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Smoke management in Western Australia's south-west forests

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ABSTRACT

Prescribed burns conducted by the Department of Conservation and Land Management (CALM) on forest blocks up to 300 km south of Perth, can result in the development of smoke haze in the Perth metropolitan area. This smoke haze can significantly reduce visibility along highways and airports, and upset residents who perceive there may be health risks associated with smoke concentration.

Active smoke management programs for burns close to Perth began in 1974, and smoke management has since been extended to all forest areas in the south-west of the State.

Studies on the impacts of various weather parameters and operational factors on the incidence of smoke haze in Perth indicated that the most important factors included atmospheric stability conditions, wind directions, location of burn in relation to other burns, accumulated areas of burns, timing of burns, and distance of burn from Perth.

A set of smoke management guidelines have been developed and tested successfully over three fire seasons. The guidelines have been incorporated into a decision model for fire managers. The model is presented in the form of a series of simple decision charts. Further research into prediction of smoke transport and dispersion is being undertaken between CALM and the WA Regional Bureau of Meteorology.

INTRODUCTION

The Department of CALM carries out an extensive prescribed burning program in the south-west forests, in order to reduce flammable fuels and mitigate the undesirable social, economic, environmental and human problems caused by destructive wildfires.

In part, CALM's burning program stems from the direction to do so, made by a Royal Commission (Rodger 1961) which enquired into the widespread bushfires in summer 1961, which destroyed Dwellingup and several other settlements.

In part, CALM is also responding to the Bush Fires Act of 1954 which requires landowners to take responsible action to minimize fire hazard. While CALM is not a landowner in this sense, it has a duty of care as a neighbour to carry out appropriate works which reduce the probability of fire spreading onto neighbouring properties.

Prescribed burning is carried out by CALM District staff, often with the assistance of volunteer bush fire brigades. The work is done in accordance with a Fire Management Plan for the district which sets out the areas to be burnt and the frequency and season of the burns. Fuel reduction burns are concentrated in the areas where the highest values need to be protected from potential wildfires. Other planned burns are lit for a variety of purposes, including wildlife habitat management and forest regeneration (McCaw and Burrows 1989).

The fuel-reduced areas which result from prescribed burning have enabled fire fighters to suppress many potentially serious wildfires, to the extent that there have been very few major fires in the past thirty-three years in the jarrah and karri forests of Western Australia (Underwood *et al.* 1985).

During this time no fire fighter has been burnt to death in a forest fire in Western Australia, as has occurred in south-east Australian states, nor has there been any civilian loss of life.

Land managers have a responsibility to ensure that prescribed burning is strategic, timely, appropriately and correctly applied. An additional responsibility of land managers extends to the minimization of impacts of smoke from prescribed burning on the community. Smoke from these burns can be more than a nuisance as it can reduce visibility along highways, close airports and upset metropolitan residents because of perceived health risks associated with smoke concentration.

