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NO. 28 TECHNICAL PAPER 1982

DEPARTMENT OF FORESTRY
QUEENSLAND

EXOTIC PINE PLANTATION PRESCRIBED BURNING USING A HELICOPTER

BY

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15920—S. R. Hampson, Govt. Printer, Qld.

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ISSN 0155 - 9664

FIRE BEHAVIOUR TABLES

(These figures refer to fires lit at a single point and allowed to spread.
Fires lit on a face or in strips will be approx. 1.5 times as hot.
R = forward rate of spread in metres/h H = flame height in metres.
Figures in brackets apply to exposed areas.)

(1) First Suitable Burning Day After Rain.

(Available Fuel = 8 t/ha, Fuel Moisture Content 30–35%)

Relative Humidity	Wind Strength			
	Force 1 1 – 5 km/h	Force 2 6 – 11 km/h	Force 3 12 – 18 km/h	Force 4 19 – 29 km/h
15%	R = 32 (41) H = 0.8 (0.9)	R = 36 (46) H = 0.9 (1.0)	R = 43 (59) H = 1.0 (1.2)	R = 63 (92) H = 1.3 (1.7)
25%	R = 27 (34) H = 0.7 (0.8)	R = 31 (41) H = 0.8 (0.9)	R = 38 (52) H = 0.9 (1.1)	R = 54 (83) H = 1.1 (1.6)
35%	R = 22 (29) H = 0.7 (0.7)	R = 27 (36) H = 0.7 (0.9)	R = 34 (45) H = 0.8 (1.0)	R = 45 (74) H = 1.0 (1.4)
45%	R = 18 (23) H = 0.6 (0.6)	R = 23 (31) H = 0.6 (0.8)	R = 31 (40) H = 0.8 (0.9)	R = 40 (65) H = 0.9 (1.3)
55%	R = 14 (18) H = 0.5 (0.6)	R = 18 (25) H = 0.6 (0.7)	R = 25 (34) H = 0.7 (0.8)	R = 32 (56) H = 0.8 (1.2)
65%	R = 11 (14) H = 0.5 (0.5)	R = 14 (20) H = 0.5 (0.6)	R = 18 (29) H = 0.6 (0.7)	R = 25 (49) H = 0.7 (1.1)
75%	R = 7 (11) H = 0.4 (0.5)	R = 11 (14) H = 0.5 (0.5)	R = 14 (23) H = 0.5 (0.6)	R = 16 (41) H = 0.5 (0.9)
85%	R = 5 (7) H = 0.4 (0.4)	R = 7 (11) H = 0.4 (0.5)	R = 11 (18) H = 0.5 (0.6)	R = 11 (34) H = 0.5 (0.8)

(2) Second Suitable Burning Day After Rain

(Available Fuel = 12 t/ha, Fuel Moisture Content 25 – 30%)

Relative Humidity	Wind Strength			
	Force 1 1 – 5 km/h	Force 2 6 – 11 km/h	Force 3 12 – 18 km/h	Force 4 19 – 29 km/h
15%	R = 38 (49) H = 0.9 (1.1)	R = 43 (54) H = 1.0 (1.1)	R = 52 (70) H = 1.1 (1.4)	R = 76 (112) H = 1.5 (2.0)
25%	R = 32 (41) H = 0.8 (0.9)	R = 36 (47) H = 0.9 (1.0)	R = 45 (61) H = 1.0 (1.3)	R = 63 (101) H = 1.3 (1.9)
35%	R = 27 (34) H = 0.7 (0.8)	R = 32 (41) H = 0.8 (0.9)	R = 40 (54) H = 0.9 (1.1)	R = 54 (90) H = 1.1 (1.7)
45%	R = 23 (29) H = 0.6 (0.7)	R = 29 (36) H = 0.7 (0.9)	R = 36 (47) H = 0.9 (1.0)	R = 47 (81) H = 1.0 (1.6)
55%	R = 18 (23) H = 0.6 (0.6)	R = 22 (31) H = 0.6 (0.8)	R = 31 (41) H = 0.8 (0.9)	R = 40 (72) H = 0.9 (1.4)
65%	R = 14 (18) H = 0.5 (0.6)	R = 18 (25) H = 0.6 (0.7)	R = 25 (36) H = 0.7 (0.9)	R = 32 (65) H = 0.9 (1.3)
75%	R = 11 (14) H = 0.4 (0.5)	R = 14 (20) H = 0.5 (0.6)	R = 18 (31) H = 0.6 (0.8)	R = 25 (58) H = 0.7 (1.2)
85%	R = 7 (11) H = 0.4 (0.4)	R = 11 (14) H = 0.4 (0.5)	R = 14 (25) H = 0.5 (0.7)	R = 18 (50) H = 0.6 (1.1)

(3) Third Suitable Burning Day After Rain

(Available Fuel = 16 t/ha, Fuel Moisture Content 20-25%)

