Forest Fire Behaviour Tables for Western Australia

by R.J. Sneeuwjagt and G.B. Peet

1985

Department of Conservation and Land Management

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3rd Edition

DEPARTMENT OF CONSERVATION
AND LAND MANAGEMENT

1. CONTENTS

2. INTRODUCTION

The 1985 edition of the Forest Fire Behaviour Tables for Western Australia is a major revision of the 1979 edition, and represents the results of continued research into fire behaviour and fire control conducted by officers of the Department of Conservation and Land Management.

Major changes have been made in the Rate-of-Spread tables for jarrah and southern forest fuels to give better predictions of fire behaviour under very dry soil and high wind conditions. These relationships were obtained from ongoing fire behaviour studies conducted by Neil Burrows and his fire research team based at Manjimup Research Station.

As in the previous editions, the Fire Behaviour Tables provide estimates of moisture content of litter fuels within the range of forest types in Western Australia. In addition to the standard forest types, additional information has been included to provide estimates for wandoo forests, and young (10-20 y/o) regrowth on pure and mixed karri sites. Improvements have been made to all fuel moisture prediction tables to ensure more accurate estimates of moisture changes during day and night conditions. In particular the prediction of the Rainfall Correction (Table 4.3.1.) has been substantially modified, incorporating up-to-date fuel moisture data.

A section has been added which provides information on the calculation and use of the Soil Dryness Index (S.D.I.).

Further major improvements and additions incorporated in the 1985 edition are summarised below:

Fuel Quantity Correction Factor
- — Modified for both jarrah and southern forest

Scorch Height and Date of Spread
- — Modified for both jarrah and southern forests

Litter Accumulation
- — Extended for older fuels

Scrub Fuels
- — Flammability Factor Table added
- — Scrub Heights/Density Profile added

Pine Slash Fuels
- —new table for fuel load calculation

Burning Guidelines
- — new for *Pinus radiata* underburning
- — new for hardwood slash fuels

Fire Suppression Guidelines
- — updated despatch and fireline construction tables to allow for modern equipment.

Karri Regrowth Stands

A research programme into the fire behaviour and fuel complex characteristics within young karri regrowth stands has been undertaken by Lachlan McCaw at Manjimup Research Station. Preliminary results of his work indicate that up to age 10, karri regrowth fuels are normally discontinuous

and insufficient to carry a ground fire except in very dry conditions under strong (20+ km/h) winds. By age 15, sufficient debris accumulates from dying scrub, tree twigs, bark and leaves, to carry ground fires. Fuel loads relate directly to stand development and available fuels of 15-19 t/ha are associated with a stem basal area of 20 m^2/ha or greater (i.e. age 15±5 yrs). In stands with a shrub understorey of either hazel *(Trymalium spathulatum),* netic *(Bossiae laidlawiana),* karri wattle *(Acacia pentadenia)* or *A. urophylla,* fuel moisture behaviour and fire behaviour are similar to those measured in mature karri 1 & 2 fuel types. The dense canopy restricts fuel drying and wind penetration into the stand.

Effective fuel-reduction burning is not normally possible until the S.D.I. exceeds 800. Important exceptions to this pattern are found in stands with a dense understorey of rushes (near Walpole) and in mixed marri-karri sites which have a more open understorey. These fuel types will burn at a younger age and behave similarly to karri 4 & 5 fuel types.

Regrowth burning should only be undertaken during stable conditions or when the hazard is falling. The best results are obtained when S.M.C.'s are between 12 to 18 per cent. The lighting pattern should take account of slope and variations in fuel type.

Further reading and reference:

Burrows, N.D. (1984) "Describing Forest Fires in Western Australia - A Guide for Managers". Forests Dept. of W.A. Tech. Paper No.9.

Burrows, N.D. (1984) "Predicting Blow-Up Fires in the Jarrah Forest". Forests Dept. of W.A. Tech. Paper No.12.

Burrows, N.D. (1984) "Radiata Pine Slash Burning Guide". Fire Research Note, Forests Dept. of W.A.

Forests Department of Western Australia (1983). Fire Protection Handbook. An abridgment of Part 9 (Fire Control) of the Foresters Manual, 1983 edition.

Sneeuwjagt, R.J. (1971) "Understorey Fuels in Karri Forest". Research Paper No. 1 Forests Dept. of W.A.

Sneeuwjagt, R.J. (1973) "Measuring Forest Fuels". Research Paper No. 3 Forests Dept. of W.A.

Underwood, R.J., Sneeuwjagt, R.J., Haswell, D.A. (1983) "Guidelines for Slash Burning in the Karri Forest". Internal report. Forests Dept. of W.A.

9.2.3. Fireline Production

9.2.3.1. Rate of fireline production by crews using hand tools

Crew Strength (includes Overseer)	Northern Jarrah Type (e.g. less than 10 tonnes/ha)			Southern Jarrah Type (e.g. more than 10 tonnes/ha)		
	F.D.I. ≤ 20	F.D.I. 21 to 60	F.D.I. 61 to 140	F.D.I. ≤ 20	F.D.I. 21 to 60	F.D.I. 61 to 100
	metres/hour			metres/hour		
1	100	80	50	70	50	30
2	180	140	90	130	90	50
3	250	190	130	160	110	60
4	300	230	160	180	120	70
5	330	260	180	190	130	75
6	350	270	190	200	140	80

N.B. Line Produced = Line Constructed and Held.

Direct hand tool attack on fire fronts burning in excess of 100 metres per hour can be dangerous and is therefore not recommended.

9.2.3.2. Rates of fireline production by bulldozers and wheel loaders

Forest Type	Rate of Production (metres/hour)		
	D8/D7E	D6	D4 and WL
Northern Jarrah	1000	1000	1000
Southern Jarrah	700	700	500
Dense Karri	400	250	100

N.B. Line Produced = Line Constructed and Held.

These are average values only, allowing for normal problems with slope, rock, large logs and backing up to deal with hopovers.

It does not take into account time where dieback washdowns are required.

9.2.2. Plant Travel Times

9.2.2.1. Rates of travel time for transporting machines

Type of Road	D4 & WL		D6		D7		D8		Transporter unladen
	1st* hour	other hours	1st hour	other hours	1st hour	other hours	1st hour	other hours	
Main Highway (km)	25	50	25	50	20	45	20	40	60
First Class Gravel (km)	25	30	25	30	20	25	20	25	50
Forest Track (km)	15	20	10	15	10	15	5	10	20
Self Travel (km) Wheeled Loader	15	Travel in excess of 1 hour or 15 km not recommended							

* Time for 1st hour includes loading machine.

9.2.2.2. Rates of travel time for gang trucks and heavy duties

Type of Road	Gang Truck (average km/hour)	Heavy Duties (average km/hour)
Main Highway	80	70
First Class Gravel	60	60
Forest Track	30	25

3. GLOSSARY

Surface Moisture Content (S.M.C.) - the moisture content expressed as a percentage of oven dry weight of the top 5-10mm of leaf litter.