SMOKE AND WEATHER CONDITIONS

Fuel reduction burns in the south-west forests of

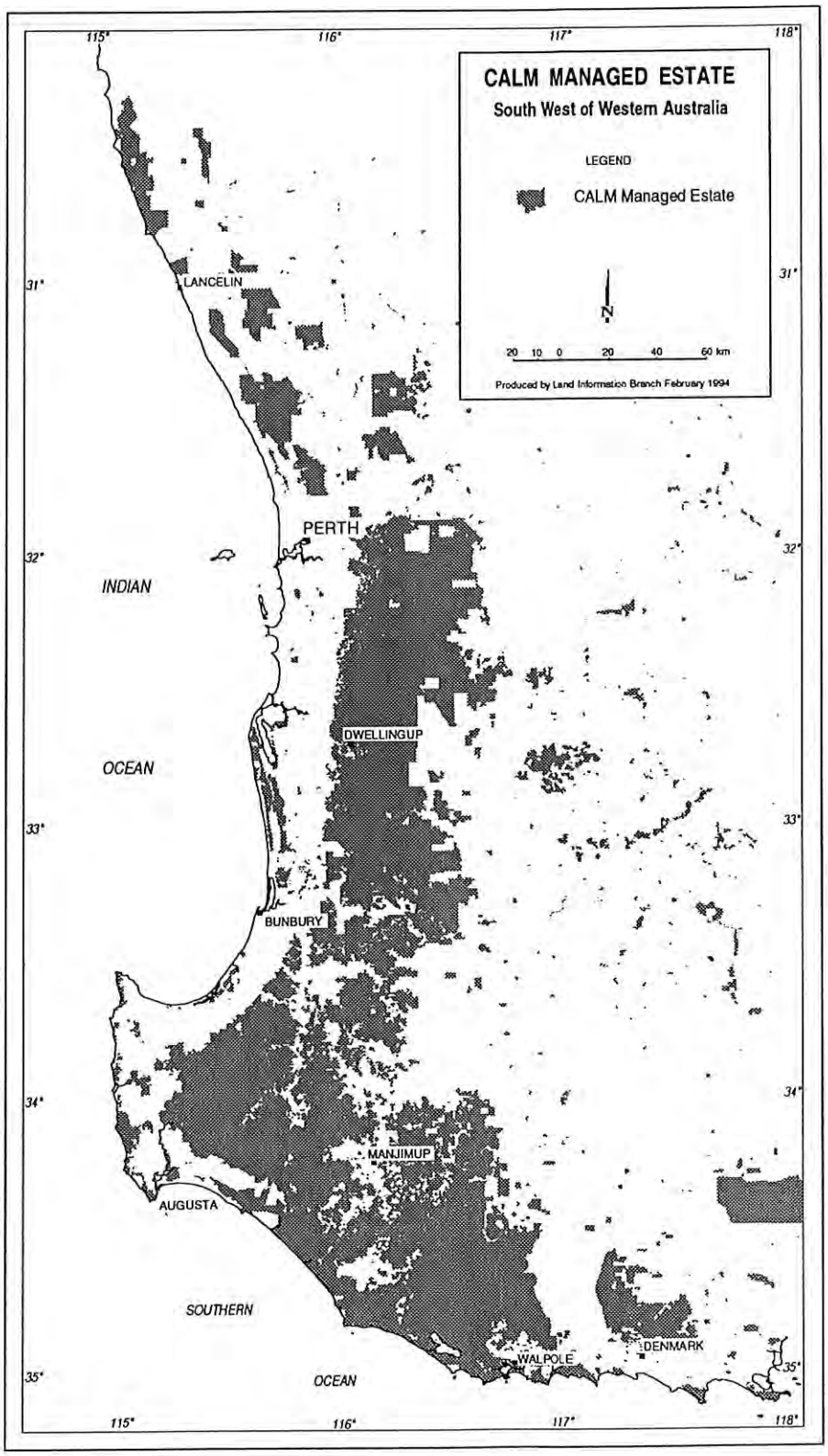

Figure 1. Areas of CALM-Managed Estate in south-west of Western Australia.

Western Australia are normally carried out in the spring, early summer and autumn months early in the cycle of anticyclones which move from west to east across the southern half of the continent. During these periods moderately warm and dry conditions occur for periods of 3 to 5 days enabling low intensity burns to be carried out safely. The range of conditions typically associated with prescribed burning for fuel reduction are shown in Table 1. The typical range of fire behaviour parameters observed at these prescribed burns is shown in Table 2.

Burns in the northern jarrah forest north of Bunbury can be carried out on the westerlies which occur as the anticyclone begins its easterly movement across the bottom part of the State. The south-easterly winds are most often used for the forest zones south of Bunbury as these coincide with moderate weather conditions and suitable levels of fuel moisture.

The winds in the southern quarter provide the safest conditions under which to light prescribed fire as these conditions are generally characterized by mild temperatures, relatively moist fuels, predictable and moderate wind speeds and relatively stable atmospheric conditions. Unfortunately those conditions that are normally suitable for a safe effective fuel-reduction burn in the forest are most often the same that lead to poor smoke dispersal and the accumulation of high levels of smoke concentration.

South-easterly winds transport smoke from burns in the northern jarrah forests directly into Perth. Further south, smoke can be carried by the south-easterlies over the Indian Ocean from where some of the smoke can be blown back over the coast and Perth by the late afternoon south-westerly sea breeze.

