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Appendix E – Report on causal and risk factors, fuel management, including grazing, and the application of the Australian Incident Management System

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REPORT ON:

CAUSAL AND RISK FACTORS,

FUEL MANAGEMENT, INCLUDING GRAZING,

& THE APPLICATION OF THE AUSTRALIAN INCIDENT MANAGEMENT SYSTEM(AIMS)

TO THE FEDERAL PARLIAMENTARY INQUIRY INTO THE 2003 BUSHFIRES

ACKNOWLEDGEMENTS

This report is dedicated to three people who have played a key role in my life as a fire ecologist, fire planner, and as a fire manager.

Jim Hickman, former Deputy Director of the Rural Fire Service of Tasmania, and for many years head of the fire management branch of Forests Tasmania. I am indebted to his frank, human, and honest appraisal and insights into the social aspects of fire management.

Tony Mount, former research officer and head of the Fire Management Branch of Forests Tasmania, whose mentoring in fire research and fire ecology, as a university lecturer and a work colleague, gave me the insights and understanding of fire behaviour and fire ecology, to apply and manage fire in many different contexts.

Neville Brogan, a former park worker with the National Parks and Wildlife Service in the Blue Mountains, whose unswerving dedication to high standards in field fire operations, is an example of what can be done, if you only spend enough time learning and doing. Neville is suffering from terminal lung cancer.

I would also like to acknowledge the help and assistance of:

- Athol Hodgson in Victoria, providing me with historical context of bushfires and prescribed burning in the Victorian Alps;
- Kevin Tolhurst, for recent studies and papers on fire management in Victoria
- Tony Mount, assisting me with the soil dryness index, and ideas on fuel management;
- Lachlan McCaw, with recent scientific papers on vegetation, fuel, and wildfire management in Western Australia;
- Phil Cheney, on fire behaviour in forests and grasslands;
- The secretariat of the House of Representatives Bushfire Committee;
- The Bilpin Bushfire Brigade, for providing me with more recent information from the Bilpin Community Fire Plan – an ongoing plan; and
- the numerous people I contacted to discuss their local knowledge and perspectives on the recent 2003 fires

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Ecosystem Management in the Alpine and Montane Regions of Victoria and SE NSW

TERMS OF REFERENCE

The House of Representatives Select Committee on the Recent Australian Bushfires, requested an independent consultancy to provide advice in relation to fire ecology and bushfire suppression planning and management.
The terms of reference supplied to EcoGIS, included the following:

1) Review the evidence the committee has received on the effectiveness and impact of prescribed hazard reduction burning and, taking account of the literature and research in the area, provide an assessment of that evidence. The secretariat will provide you access to the evidence to be considered. The assessment should discuss the extent to which the evidence is consistent with known wild fire management histories and the scientific literature.
2) Provide advice on the extent to which more extensive prescription burning programs could be undertaken and what would be the effect of any expansion of existing programs. This should include an assessment of the programs that would be needed to provide a better level of protection than was apparently available to the Australian community in recent years, and the technical/scientific issues that would need to be considered in any expanded programs.
3) Provide an assessment of the Australian Interagency Incident Management System as currently employed in Australia for bush fire suppression, and alternative approaches to the command and control of suppression activities.

CHALLENGES IN DECISION MAKING

The main challenge in managing large fires is the ability to take account of a multiplicity of factors, including fuel, fire, weather, containment strategies, as well as natural and cultural indicators in a short time frame. There is also a need make swift and accountable decisions to meet a variety of agency, social, and community needs, such as:

- limit the risk of damage to life and property;
- limit the long term impact of severe wildfires on the natural environment;
- manage the political and social environment; and
- to maintain the ecological integrity of ecosystems and species subject to severe fires

Unfortunately there are few people trained to make complex decisions in this decision-making environment. In the Alpine and Montane regions of Victoria and New South Wales, major fire seasons come around every ten to fifteen years, meaning few people get the experience to develop the skills of strategic and local fires assessment. As happened in the recent fires, decisions are based on the first criterion to protect life and property, with often little attention being given to the last three criteria. What is also often missing is a detailed local understanding of ecosystems, terrain, fire weather, and short and long term climate patterns, which can help to fashion more appropriate fire strategies to meet all of the above.

In the last ten years, decisions are now made in fire control centres, remote from the fire-ground, which often complicate, slow, and frustrate flexible and prompt decision-making. Groups of people isolated from the fire ground, and its myriad of small rapid changes brought about changes in fire weather, fuels, terrain, and success or failure of fire suppression crews, cannot respond effectively and efficiently to rapidly changing scenarios. Decision-making then becomes reactive and loses momentum in pre-emptive planning and creating opportunities to limit overall threats of a fire. In the last ten years, a trend of managing large fires, using the Australian Incident Management System (AIMS) has emerged. A major theme running through submissions from local brigades and landholders is that this management system in its present form, does not serve the interests, fears, and concerns of local people and communities.
The ability to forecast a scenario is very much dependent on key factors, such as:

- current state of vegetation and fuels,
- terrain and fire barriers the fire is traversing,
- current seasonal pattern of weather,
- local weather conditions, and
- the likelihood of a rain stopping event.

Few people can read all these indicators and signs and integrate them into a coherent strategic assessment of potential fire scenarios and then to determine which one could be the most effective action to minimise any fire threats. When an attitude of suppression at all costs prevails, it is difficult to present alternative fire scenarios, based on calm, resolute, and scientific analysis.

Decision-making in this pressure-cooker environment can lead to major long term environmental impacts, which in otherwise less stressful circumstances, would not be considered. Present fire emergency legislation focuses on protecting assets at all costs, generally at the expense of the natural, cultural and physical environment. From the evidence provided in submissions from rural constituents, they are very much concerned at the long term damage done to their property, and on adjacent public land, when Alpine Ash forests or sub-alpine Snow Gum woodlands were killed by fires. What they are seeking is an alternative land management approach that takes into account local views and opinions on the best way to protect their local vegetation, watersheds, soils, and private and community assets.

A more unified and co-operative approach to fire and land management could be found in community based fire planning, with an agreed set of objectives, indicators, and processes. This local approach could help to develop a more dynamic and responsive approach to decision-making on large fires at local and sub-regional levels. The community fire planning concept could build a decision-making framework for fuel management and response to fire, based on the principle of adaptive management (Holling 1978). Adaptive management is the process of learning from past events in an objective and impassive manner, accepting that our present knowledge and understanding is imperfect. Our learning and adaptive management could be improved if monitoring of past decisions and actions is incorporated into future decisions. Adaptive management is in a sense a distilling and filtering of past successes and failures, which leads to a more intuitive decision making process.

A local planning approach could help to build trust and engagement of local people in planning and managing fire, which could lead to better relationships before, during, and after fires. Again a strong theme of alienation from decision-making and involvement is seen in many submissions. Land management agencies could adopt such local planning, and could achieve more successful outcomes with the community if local agency people are given more latitude and involvement to develop local policies and initiatives. Successful models of local fire planning have been developed for some years, which could be adapted to a wide range of social, political, and natural environments found in SE Australia.

ANALYSIS OF CAUSAL FACTORS

Severe fire behaviour historically occurs when there is a coincidence of the following conditions:

- Stressed vegetation – wilting of the vegetation canopy;
- Maximum fuel availability – more than 15 to 25 years since areas were burnt, either by wild or prescribed fire, pronounced curing of grass and shrub fuels, and full availability of stringybark and ribbon bark fuels as spotting and ember material;
- Very high to extreme periods of fire behaviour, usually over a one to two week period in the middle of summer; and
- Prolonged summer dry spells that follow a dry winter and/or spring.

The analysis undertaken in this report demonstrates that these conditions were comparable to that experienced in 1982/83 fire season with a long drawn out period of little rain between early December and late February, although the overall drought conditions were almost as severe as that in 1997/98.

HISTORICAL WEATHER

To understand how severe the recent fires were in the Highlands of Victoria and New South Wales, long term climate records from key weather stations were obtained from the Meteorological Bureau. Data from these weather stations was then used to create historical trends in key parameters in fire behaviour:

- Soil Dryness Index – measures the level of soil dryness, and potential stress in vegetation
- Fire Danger Index – measures the potential fire behaviour, given soil dryness, and ambient weather conditions at 3pm

To obtain a range of montane and sub-alpine environments, stations were picked geographically across the area burnt by the recent fires. Two weather stations, Canberra and Omeo, had almost continuous records back to the mid 1950's, which provided almost fifty years of continuous historical weather data. Complementary weather data was obtained from other weather stations which were found at higher elevations or in different geographical places. The additional weather data came from the following stations:

- Nowra
- Cabramurra
- Falls Creek
- Noojee
- Combienbar.

The weather stations, Nowra, Falls Creek, and Noojee, comprised manual and automatic weather data sets whereas Cabramurra and Combienbar were recorded from Automatic Weather Stations (AWS). The weather data from these automatic weather stations were found to have many missing records, which meant that it was difficult to compile soil dryness indices for particular stations, without first having to infill a large number of daily records.

LEVELS OF MOISTURE STRESS SEEN HISTORICALLY

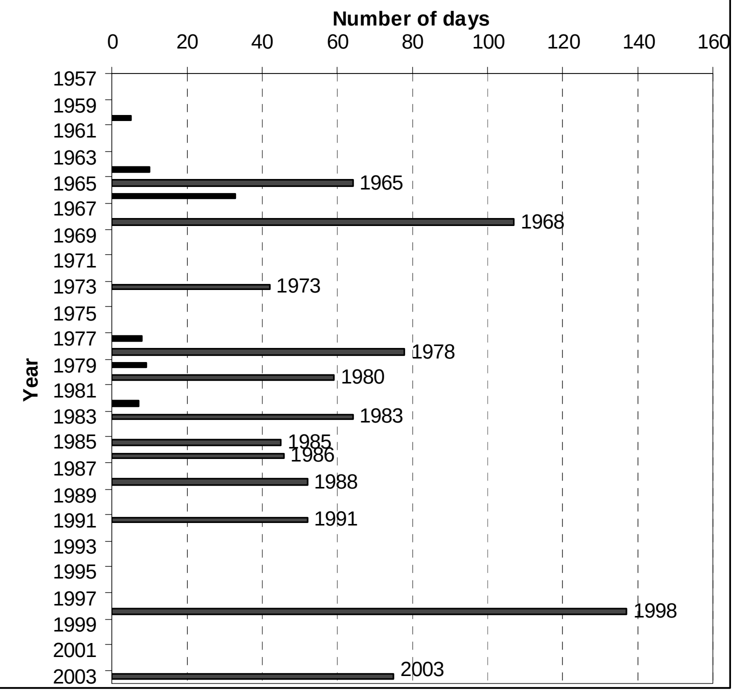
The Soil Dryness Index developed by Tony Mount for use throughout Australia has been shown to be a reliable indicator of general levels of soil moisture deficit (Mount 1964). The soil dryness index is based on two daily measurements of temperature measured at 3pm and rainfall from the previous day measured at 9 am. The index was derived from catchment run-off data and is also a useful guide to catchment conditions, including overland flow and sub-surface run-off.

The method used to compare recent levels of soil dryness in the Montane and Sub-alpine regions affected by the 2003 fires is based on a historical trend analysis of soil dryness index from the start of reliable records. The results of this trend analysis for the Omeo and Canberra airport weather stations are shown in Figure 1a and Figure 1b respectively in Appendix 1. The pattern of soil dryness in Figure 1a and 1b shows an oscillating pattern of dry periods in summer followed by cool wetter periods in most years. There are occasions when summer rainfall remains high and a much lower peak summer dryness index is reached. This occurred in the summer of 1961, 1962, 1963, 1969, 1970, 1973, 1974, 1992, 1993, 1994, 1996, 1999, and 2002. These wetter summers were generally associated with "La Nina" patterns in the Pacific Ocean when Southern Oscillation indices had either zero or positive values.

The driest summers in Omeo have occurred in the summers of 1964/65, 1968/69, 1972/73, 1977/78, 1982/83, 1984/85, 1987/88, 1997/98, and in 2002/03. Most of these dry summers are associated with "El Nino" patterns in the Pacific Ocean, with the exception of 1964/65, 1984/85, and 1987/88, where more localised climatic factors contributed to dry summers.

Based on the author's experience of relationship between Soil Dryness Index and moisture stress in the vegetation, usually prolonged periods of soil dryness in excess of 140mm will lead to wilting of trees and shrubs, and curing of grasses, in native forests, and will tend to increase flammability and curing of live forest fuels. Figure 2 shows that there have been twelve years out of a total of forty six years where the soil dryness has exceeded 140 mm for more than forty days in a year. It is notable that the years in 1968 and 1998 had significantly greater number of days than that in 2003, exceeding 100 days in a year. The most recent fire season was comparable with previous years 1965, 1978, 1980, and 1983. In the latter case, the number of days in a year was between 60 and 80, where the SDI was in excess of 140mm.

Figure 2. Number of Days in a Year when Soil Dryness Index exceeds 140mm



The most recent fire season was therefore not the worst dry period in the recent historical record. The author's field observations in south-eastern NSW in 1998 noted that there were large patches of wilted forest on exposed westerly aspects, showing up as reddish orange patterns in the forest landscape, indicating drought induced moisture stress.

FUEL LEVELS

Although detailed spatial data of recent wildfires and prescribed fires were not available for analysis, some broad assessments can be made about levels of fuels in the montane and sub-alpine landscapes. The last most significant fire season that burnt over a million hectares was in 1939/40. Since then the sub-alpine areas of Victoria and New South Wales had almost continuous levels of fuels, which contributed to these areas being burnt.

There have been some major fire seasons since 1939. In the last fifteen years in Victoria, these were in 1984/1985, 1990/91, and 1997/98. Based on the statistics provided in DSE Research Report No. 49, there has been a gradual reduction in area burnt in NE Victoria in the period from 1975/76 to 1985/86, which includes area burnt by wildfire and prescribed fire. The decline in area burnt by all types of fires corresponds with relatively moist period from 1992-1996, which could have precluded more extensive fuel management in NE Victoria. Refer back to Figure 1a which shows the lower levels of soil dryness in these periods from the weather station records at Omeo. A submission presented to the Inquiry by the Mountain Cattlemens' Association of Victoria [ ], suggests that there were significant areas in the Victorian Alps which had not burnt since 1939.

Correspondingly in New South Wales, there were significant areas burnt in 1982/93, 1984, and 1984/85. Given the 15 to 18 years since the last major fire in the sub-alpine and montane regions of Kosciuszko National Park, fuel levels would have developed sufficiently to carry intense fires, except where intense fires in the last five to ten years have caused slow vegetation recovery, in fire sensitive Alpine Ash forest or Snow Gum woodland regrowth. Most of the sub-alpine forests and open woodlands were most likely last burnt in 1939, with some areas burnt in 1972/73 in the headwaters of the Geehi, and in 1982/83 in the Tantangara precinct of central Kosciuszko National Park.

In the ACT, according to submissions received in the inquiry, the only significant fire that has occurred in the last 20 years was a fire in Southern Namadgi.

