THE MYALUP WILDFIRE

APRIL 1991

Observed Fire Behaviour and Damage

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Bunbury 1992

Contents

The Myalup Wildfire April 1991: Observed Fire Behaviour and Fire Damage.

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Summary

1. The wildfire was ignited in two places by embers blown from smoldering heaps of slash by the strong (40 km/h) winds associated with the passage of Cyclone "Fifi" down the Western Australian Coast.

2. Very high rates of spread (c. 3000 m/h) occurred when the fire travelled along windrows of slash in two compartments.

3. There were two main fire runs, the northern one (Fire 2) was estimated to have an average actual headfire rate of spread of 1300 m/h and that of the southern one (Fire 3) was about 420 m/h.

4. The Forest Fire Behaviour Tables overestimated the rate of spread of Fire 2 by a factor of 3 and that of Fire 3 by a factor of 10.

5. Fire 3 was ignited by long distance spotting (2.6 km), probably from Fire 2.

6. There was limited crown fire development even though theoretically fireline intensities were sufficient to cause extensive "torching" of trees. Widespread crowning was probably prevented by the low and high pruning of the plantation and prescribed burning which resulted in an absence of "fuel ladders".

7. The progress of Fires 1 and 2 was halted by the extensive area of newly planted pines with discontinuous fuels south of Forestry Road.

8. The progress of Fire 3 was halted by the construction of fire breaks aided by a reduction in fire intensity and rate of spread caused by rising humidity, a negative slope and perhaps a local wind change.

9. Post-fire sampling showed that even in areas which had been subjected to repeated prescribed burning litter quantities were generally over 20 t/ha and frequently more than 30 t/ha.

10. There were very few references to the wildfire's behaviour or position in the Fire Diary kept by suppression controllers.

The Myalup Wildfire April 1991: Observed Fire Behaviour and Fire Damage.

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Introduction

The Myalup wildfire on Sunday April 21 1991 which burnt 260 ha of pine plantation was one of the largest plantation wildfires in Western Australia's history. Previous notable pine plantation wildfires include the Gnangara Plantation fire of 22 January 1962 (48 ha), the Grimwade Plantation fire of 2 March 1984 (53 ha) and the Folly Plantation fire of 13 March 1988 (209 ha)[1].

This report describes the progress of the Myalup fire, documents the fuel and weather conditions at the time and summarizes the damage caused by the fire. The fire was a complex one, with highly variable fuels and five separate "runs", and because of a scarcity of documented fire behaviour data only a general analysis of this aspect of the fire is possible.

The fire burnt in conditions of very high fire danger (Fire Danger Index of 968 for *Pinus pinaster*) associated with the passage of Tropical Cyclone "Fifi" near the south west corner of Western Australia. Strong winds (> 40 km/h) throughout the day were largely responsible for the severe fire weather.

The main fire travelled for over 5.3 km across gently undulating terrain in just over 4 hours at an average forward rate of spread of 1310 km/h although this included long distance spotting of up to 2.6 km. The longest individual fire run was 1.6 km.

A wide variety of plantation fuel types was burnt by the fire including 60 year-old stands with deep litter beds, unthinned 10 year-old stands, thinned compartments and recently clearfelled areas with windrowed slash.

Wildfire case-studies (e.g. Alexander and Lanoville, 1987) provide a valuable opportunity to analyse the behaviour of large fires burning under severe weather conditions. Information gained from such studies may be used for evaluating existing fire behaviour prediction systems, and may provide useful data for future modelling.

Descriptions of the fire's behaviour were obtained from interviews with people involved in suppression of the fire, and from a few references in the fire diary kept at the Harvey headquarters of the Department of Conservation and Land Management. Weather information was obtained from the Harvey office 13 km east and from the S.C.M. Refinery at Australind 20 km south of Myalup. Fire damage was assessed by ground traverse and by the use of aerial photographs taken a week after the fire.

Headfire rates of spread given in the following narrative of the fire's progress are estimates based on the distance the the headfire travelled between observations of its position. Figure 1 shows these positions (A - L) and conjectural contours of the fire's spread based on them. Times of arrival of the fire front at positions A, D, F and L are the most reliable as they were recorded in the fire diary or confirmed by more than one observer. The other headfire positions are based on the recollection of only one observer and were not recorded at the time.

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[1]Unpublished reports on these previous plantation wildfires are on file at the Fire Protection Branch, Department of Conservation and Land Management, Bunbury.

Observed Fire Behaviour

Detection of the initial fires

The first two fires were caused by embers blowing from burning heaps of clearfell slash into C71 (ie. compartment 71) (Fire 1) and C42 (Fire 2) within the Myalup Plantation. In the week prior to the fire heaps of clearfell slash were being burnt in compartments C66 and C72. That in C66 had been lit on the April 15 and was reported as "blacked out" later in the week. The heapss in C72 were lit on April 19. A small "hopover" from C72 into C42 occurred on the same day but this was quickly extinguished and was apparently "blacked out" when the heaps were checked the next day. The heaps in C72 were checked again between 0800 h and 1000 h on April 21. At this time one burning heap eight metres from C42 was extinguished and four small heaps further from the edge were left burning. As it was a Sunday the employees went home after checking the burning heaps.

At 1150 h on the April 21 smoke was first detected in the general direction of the clearing burn in Myalup Plantation by the towerman in Mornington Tower which is 26 km south east of the plantation. The sighting was confirmed as being in the plantation at 1220 h by the Mornington towerman and also by the Harvey shire ranger. At this time a "Red Action" fire alert was called.

The five separate fire runs of the Myalup fire are illustrated in Figure 1. The three main wind-driven fires are labelled as Fires 1, 2 and 3. The observed rate of spread over several stages of the two largest fires (Fires 2 and 3) as well as spotting distance are shown in Table 1.

