WILDFIRE THREAT ANALYSIS MANUAL

**FOR LANDS MANAGED BY THE
DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT
WESTERN AUSTRALIA**

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July 1993

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PREFACE

All Districts / Regions are required to maintain a current Wildfire Threat Analysis (WTA) for lands managed by the Department of Conservation and Land Management (CALM).

WTA underpins all fire protection undertaken by CALM. It is used to identify the threat posed by wildfires, to determine the optimum course of action, to explain fire protection alternatives and the decisions made.

A current WTA is a prerequisite for:

> Preparation of the fire management section of all management plans.
>
> Annual reporting. CALM's fire protection performance indicators are defined in terms of WTA parameters.
>
> Completion of the Rating System for Prescribed Burning.

This manual replaces the 'Wildfire Threat Analysis for SW Forest Areas of Western Australia', revised 9 October 1990.

Since the introduction of the Wildfire Threat Analysis (WTA) system in the forest Regions its application has broadened. Allocation of resources including aircraft for fuel reduction burning is based on a priority rating system which requires a current WTA. Annual and long-term measures of performance are now required by parliament. For fire protection, these are based on the WTA, and it is therefore necessary that a WTA be maintained for all areas.

The WTA principles apply universally. This manual broadens the scope of the guidelines originally issued for the South West areas, and incorporates corrections and amendments suggested by users of the earlier guidelines. Many of the classifications reflect a bias to the SW where the most intensive fire management is practised, but the guidelines should be sufficiently broad for all areas. If users believe further amendment is required to clarify any part of the manual for other areas (or for the SW), please contact Fire Protection Branch with your suggestions.

OVERVIEW OF WILDFIRE THREAT ANALYSIS SYSTEM

The Wildfire Threat Analysis (WTA) is a structured approach that formalises the processes undertaken by experienced fire managers in considering the threat from and responses to wildfires . The WTA aims to:

* provide a framework to analyse the best available information on all factors contributing to the wildfire threat, and allow evaluation of alternative responses;
* provide a standard and repeatable process for decision making;
* permit objective comparisons between different areas with different problems;
* support the clear and explicit explanation of the rationale behind fire management decisions; and
* provide a rational basis for discussion and conflict resolution in the preparation of management plans.

The factors that contribute to the wildfire threat are considered to fall into four categories:

* The community and commercial **VALUES** that are to be protected.
* The **RISK OF IGNITION**. ie the probability that a fire will start.
* The **SUPPRESSION RESPONSE** possible, which is affected by a range of factors such as the location of forces in relation to the fire, terrain, and access..
* The likely **FIRE BEHAVIOUR**, which influences both the extent and severity of damage and the success of any suppression action, and is dependant on fuels, topography and weather conditions.

The wildfire threat is represented by the combination of four map overlays that summarise the values in each of the categories. In turn, each of these four maps can be supported by maps of the factors that contribute to a category value (Fig. 1).

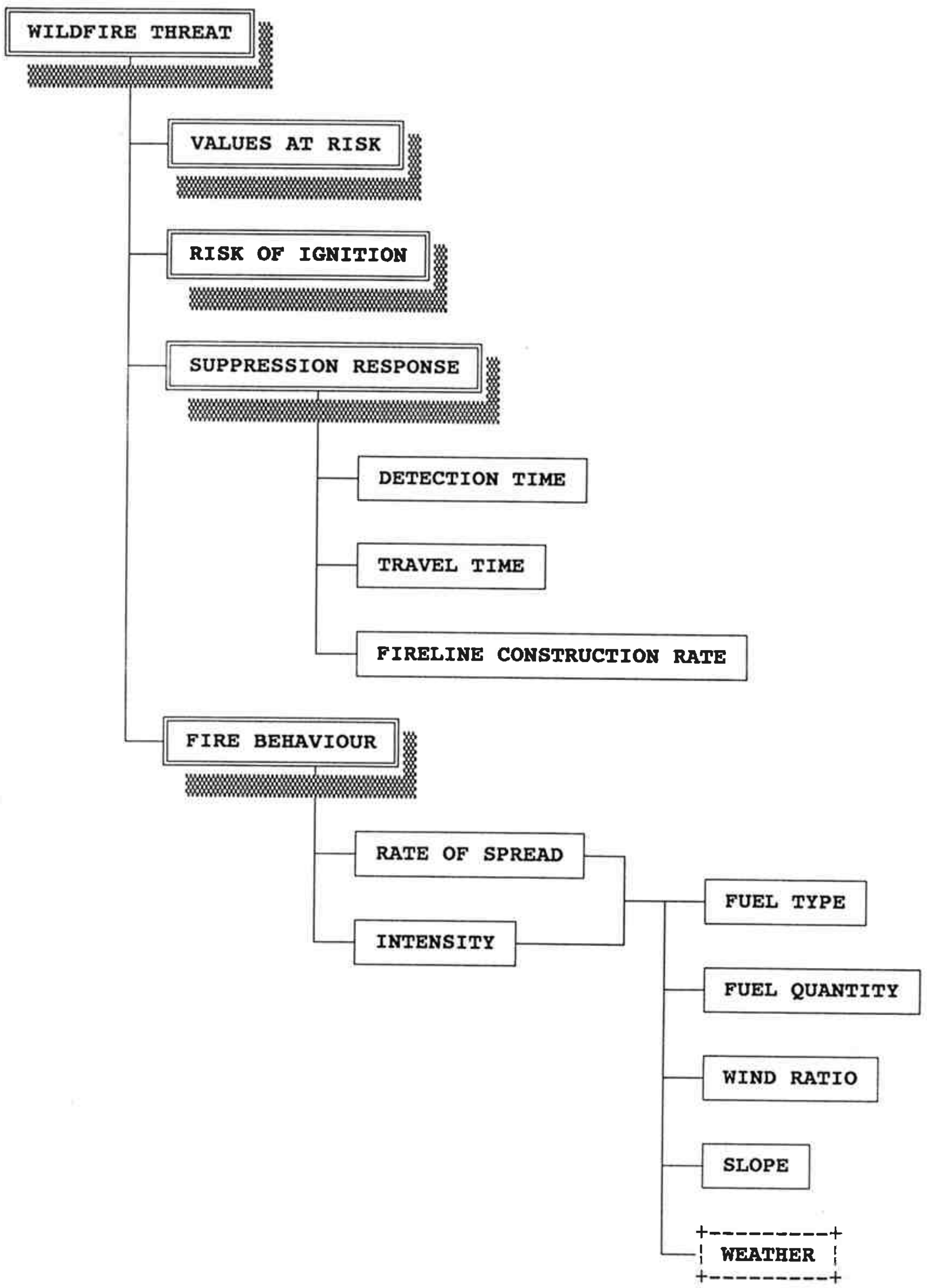
A single index value for wildfire threat is deliberately not used. The most effective response to counter the threat cannot be determined from an index, as it provides no information about its component parts. Also, while some of the relativities that make up the wildfire threat can be stated with confidence, there is not enough information for an objective and accurate rating to be made in all cases. Managers must not blindly follow a number, but must base their decisions on knowledge of the factors which contribute to the wildfire threat, and be aware of the reliability and uncertainties of the data used to identify this.