Relative Humidity	Wind Strength			
	Force 1 1 – 5 km/h	Force 2 6 – 11 km/h	Force 3 12 – 18 km/h	Force 4 19 – 29 km/h
15%	R = 43 (54) H = 1.0 (1.1)	R = 50 (74) H = 1.1 (1.5)	R = 68 (85) H = 1.4 (1.6)	R = 91 (135) H = 1.7 (2.4)
25%	R = 40 (51) H = 0.9 (1.1)	R = 46 (66) H = 1.0 (1.3)	R = 63 (78) H = 1.2 (1.5)	R = 80 (129) H = 1.5 (2.2)
35%	R = 34 (44) H = 0.8 (0.9)	R = 40 (54) H = 0.9 (1.1)	R = 52 (65) H = 1.1 (1.3)	R = 65 (112) H = 1.3 (2.0)
45%	R = 27 (34) H = 0.7 (0.8)	R = 34 (45) H = 0.8 (1.0)	R = 45 (58) H = 1.0 (1.2)	R = 58 (101) H = 1.2 (1.9)
55%	R = 23 (29) H = 0.6 (0.7)	R = 29 (40) H = 0.7 (0.9)	R = 38 (50) H = 0.9 (1.1)	R = 50 (90) H = 1.1 (1.7)
65%	R = 18 (23) H = 0.6 (0.6)	R = 22 (34) H = 0.6 (0.8)	R = 31 (43) H = 0.8 (1.0)	R = 43 (81) H = 1.0 (1.6)
75%	R = 14 (18) H = 0.5 (0.6)	R = 18 (29) H = 0.6 (0.7)	R = 25 (38) H = 0.7 (0.9)	R = 36 (72) H = 0.9 (1.4)
85%	R = 11 (14) H = 0.4 (0.5)	R = 14 (23) H = 0.5 (0.6)	R = 18 (32) H = 0.6 (0.8)	R = 29 (65) H = 0.7 (1.3)

(4) Fourth Suitable Burning Day After Rain

(Available Fuel = 18 t/ha, Fuel Moisture Content 15–20%)

Relative Humidity	Wind Strength			
	Force 1 1 – 5 km/h	Force 2 6 – 11 km/h	Force 3 12 – 18 km/h	Force 4 19 – 29 km/h
15%	R = 50 (61) H = 1.1 (1.2)	R = 59 (83) H = 1.2 (1.6)	R = 76 (99) H = 1.4 (1.8)	R = 99 (153) H = 1.8 (2.6)
25%	R = 43 (54) H = 0.9 (1.0)	R = 52 (72) H = 1.0 (1.2)	R = 67 (85) H = 1.2 (1.4)	R = 85 (137) H = 1.4 (2.2)
35%	R = 38 (47) H = 0.8 (0.9)	R = 47 (61) H = 0.9 (1.1)	R = 59 (74) H = 1.1 (1.3)	R = 74 (124) H = 1.3 (2.0)
45%	R = 32 (40) H = 0.8 (0.9)	R = 41 (52) H = 0.9 (1.1)	R = 52 (65) H = 1.1 (1.3)	R = 67 (110) H = 1.3 (2.0)
55%	R = 27 (32) H = 0.7 (0.8)	R = 36 (45) H = 0.8 (1.0)	R = 45 (58) H = 1.0 (1.2)	R = 59 (99) H = 1.2 (1.8)
65%	R = 22 (27) H = 0.6 (0.7)	R = 31 (36) H = 0.8 (0.8)	R = 38 (50) H = 0.9 (1.1)	R = 52 (88) H = 1.1 (1.7)
75%	R = 16 (22) H = 0.5 (0.6)	R = 25 (31) H = 0.7 (0.8)	R = 32 (43) H = 0.8 (1.0)	R = 45 (79) H = 1.0 (1.5)
85%	R = 13 (16) H = 0.5 (0.5)	R = 22 (25) H = 0.6 (0.6)	R = 25 (38) H = 0.7 (0.9)	R = 38 (72) H = 0.9 (1.4)

APPENDIX 2.

Prescribed Burning Guide for Slash Pine Plantations

F.D.O.490B

PRESCRIBED BURNING GUIDE

(Slash Pine Plantation) (Mk. III)

FUEL TYPES

The fire behaviour tables used in this guide apply to Slash Pine plantation fuels which have not been burnt previously, and which may exceed 18 tonnes per hectare in weight.

- Fuel Type 1. Fuel Suspension on < 50% of area.
- Fuel Type 2. Fuel Suspension on 50-80% of area.
- Fuel Type 3. Fuel Suspension on < 80% of area. Fuel is suspended in dense understorey of Xanthorrhoea, Bracken.
- Fuel Type 4. Dense understorey of Blady Grass.
- Fuel Type 5. Ladder fuels. Fuel is suspended in dense understorey of tea-tree etc.

Fuel types should be mapped on the above basis prior to the development of the burn prescription.

The Fire Behaviour Tables refer to an average fuel condition. Fires in Type 1 will be milder than indicated in the tables; Fires in types 3, 4 & 5 will be hotter.

DRYING TABLES

Select an appropriate drying table on page 2 on the basis of average maximum temperature of the drying period. Actual temperature should be used for unseasonal conditions, otherwise the mean monthly temperature indicated at the foot of page 2 may be adopted.

WARNING: ***Burning must not be attempted unless a minimum of 7 mm of rain has been registered on the burn area.***

BURN PRESCRIPTION

Any burn prescription must be based on the following maximum recommended flame heights.

LIGHTING TECHNIQUES

(1) **Strip Backfire.** Light on a face or at 20-30 metre intervals along the downwind edge of the block. This is the safest method of burning heavy fuels (types 3, 4) or in poor site index or young stands, or in very exposed sections of a block. Spread rate will be about half, and flame height two-thirds of that indicated in the tables. Use this technique where headfires may be too active, particularly when wind is Force 3-4.

(2) **Strip Headfire.** Light on a face or at 20-30 metre intervals along the windward edge of the block. Use this method when wind speed is low and fuel moisture content too high for backfires to spread, such as burning plantation edges following rain.

(3) **Grid Ignition.** Calculate a grid spacing from the predicted Rate of Spread such that the individual fires will link up in about 2 hours. Spots must never be lit to within one grid spacing of the edge of the edge of the plantation on the downwind side, or half a grid spacing on the windward side.

Grid spacing may be varied to suit changing fuel type or weather conditions. Most areas will be grid lit after burning exposed sections by strip head or back fires.

DRYING TABLES

(Figures indicate weight of fuel (tonnes per ha) available for burning).