In most of the alpine and sub-alpine regions, there was sufficient fuel to carry an intense fire in summer, which is what occurred after dry lightning storms. Equations which describe the build-up of fine fuels after fire have been described previously from fuel studies undertaken in the sub-alpine and montane regions of Kosciuszko and Namadgi National Park (Good 1994, Walker 1981). These fuel build curves assume a steady state where fuel accumulation and decomposition eventually balance out to produce a maximum equilibrium fuel load at some time after fire. The values of maximum litter and grass input, and decomposition rates are used to describe the maximum fuel levels reached, as well as the rate of accumulation.

The equation $X(t) = L/k^*(1-e^{(-kT)})$ describes a generalised fuel build-up curve, where

X(t) = the fuel level at a given time (t) after fire
L = the maximum fuel levels reached at an equilibrium fuel state
K = the rate of decomposition

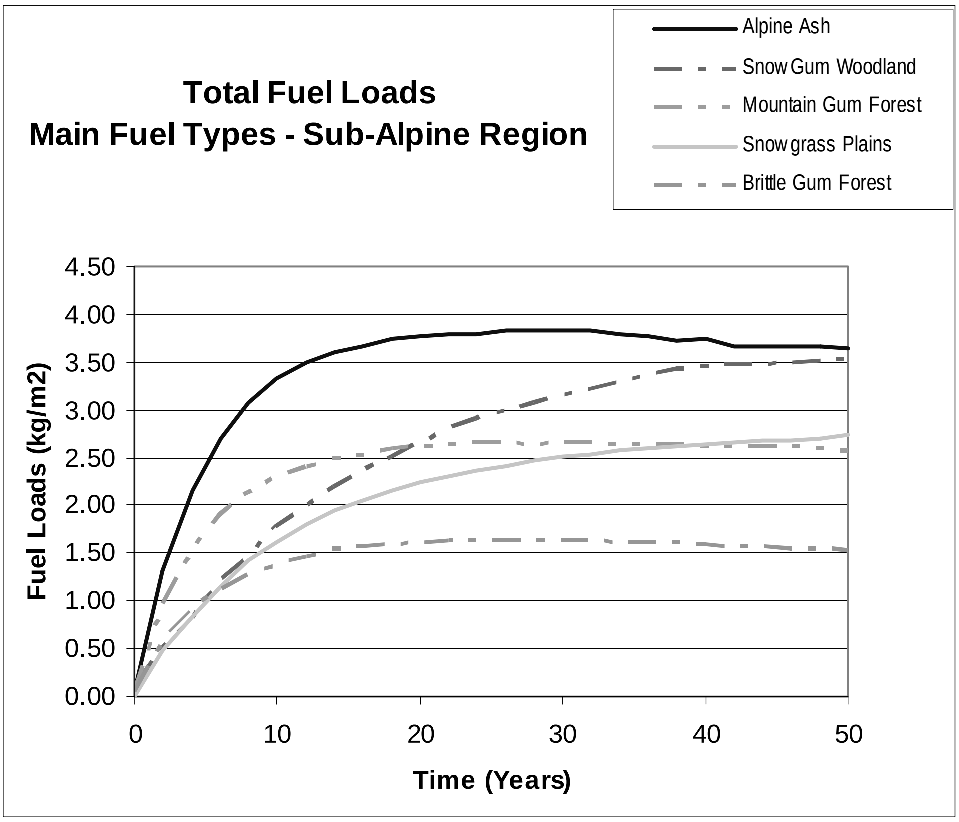
There are five principal vegetation fuel types found in the Sub-Alpine regions of the Central Highlands of Victoria and the Southern Tablelands of New South Wales: Alpine Ash Forest; Mountain Gum-Peppermint Forest, Broad-Leaved Peppermint Forest, and Snow Grass Plains. Figure 3 summarises the fuel build-up equations of these five main vegetation/fuel types. Within North-Eastern Victoria and south eastern NSW there are other fuel types in the fire affected area, which are not described in this report.

The highest fuel loads develop in Snow Grass Woodland because of the combination of litter and snowgrass build-up, combined with low decomposition. Alpine Ash forest has the highest fuel load levels, comprising mainly litter fuels, with some grass and shrub fuels present. However after 30 years, the litter layer can develop a deep duff layer, underneath the more recently deposited litter and bark. The next highest fuel loads develop in Snow Grass Woodland because of the combination of litter and snowgrass build-up, combined with low decomposition. There can be quite high local abundance of hip high flammable *Bossiaea* and other ericoid shrubs, depending on fire regimes. Fuel loads in Mountain Gum-Peppermint Forest are somewhat lower because of lower levels of litter fall and grass cover, with some patchy shrub fuels present, usually comprising *Acacia spp*. Snow grass plains comprise a dense sward of *Poa* spp. and other sub-alpine grasses, which can develop into a highly cured fuel build-up, if left unburnt for long periods. Finally the Brittle Gum-Broad Leaved Peppermint forest type has moderate fuel levels.

If most of the mountain country has been unburnt for at least 10-15 years, then most of these common fuel types would have been carrying moderate to heavy fuels, which under the drought conditions of January 2003 would have become mostly available as fuel. In addition when eucalypt forests and woodlands become stressed in a drought, further flammable material is added to the forest floor, which can increase litter fuel loads by 0.3-0.5 kilograms per square meters.

Another fuel factor which is not described in these equations is levels of flammable bark which is found in Alpine Ash forest and Brittle Gum-Peppermint forest. Generally eucalypt forests with Stringybark or Jarrah fuels, left unburnt for periods longer than 10-15 years, can develop dense ember spotting ahead of a fire front Tolhurst et al (1992), Burrows (1994). In the case of Alpine Ash forests, long distance spotting also occurs at higher fire intensities, depending on size of convection column, upper air instability, and dewpoint temperatures.

Figure 3. Fuel Build-Up Curves of Main Vegetation/Fuel Types in Areas affected by 2003 Fires



LIGHTNING IGNITIONS

Lightming has been a major ignition source of fires in the montane regions of the Victorian and NSW Alps. In Victoria, up to 25% of fires may be started by lightning (Davies 1997). This figure increases to about 35% in NE Victoria, where the bulk of the lightning started fires occurred. Between 60 and 100 lightning started fires can occur in one event. In the recent season in Victoria 87 fires occurred in one event on the 8th January in NE Victoria and Gippsland. All but eight fires were extinguished. This event is comparable with the number of lightning strikes recorded in one event in previous fire seasons. There have been up two such events in separate fire seasons since 1960 in Victoria; they occurred in 1964/65 and 1984/85. The event in 1965 resulted in 111 lightning strikes being recorded in one afternoon. All but three of the lightning strikes were extinguished. Two of them coalesced into one fire north of Briagolong and then burnt up to the New South Wales border. The other fire occurred at Bindi on the Tambo river. The area burnt by the three fires ended up being 400,000 hectares. Over 100 lightning strikes occurred in January 1985 and eventually 50,000 hectares was burnt (Hodgson pers comm.) The event in 2002/03 ranked as the fourth highest number of lightning strikes in a single event in Victoria (Tolhust pers. comm.).

Eight out of the total of 87 lightning started fires then went on to merge into one large fire in Victoria. A similar pattern occurred in Kosciuzko National Park and in the ACT where 60 fires started on the 8th January from a belt of lightning strikes that coincided with the passage of a relatively dry cold front. As statistics of the number extinguished in the first 24 hours is unavailable, it is estimated that about 17 fires were not contained and went to burn significant areas of the southern Alps in New South Wales.

It is therefore not unusual once in every fifteen to twenty years, for a significant multiple lightning started fire event to occur. It usually coincides with a significant dry period in the middle of summer, usually from January onwards. A study of the recent fire history and drought records should have revealed the possibility of such an event recurring. The event in 1964/65 also points to a few uncontained fires leading to a large area being burnt during a prolonged dry summer period. In 1964/65, 3 uncontained fires burnt 400,000 hectares in east Gippsland. In 2002/03, 8 uncontained fires burnt 1,000,000 hectares in NE Victoria and Central Gippsland. In both cases, about an average area between 125,000 and 133,000 hectares per fire was eventually burnt. The eventual magnitude of a small number of fires burning a large area should be given special recognition in planning for such scenarios during prolonged hot summer dry spells.

HISTORICAL PEAKS IN FIRE DANGER

The Macarthur forest fire danger rating integrates five weather variables:

- Seasonal soil dryness
- Recent rainfall
- Temperature
- Relative humidity, and
- Wind Speed

The weather stations recorded four days with very high to extreme fire danger during the period from early January to late February 2003. Very high to extreme fire danger occurred on the following days in both Victoria and New South Wales:

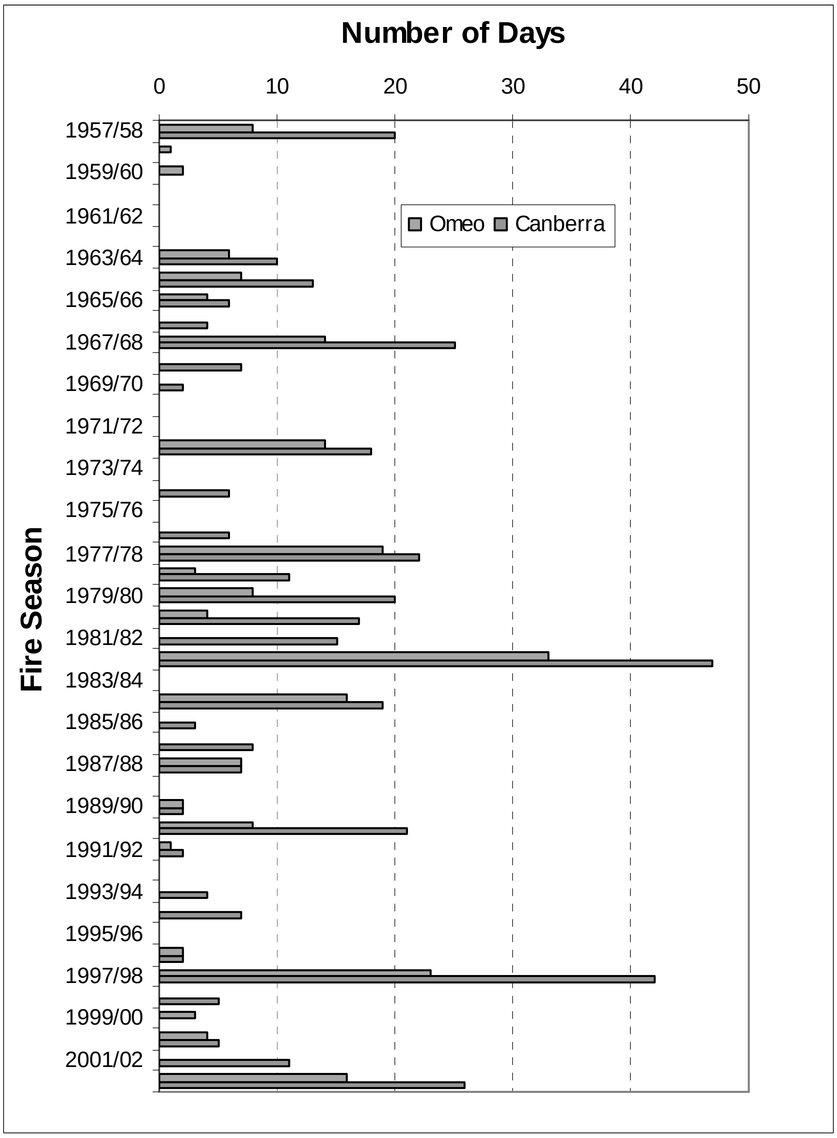
- 17/01/2003
- 18/01/2003
- 26/01/2003
- 30/01/2003

In order to rate the severity of these days in 2003, a historical analysis of combined daily fire danger ratings and soil dryness was undertaken, based on the Omeo and Canberra weather stations. Days with forest fire danger ratings in excess of 30 and soil dryness indices greater than 100m, were selected from the historical fire weather dataset from 1957 to 2003. The latter set of criteria was only applied to the months between November and February, which can be regarded as the peak period of a fire season in SE Australia. Historically severe fires have occurred between October and February in this part of Australia.

The selected dataset was then plotted against each year since 1957 in Figure 4. Reliable weather records for both Omeo and Canberra weather station commence in 1957.

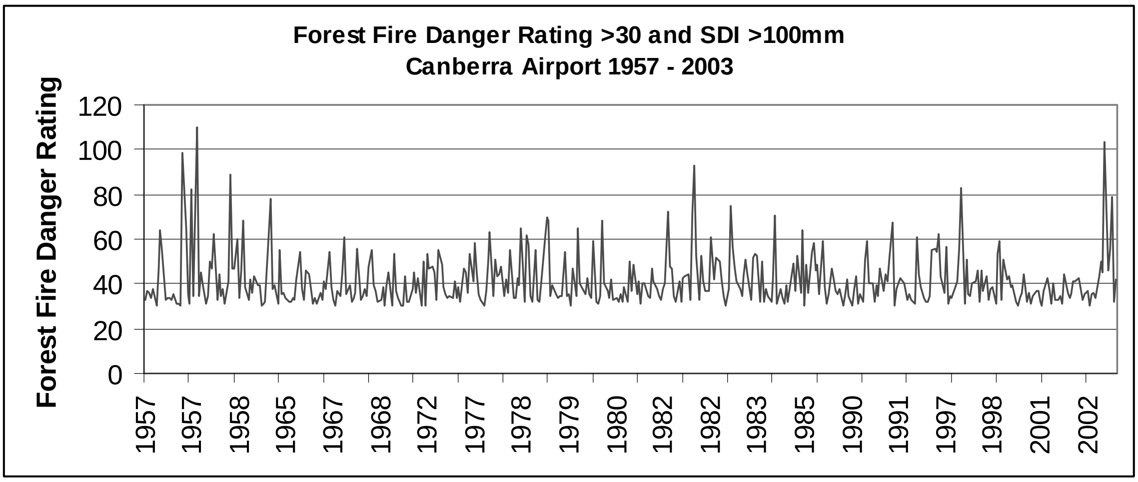
The results of this trend analysis show that the number of days with high soil dryness index and fire danger exceeding 30 in 2002/2003 was the third highest on record in Canberra, being exceeded in 1982/83, and 1997/98. Omeo has consistently fewer such days than Canberra. The frequency of such days was comparable with previous fire seasons, such as 1967/68, 1972/73, 1990/91, and similarly 1982/83 and 1997/98 had significantly more severe days. The data suggests that the occurrence of high to severe fire weather conditions in 2002/03 were comparable with those of previous fire years in both north-eastern Victoria and south-eastern NSW, perhaps being slightly higher than on an average drought year.

Figure 4. Frequency of Days with Soil Dryness Index >100mm and FFDI >30 Weather Stations – Omeo and Canberra



In order to rank the peak fire danger on the critical days in 2003, the same subset of data was then plotted as a line chart in Figure 5 for the weather station of Canberra airport. This chart shows the range of high-extreme values of FFDI between 1957 and 2003 and excludes all values of Forest Fire Danger Rating less than 30mm.

