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FIRE MANAGEMENT ON CALM LANDS IN THE SOUTH-WEST OF WESTERN AUSTRALIA

CALM*fire* Branch
DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

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CHAPTER 1

INTRODUCTION

The bushfire hazard in the south-west of Western Australia is arguably potentially more severe than in any other region of the world. This is because the south-west of Western Australia is the only region in the world that has extensive tall forests, which shed tonnes of highly inflammable material each year, and a Mediterranean climate. That is a climate which produces every year a three to six month drought with periods of high temperature and low humidity. The summer drought is also a period of frequent high winds generated by unstable frontal movements, deep coastal troughs and strong sea breezes.

Fire is a naturally occurring element of south-west ecosystems. To the vegetation and the native animals, it is simply a powerful disturbance factor from which, in time, the natural systems recover. The plants and animals have evolved in the presence of regular fire occurrence. Fire can also be an agent of death and destruction to human assets and values and large fires are extremely costly to the community.

Every year about 300 bushfires start on the public lands managed by CALM in the south-west of Western Australia. Every year, conditions occur under which some of these fires, if allowed to run, burn so fiercely as to be uncontrollable, even by well-equipped and highly trained firefighters. Every year, wildfires threaten or damage human life, property, environmental and ecological values and economic resources. Every year, CALM staff and volunteer firefighters are expected to stop the seemingly unstoppable - to protect the community and its valued assets from the ravages of intense summer bushfires in the forests, woodlands and heaths of the south-west.

Every year, debate about CALM's approach to fire management also surfaces. For just as fire is one of the greatest and most awesome of natural forces, so "fire management" (especially the use of fire to fight fire) is one of the most complex issues which land managers must deal with.

There are three fundamental responses CALM could take in response to the threat posed by bushfires.

- <u>The Suppression Approach</u>

  Here, firefighters prepare for fire through training and provision of special equipment, wait for fires to start, and then go out and try to suppress them. This is the traditional approach taken in most urban and agricultural areas and by land managers in many parts of Europe and North America. It works when fires are accessible and relatively mild, or where few fires occur simultaneously, but it fails when intense fires develop under adverse weather conditions. It is sometimes dictated, when resources are unavailable for preventative work, or where there is insufficient technical know-how to undertake such work.

- The Suppression Plus Prevention Approach

  Here firefighters, in addition to maintaining an effective suppression response, seek to mitigate potential fire behaviour by fuel reduction under controlled conditions and other preventative measures. This approach greatly improves the ability to handle fires under severe weather conditions or when there are many simultaneous fires and is the approach adopted for forest areas in Western Australia.

- Let burn Approach

  A do-nothing approach, of simply letting fires run and trying to pick up the pieces afterwards. This is not a morally responsible or legally desirable approach. This has never been seriously considered for application in the south-west forests of Western Australia.

Both the first two strategies have been tried in Western Australian forests. The second approach was adopted following the failure of the first, in the years before 1961. It involves the deliberate use of fire for fuel reduction (in a process known as prescribed burning) in strategic areas of the forest, together with the maintenance of a highly effective fire detection system and the deployment of well trained and equipped firefighters throughout the south-west. No practical way of fuel reduction in Western Australian forests other than prescribed burning has yet been developed.

Fire is also used as a tool for forest management:

- Ecological management where planned fires are used to maintain and enhance nature conservation values (eg: habitats, restoration, biodiversity, etc) and ecological processes (eg: nutrient cycling) and life support systems.
- Regenerating the forest and understorey vegetation associations. In many cases, planned burns are undertaken to achieve both protection and ecological management objectives by varying the seasons, fire intensities, and the intervals between fire.

CALM has a legal and moral responsibility to ensure that the public land which it manages does not pose a threat to human life and property as a consequence of uncontrolled wildfires. But the Department also has the responsibility of ensuring that the ecosystems on this land are sustained and that public use for a variety of purposes is optimised.

CHAPTER 2

BACKGROUND

Any consideration of bushland fire must start with the three elements of "the bushfire triangle": weather, fuel and sources of ignition. These elements are examined below in the Western Australian context.

2.1 Fire Weather

The climate of south-west Western Australia is strongly Mediterranean, ie. comprises a cool, wet winter, followed by a warming and drying trend into spring, a hot and very dry summer, which in turn is followed by a cooling, dry autumn which is broken by the onset of winter rains. The "fire season" at Collie, for example, in the centre of the forest zone, normally runs, from about mid-October to mid-April, although fires can and do occur occasionally in the winter months in all but the wettest of the south-west forests.

The south-west fire season is predictably hot, dry and windy. Some summers are hotter and drier than others, but there is never a summer in which hot, dry conditions do not occur. Similarly, the onset of the winter rains in about May can be relied upon every year to signal the end of the fire season for several months. Unlike the south-east of Australia (Victoria and Tasmania) which experience occasional drought, leading, to severe summer bushfire problems, the south-west of Western Australia experiences drought every summer.

Four consistent features dominate fire weather during the south western fire season:

- The regular passage of a series of high pressure systems from west to east across the southern half of the continent. These generate 7-10 day cycles of increasingly hotter weather, with dry continental easterly winds backing into the north and north-west; after a few days these conditions are terminated by a cold front bringing a cool change, and south-westerly and south-easterly winds, and the cycle recommences.
- On average, seven or eight times each summer, the eastward movement of an anticyclone is blocked by stationary air masses in the Great Australian Bight. An intense low pressure trough then forms between the stationary high and the next incoming high. Occasionally this occurs at a time when there is a cyclone off the coast in the, north of the State and the interacting systems produce gale-force north-easterly and north-westerly winds funnelling bone-dry air out of the centre of Australia into the south-west. This has occurred twice in the south-west in recent years – during Cyclone Alby in 1978 and Cyclone Fifi in 1991.
- Thunderstorms occur regularly in the south-west region during the summer months. These frequently generate lightning which start fires in bush lands and forests. Apart from occasional rain from thunderstorms or light showers associated with a cool change, the summers in the forest areas are generally rainless. Lightning has been the source of some of the most destructive fires which have occurred in Western Australian forests, including the worst fires in 1961.

- The vegetation, downed timber and the upper soil layers of the bush all progressively dry out as spring and summer progress, culminating at a point in autumn before the first rains. This drought (or cumulative fuel dryness) factor significantly affects fire behaviour - the drier the fuels the more easily they ignite and the more intensely they burn. This drought also affects the difficulty of fire suppression, and overlays the day-to-day factors such as temperature, wind speed and relative humidity.

The typical Progression of Key Fire Weather Parameters over Summer Months in Perth is shown in Table 1.

Table 1. Perth Weather Conditions

Month	Av. Max T (°C)	Day >35°C	Rain (mm)	Rain Days	Sunshine hrs/day
September	20.0	0	68	13	7.4
October	22.3	0	48	10	8.8
November	25.4	1	26	7	9.9
December	28.5	4	12	4	10.7
January	31.5	9	8	3	10.7
February	31.7	7	14	3	10.2
March	29.5	4	15	4	9.1
April	25.2	0	46	8	7.3
May	21.4	0	108	13	6.0

* Data supplied by Bureau of Meteorology

Tropical cyclones also have figured prominently in the weather records of the south-west of Western Australia, occurring on average every six years or so. Cyclones that inflicted major damage (including that associated with bushfires) occurred in 1843, 1872, 1915, 1937 1943, 1956, 1960, 1961, 1978 and 1991).

Summary: ***Land managers in south-west Western Australia must take into account that there will be a fire season every year without fail; that there will be regular warming and cooling cycles throughout the summer, some of which develop into extreme fire weather conditions of prolonged heatwave and strong winds; that there will be natural sources of fire in the form of lightning; and that there will be a progressive curing of bushland fuels peaking in late summer or autumn.***

2.2 Fuels

The amount and rate of heat release, or the intensity of a fire, is an indicator of its damage potential and suppression difficulty. Fuel, consisting of ground litter, twigs, bark, sticks and live and dead vegetation, is the energy source of a bushfire. The amount (or tonnage) of fuel consumed and the rate of combustion directly affect the intensity of the fire. The greater the tonnage of fuel and the higher the rate at which it burns, the more intense the fire will be.

Of all the elements of the bushfire triangle, fuel is the only one which can be managed.

Bushland in south-west Western Australia has three important characteristics in relation to its capacity to fuel a fire:

- The vegetation itself is highly flammable. Leaves of most common species of trees and shrubs contain waxes and volatile oils which ignite easily and burn fiercely. As shrubs age, a greater proportion of the foliage dies and comes to consist of flammable, aerated fuel.
- Fine, flammable dry matter, such as leaves, twigs and bark, (collectively known as "litter") is constantly shed from living plants and accumulates over time. In the absence of fire, forest floor litter continues to accumulate. Figures 1 and 2 show the litter accumulation that occurs over 40 years in karri forest stands.
- Many tree species (eg:. jarrah, marri, tingle, blackbutt) have stringy or fibrous bark which can be carried aloft as burning brands and embers in high winds, setting spot fires ahead of the main fire. "Spotting" and "hopovers" are very common features of West Australian forest fires, and are nearly always associated with heavy, dry fuels. They can extend hundreds of metres (sometimes kilometres) from the main fire edge, rendering useless narrow firebreaks , buffers or control lines.

The vegetation and litter in a forest becomes fuel when ignited. This fuel can burn in three different ways: (i) in a mild creeping, fire, where the flames are confined to the dry leaves and twigs lying on the forest floor and to ephemeral grasses; (ii) a more intense fire with flames up to eight metres in height, which will consume the ground litter and the shrub layer and mildly scorch the tree canopy; and (iii) a high intensity fire which "crowns" – ie: the fire leaps into the upper branches of the tall trees, and flames can be up to one hundred metres in height. A crown fire consumes all green and dry leaves in the tree and shrub layers and the litter, leaving only the large woody trunks standing. Under the same weather conditions, the higher the levels of fuel, the more intense the fire and the greater the likelihood of a fire moving from a creeping ground fire to a crown fire. Even under extreme weather conditions, a crown fire will not develop in areas of light fuels. This was demonstrated during the Dwellingup fires of 1961.

Crown fires in tall forest country cannot be directly attacked with current technology.

Preliminary findings from the national fire behaviour research study (Project Vesta) conducted in jarrah forest indicates that fire burning in heavy, dry fuels can increase dramatically when wind speeds increase above 15 km/hr. Lines of fires longer than 100 metres will burn at their potential rate of spread within 2 to 4 minutes after a wind change.

Summary: ***West Australian bushland carries or generates high levels of potential fuel for a fire. In forest areas this fuel progressively dries during summer months and in the absence of fire, accumulates for many years. Heavy, dry fuels contribute significantly to fire intensity and can lead to the development of crown fires, which are uncontrollable.***

Figure 1 Predicted accumulation of forest floor litter based on measured rates of litterfall and decay constants for ten karri forest litter fractions. Accumulated understorey litter fractions have been grouped for clarity.

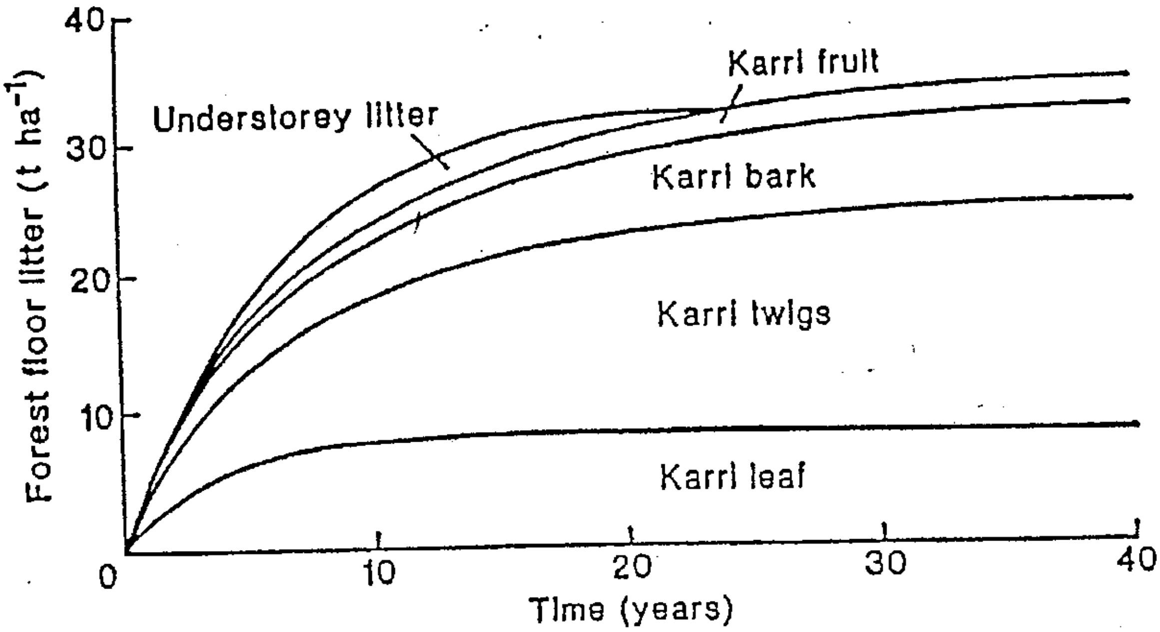
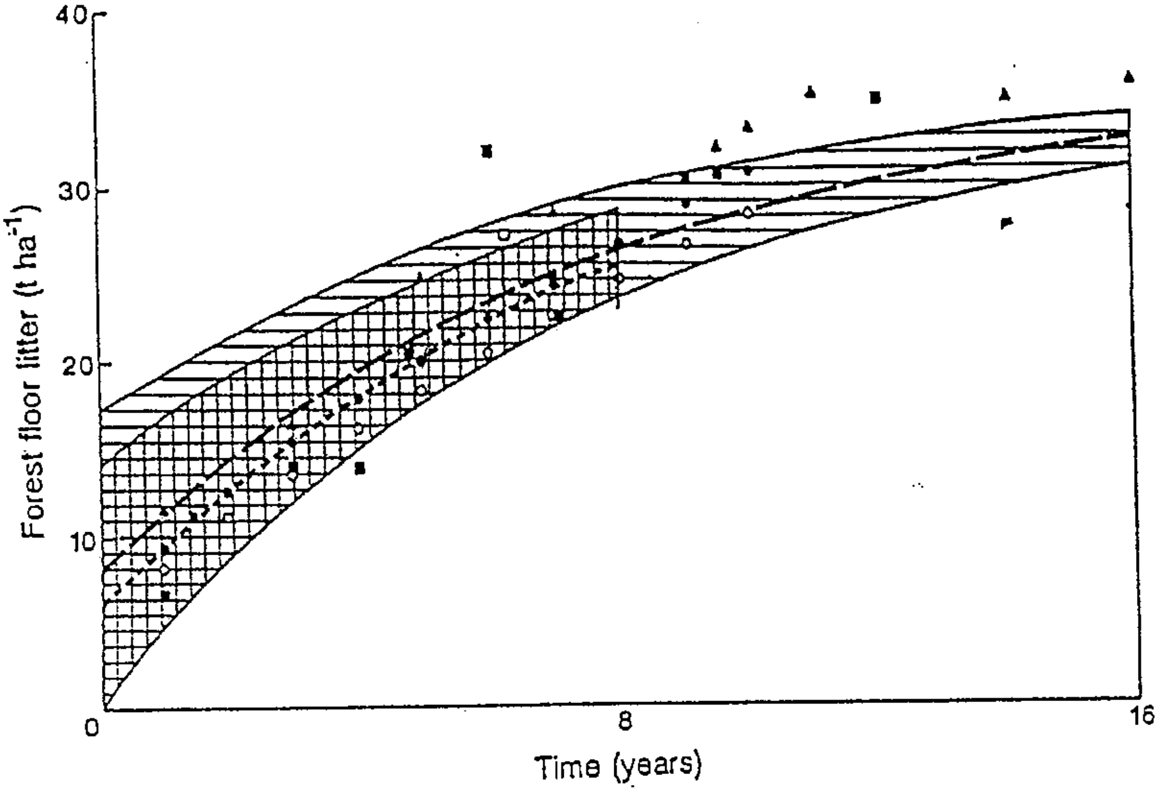


Figure 2: Comparison of predicted and measured litter accumulation in karri stands



Predicted range of forest floor mass in relation to time of accumulation for karri stands burnt with fires which are assumed to consume between 50% and 100% of each of the litter factions. Measured values of accumulated litter from the following sources:

(■) O'Connell 1987; (⌶) Hingston *et al.* 1979; (O) Peet 1971 - 70% canopy cover; (•) Peet 1971 - 80% canopy cover. (∇) Loneragan 1961.

From O'Connell (1991).

2.3 Sources of Fire

There are two primary sources of ignition for bushfires: lightning and humans. Both sources have been features of the West Australian landscape for thousands of years.

Lightning is usually associated with thunderstorms, and these occur in every month of the year in the south-west, most frequently in winter, but with most devastating effect in summer. As soon as fuels on the forest floor begin to dry out as spring progresses, the chance of bushfires starting from dry lightning strikes rises.

