conditions;
- (vi) where reasonably possible, current weather conditions;
- (vii) forecasted weather conditions; and
- (viii) any other relevant matter;

Fuel loads and ignition factors may fall into (viii) but are not explicitly stated in the Act itself.

4.2 Suggested amendment to the Act (p40)

You suggest in your report that s9(4) of the Act be amended from 'must take into account the relevant peculiarities of each region' to 'should take into account the relevant peculiarities of each region where appropriate.' It appears to me that you are trying to amend the section so that it is not compulsory for each of the factors listed to be explicitly included in the FDRS. However, your suggested amendment is not the best way to achieve this, and as set out below, this matter has already been extensively debated within the Department and an amendment has already been drafted.

An amendment to s9 (as well as sections 5 and 6) is currently contained in the National Forest and Fire Laws Amendment Bill, which has been published for public comment. This bill will probably come before Parliament in its next session in September. I attach a copy of the draft bill for your information. The amendment states:

The fire danger rating system must –

(b) take into account the relevant peculiarities of each region, including<u>, where reasonably possible</u> –

- (ix) the topography;
- (x) the type of vegetation in the area;
- (xi) the seasonal climatic cycle;
- (xii) typical weather conditions;
- (xiii) recent weather conditions;
- (xiv) **[where reasonably possible,]** current weather conditions;
- (xv) forecasted weather conditions; and
- (xvi) any other relevant matter;

<u>Underlined words</u> have been added, **words in bold** have been deleted. The effect of the amendment is to ensure that the FDRS only has to take into account the list of factors when this is 'reasonably possible'.

Again, it seems to me that the authors should have been aware of the proposed amendment to the Act, since it could affect the work that they did.

4.3 Publication of the FDRS by the media

You state on p40 that in terms of the Act, if the fire danger is high, the SAWB will contact the relevant media and 'they will have to publish or broadcast this information in terms of the Act.' This is not true. The Act requires **the Minister** to publish the information, and this duty will probably be delegated to the SAWB. There is nothing in the Act which compels the media to publish a fire danger rating, since the Constitution provides for media freedom. The media cannot be compelled to publish or not to publish anything (there are a few exceptions relating to child pornography and so on). Therefore, the Minister will have the duty to ensure publication, if need be by paying for it. Of course, it is unlikely that the media will refuse to publish the fire danger rating. However, in a legal sense, this assertion in the report is wrong.

4.4 Burning permits

You mention burning permits on a number of occasions, including p36 and p40. The Act does not require burning permits or any form of licencing for burning. If you are suggesting that the Act should do so, then this should be stated. The way in which you have consistently referred to burning permits gives the reader the impression that such permits are already part of the Act.

4.5 Use of the term 'high'

In terms of the Act, when the fire danger rating is high, certain sections come into effect (for example, the Minister must publish that fact). However, you are suggesting that these sections should only come into effect when the danger rating system is 'very high' and 'extremely high'. If this is the case, the Act will need to be amended to reflect this.

This affects Table 9.1, in which you set out the proposed categories of fire danger. The most important effect of the rating being 'high' is that s10(2) comes into effect. This states that no person may light, use or maintain a fire in the open air in the region where the fire danger rating system is high.

However, your category 'yellow', listed as 'high' in Table 8.1 states that 'Naked flames need adequate supervision at all times,' which contradicts the provisions of s10(2). The need for amendment of the Act is therefore obvious if the proposal to adopt a rating of 'high', 'very high' and 'extremely high' are accepted.

You also use the word 'high' quite loosely sometimes. For example on p37 you state 'While the legal requirement is that the ratings need only be communicated when considered high (orange and red), there was …'. In fact, according to your own classification, yellow is 'high' and orange and red are 'very high' and 'extremely high' respectively. The word 'high' has a particular legal meaning in the Act, and should be used with care. The report needs to deal early on with the problems of the word 'high' including the need to amend the Act to deal with this.