Figure 5. Range of High to Extreme Forest Fire Danger Rating since 1957 Canberra Airport



Typical peaks of forest fire danger rating during the course of a dry summer range between 50 and 60 with much fewer occurrences between 60 and 100. Most of the peak fire days tend to occur in November and December, with much less occurrence in January. The historical record of peak fire days suggests that there are perhaps 1% of days over a period of forty six years, whent there is a combination of severe drought and extreme fire weather.

However in the historical record it is unusual for 4 days of very high to extreme fire danger to occur in the one fire season. Table 1 summarises the days and dates on which very high to extreme fire danger has occurred in January. The 2002/2003 fire season had four days which exceeded a forest fire danger rating of 40, with some of the highest values of forest fire danger and soil dryness. However a comparable number of peak fire days have occurred in previous fire seasons, in 1957/58, and 1982/83. In the recent historical record then it is not unusual for recurrent days of very high to extreme fire danger to occur either in January or February, in drought years. The next most recent fire season in 1997/98 had six days in late January and February, where values of forest fire danger rating were between 40 and 60.

The conclusion from this analysis is that recurrent periods of very high to extreme fire danger have occurred in the past in the montane and sub-alpine regions of Victoria, viz. 1997/98 and 1982/83. Monitoring of soil dryness and moisture stress in the vegetation is a critical part of fire season assessment. From about December onwards, the soil dryness in these regions was approaching critical historical values. If all fires were not suppressed or contained quickly, then a few fires left uncontained could build into massive convection columns driven by severe fire weather conditions and drought induced flammable fuels and vegetation. This scenario had devastating consequences for the vegetation, soils, and fauna within the areas affected by the recent fires on the days with very high to extreme fire weather conditions. A continuous cover of fuels over a wide area also contributed to the coalescence of uncontained fires.

Table 1. Summary Records of Peak Fire Danger between 1957 and 2003 for the month of January recorded at Omeo weather station

Date	Forest Fire Danger rating	SDI
18/1/2003	104	169
30/1/2003	79	175
8/1/1983	75	157
19/1/1958	69	156
14/1/1957	64	150
9/1/1983	56	158
26/1/2003	56	173
1/1/1968	56	163
15/1/1978	55	160
26/1/1979	55	147
15/1/1957	55	151
30/1/1977	53	150
28/1/1985	52	162
23/1/1983	51	168
8/1/2003	50	164
17/1/1985	49	150
3/1/1973	48	169
10/1/1983	48	159
13/1/1957	47	149
14/1/1958	46	151
23/1/1998	46	170
18/1/1998	46	169
21/1/2003	46	171
17/1/2003	45	169
30/1/1983	45	167
7/1/2003	44	163
30/1/1998	43	167
15/1/1985	43	149
22/1/1983	43	167
30/1/1980	43	147
25/1/1958	42	161
1/1/1978	42	167
31/1/1977	41	151
2/1/1998	41	167
16/1/1983	41	163

FIRE SPREAD DURING JANUARY AND FEBRUARY 2003

A simple map of fire spread was prepared using Sentinel Hotspot data supplied by CSIRO Land and Water. An overlay of final fire perimeters was derived from data published on the web by the Department of Sustainability and Environment in Victoria, as well as published maps of fire areas in NSW prepared by the Rural Fires Service and the National Parks and Wildlife Service. Refer to Figure 6 in Appendix 1.

The accuracy of these maps at a fine scale is questionable as the Hotspot data is based on interpretation of temperature signals picked up on 500m resolution MODUS imagery and may not be able to detect low intensity fires in forest or grassland fires burning in light fuels. However at the scale of the map prepared in this report, they provide some insight into the progressive build-up and eventual containment over a period of six weeks.

The Hotspot data was queried within Arcview GIS to represent the progressive spread of fires within five discrete periods:

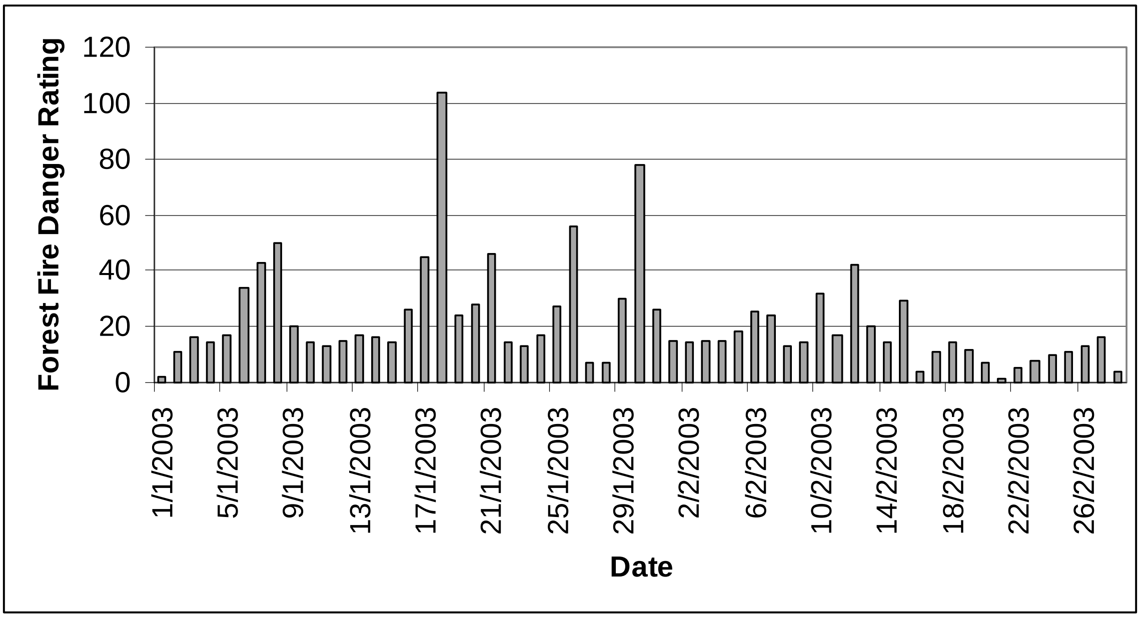
4) an initial containment period up to the 16th January – most fires are separate entities, except where close ignitions of fires on the 8th January have merged as part of containment
5) a first major breakout from containment lines on the 17th and increased area growth on the 18th, corresponding to the first major run and coalescence of separate fires prior to the 17th January
6) a second major run on the 26th January, causing most of the fires to merge into continuous line from Central Gippsland up to the Snowy Plains, near Eucumbene Dam in NSW
7) a second major run in NE Victoria on the 30th January, leading to spot-fires in northern Gippsland being lit by lightning strikes well ahead of the fire front
8) a further expansion of the fires between the 2nd and 10th February, under moderate to high fire weather conditions
9) a final round-up of fires along the southern and eastern flanks in Victoria, and in the Lower Snowy, and Jindabyne areas of NSW. Not all areas within the final perimeter appear to have been burnt in Victoria, according to the Modus imagery. This could be due to lower temperature signatures in areas burning in lower fuels, indicating that MODUS satellite imagery could not detect fire fronts burning at low fire intensities.

This approximate map indicates that major breakouts of containment lines occurred on the 17th January when the Forest Fire Danger rating was between 30 and 45 at elevation between 700 and 1200 metres. It is interesting to note that the Forest Fire Danger Index was between 10 and 15 between 1400 and 1700 metres during the peak period of the runs on 17/01/03. The fires continued to run on the following day when the Forest Fire Danger Rating peaked in both Omeo and Canberra at 104, with the most growth in area occurring in the ACT and in the Jagungal Geehi, and Upper Murray precincts of Kosciuzko National Park. It is notable that the Forest Fire Danger Rating reached a peak value between 10 and 20 between 1400 and 1700 metres.

The next major run on the 26th January enabled the separate fires in Victoria to merge into one major complex. The forest fire danger rating peaked at Omeo at 57 on the 26th January. The fire weather on the 30th January proved to be one of the second worst on record, peaking at 78 in Omeo. The convection column activity was significant enough to start major spotfires downwind of the fires, started by lightning from thunder clouds developed from the convection columns.

From about the 1st February onwards the fire weather settled, enabling containment lines in Victoria and southern New South Wales to be consolidated. Figure 6 summarises the daily peak forest fire danger ratings calculated from 3pm weather readings for the period between January 1st and 28th February in 2003. 68% of the days had Forest Fire Danger Ratings less than 20, 21% had a rating between 20 and 40, with the remaining 10% greater than 40. As there were a greater proportion of lower forest fire danger ratings during this period than high to very fire danger ratings, it is possible that alternative fire strategies could have been employed, particularly as the fires were burning into higher elevation country where fire weather conditions were more moderate.

Figure 6 Trends in Forest Fire Danger Ratings at Omeo Weather Station



A COMMENT ON CLIMATE CHANGE

Some very thoughtful and careful submissions from rural residents highlighted the climate change that has occurred in the Victorian and NSW Alps in the last one hundred years. For the most part of the nineteenth century, a mini ice age occurred in the Alps. The environment was cooler and moister than the latter part of the 20th century. Cold fronts came through with much more intensity, associated with rain and more prolonged cooler temperatures following the passage of a cold front. The author's experience in 30 years of bushwalking, monitoring fire weather as a fire manager, and analysing historical fire weather records, concurs with the general trend that the environment is getting drier and warmer in south-eastern Australia. There has a been long term decline in depth and extent of snow cover at Spencers Creek near Charlotte's Pass (Green 2002), with the last five years since 2002 having the lowest five year average since measurement began in 1954.

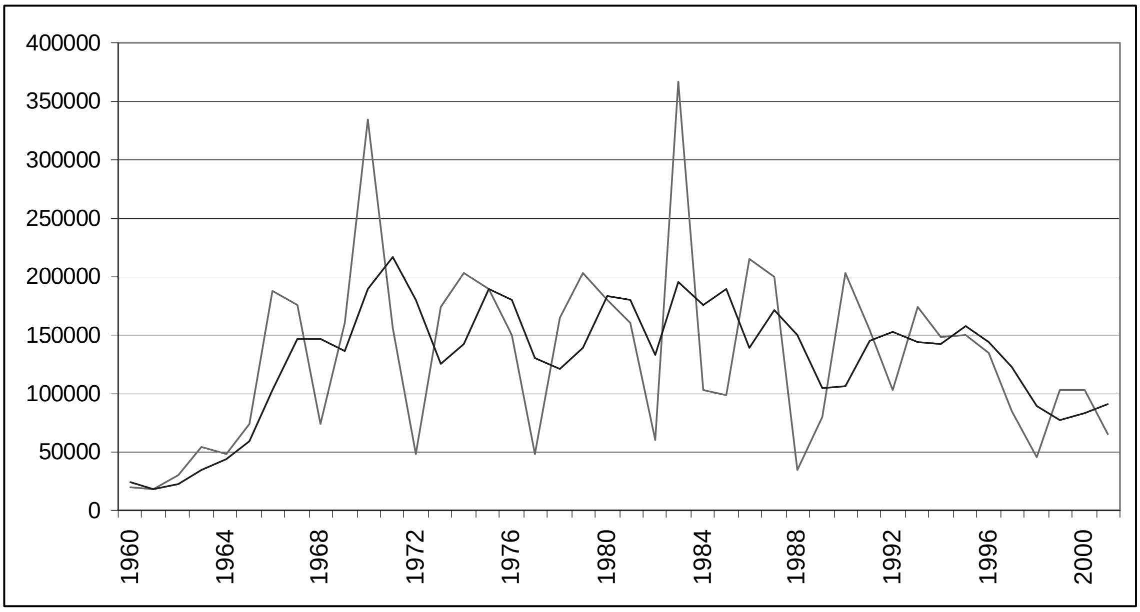
A recent program on Quantum quoted some recent research which suggests that the hole in the Ozone layer over the Antarctic has caused weather systems to move further south. The latitudinal shift south of low pressure systems then pulls cold fronts further south, which means less intense cold fronts pass through the mountain regions of south-eastern Australia. The author was surveying vegetation at nearly 1500 metres on the afternoon of the 8th January, 2003, at the time the cold front moved through. The storm cells did not appear to have much vertical development and little rain fell during the passage of the storms which lasted for less than half an hour. A similar storm was observed one month earlier, on the 3rd December, in which a series of lightning strikes started fires. The storm front lasted for about half an hour during which approximately 2mm of rain fell. "Mud" rain was observed on our vehicles that evening, similar to that which fell on the 8th January. Two days later, en route to Canberra via the Booboyan road, the author experienced a second cold front which ushered in little rain. Yet the cold front had an eerie pinkish sheen and glow to it in the afternoon sun, which was very unusual and very rarely seen in 30 years of cloud observations.

FUEL MANAGEMENT

A high number of submissions to the inquiry criticised the recent levels of fuel management on public tenure in both NSW and Victoria. There is widespread concern that fuel management is not being given sufficient attention and priority in land management.

In Victoria, the Department of Sustainability and Environment has set itself targets for fuel management across a wide range of eco-regions and vegetation communities within Victoria. Athol Hodgson (submission 450) produced evidence of the extent of prescribed burning as part of his submission in which he shows a decline in the area burnt in the last ten years. The data is based on Tolhurst's paper to the Institute of Public Affairs this year (Tolhurst 2003). This table has been reproduced in Figure 7. The black line represents a three year moving average, which reflects the underlying trend in area burnt by prescribed fire.

Figure 7 Levels of Fuel Treatment in Victoria (Tolhurst 2003)

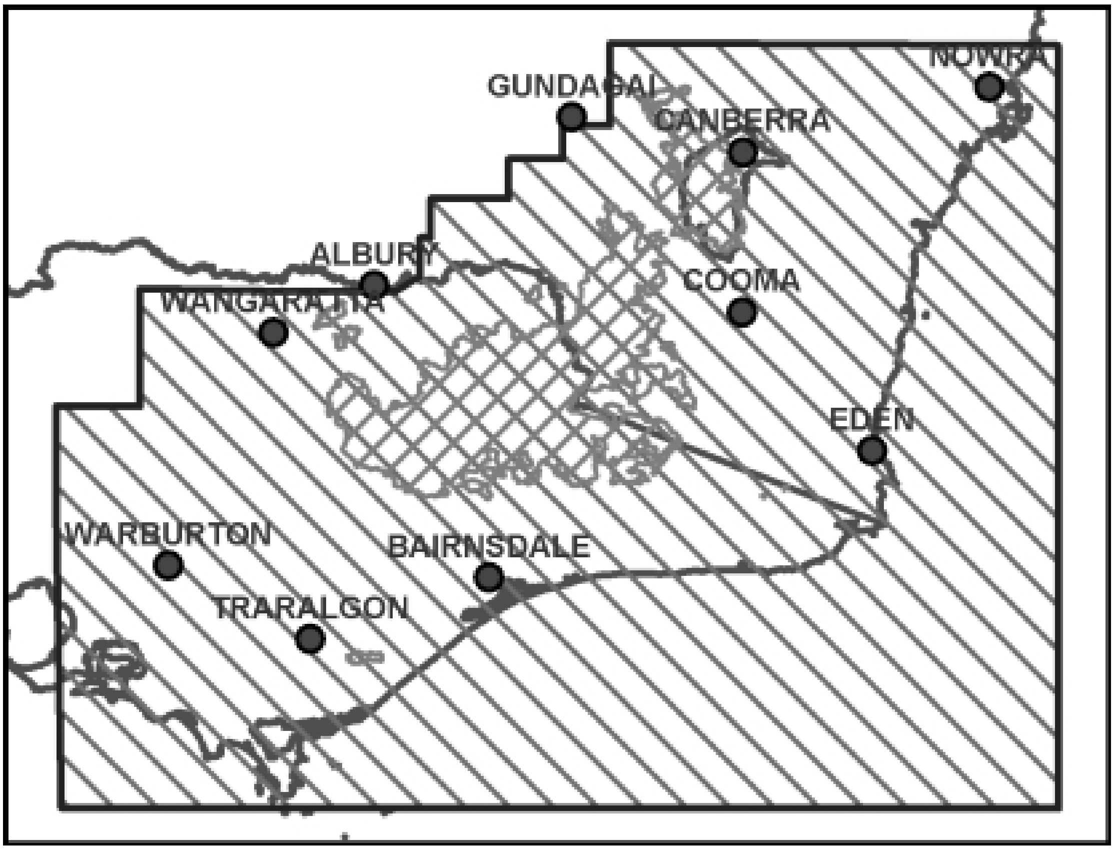


The chart in Figure 7 represents the total area burnt by prescribed burning throughout Victoria. The chart does not reflect the levels of fuel treatment that have been and could be applied within the montane and sub-alpine regions of Victoria. While these statistics are useful to understand the state-wide situation, statistics on the levels of fuel treatment were not publicly available for NE Victoria, Gippsland, and southern New South Wales. The lack of cooperation from the Victorian and New South Wales governments in the present inquiry has limited the scope of analysis into past fuel management in the areas affected by the 2003 fires.