Data are available on fire starts from lightning in south-west forests. Figure 3 shows the occurrence of lightning and human-caused fires in the jarrah forest over the past 11 years. Although the frequency of lightning-caused fires varies a great deal from year to year, on average, firefighters can expect about 35 bushfires caused by lightning in south western Australian forests every summer.

Humans are responsible for about 90 percent of all fires in Western Australia. Some fires are accidental (escapes from prescribed burning, camp fires etc.) but most are deliberate lit. In recent years arson has been the most rapidly-increasing source of fire in Western Australia, as it is world-wide. Deliberate fire lighting frequently occurs under severe fire weather conditions, and arsonists often select the most difficult areas in which to operate.

Fire causes in Western Australian forests over the last ten years by percentages are shown in Table 2.

Table 2. Causes of Wildfires Attended by CALM Fire Crews (percentages) 1989 to 1999

Cause	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99
Deliberately lit	45	49	41	52	45	38	33	29	37	49
Escapes from other burns	17	12	8	8	9	8	11	7	9	8
Accidental – Recreation (hunters, fishers etc)	7	6	5	7	9	6	7	9	5	5
Accidental – other land	5	7	4	8	4	7	5	8	7	4
Lightning	12	11	26	10	9	13	12	13	11	12
Escapes from Dept. prescribed burns	7.5	6	5	3	5	4	5	4	5	1
Unknown	10.5	8	8	9	14	18	19	23	22	17
Miscellaneous other Causes	1	1	3	3	5	6	8	7	3	4

Summary: ***There will always be abundant uncontrolled ignitions in the south-west of the State even if human caused ignitions, which the evidence indicates are increasing, could be eliminated.***

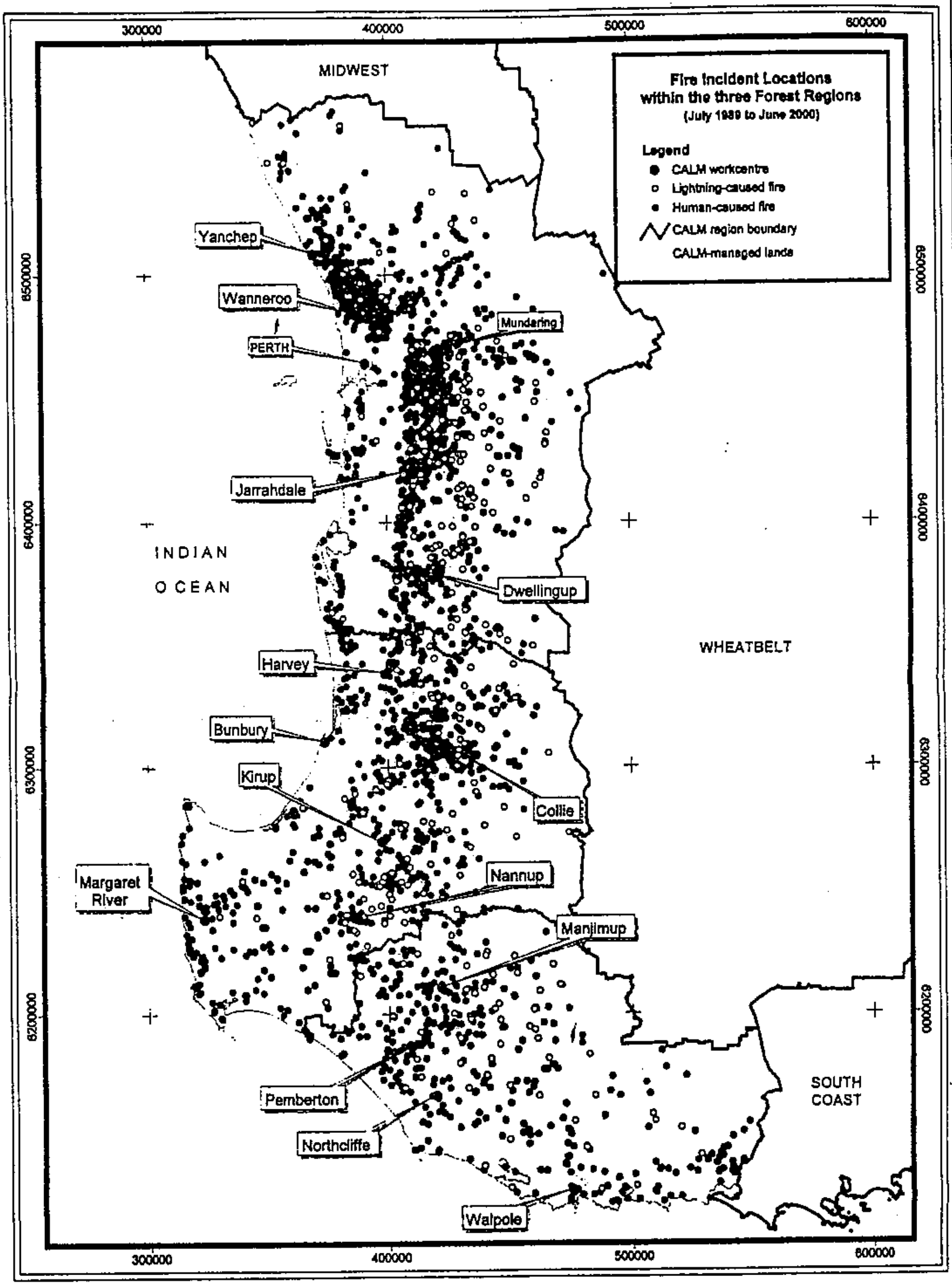


Figure 3. Southwest forests showing ignition sources within or close to CALM-managed lands (July 1989 to June 2000).

2.4 Early Fire Policies

Although bushfire ordinances were passed in the mid 1800s, there was little attempt to tackle the fire problem in the south-west until after the passage of the Forests Act in 1918 and the establishment of the Forests Department in 1919.

The development of bushland fire policy saw opposing forces in conflict over the use of fire from the very beginning. Many of the European-trained professional foresters who were appointed to the new Forests Department were opposed to prescribed burning; field foresters with long experience in the Australian bush were in favour of it.

During the 1920s and 1930s fire management involved:

- Subdivision of the forest into areas which had been cut over for timber and regenerated, and those which had not. The former were completely protected from fire. Some prescribed burning, mainly "firebreaks" (narrow strips of forest between two tracks), was undertaken in the remainder of the forest, but most of it simply burnt from time to time in wildfires, at least in the early years.

- The development of the infrastructure for fire management: forest headquarters, fire lookouts, communications systems, maps, roads, training and liaison with neighbours were all put into place.

- Programs of community education, plus law enforcement helped to reduce illegal or irresponsible fire lighting.

The policy of restricting the use of broad scale burning and improved fire suppression saw heavy fuels accumulating in most forest areas by the 1940s. From the late 1930s onwards, fires had started to become very large and difficult to control. There were major fires in the jarrah forest in 1949/50 (Wallace, 1965) and in the jarrah and the karri forests in 1937 and in 1950/51. In the long protected compartments fires became uncontrollable once they exceeded about a hectare in size, even under quite mild weather conditions.

Also at about this time there were massive fires in the southern forest national parks, notably the Walpole-Nornalup Park and adjoining areas, where whole hillsides of karri and tingle trees were killed. The remnants of these dead trees, and the regrowth forests which developed under them, can still be seen near Nornalup today.

In 1953 there was a change in Forests Department policy and broadscale prescribed burning for fuel reduction was introduced. Because of the massive fuels in most of the areas to be burnt, implementation of the policy was cautious and slow at first. Most of the initial burning in the northern jarrah forest was actually done in winter. There were also technical deficiencies, especially lack of fire behaviour information on which to base burning prescriptions, and a lack of trained staff to undertake the work. Little effective burning could be undertaken in the dense southern forests, principally because of lack of access and problems with predicting fire behaviour in complex karri and karri-tingle fuels.

The early development of fire policies and their implementation is summarised by McCaw and Burrows (1989).

2.5 The Dwellingup Watershed

The culmination of early fire policies for West Australian forests came in the summer of 1960/61. Massive fires swept through the forests of the south-west. The town of Dwellingup was burnt, as were the smaller settlements of Holyoak, Nanga Brook and Karridale. There were serious losses of pasture, stock and fencing. Fortunately no one died in the fires, but many were injured, and the cost to the community was enormous.

A brief summary of the fires in 1961 is given in Stewart (1969), from which the following, extract is taken:

> *........ after weeks of hot dry weather, on a "dangerous" day on 19 January with a temperature of 104°F, a series of lightning strikes occurred between 5.30 and 6.00pm dispersed over some 20,000 hectares of State forest within 15 to 32 kilometres of Dwellingup. Six fires were reported that evening and a further four between 5.15 am and 1.15pm the following day. Strikes also occurred in Gleneagle and Harvey Divisions.*
>
> *Gangs were promptly despatched and most fires were held, but by the time the tenth fire erupted, about 1.15pm on 20 January in century temperatures with an easterly wind, all gangs were committed. It was out of control before emergency forces could launch an attack, and made a run of six kilometres by 6.00pm, throwing spot fires ahead. That night a further series of lightning strikes occurred in Dwellingup, Collie and Harvey Divisions, thus requiring retention of forces in the two latter Divisions which could otherwise have assisted at Dwellingup.*
>
> *Despite reinforcements from southern divisions, timber industry personnel* and *farmers, there were insufficient resources over the* next *few days to* contain the *numerous outbreaks which eventually linked into one vast burn with an extremely long and irregular perimeter. With 'dangerous' weather again on Tuesday 24, a temperature of 106°F and freshening wind from the north and* north-west, many *breakaways occurred and units were recalled* to *Dwellingup for regrouping.*
>
> *The wind had dropped towards evening and with a fire front two miles north of town. forces were deployed on threatened flanks and throughout the village although no immediate danger was then apparent. About 8.00pm winds of gale force from the north showered burning debris on Dwellingup long before the ground fire reached the town perimeter. Numerous fires were set both in the open and to buildings. Women and children were quickly assembled in bare open spaces........*
>
> *..... The Dwellingup fires covered 146,200 hectares, destroyed 132 dwellings, a hospital, two sawmills, two service stations, three general stores, offices, outbuildings and 74 motor vehicles to a total value of some $2 million."*

In the wake of the 1961 fires, a Royal Commission was held. The report of the Commission (Rodger, 1961) contains numerous recommendations concerning measures necessary to prevent and control bushfires. From the point of view of the Forests Department, recommendation 20 was the most significant. It read:

> ***"The Forests Department [is to] make every endeavour to improve and extend the practice of control burning to ensure that the forests receive the maximum protection practical consistent with silvicultural requirements. "***

This did not represent a redirection of policy for south-west forests, rather it unambiguously endorsed the policy which had been adopted in 1953. The Royal Commission's recommendations were adopted in full by the Government of the day, and have not been rescinded over the intervening years.

2.6 Operational and Research Developments in the Wake of the Dwellingup Fires

The decision to use fire to fight fire in Western Australia generated a wide range of scientific work and technical development. Major progress was made in the following areas:

Fire Behaviour Research and Prescribed Burning Guides

Over a period of about 30 years, forest research scientists have developed a profound understanding of fuel accumulation rates and the effects on fire intensity and rate of spread of different temperatures, wind speeds, relative humidity, fuel dryness and slope for the jarrah and karri forests. This information was incorporated into a fire behaviour prediction system and a prescribed burning guide, which is used by field staff in planning and implementing prescribed burns (Sneeuwjagt and Peet, 1985). This information is also used when planning wildfire suppression strategies, but is less reliable, ie. the current model tends to underestimate rate of fire spread at higher intensifies, because of lack of experimental data in this range. The recent fire behaviour studies of Project Vesta will provide more reliable information on the fire behaviour in dry eucalypt forests under severe summer conditions.

The Rationale for Prescribed Burning

In conjunction with the research work on fuels leading to improved prescribed burning techniques, a quantitative assessment of the relationship between fuel loading and ease of fire suppression was developed. Using a combination of knowledge of fire intensity and flame heights and the practical experience of expert firefighters, threshold levels of fuels have been set for the main forest types, and these represent the rationale for cyclic prescribed burning: The threshold levels of available fuel for the jarrah forest have been set at 8 tonnes/hectare and for the karri forest at 17 tonnes/hectare. These limits are set because: (i) they represent the level of fuels above which headfires cannot be successfully attacked under average summer conditions and (ii) they are the upper limit of fuel quantities beyond which fire intensity will cause unacceptable damage to young trees and will generate crown fires and spotting.

These threshold fuel levels are also used as the basis for setting prescribed burning return times ("rotations") within strategic buffer zones set aside for fuel reduction for wildfire mitigation. The time taken for fuels to build up to 8 tonnes per hectare in the jarrah forest or 17 tonnes per hectare in the karri forest varies considerably, depending on climate, site fertility and forest structure. The average is 5-7 years in the jarrah, 7-10 years or more in the eastern jarrah/wandoo and 6-8 years in the karri forest.

Fire Effects Studies

Studies into the effects of fires on soil physical and chemical properties, flora, fauna, water resource values and forest regeneration commenced in the early 1960s and have continued ever since. This work has resulted in a major increase in knowledge about forest ecosystems and their response to fire disturbance. This work is referenced and described in more detail later in this paper.

Aerial Prescribed Burning

During the late 1950s and early 1960s, it became apparent that available resources of staff and number of suitable days were insufficient to enable the prescribed burning policy to be implemented by the traditional method of strip burning by gangs walking through the forest. As a result, a technique for lighting prescribed fires in jarrah forests from aircraft was conceived and pioneered in Western Australia. This work was done jointly by the Forests Department and the CSIRO, and it reduced the cost and increased the effectiveness of prescribed burning. In the late 1960s this technique was extended to the karri forest, the delay being caused by the need for further research into karri scrub classification, fuel drying rates and fire behaviour.

2.7 Other Developments

The high profile of CALM's prescribed burning policy has tended to obscure the fact that prescribed burning is only one of the measures employed in attacking the wildfire problem in the south-west forests.

In parallel with the developments described above, a number of other related and very significant fire management developments took place in Western Australia in the aftermath of the destructive 1961 fires. These included:

- the development of highly reliable prediction systems for fuel moisture content, fire behaviour and fire effects parameters;
- the introduction of spotter aircraft to augment and partly replace the fire detection system based on lookout towers;
- the development of inter-agency agreements for cooperative fire management with Shires, Bush Fire Brigades, FESA and other organisations;
- formal and structured fire training systems for CALM staff and volunteers;

- the development of structured and pre-planned fire command systems (the Inter-agency Incident Control System which is standard for all bushfire authorities in Australia) ensures that arrangements and procedures for responding to and coping with fire emergencies are integrated, effective, timely and appropriate;

- the development of Wildfire Threat Analysis as an objective way of identifying, ranking and mapping values to be protected so that priorities and procedures for fire prevention and fire suppression works can be agreed on and implemented with the resources available;

- the identification of "strategic buffers" in the forest - areas where fire protection would take priority over other forest uses, and incorporated through integrated planning across tenures.

- the use of computers and GIS software for mapping, fire behaviour computation and for aiding decision-making and fire management planning;

- In recent years the introduction of an aerial suppression capability (water bombers) to rapidly contain small initiating wildfires within a 50km radius of Perth airport has proven to be effective where the aircraft have been able to apply the water/foam drops within 30 to 45 minutes of a fire starting. The water bombers are most effective on low to moderate intensity fires (<2000 kw/m), but are ineffective once fires become fully developed and intense.

  Similar water bombing capacity has now been provided to the south-west forest areas with aircraft operating from Bunbury.

Taken as a whole, and in conjunction with the use of fire to reduce fuels in the forest, these fire control measures provided a total approach to fire management on crown land forests in the south-west. In addition, good working relations with Shires and the Bush Fires Services of the Fire and Emergency Services Authority (FESA) have been achieved to ensure integration of CALM's approach with the approach taken on neighbouring lands.

Summary: The implementation of the recommendations of the Dwellingup Fire Royal Commission Inquiry has now led to the CALM approach based on measures to reduce the impact of wildfires through planned burning, the rapid attention to fires and the maintenance of a well trained and resourced fire suppression capacity.

CHAPTER 3

THE CURRENT APPROACH

3.1 Current Policy

CALM introduced its Fire Management Policy in May 1987 (see Appendix 1), and while regularly reviewed, this document is still in force. The latest policy review occurred in 1995 following and independent Ministerial Fire Review Panel in 1994 (Lewis et al, 1994) which endorsed the Department's current fire management and prescribed burning policy and practices.

The current policy has two objectives:

(i) to protect community and environmental values on lands managed by the Department from damage or destruction by wildfire; and

(ii) to use fire as a management tool to achieve land management objectives, in accordance with designated land use priorities.

The policy is based on eight premises:

- Fire has occurred naturally from time to time in practically all lands managed by CALM. Fire has therefore played some part in determining present vegetation structures and composition.