During days of very stable atmospheric conditions this has resulted in a smoke haze in Perth when the visibility index exceeds the current standard applied by the Department of Environmental Protection (DEP). This standard is the visual range of 20 km averaged over 1 hour. This standard is determined by reference to the light-scattering properties of fine airborne particles as measured by a nephalometer. A visibility coefficient is determined from the nephalometer readings. A coefficient value of 2.3 is equivalent to a visual range of 20 km. Values which exceed 2.3 when averaged over 1 hour are considered to exceed the air quality guidelines adopted by the DEP. The smoke haze usually lasts for 2 to 8 hours overnight and disappears in the morning with the dissipation of the nocturnal inversion and the onset of the prevailing easterlies.

High intensity wildfires normally occur on north-east, north or north-west winds. While such fires generate much larger volumes of smoke that can affect southern regional centres such as Bunbury, Manjimup and Denmark, the smoke is normally carried south away from the Perth metropolitan area. Any 'pollution problem' associated with bush fire smoke in Perth is therefore more related to prescribed burning than to wildfires.

MANAGING THE SMOKE

CALM has managed smoke in the northern jarrah forest, within 100 km of Perth, for nearly twenty years. Based on smoke distribution studies conducted by the Commonwealth Scientific Industrial Research

TABLE 1

Range of weather and fuel conditions used for fuel reduction burning operations in jarrah and karri forests

	TEMPERATURE (°C)	RELATIVE HUMIDITY (%)	WIND DIRECTION	WIND SPEED (km h^{-1})	SURFACE FUEL MOISTURE CONTENT
Range of Condition	20 to 30	30 to 50	W-S-E	10 to 20	10 to 16%

* Moisture Content expressed as percentage of oven-dry weight

TABLE 2

Range of fire behaviour characteristics for fuel reduction prescribed burns in forest fuels of WA

FIRE BEHAVIOUR CHARACTERISTICS	FLAME HEIGHT (m)	HEADFIRE RATE OF FORWARD SPREAD (m h^{-1})	FIRELINE INTENSITY (kW m^{-1})
Range of Parameters	0.3 to 2.0	15 to 40	100 to 500

Organisation (CSIRO) in conjunction with the Forests Department of Western Australia in the early 1970s (Vines *et al.* 1971), a predictive model was developed to make reliable predictions about the fate of smoke plumes from planned burns. The model has been used to determine the maximum size of an area that can be burned under various wind directions at a predetermined distance from Perth so that the air quality in the metropolitan area is not significantly affected. For example, under south-easterly and easterly winds, areas burnt within the northern jarrah forest zone are restricted to a size given by the following simplified equation.

Max. Burn area (ha) = Distance from Perth Airport (km) x 20.

For example, the largest burn area for a location 80 km south-east of Perth Airport is 1600 ha.

This decision rule is applied particularly where winds are likely to lead smoke directly into Perth. Larger burns can be conducted only when winds are predominantly from the south-west. Stringent application of this model over the past twenty years has resulted in very rare instances when smoke from northern forest burns has blown directly onto Perth, usually as a result of an incorrect wind forecast.

In 1990 CALM became aware that smoke haze from southern forest burn operations was exceeding visibility standards on seven or eight occasions each summer. These instances, which occurred mostly at night, were detected on three DEP nephalometer recorders located in and around Perth. The origin of these smoke sources were confirmed by LANDSAT images to be as far as 300 km south of Perth.

As a result, CALM has undertaken studies into determining the relationship between weather and burn operation factors and the incidence of smoke haze from these southern forest burns (Smith 1991, 1992).

These studies identified a number of factors that may contribute to the incidence and extent of smoke haze in the Perth metropolitan area.

(i) Atmospheric Stability

Atmospheric stability as measured by the rate of temperature change with height. The presence and depth of low-level temperature inversion measured at 7.00 a.m. each day at Perth airport provided a good guide to the probability of smoke haze occurring in the metropolitan area. The stronger the inversion temperature change, the more likelihood that smoke will accumulate and exceed limits.

(ii) Total Area Burnt Within a Day

The area of prescribed burning that can be undertaken without resulting in smoke haze appears to be dependent on the atmospheric instability. Under weak inversion (<3°C change within the first 1000 m) the accummulated area of several burns can exceed 15 000 ha. This area is reduced to about 12 000 ha under moderate inversion (<3-6°C change); and 6000 ha for strong inversion (7-10°C change). Inversion temperature changes in excess of 10°C were rare and often associated with a west coast trough that prevented any dispersion of smoke haze on the west coast.

(iii) Burn Concentration

The concentration of smoke was related to the geographic distribution of burning operations. Separation of burns by more than 80 km reduces the smoke concentration and therefore the likelihood of high smoke haze levels recorded in Perth.