Fire 1

The first firefighter to arrive at the plantation at about 1225 h reported that the fire was in the western part of C71, was wind driven, was moving rapidly and appeared to have escaped from the clearing burn in C66. At this time the winds at Harvey (15 km east of the plantation) were northerly and between 30 and 40 km/h. By 1230 h the fire (Fire 1) had reached Forestry Road about 300 m from the origin, was about 40 m wide, and was spotting across into C1. Initial fire suppression efforts were directed at putting out the hopovers in C1. Fire 1 burnt through the narrow strip of pines immediately south of Forestry Road but was halted by the sparse fuels in the newly planted C8.

Fire 2.

Crews arriving at Fire 1 reported a second fire about 1.6 km to the north at about 1245 h. At this time Fire 2 had reached the north-eastern corner of C52 after having travelled along the unburnt windrows in the western half of C43 and through the 34 year-old pines in C42. Flame heights were only about 0.5 m in the needlebed fuels in C42 but around 3.0 m in the windrows in C43.

1245 h - 1330 h. Fire 2 travelled 750 m from point A at the NW corner of C52 to point B in the NE corner of C64 (Fig. 1, Table 1).

Over this stage of its progress the headfire passed though C52, an unthinned compartment of 35 year-old P. pinaster where drought deaths had reduced the initial 1600 stems/ha stocking to about 600 stems/ha. An active crown fire formed within C52 for the only time during the Myalup wildfire although the estimated rate of spread was only about 940 m/h over this stage. The crowned area was about 300 m long by 50 to 120 m across.

Immediately south of C52 was C55 which had been clearfelled and contained unburnt windrows of logging slash aligned north to south. In this open area the fire probably travelled very rapidly along the windrows because of higher windspeed near the ground as was observed in the other clearfelled and windrowed compartment, C43.

1330 h - 1340 h. Over this stage (points B to C) the headfire travelled about 500 m at an average around 3000 m/h. Three of the compartments crossed by the headfire during this stage were stocked with 35 year-old P. pinaster thinned to 125-250 stems/ha and one, C63, contained 10 year-old P. pinaster. Flame heights of 3 m were reported in C63 at about 1430 h as the fire burnt out at the flanks. Scattered "passive" crowning or torching of individual trees occurred in C63, where one row in 5 had not been low pruned and the crown base of the pruned trees was only 2 m above the ground.

1340 h - 1400 h. During this period the average forward rate of spread of the fire appears to have declined somewhat to average about 840 m/h. At 1400 h the fire was about 100 m north of Forestry Road and was spotting across the road. As the fire approached Forestry Road observers said it was about 50 m wide with flame heights of 4 to 5 m.

The forward progress of Fire 2 was halted at about 1420 h by the light and discontinuous fuels in the extensive area of 1 year-old pines (C8) planted south of the narrow band of mature trees along Forestry Road, as Fire 1 had been two hours earlier. Although there was abundant spotting into C8 from Fires 1 and 2 the scattered grass fuels would not carry a running fire and there was little damage in this compartment. Fires 1 and 2 continued burning out at the flanks until they coalesced. Fire behaviour on the flanks was reportedly very mild, flame heights on the eastern side of the fire in C43 and C52 were 0.25 to 0.50 m.

The fires south of Forestry Road

As noted above spotting across Forestry Road originated from Fire 1 as early as 1220 h. This spotting started numerous small fires in the newly planted area south of Forestry Road as the day wore on, but because of the lack of continuous fuels these fires did not spread far and were easily extinguished. An observer noted that the strong winds were causing burning debris to roll along the ground in C8.

Between 1430 and 1440 h a reconnaisance officer found fires on the south western side of C22, at the southern boundary of C32 and C37 and immmediately across the Harvey River Diversion Drain at the northern end of C118 (Fire 3). One observer gave the initial sighting of Fire 3 as about 1400 h, an observation which, considering the slow early spread of this fire is probably accurate. The fire in C22 which covered about 1 hectare when found was possibly started by burning debris blown along the ground from Fire 1. The fires in C32 and C118 were probably started by long distance spotting from Fire 1 however, because when they were first found they were surrounded by unburnt forest to the north.

The behaviour of the fire in C22, which was surrounded by the light and discontinous fuels of C8, was generally mild as it mainly burnt into the wind, apart from a small section in the south western corner. This fire was started about 100 m from the south western corner of this compartment and from here the fire spread rapidly to the southern edge (from the evidence of bole char after the fire) and slowly back against the wind to the north and east. According to one observer the fire took till 2300 h to reach the northern and eastern edges indicating an average spread rate of less than 40 m/h.

Similarly the fire in C32 and C37, which both carried 19 year-old P. pinaster, was mainly a backing fire. This fire covered about 2 ha when discovered at 1430 after which it spread slowly to the north and east. The spread rate of this fire was probably less than 200 m/h, although there were few observations of fire behaviour in these compartments.

Fire 3

1440 h - 1500 h. Fire 3 originated from a spot ignition in the north eastern corner of C118 at about 1400 h. At 1440 h the fire was about a hectare. Fire behaviour was reportedly quite mild in C118 with flame heights of about 1.5 m in this stand of 22 year-old P. pinaster. The relatively low forward rate of spread at this stage may have been due to the spot fire taking time to accelarate and form a distinct headfire. There may also have been a sheltering effect by the large eucalypts along the edge of the diversion drain and to the north of the fire. The fire had progressed about 400 m into C121 at the next reported position at around 1500 h indicating a headfire rate of spread of 500 m/h. At this stage it was about 70 to 80 m wide with the headfire travelling SSE as it had with Fires 1 and 2.

1500 h - 1640 h. The estimated rate of forward spread decreased in the hour after 1500 h and averaged only around 280 m/h till the next observation at 1600 h when it was about 300 m north of Emu Drive. Flame height was around 0.5 m when this observation was made. Shortly after 1600 h the fire's rate of spread increased dramatically as it progressed up a hill in the south west corner of C121 with a maximum slope of about 16 degrees.