E. POWELL
ACTING DIRECTOR
NORTHERN CAPE NATURE CONSERVATION SERVICE

1. Due to time constraints on the late receipt of the above document, it was not possible to review all relevant compliance with other legislation e.g. the Forest Act, Conservation of Agricultural Resources Act, etc.
2. In general the draft NFDRS appear to comply with the basic requirements of the National Veld and Forest Fire Act of 1999.
3. Northern Cape Nature Conservation Services (NCNCS) would like to know when Regulations would be made in accordance to the NFDRS. Regulations would be needed for guidance and enforcement of the above laws.
4. When would consultation take place to determine who would act as the Fire Protection Associations?

R.J. SCHOLES
ENVIRONMENTEK
CSIR

THE REPORT OVERALL

The report does a good job of addressing all the elements of the task, as laid out in the terms of reference.

Don't use acronyms without first defining them. I suggest, in addition, an acronym list.

It needs some language editing, especially in the Executive Summary, which is the bit that will be read by most people. The Executive Summary needs a small version of map 8.5, and a simplified table 9.1 (do it in colour, on the same page as the map).

Is the stakeholder list complete? I don't think so – it is overly dominated by the plantation industry, and this shows in the report. Fires are the second-largest cause of power failures in SA – Eskom is a big stakeholder (Richard Evert is their person 082 372 3886]. The biggest agricultural user of fire other than grazing is cane farming.

The equation on page 4 is wrong, I think. The conclusions on bottom of page 4 are unsubstantiated.

Equation 3 is incomplete – it needs the Thortwaite equation as well. Again the conclusions do not follow from the evidence provided (or not provided).

Define FOP and FBP in figure 3.1b

The first 15 pages of the report are almost reference free, then other sections are richly referenced. It is not clear that the most up to date material has always been referenced. See for instance Cheney and Sullivan 1997, which I have.

Figure 3.3 (which is repeated as 7.1) is wrong as drawn. Eliminate it, and redraw 7.1, since 3.4 is more appropriate here.

Table 3.1 needs acronyms spelled out.

The whole of section 4.1 needs to be edited, specifically asking the question What information is relevant to fire regimes? A lot of this is in Van Wilgen and Scholes (1997). Put is areas from Low and Rebelo and Thompson (1999). Incidentally, Acocks and Rutherford are both redundant, since Low and Rebelo simply used their boundaries in the main. Futhermore, Low and Rebelo is 'potential vegetation', which is a theoretical construct. Fires burn actual vegetation! Thompson 1999 land cover should be the main resource.

Put cane fields in as a land cover type, and spend a few lines on other land cover types as well. Most fires in SA are clustered around urban areas!

The discussion on climate on page 13 needs to be combined with a reduced version of the climate discussion on page 17, and specifically must define and describe bergwinds.

Conservation areas do not only consist of state reserves. Two thirds are under private management. Mention the Conservation of Agricultural Resources Act, which governs fire everywhere outside forest areas.

The climate zones as defined in 5.2 leave out two thirds of the country! Define another one to cover the rest.

Criterion 2 is also failed by the McArthur model, if narrowly defined.

Simplicity is not a reason to eliminate under Criterion 7, but absence of an appropriate empirical base is.

Don't use 1st world and 3rd world. It is patronising.

Page 22: The risk issue is a scale problem. Ignition risk is overwhelmingly a small-scale ('fine grain') issue, while these models are proposed at regional scale.

The discussion of the McArthur model on page 25 confuses the fuel load module and the fine fuel moisture model. See also Cheney and Sullivan 1997 Grassfires: fuel, weather and fire behavior. CSIRO press (I have it).

The appendices are potentially useful, but full of errors and gaps. The list of municipalities per fire zone is necessary, but is not referred to in the text where it should be (page 31), and the municipalities need to be given names, not codes.

No mention is made in 8.3 of the location of plantation forestry, which is the implicit driver behind the whole report (although it shouldn't be).

The details of the equations in Appendix 3 do not contain enough detail to allow them to be coded, and I suspect they contain errors. This is critical!

I think the regions are sound, but the fancy analysis to reach them is deeply flawed. Since the computation effort required for the McArthur model is trivial, and the SAWB data is digital already, I would greatly increase the number of computational nodes (e.g. to one per magisterial district). This would form a sounder legal basis than the current quasi-provinces, since there is clear single jurisdiction. The results could be generalised for national presentation e.g. on TV maps, by taking a maximum or mode within a region. Otherwise, what happens when Nylstroom receives a thundershower, and therefore shows no fire danger, when the rest of the province is bone dry?