Profile Moisture Content (P.M.C.) - the moisture content expressed as a percentage of oven dry weight of the entire leaf litter bed above the mineral soil surface.

Fuel Quantity - the oven dry weight of litter, trash and scrub foliage expressed in tonnes per hectare.

Available Fuel Factor - the proportion of the litter bed that is available to burn.

Trash Fuel - the component of ground fuel complex made up of dead twigs, branches and scrub debris of at least 10mm thickness. The 'available trash' is the proportion normally consumed in a low intensity ground fire.

Total Available Fuel Quantity - the sum of the fuel quantity of the litter, trash, scrub and fuels that is available to burn.

Overnight Relative Humidity Count - represents the area enclosed by the overnight R.H. trace (to 0800 hours) and the 70 per cent R.H. level. The area is made up of basic unit squares of 2 per cent R.H. by two hours duration.

Basic Drying Unit (B.D.U.) - is obtained from the daily forecasted maximum temperature and minimum relative humidity. Thus, the B.D.U. is a measure of the day drying effect.

Scrub Structural Types - designated by numbers 1 to 6, each of which represents an individual foliage density-height profile.

Slash Fuel - the waste material remaining following clearfelling and harvesting of marketable forest produce. This debris, made up of logs, branches and tree crowns, is either scattered or windrowed and subsequently burnt in preparation for pine planting or hardwood regeneration.

Standard Fuel Types

Northern Jarrah - represents the fuel type common to the jarrah dominant forests which carries a sparse, low scrub component.

Southern Jarrah (Type 6) - represents the fuels common to the jarrah dominant and jarrah-marri associations and usually carries a low (1m) dense understorey scrub layer.

Karri 3 and 6 - found in the jarrah-marri and karri-marri associations and usually carries a low (up to 2m) dense scrub layer.

Karri 4 and 5 - found in the karri-marri dominant forest types and carries a tall (up to 5m) dense scrub layer.

Karri 1 and 2 - found in the karri dominant forests and usually in wet, gully situations. Scrub type is tall (greater than 5m) and dense.

Karri Regrowth - is the fuel complex within 10 to 20 year old karri and marri sapling stands with dominant shrub understorey of either netic, hazel, karri wattle or *Acacia urophylla*. The fuel moisture and fire behaviour characteristics within dense stands are similar to karri 1 and 2 types.

9.1.3. *Pinus*

Fire Danger m/hr	Time between detection and attack															
	½ hour				1 hour				1½ hours				2 hours			
	G	HD	WL	BD	G	HD	WL	BD	G	HD	WL	BD	G	HD	WL	BD
0-40	2	1	0	0	2	2	1	0	3	3	1	0	5	5	1	1
41-60	2	2	1	0	2	2	1	1	5	5	2	1	7	7	2	2
61-140	2	2	1	0	3	3	1	1	7	7	2	2	9	9	3	2
141-240	4	3	1	0	5	4	1	1	9	8	2	2	-	-	-	-
241-400	6	5	1	1	8	7	2	2	-	-	-	-	-	-	-	-
400+	7	6	1	1	11	8	2	2	-	-	-	-	-	-	-	-

N.B. Wheeled Loaders and Bulldozers may be grouped to suit terrain or availability.

G Gang
HD Heavy Duty
WL Wheeled Loader
BD Bulldozer

9.2. INFORMATION FOR PLANNING SUPPRESSION STRATEGY AND TACTICS

9.2.1. Length of Fire Perimeter

To be used for fires running under severe conditions with constant wind direction.

To use this table, determine length of fire (i.e. start point or tail fire to head fire), select appropriate figure in column 1 and then read off perimeter in column 2.

Length of fire metres	Perimeter metres	Length of fire metres	Perimeter metres
50	150	3000	7500
100	300	3500	8500
200	600	4000	9500
400	1000	4500	11000
600	1600	5000	12000
800	2000	6000	15000
1000	2500	7000	17000
1500	3500	8000	19000
2000	5000	9000	21000
2500	6000	10000	24000

9. FIRE SUPPRESSION

9.1. DESPATCH TABLES

Shows size of fire fighting forces and equipment to be despatched for suppression of fires in Northern Jarrah, Southern Forest and Pine fuels. Size depends on time to reach the fire and level of fire behaviour.

9.1.1. Northern Jarrah

Fire Danger m/hr	Time between detection and attack															
	½ hour				1 hour				1½ hours				2 hours			
	G	HD	WL	BD	G	HD	WL	BD	G	HD	WL	BD	G	HD	WL	BD
0-40	1	1	0	0	1	1	1	0	2	2	1	0	2	2	1	0
41-60	2	2	0	0	2	2	1	0	3	2	1	0	3	3	1	0
61-140	2	2	1	0	3	3	1	1	4	4	1	1	4	4	2	1
141-240	3	3	1	0	3	3	2	1	4	4	2	1	5	5	2	2
241-400	4	3	2	1	5	5	3	3	6	6	3	3	7	7	4	5
400+	4	4	2	2	6	6	3	4	7	7	3	4	8	8	4	6

G Gang WL Wheeled Loader
HD Heavy Duty BD Bulldozer

9.1.2. Southern Forest

Fire Danger m/hr	Time between detection and attack															
	½ hour				1 hour				1½ hours				2 hours			
	G	HD	WL	BD	G	HD	WL	BD	G	HD	WL	BD	G	HD	WL	BD
0-40	1	1	1	0	2	1	1	1	2	2	1	1	3	2	2	2
41-60	2	1	1	1	2	2	1	1	3	2	1	2	4	3	2	3
61-140	2	2	1	1	3	3	1	1	4	4	2	3	5	5	3	4
141-240	2	3	2	1	3	4	2	2	4	5	2	4	6	6	3	5
241-400	4	3	3	2	5	6	2	3	6	7	3	5	7	7	4	7
400+	4	4	3	2	6	6	3	4	7	7	4	5	8	8	4	7

G Gang WL Wheeled Loader
HD Heavy Duty BD Bulldozer

Rate of Fire Spread - the forward rate of progress of the headfire expressed in metres per hour.

Fire Rate of Spread Index - the maximum rate of spread predicted from wind speed and surface moisture content for level topography, 60 per cent crown cover and standard fuel conditions for each forest type, namely:

Jarrah Five year old (i.e. five leaf falls) fuel ranging from 7.6 to 8.5 tonnes/ha.

Karri Five year old fuels which carry a combined total of 25 to 35 tonnes/ha of litter, trash and scrub fuels, or 15 to 19 tonnes/ha of available fuel.

Pines For pines, the rate of spread index will be based on 15 year old pines carrying approximately 11 to 20 tonnes/ha of litter, or 4 to 9 tonnes/ha of available fuel.

Soil Dryness Index - or S.D.I. - is a numerical value reflecting the dryness of soils, deep forest litter, logs and living vegetation. The S.D.I. estimates the amount of effective rainfall required to saturate the soil profile to a depth of 200mm. S.D.I. ranges from 0 when soils are saturated, to 2000 when soils are dry.