Managers must often make decisions on the basis of limited information, but it is important that all the information that is available is considered. The WTA provides a framework to do so. It does not require 'perfect' data before it can be applied, but the best available information should always be used to arrive at decisions, be it that the best may range from highly detailed and precise data, to 'thumb-nail dipped in tar' variety.

Many of the factors contributing to the wildfire threat are temporally as well as spatially dynamic, hence the WTA maps must be regularly reviewed to keep them current.

FIG 1

WILDFIRE THREAT ANALYSIS MAPPING HIERARCHY



GUIDELINES FOR THE PREPARATION OF A WILDFIRE THREAT ANALYSIS

GENERAL INFORMATION

Information Recording

The WTA system comprises:

the Wildfire Threat maps

a separate Wildfire Threat book or file.

The information is displayed on the maps. Record the source of the information, explanatory notes, and non spatial information in the accompanying book.

A ring binder type file is recommended for recording information to facilitate addition and retrieval of information. This should be divided with separate reference sections for each map, and a 'general' section for information pertaining to the WTA overall. ie the minimum table of contents is:

General Notes

1. Values at Risk

2. Risk of Ignition

3. Suppression Response
   - 3.1 Detection Time
   - 3.2 Travel Time
   - 3.3 Fireline Construction Rate

4. Headfire Behaviour
   - 4.1 Fuel Type
   - 4.2 Fuel Quantity
   - 4.3 Wind Ratio
   - 4.4 Slope
   - 4.5 Weather

All entries are to be dated and the source identified.

Use the best available information for the preparation of the WTA maps. Contributions from people with knowledge or expertise in a range of related areas is to be encouraged. Areas where information is lacking or poor will become apparent. Priorities for data collection and possible alternatives to fill these gaps should be identified.

Map Production

Wildfire Threat Analyses are required to be prepared wherever fire management activities are proposed to be undertaken on CALM land. The approach is consistent, but the scale at which the WTA maps are prepared depends on the scale of the planning undertaken. In the forest areas the standard scale for mapping is 1:50,000. Elsewhere the scale may be smaller, commensurate with the areas being considered, and the detail of the information available. In all cases larger scales may be used for specific areas if more detailed analysis is required. Use the scale appropriate to your task.

WTA maps can be produced using CALM's grid-based GIS 'FMIS' and ESRI's Arc-Plot where digitised data and the appropriate models are available. Access to the programs developed for this will be progressively provided to Regions as the data is captured. Regions with such access can produce updated prints for Districts.

For those areas where digitised data is not available, the maps will need to be prepared by hand.

Support for both GIS and manual preparation is provided by Fire Protection Branch.

The Use of Percentile Weather Conditions

Fires (and our planned response to them) are greatly influenced by weather conditions, which vary widely in time and from place to place. An analysis can be undertaken for any chosen conditions. To provide a consistent basis for planning and comparison between areas the 95 percentile conditions for the restricted and prohibited periods (the 'fire season') are chosen. ie fire weather conditions will be more severe on 5% of days. In areas of high values and a high probability of fires starting which cannot be reduced, this level of risk may be unacceptable, and a higher percentile selected at which to conduct an additional analysis. (An analysis at the 95 percentile will still be required to permit comparison with other areas.)

To determine the 95% conditions, the records for all available years at a particular location are ranked according to the calculated Fire Danger Index, and the weather conditions for the 95% record are identified. For forest areas, the Northern Jarrah FDI should be used, and the Grasslands FDI elsewhere. Fire Protection Branch can provide this information for those weather stations where the records are entered via the computer network. Local records or Bureau of Meteorology records will need to be used elsewhere.

Hatching System for Major Theme Maps

Hatching is used on the Values, Risks, Suppression Response, and Fire Behaviour overlays to show the value in each category, the density of hatching representing the severity at that point. Each overlay is hatched at a different angle (45^{o} to the previous one), so when overlaid the combined hatching shows the patterns of the wildfire threat, and the extent of the contribution by each factor.

The hatch angle and spacing used for GIS maps is stated in the following notes. The spacing has been modified from the earlier guidelines, and has been chosen to provide an acceptable visual display of the severity. For manually produced maps the same angles are to be used, but the spacing may be increased to reduce the work involved. For most manual preparation it is recommended the spacings be increased to approximately three times that used in the GIS maps.

Supporting Data Maps

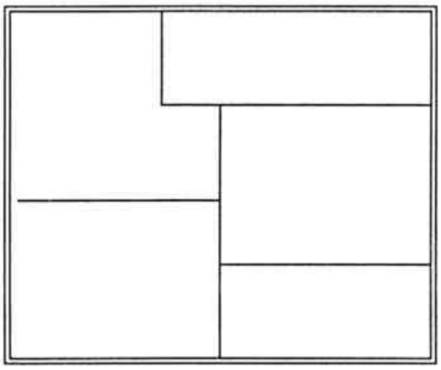
In many cases data maps may already have been prepared for other purposes (eg fuel age/fuel quantity maps). Where such information exists in a suitable format new maps do not have to be specifically prepared for the WTA.

Where maps are manually prepared, the 'Values' and 'Ignition Risk' are usually mapped directly, but the 'Suppression Response' and 'Fire Behaviour' maps are derived from supporting data maps (see Fig 1). In the GIS mapping there may be additional layers or intermediate themes where updating of mapped information involves modelling (eg see Fig 3). In all cases where the final value is not mapped directly, there is scope for errors to be introduced. Grouping into classes at the supporting data map level and then using the mid-class values in subsequent calculations will lose accuracy and can introduce cumulative errors.

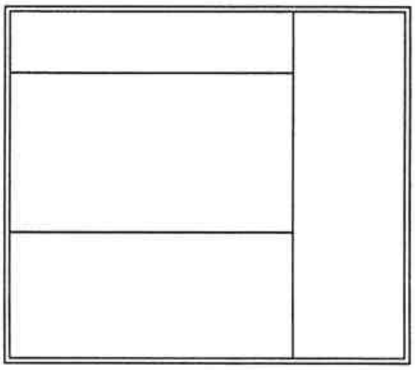
Some grouping or averaging is inevitable as we define a boundary (create a polygon) on a non-uniform area. This occurs for example when large areas are assigned the same fuel quantity despite variations in previous burn and subsequent fuel accumulation. Don't compound these inherent errors by hatching in a standard class with a mid-point value that may be quite different from your 'average' value, but show the actual values to be used in any calculations.

In all cases, collect the best available data. Do not amalgamate information into larger areas or classes at the data map level if it can be avoided. Any such grouping should only be done when the calculations have been completed and the final overlay is produced. For manual preparation of the WTA maps, some grouping at the data map level may be necessary to reduce the number of individual calculations required to a manageable level, but keep this to a minimum.