There is much confusion on page 28, 29 and in Appendix 3 about which drought index to use, and why. Be clear.
Table 9.1 is good, but I would reprase the 'orange' recommended actions to 'No prescribed burning unless a specific permission has been obtained to burn under Very High danger conditions'.

The structure of the report hops about a bit in 7 and 8. The steps should probably come later. Similarly, there is much repetition between section 11 and 12.5.

Under 11.1, surely DWAF has responsibility for education and awareness, as well as ongoing research?

I question whether NDMC has the mandate, facilities, expertise or mission to be a data repository.

Far better than amending the act around FPAs, which is non trivial, would simply be to define all municipalities as FPAs, then encourage them to club together in executing these responsibilities. Organic FPAs would then emerge without regulation and without an initial gap.

The questions in table 12.1 about how long a fire will last are meaningless.

I have drafted some paragraphs on satellite fire monitoring for page 43.

Section 12.4. The total cost of the fire (i.e. summed damages plus control costs) would be much better than total area burned as a danger index (see how poorly area burned performs in fig 12.1b.

Fig 12.2 could use some other inputs, e.g. satellite data, and a feedback from the NDMC to the FPAs and DWAF.

Appendix 5, the fire report form, is lousy. It is poorly laid out and asks for some data which are either easily calculated from information already supplied (or available in other databases), or are impossible to give. It fails to ask for other information (e.g. human mortality/injury)

THE CONCLUSIONS OF THE REPORT

While I concur that the McArthur approach is preferable to either the US or Canadian approaches, I strongly disagree with the statement, made in several places, that multiple versions of this FDI would be impractical. Firstly, the failure to apply multiple versions would be *wrong*, which is much more serious than being impractical. Secondly, the model will be run at least for nine regions in the country (I would recommend more, but that is another issue, see discussion above). There is absolutely no problem in specifying a different dominant fuel type/impact model in each, and it does not add at all to the computation effort (which is trivial, anyway). Thirdly, the report decides to apply different thresholds in different areas – this is tantamount to different models anyway! Finally, all the above is based on a claim that the MacArthur model is biome independent, since it only uses climate data. Rubbish. The empirical relations *coded into the model* are based on fuels found in open *Eucalyptus* woodlands. The Australians themselves found it inapplicable to their own grasslands, and therefore developed other models for those cases. *Eucalyptus* woodland fuel types are neither representative of South African plantations (which is why the lowveld scheme had to fiddle them), nor for our savannas and grasslands. The dominant fuel type in Eucalypt woodlands is fallen bark, twigs and leaf litter; these do not figure prominently in South Africa.

I would recommend the McArthur *system*, but include at least 3 fuel models: grassland (including savannas), fynbos and plantation. The fynbos one would have to be developed, the others already exist. The ‘worst risk’ model should be applied in each calculation node.

2.3: Summary of the main issues raised in the comments from stakeholders and how they have been addressed

Comments were received from several of the key stakeholders as well as from members of the DWAF Veld and Forest Fire Committee (in their individual capacities). All these comments are attached in Appendix 2, unedited except for typographical errors. Many of the comments were of a minor nature (corrections of typing, changing of a word to improve the context, etc.). These have been addressed by direct editing of the report. Yet there are also some issues that were raised by more than one stakeholder and reflect concerns which cannot merely be corrected by editorial changes. These issues, and the way in which they have been addressed in the report are summarized below.

ISSUE 1: THE IDENTIFICATION OF KEY STAKEHOLDERS

Questions concerning the choice of stakeholders were raised. The list of people consulted was considered by some commentators to be incomplete.

Response: As mentioned in section 2 of the report, time and budgetary constraints of this project did not allow for full consultation with all stakeholders. However, a list of key stakeholders was identified with the approval of the Veld and Forest Fire Committee of DWAF.