Where the effect of one rain period is superimposed on that of another, all rain registered should be taken into account.

30°C

No. Days Since Rain	Rainfall (mm) 2.5	7.5	12.5	25	40
1	18	12		TOO	WET
2		18	12	12	
3			18	18	12
4	TOO	DRY			18
5					

28°C

No. Days Since Rain	Rainfall (mm) 2.5	7.5	12.5	25	40
1	18	12		TOO	WET
2		18	12		
3			18	12	12
4	TOO	DRY		18	16
5					18

26°C

No. Days Since Rain	Rainfall (mm) 2.5	7.5	12.5	25	40
1	12			TOO	WET
2	18	12	12		
3		18	16	12	8
4			18	16	12
5	TOO	DRY		18	16
6					18
7					

24°C

No. Days Since Rain	Rainfall (mm) 2.5	7.5	12.5	25	40
1	12				
2	16	12		TOO	WET
3	18	16	12		
4		18	16	12	8
5			18	16	12
6	TOO	DRY		18	16
7					18

22°C

No. Days Since Rain	Rainfall (mm) 2.5	7.5	12.5	25	40
1	8				
2	12	8			
3	16	12	8		
4	18	16	12	8	
5		18	16	12	8
6			18	16	12
7				18	16
8					18
9	-				
10					

20°C

No. Days Since Rain	Rainfall (mm) 2.5	7.5	12.5	25	40
1					
2	8				
3	12	8			
4	16	12	8		
5	18	16	12	8	
6		18	14	12	8
7			16	14	12
8			18	16	14
9				18	16
10					18

5 tonnes per ha = 1 cm of dry surface needles
10 tonnes per ha = 2 cm of dry surface needles
15 tonnes per ha = 3 cm of dry surface needles
20 tonnes per ha = 4 cm of dry surface needles

MEAN DAILY MAXIMUM TEMPERATURE

Locality	March	April	May	June	July	August
South Queensland	28	26	23	21	20	22
Central Queensland	30	28	25	23	23	24
North Queensland	30	29	27	26	25	26

EXPOSED AREAS

Moisture conditions suitable for effective burning of exposed edges will occur one to two days earlier than indicated in the above drying tables.

ABSTRACT

Three trials were conducted in 1978 and 1980 to test the cost effectiveness of aerial ignition from helicopters for prescribed burning of slash and Caribbean pine plantations.

A system using a Bell 206 Jet Ranger helicopter and an incendiary priming device has been developed which allows large areas of plantation to be burnt on suitable burning days at a cost equivalent to manual ignition. Areas to be burnt need to be large (greater than 300 ha); be carrying similar fuel types with similar burning histories; be roughly rectangular in shape with boundaries which are distinct from the air; and be within a reasonable distance from a base where a suitable helicopter is available for hire.

INTRODUCTION

Prescribed burning of exotic pine plantations on Queensland coastal lowlands became routine practice in 1975 (Byrne 1980). The area burnt in any year has varied considerably mainly due to the variation in seasonal rainfall and the limited capacity of the workforce to ignite areas on suitable burning days. For example, 2360 ha of plantation were burnt in 1977, a particularly dry year, while 5970 ha of plantation were burnt in 1978, a good burning year in most areas.

Dry years are also the most fire dangerous, and it is desirable that a greater area, rather than less, be burnt in these years to give adequate protection. Some improvement in technique is therefore necessary to allow burning of greater areas when suitable burning days occur.

Plantation prescribed burning clashes with other high priority operations such as planting, and large numbers of workers are not readily available for burning operations. Aerial ignition has been used successfully for a number of years in conducting broadscale burning of native eucalypt forest, and it was logical that ignition of plantations from a helicopter should be trialled.

LOCATION AND METHODS

Equipment

The initial trial was carried out at Toolara State Forest in July 1978 using a Bell 47 Alpine helicopter. Cylindrical plastic vials containing 2.5 g of potassium permanganate were manually injected with 1 ml of ethylene glycol. The 25 seconds reaction period allowed sufficient time to throw the injected vial from the helicopter and for the vial to reach the ground before ignition. This system was developed by Packham and Peet (1967) for automatic injection by a machine in fixed-wing aircraft.

This system did not give a sufficiently accurate ignition pattern and was replaced for the second series of trials at Toolara and Byfield State Forests in May 1980. A Bell Jet Ranger 206 helicopter was fitted with an incendiary priming machine replacing the manual injection method. This machine injects spherical capsules of potassium permanganate with ethylene glycol at speeds which can be regulated precisely from one capsule per second to one per three seconds. Safety features include an extinguishing and flushing system which will prevent ignition in the chamber in the event of a machine malfunction, plus a separate carbon dioxide fire extinguisher. The Bell Jet Ranger 206 is very suitable for this work, with ample power and manoeuvrability under full load. The aircraft operated at about 50 to 100 metres above the tree canopy and at speeds of 50 to 60 knots on all three trials.

Radio equipment has been developed to allow contact between the navigator and machine operator and the navigator and ground crew.

Description of Areas

Fuel types are described using the system detailed in Appendix 1.

The July 1978 trial at Toolara State Forest was carried out in slash pine (*Pinus elliottii* Engelm var. *elliottii*) plantation aged between 22 and 25 years. Fuels were predominantly type 3 containing grass tree (*Xanthorrhoea* sp), a typical fuel type in slash pine plantations in Queensland.[1] Smaller areas of type 3 fuel contained blady grass, bracken fern, and various grass species. Type 1 and type 5 fuels occurred in small sections with type 4 fuels on some exposed edges. The total area was 145 ha, which had been burnt[2] three years previously. The design of the block is shown in Figure 1.