(iv) Wind Direction

The transport of smoke from southern burns into Perth occurs predominantly under southerly winds. Afternoon seabreezes have substantial influence on the occurrence and timing of arrival of smoke haze in Perth.

Winds with a northerly component reduced the likelihood of smoke haze in Perth, but can disperse smoke over regional centres in the lower south-west.

(v) Scheduling of Burns

Delaying the ignition of burns can reduce the chances of smoke reaching the Perth area. In some circumstances, smoke from burns ignited later in the day is blown over the Indian Ocean and is not widely dispersed because the influence of the seabreeze has diminished by the time the smoke reaches Perth.

SMOKE MANAGEMENT GUIDELINES

Smoke management guidelines have been developed over the past three years which take into account atmospheric conditions, wind direction, forecast of seabreeze, location of burn in relation to metropolitan area, the size of burns, location in relation to other large CALM burns, total area likely to be burnt on the day, burn priority and recent history (e.g. already partly alight), availability of resources including aircraft for ignition, and incidences of other burn operations undertaken by other agencies and landholders.

To assist fire managers co-ordinate the complex burning program in accordance with these smoke management guidelines, a decision model has been recently developed and applied in 1992-93 and will be further tested in the 1993-94 burning season. This model is presented in the form of a series of simple decision charts (Figs 2 to 7).

The application of the smoke management guidelines during the 1992 and 1993 burning seasons resulted in a low incidence of smoke haze in Perth. There was one serious haze occurrence that plagued Perth for three days from 21 to 23 October 1992 (Rye 1994). This appeared to be a result of an unusually intense inversion over the Swan Coastal Plain which trapped smoke from wildfires and private burning operations to the north of Perth. CALM's burning operations were cancelled during this period to avoid contributing to the problem.

PRESCRIBED BURNING AND SMOKE MANAGEMENT DECISION SYSTEM FOR SOUTH-WEST FORESTS OF WA

POSSIBLE PATHWAYS OF SYSTEM

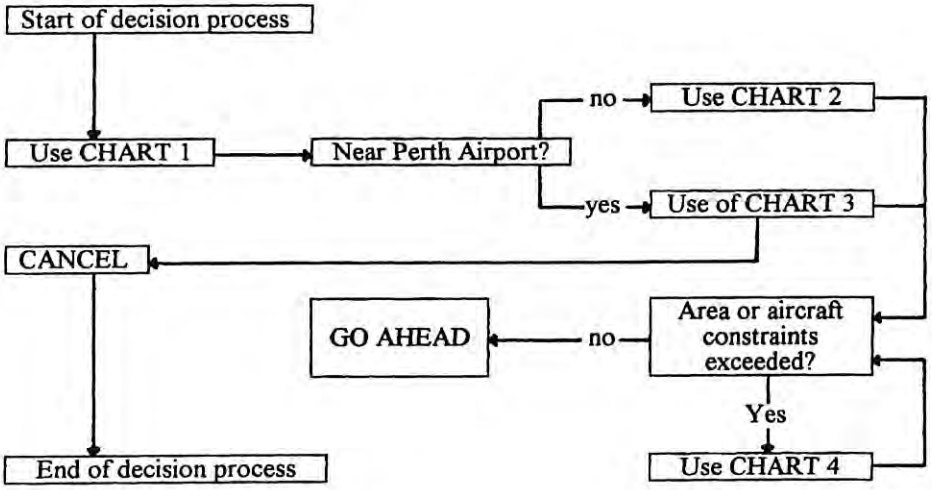

Figure 2. Decision Chart for Smoke Management.