As it spread up the hill the fire moved from 21 year-old P. pinaster into a stand of P. radiata of the same age which may have had heavier litter fuels as it had not been burnt for fuel reduction in 1988 as the P. pinaster had been. From a height of 0.5 m at the base of the hill the flames of the headfire grew to 5 to 6 m tall as it progressed rapidly up the hill. Although precise times for the spread of the fire up the hill are not known the fire covered the final 420 m to Emu Drive in about one hour. The rate of spread up the slope may have been considerably higher than this, the reported flame heights of 5 to 6 m indicate an intensity (if flame height = flame length) of over 12000 kW/m (Alexander, 1982).

By 1620 h the fire had crossed Emu Drive and proceeded down the slope at a much reduced forward rate of spread. Flame height was observed to be only 0.5 m on the lee side of the hill and the running fire was stopped by a recently constructed fire break about 100 m into C120 and C123 at 1645 h. An observer reported that there was a gusty SW component in the wind at this time and that this had contributed to the unexpectedly mild behaviour of the fire in C120 and C123. The weather records for Harvey show that although the wind was still 36 km/h from the NW at this time, by 1500 h the relative humidity had risen to 61 % and presumably was significantly higher over an hour later

After 1600 h the most intense fire behaviour was reported to be on the eastern flank of the fire and 3 m flame heights were observed in the southern section of C122 at 1645 h. This flank, and the fire as a whole, was secured by the construction of firebreaks by 1700 h.

Weather and fuel conditions

Weather and fuel moisture

The weather at Myalup plantation on the day of the fire was dominated by the effects of Tropical Cyclone "Fifi" which was moving down the west coast about 350 km out to sea. The maximum temperature of 28^{o} C and minimum relative humidity of 33 % recorded at 1200 h were not extreme but the strong winds caused by the passage of the cyclone produced extreme fire danger. Wind speed and direction recorded at Harvey during the day and at the S.C.M. Refinery during the afternoon are shown in Table 2. These recordings indicate that winds in the area were around 40 km/h from a northerly direction during most of the afternoon of April 21.

There had been no rain at Harvey for nine days before the fire and because maximum temperatures had been warm to hot during this period the effects on soil and fuel moisture of the 50 mm of rain which fell from April 9 to 11 had dissipated. Weather data, predicted minimum fine fuel moisture contents ("SMC") (Sneeuwjagt and Peet, 1985) and the soil dryness index ("SDI") (Burrows, 1987) at Harvey for the week prior to the fire are shown in Table 3. The SDI of 1497 for April 21 is indicative of low moisture levels in large dead woody fuels and deep forest litter and under these conditions "fire behaviour is often severe, crown fires are common and spot fires develop downwind of the main fire" (Burrows, 1987). Needlebeds up to 1 metre deep (in C53) and dead trunks over 30 cm in diameter burnt away in the wake of the Myalup fire which confirmed the prediction of the SDI.

Fuel quantity

Unfortunately little quantitative information on fuel conditions is available for the compartments burnt by the wildfire. The most recent litter fuel weight sampling had been done a year previously prior to prescribed burning and this included only three of the compartments burnt by the wildfire. Because of the large range of tree ages within the area burnt by the wildfire some sampling was done immediately after the fire to quantify the range of fuel conditions in similar unburnt areas adjacent to it. These areas were representative of those burnt but were protected by fire breaks put in along the flank of the fire.

Fine fuel quantities were measured using a litter depth guage and tables relating litter depth to litter weight for P. pinaster and P. radiata (Sneeuwjagt and Peet, 1985). Some of the compartments burnt by the wildfire had recently been thinned and slash fuel loadings were estimated by using a modification of the method of Burrows (1980). The results of these field measurements and estimates for particular compartments are shown in Table 4.

Based on these fuel quantity measurements and estimates the 27 compartments burnt by the wildfire are placed in one of six fuel quantity groups as shown in Table 5. The silvicultural history of each of the compartments burnt or partly burnt by the wildfire is shown in Table 6. Fuel quantity and arrangement were related to tree age and Figure 4 shows the distribution of different plantings within the wildfire area of Myalup plantation.

Fire damage

Using colour aerial photographs the crown damage at Myalup plantation was divided into three categories; 100% crown burnt ("crowned" areas), 100% crown scorched and less than 100% crown scorched and mapped (Fig.2). The areas in each of these categories were;

100% defoliation	4 ha
100% of crown foliage scorched	153 ha
< 100% of crown foliage scorched	38 ha
	195 ha

The area of 1 year-old pines (C8) which was barely touched by the fire was not included in this assessment of damage.

In general the areas of pine with less than 100% of the crown scorched, that is with the upper surface of the crown visible on the aerial photograph unscorched, were on the northern, eastern and western flanks of the fire where fire behaviour was observed to be least intense. There were several smaller areas with less than 100% crown scorch scattered amongst the completely scorched areas which may indicate areas which had lighter fuel loads (Fig.2).

The trees within the 100% crown scorch areas were of a range of heights and ages ranging from about 7 m at 10 years to around 28 m at 60 years of age. The majority of the trees burnt by Fires 1 and 2 were 34 to 41 years old and were 20 to 22 m high. Fire 3 burnt through 21 year-old P. radiata and P. pinaster 14 to 18 m high.

The trees which were less than 100% scorched were of a similar range of sizes. The proportion of the total crown scorched in these trees ranged from nil to about 70%. Measurements taken with a clinometer in C22 of top height and maximum scorch height on trees just outside the 100% scorch area (Fig.2) showed a mean upper scorch height of 17 m on trees which averaged 19.5 m high. The crown base was about 13 m on these trees so the crowns were scorched to 60% of their crown height which indicates that about 80 % of the crown volume was damaged. The trees with scorch to greater heights than this in C22 (and in the other compartments) were clearfelled shortly after the fire.