The May 1980 trial at Toolara State Forest was carried out in slash pine plantation ranging in age from 12 to 28 years. Fuel types were again predominantly type 3 with smaller sections of type 2 and type 1 with some type 4 occurring on exposed edges. The total area burnt was 601 ha. The bulk of the area had been burnt three years previously, but small sections received their first burn in the trial. The design of the block is shown in Figure 2.

The May 1980 trial at Byfield State Forest was carried out in 660 ha of Caribbean pine (*P. caribaea* Mor.) plantation and 490 ha of native forest surrounded by plantation. Fuel types were again predominantly type 3, the suspension being caused by grass tree and various species of grass. Type 1 and 2 fuels occurred in smaller sections with type 5 fuels associated with lantana (*Lantana camara* L.) in gullies. All areas had been burnt previously. The design of the trial area is shown in Figure 3.

Weather Conditions

Antecedent weather and fuel moisture conditions for the three trials are shown in Table 1.

Table 1. Antecedent weather and fuel moisture conditions for three helicopter ignition trials

	Toolara 13.7.78	Toolara 19.5.80	Byfield 16.5.80
Antecedent rainfall (mm)	57.2	186.1 †	29.0
Drying period (days)	4	8	11
Mean daily maximum temperature during drying period (° C)	20	26	24
Fine fuel moisture content (per cent of oven dry weight) ‡			
Tops	37	24	25
Profile	54	N.R. §	N.R.

† A series of light to moderate showers over six days with little or no drying period between showers

‡ Means of ten recordings. Tops: top 1 cm of litter layer. Profile: full litter layer.

§ Not recorded

[1] *Fuel types as described in Appendix 1*

[2] *'Burnt' in this paper means 'prescribed burnt' and not burnt by wildfire*

APPENDIX 1

Description of fuel types in Queensland exotic pine plantations

- Fuel type 1. Fuel suspension caused by understorey species occurs on less than 50 per cent of the area. Fire behaviour is very uniform. The upper parts of the litter layer tend to dry out quickly but the lower parts are partly insulated from drying by the compacted litter. It is possible to obtain a 100 per cent burn coverage of these fuels while removing only 20 to 30 per cent of the fuel quantity. Fuel weights are often greater than 10 tonnes per hectare. This fuel type often becomes invaded with passion vine (*Passiflora* sp.), couch grass (*Cynodon dactylon* (L) Pers.), and rain forest elements such as *Smilax* sp. and *Austromyrtus* sp. These species tend to delay drying even further and form a green blanket over the fuel, resulting in unburnt patches after the burn.

- Fuel type 2. Fuel suspension caused by understorey species on 50 to 80 per cent of the area. Suspension depth is in the range 15 to 45 cm. Fuel weights range from 10 to 20 tonnes per hectare, the lower values being associated with kangaroo grass (*Themeda australis* (R. Br.) Stapf.) and the higher values with grass tree (*Xanthorrhoea* sp.). Drying of the fuel is reasonably rapid especially when the understorey species causing suspension are grasses occurring on exposed ridge sites. The fire behaviour of the fuel type is fairly uniform, some flaring occurring in the suspended fuels.

- Fuel type 3. Fuel suspension caused by understorey species occurring on greater than 80 per cent of the area. Suspension can be caused by grass tree, sedges and grasses. Fuel depths average about 45 cm with some fuels reaching 100 cm in depth. Drying rates are variable. Fuels with sedges as the suspending agency dry rapidly because of the free movement of air through the fuel layer. Dense grass tree fuels tend to dry more slowly. Problems are experienced in burning these types due to the variable drying rates, flaring, especially in the sedge sub-types, and the fact that the sedge sub-types are usually associated with low lying areas of low site index. Wind influences fire behaviour markedly in these types. Fuel quantity is variable but is usually greater than in other fuel types. Fuel consumption is generally high when the fuels are dry enough to burn because a large proportion of the fuel is suspended.

- Fuel type 4. Dense understorey of blady grass (*Imperata cylindrica* (L) Beauv. var. *major* (Nees) C.E. Hubbard.) and/or bracken fern (*Pteridium esculentum* (Foist. f.) Cockayne) occurs on 80 per cent or more of the area. This type occurs on plantation edges, in failed areas or in areas of low site index where light conditions are favourable for the development of the above species. The fuel dries rapidly and is prone to flaring particularly on edges exposed to prevailing winds. Fire behaviour in this type can be intense when associated fuel types 1 and 2 will barely burn.

- Fuel type 5. This type can best be described as a type 3 fuel with an intermediate stratum one to five metres tall, causing some of the suspension. Pine needles suspended in this intermediate stratum form 'ladder fuels'. Many species cush as *Baeckea* sp., *Leptospermum* sp., *Casuarina* sp., *Lepidosperma* sp., cause the suspension. Ground fuel quantities are low because of the large amount of fuel suspended.

  Heavy shading causes the ground fuels to be very slow to dry. Usually these types occur in small areas associated with fuel types 1, 2 and sometimes 3. The type 5 fuels generally remain unburnt. Intense lighting will usually result in partial burning of ground fuels. Flaring regularly occurs in the 'ladder fuels', sometimes causing scorch.

- Timing and execution of helicopter ignition should be on the same basis as for manual ignition. Areas to be burnt for the second and subsequent times should be lit when fine fuel moisture content is between 20 and 25 per cent of oven dry weight (third suitable burning day after rain, as determined from the plantation prescribed burning guide). Areas to be burnt for the first time should be done on the first suitable burning day after rain.

- Ignition pattern can be controlled by regulation of capsule ejection rate and ground speed of the helicopter.

- Flight plan should be drawn on a map (1:10 000 scale) and the operation should be planned on the basis of lighting exposed edges first and then flying the long axis of the block progressively into the wind.