4. SURFACE MOISTURE CONTENT (S.M.C.)

Records should be commenced in early spring when litter beds are saturated. Moisture contents at that time to be determined by direct sampling or by approximations, i.e.

On first day after rain exceeding 10 mm assume:

S.M.C. = 60 per cent (Northern Jarrah)
P.M.C. = 100 per cent (Karri 4 and 5)

4.1. METHODS

N.B.—For purposes of recording:

Maximum S.M.C. applies to values at about 0800 hours.

Minimum S.M.C. applies to values at about 1500 hours.

4.1.1. If rain recorded in the 24-hour period to 0800 hours use table 4.3.1. to derive today's maximum S.M.C. See columns 2, 7, 8, 9 in example record sheet (page 9).

4.1.2. If no rain has fallen before 0800 hours use table 4.3.2. instead of table 4.3.1. See columns 3, 7, 8, 9.

4.1.3. Use table 4.3.3. to obtain today's basic drying unit (B.D.U.). Columns 4, 5, 6.

4.1.4. Apply B.D.U. in table 4.3.4. to derive day-drying and correct maximum S.M.C. at 0800 hours to obtain minimum S.M.C. for today. Columns 9, 10, 11.

4.1.5. Use table 4.3.5. to adjust northern jarrah S.M.C. for southern forest types. Columns 12 to 19.

4.1.6. Use table 4.3.6. to adjust northern jarrah S.M.C. for minimum S.M.C. in *Pinus pinaster* and *Pinus radiata* needle beds. Columns 20 to 23.

4.1.7. The number of columns 12 to 23 should be adjusted for local requirement to cover range of fuel types required.

4.1.8. S.M.C. values between 0800 hours and 1500 hours can be derived from the nomogram (figure 4.3.7.) for planning prescribed burning.

8.3. DEW POINT CALCULATION

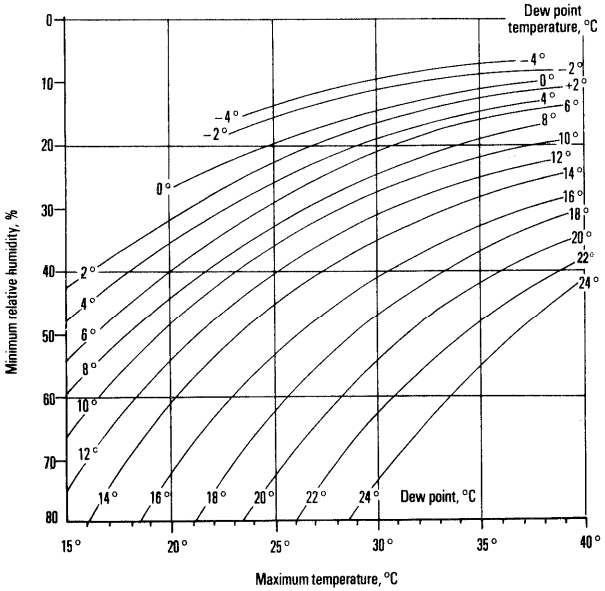
(Required for prediction of minimum relative humidity—see figure 8.2.)

Dry Bulb Temp. (°C)	Wet bulb depression (°C)																				
	0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0
36	36	34	33	32	31	29	28	26	25	23	21	19	17	15	13	10	7	4	0
35	35	33	32	31	30	28	27	25	24	22	20	18	16	14	11	9	5	2	-3
34	34	32	31	30	29	27	26	24	22	21	19	17	15	12	10	7	3	-1	-7
33	33	32	30	29	27	26	24	23	21	19	17	15	13	11	8	5	1	-4	
32	32	31	29	28	26	25	23	22	20	18	16	14	12	9	6	2	-2		
31	31	30	28	27	25	24	22	20	19	17	15	12	10	7	4	0	-5		
30	30	29	27	26	24	23	21	19	17	15	13	11	8	5	2	-3			
29	29	28	26	25	23	22	20	18	16	14	12	9	6	3	-1				
28	28	27	25	24	22	21	19	17	15	13	10	8	5	1	-4				
27	27	26	24	23	21	19	17	16	13	11	9	6	3	-2					
26	26	25	23	21	20	18	16	14	12	10	7	4	0	-4					
25	25	23	22	20	19	17	15	13	11	8	5	2	-2						
24	24	22	21	19	18	16	14	12	9	7	4	0	-5						
23	23	21	20	18	16	15	12	10	8	5	2	-2							
22	22	20	19	17	15	13	11	9	6	3	0	-5							
21	21	19	18	16	14	12	10	7	5	1	-3								
20	20	18	17	15	13	11	9	6	3	-1	-5								
19	19	17	16	14	12	10	7	4	1	-3									
18	18	16	15	13	11	8	6	3	-1	-5									
17	17	15	13	11	9	7	4	1	-3										
16	16	14	12	10	8	6	3	-1	-5										
15	15	13	11	9	7	4	1	-2											
14	14	12	10	8	6	3	-1	-4											
13	13	11	9	7	4	1	-2												
12	12	10	8	6	3	0	-4												

1. Obtain wet bulb depression by subtracting wet bulb temperature from dry bulb temperature.
2. Apply dry bulb temperature and wet bulb depression and read off the dew point temperature.

N.B. It will be necessary to interpolate if temperatures are to read to nearest 0.5°C.

8.2. PREDICTION OF MINIMUM RELATIVE HUMIDITY



1. Obtain dew point temperature for today from wet and dry bulb temperature.
2. Apply maximum temperature (calculated or forecast) and dew point temperature and read off the minimum relative humidity.

4.2. WORKED EXAMPLE — SURFACE MOISTURE CONTENT RECORD SHEET

Station: MANJIMUP Year: 1985

Date (day, month)	Rain to 0800 hours	Overnight R.H. count and dew	Forecast maximum temperature, °C	Forecast minimum R.H.	Basic drying unit (Table 4.3.3)	Northern jarrah surface M.C., %					Other fuel types (Tables 4.3.5 and 4.3.6)													
						Minimum yesterday (1500 hours)	S.M.C.% correction for rain or R.H. count (Table 4.3.1 or 4.3.2)	Maximum S.M.C. today, 0800 hours	S.M.C. day-drying correction (Table 4.3.4)	Minimum S.M.C. % today (1500 hours)	Southern jarrah		Open karri (Types 3 and 6)		Medium/dense karri (Types 4 and 5)		Dense karri (Types 1 and 2)		*Pinus pinaster* needlebed		*Pinus radiata* needlebed	
											a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.
1	2	3	4	5	6	7	8	9	10†	11†	12	13	14	15	16	17	18	19	20	21	22	23
1/12 Mon	2.5	N/R	20	45	16	9*	+22 (rain)	31	-10	21	35	24			Too high				24	17	28	19
2/12 Tues	0	36	28	35	23	21	0	21	-11	10	24	11	27	13	34	16	38	18	17	10	19	10
3/12 Wed	0	65	26	40	21	10	-9	19	-8	11	21	12	24	14	28	17	32	19	16	9	17	10
4/12 Thur	0	50	30	35	24	11	+6	17	-10	7	19	9	22	9	26	11	30	14	14	7	15	7
5/12 Fri	0	75	24	50	18	7	+12	19	-7	12	21	13	24	15	28	18	32	20	16	10	17	11
6/12 Sat	4·0	N/R	16	65	11	12	+35 (rain)	47	-12	35						Too high						
7/12 Sun	1.5	N/R	18	60	12	35	48	53	-15	38						Too high						

* Starting S.M.C. percentage value may be obtained from previous day's calculations or from field measurement.
† As values in columns 10 and 11 are based on forecasted weather, these values must be corrected according to the actual weather before proceeding with the next day's calculations.
N.R. - Not required

4.3.3. Basic Drying Unit (B.D.U.)

B.D.U. is a relative measure of day drying effect.