The probability that the completely scorched trees would have died was very high. Burrows et al. (1989) found that Pinus radiata with greater than 80% foliage scorch suffered 90% mortality. The main factor in the rapid death of trees with heavy foliage scorch is the permanent loss of buds and twigs (Ryan, 1990).

Discussion

Fire shape and fire behaviour

The Myalup plantation wildfire was typical of fires driven by strong winds in that it had a high length to width ratio during its main run cf. the "Caroline" fire (Billing, 1980) and the "Avoca" fire, (Billing, 1985). Although the headfire was fast moving the flanks and rear of the fire were relatively mild and this allowed firebreaks to be bulldozed along the flanks well ahead of the flames. As is mentioned in the fire narrative firefighters had time to watch the 0.25 - 0.5 m flames on the eastern flank trickle out to the break at the same time as the headfire was travelling at over 1000 m/h. The rear flank of wind driven fires have the lowest rate of spread (Anderson, 1983) and the fire behaviour and low amount of damage at the northern edges of C22, C32 and C37 are in accord with this

Wind speed and direction

The complex arrangement of fuel types and large variation in fuel loadings within the wildfire area at Myalup would have caused major fluctuations in headfire rate of spread and intensity. These fluctuations can only be hinted at in Figure 1 based as it is on so little information about spread rates. The expected large increase in wind speed near the ground within the clearcut areas is confirmed by one firefighter's observations. This increase in wind speed would probably have continued for some distance into the northern edge of compartments downwind of the clearfelled areas (Raynor, 1971).

Because Myalup plantation is nearer to the coast than Harvey and therefore was nearer to the cyclone average windspeeds may have been somewhat higher. The SCM Refinery is about the same distance from the coast as the plantation and it recorded gusts up to 60 km/h and at Cape Naturaliste 90 km away wind speeds reached 129 km/h. It is not known if one of these much stronger gusts actually occurred at the Myalup but one of them may have caused the limited amount of crowning that occurred.

Although the wind direction at Harvey and the SCM Refinery was mainly north westerly during the afternoon one of the firefighters present in the latter stages of Fire 3 observed that there was a south westerly component to the wind as the fire burnt through C121 and C118. South westerlies were not recorded at Harvey or the SCM Refinery so there is no verification of this. This apparent south westerly component may have been caused by the fire drawing in air but the way the fire spread out to the east into C122 and exhibited increased fire intensity on its eastern flank lends some support to the firefighter's observation of a wind direction change. The dramatic decrease in fire intensity soon after the headfire crossed Emu Drive may have been partly due to a number of factors one of which may have been a local wind change.

Headfire rate of spread

Although definite indications of the actual rate of spread of the Myalup fire are restricted by the limited amount of observational

Intermediate rates of spread within these major fire runs are largely conjectural based as they are on very limited evidence.

The estimated actual headfire rate of spread for Fire 2 at Myalup is much lower than that which would be predicted using the Forest Fire Behaviour Tables for Western Australia (FFBT) (Sneeuwjagt and Peet, 1985). The wind speed and fuel loadings at the Myalup wildfire are at the upper limits for these factors catered for by the FFBT which were primarily designed for prescribed burning in native jarrah forest under relatively mild conditions. A prediction from these tables based for *Pinus pinaster* based on 7 % SMC, 11 km/h winds at ground level and 18 t/ha available fuel predicts a headfire rate of spread of around 4400 m/h which is over three times the estimated actual rate of spread. The over-estimate is even greater for Fire 3. One of the reasons for the tendency of the FFBT to overestimate head fire rates of spread is because they over-adjust rate of spread for above average fuel quantities (N. Burrows, personal comment).

Crown fire

Crowning was limited at the Myalup wildfire even though average intensities, especially in Fire 2 (Table 6) were far above those which initiate extensive active crown fires in Canadian jack pine forests (Stocks, 1987; 1989). The main reason for this difference is that the jack pine forests are unpruned and at densities 10 - 50 times higher than at Myalup. Crowning was extensive in a *P. radiata* plantation at the Longford wildfire reported by McArthur (1962). However the pines at Longford were unthinned and unpruned with the base of the live crown foliage only 3 to 4 m above the ground which carried 11 t/ha of fine fuels. These conditions together with the maximum headfire rate of spread at Longford (800 m/h) were more than enough to initiate a crown fire (Alexander, 1988).

The reasons for the very limited crown fire development at Myalup are not clear. Even though fireline intensities were theoretically above those needed to intiate widespread passive crowning (ie. "torching") these intensities may be over-estimated. In Table 6 it is assumed that 70 % of the fuel was consumed in the flaming zone. To the extent that this was not the case and that more of the fuel was burnt in the secondary and residual combustion phases then intensity will be over-estimated (Alexander, 1982).

Another possible reason for the general absence of passive crown fire was the lack of ladders of fuel to carry the fire up into the crowns because all compartments (except C63) had been high pruned and past prescribed burning had also removed suspended needles. Billing (1980) reports on a number of instances at the Caroline fire where pruning dramatically reduced fire intensity and prevented crowning.

Even if surface fire intensities had been above the critical level to sustain passive crown fire thinning in most compartments at Myalup had probably reduced the volume of crown material below that needed to sustain an active crown fire.

Spotting

As shown in Table 1 spotting occurred over a distance of up to 2.6 km at the Myalup wildfire to initiate Fire 3. This is much further than that which McArthur reports for two other severe fires in pine

Spotting

As shown in Table 1 spotting occurred over a distance of up to 2.6 km at the Myalup wildfire to initiate Fire 3. This is much further than that which McArthur reports for two other severe fires in pine plantations where spotting distance was 300 - 400 m, however maximum wind speed was less than 30 km/h at these fires (McArthur, 1962). Watson et al. (1983) report spotting distances of up to 1.8 km at the Bright plantation fire where the winds were also averaging 40 km/h and the spots emanated from 51 y/o P. ponderosa and 43 y/o P. radiata.