- Under natural conditions, practically all ecosystems are made up of a mosaic of vegetation associations and structural stages which vary according to their fire histories. The scale of the mosaic varies in different ecosystems.

- Fires from natural causes (eg. lightning) will inevitably occur. Fires resulting from human activities, either deliberate or accidental will also occur, but may be reduced by effective public education and awareness, and by legislation.

- In Western Australia, weather conditions occur every year under which fires can be so intense as to be impossible to contain with currently available technologies and resources. Such fires can threaten human lives, and resources valued by the community, and their control involves considerable public expenditure and risks to firefighters.

- The speed and intensity at which fire burns is related to the quantity of accumulated dry litter or other fine plant material. In the majority of the vegetation types occurring in the south-west, accumulated fuel loads can be reduced by prescribed burning. This significantly reduces the likelihood of intense fires even under extreme conditions, and markedly improves the capacity for firefighters to safely control a fire.

- Within each major fuel type there is a recognised weight of dry fuel above which firefighting forces are not likely to be able to contain wildfires burning under normal hot summer conditions.

- Much of the public land managed by CALM, particularly in the south-west, has a common boundary with well developed private assets such as towns and farms, the protection of which reduces the flexibility for fire management. Managers of both public lands and adjoining private lands have a responsibility to reduce the occurrence and spread of bushfires and to protect life, assets and ecosystems.

- Information about the long-term effects of different fire regimes, including fire exclusion on many ecosystems is continually evolving, and any management policy must be under constant review and accompanied by research and monitoring programs.

- The Department has a moral and legal obligation to comply with those provisions of the Bush Fires Act, and CALM Act relating to fire prevention and control of wildfires on or near CALM lands.

The CALM Fire Management Policy deals holistically with the fire issue. It covers fire preparedness and suppression, scientific research, public liaison and education as well as prescribed burning. There have been claims by some critics that CALM's fire management policies do not involve strategies other than prescribed burning.

The Policy imposes specific constraints on the use of fire. In particular, fire may be used only in accordance with an approved management plan, or to protect a designated priority land use; prescribed fires must be properly planned and proposals approved by a senior officer; conservation of biodiversity is to be promoted in conservation reserves; frequency of fire must be governed by fuel build-up as well as risk to human values, and the sensitivity to fire of plants and animals.

The Policy recognises that knowledge of fire effects of fire regimes or ecosystem components is incomplete and that there must be constant reviews of Policy in the light of research and monitoring information. However we do not have the luxury of doing nothing until there is a perfect understanding of the effect of fires on ecosystems, and that current policies and practices must proceed on the basis of the following guiding and scientific principles that have been accepted as best practice.

3.2 Guiding Principles

The following guiding and scientific principles provide the framework for the implementation of the Fire Management Policy for the Department of Conservation and Land Management of Western Australia.

- **Fire fighters and public safety is the first priority in every fire management activity.** Property and natural/cultural resources jointly become the second priority, with protection decisions based on values to be protected and other considerations.

- **The role of fire as an essential ecological process and natural change agent is to be incorporated into the planning process.** Considerations of fire protection, fire ecology, and fire use will be integrated into the formulation and evaluation of land and resource management objectives, prescriptions and practices. Variations in intensities, frequencies, seasons and scales of burning will be considered for fire management plans that aim to optimise the conservation of biodiversity.

- **Sound risk management is the foundation for all fire management activities.** Risks and uncertainties relating to wildfire impacts, and fire management activities must be understood, analysed, communicated and managed as they relate to the achievement of Corporate goals and the cost of either undertaking or not undertaking an activity. Net gains to the public benefit will be an important component of resultant decisions.

- **Fire management programs and activities are cost effective, based upon the values to be managed and protected, and land and resource management objectives.** This requires the provision and the maintenance of an adequate state of preparedness and adequate levels of resources for safe, cost effective fire management programs in support of land and resource management plans through appropriate planning, staffing, training and equipment.

- **Fire management plans and activities are based on the best available science and experience.** An active fire research program combined with collaboration with other agencies and research institutes provides the basis for making this knowledge available to all fire managers. New knowledge and monitoring results are to be used to periodically revise fire management goals, strategies and practices.

- **Fire management plans and activities incorporate considerations of public health, social concerns and environmental damage.** Smoke emanating from prescribed burns will be managed to avoid affecting population centres and other sensitive areas by development and application of smoke management guidelines. Potential impacts on water catchment values, road traffic, neighbours and visitors are to be given full consideration when planning and implementing fire management programs.

- **State and local inter-agency coordination and cooperation are essential.** Increasing costs and reducing work forces require public agencies and community volunteers to pool their human resources to successfully deal with the ever increasing and more complex fire management tasks.

- **Public understanding of the role and use of fire is essential to allow effective community participation in open and constructive discussions, and deliberations on adaptive, innovative and effective fire managed programs.** Clear and consistent information is provided to internal and external audiences about land management goals and objectives. The role of fire in achieving these objectives, and alternatives and consequences of various fire management strategies including fire exclusion are communicated. Opportunities are provided for informed audiences to participate fully in the land and fire management processes.

3.3 Implementation of Policy

The translation of policy into operations on the ground requires a major management and organisational effort. The principal components of this are:

The Wildfire Threat Analysis

Limited resources, and a range of social and environmental factors which are spatially and temporally dynamic, require land managers to make exceedingly difficult decisions about priorities on how to best utilise available resources. The decision support system, called a Wildfire Threat Analysis (WTA) has been developed to assist decision making by land managers (Muller, 1993).

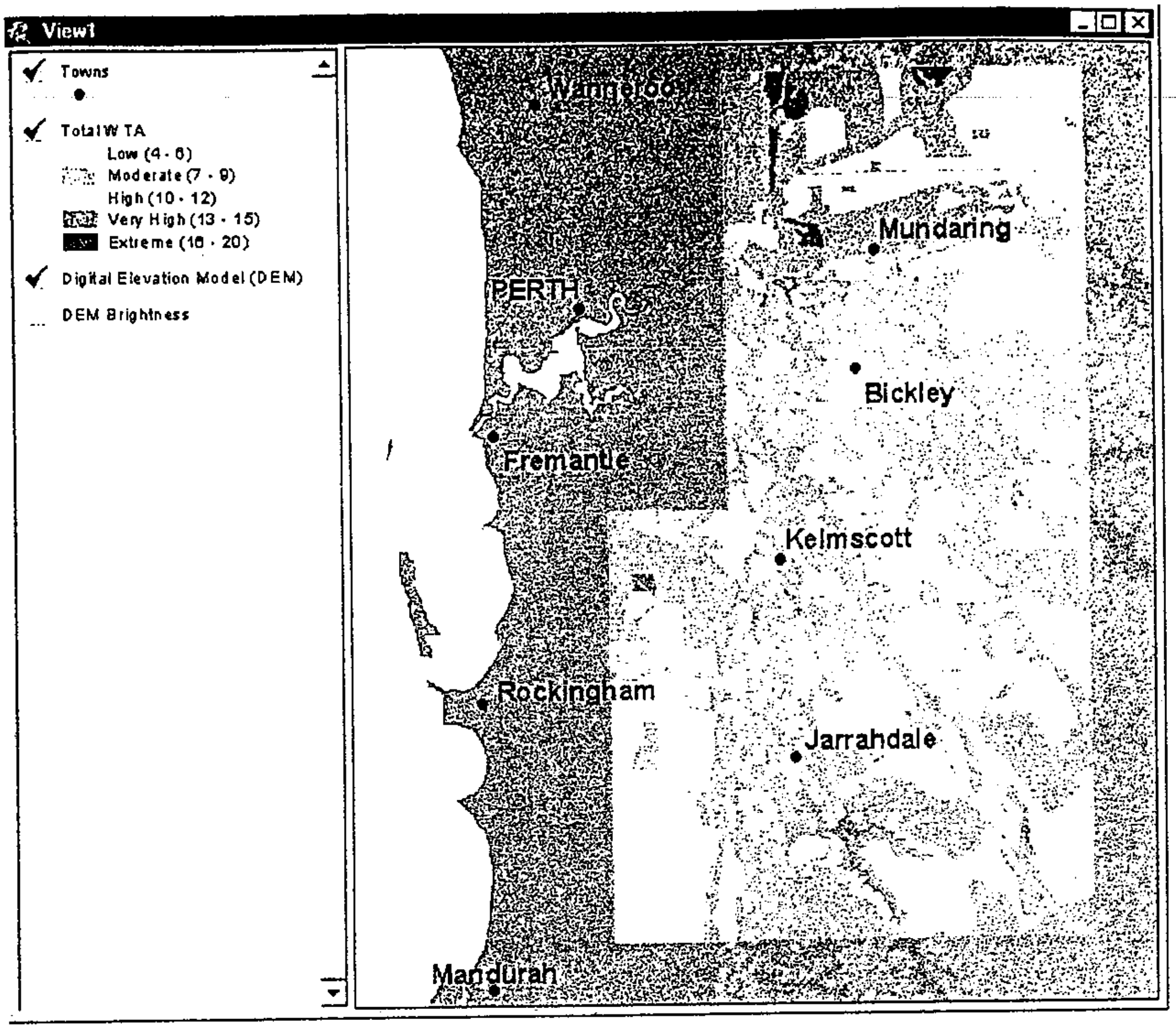
WTA provides an objective and repeatable means of integrating the key factors that contribute to a wildfire threat to a specified value. These factors are the risk of a fire starting, the suppression response which can be mounted and the likely fire behaviour at the site of the fire. These factors can be mapped and ranked, so that it is possible to determine which values are most at risk.

WTA forms the basis of CALM's fire management planning, in the south-west of Western Australia (and is being routinely used in other areas as well). Not only does the process highlight the problems and therefore the priorities for fire prevention and pre-suppression work, it can be used to design a range of ancillary fire services and requirements, such as the detection system, suppression response plans, standby arrangements and inter-agency work.

Figure 3 shows the Wildfire Threat Analysis of the "fire prone" rural-urban interface between Mundaring and Jarrahdale. The threat zones reflect the interaction of the factors that contribute to bushfire threat. These are (i) the values at risk to bushfires particularly human life and community and environmental assets (ii) the potential for bushfires to start (iii) the capacity for CALM and volunteer brigades to respond to bushfires and (iv) the expected fire behaviour.

Wildfire Threat Analysis provides an objective basis for fire managers to develop fire prevention programs based firstly on the geographic distribution of wildfire threats and secondly on the relative contributions the above factors make to a given threat. Where fire behaviour potential is the most significant contributor to the overall fire threat fuel reduction burns may be the most effective means of reducing the threat and impact of summer wildfires. In areas where there is a high probability of fires starting from accidents or deliberate lightings then a combination of fire prevention measures that include effective public education and awareness programs, increased fire detection and fire response capabilities may be needed to reduce the overall threat.

Figure 3: Wildfire Threat Analysis in Rural-Urban Zones between Mundaring and Perth



Standards of Fire Management Cover (The Fire Model)

In order to meet its legal and operational requirements to provide an adequate level of fire management services, the Department needs to maintain a minimum number of trained fire officers and fire fighters as well as fire equipment and infrastructure. These fire management service requirements include fire suppression, prescribed burning and other fire prevention works.

The minimum number of fire resources needed to meet the fire suppression requirements are defined by the Standards of Fire Cover.

The Standards of Fire Cover (SFC) for Fire Suppression comprise both the quantum and the location (ie: STANDARD) of fire fighting resources (both personnel and equipment) necessary to provide an appropriate response (ie: COVER) to wildfires occurring in a particular area, given the prevailing fire threat.

In the south-west forest regions where the incidence of fires is high, and where there are many lives, properties and natural resources at risk from those fires, the SFC is based on two fire response scenarios:

Situation (1) – Initial Attack

The capacity to contain initiating fires that start in high value zones (Priority 1 and 2 WTA Areas)* burning under 95 percentile weather conditions before they reach critical size beyond which they become uncontrollable. Based on the calculations using the CALM Forest Fire Behaviour Tables (Red Book) (Sneeuwjagt and Peet, 1998) it was determined that 20 fire fighters with 5 tankers and dozer or wheel-loader, plus 10 officers are required to be available to keep fires to less than one hectare in Priority 1 WTA Areas, or two hectares in Priority 2 WTA Areas.

In order that sufficient forces are able to attend to initiating fires before these exceed one hectare in the Priority 1 areas, the distance from the work centre to the fire should not exceed 40km in jarrah forest and 30km in karri regrowth and pine plantation forests.

Based on the WTA analysis and the locations of existing major work centres, nine fire response zones have been identified to cover the high priority WTA areas in the south-west. Figure 4 shows these response zones in relation to the mapped high value areas in the south-west. Figure 5 shows the 9 response zones in relation to the ignitions attended by CALM forces in the past 11 years. Table 3 lists the minimum officers and fire fighter crew requirement to meet this scenario in the 9 fire response zones.

Table 3: Standards of Fire Suppression Cover

Situation 1 — Staff and Fire Fighter Numbers Required to Deal with Initiating Fires in each of 9 Response Cells – Assume 25% Unavailability

Staff	Number	Plus 25% Unavailability	Total
Officers			
District Duty Officer	1		
Incident Controller	1		
Planning Officer	1		
Logistics Officer	1		
Despatcher/Supplies	1		
Operations Officer	1		
Sector Commanders	2	+ 2	10
	8		
Fire Crews 4 crews (O/S + 4) (includes Dozer/ Wheel-Loader Operators)	20	+ 5	25

* The WTA Analysis is used to identify the location of high priority value zones, high ignition potential zones; fire behaviour potentials; and likely travel times from all work centres.

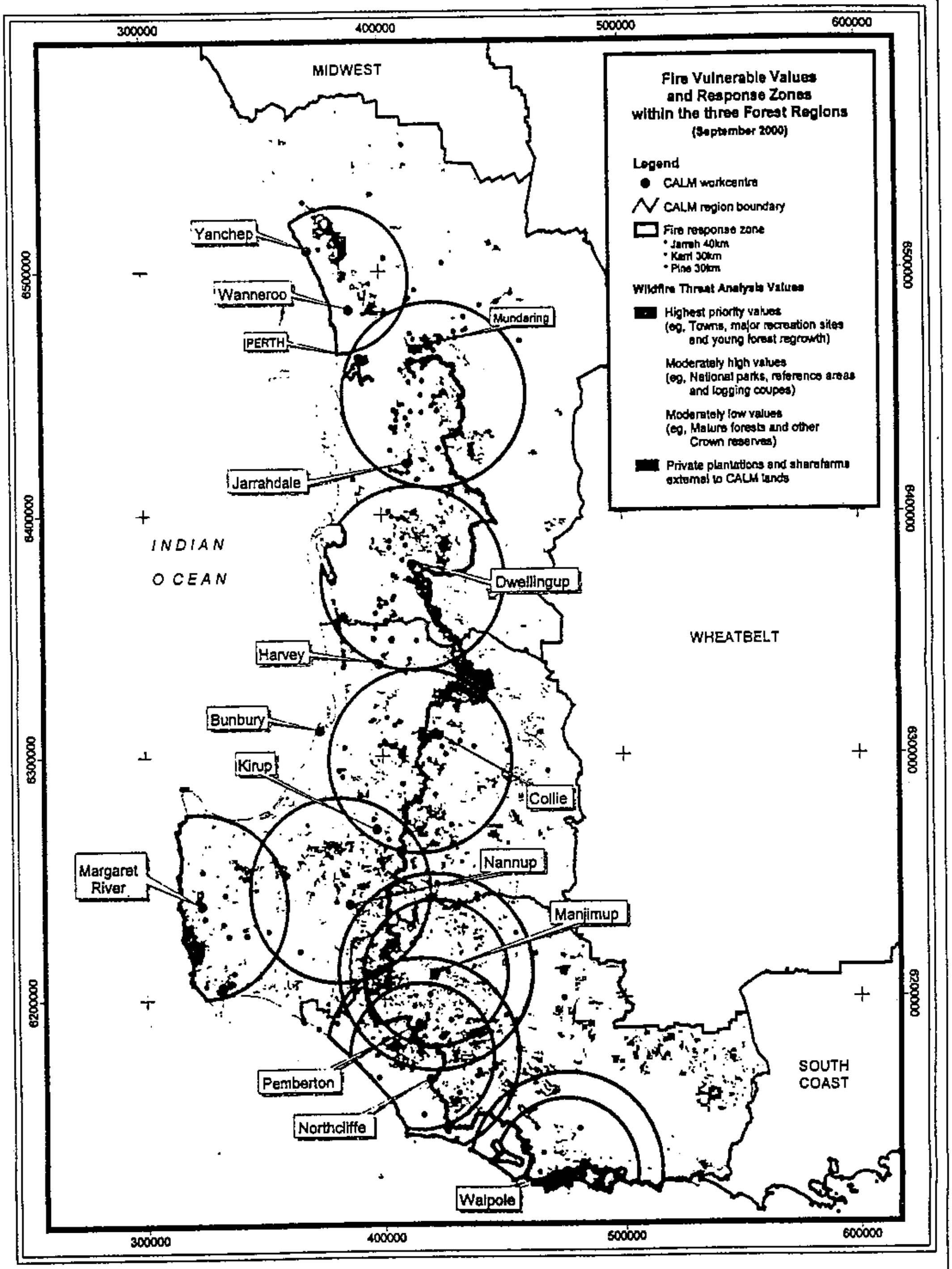


Figure 4. Southwest forests showing high value areas and fire response zones.