ANALYSIS OF POTENTIALLY TREATABLE FUELS

To enable a scientific analysis of potentially treatable fuels, an alternative method was applied to the areas affected by the January 2003 fires. A study area was drawn up based on south-eastern NSW, which provides a comprehensive approach to estimating annual estimates of fuel treatment. Figure 8 illustrates the area agreed to for the analysis of potentially treatable fuels in south eastern New South Wales and eastern Victoria. The study area covers an area to the south from Nowra on the South Coast of New South Wales, to the south-east from Gundagai and down the Hume Highway to Melbourne, all the way to the eastern Victorian and New South Wales Coast.

Figure 8. Analysis Area for Estimation of Fuel Management Targets



The levels of fuel treatment that could be applied to native vegetation within the study area is based on the following key factors:

- The Type of Fuel Treatment
- Treatable vegetation;
- Seasonal dryness conditions;
- Mosaic of wildfire or prescribed fire burns in the recent past;
- The number of burning days that meets burning prescriptions;
- The complexity of land tenure involved in fuel treatments;
- Well resourced, trained, and skilled fire managers; and
- Political and community will to undertake burning.

TYPE OF FUEL TREATMENT

Tolhurst (2003) has emphasized that fuel treatments have focussed on the more intensive and strategic fuel management in the last ten years, rather than fuel management over a broader area, focussing on ecological burning. The former type of fuel management covers about 20% of the public land area, while the balance (80%) covers the balance of public land area. He argues that there is a case for undertaking more ecological broad area burning, away from intensive strategic fuel management, creating a mosaic of treated country from recently unburnt to very long unburnt.

The author's experience of fuel management in New South Wales mirrors the ideas of Tolhurst, presented in his recent paper to the Institute of Public Affairs conference this year. Much of the fuel management on National Parks in New South Wales tends to focus on the perimeters of reserves, with the result that landscape mosaics of different fuel ages are not created within core areas of reserves. If a broad area mosaic has been created by diligent management of summer wildfires, and subsequent prescribed burning, often these mosaics are erased by large summer wildfires, which overrun the previously created fuels. Incident management teams need to give special attention to the protection of fuel mosaics created previously, as part of reserve or State Forest management. This means that local knowledge and experience, combined with detailed mapping of previous fires, needs to be used more effectively to limit the size of summer wildfires. Otherwise previous fuel management will be written off as ineffective and not beneficial in the broader ecological picture.

However, in the montane and sub-alpine regions of south-eastern New South Wales, there has been little focus given to creating fuel mosaics within fire sensitive vegetation in the sub-alpine areas or in the more fire tolerant montane vegetation types. The assumption has been that these areas are too moist to burn, with a relatively low risk of being burnt by intense wildfires. The recent fire history points to serious widespread intense fires occurring in 1926/27 and in 1939/40. The build-up of available also occurs within the sub-alpine zone, which occurs over time as alpine grasses and shrubs accumulate dead fuel (refer back to Figure 3).

The debate over fuel management has tended to focus on the ecological impacts of fuel management, usually over short return periods of fuel treatment. In particular, the ecological issues of repetitive fuel treatment over a relatively small area have overshadowed the potential impact of large intense summer wildfires, killing large tracts of fire sensitive Snow Gum woodlands or Alpine Ash forests in the sub-alpine zones burnt in the 2003 fires. The loss of oldgrowth Snow woodland/forest or mature and regrowth Alpine Ash forest in 1939 and now in 2003 will take a century for fire killed patches of forest to recover.
With the limited number of burning days available in any one year, a strategic assessment will need to be made of the levels of fuel treatment in three broad categories:

- Asset protection
- Strategic burning to limit wildfires
- Broad Area ecological burning

Asset protection burning is an intensive expensive operation, which will tend to treat smaller areas mostly around the perimeters of reserves or close to human assets. Broad scale prescribed burning can be less intensive, and cheaper to manage than the current method of treating perimeter fuels, usually to protect life and property. Strategic fuel management to limit wildfires could be difficult to implement, without at first establishing some anchor points of recently burnt areas, in otherwise heavy fuels. A classic example is the extensive areas of heath and heath forest in Nadgee National Park, south of Eden, which was last completely burnt in 1972/73 fire season. With relatively old fuels, National Parks managers are apprehensive about establishing the first prescribed burn in thirty years in the heart of the reserve.

In coming up with some realistic and practical fuel management targets, a proportional target of area burnt was assigned to each broad management category within treatable vegetation types.

This assignment was based on the author's experience in the management of wildfires and in the practical application of prescribed burning in a range of environments. The approximate proportion of treatment area was assigned to each fuel management category:

- Asset Protection and Strategic (5%)
- Strategic Wildfire (15%)
- Broad Area Ecological Burning (40%)
- Non Treatment (40%)

The non-treatment category recognises that there will be areas of each vegetation type in a reserve which will have special management requirements, threatened species, or could be burnt by summer wildfires of moderate to high intensity, without much damage to soils, fauna habitat, or vegetation structure. Treating approximately 70% of the area of treatable vegetation types is a practical achievable target, which overall could lead to approximately 25% of a region in a given fire cycle.

DEFINITION OF TREATABLE VEGETATION TYPES

Treatable vegetation was defined as having the following attributes

- Dry eucalypt forest or woodland with either a grassy and/or dry shrub understorey; and
- Sufficient accumulation of dry available fuel
- Treatable in late summer, autumn or spring

Less treatable vegetation was defined as having the following attributes

- Generally not treatable in late summer, autumn or spring
- Less available fuels for burning Non-eucalypt dominated rainforest canopy and understorey
- Moist eucalypt forest with either a rainforest or wet shrubby understorey
- Fire sensitive vegetation, adapted to long fire frequencies, more than 25-50 years
- Vegetation along riparian zones
- Fire Sensitive regrowth forests derived from moist forest types

Within the study area, less treatable vegetation includes:

- Rainforests
- Moist montane forests
- Fire sensitive Callitris, Acacia, or Casuarina forests
- Regrowth forests regenerating from recent wildfire or recent harvesting, and
- Riparian vegetation
- Pine or Eucalypt Plantations, except when mature and/or thinned

The less treatable vegetation types also tend to be the areas which burn less frequently and require some protection from summer wildfires. Note that sub-alpine snow gum woodlands and Alpine Ash forests are not included in the less treatable vegetation type category. Hodgson (pers. comm) contends that prescribed burning under Alpine Ash can be achieved with a modicum of effort and careful application of burning prescriptions. Mosaic burning of Snow Gum forests has been a feature of lessee burning in the Victorian Alps for a century or more, particularly when done in autumn. The latter vegetation builds up sufficient fuel around the bases of trees to kill either regrowth, mature, or oldgrowth forest or low forest/woodland.

Table 2 summarises the list of vegetation categorised into the two categories of fuel treatability within south-eastern New South Wales. About 70% of this area contains vegetation which potentially can be treated, with about 30% of the remaining vegetation either being protected from fire or generally not suitable for treatment.

Table 2 Summary of Treatable and Less Treatable Vegetation in the South-eastern section of the Study Area

GpNo_Fuel	Broad Fuel Group Description	Treatable	Area (ha)	Fuel Availability	Fuel Levels
33	Montane/Sub-alpine Carex Fen	N	13,456	Mostly Wet	High
34	Swamp Grasslands	N	2,644	Mostly Wet	High
13	Riparian River Red Gum Forest	N	12,185	Mostly Moist	Moderate
23	Coastal Swamp Forest Complex	N	2,702	Mostly Moist	Moderate
32	Sub-alpine Herbfield	N	85,532	Mostly Moist	Moderate
1	Rainforest	N	37,846	Moist	Low
2	Ecotonal Rainforest/Eucalypt Forest	N	63,937	Moist	High
3	Moist Layered Forest	N	47,706	Moist	High
4	Moist Fern Shrub Forest	N	329,414	Moist	High
5	Montane Fern Herb Forest	N	169,746	Moist	Moderate
28	Estuarine Mudflats	N	2,735	Moist	Negligible
17	Lower Snowy White Box Forest	N	37,064	Dry	Low
21	SWS Acacia/Callitris Woodlands	N	5,129	Dry	Low
22	SC Acacia Rocky Shrubland	N	7,938	Dry	Low
35	Eden Riparian Shrublands	N	7,253	Dry	High
36	Pine Plantation	N	222,102	Dry	High
		Sub-Total	**1,047,388**	**30%**	
7	SWS Ironbark Forest	Y	316	Mostly Dry	Moderate
9	Tablelands Dry Grass Shrub Forest	Y	408,644	Mostly Dry	Moderate
12	South Coast Dry Shrub Forest	Y	700,143	Mostly Dry	Moderate-High
16	Dry Heathy Forest	Y	109,375	Mostly Dry	High
18	Savannah White Box Woodland	Y	5,590	Mostly Dry	Moderate
19	SavannahYellow Box Woodland	Y	11,617	Mostly Dry	Moderate
24	Coastal Swamp Shrubland Complex	Y	9,470	Mostly Dry	High
25	Coastal/Hinterland Dry Heath	Y	12,770	Mostly Dry	High
26	Mallee Heath Complex	Y	40,199	Mostly Dry	High
27	Coastal Dune Complex	Y	5,064	Mostly Dry	High
31	ST Temperate Grasslands	Y	2,762	Mostly Dry	Moderate-High
6	Sub-Alpine Tall Shrub Forest	Y	99,453	Sometimes Dry	High
8	Dry Grass Forest	Y	42,079	Sometimes Dry	Moderate
10	Western Montane Dry Grass Shrub Forest	Y	131,922	Sometimes Dry	Moderate-High
11	Tablelands Valley Floor Grass Forest	Y	309,614	Sometimes Dry	Moderate
14	Eastern ST Montane Grass/shrub Forest	Y	415,155	Sometimes Dry	Moderate-High
15	Frost Hollow Grassy Woodlands	Y	5,739	Sometimes Moist	Moderate-High
20	Sub-alpine Snow Gum Woodland	Y	112,957	Sometimes Moist	High
29	South Coast Escarp Heath	Y	7,325	Sometimes Moist	High
30	Namadgi Heath Complex	Y	11,644	Sometimes Moist	High
		Sub-Total	**2,441,838**	**70%**	
		Total Area	**3,489,226**		

The detail in Table 2 provides strategic fire planners with a better guide as to the overall desired conditions of fuel within a particular region. If the proportion of treatment, such as asset protection, strategic fuel management, is applied to each of the treatable fuel types in the bottom half of the table, this produces an estimate of area of potential fuel treatment for each vegetation type.

Table 3 summarises the overall fuel management targets for each category of fuel treatment, and then provides an annual target, based on a ten year or a fifteen year cycle.

SETTING OF BROAD FUEL MANAGEMENT TARGETS

The detail in Table 2 provides strategic fire planners with a better guide as to the overall desired conditions of fuel within a particular region. If the proportion of treatment, such as asset protection, strategic fuel management, and broad area ecological burning, is applied to each of the treatable fuel types in the bottom half of Table 2, the results are produced in Table 3.

Table 4 summarises the overall fuel management targets for each category of fuel treatment, and then provides annual targets, based on a ten year or a fifteen year treatment cycle.

The net effect of a strategic treatment of fuels over a ten or fifteen year period would amount to nearly 1.6 million hectares of forest being treated, amounting to 45% of the total area of native vegetation. 55% of the vegetation would be left untreated. If an annual cycle of ten years is selected, then this amounts to a target of 155,000 hectares being treated. If a more conservative fuel management cycle is preferred, an annual target of 104,000 hectares could be set. Most of the recent studies of fire behaviour in dry shrubby forest types suggest that the effectiveness of fuel management is very limited once forests are left unburnt for more than fifteen years. This mainly relates to stringybark fuels on tree trunks becoming more available after fifteen years, which increases the propensity for dense ember spotting in forest dominated by rough barked eucalypt trees.

Table 3 Broad Setting of Fuel Management Targets in south-eastern NSW

Category	Overall Area	Annual Target (10 Year Period)	Annual Target (15 Year Period)
Asset Protection	130,000	13,000	8,667
Strategic Wildfire	388,500	38,850	25,900
Broad Area Ecological Burning	962,776	96,278	64,185
Sub-Total	**1,481,276**	**148,128**	**98,752**
% of Total Vegetation	**42%**	**4%**	**3%**
Non-Treated	**2,007,900**		
Total	**3,489,176**		

CALCULATION OF AVAILABLE BURNING DAYS

A similar analysis to that undertaken by Tolhurst (2003) was undertaken, using historical weather records from Canberra, Omeo, Cabramurra, Falls Creek, and Coilimblar in eastern Gippsland. Suitable weather for burning is recognised as a major constraint in achieving a successful burn in the field. Suitable weather periods for burning can be found at the start of a fire season, in spring between August and October, and in autumn between late February and April. Suitable weather periods can also be found in the high country between early February and March when stable periods of fire weather can be found in non-drought years.

The estimation of available burning days is based on prescribed burning guides, in Tasmania, Victoria, and New South Wales, which determine a range of suitable litter and grass fuel moistures, and wind conditions during a burn. A factor not considered in this analysis is the likelihood of a more severe run of fire weather which could lead to potential escapes. The time available in this report did not allow more sophisticated analyses to be done, although the burning prescriptions in spring do take account of the likelihood of more difficult post-burn conditions. The prescriptions applied here are also based on the author's profound knowledge and experience in applying prescribed fire over a period of twenty years in Tasmania and New South Wales.