Notwithstanding that when collating data actual (unclassified) values are to be recorded, a classification and hatching system is outlined for supporting data maps. It is sometimes useful to be able to demonstrate the relative importance of the components of the final theme overlay. eg is the predicted severe fire behaviour due to fuel, or slope, or both? Often, however, the combination of the data maps becomes complicated with too much information to be useful. When maps are overlaid, new polygons are formed, as illustrated.



Map 1 (5 areas or polygons)



Map 2 (4 areas or polygons)

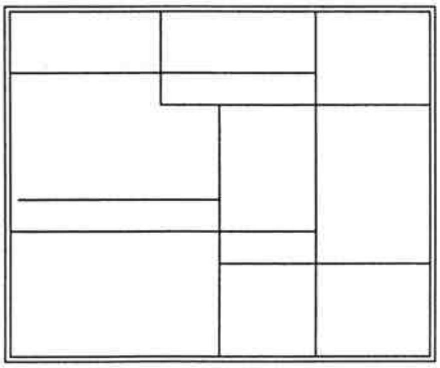


Fig 2 Overlay Polygon formation

Maps 1 and 2 overlaid.
(combined)
(12 areas or polygons)

Where the initial data maps are detailed, with many polygons each with a discrete value, there are too many polygons in the combined map to be meaningful, This is especially the case where values are calculated/modelled within the GIS (eg slope calculations, wind ratio modelling, travel time modelling). In the extreme case, each pixel (FMIS grid cell) may have a different value, and thus a separate polygon. A map showing thousands of polygons many with only sightly different values would be too complex to be readily interpretable. The hatching system and classes outlined amalgamates many of these polygons, which is useful where a visual display is to be generated.

Prints of the classified values for the supporting maps are produced as a matter of course where any modelling has been carried out in the GIS to facilitate quick checking for gross errors and inconsistencies. These prints can also be used to demonstrate the contribution of each component. The hatching system also allows for the supporting maps to be overlaid in a similar manner to the four major theme maps which summarise the wildfire threat, but such overlays are more expensive and only produced as required.

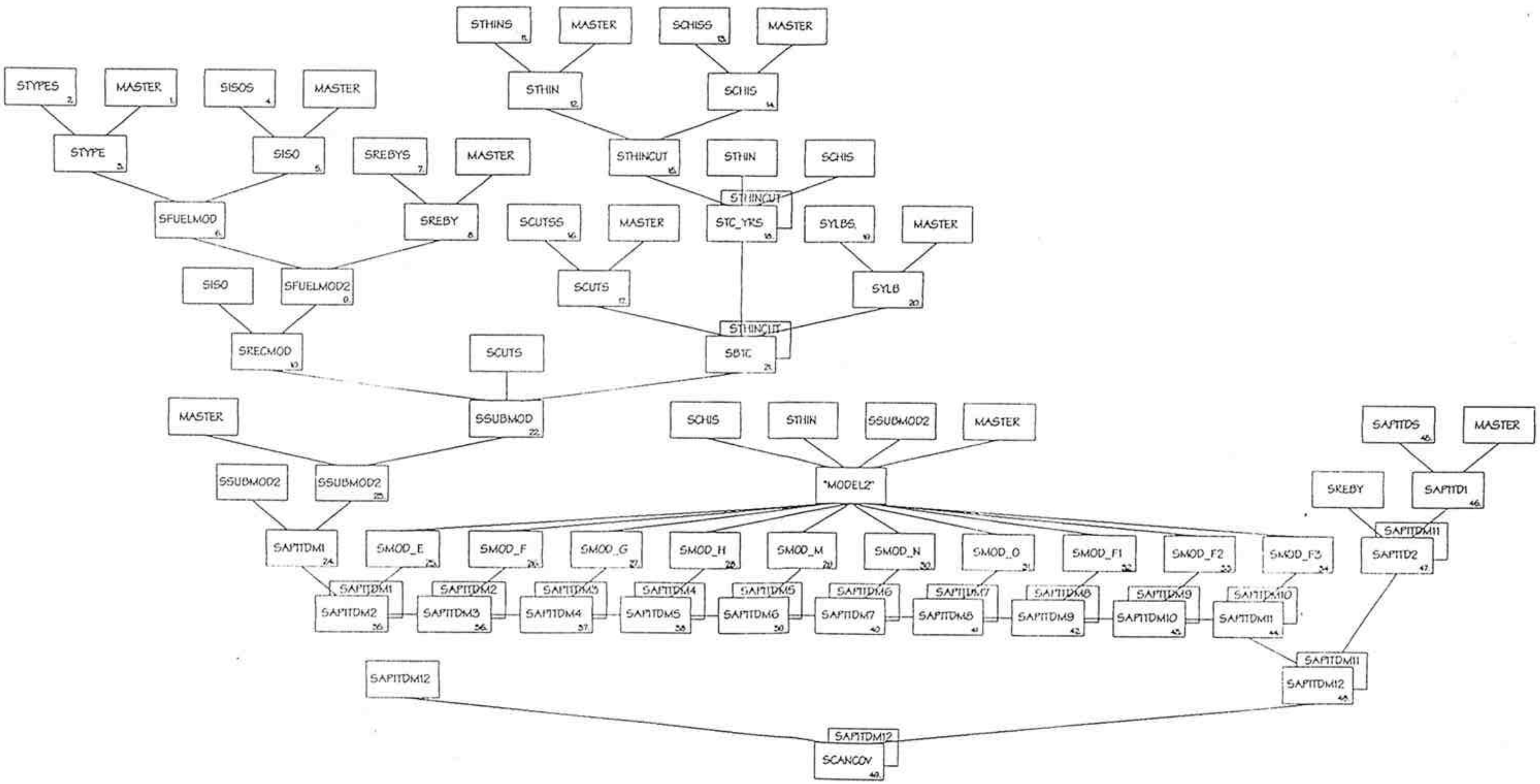


Fig 3 **Flow-chart of procedure for modelling canopy cover.** Modelling procedures can involve many layers. Data is stored at pixel level and not grouped into classes until required for display. Earlier classification leads to a cumulative loss of accuracy.

PREPARING MAP 1 - VALUES AT RISK

Comparing market and non-market or intangible values has long been a difficulty in natural resource planning. For wildfire threat analysis no attempt is made to assign discrete dollar amounts to the various values. Both market (tangible) and non-market (intangible) values are grouped into broad classes. The members of a class are those perceived to be approximately equal.

The classification of values outlined in Table 1 was initially developed for CALM lands in the forest areas of south western Australia. It is not an exhaustive list of all possible values either in the forest areas or elsewhere, but provides a guide to permit local values to be classified in a consistent manner.

Where special circumstances exist and a value is allocated to other than its obvious group or the allocation is open to interpretation, the **reasons for the assignment must be recorded** in the WTA Book.

Individual values are identified by symbol or text, and coloured according to their value group (Table 1).