The model given by Albini (1983) predicts spotting distances of the order of those which occurred at Myalup (> 2.5 km) and the model of McArthur given in equation form by Crane (1982) estimates spotting of up to 2.6 km for the rate of spread of 840 km/h and 20 t/ha of available fuel which occurred in the southern part of Fire 2.

Although spotting is most commonly associated with crowning or torching of individual trees because of the mechanical barrier formed by crowns which can intercept entrained firebrands and interfere with the development of strong updrafts from ground fires (Albini, 1983), ground fires of sufficient intensity may also produce long distance spotting (Rothermel, 1983). The large open area to the south of Forestry Road may have helped to increase the production of a strong updraft and lofting of firebrands from the trees along the road.

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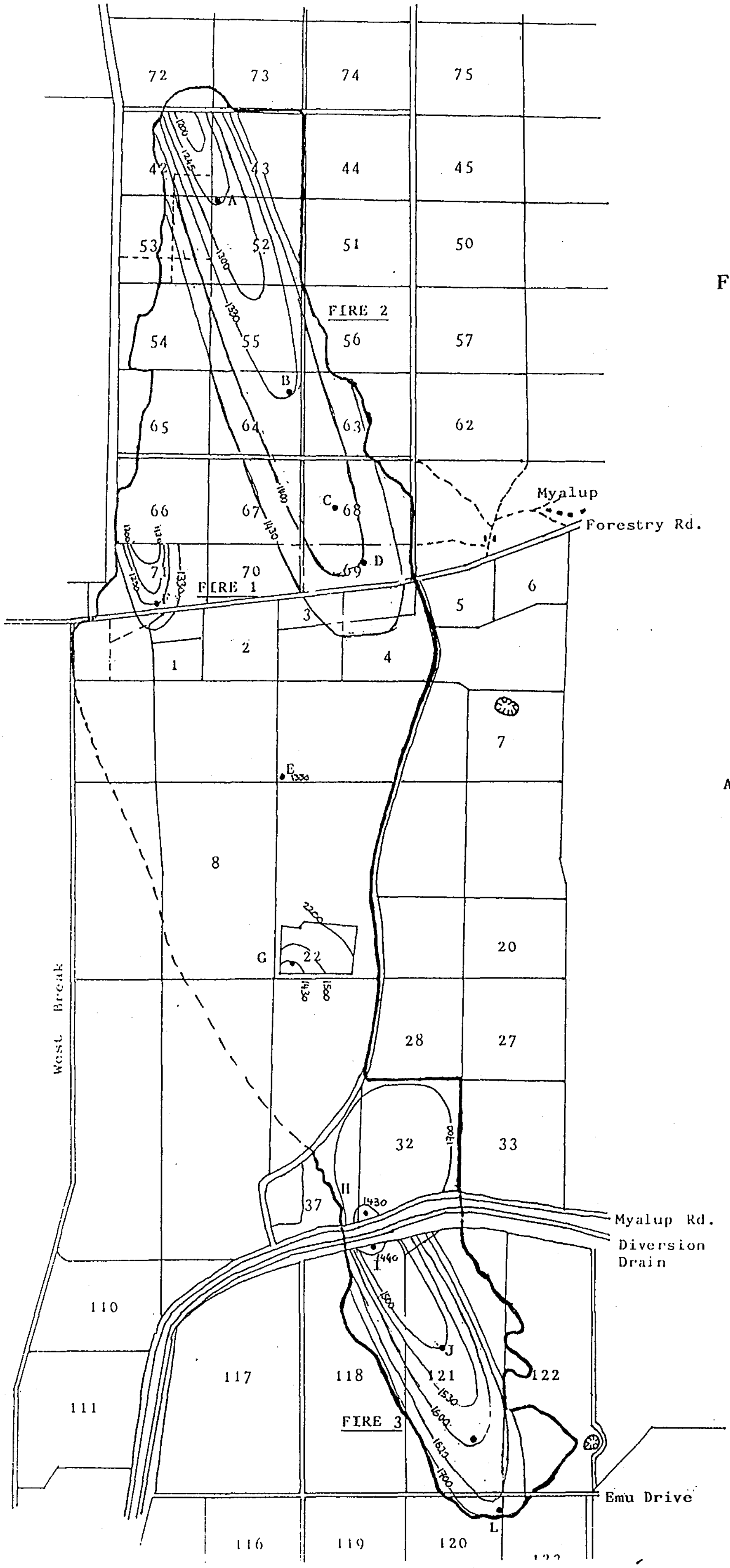