Table 4 shows the two sets of weather and fuel prescriptions which were applied to each historical weather dataset, in order to derive a possible number of burning days.

Table 4 Applied Set of Fuel and Fire Weather Conditions

Weather of Fuel Variable	*Autumn*	*Spring*
Soil Dryness Index (mm)	**30 – 100**	**25 – 60**
Temperature (degrees C)	**18 – 30**	**16-25**
Relative Humidity	**30-55**	**40-60**
Wind Speed	**< 25 km per hour**	**< 20 km per hour**
Rain Falling on Day	**None**	**None**
Rain Falling in Last Day	**None**	**None**

Results of applying these filtered conditions on the historical weather datasets are summarised in Table 5. The results assume that burning can be carried out on any day during the week.

Table 5 shows that in the lower montane parts of the Victorian and New South Wales Alps that there are 18-23 burning days in an average year. Higher up in the sub-alpine zone the number of burning days falls to about 3 to 5 days a year, if burning is done in February and March, and extends into November during late spring. In East Gippsland and along the South Coast, the average number of burning days increases to between 23 and 30, with the number of burning days increasing with decreasing latitude.

The pattern of burning days in each part of the study area conforms to the patterns of seasonal rainfall. In the western and central parts of the study area, winter and spring rainfall predominates, resulting in less opportunity for spring burning during most fire seasons, except during a dry spring, which occurs about one year in every three, based on the Omeo weather station. In the eastern part of the study area, which includes Eastern Gippsland and the South Coast and Escarpment, there is a bias towards summer rainfall, resulting in a greater number of burning days in spring between Narooma and Nowra, whereas the south-east corner from Bega to Bairnsdale has about equal number of burning days in spring and autumn.

The analysis of burning days also reveals that there were a significant number of burning days in the last five years in the montane regions of the Alps and East Gippsland in both eastern Victoria and southern New South Wales. Over 85 burning days were identified as being potentially suitable for prescribed burning within the last five years, with 70 days in Autumn with the balance of 15 days in Spring. As the Omeo and Canberra weather stations are found at lower elevations in the Alps, there could have been fewer burning days, found at higher elevations. It is estimated about 1/3 the number of burning days could have occurred, amounting to between 20 and 28 days. With the great variation in elevation and topography in the Alpine regions, careful identification of suitable areas for burning could still have been found, based on local knowledge of rainfall patterns. A number of submissions from the Victorian Alps points to a number of suitable burning days being available throughout the Alps in the last five years.

Table 5 Number of Burning Days in Autumn AND Spring at Selected Station

	Falls Creek		*Coilinblar*		*Omeo*		*Canberra*	
Burning Day Parameter	***Autumn***	***Spring***	***Autumn***	***Spring***	***Autumn***	***Spring***	***Autumn***	***Spring***
No of Years of Records	8		8		42		47	
Elevation of Station	**1550**		**400**		**700**		**680**	
Total Number of Burning Days in records	**44**	**0**	**102**	**97**	**576**	**125**	**482**	**164**
Average Number of Burning Days	**3**	**0**	**11**	**12**	**11**	**3**	**13**	**5**
Average Number in Dry Years	**8**	**0**	**15**	**20**	**23**	**6**	**15**	**9**
Average Number in Intermediate Years	**3**	**0**	**11**	**12**	**14**	**3**	**8**	**8**
Average Number in Wet Years	**1**	**0**	**6**	**1**	**1**	**0**	**5**	**2**
Predominant Months	**Feb, March**	**-**	**March, April**	**Sep, Oct**	**March, April**	**Sep, Oct**	**March, April**	**Sep, Oct**

AGENCY CAPABILITY IN MEETING TARGETS

The variability in fire seasons, in terms of dryness, and the basic capability of agencies to undertake burning will determine the final amount of burning that can be achieved over a given return period. Given that the Alpine regions of Victoria and New South Wales have experienced the recent scenario three times in the last forty years, a fifteen year period is assumed to cover a potential area burnt by planned application of prescribed fire. As well as this, certain assumptions have been made regarding the variability of fire seasons in each part of south-eastern NSW, as well as the likely average area to be treated in one day for the three main categories of burning, whether it is asset protection, strategic wildfire, or broad area ecological burning. Table 6 summarises the assumptions made in estimating how much area can be treated in a fifteen year period in two distinct zones, Southern Tablelands, and South Coast, which have two distinct climates.

Table 6 Assumptions in estimating potential area burnt over a fifteen year cycle in SE NSW.

Zone	Southern Tablelands	South Coast
Number of Agency Work Centres	8	6
Number of Burning Days in a Dry Fire Season	12	25
Ratio of Dry, Intermediate, and Moist Fire Seasons	4 : 8: 3	3 : 10 : 2
Ratio of Number of Burning Days (Dry, Intermediate, and Moist Fire Seasons	1.0 : 0.65 : 0.15	1.0 : 0.65 : 0.3
Area Treatment – Asset Protection	200	200
Area Treatment – Strategic Wildfire	800	1200
Area Treatment – Broad Area Ecological Burning	6000	8000

The ratio of burning days in moist and intermediate fire seasons, relative to a dry fire season is based on historical weather data and then generalised for a particular part of the region in south-eastern NSW. The actual number of days selected for burning assumes a 70% success rate in picking the right days, and being ready to burn on the selected days. The available number of burning days also assumes that there are sufficient resources to burn every day of the week.

The analysis of forecasted area burnt applies primarily to public land tenure, where there are continuous widespread areas of potentially treated fuel within various classes of public land tenure. In the 2003 fires, most of the fire burnt large areas of public land, with some areas of private land within or adjacent to large areas of public tenure. Because of the range in size and ownership of private land tenure, a much more sophisticated analysis would need to be undertaken, which would take into account parcel size, owners' attitude to fires, and the landscape pattern of private ownership.

DISCUSSION OF RESULTS

Table 7 summarises the forecast area burnt over a fifteen year cycle in south-eastern NSW. The actual area burnt would amount to 44% of the original target. The lower figure of 655,000 hectares is mainly because of the less burnt area achieved in intermediate dry/moist and moist fire seasons. Over a fifteen year period, only 19% of the vegetation could be burnt by prescribed fire, amounting to an average of 44,000 hectares per annum. McCarthy and Tolhurst (2003) undertook a study in Victoria, which demonstrated that a total of 59% of all wildfire studies encountered a fuel reduction burn, which had a measurable supportive effect on fire suppression. The specific fuel management zones occupied only about 20% of the total public estate area in Victoria. The net effect of this suggested management approach is similar in scale to that recommended by Tolhurst (2003), and may yield benefits in reduction of severe wildfire impacts, particularly in zones where there are identified risks from repeated lightning fires over a 15 to 20 year period.

In this analysis, more emphasis is placed on strategic wildfire, and broad area ecological burning, rather than perimeter asset protection burning. The recent fires in SE New South Wales did however show that burning around assets had a demonstrable effect on lowering damage to those assets. However if wildfire management moves from an emergency response and reactive approach to a more proactive role in managing fuels in the zones away from assets, the latter approach could eventually limit the potential size of intense fires, and lead to management of fires on a more ecological basis, and potentially reduce suppression costs.

A more proactive fuel management approach also necessitates that fire suppression efforts move away from the present bureaucratic emergency response to a fire, where significant funding and resources are provided when an emergency situation is declared. The present Section 44 provisions of the Rural Fires Act in New South Wales are often invoked at an early stage, without at first providing the land management agency the resources to manage the fire in a non-emergency environment. Often incident management teams are brought into an area without the attentive knowledge of the local environment, and can lead to much larger fires, than if operations were kept to a more local level.

In non-drought years, or earlier in summer, lightning fires could be managed to burn out prescribed areas, which could provide useful zones where later fires in much drier conditions could be contained, with a back-up of some recently fuel reduced areas. Management of wildfires in a summer period is generally more expensive than that of prescribed burning undertaken in autumn. There needs to be greater flexibility and provision to manage rather than suppress lightning started fires in non-drought situations in emergency management legislation. There also needs to be greater community understanding and acceptance that not all wildfires in summer are severe fires, and are part of the dynamics of pattern and process in natural landscapes. If these could be managed successfully to preferred burning prescriptions, then the area burnt by managed summer wildfires could be added to the area burnt by prescribed fire in late summer or autumn, and occasionally in spring where the attendant risk of fire escapes is kept low. The overall percentage achievement in fuel management on the ground could be improved, and the desired fire mosaics be kept more in line with management goals. The additional area burnt by managing, rather than putting out lightning started fires, could add 150,000 to 300,000 hectares to the fuel management total, enabling 25% or more of the fuel management target to be reached.

Given the results achieved summarised in Table 7, the levels achieved in asset protection burning are well below the target figure of 130,000 hectares. Additional area burnt in this category of burning is probably more likely to occur on private land. A key limiting factor is that the average size of land parcels is much smaller than that on public land. Further land subdivision in rural areas will only make the task more difficult and complex. It is the author's belief that fuel management targets on private land will generally be well below the target set for asset protection in Table 3, because of the fragmentation of land tenure and poses a particular problem for fuel management. Fire planning in Australia so far has not recognised historical fragmentation of land tenure as a major factor in modifying fuel management and fire regimes. Building houses within forests further complicates a fuel management strategy, requiring further emphasis be placed on asset protection, rather than broad area burning.

Table 7. Summary of Actual versus original target of area burnt by prescribed fire in South-East New Wales

Category	Overall Area	Forecast Target Achieved	% Achievement
Asset Protection	130,000	38,960	30%
Strategic Wildfire	388,500	156,320	40%
Broad Area Ecological Burning	962,776	459,880	48%
Sub-Total	**1,481,276**	**655,160**	44%
% of Total Vegetation	**42%**	**19%**	
Non-Treated	**2,007,900**		
Total	**3,489,176**		

EFFECTIVENESS OF FUEL MANAGEMENT

McCaw (1996) notes that the severity of burning conditions has a profound influence on the effectiveness of fuel reduced areas in moderating fire behaviour. He also notes that most of the field studies have documented the contribution of recently burnt fuels, generally less than three years old in assisting the suppression of wildfires. There are generally few studies where the fuel age is between 4 and 8 years. He also provides an example where 3 year old Jarrah Forest fuels were capable of supporting a high intensity crown fire although long distance spotting potential was reduced (McCaw et. al. 1993). The author also has similar evidence of three year fuels in Sydney Sandstone Forest supporting a crown fire in the 1994 fires in the Blue Mountains, under extreme forest fire danger conditions (FFDI between 60 and 70).

The effectiveness of fuel management relates to the following field conditions:

- the age of the fuels;
- the rate of recovery of fuels after treatment;
- the degree of curing and availability of aerial fuels;
- the fire behaviour conditions;
- the position of fuel reduced areas in relation to the head-fire, flank-fire, or backfire.

Some recent observations of fire behaviour during extreme conditions in Canberra demonstrated that even very low grass fuel loads could carry fast moving fires at very high intensity during the peak fire danger conditions (FFDI >80). To put these observations in perspective, peak fire danger conditions lasted for a period of three to four hours between 1400 and 1700 hours. Once the wind speed dropped in this period, fires would reduce in intensity very quickly. To support this contention, streaky runs of fire were observed in the Murrumbidgee corridor west of Tuggeranong, suggesting that gustiness of wind played a very important part in driving the grass driven fires towards the city, away from the very intense fire behaviour of the lower Cotter catchment and Mount Stromlo, which had a mixed landscape mosaic of pine plantation and grassland.

Elsewhere in south-eastern New South Wales, fires burnt intensely in low grassy fuels beneath open woodlands under extreme conditions. Once these conditions moderated in late afternoon or evening, low fuel conditions helped to contain the flanks or back edges of fires burning in low fuels.

As the forest fire danger rating subsides to values between 40 and 50, recently burnt fuels start having an effect on lowering the rate of spread and intensity of fires on their flanks. Several well documented studies in Victoria demonstrate the effectiveness of recently burnt areas, generally less than 5 years of age (Rawson et al 1985) have on the overall behaviour of a wildfire at this range of forest fire danger ratings. Long distance spotting potential is also reduced.

As the fire danger rating further drops to between 20 and 30, some further effect on the flame height and rate of spread occurs, in situations where fuels are between 3 and 5 years of age. Some breaking up of the head-fire can occur.

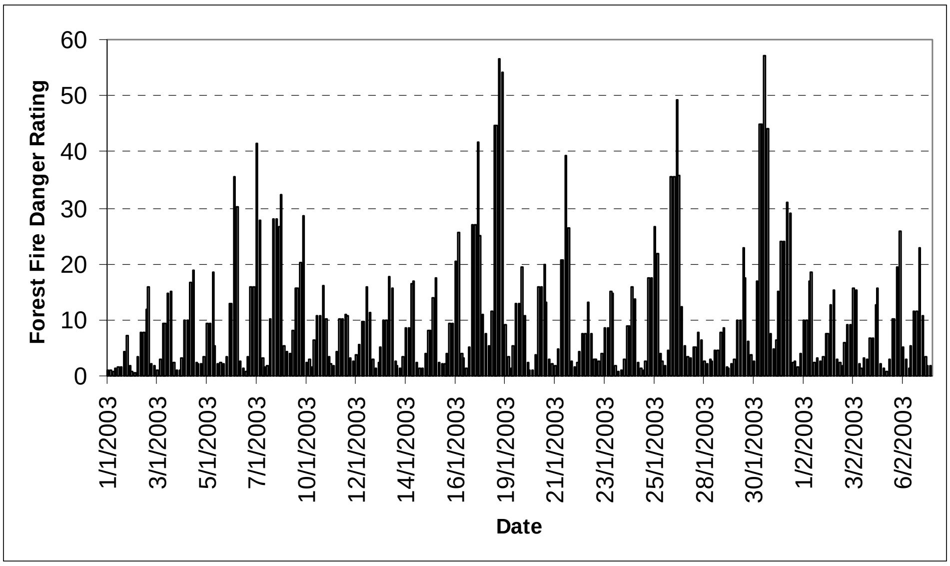
At forest fire danger indices less than 20, which occurs on mild days with little wind, mild temperatures, and moderate relative humidity, vegetation with low fuels less than 12 tonnes per hectare can be worked on safely.

LOW FIRE DANGER PERIODS DURING RECENT FIRES

For fuel management to work during the management of a major wildfire, there needs to be periods when the forest fire danger rating drops below 20 for a sufficiently long enough period for crews to work safely along a fire-trail, or on a constructed rake-hoe line. Figure 9 illustrates the weather sequence from 1st January up until 6th February. The diurnal pattern of forest fire danger rating usually shows an increase in fire danger rating till mid evening and then there is a rapid fall after about 9pm. The period between 9pm and 9am the following day is when fires can be worked on safely. Lower fuel loads in forest will help considerably to reduce spread and intensity while working on fires during this overnight period. There were about 59% of occasions overnight when the Forest Fire Danger Rating was less than or equal to 10. At higher elevations, this relative frequency of low fire danger ratings would have been closer to 66-70% of occasions. Lower fuel loads in strategic zones could have enabled fire fighters to work on fire flanks in slightly worse conditions during the middle of the day when fire danger usually peaks and allowed some strategic flanking of fires to limit the sideways growth of some of the fires. This tactical flanking could have deferred the possible coalescence of fires on the peak days of the 17th, 18th, 26th, and the 30th January. Between the 16th and 18th January there would have been limited opportunity to work in the forest at lower elevations. At higher elevations, fire were observed going out between 9pm and midnight, once the air moisture started being adsorbed by fine fuels on the forest, woodland, or grassy plains. This can have a marked effect on the success of backburning operations, particularly in grass dominated fuels. Lower fuel loads in grassy woodlands and grasslands can considerably help direct attack because of less dense grass tussocks and litter accumulation.