A zone of influence or buffer - the area in which it is considered a running wildfire would pose a significant risk - is shown around each value. The size and shape of this zone varies to reflect directional variation in the perceived threat from wildfire due to predominant wind direction. The influence zone is extended furthest in the direction of prevailing winds associated with severe fire weather. In much of WA these are winds from E to NW, although in some areas the SE or SW winds may result in more severe conditions. Analysis for the 95% weather conditions should identify this.

Experience has demonstrated that for fires burning in WA forests under adverse weather conditions, at least 3km of low fuel/moderate fire behaviour area is required to catch spot fires and provide the opportunity for suppression before the fire burns through the area. Whilst spotting is less of a problem with fires in other fuel types (woodlands, grasslands and shrublands) fires spread faster and therefore further during the time taken for suppression, and so the potential threat from fires in a similar influence zone is considered.

The standard (default) influence zone extends:

3km NW to E of the value; and

1km in other directions.

These zones may be varied, but the reasons must be recorded in the WTA Book.

Influence zones are shown hatched on an overlay, the density corresponding to the category of the value generating the zone. Where zones overlap, only the highest value zone is shown.

TABLE 1

GUIDE TO CLASSIFICATION AND MAPPING VALUES FOR WILDFIRE THREAT ANALYSIS BASED ON FOREST AREAS OF SOUTH WESTERN AUSTRALIA

	Colour	Line Spacing	Hatch Dir
GROUP I VALUES: * Human Life - Areas where there is a significant threat to lives in the event of wildfire; Eg: Bush townships, settlements, summer camps etc, where access and surrounds and/or the numbers and ages of the population makes evacuation or safe refuge impracticable. Does not include sites where adequate refuge exists (eg beachside camp-sites) or relatively low numbers of people and good access provide for reasonable egress/ evacuation.	**Red**	**1.4mm**	**45° (NE-SW)**
GROUP II VALUES: * High property values; possible risk to life in event of fire, but generally low. Eg., developed 'Special Rural Sub-divisions' (moderate density housing - block size 2-10 ha) with good access/egress. * Sole known sustainable populations of fire vulnerable threatened species (as defined below).	**Orange**	**2.25mm**	**45°**
GROUP III VALUES: * Local sustainable populations of fire vulnerable threatened spp. * Major softwood plantations (> 100 ha) 8-20 year old. (ie maximum investment, minimum salvage, and high re-establishment costs following fire).	**Yellow**	**3.6mm**	**45°**
GROUP IV VALUES: * Scientific reference areas not to be burnt. * Known sustainable populations of designated uncommon fire vulnerable spp. * Major Plantations Softwood: > 100 ha, < 8 or > 20 years old; < 100 ha, 8-20 year old Hardwood: > 250 ha, > 5 year old. * Hardwood regeneration/saplings/poles in areas designated for timber production - consolidated areas > 250 ha . * Scattered houses near CALM land.	**Green**	**4.9mm**	**45°**
GROUP V VALUES: * Developed farmland. (Exceptional crop/stud values at risk may be rated higher). * Other plantation areas (Hardwood & Softwood). * Scattered patches of regeneration/sapling or pole regrowth. * Harnessed catchments with erodible soils. * Fire vulnerable anthropological/historical sites. * Outstanding landscapes (on which fire would have a long term impact). * High erosion susceptible areas. * Restricted populations of common fire vulnerable spp.	**Light Brown**	**6.4mm**	**45°**
GROUP VI VALUES: * Common fire vulnerable species.	**Pale Blue**	**8.0mm**	**45°**
GROUP VII VALUES: * 'Base' values such as multiple use forest or park areas. These are not separately highlighted on the map.	**Uncoloured**	**Blank**	

(Table ctd. next page)

TABLE 1 (Ctd.)

Definitions:

Sole Population:

Includes discreet groups (populations) in a restricted area that are susceptible to damage by a single wildfire event.

Local Populations:

One of several known populations.

Sustainable:

The population can reproduce and sustain itself in the wild.

Fire Vulnerable:

Vulnerability may depend on the stage of the species and recent fire history. For example it is unlikely that a single fire event will be catastrophic to most plants, but it would render an obligate seeder vulnerable for a period till a sufficient seed store is re-established.

Classifications often change with time and must be regularly reviewed.

Threatened

Any animal taxon declared under Section 14(2)(ba) or any plant declared under Section 23F(2) of the Wildlife Conservation Act as "likely to become extinct or rare".

Threatened species rate very highly as they are irreplaceable if lost. Care must be taken not to assign the classification "fire vulnerable" lightly. In the absence of complete knowledge of an individual species Wildlife Research staff are required to provide an expert written opinion based on best knowledge (Eg closely related species), or conduct necessary research to justify specific protection against wildfire.

PREPARING MAP 2 - RISK OF IGNITION

Ignition risk is the probability that a fire will start, not that it will necessarily spread or cause damage (factors that are addressed separately in the Fire Behaviour and Values themes).

Fires are caused either by lightning or human activity. Fire history alone is not an entirely satisfactory measure of ignition risk as not all fires are reported (particularly in less populated areas) and because circumstances may change with time. Activities which caused fires in the past may now occur less frequently or nor at all. eg where the land clearing phase is replaced by the management of developed farmland, there is a marked reduction in the risk of escapes from such burns.

Historical data can identify lightning prone areas, and provides information on correlations between activities and fires. To help analyse historical data, the cause and origin of all fires should be recorded on a separate map.

As the influence of activities leading to an ignition risk extends over an area, risk zones are mapped. These are shown hatched on an overlay according to the peak frequency of occurrence of ignition sources during the fire danger period (Table 2). The greater the risk, the closer the line spacing.

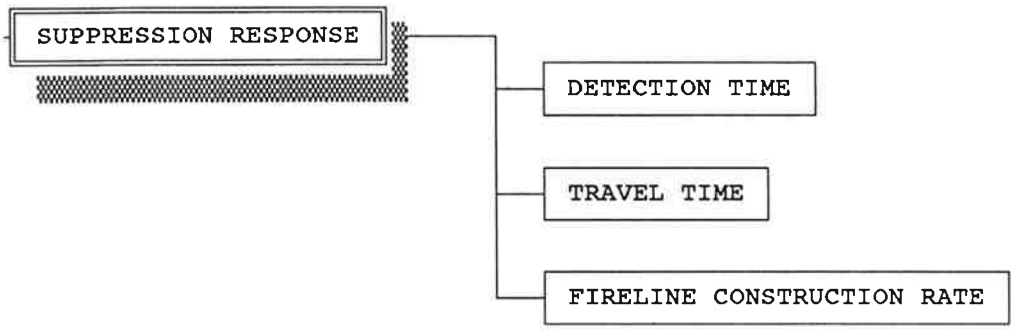
TABLE 2

IGNITION RISK CLASSES

	Line Spacing	Hatch Dir
HIGH: (potential ignitions on >4 days/month)	2.25mm	90° (Horizontal)
Examples:		
Regular path of summer storms and lightning strikes recorded.		
Areas within spotting distance (up to 3km) of active land clearing involving burning, or other planned burning (eg regeneration burning, stubble burning)		
High visitor use areas involving camping, barbecues, or marron fires.		
Recent history of ignitions from other sources. (Eg, deliberate lightings) and activity pattern believed unchanged.		
MODERATE: (1-4 sources/month)	4.9mm	90°
Examples		
History indicates little/no past ignition, moderate visitor use, reasonable access for visitors.		
LOW: (<1 source/month)	8.0mm	90°
No recorded history of fires. Little/no human activity at or near site, poor access for visitors.		
Summer storms rare. No recorded lightning strikes.		