PRESCRIBED BURNING AND SMOKE MANAGEMENT - DECISION CHART 1

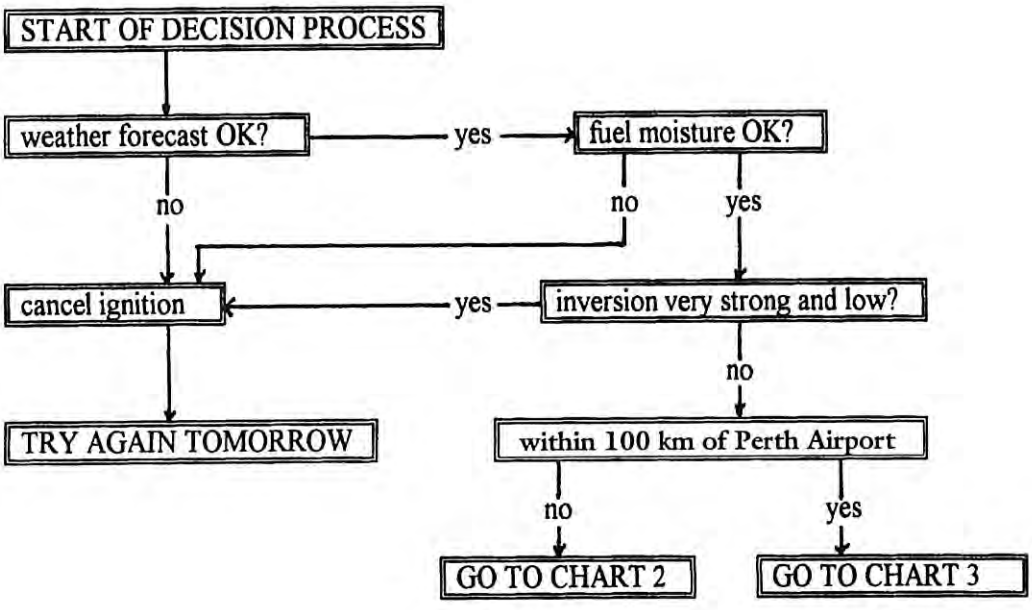

Figure 3. Decision Chart 1.