Max. temp. °C	Minimum Relative Humidity, %								
	0-5	6-8	9-13	14-18	19-23	24-28	29-33	34-38	39-43
8	15	14	13	13	12	12	11	10	9
9	15	15	14	13	13	12	12	11	10
10	16	15	14	14	13	13	12	11	10
11	16	15	15	14	14	13	13	12	11
12	16	16	15	15	14	14	13	12	11
13	17	17	16	15	15	14	14	13	12
14	18	17	17	16	15	15	14	13	13
15	18	18	17	17	16	15	15	14	13
16	19	18	18	17	17	16	15	14	14
17	19	19	18	18	17	17	16	15	14
18	20	20	19	19	18	17	16	16	15
19	21	20	20	19	18	18	17	16	16
20	22	21	20	20	19	18	18	17	16
21	23	22	21	20	20	19	18	18	17
22	23	23	22	21	20	20	19	18	18
23	24	23	23	22	21	21	20	19	18
24	25	24	23	23	22	21	21	20	19
25	26	25	24	23	23	22	21	21	20
26	26	26	25	24	24	23	22	21	21
27	27	26	26	25	24	23	23	22	21
28	28	27	26	26	25	24	23	23	22
29	28	28	27	26	25	25	24	23	22
30	29	28	28	27	26	25	25	24	23
31	30	29	28	28	27	26	25	24	24
32	30	29	29	28	27	27	26	25	24
33	31	30	29	29	28	28	27	26	25
34	31	31	30	30	29	28	27	26	26
35	32	31	31	30	29	29	28	27	26
36	33	32	32	31	30	29	28	28	27
37	33	33	32	31	31	30	29	28	28
38	34	33	33	32	31	30	30	29	28
39	34	34	33	33	32	31	30	29	28
40	35	34	34	33	32	32	31	30	29
41	35	35	34	34	33	32	31	30	29
42	36	35	35	34	33	32	32	31	30
43	36	36	35	35	34	33	32	32	31
44	37	36	36	35	34	34	33	32	31
45	37	37	36	35	35	34	33	32	32
46	38	37	37	36	35	34	34	33	32
47	38	38	37	36	36	35	34	33	32
48	39	38	37	37	36	35	34	34	33

1. Calculate B.D.U. from maximum temperature and minimum relative
2. Apply the B.D.U. in table 4.3.4. to determine day drying correction.

7.9. Prescribed Conditions for Pine Underburning

Type of Burn	Needlebed S.M.C.	Needlebed P.M.C.	A.F.F.	Aerial Needle S.M.C.	Temp °C	RH%	Ground Wind km/h	S.D.I. Limit
NEEDLEBED BURN*								
a. *P. radiata*	15-22%	>60	0.3-0.6	N/A	< 22	45-60	2-6	< 250 or fall of 500 from summer maximum
b. *P. pinaster*	20-30%	> 60	0.3-0.6	N/A	< 20	50-70	2-6	< 250 or fall of 500
SLASH BURN*								
a. *P. radiata*	18-24%	>60	0.2-0.4	16-24	< 22	50-65	0-3	< 250 or fall of 500
b. *P. pinaster*	28-35%	>60	0.2-0.4	22-28	< 20	60-75	0-3	< 250 or fall of 500

* Conditions apply to headfiring. Use the lower moisture range if backfiring.

7.8. OVERSEER'S BURNING TABLES

1. From table 6.7. for jarrah (table 6.12. for karri), use the surface moisture content and wind speed to determine the rate of forward spread for five-year-old fuel (7.6 to 8.5 tonnes/ha for jarrah; 15 to 19 tonnes/ha available for karri).
2. In table 6.14.1. for jarrah (table 6.14.2. for karri), locate the calculated rate of spread in the standard fuel (five-year-old) column and determine the corrected forward spread by reading across to the actual fuel quantity. Read off the corresponding maximum acceptable scorch height for this fuel and decide if this is acceptable for the forest type under consideration.
3. From table 7.7.1. or figure 4.3.7. determine the hours of burning time available.
4. Use table 7.7.2. to derive strip width and spot distance.

Example 1 - Northern Jarrah Forest Spring Burn

Predicted minimum S.M.C.	13 per cent
Wind at nearest tower (5:1 ratio)	16 km/hr
Rate of spread index (Table 6.7.)	22 m/hr
Total weight of fuel (all available)	10.5 tonnes/ha
Rate of spread corrected for fuel (Table 6.14.1)	26 m/hr
Scorch height estimated (Table 6.14.2.)	6 metres
Hours of burning available (Table 7.7.1.)	6 hours
Strip width (Table 7.7.2.), 26 x 6 hours	= 156 metres
Spot distances, 156 x ½	78 metres

Example 2 - Karri (4 and 5) Forest Spring Burn

Predicted minimum S.M.C.	14 per cent
Wind at nearest tower (scrub types 4 & 5)	15 km/hr
Rate of spread index (Table 6.12.)	22 m/hr
Total available fuel weight (include litter, trash, scrub)	24 tonnes/ha
Fuel quantity correction factor	1.3
Rate of spread corrected for fuel (Table 6.14.2.)	29 m/hr
Table 6.14.2. indicates scorch height about	10 metres
Hours of burning available (Table 7.7.1.)	5 hours
Strip width (Table 7.7.2.), 29 x 5 hours	= 140 metres
Distances between spots, 140 x ½	70 metres