PREPARING MAP 3 - SUPPRESSION RESPONSE

Suppression response reflects the time taken to detect a fire, for firefighters to reach the fire, and for effective fireline to be constructed around the fire. Detection Time, Travel Time, and Fireline Construction Rate maps can be prepared as separate overlays that, when combined, show the variation in times which are grouped into the suppression response classes.



'Suppression Response' is expressed in five classes (Table 3). It is assumed that any fire can be suppressed provided adequate resources are available on site at the time of ignition. The "Immediate" category reflects the initiating phase of fire development, where suppression has a high probability of success. Other class divisions are more arbitrary, but using such standardised classes permits comparison between areas.

TABLE 3

SUPPRESSION RESPONSE CLASSES

			Line Spacing	Hatch Dir
POOR:	Response* + Production# time	> 6 hours	2.25mm	135°
SLOW:	Response + Production time	4.1-6 hrs	3.6mm	135°
MODERATE:	Response + Production time	2.1-4 hrs	4.9mm	135°
RAPID:	Response + Production time	0.5-2 hrs	8.0mm	135°
IMMEDIATE:	Response time only **	< 0.5 hrs	Leave blank	

* Response time = Detection Time + Travel Time

\# Production time = Time to construct 1000m fireline.

** In the first 0.5 hours the fire is considered still in the developing stage, suppression difficulty is at a minimum, and length of fireline required not considered significant in the overall time.

Supporting Data for Suppression Response

To prepare the 'Suppression Response' map, data is required for detection and travel times and fireline construction rates. To minimise errors the actual times should be recorded on each data map and added to give the overall suppression time which is then grouped into the classifications shown in table 3. (See also 'Supporting Data Maps' at the beginning of this section).

Map 3.1 - Detection Time

The time taken for detection depends on the detection facilities available (firetowers, planes, neighbours) and on the level of preparedness, which usually depends on the prevailing conditions. Surveillance schedules and the concern and vigilance of neighbours usually increase with increasing fire danger. To provide a basis for comparison, the 95 percentile weather conditions (see previous note) are chosen.

Time zones are mapped, representing the likely time between ignition and detection assuming the normal detection system is operating for the selected weather conditions. The actual time for each zone from the best available information is to be recorded, not necessarily the classes shown in Table 4. These classes and hatching are recommended for display purposes only.

TABLE 4

DETECTION CLASSES

		Line Spacing	Hatch Dir
POOR - no spotter or tower coverage, sparsely populated. Likely time to detection	> 2 hours.	**2.25mm**	**45°**
FAIR - infrequent spotter coverage, few towers, moderately populated. Likely time to detection	1 - 2 hours.	**3.6mm**	**45°**
GOOD - regular spotter coverage. Likely time to detection	0.6 - 1 hour	**4.9mm**	**45°**
EXCELLENT - likely time to detection	0.25 - 0.5 hour	**8.0**	**45°**
IMMEDIATE - likely time to detection	< 0.25 hour	**Leave blank**	

Map 3.2 - Travel Time

The time required for suppression forces to reach a fire depends on the location and mode of transport. The map is standardised by using the time from the crews' normal stand-by locations (usually the work centre), using their standard mode of transport (usually a gang truck and heavy duty tanker). Allowance is made for off road travel.

In many cases fire suppression will require the use of heavy machinery. Separate travel time maps can be prepared for a more detailed analysis, but for a broad comparison the relative times to get such equipment to different sites are assumed to be similar to the relativities for crew travel times.

Travel times are recorded to the best detail available. (In the case of GIS maps when networking models are implemented each individual pixel will have a different value.) For display purposes travel time zones are shown in classes. Table 5 shows classes suitable for more populated areas.

TABLE 5

TRAVEL TIME CLASSES

		Line Spacing	Hatch Dir
POOR	> 2 hours.	2.25mm	135°
FAIR	1 - 2 hours	3.6mm	135°
GOOD	0.5 - 1 hours	4.9mm	135°
EXCELLENT	0.25 - 0.5 hours	8.0mm	135°
IMMEDIATE	< 0.25 hours	Leave blank	

Map 3.3 - Fireline Construction

The time required to complete fireline construction depends on the fire itself as well as on the method of construction, the vegetation , and terrain. To compare only the factors that are inherent in the site itself, fireline construction is expressed as a rate (Table 6), thus making it independent of fire size.

As construction rate is expressed as elapsed time, it can be readily added to the detection and travel times to classify areas for suppression response. Construction rate is the time taken to construct a standard length of fireline by the method and machinery/equipment appropriate to and commonly available in the area. This time is a measure of the physical difficulties of fireline construction at that site, not the time required to suppress a fire (which will also depend on the fire behaviour, the forces available, and the fire size).

The actual time taken to construct 1000m of fireline should be recorded. ie do not be constrained by the classes shown in Table 6. It will be necessary to stratify the area into classes of approximately equal fireline construction difficulty, but if the times for these categories differ from those shown in Table 6, use the actual values for your classes. The classes shown in Table 6 are recommended classes for display purposes only, and these can also be altered where appropriate.