Fuel management has limited impact on major runs of fire once there are extensive head-fires being driven by extreme fire weather conditions in stressed forest vegetation. At this stage, previous asset protection burning was a major factor in reduction of damage to property, and reduced potential losses to human life, through reduction in fire intensity, and reduction in spotting.

Figure 9. Weather Sequence from 1st January till 6th February, 2003. Tuggeranong Automatic Weather Station



LIKELY EFFECTS OF RECENT FUEL MANAGEMENT OF GRAZING ON FIRE BEHAVIOUR IN SUB-ALPINE GRASSLANDS AND WOODLANDS

Fire behaviour in grassland or grassy woodlands relates to four main factors:

- Cured fine needle fuels on the top of a grass fuel bed
- Fuel Moisture Content
- Wind Speed
- Wind reduction factor of canopy

Grass fires will burn when fuel moisture content of the cured component of the grass fuel bed is between 0 and 24% moisture content. Above 24% moisture content, the dead component generally does not sustain fire spread and fires tend to go out. This is a frequent occurrence at high elevations, above 1400 metres, even during the recent 2003 fires in the Victorian and NSW Alps. A critical factor in the rate of spread and intensity is the degree of curing, usually expressed as a proportion of dry grass stems of the total dead and live grass stems.

The spread of a fire seems to be determined by the general dryness and curing of the top layer in a grass fuel bed, usually arising from the rest of the clump. From experimental studies of grass fires in the Northern Territory, total fuel loading did not appear to play a key role in fire spread. The propagating layer in grass fuels tends to be the top layer of the grass fuel bed, which often burns ahead of the lower and more compact grass bed (Cheney pers. comm.). The lower part of the grass fuel bed is a significant factor in fire intensity, and hence heat load on fire sensitive snowgums in a sub-alpine woodland in either the canopy or at the base of snow gums (personal observation). A key factor in the spread of fires across tussocky fuels is the cured component of the fuels, which can be reduced by burning. Within Kosciusko National Park there are extensive areas of snowgrass plains and snowgum woodlands, which can be burnt safely during the later summer and autumn months. If these snowgum plains were considered as potential fire advantages, then some of the open plains could be burnt on a mosaic basis. Hence this would reduce the cured component of the grass fuel bed and reducing the size of the snow grass tussocks, and their potential to burn intensely under snowgums.

Some of the submissions from the High Country contend that a combination of burning and grazing will lead to less fuel loads over a reasonable length of time. From the evidence of the long term plots in the Rocky Valley in the Bogong High Plains, grazing does reduce the overall fuel loads outside of the unburnt and ungrazed plots. These grazing exclusion plots have been established since the 1940's. Moriarty (1993) has an excellent photo series in which he maintains that the build-up of grassland in long unburnt Snowgrass swards leads to rotted inflammable grasslands. He bases his ideas on the graziers' preferred grazing regime to maintain a short, thick, and green sward. This condition is probably only maintained with an intensive grazing and burning regime

Careful inspection of Moriarty's extensive collection of photographs reveals similar curing levels in the top component of the grass sward, which is what tends to burn in a fast moving grass fire. Grazing does not appear to reduce the curing component and appears to reduce the overall fuel loads, leading to a more discontinuous ground cover. A less continuous grass cover could reduce the risk of smoldering fuels staying alight near the ground and lessen the chances of reignition during the hotter part of the day.

However the issue with grazing is that following burning, much of the palatable herbaceous layer is preferentially eaten, along with snowgrasses, until a full grass sward develops. Wahren et. al (1999) in their detailed plots studies showed that post-fire regeneration is delayed by grazing, and in some instances there are still low levels of ground cover after 15 years. The browsing of the *Poa* and *Danthonia* tussocks also maintain a more open grassy sward, which is a desirable outcome, as it tends to reduce the overall fuel loads. Studies by (Wahren et.al 1999) indicate that grazing in heath dominated woodlands can sometimes reduce the overall grass tussock cover. The issue of dense heath cover under fire sensitive snowgums is a dilemma for alpine reserve management. Leaving these areas to build up dense flammable fuels can inevitably lead to fire killed snowgum trees under moderate to high intensities. Burning the same woodlands can also promote flammable heath understorey.

To illustrate the range of potential fire spread in sub-alpine grassland during the 2003 fires, a trend analysis was undertaken for Mt Hotham weather station in the Victorian Alps. Fuel moisture contents were calculated from Macarthur Grassland Mark V fire danger index to find periods when fire would and would not burn in the sub-alpine environment. The trends in fuel moisture, estimated in three hourly periods are shown in Figure 11. When the estimated fuel moisture content stays above 20%, fires are more likely to go out overnight. The graph shows that there were significant periods of fuel recovery overnight between the 1st January and the 12th January. However in the period between the 13th and the 28th January, fuel moistures stayed lower than 20%. Some fuel recovery periods can be found in the period after the 28th January. These intermittent periods of fuel moisture recovery are usually associated with a stronger easterly wind.

Figure 12. Estimates of fuel moisture content in the period from 1st January and 6th February 2003

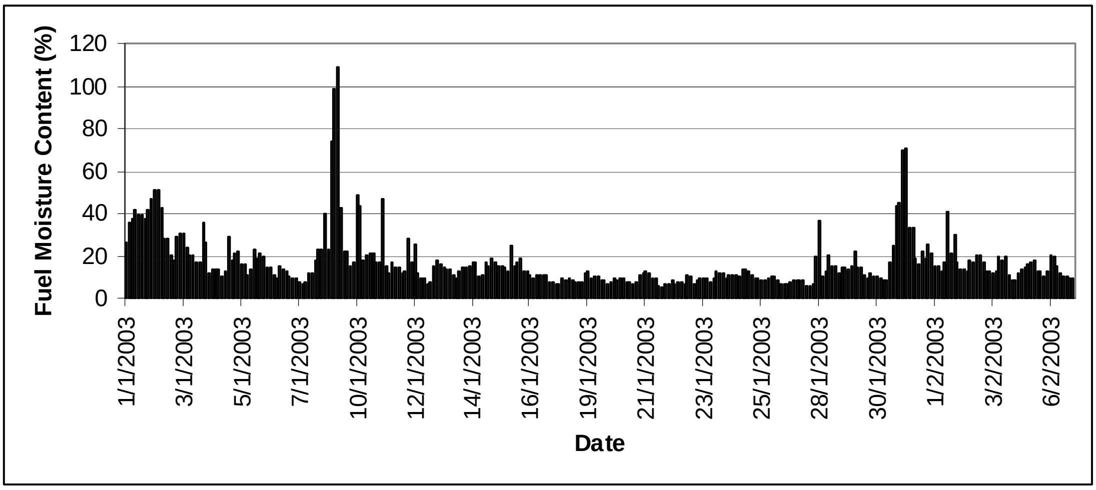
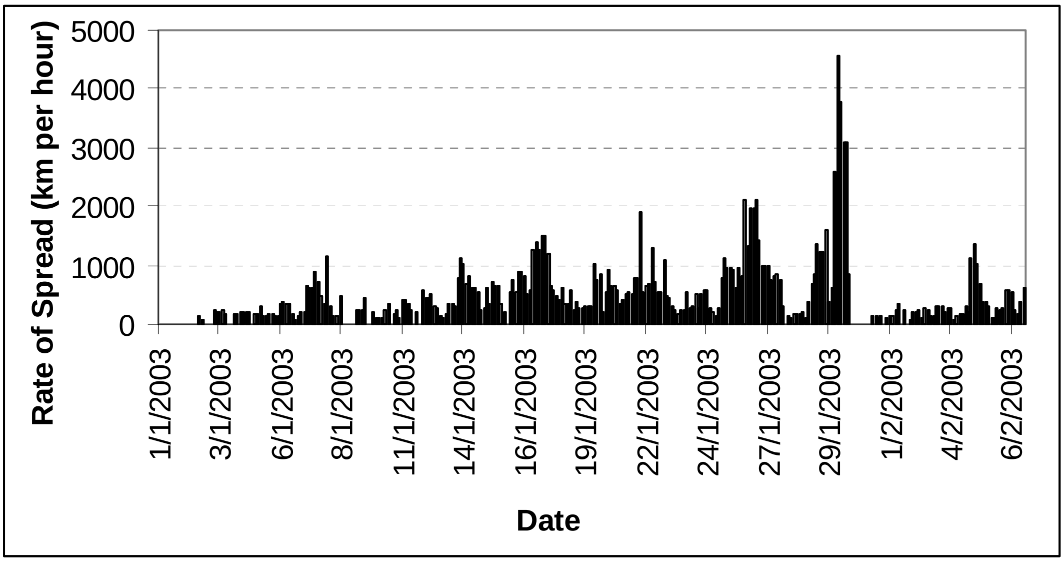


Figure 13 shows the trends in estimated rate of spread at Mount Hotham weather station between the 1st January and the 6th February, using the Macarthur Grassland Fire Danger Mark III equation. The graph shows that high rates of spread were found on the worst fire days on the 17th, 26th, and the 30th January, when rate of spread usually exceeded 1 kilometre per hour. Outside of these peak periods rates of spread were much lower, generally less than 300 metres per hour. The variability in spread during the 2003 fires indicates that burning in sub-alpine environments is possible as a fuel management practice or a tactic during the management of a major fire in the sub-alpine environment.

Figure 13. Estimates of forward rates of spread in sub-alpine environments



Heathland, grassland, alpine bogs, and snow gum woodlands usually occur as a vegetation mosaic. Managing these vegetation mosaics to conserve the ecological integrity of the alpine and sub-alpine area requires active management. Mosaic burns plays a part in creating some fuel reduced zones to increase the chance of late summer fires going out overnight and not reigniting the following day. This enables ground crews to put out any smoldering tussocks overnight.

Recently burnt grasslands generally have less available fuels for a period between three and five years after a fire. It would appear that full recovery of sub-alpine grassland could take between 5-10 years after a fire. There is a general parallel here with fuel reduction burning in forests – there appears to be some overall benefit from fires burnt in the last 10 years (Tolhurst 1993). The reduction in cured fuel is a significant factor in managing the spread of a fire. The overall fire potential in a recently burnt grassland fuel is reduced because of the higher proportion of green to dead fuel. As a result, fires will burn less quickly and be less intense than in long unburnt grass swards. Even during the fires, there could have been a role for aerial ignition to burn out patches of snow grass plains ahead of the main fire front, if smoke conditions permitted. This can be achieved if forecast temperatures and relative humidity can produce a higher fuel moisture content overnight, causing the fires to self extinguish on dusk in late evening. Old-growth snow gum forests and woodlands could have been protected in this manner.

A PERSPECTIVE ON THE AUSTRALIAN INCIDENT MANAGEMENT SYSTEM

The Australian Incident Management System (AIMS) was designed to improve coordination between the various fire agencies during fire emergencies. The system was brought into Australia in the early 1990's to help improve management of emergency incidents. The system was originally designed in the United States. It is designed to scale up from small incidents to major ones, and the various sections within the incident control system expand accordingly, according to a principle of span of control. Usually if one person is in charge of five people, and that ratio is exceeded, then that role is split between two people and so on.

An incident management system comprises three main sections:

- Operations
- Planning
- Logistics

There is a person in charge of each of these main sections, and an overall incident controller, who oversees the coordination and communication between these three sections. Incident management teams usually set up in a fire control centre, which can be some distance from a fire. The reason for this is that these teams usually require a range of modern technology to function effectively, such as telephones, radio communications, faxes, e-mail, and other support services. Once upon a time a lot of these technologies were unavailable in remote areas, and fire fighters had to put up with simple radio communications, local support networks in rural areas, and simple field technologies, like a pencil and paper, and map and compass.

One of the major issues with an incident management team is that it takes time to set up one properly in a remote location, close to a fire. An incident controller usually has to set up his social networks from scratch, bringing in people from a variety of agencies and backgrounds, and experience. Often people are brought in with credentials and accreditation in the key functions of the incident command system, but not necessarily with the local knowledge. Before these formalised incident management teams came along, there used to be rural social networks in place, where people had trust in one another, and knew how to get a response together quickly. These social networks still exist in rural areas and play an important sociological support role in a cohesive rural community.

From the evidence supplied to the Federal Inquiry from rural constituents, incident management teams were not always in contact with local people from the start, and did not always involve local people with local knowledge in an incident management team. There were often cases where highly experienced yet not accredited people were advised that their services were not required. This can create a lot of angst and frustration in local rural people, who have fought and managed fires without any formal accreditation in fire fighting or management within an incident management team. It would appear that training in the incident management system has not always filtered down to a local level, so that in the event of a major fire emergency, these local resources could not be readily drawn into the fire fighting effort. A common field situation now is having fire fighters who have been trained on paper, having the right personal safety equipment, yet not having the many years of experience on the fire ground. Right next to them there could be people with the local knowledge of the area, and of the history of fire behaviour, yet lacking the formal accreditation. There were plenty of examples of lack of involvement or exclusion of local bushfire brigades who had the social networks, local knowledge of fire behaviour, the firetrail system, and the lessons learnt from previous large fires. Many of the submissions told of this experience of being excluded.

As a result incident management teams are seen as bureaucratic and insensitive to the local needs of rural communities. Decision-making has been taken away from the local leaders in a rural community, such as the bushfire brigade captains and group captains, in which the local community have entrusted their faith to manage fires on their behalf.

A COMMENT ON FIRE PLANNING

Fire planning within an incident management team presently is focussed on incident action plans in the short term, which usually means in the 12 to 24 hour period. These plans are incredibly detailed and reflect the fire control view of likely scenarios which can unfold in the next 24 hours. Often these plans are out of date and discarded by the time they reach the fire-ground. The present format and detail of an incident action plan needs to be simplified and readily updatable when local fire-ground conditions change. Fire scenario forecasting should be given more attention in the format of an incident action plan, providing field operations with summary risks of threats in a given fire strategy, and the likelihood of success, with the given forecast and possible changes to that forecast.

Closer links between the fire-ground and the planning section within an incident management team, are imperative in a proactive and adaptive management of a fire. This is where the present structure of an incident management team does not enable rapid contingency planning as often the intelligence from the fire-ground is not returning to the command centre in a timely manner to respond to a new fire scenario.

Often there are people placed in planning roles within an incident command team, who have not spent much time on the end of a rakehoe or working with a dozer, and have not been given much opportunity to develop strategic fire assessment skills. Strategic assessments need to be broad based and must include local knowledge of on-ground information. With this detailed local knowledge, blended with what is happening in a broader picture, an accurate fire scenario can be developed. Further training in fire strategy assessment is imperative if incident management teams are going to be successful in limiting the impacts of potentially large blow-up fires.