44-48	49-53	54-58	59-63	64-68	69-73	74-78	79-83	84 +
9	8	7	6	5	4	3	2	1
9	8	7	6	6	5	4	3	2
10	9	8	7	6	5	4	3	2
10	9	8	7	7	6	5	4	3
10	10	9	8	7	6	5	4	3
11	10	10	9	8	7	6	5	4
12	11	10	10	9	8	7	6	5
12	12	11	10	9	8	7	6	5
13	12	12	11	10	9	8	7	6
14	13	12	12	11	10	9	8	7
14	14	13	12	11	10	9	8	7
15	14	14	13	12	11	10	9	8
16	15	14	13	12	11	10	10	9
16	16	15	14	13	12	11	10	9
17	16	16	15	14	13	12	11	10
18	17	16	15	14	14	13	12	11
18	18	17	16	15	14	13	12	11
19	18	17	17	16	15	14	13	12
20	19	18	17	16	16	15	14	13
20	19	19	18	17	16	15	14	13
21	20	19	18	18	17	16	15	14
22	21	20	19	18	17	16	15	14
22	21	20	20	19	18	17	16	15
23	22	21	20	19	19	18	17	16
23	23	22	21	20	19	18	17	16
24	23	22	22	21	20	19	18	17
25	24	23	23	21	20	19	18	17
25	25	24	23	22	21	20	19	18
26	25	24	23	23	22	21	19	18
27	26	25	24	23	22	21	20	19
27	26	25	25	24	23	22	21	20
28	27	26	25	24	23	22	21	20
28	27	27	26	25	24	23	22	20
29	28	27	26	25	24	23	22	21
29	28	27	26	27	25	24	23	22
30	29	28	27	26	25	24	23	22
30	29	28	27	26	26	25	23	23
31	30	29	28	27	26	25	24	23
31	30	29	28	27	26	25	24	23
32	31	30	29	28	27	26	25	24
32	31	30	29	28	27	26	25	24

humidity. Record in column 6 of Record Sheet.

7.3.4. Jarrah Surface Moisture Content Day Drying Units

Todays Max. (0800 hours) SMC%	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27	28-29	30-31	32-33	34-35
	DAY DRYING CORRECTION %														
6 to 7	+ 5	+ 4	+ 4	+ 3	+ 2	+ 2	+ 1	0	- 1	- 1	- 1	- 1	- 2	- 3	- 4
8 to 10	+ 4	+ 3	+ 2	+ 2	+ 1	+ 0	- 1	- 1	- 2	- 3	- 3	- 4	- 5	- 5	- 6
11 to 12	+ 2	+ 1	+ 1	+ 0	- 1	- 2	- 2	- 3	- 4	- 5	- 5	- 6	- 6	- 7	- 8
13 to 15	+ 1	+ 0	- 1	- 2	- 3	- 3	- 4	- 5	- 6	- 6	- 7	- 8	- 9	- 9	-10
16 to 17	+ 0	- 1	- 2	- 3	- 4	- 5	- 5	- 6	- 7	- 8	- 9	- 9	-10	-11	-11
18 to 20	- 1	- 2	- 3	- 4	- 5	- 6	- 7	- 7	- 8	- 9	-10	-11	-11	-12	-13
21 to 23	- 2	- 3	- 4	- 5	- 6	- 7	- 8	- 9	-10	-11	-12	-12	-13	-14	-14
24 to 26	- 3	- 4	- 5	- 6	- 7	- 8	- 9	-10	-11	-12	-13	-14	-15	-15	-16
27 to 29	- 4	- 5	- 6	- 7	- 8	- 9	-10	-11	-12	-13	-14	-15	-16	-16	-17
30 to 32	- 5	- 6	- 7	- 8	- 9	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19
33 to 35	- 6	- 7	- 8	- 9	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20
36 to 40	- 7	- 8	- 9	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20	-21
41 to 47	- 8	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20	-21	-22	-23
48 to 57	-10	-11	-12	-13	-15	-16	-17	-18	-19	-20	-21	-22	-23	-24	-25
58 to 67	-12	-13	-14	-15	-16	-18	-19	-20	-21	-22	-23	-24	-25	-27	-28
68 to 79	-13	-15	-16	-17	-18	-19	-20	-22	-23	-24	-25	-26	-28	-29	-30
80 to 95	-16	-17	-18	-20	-21	-22	-23	-24	-25	-27	-28	-29	-31	-32	-33
96 to 114	-18	-19	-21	-22	-23	-25	-26	-27	-28	-30	-31	-32	-34	-35	-36
115 to 134	-21	-23	-24	-25	-27	-28	-29	-31	-32	-33	-35	-36	-37	-38	-40
135 to 154	-25	-26	-27	-29	-30	-31	-33	-34	-36	-37	-39	-40	-41	-42	-44
155 to 170	-29	-31	-32	-34	-35	-37	-39	-40	-42	-43	-44	-46	-47	-48	-50
171 +	-34	-36	-38	-39	-41	-43	-44	-46	-48	-49	-50	-52	-53	-54	-56

1. Calculate S.M.C. day drying correction percentage using the B.D.U. and today's maximum S.M.C. percentage. Record in column 10.
2. Deduct or add correction to today's maximum S.M.C. percentage to give the minimum S.M.C. (jarrah) today. Record in column 11.
3. If the minimum S.M.C. calculates to be less than 3 per cent, set minimum S.M.C. at 3 per cent.

7.7.2. Estimation of Strip Width

Strip width = Hours of burning time available x R.O.S.
Spot width = Half strip width.

Forward rate of spread (m/hour)	Hours of burning time available								
	2	3	4	5	6	7	8	9	10
10	20	30	40	50	60	70	80	90	100
12	24	36	48	60	72	84	96	108	120
14	28	42	56	70	84	98	112	126	140
16	32	48	64	80	96	112	128	144	160
18	36	54	72	90	108	126	144	162	180
20	40	60	80	100	120	140	160	180	200
22	44	66	88	110	132	154	176	198	220
24	48	72	96	120	144	168	192	216	240
26	52	78	104	130	156	182	208	234	260
28	56	84	112	140	168	196	224	252	280
30	60	90	120	150	180	210	240	270	300
32	64	96	128	160	192	224	256	288	320
34	68	102	136	170	204	238	272	306	340
36	72	108	144	180	216	252	288	324	360
38	76	114	152	190	228	266	304	342	380
40	80	120	160	200	240	280	320	360	400
42	84	126	168	210	252	294	336	378	420
44	88	132	176	220	264	308	352	396	440
46	92	138	184	230	276	322	368	414	460
48	96	144	192	240	288	336	384	432	480
50	100	150	200	250	300	350	400	450	500

7.6. FIRE DANGER CLASSES

Fire Danger	Rate of spread	Type of burn
LOW	0.0 to 11.9 metres/hour	Coppice and pine
	12 to 20 metres/hour	Prescribed burning range
MOD.	21 to 40 metres/hour	
HIGH	41 to 60 metres/hour	
	61 to 140 metres/hour*	Warm burn
VERY HIGH	141 to 240 metres/hour	
EXTREME	241 to 320 metres/hour	Large fire organisation
	321 to 400 metres/hour	
	401+ metres/hour	

7.7. LIGHTING PATTERN

7.7.1. Hours of Burning Time Available

Predicted minimum S.M.C. %	Start time	Jarrah burning hours		Karri burning hours	
		Spring*	Autumn	Spring*	Autumn
20	1430	0	1	0	1
18	1400	1	2	1	2
16	1230	4	5	2	3
14	1100	6	7	5	6
12	1000	8	9	7	8
10	0900	10	12	9	10
8	0830	12	14	11	12

Enter table 7.7.1 with predicted minimum S.M.C. and season. Read off the hours of burning time available and the likely start time of burning for either jarrah or karri forests.