ISSUE 2: THE CHOICE OF THE FDR MODEL FOR SOUTH AFRICA

This issue encompasses several aspects including:

- the validity of choosing the McArthur FFDRS over other models
- the validity of having only one model for the entire country (i.e. why not use the McArthur GFDRS *as well as* the FFDRS?)
- Several comments which pertain to fire *behaviour*

Response: The choice of model for South Africa was debated extensively amongst experts, with stakeholders and with members of the Veld and Forest Fire Committee of DWAF.

The report explains the difference between fire *behaviour* and fire *danger*, an aspect which has resulted in much confusion in understanding the logic for the choice of model and how it would be applied.

The report recommends further studies into four models in order to establish the best choice for South Africa, given that current understanding of the models suitability for South African conditions is limited.

ISSUE 3: THE NEED FOR A NATIONAL DATABASE AND THE STRUCTURE OF THE DATA FORM

Concern was raised around the establishment of a national database and some of the issues included:

- The need for a national database.
- The collection of data (How can one ensure that the data will be collected and if it is, will it be standardized and accurate?).
- The format of the data form was questioned by several commentators.

Response: The purpose of the national database is to provide data from which the NFRDS can be evaluated and refined. Data is currently collected (for example by the forest industry) but it is not necessarily the type of data needed to verify and improve a *national* NFDRS. The format of the data form (previously Appendix 5 in earlier drafts) has been excluded from this final report as a separate project to develop the information system for the NFDRS will address this issue in greater detail.

ISSUE 4: THE ZONATION OF THE COUNTRY INTO AREAS OF HOMOGENOUS FIRE DANGER

The comments revolved around the choice of zones, the delineation of the boundaries and the method used to determine the zones.

Response: The process included the participation of all those stakeholders able to attend the second day of the Kwalata workshop and was based substantially on their 'on-the-ground' knowledge of the vegertation and associated fire behaviour in the regions. However, after further discussions with the SAWB, the team proposed a different system of zonation based on the availability of accurate weather data. The process is described in detail in section 8 of the report.

ISSUE 5: THE CHOICE OF NODAL WEATHER STATIONS

The choice of the nodal weather stations was questioned as to whether those listed in Table 7.1 were the most appropriate.

Response: No longer relevant as the process being proposed in section 7 does not make use of nodal weather stations.

ISSUE 6: THE USE OF PERMITS TO CONTROL BURNING

The need for permits to control burning on orange days was raised at the Kwalata workshop because while land managers recognize the need for restricting the fire risk on hot, dry days, they also recognize the need to burn under these relatively extreme conditions. This is a management practice which is essential in certain vegetation types. The current Act does not make provision for these permits.

Response: This report recognizes that because burning permits are already issued under different legislation , it would not be sensible to create an additional permit under this Act. The recommendation to include certain exemptions or restrictions in the current permit systems (in order to ensure that fire danger is considered) is suggested in section 10.

ISSUE 7: THE USE OF THE WORD 'HIGH' TO DESCRIBE FDR CATEGORIES

The use of the word 'high' to describe three of the fire danger rating categories (yellow, orange, red) was questioned due to the legal interpretation of the word 'high' in the Act.

Response: The issue was debated at great length in both workshops. While it was originally agreed to use the word 'high' liberally and amend the Act to be more specifically applicable to orange and red categories, this has now been revised based on the comments received. This debate is discussed at the beginning of section 8.

ISSUE 8: THE IMPLEMENTATION OF THE NFDRS

Generally, positive comments concerning the development of the NFDRS were received from most stakeholders, but several questioned the practicalities of implementation including:

- The need for a NFDRS
- The costs of implementation
- The time it will take before the system can be implemented

Response: The need for a NFDRS is not an issue to be addressed in this report. The Act demands it and DWAF has requested that its development be undertaken. The issue of whether or not it is needed, implementable and affordable lies outside the scope of this report. This concern is one which should have been raised (and probably was!) at the time of the drafting of the Act. The implementation of the NFDRS will require a detailed implementation plan addressing issues of schedule, budget and infrastructure. This too lies beyond the scope of this project, although some guidelines and recommendations have been made in sections 10 to 11 of the report.

APPENDIX 3.1: McArthur's Forest Fire Danger Index Equations

Formulae from Noble, I.R., Bary, G.A.V. and Gill, A.M. (1980) McArthur's fire danger meters expressed as equations, *Aust. J. Ecol*., **5**:201-203.