- Helicopter should be flown 50 to 100 metres above tree canopy at a speed of 50 to 60 knots. Turning should be done outside the block so the helicopter can be aligned on the flight line before capsule dropping recommences.

ACKNOWLEDGEMENT

This work forms part of the Queensland Department of Forestry's fire research programme. Assistance from various officers of the Department of Forestry involved in the trials is gratefully acknowledged.

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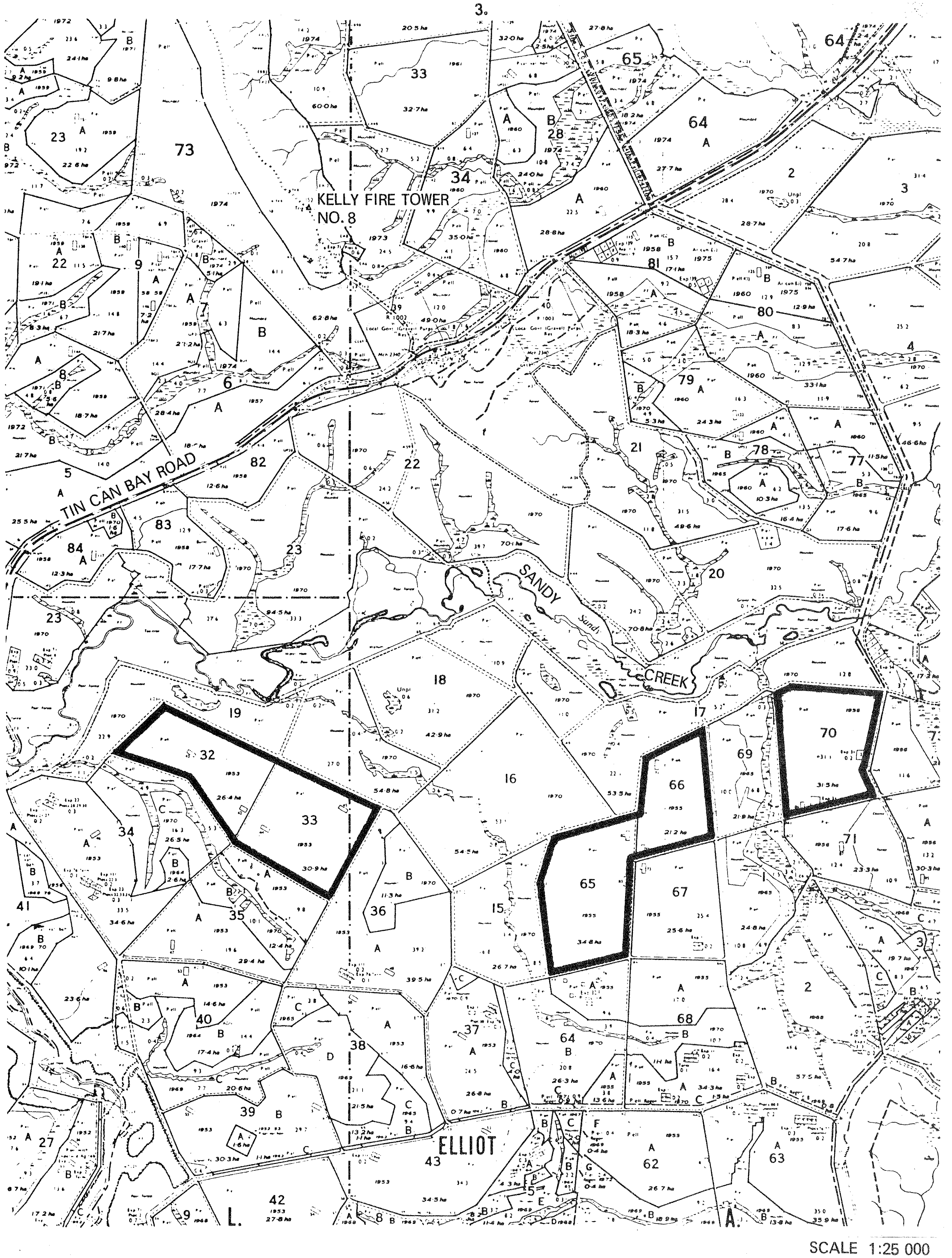