N.B. Spring condition when S.D.I.< 800.

4.3.5. Surface Moisture Content Adjustments for Other Major Hardwood Fuel Types.

Northern Jarrah *	S. Jarrah, J., J.M.	Karri 3 & 6 K.M., K.M.J.	Karri 4 & 5 K.M., K. dom.	Karri 1 & 2 K. dom. K. regrowth	Open slash (sheltered)
	Surface moisture content adjustments, %				
4-6	+ 1	+ 2	+ 3	+ 5	0
7-9	+ 1	+ 2	+ 4	+ 7	- 1
10-12	+ 1	+ 3	+ 6	+ 8	- 2
13-15	+ 2	+ 4	+ 7	+10	- 3
16-20	+ 2	+ 5	+ 9	+13	- 5
21-30	+ 3	+ 6	+13	+17	- 7
31-40	+ 4	+ 8	+19	+23	-10
41 +	+ 6	+10	+24	+30	-14

1. Enter table 4.3.5. with northern jarrah S.M.C. percentage and obtain S.M.C. adjustment percentage for appropriate fuel types.
2. Make adjustments to northern jarrah S.M.C. percentage to yield S.M.C. percentage for particular fuel types. Record these in columns 12 to 19 in Record Sheet.

* Use northern jarrah S.M.C. value for upslope wandoo.
Use southern jarrah S.M.C. for gully wandoo.

** Use Karri 1&2 S.M.C. for 10-20 year old karri regrowth on pure karri sites.
Use Karri 4&5 S.M.C. for 10-20 year old karri regrowth on mixed K.M. sites.

4.3.6. Surface Moisture Content Adjustment for Pine Fuels

Northern Jarrah S.M.C. %	*Pinus pinaster*		*Pinus radiata*	
	Needlebed litter	Tops/aerated needles	Needlebed litter	Tops/aerated needles
5-10	0	– 1	0	0
11-15	– 2	– 3	– 1	– 1
16-20	– 3	– 5	– 2	– 2
21-25	– 4	– 6	– 2	– 3
26-30	– 5	– 8	– 3	– 4
31-35	– 7	–10	– 3	– 5
36-40	– 9	–12	– 4	– 6
41-50	–11	–15	– 5	– 8
51-60	–13	–18	– 6	–10
61-70	–15	–21	– 8	–13
71-80	–17	–24	–10	–16

1. Enter table with predicted minimum S.M.C. (northern jarrah) and obtain S.M.C. adjustment for the particular pine fuel type.
2. Add or deduct adjustment to northern jarrah S.M.C. to yield the pine fuel S.M.C. percentage. Record in columns 20 to 23.
3. Apply the pine S.M.C. in table 6.7 to give the pine fire R.O.S. uncorrected for fuel quantity (see table 6.9).

N.B. The desirable S.M.C. percentage ranges for safe, successful needlebed burns under *Pinus radiata* and *Pinus pinaster* are 15-25 per cent and 20-30 per cent respectively.

The table values for needlebeds refer to those pine fuels found on loamy (*P. radiata*) or sandy (*P. pinasta*) soils below a closed canopy inside a level compartment.

It is important to realise that fuels found on exposed edges, ridges or north slopes, or below open canopy will be somewhat drier than the table values. The opposite is true for fuels in gullies, or south slopes, or unpruned, unthinned stands.

7.5. *P. radiata* Thinning Slash Quantity

Age and Thinning Schedule	No. of Stems Removed/ha	Aerial (1) Needles Tonnes/ha		Branchwood (2) Tonnes/ha	
		Fresh	Grey	Available	Total
10-14 y/o 1st Commercial Thinning	800	6.8	4.0	1.6	8
	700	5.9	3.5	1.4	7
	600	5.1	3.0	1.2	6
	500	4.2	2.5	1.0	5
	400	3.4	2.0	0.8	4
	300	2.5	1.5	0.6	3
	200	1.7	1.0	0.4	2
Pruning Only	Various	3.0	1.8	0.7	3

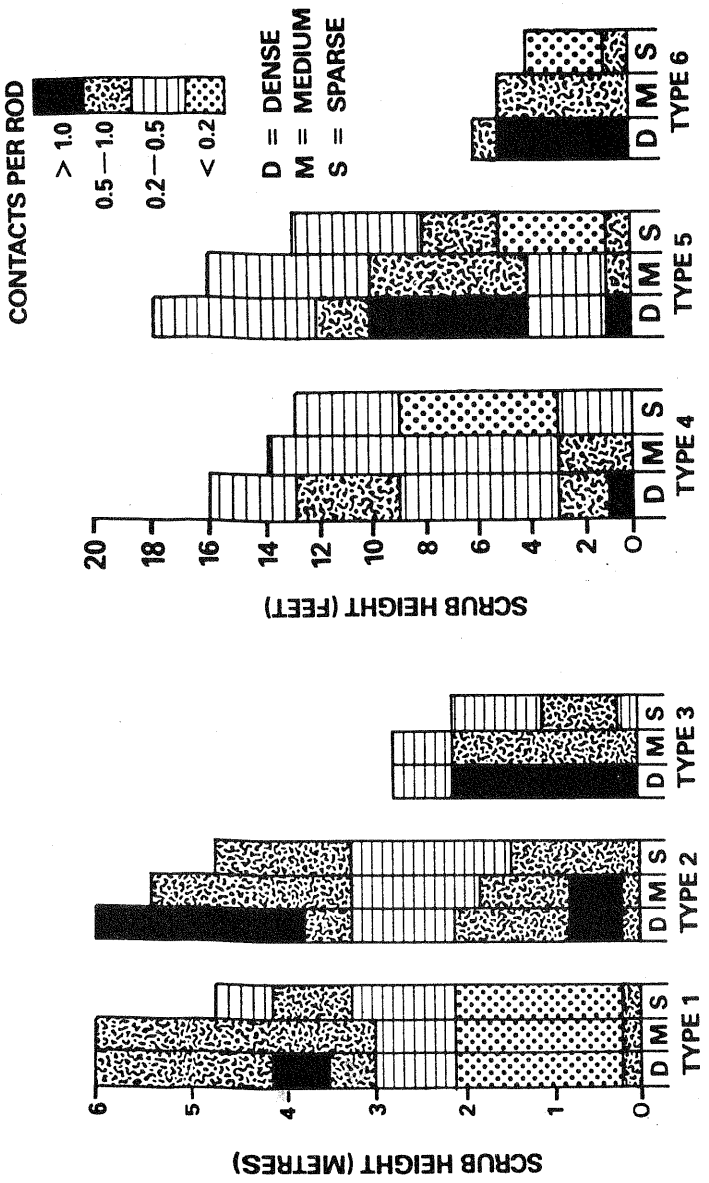
Note: (1) Fresh aerial needles are less than 1 year old. Grey needles are 2 or more years old.