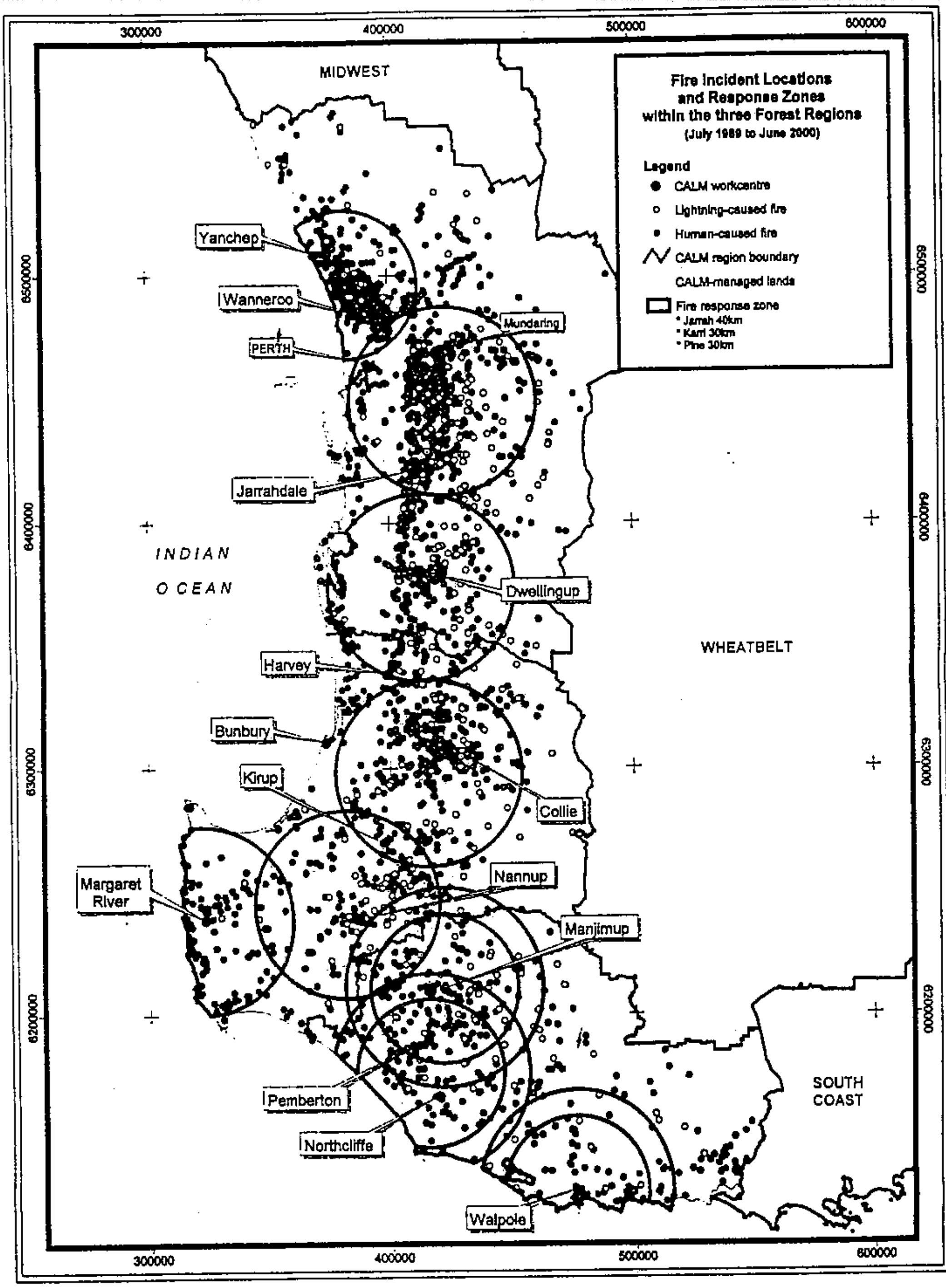


Figure 5. Southwest forests showing ignition sources (July 1989 to June 2000) and fire response zones.

Situation (2) – Major Fires

The capacity to meet a reasonably likely (based on historical data) scenario of three large, multi-shift forest/plantation fires burning simultaneously, in each of the three forest regions, whilst maintaining a strategic reserve within each of the 9 initial attack response zones.

Table 4 lists the number of officer positions and fire crews required to deal with the 3 large fire/strategic reserve scenarios.

The situation 2 scenario for Standards of Fire Cover limits in the south-west is based on reasonably common situations and is far from being a worst case scenario.

Some of the worst recorded fire situations occurred in March 1969 (Boorara, and Northumberland Block fires); 20 December, 1974 (12 large fires in Southern Forest Region; 4 April, 1978 (93 fires driven by Cyclone Alby), 1989 and 1996 (Pine fires in Wanneroo Plantations) and December 1997 (9 complex fires in Southern Forest Region).

The commitment indicated for the situation 2 scenario will be exceeded if only one of the three fires is very large and complex. In addition there has been no allowance made for the unavailability of fire personnel due to events such as ongoing fires where personnel are required to take 48 hours rest after several days of arduous fireline duty.

Table 4: Standards of fire Suppression Cover

Situation 2: ***Officer and Fire Fighter Numbers needed to Deal with 3 Large Complex Wildfires in each of the 3 Forest Regions, plus a Strategic Reserve in each of 9 Districts***

Staff	Number	Total
Officers		
1. Region Requirement (x3)		6
Reg. Duty Officer	2	6
Reg. Planning	2	6
Reg. Admin	2	18
2. District Requirement (x9)		9
District Duty Officer	1	18
District FEA	2	9
District Admin	1	36
3. Large Fires (x3) (Two Shifts)		6
Incident Controller	2	6
Operations Officer	2	12
Divisional Commander	4	36
Sector Commander	12	6
Planning Officer	2	6
Situations	2	6
Resources	2	6
Information	2	12
Management Support	4	6
Logistics Support	2	6
Supply	2	6
Facilities	2	24
Ground Support	8	18
Catering	6	3
Communications	1	3
Finance	1	162
Total Officers		

Fire Crews	(6 Sector Fires)	Two Shifts (x2)	3 Fires	
On Fire	42	x2	x3	252
Strategic Reserve (x9)		4x9 = 36		36
Total Fire Fighter Crew Requirement				**288**

3.4 Current and Future Fire Staff Levels

Recent analysis of the numbers of qualified staff that are currently available within CALM (including the Forest Products Division [FPD]) clearly indicates that there are insufficient to support the fire model scenarios proposed. The shortfall is of concern in the ranks of the senior to middle ranked fire command and fire operations officers which require competencies that can only be acquired by many years of training and operational exposure to fires and planned burning.

It has been assumed in these analyses that the FPD staff and other Specialist Branch staff (eg: CALM*Science*, Forest Management Branch [FMB]) working in the south-west Regions will continue their participation with fire management roles in the future.

Should these staff be reduced or withdrawn then the Department's capacity to meet its fire control obligations (and prescribed burning program) will be severely restricted.

Staff working within the South Coast, Wheatbelt and Midwest Regions have not been included in this analysis. The number of qualified fire officers from these Regions are small, and are rarely in a position to leave their home work areas to assist the Forest Regions. There are limited fire crews in these Regions. Forest Regions often provide resources when large fires occur in the adjacent regions.

The fire model includes an assumption that 25 percent of the total pool of qualified personnel are likely to be unavailable for fire duties due to a combination of reasons including leave commitments, rostered days off, and prior work related commitments. Expanding contracted work for recoupable projects and Service Provider Agreements will exacerbate this situation.

The attrition rate for staff in CALM currently stands at 5.7 percent per annum. This amounts to a 25% loss of staff over 5 years. It is assumed that the annual loss through resignations or transfers will be through promotion of existing staff. The replacement of an experienced/qualified fire officer with an inexperienced or unqualified one has significant implications for training and development.

3.5 Strategic Fire Plans

Master Burn Planning in Districts

Each CALM district in the south-west prepares a master fire management plan for the area managed. This is based on WTA, and looks many years ahead, but is revised annually in the light of burning programs achieved, fires which have occurred and appraisals of values and priorities. The district fire management master plan is a key planning tool with five key features:

Firstly, it allows a map-based presentation of the integrated wildfire threat analysis, demonstrating the various values and ignition risks, the full range of the suppression task, and the fire behaviour which is likely to occur at any given site.

Secondly, the master plan is the document in which fire management is integrated with all the other activities occurring on CALM managed lands. Activities and values such as logging coupes and regeneration areas, softwood and hardwood plantations, nature conservation requirements (eg: habitat management), mining areas, archaeological sites, recreation sites, research plots, special catchment zones, power lines and dieback quarantine areas are identified, mapped and considered in fire planning, for the area.

Thirdly, the master plan provides the basis for ranking the fire control effort, in particular the prescribed burning effort. On the basis of WTA, each district is zoned into three priority areas. Priority One areas are those with the highest values to be protected and the greatest risk of fire. In these highest priority areas districts attempt to maintain at least 75 percent of the forest that is available to burn at "standard" fuels or better. In Priority Two zones the aim is 60 percent and in the Priority Three Areas it is 50 percent, or better.

Fourthly, the master plan is the place in which Strategic Buffers and Fire Protected, or Fuel Datum Areas are defined. The former are areas where fire protection policy takes precedence over other land uses. They are moved about, depending on areas available, but the main intention is to stop the run of major fires. In the jarrah and karri forest the Strategic Buffers are designed with an "acceptable loss" (ie. fire size) of 4000 hectares in mind.

"Fuel Datum Areas" are areas set aside as No Planned Burns. The intention is to have a sample or "control" areas located throughout the forest where prescribed burning does not occur and where every effort is made to keep fire out. These areas are valuable for future research.

Finally, the master plan is the place where fire regimes are set down. In areas to be burnt by prescription, the plan shows which areas will be burnt in spring and which in autumn, as well as the frequency of burning in order to meet general or specified nature conservation objectives.

The Annual Burning Plan

An annual burning program is drawn up each year for each district. This is derived from the Master Plan, which in turn is derived from the Wildfire Threat Analysis. In the annual plan, individual "jobs" are identified, numbered, ranked in priority, and listed either for an aerial or a hand burn. A final program is adjusted according to available resources, with priority being given to the most strategically important burns.

Area Management Plans for Conservation Reserves

Management plans for specific areas within districts are progressively being drawn up and published as required in the CALM Act. These mostly apply to National Parks, but also to some Nature Reserves and Conservation Parks. Examples are the management plans for Yanchep National Park, John Forrest National Park, Lane Poole Reserve, Leeuwin-Naturaliste National Park, Shannon D'Entrecasteaux National Park and Walpole Nornalup National Park.

These plans contain specific directions on fire management. Access roads are specified, fire exclusion areas nominated and special fire regimes designated.

In some parks and reserves, Interim Management Guidelines (IMG) are prepared to guide CALM managers until a formal management plan is prepared. These also designate the fire management scheme to be adopted so as to maintain park and reserve values. There is a high degree of integration of the IMGs with district master plans.

The Fire Control Working Plan

In addition to the master plan, each district produces each year a fire control preparedness and response plan called the Fire Control Working Plan (FCWP). These are prepared to a standard format to ensure ready familiarity for officers transferred from one area to another, or for staff coming in at the time of a fire to relieve local staff.

The FCWP is the primary operational document used by CALM field staff to prepare themselves for fire suppression at the start of each fire season. It establishes the objectives for different forest zones, and provides a full inventory of all the human and other resources available locally for fire-fighting. It details the Standing Orders - ie. the action to be taken in the event of a fire, the detection and standby arrangements and provides all the contacts with other firefighting agencies and brigades.

The Fire Operations Manual

This is a compendium of all the instructions and standards which must be applied by field staff in their fire control operations. It is the legal guideline, in that it contains all the legislative and official departmental requirements, plus it is the unofficial guidebook, in that it contains a distillation of decades of field experience in fire planning, fire suppression and prescribed burning operations translated into standing orders or Fire Protection Instructions.

Copies of the fire operations manual are held by fire managers in each of the districts, and it forms the basis of training programs. It is updated with new procedures annually.

Inter-Agency Agreements

Over the years CALM has established a number of mutual-aid agreements with different agencies and organisations. These aim is to share fire management tasks and costs in an agreed way, and to determine arrangements well before the event. An example of a wider agreement which focuses on a particular area is the Denbarker Fire Protection Scheme, which incorporates agreement between CALM, FESA, local Shire councils and local Bush Fire Brigades, and deals with the protection of an area of over 70 000 hectares of State forest, conservation reserves, private farmland and Unallocated Crown land.

3.6 Prescribed Burning Programs

Use of Fire for Conservation

Fire management in the State's forests, parks and reserves has two objectives. Firstly to protect life, property, flora and fauna from uncontrolled and damaging summer wildfires and secondly to manage natural ecosystems so as to maintain the greatest diversity and species richness. These objectives appear mutually exclusive because the regime required to maintain species richness may not always be compatible with the regime required for protection. The challenge for land managers and scientists is to develop and implement practical fire regimes in terms of season, frequency, intensity and "patchiness" that satisfy these dual objectives.

The ecological impacts of fire are many and complex and it is unlikely that they will be completely understood for all species, habitats and ecosystems. In the absence of perfect knowledge CALM uses indicators to develop appropriate fire management strategies to achieve positive ecological and community protection outcomes. These include climatic indicators and historic indicators (Burrows et al, 1999). Minimum intervals between fires necessary to sustain biodiversity are estimated from the juvenile periods of the slowest maturing plants, particularly obligate seeders and from post fire responses of fire sensitive taxa of flora and fauna.

Given these climatic and historic indicators fire has had a significant role in determining the assemblage of wildlife species present on the State's natural lands. In addition many of the species present have specific adaptations, such as resprouting, that resist the impact of periodic fire. Appropriate fire management regimes therefore aim to encourage and maintain diversity, natural abundance and composition of vegetation associations and wildlife habitats. In addition the regimes aim to minimise the risk of wildfires burning-out extensive areas so as to protect fire-vulnerable wildlife species, ecosystems, soils and landscapes as well as community assets. Fire regimes also are designed to obtain information about natural processes through the use and non-use of planned fire.

Burning for habitat manipulation is now widely practised, and new techniques are being developed progressively as special requirements are identified. For example, moderate intense burns applied under dry soil conditions are used in the regeneration of Gastrolobium (Heartleaf Poison), Melaleuca or *Acacia* thickets in some lower rainfall forests and woodlands where these provide essential shelter for threatened mammals such as Tammar Wallabies and Woylies. Other habitat burning regimes have been developed for quokka and quenda and the management of wetlands, stream reserves and other diverse ecotype zones.

Fire is used to enhance ecological processes including recycling of nutrients that are otherwise locked up in litter, bark and branch materials that are very slow to decompose. In the long absence of fire, both the understorey and overstorey vegetation communities may become affected by the lack of available nutrients. In some situations such as the coastal Tuart Woodlands, a lack of regular fire can severely affect the health and vigour of Tuart trees that are unable to compete for water nutrients and space against the peppermint understorey which thrives in the absence of fire (Ward, 2000).

Fires set to meet specific native conservation objectives also contribute to the wildfire protection of the natural assets in the area.

Use of Fire for Regeneration and Commercial Forest Operations

Fire is also used in Western Australian forests for regeneration and habitat manipulation. In the karri forest, regeneration burns are lit in areas where timber harvesting has occurred for the dual purposes of reducing the volume of logging debris and preparing seedbed for the re-establishment of karri. Similarly, post-logging burns are carried out in jarrah forests where gaps have been created in which advance growth saplings can be released, or in shelterwood areas for the purpose of establishing lignotuber advance growth; and in the wandoo forest to create ashbeds for wandoo seeding regeneration.

These operations have become well established over many decades, and are carried out by district staff as part of the annual burning program. Similar planning and controls apply.

Regeneration and other silvicultural burn operations also reduce fuels, so that they add to the mosaic of fuel-reduced areas within the forest, even though this is not their primary purpose.

Use of Fire for Community Protection

Fuel reduction burning is a pivotal part of the overall strategy for the prevention of damaging wildfires that can impact on townships, forest communities and the urban/rural interface. The urban/rural interface in particular, is one of the most fire vulnerable parts of the Australian environment. This is also the case in other parts of the world. The report of the Ministerial Review of the Fire Hazards in the Darling Escarpment (The Day Report) contained an analysis of wildfire threat in the Darling Range between Mundaring and Dwellingup which clearly indicated a high level of exposure and vulnerability of these communities to wildfires.