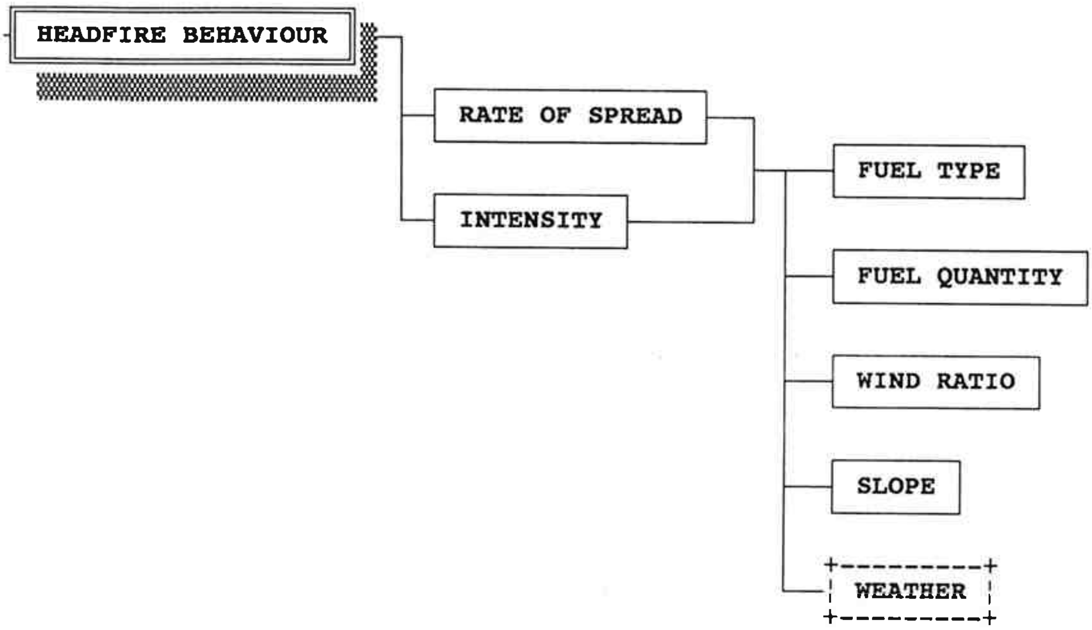
TABLE 6

FIRELINE CONSTRUCTION RATE CLASSES

		Line Spacing	Hatch Dir
DIFFICULT CONDITIONS :		**2.25mm**	**90°**
Area poorly roaded. Off road access difficult (heavily timbered, dense scrub, steep slopes, creeks and gullies).			(Horizontal)
Time for single unit (machine/crew) to produce 1000m fireline	> 2.5 hrs.		
MODERATE CONDITIONS :		**4.9mm**	**90°**
Access moderate, moderately open forest, moderate scrub density, gentle slopes.			
Time for single unit (machine/crew) to produce 1000m fireline	1.6 - 2.5 hrs.		
STRAIGHTFORWARD CONDITIONS :		**8.0mm**	**90°**
Area well roaded. Off road access easy, open country, flat.			
Time for single unit (machine/crew) to produce 1000m fireline	0.5 - 1.5 hrs.		
EASY CONDITIONS :		**Leave blank**	
Open, groomed paddocks. Flat or gently undulating terrain.			
Time for single unit (machine/crew) to produce 1000m fireline	< 0.5 hrs.		

PREPARING MAP 4 - HEADFIRE BEHAVIOUR

Headfire behaviour determines the suppression action crews can take in fighting a fire. It is a function of fuels, weather and topography. The relative importance of each factor at any point can be readily seen if theme overlays are prepared as follows:



The Headfire Behaviour is mapped in classes that have practical application (Table 7). The limits of these classes based on both published and unpublished research findings, and experience. References include H.G. Styles (pers. comm.), L McCaw (pers comm), the limits for direct attack quoted by Loane and Gould (1986), McArthur (1972) and Wilson (1988). These limits represent the best planning information currently available, but may be modified if proved incorrect or better information becomes available.

Despite the direct relationship between headfire rate of spread (HFROS) and the fireline intensity (I) of the headfire (Byram, 1959) both are considered as either may be a limiting factor in particular circumstances.

Calculating Headfire Rate of Spread and Intensity

The fuel type will determine the fire behaviour model used to calculate the HFROS. Fuel models are now available for forest, grass, hummock grass and mallee heath. The latter two have not been widely tested. If none of the existing models adequately suit the particular fuel types, the fire behaviour classes should be assigned on the basis of local experience.

HFROS can be calculated from tables and meters, but this is more rapidly done using the 'FIRE' program (Muller, 1990). This program and User Manual were distributed to all Forest Districts in 1990. The program has been updated to include McCaw's preliminary findings from his shrubland fire research, and is appended to this manual. The program and GIS use the same equations, and have been written in a format that will allow new models to be added as they are developed.

Whether using tables or the FIRE program, the work of preparing or updating the fire behaviour map can be minimised by using a systematic approach. The combined map overlays can result in many polygons (areas) with different combinations of fuel type, fuel quantity, wind ratio and slope. All combinations can be rapidly calculated by the FIRE program, creating a large output. Rather than try to identify individual polygons to which to relate the figures, it is recommended that the limiting values for each class first be identified. Classification then becomes rapid.

Because little of the research on which fire behaviour tables are based has been carried out at under severe conditions, the application bounds of the tables may be exceeded. This is highlighted in the FIRE program, and where this occurs is to be noted on the map and in the WTA book. This information is automatically tracked and displayed on the GIS produced maps.

Separate maps may be produced for HFROS and Intensity if required. If the Fire Behaviour map is produced manually using tables rather than the FIRE program, it is easier to first produce the HFROS map, and then calculate the intensity from the following expression:

$$I = 0.47 \times HFROS \times W$$

where	I	= Intensity	kW/m
	HFROS	= headfire rate of spread	m/hr
	W	= weight of fuel consumed	tonnes/ha

Where Headfire Rate of Spread and Headfire Intensity maps are prepared as separate maps for display, the classes and hatching are the same as the values shown in table 7.

TABLE 7

HEADFIRE BEHAVIOUR CLASSES

	Line Spacing	Hatch Dir
Indirect attack unlikely to succeed Intensity > 3000 kW/m in forest Intensity > 8000 kW/m shrubland and grassland	1.4 mm	180^{o} (Vertical)
Direct attack not possible/unlikely to succeed. Intensity > 2000 kW/m and/or ROS > 400 m/hr in forest Intensity > 2000* kW/m and/or ROS > 1000 m/hr in shrubland Intensity > 5000 kW/m and/or ROS > 6500 m/hr in grassland	2.25mm	180^{o} (Vertical)
Machine and tanker attack possible Intensity < 2000 kW/m and/or ROS < 400 m/hr in forest Intensity < 2000* kW/m and/or ROS < 1000 m/hr in shrubland Intensity < 5000 kW/m and/or ROS < 6500 m/hr in grassland	3.6 mm	180^{o} (Vertical)
Hand tool attack possible Intensity < 800 kW/m and/or ROS < 140 m/hr) in forest and shrubland Intensity < 800 kW/m and/or ROS < 300 m/hr in grassland	6.4 mm	180^{o} (Vertical)
Readily suppressed. Intensity < 800 kW/m and/or ROS < 60 m/hr in all fuels	8.0 mm	180^{o} (Vertical)

* This assumes fire requires fireline construction to provide access to tankers, and the same limits as for forest apply. Where access permits direct attack with water, this should be 5000 kW/m applies.

Supporting Data for Fire Behaviour Map

The spatial data to be collated depends on the requirements of the fire spread models being applied. As previously noted, the actual value of the data is recorded and used in calculations, with grouping into classes deferred until required to provide visual displays. The source and reliability of the data is to be recorded in the WTA book. In the GIS the reliability of all data is tracked and recorded on each map.

Map 4.1 - Fuel Type

Fuel type determines the fire behaviour model which will be applied. Standard vegetation (eg Beard, Smith) or API (aerial photo-interpretation) maps are used to identify the vegetation types. to which fuel models are assigned. Table 8 is a guide to the application of the fuel models.