Figure 1

SPREAD OF
MYALUP WILDFIRE
21 April 1991

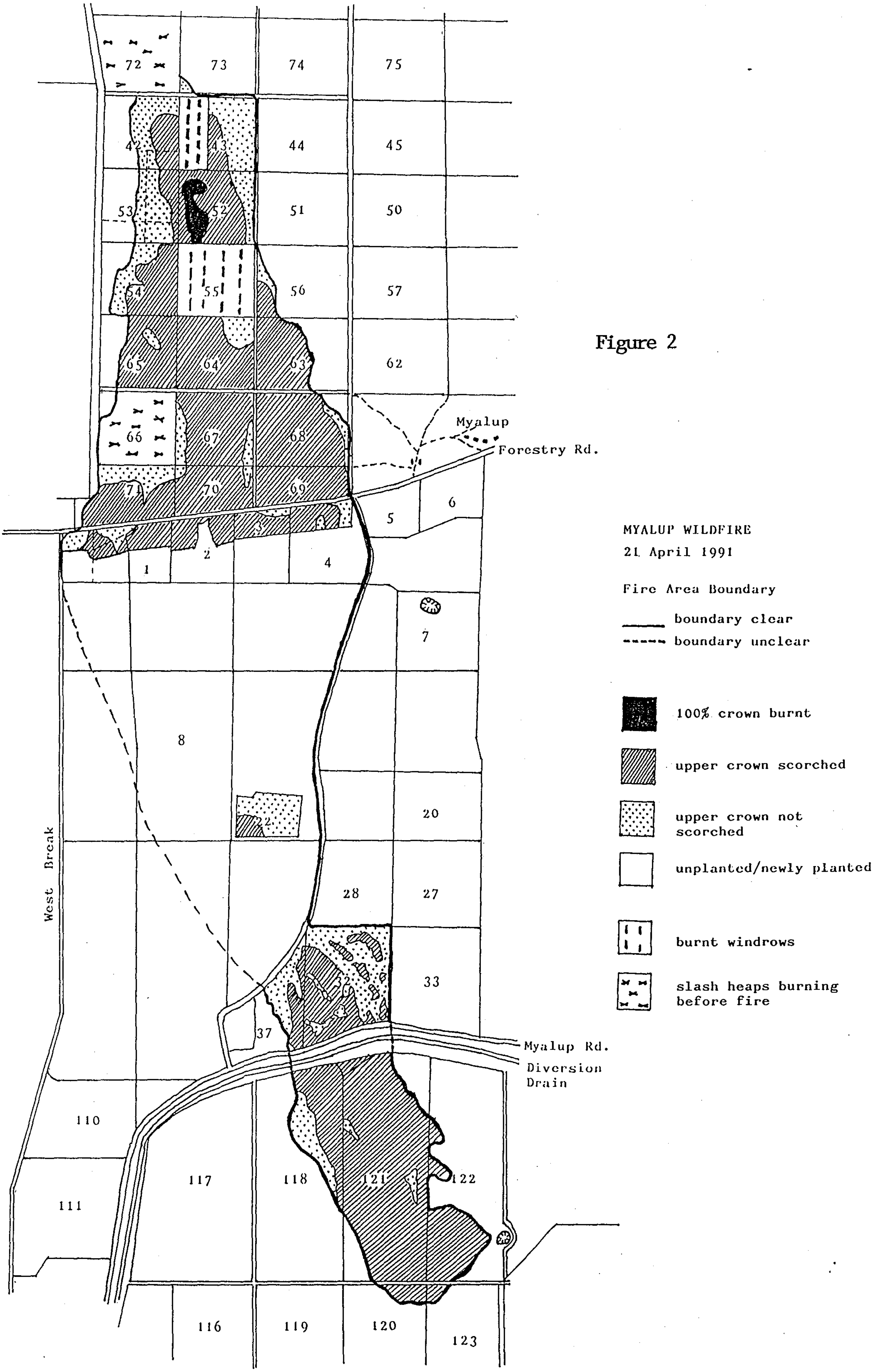
Fire Area Boundary

_____ boundary clear

----- boundary unclear

A - L observed position of fire

Figure 2


MYALUP WILDFIRE
21 April 1991
Fire Area Boundary
boundary clear
boundary unclear
100% crown burnt
upper crown scorched
upper crown not scorched
unplanted/newly planted
burnt windrows
slash heaps burning before fire
Myalup Forestry Rd.
Myalup Rd.
Diversion Drain
West Break
72
73
74
75
42
43
44
45
53
52
51
50
54
55
56
57
65
64
63
62
66
67
68
71
70
69
1
2
3
4
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122
116
119
120
123