Whilst prevention measure such as house design; maintenance of clear areas and firebreaks around buildings, provision of sprinkler systems and fire equipment are important strategies for survival at interface fires, only fuel reduction, achieved primarily through burning, can prevent high intensity fires that are accompanied by burning embers and intense flames from assaulting local communities from nearby natural areas carrying heavy vegetation.

Alternatives to prescribed burning, which include mechanical and manual removal of fuels and vegetation, grazing, and herbicide treatments, do not provide for a sufficiently wide fuel break to prevent the spread of intense wildfires. The likelihood of long-distance "spotting" means that low fuel zones need to be at least one kilometre wide. Mechanical fuel removal on such a scale is not only environmentally and ecologically unacceptable, but would be cost prohibitive to maintain on a regular basis.

Since 1961 there have been numerous instances where rural and rural/urban interface communities have been saved from wildfires by the presence of strategically located burn buffers maintained by CALM. The risk of major wildfires burning out towns and settlements, rural properties, large areas of forests and conservation reserves has increased dramatically over the past three years as few burn buffers are burnt on schedule.

3.7 Constraints to Prescribed Burning

The prescribed burning program undertaken by CALM is subjected to a wide range of constraints. These include:

Legal Constraints

The Bush Fires Act (1954) lays down legislation which must be complied with before and during prescribed burning. These include a requirement that prescribed burning is limited to those months outside of the Prohibited Burning Period, and cannot be commenced when the Fire Danger for the area is Very High or Extreme.

Weather Conditions

The weather conditions that are normally suitable for safe fuel-reduction burning in the south-west forests are most often the same that lead to smoke being blown by southerly winds into the Perth metropolitan area. Atmospheric conditions can also lead to smoke becoming trapped beneath overnight inversion layer that develops along the Swan Coastal Plain. There are relatively few days each season when conditions suit both planned burning objectives and the air quality objectives. For example, based on the analysis of weather records over the past 10 years, Mundaring District can expect to experience about 10 days during the "Restricted Burning Time" when weather and fuel moisture conditions are suitable for safe and effective prescribed burns without smoke impacting on the Perth metropolitan area.

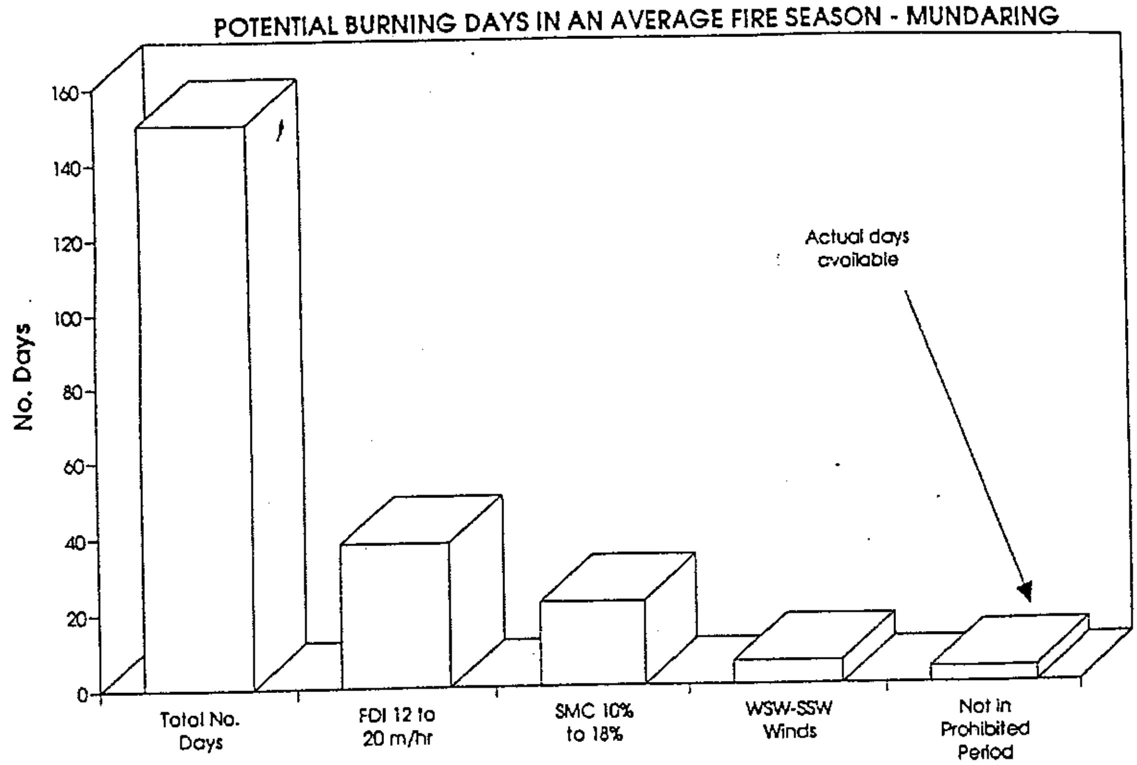
Figure 5 demonstrates the restrictions in the number of suitable burning days that are experienced, on average, each year in the Mundaring District. These restrictions include the narrow range of suitable Fire Danger Indices; suitable fuel moisture content; winds from the west/south-west that will blow smoke away from Perth; and prohibited burning times as laid down under the Bush Fires Act.

Smoke Management

CALM has applied a Smoke Management Decision Model (Sneeuwjagt 2000) since 1994. This model, developed in consultation with other agencies, relies heavily on accurate weather forecasts supplied by the Bureau of Meteorology for up to 4 days ahead. The reliability and performance of these forecasts and the efficiency of the Smoke Management Decision Model has improved markedly over the past five years largely as a result of ongoing research and monitoring into the weather and burn factors that influence smoke transport and accumulation. Appendix 2 shows the 4 components that make up the current smoke management decision model.

The application of this decision support system has resulted in significant reductions in the number of incidents each year in which smoke from CALM burns has resulted in highly visible haze in the Perth metropolitan area. Over the past five years the annual number of instances of reduced visibility has decreased from about eight incidents per year to two or three per year.

Figure 5: Potential burning days in an average fire season – Mundaring



Haze Particulates

Since November 1994, there have been no exceedences of the new National Environmental Protection Measure (NEPM) (Department of Environment, 1999) standard for fine particulates (PM_{10}) at any of the air quality monitoring stations in Perth as a result of smoke emissions from CALM prescribed burns.

Appendix 3 shows the PM_{10} observations recorded by the DEP at 4 monitoring stations in Perth since January 1996. The "Health" standard of 50 ug/m^3 has been exceeded on several occasions during the winter months (due to domestic wood stoves) and during mid-summer periods (wildfires and vehicle emissions). There have been no exceedences during the spring and autumn months when all of CALM's large prescribed burning programs in the south-west forests are undertaken. Despite the fact that smoke from CALM's prescribed burns have not resulted in PM_{10} standard exceedences over the past five years, there is a strong public perception, fuelled by the media and opponents to prescribed burning that CALM's smoke constitutes a serious health hazard to the general public.

Operational and Burn Security Constraints

The mixed karri-jarrah-tingle forests of the Southern Forest Regions dry out at different rates, and therefore burn at different times. In order that these mixed forest areas are burnt at prescribed fire intensities and fire spread rates, they require several ignitions. Each ignition is targeted to burn each major vegetation type as the fuel moisture dries out. Once such an area is lit on the first occasion, it is important for the security of the burn and the safety of the adjoining values, that subsequent ignitions are undertaken as soon as each fuel type becomes available. If this is not done, there is a serious risk that the smouldering fires within the burn block will become fierce, uncontrollable fires should severe fire weather occur before they are completed or as soon as summer weather conditions prevail.

The risk of fire escapes from partially completed mixed-forest burns can increase dramatically in the period of late November to early January when the sudden onset of severe weather conditions involving strong, hot and dry north-east and north-west winds can occur. This risk can best be minimised by restricting the number of "live" and incomplete burns within the Southern Forest Region. This operational constraint can become particularly restrictive during those seasons when weather conditions are unsuitable for safe, low intensity burns and smoke dispersion.

The requirement to apply multiple ignitions to ensure the safety of the burn, will often override the smoke management constraints, and thus there is occasionaly a risk of unfavourable smoke accumulation in the Perth metropolitan area from these follow-up ignitions.

Environmental Constraints

All prescribed burns must meet stringent environmental protection constraints. For example

- burns cannot be lit if it is predicted that they will deposit ash on water supply dams;
- declared rare flora and threatened fauna must be considered and the burn modified if there is a risk of permanent damage;
- fire is minimised in and around granite outcrops where many important "relictual" species occur;
- wherever possible areas containing important wetlands are burnt early in the spring while the wetlands are submerged or too damp to burn; and
- aesthetics along roadsides must be considered (burning is limited to only one side of a main road in the one summer)

3.8 Issues for the Delivery of Fire Management Services

Increased Costs for Burning and Fire Suppression

Where burns are surrounded by long-unburnt and highly flammable fuels the costs of preparing, igniting and controlling prescribed burns are much higher than where burns are adjacent to recently burnt fuels. The backlog of prescribed burns has meant that there are few opportunities to locate current burns where they can be lit against low fuel buffers. The higher costs are incurred because of the need to take more care and more time to light up the burn perimeter. There is also greater risk of escape from the burn into the heavy fuels adjacent to the burn. The costs of mopping-up the smouldering logs, stumps and trees are also greater. As a result the average unit costs for prescribed burns has increased steadily in the past 5 years from $8.60/ha in 1994/95 to $13.20/ha in 1998/99.

CALM's data indicates that as the annual area prescribed burn has declined, there is a tendency towards larger wildfires and higher costs of fire suppression. For example the average size of forest wildfires has increased steadily in the past 10 years. The 5 year rolling average at 1989 was approximately 14 ha; as at 1995 it was 46 ha; as at 1999 it was 80 ha. The suppression costs increase exponentially with the average size of wildfires. For example the average suppression cost of a small fire (less than 10 ha) is $1,500, whilst a 100 ha forest fire costs more than $45,000. Thus, whilst burning programs are not able to be achieved, the costs of fire suppression and the associated losses will inevitably increase well above current levels.

Recent Declines in Areas Prescribed Burnt

Gill and Moore (1996) using CALM's fire history data clearly shows a gradual decline in prescribed burning since a peak in 1970. Figure 6.

In order to maintain an adequate system of low-fuel protection buffers, approximately 200,000 hectares is required to be burned each year in the forest regions. In addition, jarrah and karri forest silvicultural/regeneration burns totalling about 20,000 hectares per annum must also be completed.

Prescribed burning for other purposes such as restoration of special fauna habitats, and research studies, vary from 5,000 to 20,000 hectares per year.

even greater potential to destroy local communities and forest values. The situation is only slightly better in the Central Forest and the Southern Forest Regions where approximately 65 percent of all forests, including regrowth stands, are carrying heavy fuel loads.

Figure 5 shows those areas of very high, moderately high and low hazard levels in each of the three forest regions. Where fuel loads have accumulated to high levels (ie: Red and Yellow areas), damaging wildfires will occur under severe summer conditions.

Declining Resources

Despite the significant advantages of operating as an integrated agency, CALM (along with most Government agencies in Western Australia) has had to deal with a serious problem of declining funding and human resources during the late 1980s and 1990s. This has been exacerbated by the increase in the CALM estate (especially through transfer to CALM management of Unallocated Crown Land) without any significant increase in budget, but with a clear public expectation for improved management. These issues have affected the capacity of the Department to implement fire management programs and to carry out fire research studies. Some relief to this situation was provided through an additional allocation of $737,000 in 2000/01 and subsequent years to implement some of the recommendations of the Ferguson (1999) report.

A number of new constraints has also emerged including:

- The formation of Forest Products Commission and subsequent changes to CALM's finances, staff and resources available for fire management may have a deleterious impact on the Department's capacity to meet its legal obligations.

- Further reductions in the availability of qualified fire staff are almost certain to occur if budgets for Departmental salaries and wages are reduced as a result of the formation of FPC and the restructuring of the CALM Regional Services Division. A response to this situation through increased training for staff is required.

- The budget deficit that exists within the 3 Forest Regions will inevitably place significant pressures on the Department to reduce both salary and wages positions in future. If numbers of staff and wages personnel are significantly reduced the capacity for Forest Regions to gain revenue from recoup works will also diminish thereby further aggravating the deficit in current budgets.

The possible withdrawal of FPC fire staff from participating in fire control/prescribed burning roles over the next 2 to 5 years will likely have a serious impact on the capacity to meet fire management obligations and program. The loss of these experienced FPC staff cannot be wholly made up by developing competent key fire staff from CALM staff that are not already part of the fire training and development program. It is not possible to expect to transform Specialist Branch and Administrative staff into skilled fire controllers and operational officers without more than 5 years of regular involvement in fire control operations. The majority of these staff are not likely to have the desire, aptitude and time available to develop these high level skills. However there are numerous fire support roles (eg: logistics, planning and administration) that can be filled by Specialist Branch personnel if they can be made available for the necessary training and regular exposures to fires and prescribed burns.

The decline in timber harvesting activity within native forests that is set to accelerate further in 2004, has significantly reduced the number and availability of contract machinery and operators needed in the suppression of wildfires in the south-west.

Other Issues

The following trends are likely to have significant impacts on CALM's capacity to deliver fire management services to the Output Programs.

- CALM has supported a substantial expansion of conservation reserves on areas which were formerly State forest. Within these reserves large sections containing Fire Exclusion Areas or areas with extended burn frequencies have been identified. This has reduced the area available for regular fuel reduction burning and exacerbated the opportunity for high intensity, destructive wildfires.

- There has been a major change in demography in the south-west over the last 25 years. This has seen a decline in land ownership by traditional farmers and their replacement by "hobby farmers" and environmental communities, many of whom are strongly opposed to prescribed burning on neighbouring forests.

- There has been a dramatic decline in the number of experienced volunteer bushfire brigade members throughout the south-west of WA, and their capacity to assist in forest fire control and prescribed burning is very limited and cannot be relied upon.

- The increasingly lower tolerance of Perth residents to put up with smoke haze from prescribed fire is resulting in a severe reduction in the number of suitable burning days where planned burns can be done safely without a risk of smoke affecting Perth and other population centres.

- There is a socio-political trend for increased public consultation and participation in the planning for and the delivery of fire management services. These new directions are liaison intensive and will increase the cost of fire prevention works, particularly prescribed burning. These community consultation priorities will impact on resources available to meet the outputs of Nature Conservation, Parks and Visitor Services, and Sustainable Forest Management.

CHAPTER 4

THE ECOLOGICAL IMPACT OF PRESCRIBED BURNING

4.1 Introduction

Any and every fire which burns through bush lands has some environmental and ecological impact. This is because every fire consumes some part of the vegetation living or dead) which is currently being used for food or shelter by some organisms; the fire consumes some of the organisms which feed on or pollinate or help to germinate some plants; it may bare the soil and stimulate seed fall; it may consume or create habitat; and fire emits smoke and ash which is carried into the atmosphere or is redistributed to some other part of the landscape.

At the same time, disturbance is a key process in natural ecosystems. Moderate disturbance over the long-term allows maintenance of biological diversity. One of the advantages conferred on an ecosystem by a high degree of biological diversity is an increased buffering against severe disturbance and an increased capacity to recover speedily from disturbance.

The degree to which a site is disturbed by a fire, and the rate of recovery from the disturbance depends on the intensity of the fire, the season in which it burns, the size of the fire and the time since the previous fire. Thus it is insufficient to consider merely the impact of a single fire. It is also necessary to consider the cumulative impacts of more than one fire and the varying effects of different fires.

4.2 Fire Ecology Research

There is a long history of fire effects research in Australia, in particular in Western Australia. This work has focused on the impacts of fires on nearly every element of the ecosystem, including the vascular plants, the vertebrate and invertebrate animals, the soil and litter micro-organisms, reptiles and amphibians, soil nutrients and air quality.

Although the research base is incomplete (there will always be a need for additional work on the long-term cumulative effects of different fire regimes), a relatively clear picture has emerged.

A comprehensive review of the effect of fire on south-west Western Australian ecology has been carried out by Christensen and Abbott (1989). They examined pre-European fire regimes, the effect on soils of low intensity and moderate to high intensity fires, nutrient cycling in the jarrah and karri forest, the effects of fire on micro-organisms, vascular flora, jarrah and karri trees, forest understorey plants, the establishment of exotic plant species, soil and litter invertebrates, birds and mammals.

On the basis of their review, Christensen and Abbott concluded that there is irrefutable evidence that fires occurred periodically in the jarrah and karri forests over many thousands of years. There is less certainty about the frequency of occurrence, the intensity and season of pre-European fires, but they considered it likely that a combination of lightning fires and burning by aborigines would have achieved a mosaic pattern of fire ages and fire intensifies through the forest.

Christensen and Abbott also found no evidence of any decline in plant species richness after several cycles of spring/autumn burning, and they concluded that the forest had a high capacity to cope with the changes associated with periodic fire and to return to the pre-fire situation.