PRESCRIBED BURNING AND SMOKE MANAGEMENT - DECISION CHART 2

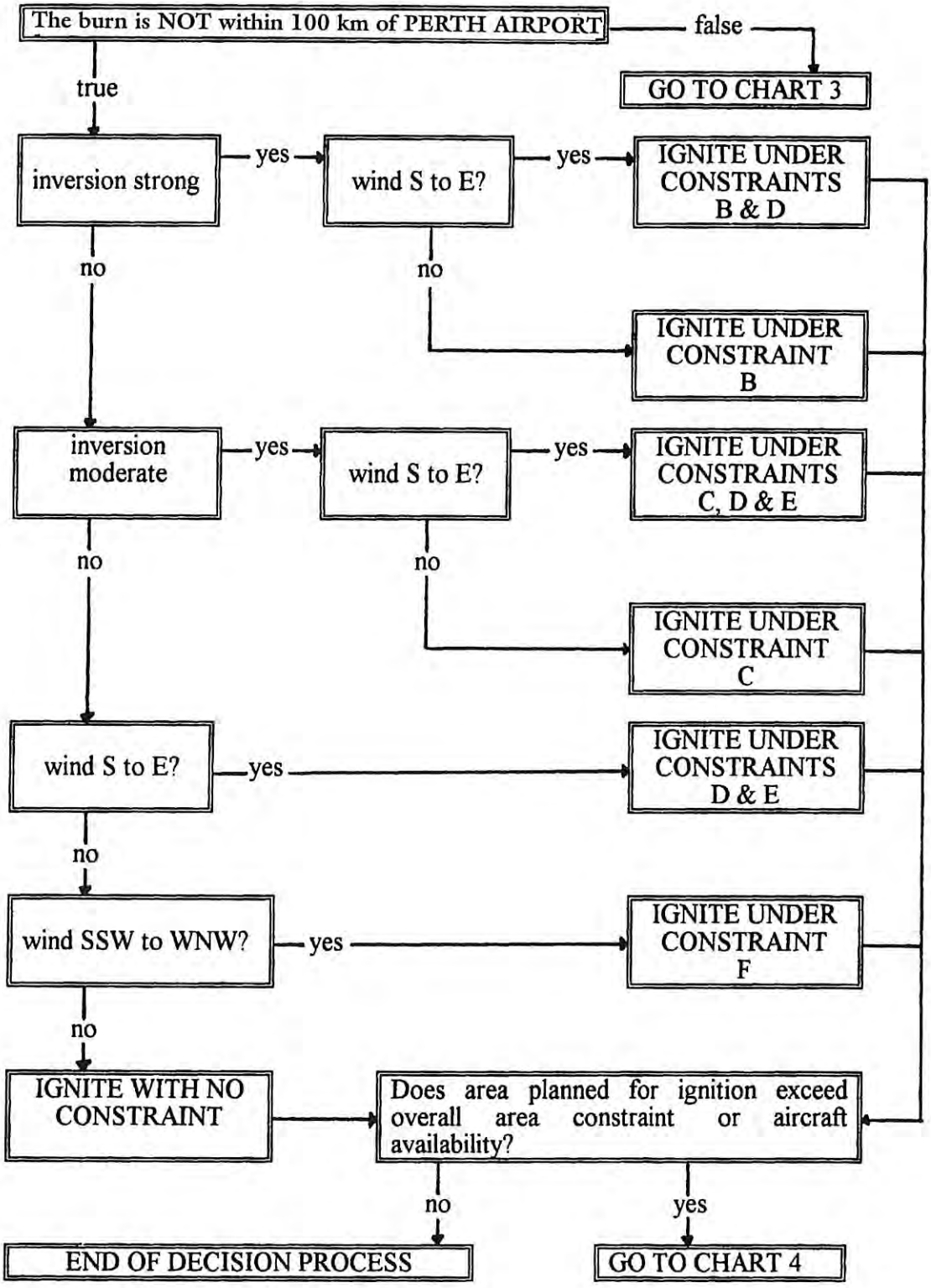

Figure 4. Decision Chart 2.

PRESCRIBED BURNING AND SMOKE MANAGEMENT - DECISION CHART 3

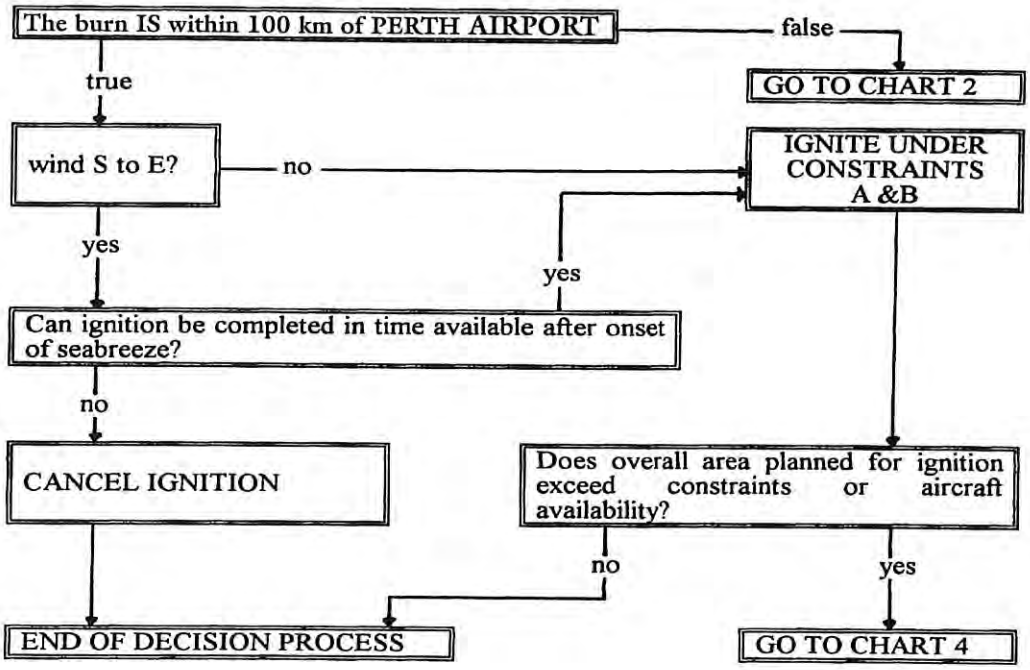

Figure 5. Decision Chart 3.