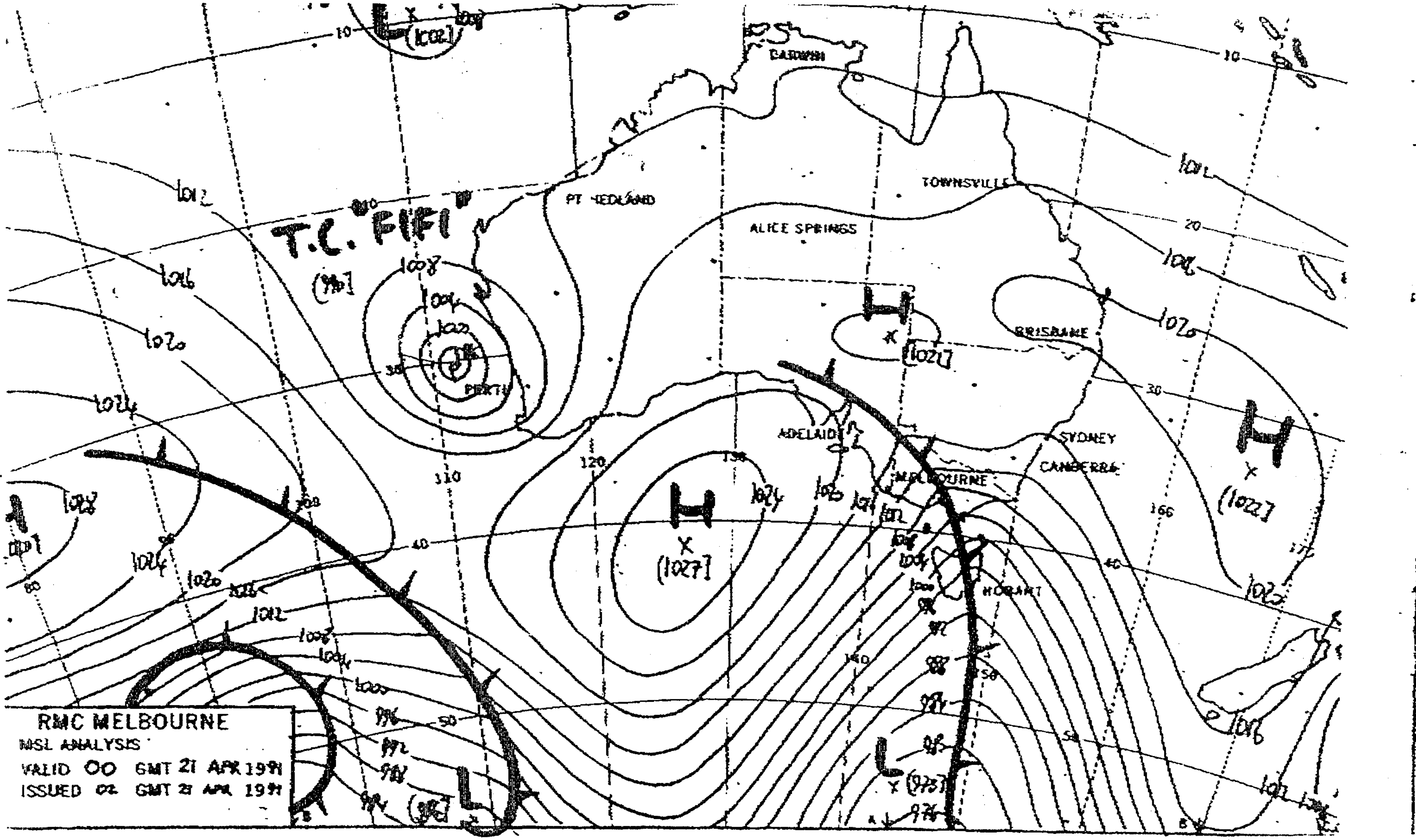

Figure 3. Surface analysis barometric chart for 0800 hrs on April 21 1991.

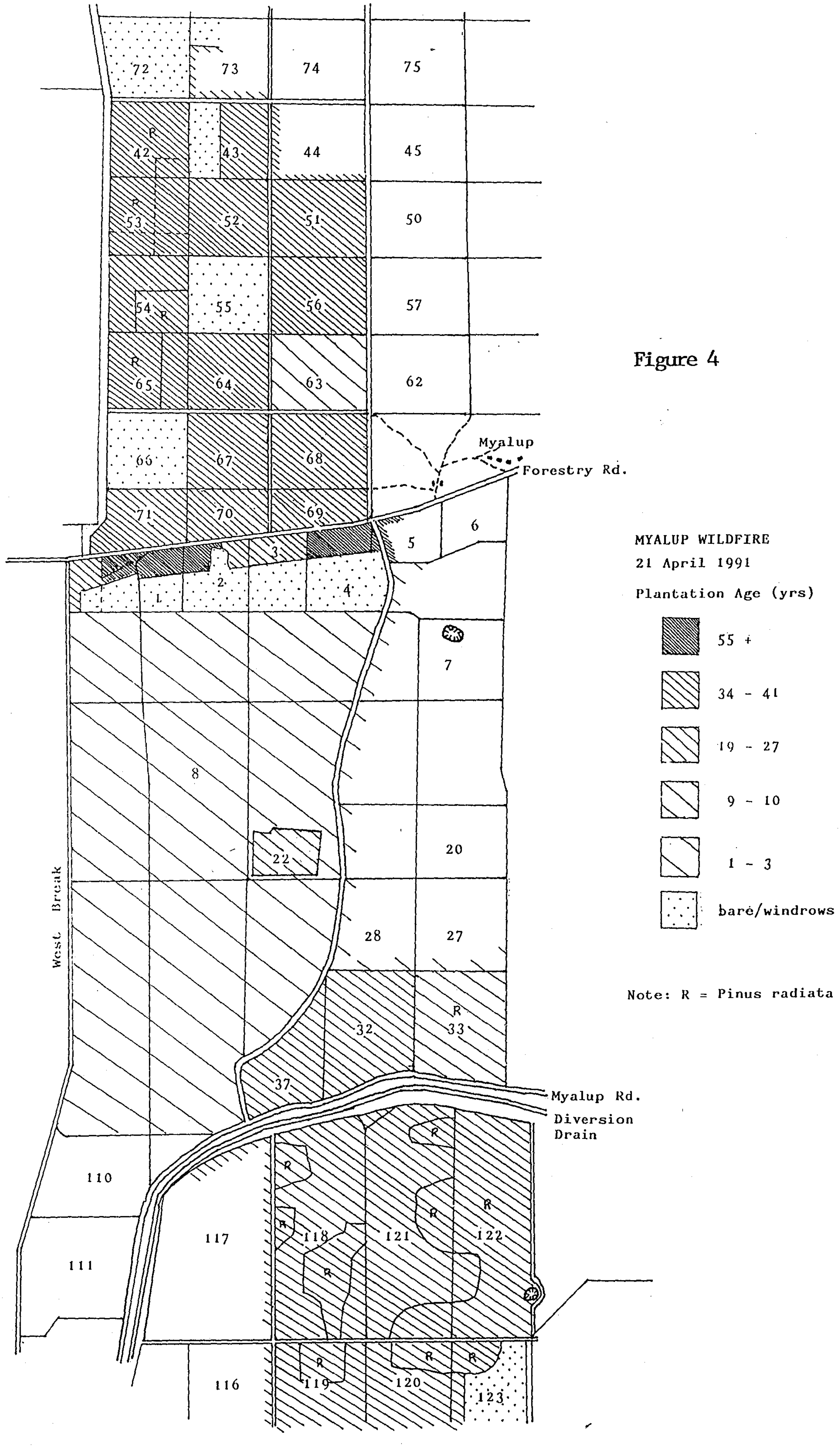
MYALUP WILDFIRE
21 April 1991
Plantation Age (yrs)
55 +
34 - 41
19 - 27
9 - 10
1 - 3
bare/windrows
Note: R = Pinus radiata
Myalup
Forestry Rd.
Myalup Rd.
Diversion
Drain
West Break

Figure 4

TABLE 1

Estimated rates of spread of the Myalup Wildfire

Points*	Distance (m)	Time (mins)	HFROS (m/hr)
Fire 2			
A - B	750	45	940
B - C	500	10	3000
C - D	280	20	840
A - D	1630	75	1300
Fire 3			
I - J	500	60	500
J - K	280	60	280
K - L	420	60	420
I - L	1250	180	417
Spotting			
F - G	1440		
F - I	2625		
Total fire run			
A - L	5350	245	1310

Note: * Points refer to letters on Figure 3 showing observed positions of the headfire during the day.. Only point A was recorded in the headquarters Fire Diary as the fire reached it, and only point L was recorded in the Fire Controller's diary. The other points are based on firefighter's recollections.