LOCAL FIRE PLANNNG - BUILDING TRUST AND COOPERATION

The real issue here is how to create better relationships and co-operative fire fighting strategies between local people and incident management teams who are largely brought from outside to manage a local situation. A key element in this is local planning for fires, which takes into account:

- The local fire environment
- Local fire risks and threats
- Vegetation and fuels
- Fire history both wild and prescribed fire
- Documentation of assets at risk, both natural and cultural;
- fuel management Plans;
- maintenance and development of the local fire trail system;

- location of natural fire advantages;
- location of water sources for helicopters and tankers, and
- other key facilities, such as halls, fuel and food outlets

The author has had considerable experience in local fire planning, having been involved in co-operative local fire planning since the late 1970's. Having worked with a number of local communities and bushfire brigades in the Blue Mountains, and in Tasmania, the benefits of this local fire planning have been found during fire emergencies, in 1994 and 2001 in the Blue Mountains. These local fire plans form the basis for an integrated fire protection network both within and adjoining natural areas of bushland.

However local fire planning has not found favour within the rural fire services, whose focus presently has been on broader risk management planning. Risk fire management plans are general regional planning documents, which often do not have validated assessments of fire risk and threat, and an evaluation of broad fire scenarios, and how best to deal with them. A local community fire plan is a bottom up approach to fire management, which plans with local rural communities on how best to deal with local and bigger fire scenarios. A local fire plan can also put in place some basic principles of operation, which can be documented for incident management system teams to use, and to establish who are the leaders in the local community, and how best to make use of all people in a local community.

These community fire plans can be integrated into broader risk management plans. When this level of local planning is incorporated into a regional risk management, they provide a useful level of detail, which can bear fruit in a fire incident, whatever its size. They also provide the link between local knowledge and its use in the development of appropriate fire strategies in a major fire incident.

AN EXAMPLE – THE MOUNT TOMAH-BILPIN-KURRAJONG HEIGHTS COMMUNITY FIRE PLAN

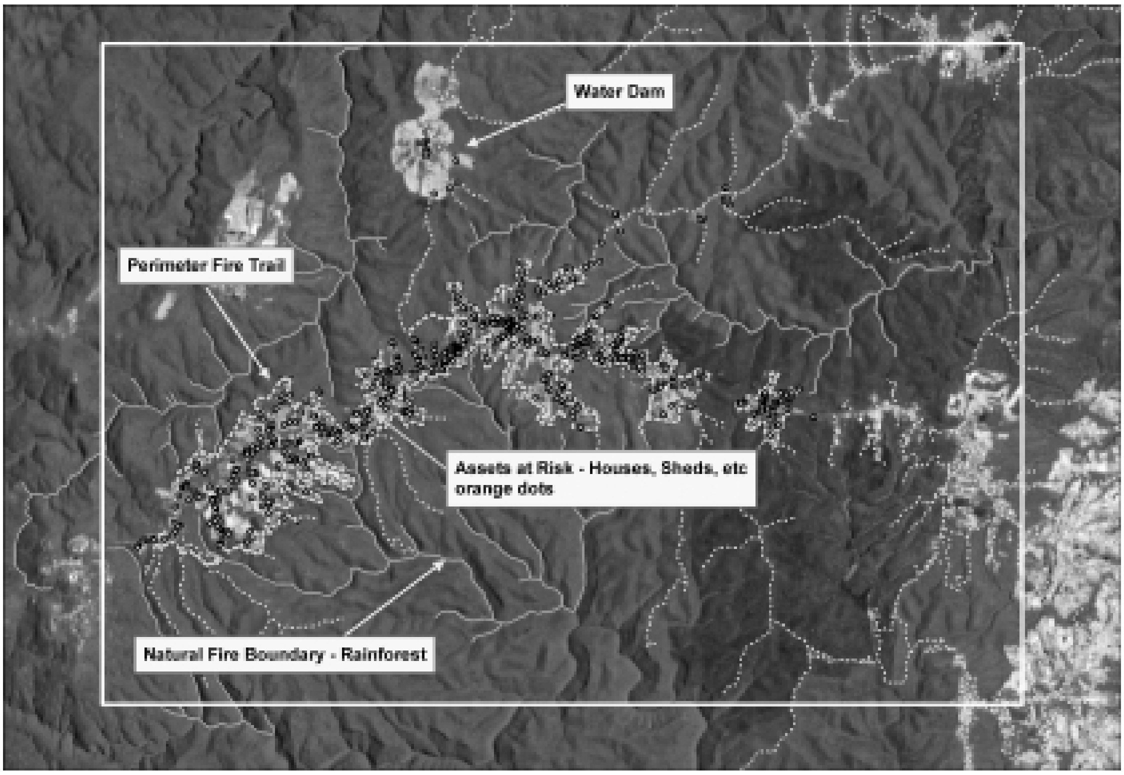
Between 1987 and 1994, the author as part of his job as a fire management officer in the Blue Mountains District, of the National Parks and Wildlife Service, undertook a joint project with local bushfire brigades to develop a community fire plan along the eastern section of Bells Line road between Mount Tomah and Kurrajong Heights. This local plan crossed two local government area boundaries: Blue Mountains and Hawkesbury City Council.

Time was spent on the ground documenting all the necessary information to support a community fire plan with the local bushfire brigade captains, and at the same time informing the community through local meetings what the process of community fire planning was , and how the community could become involved. The results of the community fire planning were annotated onto maps and later information on individual landowners and their assets was entered into a database, including the availability and suitability of privately owned water sources.

Figure 13 shows the basic information in the Bilpin-Kurrajong area, against a backdrop of a SPOT infra-red image of the area. The darker areas on the right hand side of the diagram indicate areas burnt in the January 2001 fires in this area.

Much of this information is now stored on a geographical information system (GIS) which enables rapid retrieval and analysis of data in a local emergency.

Figure 13. Overview Map of Bilpin-Kurrajong Area



CONCLUSIONS

CAUSAL FACTORS

1) The risk of multiple lightning strike events in drought years once every fifteen to twenty years in the Victorian and NSW alpine regions should be highlighted in preparation and risk management for such events,
2) The fire potential of fires in remote areas during drought years in January and their likelihood of coalescing into major fire complexes, should be considered as highly likely. Such events could occur once every forty to fifty years in the Alpine Regions of Victoria and New South Wales.
3) The frequency of severe fire weather days in a drought can be up to 5 or 6 in a sequence, with the ongoing likelihood of no rain-stopping event
4) There is a suggestion from the study of the fire weather records and drought that climate change may have played a role in the fire weather recorded in 2003.

FUEL MANAGEMENT

1) Further strategic evaluation of fuel management should be undertaken in all regions within south-eastern Australia, based on the results presented in this report
2) Management of fuel mosaics, as well as flammable weeds, needs to be adequately funded on a recurrent year basis. Present funding of such programmes within land management agencies may need further boosting of funds to achieve satisfactory targets for fuel management.
3) While grazing can play a role in reducing overall fuel loads in the Alps, strategic burning should be given a greater role in the protection and management of fire sensitive forests and woodlands. Fuel management prescriptions, based on ongoing vegetation and fire monitoring, would further refine management of fuels loads within the sub-alpine and montane zones of the Alps, to achieve a variety of fire management objectives
4) The effectiveness of fuel management needs further research and documentation during wildfires in a wider range of vegetation types in SE Australia, including fire ages between 4 and 10 years
5) There needs to be national standard of fire mapping, which accurately maps the extent, intensity, spread, and overall pattern of prescribed and wildfires in Australia.
6) Results of annual fuel management in each State should be publicly reported and audited.

AUSTRALIAN INCIDENT MANAGEMENT SYSTEM

1) Training of incident management personal should include how to engage and involve local people in planning and management of fires.
2) Training and mentoring in fire scenario planning be given further emphasis is incident management training, to improve strategic planning on fires
3) Further refinement in the structure and function of planning within an incident management team to make it more field based, using local intelligence.

4) The Australian Incident Management needs further refinement in setting up simple command and control structures, operating closer to the fireground, responsive to the ever changing local fireground conditions and needs of local communities
5) National models for community fire planning should be developed, in consultation with State agencies and local communities. Community fire plans then need to be integrated back into incident management.
6) National Reporting of the Success of incident management of fires should be prepared on a national basis, as a means of auditing the cost-benefit of incident operations, in terms of the triple bottom line of economic, social and ecological criteria.

REFERENCES

Burrows N.D. (1994). Experimental development of a fire management model for jarrah (Eucalyptus marginata) forest. Unpublished PhD Thesis, Department of Forestry, Australian National University, Canberra

Davies, C. (1997) Analysis of Fire Causes on or Threatening Public Land (1976/77 – 1995/96). Research Report No. 49. Fire Management Branch. Department of Natural Resources and Environment in Victoria.

Good R.B. (1994). The Effects and Effectiveness of Fire Management. Biodiversity Series, Paper No. 8. Proceedings of the Conference held 8 - 9 October 1994, Footscray, Melbourne

Green R (2003). Proceedings of a workshop into Climate Change Impacts on biodiversity in Australia. Sponsored by the Biological Diversity Advisory Committee. CSIRO Sustainable Ecosystem, Canberra.

Holling CS (ed.) 1978. Adaptive environmental assessment and management. International Series on Applied Systems Analysis 3. John Wiley and Sons. Chichester, 377 pp.

McCarthy, G.J. and Tolhurst, K.G. (2001) Effectiveness of broadscale fuel reduction burning in assisting with wildfire control in Parks and Forests in Victoria. Fire Research Report No. 51. Fire Management, Dept. Natural Resources and Environment, Victoria. 26pp.

McCaw L, Simpson G, and Mair G. (1993). Extreme wildfire behaviour in 3 year old fuels in a Western Australian mixed Eucalypt forest. Australian Forestry **55**, 99-109

McCaw W.L., J.E. Neal and RH Smith (1996). Effects of fuel reduction burning on behaviour and suppression difficulty of an intense wildfire in Jarrah (Eucalyptus marginate) forest – a case study.

Moriarty, O. (1993). Conservation or Destruction of Natural Resources of Alpine Regions of South Eastern Australia. Report to the Australian Academy of Science

Mount A.B. (1972). The derivation and testing of a soil dryness index using run-off data. Forestry Commission, Tasmania

Noble I, Bary G.A.V and Gill AM (1980). McArthur's Fire danger Meters, expressed as equations. Australian Journal of Ecology **5**, 202-203

Rawson R, P. Billing, B Rees (1985). Effectiveness of Fuel-Reduction Burning. Fire Protection Branch Research Report No. 25. Victorian Department of Conservation and Environment.

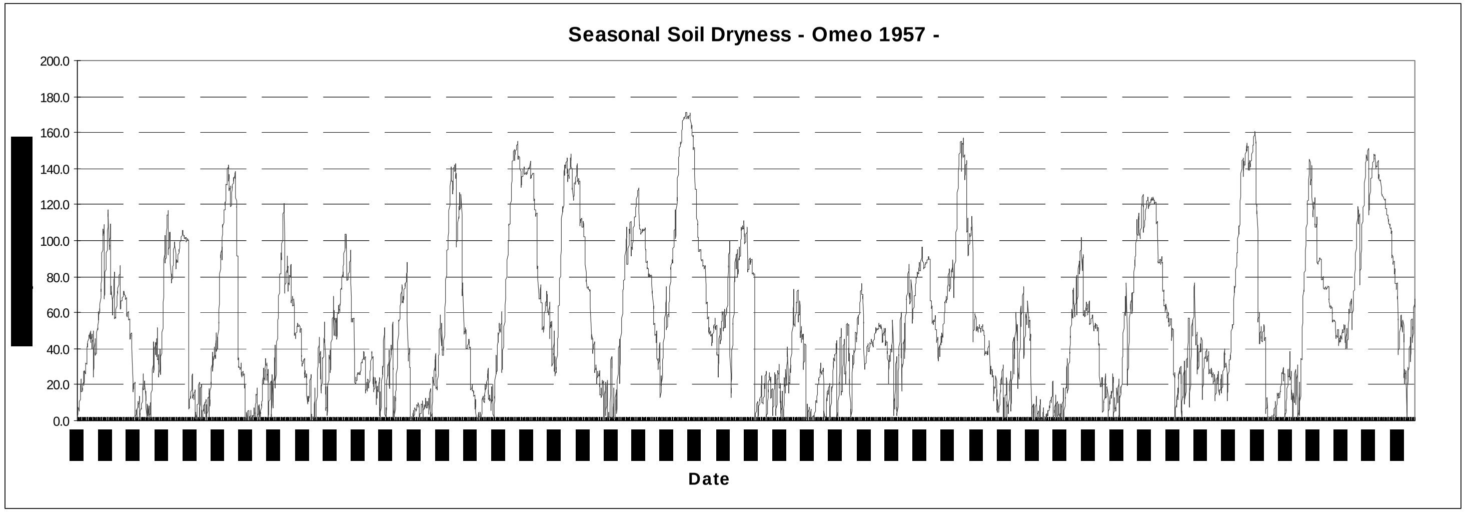
Tolhurst K. (1993). Prescribed Burning in Practice: Policy and Practice. Paper to the "Bushfire Prevention – Are We doing Enough" Conference. Institute of Public Affairs, Melbourne

Wahren C.H., W.A. Papst, and RJ Williams (1999). Post-fire regeneration in Victorian alpine and sub-alpine vegetation. Paper presented to Australian Bushfire Conference, Albury.

Walker, J. (1981). Fuel Dynamics in Australian Vegetation. Fire and the Australian Biota. Australia Academy of Science Conference 1979.