These authors went on to postulate a general pattern of the response to fire by living organisms in an ecosystem as follows:

- There is a reduction in numbers and sometimes in species of organisms immediately after fire.

- There is a recovery in numbers and species of organisms after fire. This recovery is often characterised by the appearance of species which were rare before the fire or were present in the ecosystem only as stored seed in the soil.

- Changes may occur in species dominance and relative density after fire. These changes are often spectacular (eg. fire weeds) but are almost always transient.

- Recovery from fire is achieved almost totally by propagation from within the burnt area, although recovery of vertebrates is often assisted and sometimes is achieved entirely from unburnt areas.

- The rate of post-fire recovery of animal species depends largely on vascular plant recovery patterns which are in turn influenced by the intensity and season of the fire, and by the length of intervals between fires.

- Each species of organism has a well-defined response to fire. This response is flexible, allowing organisms to react across a wide range of possible fire regimes. Nevertheless, there are limits to responses, associated with individual life history strategies.

4.3 Fire Intensity

Forests

The impact of a forest fire is dramatically influenced by the degree to which elements of the pre-fire ecosystem are carried through into the post-fire ecosystem. A very high intensity fire may consume almost the entire above-ground vegetation of the forest leaving behind bare ground and dead tree trunks. At the other extreme a mild, patchy fire leaves a high proportion of the pre-fire (or "parent") ecosystem unscathed. A very significant ecological advantage of low intensity over high intensity fire is that the former maximises the threads of continuity, or biological legacies, from the parent to the succeeding ecosystem. On the other hand, there are some elements of a forest ecosystem which will gradually decline without the regenerative perturbation of a high intensity fire. It is clear that in nature both types of fire have co-exist over time.

The intention of prescribed burning is to help firefighters reduce the number and size of high intensity wildfires. Prescribed burns are lit under carefully selected conditions of air temperature, fuel moisture content and wind, so that the rate of spread and the intensity of the fire, are at the lower end of the scale. Occasionally a burn will be hotter than prescribed, especially if forecast conditions are exceeded, and autumn burns tend to be more all-consuming than spring burns. In general, in a spring burn, a proportion of the pre-fire ecosystem (ie: the tree canopy, the tree trunks, the tall shrubs, the moister gullies and damplands and patches of litter) survive the fire unburnt or moderately burnt.

Heathlands

Many areas adjoining the forest along the south and west coastline, or interspersed through the stands of jarrah and karri, are treeless plains. These are variously known as heaths, sedgelands, swamps, flats and wetlands. They vary in size from a few hectares to several hundred hectares.

Heathland generally comprises a dense single story vegetation of shrubs and grass, but occasionally (especially on the recently consolidated sand dunes along the south coast) has a scattered low overstorey of peppermint *(Agonis flexuosa)* banksia (various species) or yate *(E. cornuta).*

Dense single-layered heathlands have a completely different fuel structure and fire behaviour to multi-layered forest and when they burn the whole vegetation complex is consumed at once in a very fierce fire. The option to run mild fires through these areas generally does not exist. On the other hand, their powers of regeneration are very great. Usually within days of a fire new shoots have emerged and the dense mat of roots found in these ecotypes is uneffected.

4.4 Frequency of Burning

The interval between successive prescribed burns is determined by the rate of fuel accumulation. CALM's fire management objective is to consider burning when jarrah forest fuels accumulate beyond about eight tonnes per hectare and karri fuels beyond about 17 tonnes per hectare. These weights convert to an interval of approximately six years for most jarrah forest and eight years for most karri forest - shorter intervals apply in some localised strategic areas, but none shorter than five years. Longer intervals apply in others. To minimise any ecological impact of repetitive burning, it is necessary to ensure that sufficient time elapses between fires for all plant species to flower and seed, especially the "obligate seeders" - ie. those plants which do not re-sprout after fire and which depend on soil or plant-stored seed to regenerate (Burrows et al, 1999).

The fate of flowering plants in areas subjected to rotational burning in Western Australian forests has been studied by Muir (1987) and Burrows et al (1999).

Among the species he studied, Muir was not able to identify a single one growing in the forest zone which did not flower and seed within five years of a fire. Burrows has studied several hundred jarrah forest species considered to be threatened. He has developed a flowering calendar for 255 species and has described the post-fire regeneration strategies and age to first flowering of 187 species. All understorey species studied reached flowering within three years of fire.

The research is continuing; however, to date no plants have been identified which are threatened by the fire frequencies being employed by CALM in Western Australian forests or heathlands.

4.5 Season of Burn

One of the most contentious aspects of CALM's prescribed burning program is the debate concerning spring versus autumn burning.

The relative effects of spring and autumn burning in an ecosystem is still incomplete but there has been extensive research which is summarised below.

Soils and Litter

- Hatch (1959) found no significant difference in pH, macro and micro nutrients between jarrah forest burnt in spring every three years for 15-25 years and forest lon. Unburnt (25 years). Abbott *et al.* (1984) reported similar findings.

- Soil surface temperatures during spring fires are considerably lower than those measured in autumn (Shea et al. 1979, Burrows 1987) but in both cases, is highly variable (Christensen and Kimber 1975). O'Connell and Menage (1983) found that the fire history of three jarrah forest sites had an insignificant effect on litter decomposition.

- Fuels are considerably drier during autumn so autumn fires tend to consume a higher proportion of the forest litter (leaves, twigs and logs) than spring fires (Burrows 1987). Spring fires tend to leave unburnt patches, particularly wetlands, damplands and around rock outcrops, while autumn fires tend to be all-consuming.

- Although there is no research to support the fact, field observation indicates that some erosion is more likely following autumn than spring burns, since spring burnt areas tend to have more advanced regeneration at the time of the onset of winter rains, mainly associated with the regrowth of coppicing species ("resprouters"), and autumn burns tend to expose the surface soil while spring burns leave part of the litter bed intact.

Micro-organisms

There is little published work on this group and nothing published which compares spring and autumn fires. Malajczuk and Hingston (1981) and Malajczuk *et al.* (1987) have shown that numbers of ectomycorrhizal root types in jarrah forest were highest in a stand unburnt for 45 years and lowest in a stand burnt one year previously.

Vascular Plants

Jarrah and karri forest ecosystems comprise plants which have evolved a variety of adaptive traits which enable them to survive fire, or regenerate after fire. About 70 percent of the species in the jarrah forest are resprouters; the remainder depend on soil or canopy stored seed (Bell and Koch, 1980). These adaptive traits cut in to ensure the survival of the plant species irrespective of the season in which are fire burns.

In general, autumn fires (even those of relatively low rate of spread) cause considerably more physical crown and bole damage to trees and shrubs than low intensity spring fires (Burrows, 1987). During autumn fires, heavy fuels such as logs and limbs are dry and ignite, causing damage to nearby trees. Hollow-butt and fire-injured trees often burn down in autumn fires, but persist in spring, fires. Eucalypt tree crowns scorched by spring, fire recover more quickly than those scorched by autumn fire (Kimber 1978, Peet and McCormick 1971, Burrows 1988), because eucalypts flush their leaves during summer.

Low intensity fires (spring or autumn) have no long-term effects on the survival or growth of jarrah (Peet and McCormick 1971, Abbott and Loneragan 1983).

No changes in the number of understorey species were recorded by Christensen and Kimber (1975) and by Abbott (1984) following a series of low intensity fires in spring and autumn. This is supported by Bell and Koch (1980).

A study of the long-term effects of frequent (spring and autumn) fire on plants in high rainfall forest near Manjimup has shown no significant change in species numbers. Only four species showed significant changes in numbers; three species increased under an autumn burn regime and one species increased under a spring burn regime (Christensen, 1990).

Legumes which rely on soil stored seed for regeneration following fire increase in numbers following an autumn fire under dry soils. Repeated spring burning under moist conditions can reduce the number of above-ground plants, although the soil store of seed from which plants can regenerate does not appear to be affected (Shea *et al.* 1979, Skinner 1984, Christensen and Kimber 1975, Christensen and Skinner 1978). Frequent (two to three years) repeated autumn burning could diminish above-ground plants and the store of seed in the soil.

Repeated high intensity summer fires, or high intensity autumn fires would also diminish the regenerative capacity of resprouters.

A study of seedling regeneration of understorey species following spring and autumn fires in jarrah forests near Nannup revealed no significant difference in number of species, but significant difference in numbers of individuals. One year after fire, numbers of individual seedlings were higher following an autumn burn (Burrows, 1990).

Species which require ashbed for seed regeneration, such as *Eucalyptus wandoo*, are favoured by autumn fires under dry conditions for their regeneration.

Both spring and autumn fires disrupt flowering. About 70 percent of plants flower in spring. Almost all forest plants flower within three years of fire (Muir 1987, Burrows, (1990). Most forest areas are burnt on a cycle of five to seven years or more, thus allowing adequate time for plants to flower and seed.

The plant species most vulnerable to "frequent" fire are those which rely on canopy-stored seed for regeneration, and which take a relatively long time to mature. These species tend to be found in moist sites which rarely burn in spring fires, but can burn ferociously in the autumn.

Infrequent autumn fires are necessary to regenerate some thicket forming species which rely on capsule stored seed (eg: *Melaleuca viminea*). These thickets often form important animal habitat (Christensen 1980).

Higher intensity fires in summer or autumn can sometimes induce flowering in some species *(eg. Xanthorrhoracaea),* whereas mild spring fires do so only rarely. Both spring and autumn fires can stimulate massive and synchronised seed release and simultaneously provides ideal seedbed conditions for the germination and survival of seedlings (Bell *et al.*, 1989).

Birds

Prescribed burning under moist soil conditions (spring in jarrah forest, early summer in karri forest) had no impact on bird species richness in jarrah forest (Kimber, 1974), largely because unburned patches (in two dimensions) within the burned forest and unburned forest blocks adjacent to the burned forest act as a reservoir from which birds repopulate burned areas as soon as they refoliate. In karri forest, however, species richness increased for 3-6 years after fire. This type of fire tends to increase total abundance of birds in jarrah forest and karri forest.

Kimber (1974) found an immediate, temporary reduction in the bird populations resident in the lower 10 metre stratum of the forest after a spring fire followed two years later by an increase. Similar responses were observed by Christensen et al. (1986), Tingay and Tingay (1984) and Wooller and Brooker (1980) for both spring and autumn fires. All workers report that the level of disturbance to the bird population is proportional to the level of vegetation scorched or damaged by fire and the rate of vegetation recovery. Low intensity spring burns only affected birds utilising the ground and low shrubs, whereas autumn burns which scorched the entire forest profile, affected most bird species.

There is some mortality of nestlings following spring fires, especially of those species which nest near the ground. However, 70 percent of breeding is completed by the time spring fires are set. Also, parent birds are highly mobile, and the lengthy breeding season in the south-west allows disturbed birds to nest elsewhere. More than 90 percent of the forest is unburnt in any year, and over half the forest is always more than five years unburnt.

Another reason that mild fires have no or few detrimental effects on species richness/total abundance is that most fires are lit after September. Most forest bird species commence nesting in July and August. This fact, together with the deliberate spatial and annual dispersal of burning, ensures that any mortality caused to species nesting on the ground or in foliage scorched can be made good by dispersal of newly fledged birds from nearby unburned forest.

Planned burning under dry soil conditions (in autumn) results invariably in scorching of foliage to a greater height than in mild (moist soil) fires (Burrows, 1997). Even so, more bird species are recorded after autumn burning. It is noted that wildfire (in autumn) has the opposite effect – bird species richness is reduced relative to long unburned forest and mildly-burned forest (Christensen et al, 1985). Because wildfires are unplanned, they are often extensive. Total bird abundance also increases after autumn fire but is much reduced after wildfire. Burning in autumn has minimal impact on nesting bird species (Christensen et al, 1985).

Mammals

Mammals are affected according to the impact of fire on their food and shelter. Impact is greatest when fires are large, intense and frequent. In most spring burns, the individual spot fires move less than 30 metres in an hour. Mammals are able to easily move out of the way of these slow, low intensity fires. Spring fires also cause less damage to live and dead vegetation (including hollow logs and trees) than do summer or autumn fires. Spring fires are usually patchy, with moist gullies and areas carrying light fuels remaining unburnt. Autumn fires tend to burn most of the forest. In the presence of foxes, some animals, such as the Tammar wallaby, benefit from infrequent (20-30 years) summer or autumn fires which regenerate the thickets they depend upon for cover. Some animals, such as the mardo, favour long unburnt areas including the unburnt mosaic within spring burnt areas (Christensen and Abbott, 1989). Other animals, such as the chuditch, appear to be more favoured by areas burnt in the spring than those burnt in autumn.

Of the 31 species of mammals which were believed to have inhabited south-west forests at the time of European settlement, only three have become locally extinct: the Long Nosed Potoroo, Lesueur's Rat Kangaroo and the Rabbit Eared Bandicoot. All became locally extinct (they still occur elsewhere in Australia) before the initiation of prescribed burning in the south-west. The most likely cause of local extinction is predation by foxes. Compared with other major vegetation types in southern Western Australia, forest ecosystems have survived relatively intact.

Weed Invasion

Invasion of burnt areas by exotic weed species, especially grassy annuals, occurs on the fringes of some eastern forests where they are interspersed with agricultural lands carrying crops and pasture. Invasion is more prevalent after autumn than after spring burns because in the spring the exotic grasses do not carry mature seed. Weed invasion is most likely where forests adjoin farm paddocks and where there is some fertiliser drift into the forest from farming operations.

In the interior of the forest, exotic annual grasses are rarely found.

Operational aspects of Seasonal Burning

Spring burning is much easier and safer to implement, and usually cheaper than autumn burning. In spring, fuels are moist and weather is more stable, so fires are more secure and easier to implement. There are more days in spring when prescribed fires can safely be set. Control and mop-up costs are substantially less in spring as fewer logs catch alight and therefore the risk of fires escaping are also less in spring than in autumn. In autumn, many trees burn down, sometimes across roads, farmers' fences or power lines.

Because autumn burns tend to consume more of the available fuel than do spring burns, and in particular, they tend to consume more of the large woody debris on the forest floor, they generate more smoke.

The autumn season weather is less predictable. If the opening rains are early and persist, the season can close before it opens. If they are late, no suitable days for safe, effective burning might occur.

The relative benefits and disadvantages of spring and autumn burning are summarised in Table 5.

Table 5: Spring vs Autumn Burning

Autumn: The beginning of the rainy season which establishes rapidly and is usually characterised by conditions experienced in March-May. Wetting of a dry soil, vegetation and fuel profile.

Spring: The end of the rainy season which tapers off into a dry summer period and is usually characterised by conditions experienced in September-November. Drying of a wet soil, vegetation and fuel profile.

Spring Burning	*Autumn Burning*
Operational considerations	
• More days available to safely execute fuel reduction burns, therefore: ➢ better able to achieve protection program.	• Fewer days available.
• Fire weather and behaviour more predictable and stable, therefore: ➢ facilitate good planning and efficient resource allocation; ➢ low risk of escapes ➢ lower intensities therefore easier, cheaper control; ➢ low ignition rate of logs etc. so reduced pre-suppression and mop-up costs.	• Fire weather and behaviour less predictable and more unstable, therefore: ➢ burning opportunistic, poorer allocation of resources; ➢ high risk of escapes; ➢ higher fire intensities so increased costs; ➢ higher ignition rate of logs and trees, so increased pre-suppression and mop-up costs.
• Low impact on commercial and aesthetic values.	• High impact of commercial and aesthetic values.
• Higher risk of re-ignition over following summer.	• No risk of re-ignition over following summer.
Environmental Considerations	
• Less physical damage to vegetation/habitat.	• More physical damage (higher levels of scorch and defoliation).
• Incomplete removal of litter and vegetation.	• Complete removal of fuel, especially leaf litter, scrub, logs and some trees.
• Burns patchy, with pockets of unburnt vegetation especially along streams therefore greater habitat diversity, refuge areas.	• Burns complete, entire area including streams burnt therefore reduced habitual diversity, no refuge sites.
• High retention of hollow logs, dead and old trees therefore available habitat.	• High consumption of logs, dead trees and old trees often burnt down.
• Lower losses of volatile nutrients (function of fuel consumption).	• High losses of volatile nutrients especially from green foliage.
• Disruption to flowering at peak flowering period.	• Flowering not disrupted during peak flowering period.
• Gradual depletion of soil stored seed (but not eliminated).	• Superior germination of soil stored seed.
• Lower germination and seedling survival rate.	• High seedling germination and survival rate.
• Decreased abundance of hard seeders (acacias, legumes, obligate seed species), but these are not eliminated.	• Increased abundance of hard seeders and obligate seed species.
• No effect on resprouting vegetation. These are often favoured.	• Resprouting vegetation can be reduced in density, but not eliminated.
• Low impact on fauna (mammals, birds).	• High adverse short-term impact on fauna.
• Short-term disruption to birds nesting and foraging in low shrubs.	• Short-term disruption to birds using shrubs and trees for food shelter.
• Lower emission of smoke and of greenhouse gasses especially CO_2.	• High emission of smoke and greenhouse gasses due to higher levels of fuel consumption.