TABLE 2

Wind speed and direction recorded at 15 m above the ground in the open at Harvey CALM Office and S.C.M Refinery Weather Station on 21 April 1991.

Harvey Time	Speed km/h	Direction	S.C.M. Refinery Time	Speed km/h	Direction
0700	28	E			
0900	30	NE			
1100	26	Var			
1200	30	N			
1300	40	Var			
			1430	40	N
1500	40	NNW	1500	40/60	N
			1530	13/40	NNW
			1600	35/40	NNW
1700	36	NW			

Note: Myalup Plantation is 12 km west of Harvey near the coast, there are no coastal weather stations in the area but at Cape Naturaliste lighthouse 90 km SW of Myalup wind gusts up to 129 km/h were noted on 21/4/91. Wind speeds from Harvey are 10 minute averages, those from the S.C.M. Refinery are spot values and indicate a range.

TABLE 3

Harvey weather data, minimum surface moisture content (SMC), Fire Danger Index (FDI, *Pinus pinaster*) and Soil Dryness Index (SDI) in the week prior to the Myalup Wildfire.

Date (April)	15	16	17	18	19	20	21
Max. temp (C)	28.0	31.5	31.5	32.0	29.0	24.0	28.0
Min. R.H. (%)	36.0	34.0	34.0	24.0	28.0	59.0	33.0
Min. SMC (%)	6	6	6	6	6	NA	7
FDI	255	352	255	NA	255	NA	968
SDI (dense)	1455	1465	1476	1487	1495	1498	1497
SDI (open)	1400	1419	1430	1439	1448	1445	1438

TABLE 5

Compartment fuel quantity groups at Myalup plantation.

Group	Age (yrs)	Litter (t/ha)	Slash (t/ha)	Total fuel (t/ha)	Slope (deg.)
A 1, 2, 4	55+	25	nil	25	0
B 1, 2, 3, 32, 37 42, 52, 53, 56, 67, 69, 70, 71	34-41	27	nil	27	0
C 43, 64, 68	34-41	23	7	30	0
D 22, 118, 121, 122	19-27	22	10	32	0
E 118, 120, 121	20	12	nil	12	0, 15
F 63	10	3	nil	6	0

Description of Fuel Groups

A. Small areas of mature trees near highway, not low pruned since 1949.
B. Mostly *Pinus pinaster* thinned to 100-250 stems/ha no slash.
C. Mostly *Pinus pinaster* thinned to 250-300 stems/ha partly burned slash.
D. *Pinus pinaster* thinned to 300 stems, unburnt slash.
E. *Pinus radiata* thinned to 250 stems/ha, no slash, lighter needlebed fuels than *P. pinaster*.
F. Young *Pinus pinaster*, discontinuous needlebed, medium dense understorey of native shrubs.

TABLE 6

Recent prescribed fire and silvicultural history of Myalup Plantation compartments affected by the wildfire of April 21 1991.

Compartment	Planted	Thinned	Pruned	Burned
1	1926/28/50		1949 LP	1987/88 N*
2	1926/55		1949/66 LP/69 HP	1987/88 N
3	1955		1964 LP/70 HP	1987/88 N
4	1928		1949 LP	1987/88 N
8	1990			
22	1964	1989 300 stems	1971 LP	1987 N
32	1972		1983 HP	1988/89 N
37	1972		1983 HP	1988/89 N
42	1957	1986 100 stems (pt)	1965 LP/68 HP	
43	1957	1989 300 stems	1966 LP/70 HP	1990 T#
52	1955/57	Unthinned c.590 stems	1966 LP/70 HP	
53	1955/57	1986 100 stems	1964 LP/68 HP	
54	1955	1986 100 stems (R)	1966 LP/70 HP	
55	C/F 1989			
56	1957	1979 300 stems	1965 LP/70 HP	
63	1981	Unthinned c.700 stems		
64	1955	1989 125 stems	1965 LP/70 HP	1990 T
65	1955	1986 100 stems (R)	1966 LP/HP	
66	C/F 1989			
67	1953	1978 250 stems	1964 LP/69 HP	1988 N
68	1954	1989 125 stems	1966 LP/69 HP	1987/88 N/90 T
69	1954	1980/83 250 stems	1966 LP/69 HP	1987/88 N
70	1953	1978/83 250 stems	1964 LP/HP	1987/88 N
71	1953	1986 100 stems (R)	1964 LP/HP	1987/88 N (P)
118	1969	1983 250 stems (R)	1975 LP/78 HP	1988 N/90 T (P)
		1989 300 stems (P)	1976 LP	
120	1970	1983 250 stems (R)	1986 HP	1988 N (P)
	1990	300 stems (P)	1980 HP	1990 T (P)
121	1970	1983 250 stems (R)	1986 HP	1988 T (P)
	1990	300 stems (P)	1980 HP	
123	1970	1983 250 stems (R)	1986 HP	1988 N (P)

*N = needlebed burn #T = logging tops burn (R) = *Pinus radiata* (P) = *Pinus pinaster*. LP = low prune, HP = high prune, stems = number of stems standing per hectare.

TABLE 7

Headfire intensities and flame lengths calculated using Byram's (1959) formula in various compartments at the Myalup wildfire.

Compartment	Fuel group	Intensity ($kW\ m^{-1}$)*	Flame length (m)+
52	B	9340	5.2
64	C	32600	9.2
69	B	8170	4.9
118	D	5760	4.2
121	D	3290	3.2
121	E	1795	2.4

* Intensities were derived from the estimated actual headfire rate of spread within each compartment (see Fig.1, Table 1) assuming 70 % fuel combustion in the flaming zone, and a net low heat of combustion of 18700 $kJ\ kg^{-1}$ (Alexander, 1982). + As predicted by the equation in Alexander (1982).