Figure 1. Design of the 1978 trial at Toolara

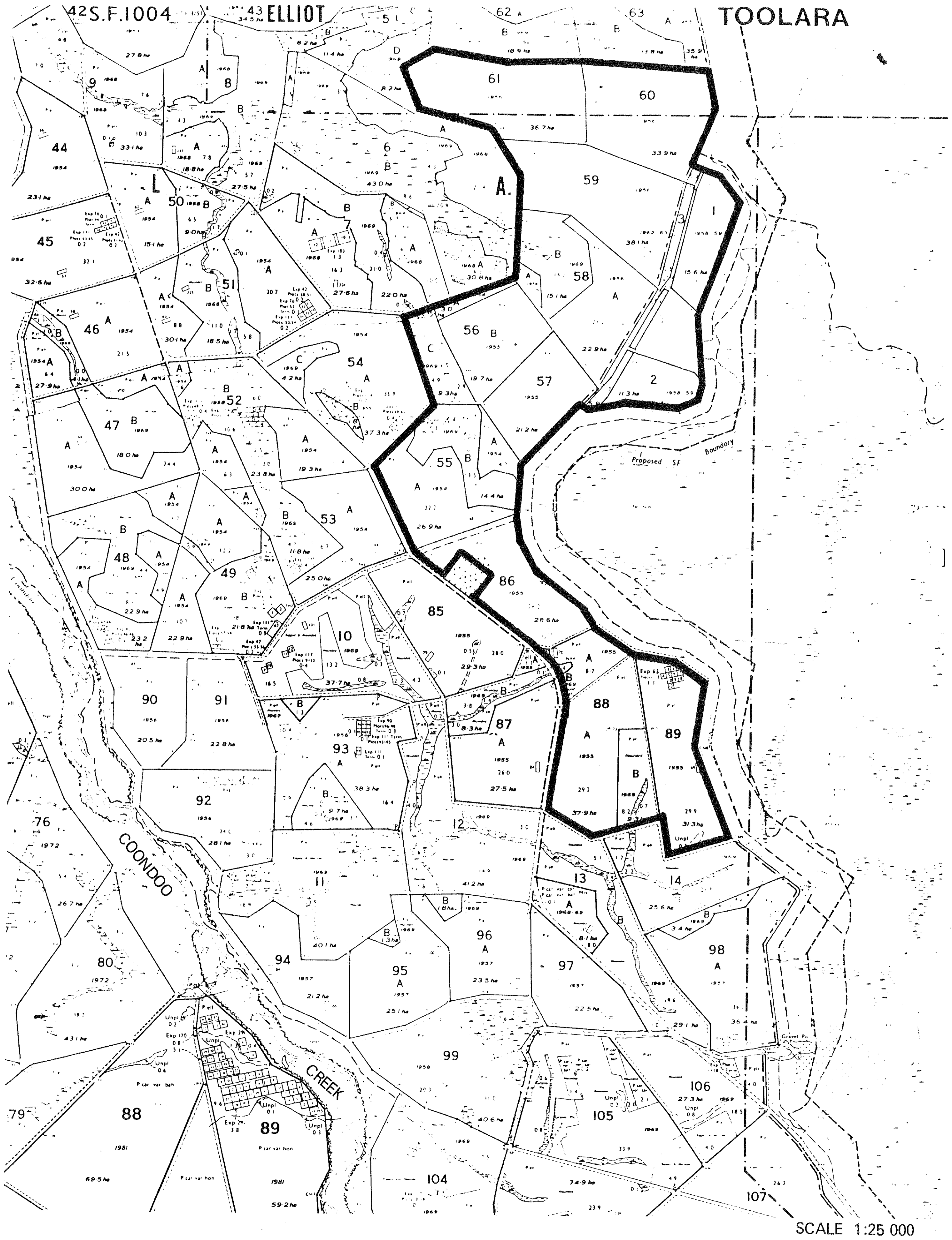

Figure 2. Design of the 1980 trial at Toolara

Table 3. Comparison of costs (1980 $/ha) between helicopter ignition trials and manual ignition, excluding salary costs

	Toolara 1978	Toolara 1980	Byfield 1980
Manual ignition †			
Preparation ‡	1.20	2.00	0.75
Burning	0.95	0.80	0.72
TOTAL	2.15	2.80	1.47
Helicopter ignition			
Preparation §	1.20	0.60	0.75
Helicopter hire ¶	1.30	2.86	1.32
Wages for burning	0.18	0.10	0.62
Capsule Cost	0.30	0.10	0.10
TOTAL	2.98	3.66	2.29 ††

† Combined wages, materials and plant hire costs

‡ Costs of all roads and track maintenance done in preparation for burning

§ Wages and plant hire for preparation

¶ 1978 helicopter hire was $110/hr; 1980 cost - $330/hr

†† Byfield helicopter ignition costs based on 660 ha plantation and 490 ha native forest burnt

CONCLUSIONS

Helicopter ignition can be used as a means of burning large areas of plantation on suitable burning days. The need to do this is well established.

Ignition from a helicopter is successful provided that the following guidelines are met:

- A helicopter of a type similar to the Bell Jet Ranger 206 is available at short notice within a reasonable ferrying distance from the burn site.
- Compartments to be burnt can be grouped into long rectangular blocks inside regular boundaries which are distinct from the air. Minimum size for blocks should be about 300 ha. The larger the block, the lower will be the unit cost of helicopter hire. About 600 ha is considered to be a suitable upper limit of block size.
- Areas to be burnt for at least the second time are preferred. Most first burn areas should be burnt using manual ignition even if these areas occur within the boundaries of the proposed helicopter ignition area. Some difficult fuel types may need manual ignition for second and even subsequent burns. First burn areas may be burnt using a helicopter when a series of compartments carrying similar fuel types are grouped together.
- Large unplantable swamps within burning blocks should be burnt before helicopter ignition of surrounding plantation.
- Areas to be left unburnt (experiments, fire susceptible underplantings, seed production areas) can be treated by manual ignition of the surrounding plantation or by extinguishing ignition points during the progress of the actual helicopter operation.

Although no detailed mapping of ignition points was carried out during the 1980 trials it can be assumed that more regular drop intervals are obtained with the priming machine. Different pilots were employed in each of the 1980 trials. Their impression was that flying along lines at equidistant intervals can be achieved with reasonable accuracy, particularly if boundaries are regular and flight lines can be set on a certain compass direction. Preplanned flight lines drawn on a map are a good guide to pilots.

The size of areas to be burnt is critical to the economics and ease of execution of the operation. The 1978 trial included a single compartment of 21.2 ha. The time taken in turning the helicopter was excessive compared to time spent productively in lighting. The ejection of a small number of capsules per run was difficult and the risk of dropping of capsules outside the burn area was increased. Obviously, burn areas need to be considerably larger than 20 ha for efficient operation. Block size also affects the costs of ground patrol as similar patrols are needed regardless of block size.