CHAPTER 5

THE EFFECTIVENESS OF PRESCRIBED BURNING FOR BUSHFIRE MITIGATION

5.1 Fire Control Benefits

It is a matter of simple physics that the damage potential a bushfire is directly proportional to the amount and the rate of heat energy released by the fire, and this in turn is a function of the amount of fuel burnt and its rate of consumption.

It is a matter of long experience and observation by those who practise it, that fuel reduction by prescribed burning in the south-west of Western Australia is essential to reduce the incidence and damage from wildfires.

The main advantages of fuel reduced buffer zones are:

- It is highly effective in decreasing fire intensity and rate of spread allowing easier suppression.
- It results in less damage to areas burned by a fire.
- It allows land managers the flexibility to implement special fire regimes for habitat management, regeneration and control of weeds and pests.
- The presence of areas of reduced fuel widens the strategic options for the firefighter, especially in situations of multiple simultaneous fires. Priorities can be assigned to the fires or to the sectors of fires where either the problem is greatest, or the opportunity to do useful work is highest.
- It is an excellent way of providing practical experience for fire management personnel in fire behaviour and control, thus increasing their confidence and safety in dealing with wildfires.
- It provides safer working a conditions and refuges for firefighters.

Fire intensifies under most summer weather conditions will exceed 2000 kW/m when jarrah fuel exceed 8-10 tonnes, and when fires reach intensities above 2000 kW/m they are uncontrollable.

From an operational viewpoint, the reduction in fire intensity which occurs when a fire runs into an area of reduced fuel is always welcomed by the firefighter. If fire intensity drops to below 2000kW/m a direct attack can be made on the fire with machines or hand tools. If direct attack cannot be attempted on the headfire, it can frequently be successful on the backfire and along the flanks, thus "pinching in" the head.

In situations where none of the flanks of a fire can be attacked and back burning or burning out to roads is the strategy adopted, the presence of lighter fuels is also a significant advantage. Backburning can be very dangerous in forest country, especially under the unstable atmospheric conditions and high winds which are usually associated with bad fires. This danger is minimised if the back burn is done up against light fuels in which the inevitable hopovers can be more readily attacked.

The question of the relationship between fuel and fire suppression difficulty in Australian forests was examined by Dr Malcolm Gill of CSIRO in 1986. Gill calculated the number of days on which fire intensity would exceed 2000 kW/m for different fuel tonnages in the forest. He found that even for the hot, dry conditions experienced in Western Australia each summer, if fuels are below eight tonnes per hectare, there are few days on which fire intensities exceed 2000 kW/m and therefore few days on which fire attack would not succeed. On the other hand, if fuels accumulate to 20 tonnes/hectare, uncontrollable fires can occur on about 130 days each year. This period extends to over 200 days/year where fuels exceed 30 tonnes/hectare.

5.2 Fire Fighter Safety

Fighting wildfires in forests is one of the most dangerous tasks undertaken by any Australian worker. This is because there are inherent perils associated with falling limbs and trees, the rain of burning embers ahead of the front, intense heat, searing flames and choking, blinding smoke, all of which are overlain by a high probability of unexpected or unpredictable changes in fire behaviour caused by sudden wind, topographic or fuel changes. To these problems can be added the personal ones of extreme stress (especially in life-threatening circumstances) and fatigue, which unfortunately is also sometimes accompanied by inexperience and lack of physical fitness; and costly damage to vehicles and equipment.

In these situations firefighters are sometimes "caught" by a fire - that is, surrounded, with no way out but through the flames. When this happens crews are trained to move to the areas where fire behaviour will be least intense and then "bed down" inside a vehicle cab or underneath a bulldozer, or dig themselves in behind a log, until the flame front has passed. The best area into which to retreat is one which has been recently prescribed burnt, and in which the fuels are light. If conditions are hot and windy, the fire will still run through these areas, but the intensity of the fire will be significantly reduced, and the probability of survival of the crew will be considerably increased.

CALM has a good record of firefighter safety in the forest regions since the advent of broadscale prescribed burning. No staff have been killed in over 40 years, and many have used light fuel areas to ensure their safety in dangerous situations.

5.3 Fire at the Urban Interface

The urban/rural interface is the most fire vulnerable part of the Australian (and world wide) environment. The mixture of bushland, houses, people, paddocks and stock is optimum for the occurrence of difficult fires which cause maximum damage.

In Western Australia there are many urban interface areas of great concern, particularly the hills area east of Perth, the new suburbs north of Perth, the "hobby farm" and rural retreat areas along the Leeuwin-Naturaliste ridge and similar areas in and around the karri forest and along, the south coast.

The solution to the fire threat in these areas must involve a package of strategies, including house design and protection measures, maintenance of fire breaks and clean areas around buildings, sprinkler systems, well trained and well disciplined householders and the nearby presence of well equipped and highly readied fire suppression crews. However, central to all these things being effective is the prevention of high intensity fires with long flames and heavy spotting, driving out of the bushland which surrounds the settlements. Even highly trained and experienced crews cannot contain such fires, and if the intensity is high enough, the fires will overwhelm nearly all other precautions, leading to houses, homesteads, out-buildings, stock and crops, etc. being consumed in the fire.

This happens quite regularly in the USA (especially southern California), and has occurred in recent years in South Australia, Tasmania, Victoria and New South Wales. Repeated experience has shown that when high intensity bushfires are driving in, settlements catch alight and burn well before the arrival of the flame front. Ignition results from the rain of burning embers which precedes the fire and which, swirling on high winds, penetrates buildings and sets fire to shrubbery, trees, hedges, wood heaps etc. surrounding houses. The only way to minimise this is to reduce the intensity of the fire driving at the settlement by burning to reduce the fuels to a depth of at least one kilometre in the area, well before the worst heat of summer.

Fuel reduction is therefore a pivotal part of the overall strategy for preparing for wildfire at the urban interface. As in the forest, not every area needs to burned every year, or even every four or five years. It is essential to have a network of bush in which fuel has been reduced throughout the matrix of bush and settlement. This will not prevent bushfires! But it will ensure that those fires which do occur will tend to be less intense and therefore easier to control and less damaging and therefore less costly to the community.

There are numerous examples of this strategy working in Western Australia (Underwood et al, 1985 and McCaw, 1993).

5.4 Fire Fighting Options

The presence of areas where the fuels have been reduced within the forest provides fire fighters with additional options, especially when they are hard pressed in multiple fire situations.

The most classic demonstration of this in recent times in Western Australia occurred during the Cyclone Alby fire emergency in April 1978. During the height of this emergency there were about 90 bushfires burning simultaneously in south-west forests (van Didden, 1978). These fires were being driven by cyclonic force winds, and many fires threatened towns, bush settlements and farms. Fire controllers could not possibly attack all fires, as there were simply not enough forces available. So decisions were made to attack only those threatening the highest values. Many fires were burning in light fuels which had been reduced, by prescribed burning up to four years before, and attack on them was deliberately deferred. or was assigned to inexperienced, crews. One fire in State forest which was burning in fuels less than one year old was allowed to burn unattended for nearly two days, because it was causing no damage and posed no threat.

The presence of light fuels also increases the strategic options when deciding how to tackle an individual fire. The headfire can be allowed to burn into light fuels before attack is initiated, thus saving effort and risk, or flanks can be allowed to burn out to light fuel areas rather than construct firelines along them. Back burning is always safer and easier when the fire fighters' backs are up against light fuels, than it is when the adjacent fuels are heavy, and hopovers are uncontrollable.

5.5 Fire Training Opportunities

When fire officers and their crews undertake a prescribed burning program, they are required to become very familiar with fire. This takes the form of measuring fuels, calculating fire behaviour, studying fuel moisture changes, prescribing fires for given situations, lighting and controlling fires, assessing impacts and monitoring actual versus predicted fire behaviour. The control of a large aerial prescribed burn in the karri forest, for example, requires personnel to carry out most of the managerial and technical functions they perform at a wildfire - planning, organising, supplying, directing and controlling, plus suppression, mopping-up, patrol, preparing and back burning edges and building firelines.

Thus, a regular prescribed burning program provides the ideal training ground for fire management staff in developing this experience and the confidence which goes with it, as well as in the straight forward technical skills of fire suppression.

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DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT
POLICY STATEMENT NO. 19
FIRE MANAGEMENT POLICY
MAY 1987 (REVISED MAY 1997)

1 INTRODUCTION

This policy is based upon the following premises:

1.1 Fire has occurred naturally from time to time in practically all lands managed by CALM. Fire has therefore played some part in determining present vegetation structures and composition.

1.2 Under natural conditions, practically all ecosystems are made up of a mosaic of vegetation associations and structural stages according to their fire histories. The scale of the mosaic varies in different ecosystems.

1.3 Fires from natural causes (eg: lightning) will inevitably occur. Fires resulting from human activities, either deliberate or accidental will also occur, but may be minimised by effective public education and awareness, and by legislation.

1.4 In Western Australia, weather conditions occur every year under which fires can be so intense as to be impossible to contain with currently available technologies and resources. Such fires can threaten human lives, and resources valued by the community, and their control involves considerable public expenditure and risks to fire fighters.

1.5 The speed and intensity at which fire burns is related to the quantity of accumulated dry litter or other fine plant material. In some ecosystems, or in some high risk/high value situations, accumulated fuel loads can be reduced by prescribed burning. This reduces the likelihood of intense fires even under extreme conditions, and improves the capacity for fire fighters to safely control a fire.

Within each major fuel type there is a recognised weight of dry fuel above which fire fighting forces are not likely to be able to contain wildfires burning under normal hot summer conditions.

1.6 Much of departmental land, particularly in the south-west, has a common boundary with well developed private assets such as towns and farms, the protection of which reduces the flexibility for fire management.

1.7 Information about the long term effects of different fire regimes, including fire exclusion on many ecosystems is limited, and any management policy must be under constant review and accompanied by research and monitoring programmes.

1.8 The Department has a moral and legal obligation to comply with those provisions of the Bush Fires Act, and CALM Act relating to fire prevention and control of wildfires on or near CALM lands.

2 OBJECTIVES

The fire management goal of the Department of Conservation and Land Management is:

2.1 To protect community and environmental values on lands managed by the Department from damage or destruction from wildfire.

2.2 To use fire as a management tool to achieve land management objectives, in accordance with designated land use priorities.

3 POLICY

3.1 Fire Suppression

1. The Department will meet its legal obligations under the Bush Fires Act and Conservation and Land Management Act by responding to fires occurring on or near CALM land to a degree that is appropriate to the values at risk.

2. The Department will assess its response to a fire in the light of potential damage to the following values in order of priority.

   (i) Human life;
   (ii) Community assets, property or special values (including environmental values);
   (iii) Cost of suppression in relation to values threatened.

3. Where values dictate the Department will:

   (i) provide a detection system which will give timely warning of the presence of a fire threatening community or environmental values;
   (ii) provide a well trained and equipped suppression organisation capable of containing several simultaneous unplanned fires under extreme weather conditions in conjunction with other fire fighting organisation.

3.2 Use of Fire

The Department will:

1. Use planned fire only where this use is in accordance with an approved management plan, or, where such a plan does not exist, to protect and maintain the designated priority land use.

2. Prepare written prescriptions in advance, for approval by senior designated officers, before any planned fires are undertaken.

3. For areas where primary land use is wildlife conservation, use fire in such a way as to promote the greatest possible diversity and variety of habitats within prevailing physical or financial constraints.

   In small conservation reserves and where information on the impact of fire is limited, fire will be used conservatively. In such areas the use of fire will be restricted to:

   (i) protection of neighbouring community assets; and
   (ii) as far as is achievable and within safe limits, ensuring that different seral stages following fire are represented.

4. Use prescribed fire or other methods to reduce fuels on appropriate areas of CALM lands, where it can be demonstrated that this is the most effective means of wildfire control, and where undesirable ecological effects do not result.

   The frequency of fuel reduction measures will be governed by the rate of build-up of fuels; the degree of risk to human lives, the value of the assets to be protected; the known sensitivity to fire, or dependence on fire, of the kinds of plants and animals present; and the resources available to carry out the work.

3.3 Liaison

The Department will:

1. Ensure effective liaison with neighbours, Bush Fires Board Brigades, Shires, Bush Fires Board and other fire control organisations.

2. Support the concept of Shire District Fire Plans and promote mutual aid interagency agreements for fire control on lands of mixed tenure with common fire problems.

3.4 Public Awareness

The Department will provide for public education in relation to the prevention of fire, and the role and use of fire in ecosystem management, and hazard and risk reduction.

3.5 Research

The Department will undertake research into fire prevention and control, fire ecology and fire behaviour on CALM lands to improve the scientific basis for, and effectiveness of Fire Management Programmes.

4 STRATEGIES

4.1 Fire Suppression

Suppression of unplanned fires on or threatening departmental land will be given priority over normal activities, except for those involved with safeguarding human life.

A detection system based on aircraft, lookout towers or ground patrol, will be used in designated areas where early warning of a fire occurrence is essential to enable rapid control measures.

In other areas, the Department will rely on neighbours, staff presence, the public, or commercial aircraft for reports of fire outbreaks.

When a fire is detected an appreciation will be made to estimate its likely spread and potential to cause damage to life, property or environmental value.

Unplanned fires will be contained to the smallest possible area by the most appropriate means available taking into consideration the values at risk and the impact of the suppression activity on the environment.

4.2 Use of Fire

Prescribed fires will be used to achieve a range of management objectives, including fuel reduction, habitat management, forest regeneration and the management of scenic values.

According to management objectives, appropriate prescriptions will be developed, and staff will be trained in their application.

Monitoring of the effects of fires will be undertaken wherever effective systems have been developed and resources are available.

4.3 Liaison

The Department will participate in the preparation and implementation of Shire District Fire Plans and interagency agreements.

Departmental staff will attend Bush Fire Advisory Committees and Brigade meetings where appropriate, to foster and encourage good working relationships with other fire fighting organisations.

Where practical, departmental staff will assist with fire control activities on a neighbour to neighbour basis with local bush Fire Brigades and other fire control organisations.

4.4 Public Awareness

Education of the public on the prevention of wildfire and on the use and role of planned fires will be promoted through the provision of literature, films and talks. Special attention will be directed towards school groups.

4.5 Research

The Department will undertake research and will encourage research by other agencies and institutions into the fields of:

1. Fire behaviour in major vegetation types;
2. Fire ecology;
3. Fire equipment development;
4. The application of information technology to fire management;
5. Fire detection, prevention and suppression systems;
6. Remote sensing for fire mapping and detection purposes;
7. Alternative methods of fuel reduction;
8. Social aspects of fire prevention and arson.

4.6 Operations-Research Interface

The Department will ensure that there is a rapid transmission of research results into policy and operations. Research and specialist staff will help to develop and update operational prescriptions and monitoring systems.

The Department will sponsor relationships between its staff and other agencies or organisations concerned about fire by the publication of research findings, holding workshops and seminars, and public participation in management plans.