TABLE 8

FUEL MODELS ASSIGNED TO VEGETATION CLASSES

Karri 1/2[#]	**Karri 3/6**[#]
Pure Karri (SFR)	MJK ,KMJ, JMK (SFR)
Karri (SFR)	Marri (SFR)
	Karri/Yellow Tingle
Karri 4/5[#]	Yellow Tingle/Karri
Karri/Marri	Karri/Red Tingle
Marri/Karri	Red Tingle/Karri
Karri/E muellerana	Karri/Rates Tingle
All Karri (CFR)	Warren River Cedar
Southern Jarrah[#]	**Northern Jarrah**[#]
HR Jarrah[*]	Jarrah[*]
HR Jarrah/Marri[*]	Jarrah/Marri[*]
HR Marri/Jarrah[*]	Marri/Jarrah[*]
Red Tingle/Jarrah	Jarrah (+Marri,Yate,Bullich,Blackbutt)
Jarrah/Red Tingle	Wandoo (inc. Paperbark, Scarp Wandoo)
HR Yate, Bullich, Blackbutt[*]	Peppermint, Dune Vegetation
HR Exotic eucalypts, E muellerana[*]	Mallet
Pinaster[#]	**Radiata**[#]
P. pinaster plantations	P. radiata plantations
Grassland[##]	**Shrubland**[***]
Tuart[**]	Northern Coastal Woodland
Pasture	Mallee Heath
Swamps	Heath
	Non-forest, scrub, flats.
Hummock Grassland[****]	
Spinifex	
Hummock Grasslands	

Table footnotes continued next page ....

Table 8 ctd.

Models as per the Forest Fire Behaviour Tables (Sneeuwjagt & Peet, 1985).

WA Grassland Meter / McArthur Grassland Meter Mk III

* Classified Southern Jarrah if rainfall >1100 mm pa, (HR=high rainfall), otherwise Northern Jarrah

** Grass model used with Tuart (with wind ratio applied) as most has grassy understorey. Apply Northern Jarrah model if this is not the case.

*** Shrubland model not yet published. Interim equation (McCaw, pers. com.) used in programs. An approximation is HFROS = wind speed x 100 m/hr provided fuels below threshold SMC (7-8%).

**** The grassland model should be used where there is a continuous sward as after heavy rain.

Map 4.2 - Fuel Quantity

Fuel quantity is required to calculate the headfire rate of spread (HFROS) for forest fire models, and its intensity (I) for all fires. In many cases the fuel quantity will be derived from fuel age maps. Fuel accumulation rates used to determine the fuel quantities are to be verified by comparison with fuel sampling carried out for prescribed burning in the area. The year and estimated (or actual where sampled) fuel quantity for each area should be written on the fuel age plan. Details of how fuel quantities were determined must be recorded in the WTA book.

Table 8 provides a useful format to generate visual displays where the contribution from each component is to be portrayed.

TABLE 9

FUEL QUANTITY DISPLAY CLASSES

Fuel Quantity:		**Line Spacing**	**Hatch Direction**
>40	tonnes/ha	1.4mm	180^{o}
29 - 40	"	2 mm	(Vertical)
20 - 29	"	2.6mm	"
14 - 20	"	4 mm	"
10 - 14	"	5 mm	"
6 - 9	"	8 mm	"
< 6	"	16 mm	"

Map 4.3 - Wind Ratio

Standard wind forecasting and recording is for a 10m tower in the open. For all practical purposes this is considered to be about the same as the tower wind recorded 15m above a forest canopy (provided this is beyond the 'edge effect'), and the guide in the Forest Fire Behaviour Tables for WA (FFBT) can be applied.

The FFBT is based on empirical data derived from wind speed measured at 1-2m above ground. Wind ratio is an estimate of the reduction in ground wind speed compared with tower wind speed due to friction, which varies with the vegetation type.

The equations used to calculate HFROS in both the "FIRE" program and the GIS for both grass and forest fuels have been written for ground winds, therefore wind ratios must be mapped. In the GIS wind ratio is modelled from old API data, cutting history, and subsequent stand growth modelling. It is printed for checking in the classes shown in table 9.

TABLE 10

GUIDE TO WIND RATIOS

		Wind Ratio	Line Spacing	Hatch Direction
Open Grassland		1.33 : 1	1.4 mm	135^{o}
Flats, low coastal heath		2 : 1	1.4 mm	135^{o}
Mallee Heath Shrublands		2.5 : 1	2.25mm	135^{o}
Jarrah, Wandoo,	30% canopy, ridge	3 : 1	2.25mm	135^{o}
Jarrah, Wandoo	30% canopy, lower slopes	4 : 1	3.6 mm	135^{o}
	60% canopy, ridge	4 : 1	3.6 mm	135^{o}
	60% canopy, lower slopes	5 : 1	4.9 mm	135^{o}
Thinned Pine Plantations		4 : 1	3.6 mm	135^{o}
Southern Jarrah		5.5 : 1	4.9 mm	135^{o}
Karri 3 & 6, unthinned pine plantations Eucalypt plantations		6 : 1	6.4 mm	135^{o}
Karri 4 & 5		7 : 1	6.4 mm	135^{o}
Karri 1 & 2, Karri regrowth		9 : 1	8.0 mm	135^{o}

Map 4.4 - Slope

Slope is recorded in the GIS in one degree classes. For display or manually prepared maps it is portrayed in five degree classes as in table 9.

TABLE 11

SLOPE CLASSES

		Line Spacing	Hatch Direction
Slopes < 2.5°		Leave blank	45°
Average Slope 5°	(2.6° - 7.5°)	8.0 mm	45°
Average Slope 10°	(7.6° - 12.5°)	6.4 mm	45°
Average Slope 15°	(2.6° - 17.5°)	4.9 mm	45°
Average Slope 20°	(17.6° - 22.5°)	3.6 mm	45°
Average Slope 25°	(22.5° - 27.5°)	2.25mm	45°
Slopes > 27.5°		1.4 mm	45°

Map 4.5 - Weather

Weather inputs are not normally mapped because:

* the size of the areas involved in each analysis is usually sufficiently small to assume the weather parameters are reasonably uniform across the area, and

* there are too few recording stations and insufficient data available to interpolate.

Where these two factors do not apply, the spatial variation should be mapped and the weather parameters relevant to the particular site are used in the fire behaviour calculations. In all other cases the same weather parameters are applied across the area. (See previous note on 'The Use of Percentile Weather Conditions).

ACKNOWLEDGMENTS

The Wildfire Threat Analysis system evolved over a period of time, and numerous people have contributed, including the following:

R Underwood provided the initial impetus and ongoing policy support for the WTA system.

C Schuster identified the need for and initiated a rating system for prescribed burning.

N Burrows, I Herford, and K Vear drafted the initial approach with C Muller, particularly the difficult task of the initial "Values" ratings.

P Bowen provided valuable assistance in project mapping.