PRESCRIBED BURNING AND SMOKE MANAGEMENT - DECISION CHART 4

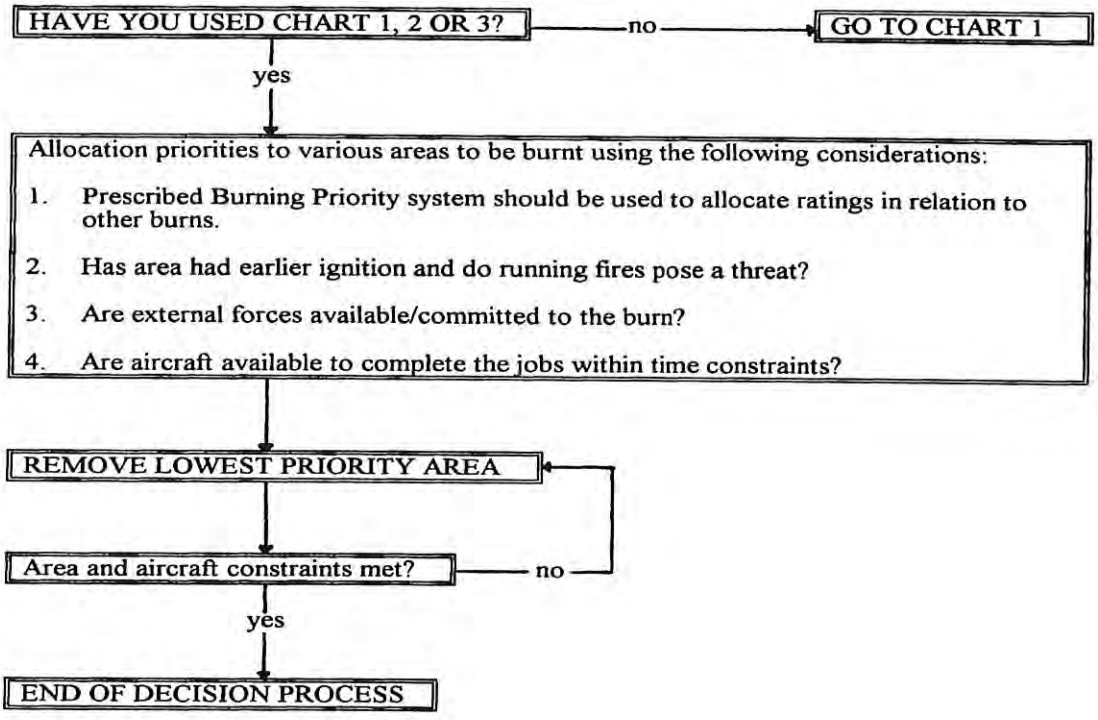

Figure 6. Decision Chart 4.

CONDITIONS OF BURNING

A....Individual burn areas limited by ratio rule*.

B....Total area burnt not to exceed 6,000 ha.

C....Total area burnt not to exceed 12,000 ha.

D....Burns greater than 4,000 ha to be at least 40km from any other burn on first and following day.

E....Total area burnt within any 80km radius not to exceed 15,000 ha.

F....Total area burnt within any 80km radius not to exceed 15,000 ha

* Area = 20 x Distance to Perth Airport (km)

Figure 7. Limitations on Burning for Smoke Management.

FUTURE DEVELOPMENTS IN SMOKE MANAGEMENT

Monitoring of smoke haze incidence in Perth during the 1992 and 1993 burning seasons indicated that the application of simple decision rules has significantly improved smoke management from prescribed burning in Western Australian forests. However, more remains to be done. Unpredicted weather events can still surprise weather forecasters and fire managers, and re-ignition of unburnt fuels on subsequent days can cause smoke to accumulate over population centres.

There is still much to learn about smoke transport and dispersion. CALM and the Bureau of Meteorology are to conduct a joint study that aims to provide a means of accurately predicting the trajectories of smoke parcels on the days of proposed burns. The Bureau's current operational numerical model (RASP) runs a trajectory plotting routine, but the model's grid resolution (150 km) is too coarse to capture the detail required. It is proposed a mesoscale numerical model with a grid resolution around 10 km be developed by the Bureau to predict the transport of smoke emitted from sources throughout the south-west.

In addition, the Bureau is investigating the synoptic situations during which smoke haze problems have occurred. It is hoped this will help improve the identification of dispersion factors and the development of a Dispersion Index similar to that used in South-eastern United States (Lavdas 1986).

CONCLUSION

While the applications of smoke management guidelines and appropriate burning prescriptions will help to minimize the occurrence of smoke haze over Perth, there is no guarantee that it can be eliminated altogether.

The complete cessation of prescribed burning may have short-term impact on the incidence of smoke haze, but will inevitably create another social problem; the cost and tragic impact of destructive wildfires on communities, properties and forest ecosystems in the south-west. It is simply not acceptable to put rural communities and our natural assets at risk to wildfire damage and destruction in an attempt to eliminate occasional bush fire smoke from the city.

ACKNOWLEDGEMENTS

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