Variables:
D = drought factor
N = number of days since rain
P = amount of rain in last period – rainfall in mm during an event (24 hour period to 09h00 each day
DI = Keetch Byram drought index
FDI = fire danger index
T = air temperature
RH = relative humidity
V = average wind velocity in the open at a height of 10m (km/hr)
FROS = forward rate of spread (km/hr)
FROSM = FROS (m/min)
FUEL = fuel weight (t/ha)
SLOPE = ground slope (degrees)
FLAMEHT = flame height (m)
SPOT = spotting distance from flame front (km)
SPOTM = spotting distance (m)
INTENS = fire line intensity (kW/m)
HEAT = heat output per unit area (kW/m^2)

Calculate the Drought Factor (*see also Griffiths improved formula below which can be used in place of this equation*)

$$D=0.191(DI+104)(N+1)^{1.5}/(3.52(N+1)^{1.5}+P-1)$$

Calculate FDI

FDI=2.0EXP(-0.450+0.987Ln(D)-0.0345RH+0.0338T+0.0234V)

Calculate FROS, FLAME HT, and SPOTTING DISTANCE

FROS=0.0012*FDI*FUEL*EXP(0.069*SLOPE)
FROSM=FROS*1000.0/60.0
FLAMEHT=13.0*FROS+0.24*FUEL-2.0
SPOT=FROS*(4.17-0.033*FUEL)-0.36
SPOTM=SPOT*1000.0
INTENS=516.7*FUEL*FROS
HEAT=1860.0*FUEL

APPENDIX 3.2: Calculating the Keetch–Byram Drought Index

Reference: Crane, W.J.B. (1982) Computing grassland and forest fire behaviour, relative humidity and drought index by pocket calculator. *Aust. For.* **45**(2), 89-97

VARIABLE LIST:

KBDI = drought index (mm equivalent)
RAINPA = average annual rainfall or precipitation of the station (mm)
EFFRAIN = net 24 hr rainfall or precipitation in mm
RAIN = gross 24 hr rainfall or precipitation to 0900 hrs (today's rain) in mm
OLDDI = yesterday's drought index, also moisture deficit (mm)
DQ = drought factor
TMAX = maximum daily temperature (deg.C)
OLDRAIN = yesterday's rainfall
LEFT = amount of the 5.08 mm of interception capacity left

DQ=((203.2-OLDDI)*(0.986*EXP(0.0875*TMAX+1.5552)-8.30))/(1+10.88*EXP(-0.001736*RAINPA))/1000.0

If OLDRAIN > 5.08 then EFFRAIN = RAIN
If 0 < OLDRAIN < 5.08 then EFFRAIN = RAIN – LEFT
Else EFFRAIN= Max [(RAIN – 5.08), 0]
LEFT = Max [(5.08 – RAIN), 0]

KBDI = Max [((OLDDI – EFFRAIN) + DQ), 0]

APPENDIX 3.3: Drought Factor (Improved formula by Griffiths)

Reference: Griffiths, D. (1999) Improved formula for the drought factor in McArthur's Forest Fire Danger meter. *Aust. For*. **62**(2), 202-206.

Variables:
D = Drought Factor (0-10)
I = Soil dryness index, either the Keetch Byram Drought Index or Mount's (1972) Soil Dryness Index
P = rainfall in mm during an event (24 hour period to 0900 each day)
N = time since the rain event in days

$$D = \max\left[10.5\left(1-\exp\frac{-(I+30)}{40}\right)\frac{y+42}{y^2+3y+42},10\right]$$

where:

$$y = \max\left\langle \begin{array}{ll} (P-2)/N^{1.3}, & \text{if } N \geq 1 \;\&\; P > 2, \\ (P-2)/0.8^{1.3}, & \text{if } N = 0 \;\&\; P > 2, \\ 0, & \text{if } P \leq 2 \end{array} \right\rangle$$

calculated for the past 20 days

Alternatively, the Drought Factor can be calculated for each rain event in the last 20 days and the minimum value calculated is taken to be the Drought Factor.