Irregular shape of blocks became a problem in the 1980 Byfield trial. A creek was used as one boundary and some compartments within the burn block were to be excluded from burning. Regular boundaries with blocks roughly rectangular in shape are necessary for ease of aerial ignition. Boundaries not easily distinguishable from the air were also a problem in both of the 1980 trials. Such problems can be minimised by lighting leeward edges, preferably from the helicopter, before the main burning commences. Boundaries to be used as the ends of light lines can be lit similarly. A flying height of 50 to 100 m above the canopy was adequate for navigational purposes at speeds of 50 to 60 knots. An experiment area of 2.5 ha which was to be excluded from the Toolara burn was isolated by a hand-chipped fireline, and men were stationed within the area during the fire to locate and extinguish any capsules as they ignited. This was successful and could be extended to much larger areas in future operations.

In the 1980 Toolara trial the included young areas, which had been manually burnt, presented no problems during the helicopter ignition. These areas were included in the flight paths and capsules were dropped into some parts of them with no harmful results.

Comparison of Costs

Table 3 gives a comparison of costs between the three helicopter ignition trials and manual ignition at the two centres in the years specified. Variation in costs for manual ignition and helicopter ignition is evident, however a constant difference, approximately $0.80/ha, between the costs for the two methods exists at both centres.

Some reasons for the cost differences are apparent:

- Preparation costs for manual ignition at Toolara are high because long distances of track are established and maintained between plantations to be burnt and adjacent swampy areas or areas of young plantation. This problem is not as extensive at Byfield.
- Little preparation was necessary for the 1980 helicopter trials at Toolara.
- Hire rate on the helicopter used in 1978 was $110/hr. Hire rate was $330/hr in 1980 for the bigger helicopter.
- The high cost of helicopter hire in the 1980 Toolara trial includes costs for an earlier unsuccessful burning attempt. A more realistic cost for the successful burning would be $2.10/ha.
- Byfield costs are based on 1150 ha flown (660 ha plantation and 490 ha native forest). Native forest does not require as many ignition points per unit area.

From the costs presented, it can be expected that a helicopter ignition system will cost about $3.00/ha flown, including preparation costs but excluding any salary costs for the air crew. Manual ignition may continue to be slightly cheaper, by about $0.80/ha, depending on the amount of track and establishment maintenance required.

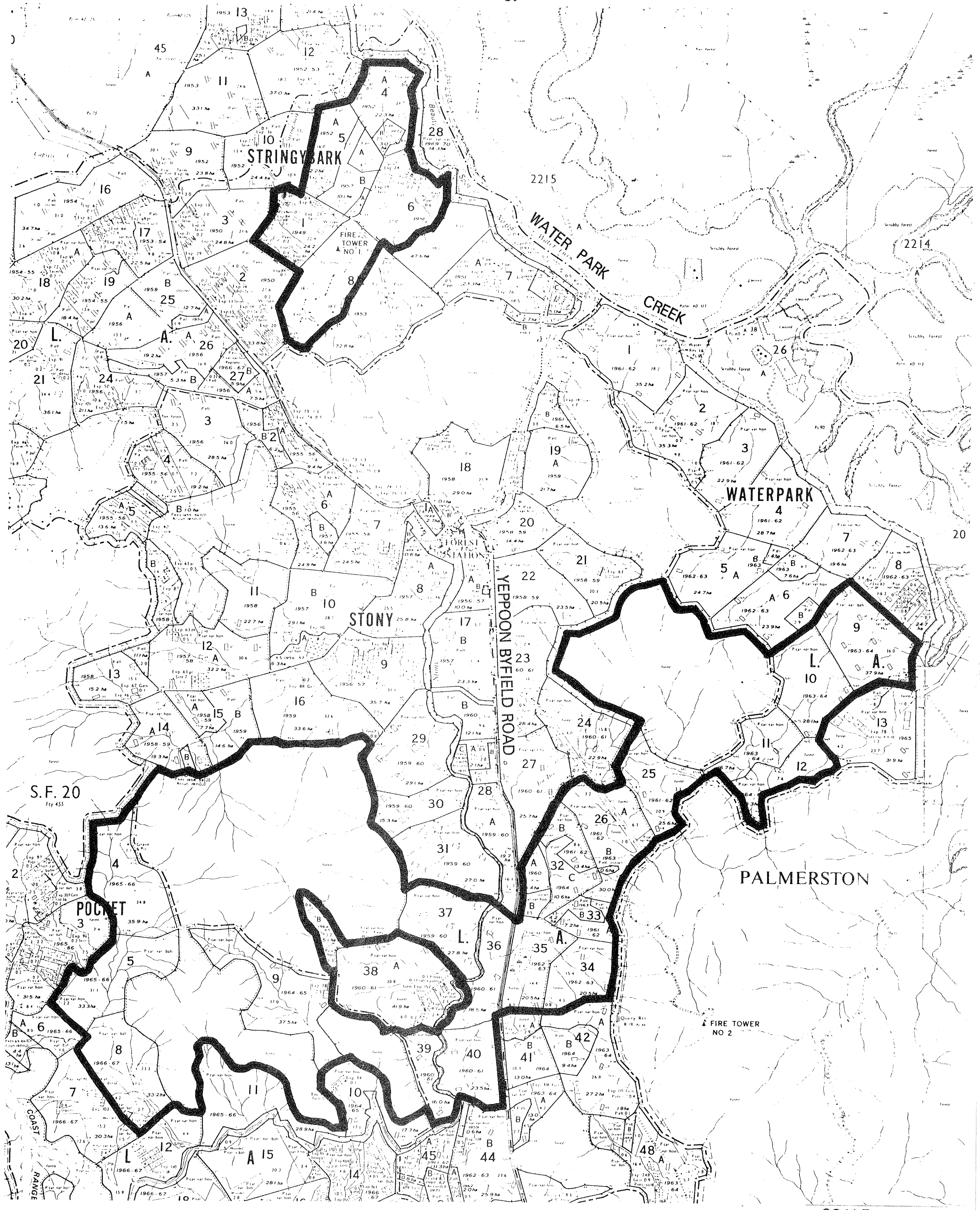

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Figure 3. Design of the 1980 trial at Byfield

As a precautionary measure, the initial trial in July 1978 was carried out when antecedent rainfall had raised the fuel moisture content above the optimum for burning.