J Beck developed the equations for the Forest Fire Behaviour Tables (Sneeuwjagt and Peet, 1985) that made the programs possible, and produced map algebra tools to enable modelling within FMIS (Beck, 1990).

B Snowdon investigated the application of Beck's general modelling and map algebra tools to automate the production of WTA theme maps.

J Vodopier has written the programs for the GIS version of the WTA System.

The many District and Regional and Protection Branch officers who have made valuable contributions both in compiling data and providing feedback.

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APPENDIX 1

SUMMARY OF INFORMATION REQUIRED FOR GIS WILDFIRE THREAT ANALYSIS

SUMMARY OF INFORMATION REQUIRED FOR GIS WILDFIRE THREAT ANALYSIS

	Display Requirements	Data/Analysis Requirements
Map 1 MAJOR VALUES	* Values to be identified as to type (eg. recreation camp) by symbol. * All values belonging within group to be identified by colour. * Buffer zones generated around values shown by hatch (45^{o} from vertical).	* Location of defined values. The "Classification of Values" attached) is indicative, not exhaustive. Additional values may be defined for particular areas.
Map 2 RISK OF IGNITION	* Risk classes shown as horizontal hatch.	* Statistical (non GIS) information on fire causes. * Ignition history - a GIS data base to be established and maintained annually to record location and cause. * Geographic location of activities.
Map 3 SUPPRESSION RESPONSE	* Suppression base (work centre). * Time zones (hatch 135^{o} from vertical - NW-SE).	(* Derived from maps 3.1, 3.2, 3.3.)
3.1 Wildfire Detection	* Hatch (45^{o}) in nominated time zones.	* "Contours" of seen areas and levels below seen area (eg. areas 20m below line of sight, 40m below etc.) based on detection system (towers, spotter aircraft, land-holders).
3.2 Travel Time	* Hatch (135^{o}) in nominated	* Road classification for <u>all</u> time zones roads and tracks (incl. non-maintained). * Terrain classification: Slope, vegetation, soil type, streams, swamps. * Network analysis of road and track system.

SUMMARY OF INFORMATION REQUIRED FOR GIS WILDFIRE THREAT ANALYSIS Continued ...

	Display Requirements	Data/Analysis Requirements
		* Buffer generation (dependant on terrain class) from points at short time intervals along road/track network. (ie. total time to a buffer boundary requires optimising the travel time along road system plus off-road travel.)
3.3 Fireline Production	* Hatch (horizontal) in nominated time zones.	* Terrain classification (data as required in 3.2).
Map 4 HEADFIRE CLASSIFICATIONS	* Hatch (vertical) in suppression difficulty classes. * Weather inputs.	* Derived from 4.1 and 4.2.
4.1 <u>Headfire Rates Of Spread</u>	* Hatch (vertical) in defined classes. * Weather inputs.	* Calculated from data in 4.3.1 - 4.3.5 by equations supplied (see Appendix 2). These may be replaced if future approved fire spread models are derived.
4.2 <u>Headfire Intensity</u>	* Hatch (vertical) in defined classes. * Weather inputs.	* Calculated from data in 4.3.1 - 4.3.5 by equations supplied.
4.3.1 Fuel Type	* Hatch (horizontal) type classes as defined.	* Vegetation map.
4.3.2 Fuel Quantity	* Hatch (vertical) in nominated classes.	* Vegetation type. * Year last burnt. * Crown cover (density). * Co-dominant vegetation height (tree, shrubland or grass) OR * Direct input of fuel quantities where known.
4.3.3 Wind Ratios	* Hatch (135^{o}) in defined ratio classes.	* Crown cover (density). * Vegetation height.

SUMMARY OF INFORMATION REQUIRED FOR GIS WILDFIRE THREAT ANALYSIS
Continued ...

	Display Requirements	Data/Analysis Requirements
		* Exposure (ridge, slope, gully).
4.3.4 Slope	* Hatch (45^{o}) defined slope classes.	* Slopes.
4.3.5 Weather	* Not normally a separate map display but conditions identified in 4.1 and 4.2.	* Long term weather and SMC records. (non GIS)

* Footnote: Some of these may in turn be derived from other data, eg crown cover may be derived from API (aerial photo interpretation) type mapping, subsequent logging history and growth models.

APPENDIX 2

RATING SYSTEM FOR PRESCRIBED BURNING.

RATING SYSTEM FOR PRESCRIBED BURNING.

(Revised July 1993)

		Index Value
1. Fire Protection Values.		
Factor 1.1:	**Values at or Near Sites.**	
	(Site is defined as the area proposed for prescribed burning.)	
	A. Within Wildfire Threat Analysis (WTA) values zone category 1	80
	B. Within WTA values zone category 2	50
	C. Within WTA values zone category 3, or within 3 km of WTA values zone 1	30
	D. Within WTA values zone category 4, or within 3 km of WTA zone category 2	20
	E. Within WTA values zone category 5, or within 3km of WTA zone category 3	15
Factor 1.2:	**Risk of Ignition. (As per WTA maps)**	
	A. High Risk areas within burn	30
	B. Moderate Risk areas within burn	15
	C. Low Risk areas within burn	5
Factor 1.3:	**Suppression Response. (As per WTA maps)**	
	A. Within Poor response zone	40
	B. Within Slow response zone	30
	C. Within Moderate response zone	20
	D. Within Rapid response zone	10
	E. Within Immediate response zone	0
Factor 1.4:	**Fuels/Fire Behaviour. (Refer WTA maps)**	
	A. Category 1 - indirect attack unlikely to succeed	80
	B. Category 2 - direct attack not possible	60
	C. Category 3 - machine attack possible	30
	D. Category 4 - hand attack feasible	10

Index Value

Factor 1.5: **Strategic Value of Burn.**

To stop the run of major fires, strategic fuel reduction in forest fuels should be planned to be 3 km wide. Small burns (hand-burns) would thus not normally rate under this factor.

When considering potential fire run, include all uncleared land, irrespective of tenure.

A.	Burn forms part of a strategic buffer or will break up a major fire run of >15 km (including private property) in fuels older than half rotation length.	60
B.	Burn will break up a fire run of 10-15 km in fuels older than half rotation age.	30
C.	Burn will break up a fire run of <10 km in fuels older than half rotation age.	10
D.	No strategic value.	0

2. Other Management Values

Factor 2.1: **Dieback Impact on Site of Potential Fire Suppression activities.**

A.	High.	20
B.	Moderate.	10
C.	Low.	0

Factor 2.2: **Compliance with Other Departmental Objectives.**

Burn is required to meet objectives other than fire protection (eg advance burn, habitat management), or the timing of a fire protection burn affects another operation. (eg dieback photography program).

A.	Burn is a <u>critical</u> prerequisite for another operation	40
B.	Burn is an <u>important</u> prerequisite for other objectives.	20
C.	Burn is a <u>desirable</u> prerequisite for other objectives.	10
D.	Burn has <u>minor</u> significance for other operations.	0