(2) Available branchwood represents the amount normally available when the S.D.I. is less than 250 or autumn S.D.I. has fallen by 500 units.

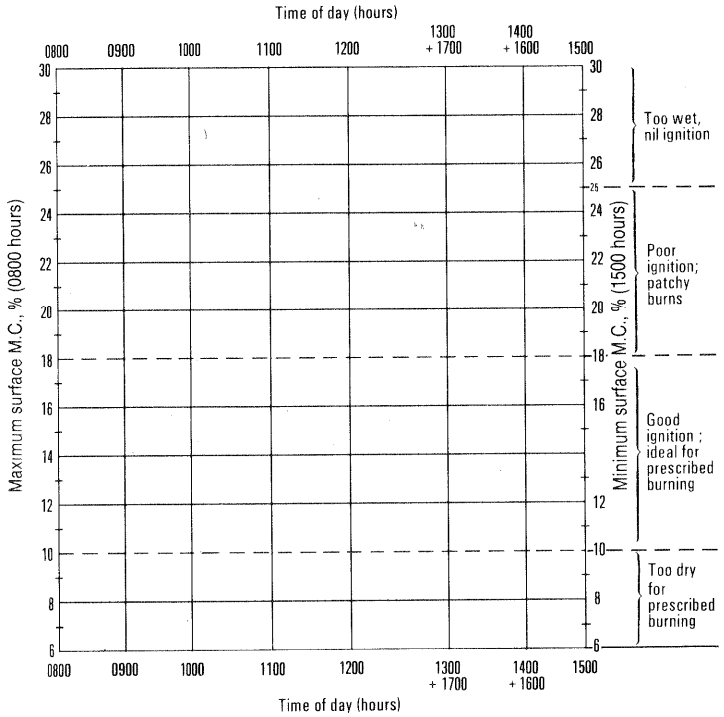
Calculate total fuel quantity available for burning by adding weight of each fuel component;

i.e.: Total = Available Needlebed (Table 7.2.1.) + Aerated needles + Available Branchwood.

7.4.3. Scrub height density profiles of six standard structural types



4.3.7. Surface Moisture Content During the Day



1. Place a ruler on predicted maximum (left axis) and minimum S.M.C. percentage (right axis).
2. Read off the expected S.M.C. percentage at the intersection of the ruler at the required time(s) during the day, or read off the time of day that S.M.C. percentage will be suitable for prescribed burning.

5. PROFILE MOISTURE CONTENT (P.M.C.)

5.1. METHOD

N.B. P.M.C. calculations are required for fuel beds exceeding 20 mm in depth (mainly southern forest and pine plantation).

P.M.C. values determine in the tables apply to litter beds that average 25 mm in depth. Shallower fuels will have a lower P.M.C., and deeper fuels will have higher P.M.C. values.

P.M.C. values apply to karri types 4 and 5. P.M.C. for other southern types and pine fuels are derived from table 5.3.2.

5.1.1. Use table 4.3.1. to obtain today's maximum P.M.C. for karri 4 and 5 if rain recorded up to 0800 hours. Columns 29, 30, 31 of P.M.C. record sheet (page 19).

5.1.2. If no rain recorded, yesterday's minimum P.M.C. is carried forward as today's maximum P.M.C. (i.e. no over-night change). Columns 29, 31.

5.1.3. Use table 5.3.1. to derive the drying correction and the minimum P.M.C. percentage for karri 4 and 5. Columns 32, 33.

5.1.4. Adjust P.M.C. karri 4 and 5 in table 5.3.2. for other fuel types. Columns 34 to 38.

5.1.5. Derive available fuel factor (A.F.F.) for required fuel type from table 5.4.1H (hardwood) or table 5.4.1P (pines) by inserting today's minimum surface and minimum profile moisture content. Columns 39 to 44.

7.4.2. Scrub Flammability Factor
- used to determine Scrub Fuel Loading for Rate of Spread calculation.

Scrub Flammability	Scrub Foliage Condition		
	Young/Green	20% Dead	50+% Dead
LOW Foliage dispersed; coarse; sparse; compacted or moist.	0.5	1.0	1.5
MEDIUM Foliage moderately fine; mixed size classes; medium dense.	1.0	2.0	3.0
HIGH Foliage aerated; fine; dense or continuous	1.5	3.0	5.0

Obtain appropriate scrub flammability factor (S.F.F.) from table. Multiply available scrub fuel weight (Table 7.4.1.) by S.F.F. to determine scrub fuel loading (S.F.L.)

7.4. WEIGHT OF UNDERSTOREY SCRUB FUEL AVAILABLE FOR BURNING

7.4.1. Scrub Fuel Weight (tonnes/ha)

Scrub structural type	Average scrub height (m)	Total live scrub (consumed in intense wildfire)			Total foliage (consumed in moderate wildfires)			Low foliage (consumed in prescribed burning)		
		Dense	Medium	Sparse	Dense	Medium	Sparse	Dense	Medium	Sparse
1. For example, hazel, netic, karri wattle	7·0 + 6·0 5·5 5·0–	40 35 30 23	35 31 27 20	31 26 23 17	9 8 7 5	8 7 6 5	7 6 5 4	0·5 0·5 0·5 0·5	0·3 0·3 0·3 0·3	0·3 0·3 0·2 0·2
2. For example, hazel or netic, with *Acacia* sp. understorey	7·0 + 6·0 5·5 5·0–	49 43 38 33	43 38 34 29	39 33 29 25	10 9 8 7	9 8 7 6	8 7 6 5	3 3 3 2·5	2·5 2 2 1·5	1·5 1·5 1·2 1·0
3. For example, hovea, *A. pulchella, A. strigosa, A. pentadenia*	3·5 + 3·0 2·5 2·0 1·5–	19 16 13 9 6	13 11 9 7 4	9 7 6 5 3	6 5 4 3 2·5	5 4 3 2·5 2	3·5 3 2·5 2 1·5	2 2 2 2·5 2·5	1·5 1·5 1·8 2 2	1 1 1·2 1·5 1·5
4. For example, *Agonis* sp. *pimelia*	5·5 + 5·0 4·5 4·0 3·5–	32 26 23 20 16	25 20 17 14 10	20 15 11 8 7	6 5 4 4 3	5 4 3 3 2·5	4 3 2·5 2 2	1·5 1·5 1·2 1·2 1	1·2 1·2 1 1 1	1 1 1 1 0·8
5. For example, netic, *A. urophylla*, young hazel	5·5 + 5·0 4·5 4·0 3·5–	35 28 22 19 14	28 22 18 15 12	20 16 14 11 9	6 5 4 4 3	5 4 3 3 2·5	4 3 2·5 2 2	2 2 2 1·5 1·5	1·5 1·5 1·5 1·2 1·2	1 1 1 1 1
6. For example, young scrub, creeper, tall grasses, jarrah scrub	1·5 + 1·2 0·9 0·6–	7 5 3 3	5 4 3 2	4 3 2 1·5	3·5 3 2·5 2	3 2·5 2 1·5	2·5 2 1·5 1	2·5 2 2 1·5	2 1·5 1·5 1	1·5 1 1 0.8

Enter table with scrub structural type, average height, and scrub density rating. Read off the scrub weight (tonne/ha) or either the total scrub (consumed by intense wildfires), total foliage (burnt in moderate wildfires), or foliage below 1.5 metres (burnt by prescribed fires).