APPENDIX 1

Figure 1a Historical Trends in Soil Dryness – Omeo Weather Station 1957-2003



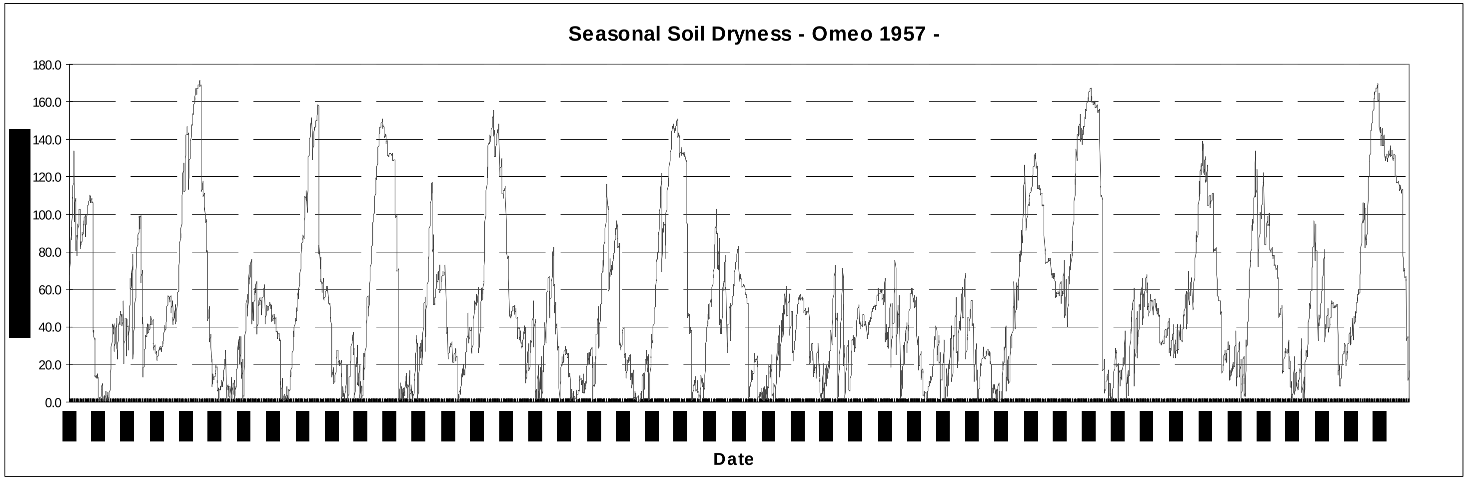
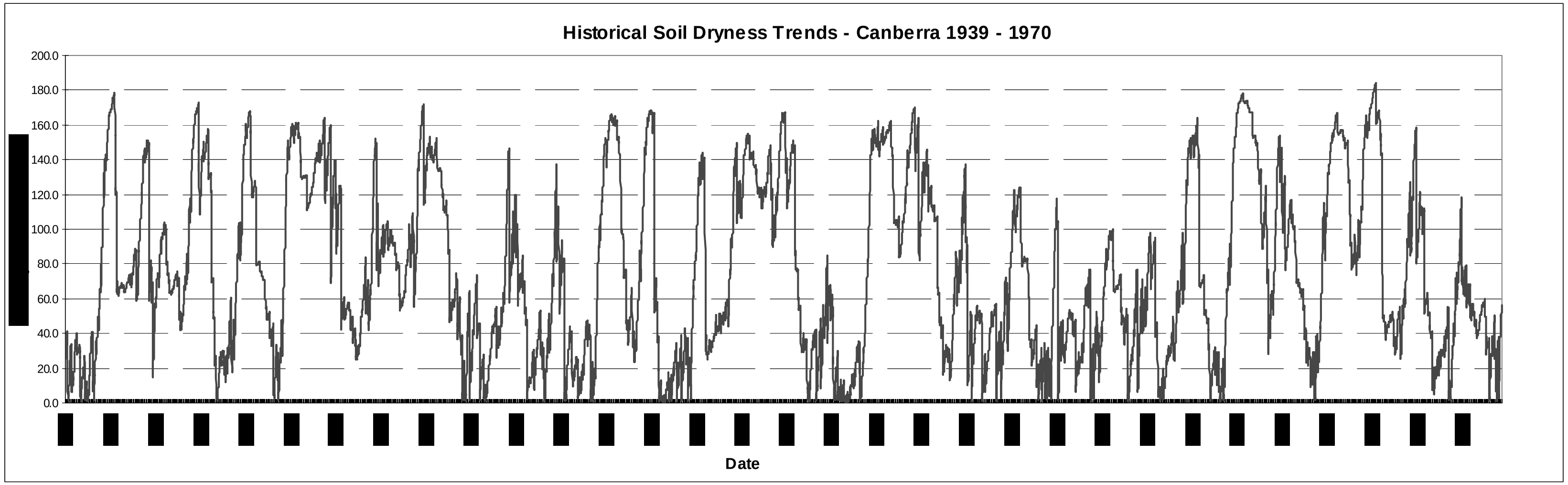


Figure 1b Historical Trends in Soil Dryness – Canberra Weather Station 1957-2003



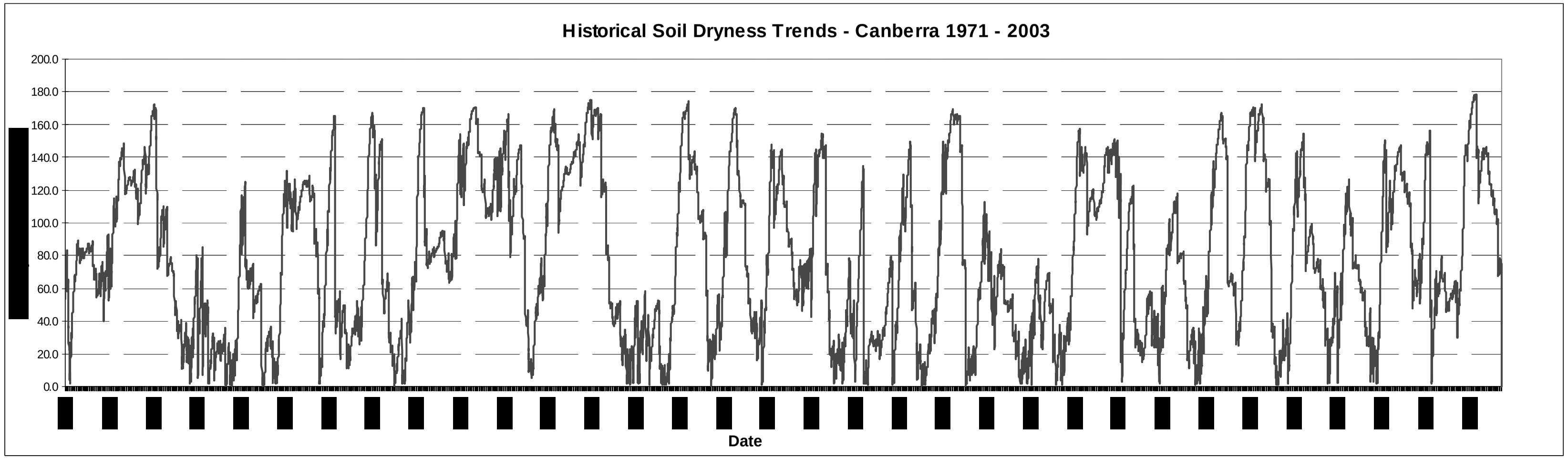


FIGURE 6 MAP OF PROGRESSIVE SPREAD OF FIRES DURING JANUARY AND FEBRUARY 2003

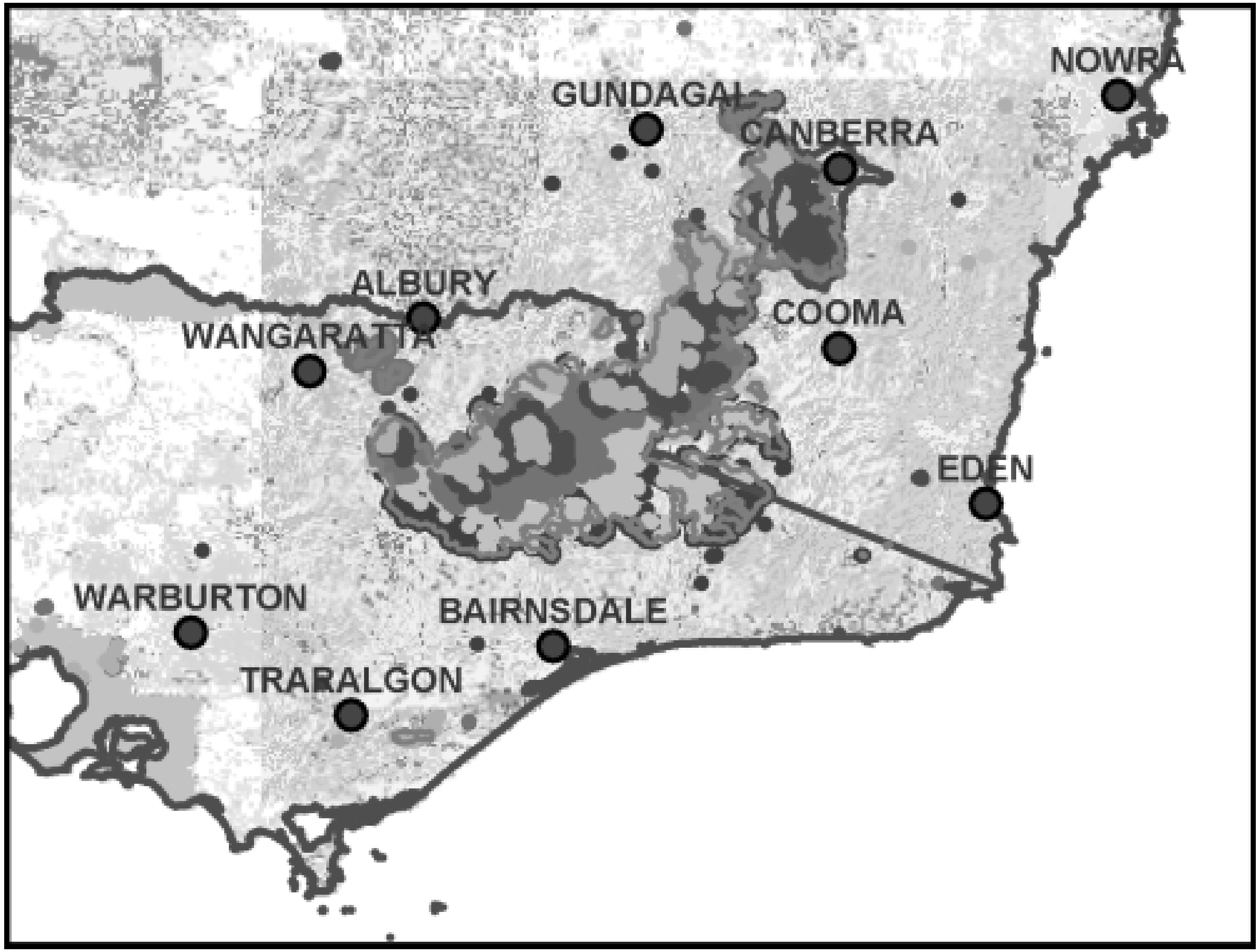


TABLE 6. STATISTICS OF POTENTIAL FUEL MANAGEMENT TREATMENT IN SE NSW

Code No	Broad Fuel Group Description	Treatable	Total Area (ha)	Asset Protection	Strategic Wildfire	Broad Area	Untreated	Fuel Condition	Fuel Levels	Fire Frequency	Intensity
1	Rainforest	N	37,846	0		0	37,846	Moist	Low	25-100	Low
2	Ecotonal Rainforest/Eucalypt Forest	N	63,937	0		0	63,937	Moist	High	25-50	High
3	Moist Layered Forest	N	47,706	0		0	47,706	Moist	High	30-100	High
4	Moist Fern Shrub Forest	N	329,414	0		0	329,414	Moist	High	15-50	Moderate-High
5	Montane Herb Shrub Forest	N	169,746	8,487	25,462	67,898	67,898	Partially Moist	Moderate	15-50	High
6	Sub-Alpine Tall Shrub Forest	Y	99,453	4,973	14,918	39,781	39,781	Partially Moist	High	20-50	High
7	SWS Ironbark Forest	Y	316	16	47	126	126	Mostly Dry	Moderate	15-30	Moderate
8	Dry Grass Forest	Y	42,079	2,104	6,312	16,831	16,831	Sometimes Dry	Moderate	3-15	Moderate
9	Tablelands Dry Grass Shrub Forest	Y	408,644	20,432	61,297	163,457	163,457	Mostly Dry	Moderate	12-30	High
10	Western Montane Dry Grass Shrub Forest	Y	131,922	6,596	19,788	52,769	52,769	Sometimes Dry	Moderate-High	12-30	Moderate-High
11	Tablelands Valley Floor Grass Forest	Y	309,614	15,481	46,442	123,846	123,846	Sometimes Dry	Moderate	6-20	Moderate
12	South Coast Dry Shrub Forest	Y	700,143	35,007	105,021	280,057	280,057	Mostly Dry	Moderate-High	8-15	Moderate-High
13	Riparian River Red Gum Forest	N	12,185	609			11,575	Mostly Moist	Moderate	3-15	Moderate
14	Eastern ST Montane Grass/shrub Forest	Y	415,155	20,758	62,273	166,062	166,062	Sometimes Dry	Moderate-High	12-26	High
15	Frost Hollow Grassy Woodlands	Y	5,739	287	861		4,592	Mostly Moist	Moderate-High	5-25	Moderate
16	Dry Heathy Forest	Y	109,375	5,469	16,406	43,750	43,750	Mostly Dry	High	10-30	High
17	Lower Snowy White Box Forest	N	37,064	0		0	37,064	Dry	Low	15-30	Moderate
18	Savannah White Box Woodland	Y	5,590	280	839	2,236	2,236	Mostly Dry	Moderate	5-20	Moderate
19	SavannahYellow Box Woodland	Y	11,617	581	1,743	4,647	4,647	Mostly Dry	Moderate	5-20	Moderate
20	Sub-alpine Snow Gum Woodland	Y	112,957	5,648	16,944	45,183	45,183	Mostly Moist	High	25-100	High
21	SWS Acacia/Callitris Woodlands	N	5,129	0		0	5,129	Mostly Dry	Low	25-50	High
22	SC Acacia Rocky Shrubland	N	7,938	0		0	7,938	Mostly Dry	Low	20-40	Moderate
23	Coastal Swamp Forest Complex	N	2,702	0		0	2,702	Mostly Moist	Moderate	15-40	Moderate
24	Coastal Swamp Shrubland Complex	Y	9,470	473	1,420	3,788	3,788	Mostly Dry	High	7-25	High
25	Coastal/Hinterland Dry Heath	Y	12,770	638	1,915	5,108	5,108	Mostly Dry	High	12-25	High
26	Mallee Heath Complex	Y	40,199	2,010	6,030	16,080	16,080	Mostly Dry	High	12-25	High
27	Coastal Dune Complex	Y	5,064	253	760	0	4,051	Mostly Dry	High	7-25	High
28	Estuarine Mudflats	N	2,735	0		0	2,735	Moist	Negligible	-	-
29	South Coast Escarp Heath	Y	7,325	0		2,930	4,395	Mostly Moist	High	12-25	High
30	Namadgi Heath Complex	Y	11,644	0		4,658	6,987	Mostly Moist	High	25-40	High
31	Native Grasslands	Y	2,762	0		0	2,762	Mostly Dry	Moderate-High	3-12	Moderate
32	Sub-alpine Herbfield	N	85,532	0		0	85,532	Mostly Moist	Moderate	25-40	Moderate
33	Montane/Sub-alpine Fen	N	13,456	0		0	13,456	Mostly Wet	High	3-15	High
34	Swamp Grasslands	N	2,644	0		0	2,644	Mostly Wet	High	3-15	Moderate
35	Eden Riparian Shrublands	N	7,253	0		0	7,253	Mostly Dry	High	12-25	High
36	Pine Plantation	N	222,102	0		0	222,102	Mostly Dry	High	-	-
	Totals		**3,489,226**	**130,102**	**388,478**	**1,039,207**	**1,931,439**				
			10 Year Freq	**13,010**	**38,848**	**103,921**	**155,779**				
			15 Year Freq	**8,673.5**	**25,898.5**	**69,280.5**	**103,852**				