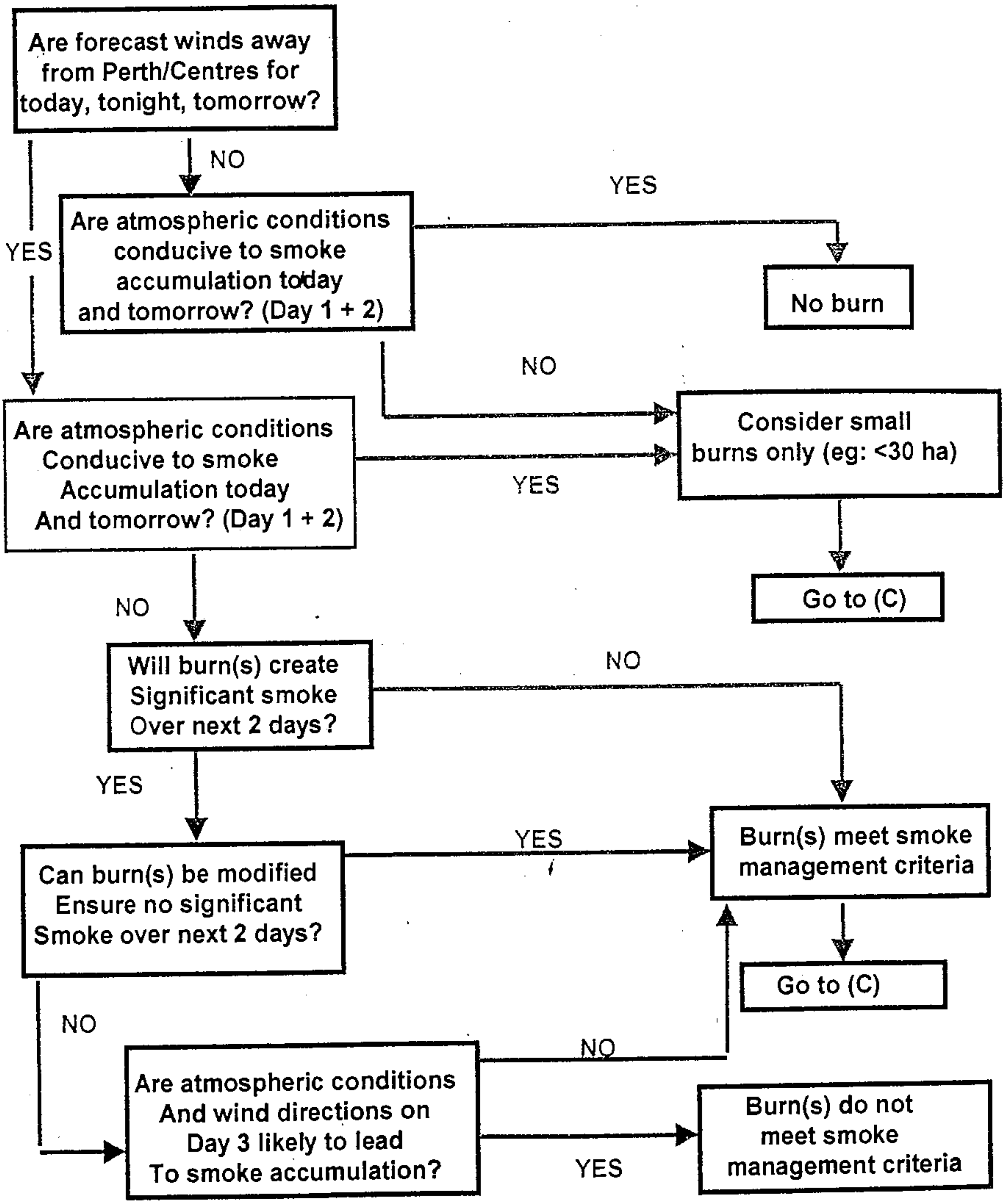
APPENDIX 2

SMOKE MANAGEMENT DECISION PROCESSES DEVELOPED BY CALM (as at July 1999)
Factors requiring consideration

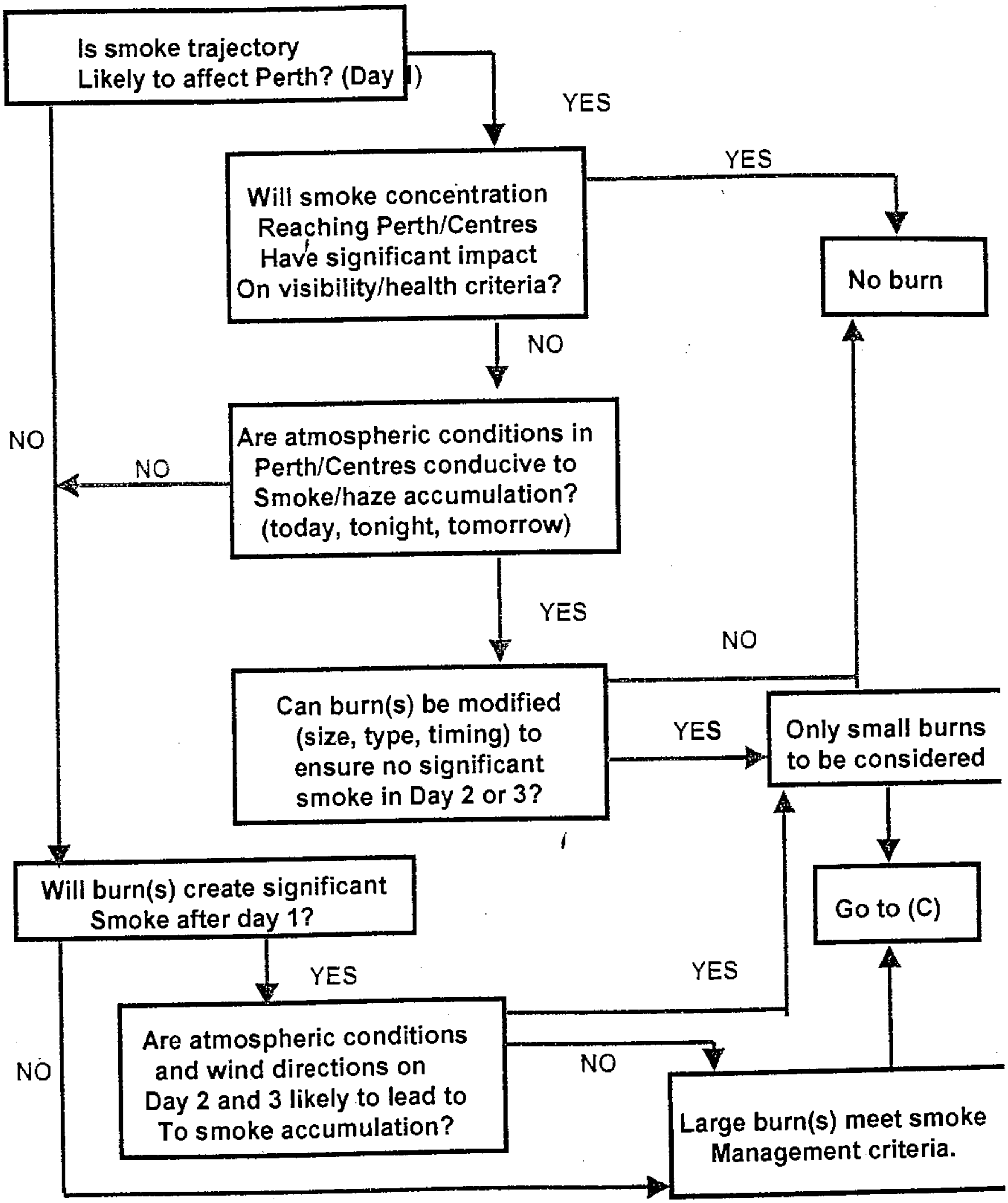
1. Pre-conditions factors →	2. Synoptic analysis →	3. Burns proposed →	4. Smoke-weather model →
1. Presence/absence of smoke "in the system" (previous burns/ wildfires). 2. Burns started that will require follow-up lighting. 3. Burn security (ie:, risks of escape). 4. Political sensitivity. 5. Commitment to wildfires, burn mop-up and patrol. 6. Availability of resources. 7. Burn prescription matches forecast weather, fuel moisture etc.	1, Weather pattern (4 day outlook). 2. Trough formation/structure/ likely movement. 3. Future weather conditions that lead to smoke accumulation.	1. Location with regard to Perth/ other residential areas. 2. Size of burns. 3. Concentrations of burns. 4. Type of burns (eg: slash, hazard reduction, etc). 5. Time taken to ignite and burn-out time (risk of smouldering). 6. Extent to proportion of areas already burnt. 7. Risk of burn delay to safety. 8. Importance of burn to community safety. 9. Will burning require follow-up lighting in current period?	See Section B1 or B2 depending on location of burn from Perth. B1 – for < 100 km B2 – for > 100 km

B1

Smoke-Weather Decision Model
Swan Region (<100km South of Perth)



Smoke-Weather Decision Model
Central Forest and Southern Forest Region
(>100km South of Perth)



C

FACTORS AFFECTING FINAL DECISION ON WHETHER OR NOT TO PROCEED WITH BURN PROGRAM

1. Risk of delaying "follow-up" lighting on burns already partly lit

   - Safety of burn
   - Risk to neighbours/other assets
   - Future smoke during unfavourable atmospheric/wind direction conditions
   - Risk of CALM staff
   - Risk of bad publicity

2. Contribution of smoke from "non-CALM" burns to overall smoke/haze situation.

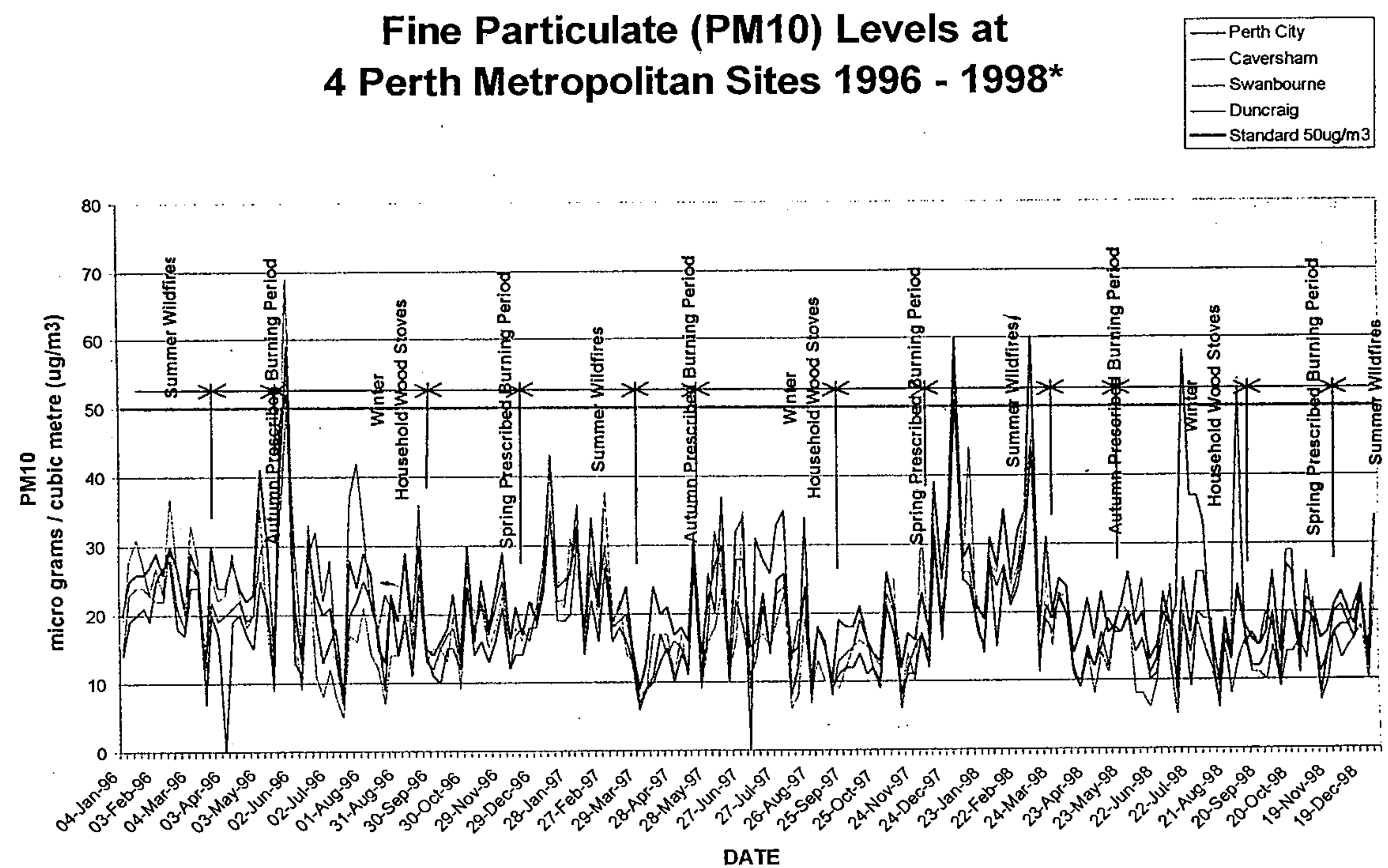
3. Accuracy/reliability of weather forecasts and smoke plume projection.

4. Capacity to light-up and complete ignition within time constraint.

5. The number of burns already lit up and not yet completed.

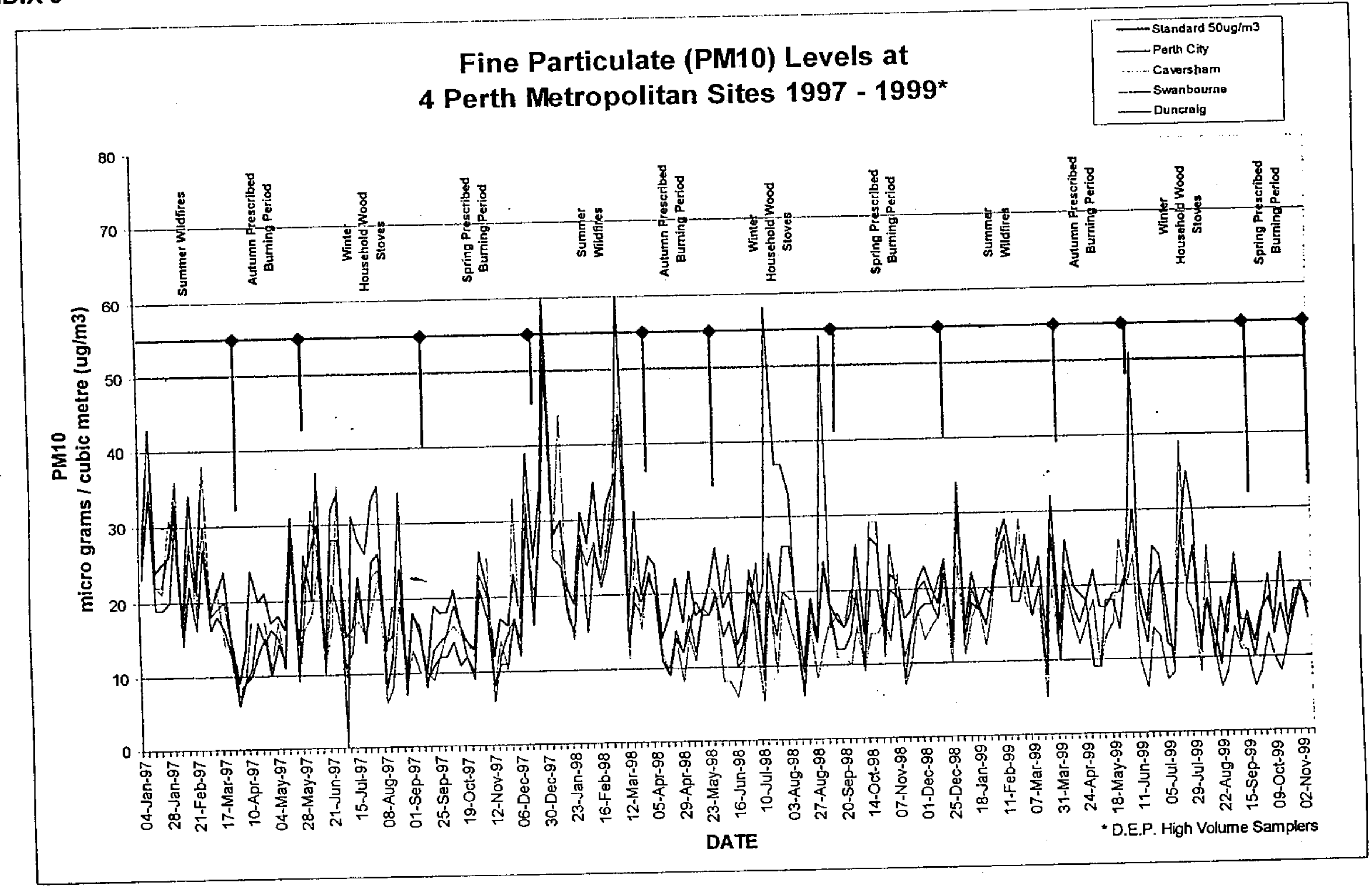
6. Balance between exposing some residents to smoke in order to avoid major centres.

APPENDIX 3



* D.E.P. High Volume Samplers

APPENDIX 3


Fine Particulate (PM10) Levels at
4 Perth Metropolitan Sites 1997 - 1999*
Standard 50ug/m3
Perth City
Caversham
Swanbourne
Duncraig
PM10
micro grams / cubic metre (ug/m3)
80
70
60
50
40
30
20
10
0
Summer Wildfires
Autumn Prescribed Burning Period
Winter Household Wood Stoves
Spring Prescribed Burning Period
Summer Wildfires
Autumn Prescribed Burning Period
Winter Household Wood Stoves
Spring Prescribed Burning Period
Summer Wildfires
Autumn Prescribed Burning Period
Winter Household Wood Stoves
Spring Prescribed Burning Period
04-Jan-97
28-Jan-97
21-Feb-97
17-Mar-97
10-Apr-97
04-May-97
28-May-97
21-Jun-97
15-Jul-97
08-Aug-97
01-Sep-97
25-Sep-97
19-Oct-97
12-Nov-97
06-Dec-97
30-Dec-97
23-Jan-98
16-Feb-98
12-Mar-98
05-Apr-98
29-Apr-98
23-May-98
16-Jun-98
10-Jul-98
03-Aug-98
27-Aug-98
20-Sep-98
14-Oct-98
07-Nov-98
01-Dec-98
25-Dec-98
18-Jan-99
11-Feb-99
07-Mar-99
31-Mar-99
24-Apr-99
18-May-99
11-Jun-99
05-Jul-99
29-Jul-99
22-Aug-99
15-Sep-99
09-Oct-99
02-Nov-99
DATE
* D.E.P. High Volume Samplers