The 1980 trials at both Toolara and Byfield were carried out when fuel moisture and weather conditions were optimum for burning on the bulk of the area, although fuel moisture content was known to be lower than desired for the small areas which had not been burnt previously. Temperature, relative humidity, wind and drought index (Keetch and Byram 1968) were within acceptable limits for burning in all three trials, and are shown in Table 2.

Table 2. Weather conditions recorded on days of three helicopter ignition trials

	Toolara 13.7.78		Toolara 19.5.80		Byfield 16.5.80	
	0900 hr	1500 hr	0900 hr	1500 hr	0900 hr	1500 hr
Temperature (°C)						
Dry bulb	10.3	17.8	20.5	21.2	19.8	22.4
Wet bulb	7.3	12.4	17.5	17.7	18.0	17.8
Relative humidity (per cent)	62	50	73	69	83	61
Wind						
Direction	SW	SE	SE	E	SE	SE
Speed †	1	1	1	3	3	1
Cloud	0/8	2/8	1/8	2/8	1/8	1/8
Drought index ‡	8	8	69	69	84	84

† Beaufort scale

‡ Byram-Keetch drought index expressed in points

Lighting Pattern

The forward rates of spread of the fire under the prevailing fine fuel moisture contents, relative humidities and wind speeds were estimated using the slash pine plantation prescribed burning guide (see Appendix 2). Spacing of ignition points was calculated as double the estimated rate of spread in each case to enable the fires to coalesce within two hours of ignition. The lighting pattern adopted was the same square grid system normally used for manual ignition.

The capsule priming machine used in the 1980 trials is capable of ejecting primed capsules at accurate intervals. The capsule ejection rate and the ground speed of the helicopter were adjusted to give the desired spacing of ignition points. This was not possible with the manual priming method, and hence accurate control of ignition pattern was not achieved in the 1978 trial.

In the 1978 trial, the flight lines were organised to follow row directions and the ends of each flight line were marked by spot fires. This was not possible in either of the 1980 trials because row directions varied from one compartment to the next and did not coincide with the most economical flight pattern.

In the 1980 trials, flight lines were drawn on a map, and the pilot commissioned to fly these flight lines. He was able to do this with acceptable accuracy.

The helicopter was used to do both the edge lighting of exposed edges and the grid ignition of the balance of the block. As stated previously, the flight path was marked by spot fires from the ground in 1978. In 1980, a few spot fires were used to facilitate boundary identification, but the bulk of the boundary definition was done from the helicopter.

Lighting of an exposed edge was carried out by passing over the edge twice to give a grid interval of half that calculated for the area in general.

Some areas of young plantation within the boundaries of the 1980 trial at Toolara contained highly flammable fuel types. Poor height development in these areas precluded their inclusion in the trial. As a precautionary measure, they were burnt by manual ignition four days before the helicopter ignition.

RESULTS

Effectiveness of the Burn

The 1978 trial met with mixed burn success. About 87 per cent of the total area was burnt, the range for individual compartments being 69 to 100 per cent. The unburnt areas were mainly areas of type 3 fuels with grass tree in heavily shaded and protected situations.

The two major fuel sub-types, type 3 with grass predominating and type 3 with blady grass, bracken fern and various other grasses, were reduced in quantity on the burnt areas by 41 and 27 per cent respectively.

Overall, the burn was too mild. This result had been predicted before the fire provided that there were no errors in lighting pattern. It was concluded that aerial ignition could produce a lighting pattern comparable to that of manual ignition, and results similar to those obtained by manual ignition.

The 1980 Toolara trial was conducted under fuel and weather conditions which were assessed as ideal for areas which had been burnt previously, but slightly dry for first burn areas. The burn results indicate that this prediction was accurate. A total of about 6 ha of plantation being burnt for the first time was scorched such that less than 4 m of green crown remained. These patches of scorch coincided with areas of low site quality. No scorch was recorded on areas which had been previously burnt. About 15 ha of previously burnt plantation remained unburnt where heavy shading of ground fuel was caused by a dense understory of grass trees.

The 1980 Byfield trial was done at a time when it was predicted that the major part of the plantation would burn well. It was predicted that one compartment being burnt for the first time would burn more intensely than those which had been burnt previously. It was also predictable that some gully areas would probably not burn. This assessment was again accurate.

A total of about 53 ha scattered over seven compartments totalling 660 ha did not burn. There were a number of reasons for this:

- Some areas were not lit because of temporary malfunction in the priming machine.
- Gully areas carrying damp fuels and green grass were too wet.
- In two compartments, tracks had been pushed along each alternate inter-row to allow access for pruning in 1978 thus preventing the fire from spreading.
- The irregularity of the boundaries of the burn made regular lighting patterns difficult to achieve.

Moderate scorching (2 to 4 metres of green crown remaining) occurred over 7 ha of the compartment having its first burn. High burn coverage (greater than 90 per cent of the area) occurred over the remainder of the plantation.

The included native forest burn showed a similar result. An area of 125 ha which had not been burnt for fifteen to twenty years burnt completely. The remainder which had been burnt three years previously showed a patchy burn coverage.

Operational Problems

During the 1978 Toolara trial, the ignition points were mapped in one compartment and compared to the planned ignition system.

The ignition pattern obtained was not very accurate, compared to the standard normally achieved in ground ignition. The variation was due to:

- the difficulty experienced in regulating the manual injection of capsules so that regular drop intervals could be obtained; and
- the pilot's experiencing some difficulty in flying along marked rows.