5.2 WORKED EXAMPLE

PROFILE MOISTURE CONTENT RECORD SHEET

Station: MANJIMUP Year 1985

Date (day, month)	Rain to 0800 hours (mm)	Basic drying unit (see column 6, S.M.C. Record)	Karri 4 and 5 profile M.C., %					Minimum P.M.C. (1500 hours) for other fuel types (Table 5.3.2)					Available fuel factor (Tables 5.4.1H or 5.4.1P)					
			Yesterday's minimum P.M.C., %	P.M.C. % correction for rain (Table 9.3.1)	Maximum P.M.C. % 0800 hours today	P.M.C. % day-drying correction (Table 5.3.1)	Minimum P.M.C. % today (1500 hours)	Southern jarrah	Karri 3 and 6	Karri 1 and 2	*Pinus pinaster*	*Pinus radiata*	Southern jarrah	Karri 3 and 6	Karri 4 and 5	Karri 1 and 2	*Pinus pinaster*	*Pinus radiata*
26	27	28	29	30	31	32†	33†	34	35	36	37	38	39	40	41	42	43	44
1/12 Mon.	2.5	16	80*	+10 (rain)	90	-8	82	62	67	107	102	107	0.1	0	0	0	0.4	0.4
2/12 Tues.	–	23	82	0	82	-10	72	57	62	92	90	92	0.5	0.3	0.3	0.2	0.6	0.6
3/12 Wed.	–	21	72	0	72	-8	64	49	54	84	82	84	0.5	0.4	0.3	0.1	0.7	0.6
4/12 Thur.	–	24	64	0	64	-8	56	46	49	74	68	76	0.6	0.6	0.5	0.3	0.8	0.8
5/12 Fri.	–	18	56	0	56	-4	52	42	45	70	64	72	0.4	0.4	0.3	0.2	0.7	0.7
6/12 Sat.	4.0	11	52	+22 (rain)	74	-4	70	55	60	90	92	90	0	0	0	0	0	0
7/12 Sun.	1.5	22	70	+10 (rain)	80	-4	76	61	66	96	98	96	0	0	0	0	0	0

*** Starting P.M.C. percentage value obtained either from previous day's calculations or from field measurement.**

† As values in columns 32 and 33 are based on forecasted weather, these values must be corrected according to the actual weather before proceeding with the next day's calculations.

5.4. AVAILABLE FUEL FACTOR (A.F.F.)

5.4.1H. Available Fuel Factor for Hardwood Litter

Defines proportion of *litter* fuel available for burning.

Minimum surface moisture content %	Minimum profile moisture content, %									
	10 to 14	15 to 19	20 to 24	25 to 30	31 to 40	41 to 60	61 to 80	81 to 120	121 to 160	161 plus
3-6	B	B	1·0	0·9	0·9	–	–	–	–	–
7-9	B	B	1·0	0·8	0·7	0·6	0·5	0·4	0·3	0·3
10-12	B	A	1·0	0·8	0·6	0·5	0·4	0·3	0·3	0·2
13-15	B	A	1·0	0·7	0·5	0·4	0·3	0·3	0·2	0·2
16-18	A	A	1·0	0·6	0·4	0·3	0·3	0·2	0·2	0·1
19-21	A	1·0	0·9	0·5	0·4	0·3	0·2	0·1	0·1	0·1
22-25	A	1·0	0·8	0·5	0·3	0·2	0·1	0·1	0·1	0·1
26 +	–	–	–	–	–	–	–	–	–	–

1. Enter table with the predicted minimum surface and profile moisture contents for the particular fuel type.
2. Read off the available fuel factor (i.e. the fraction of fuel that is available to burn). Record in columns 39 to 44.

N.B. Prescribed burning is most successful when the A.F.F. is between 0.3 and 0.7 inclusive.

Indices *A* and *B* equal 1.0 and represent dangerously dry fuel conditions.

7.1.3. Wandoo Litter (tonnes/ha)

Litter weight includes leaf, bark*, capsules and twig components up to 10 mm diameter only.

No. of Annual Leaf Falls	Basal Area (m^2/ha)			
	< 5	5-10	10-15	> 15
	or Canopy Cover (%)			
	20%	40%	60%	80%
1	0.6	1.0	1.6	2.2
2	1.1	1.6	2.4	3.8
3	1.6	2.3	3.2	4.8
4	2.0	2.8	4.0	5.7
5	2.3	3.3	4.6	6.6
6	2.5	3.7	5.1	7.8
8	2.8	4.3	6.0	8.2
10	3.2	4.8	6.7	9.2
12	3.6	5.4	7.3	10.0
15	4.0	6.0	8.2	11.2
20	4.6	7.0	9.5	12.8
25	5.0	7.7	10.4	14.4
30	5.4	8.3	11.2	15.8

* Data also applies to mallet forest (natural and plantation) at Dryandra.

7. AIDS FOR PRESCRIBED BURNING

7.1. RATE OF LITTER ACCUMULATION

Litter weights (in tonnes/ha) includes leaf, bark and twig material up to 10 mm diameter only.

7.1.1. Jarrah Litter (tonnes/ha)

No. of Annual Leaf Falls	Canopy Cover %				
	20	40	50	60	80
1	1.0	1.4	2.4	3.0	3.5
2	1.6	2.6	4.0	4.4	5.0
3	2.5	4.0	5.2	6.2	7.2
4	3.4	5.2	6.3	7.4	8.5
5	4.2	6.2	7.5	8.6	9.8
6	5.0	7.2	8.5	9.6	10.8
7	5.8	8.1	9.5	10.6	11.8
8	6.5	9.0	10.3	11.5	12.8
10	7.7	10.3	11.5	13.0	14.4
12	8.8	11.5	12.7	14.2	15.5
15	10.5	13.0	14.2	15.6	17.5
20	12.7	15.0	16.5	17.8	20.2
25	14.8	17.0	18.5	20.0	22.5

7.1.2. Karri Litter (tonnes/ha)

No. of Annual Leaf Falls	Canopy Cover %				
	30	50	60	80	100
1	4.0	6.0	7.0	9.5	12.5
2	6.2	8.5	9.7	12.7	16.0
3	8.2	10.7	12.2	15.5	19.0
4	10.0	13.0	14.5	18.0	21.7
5	11.7	15.0	16.7	20.2	24.2
6	13.5	16.7	18.7	22.5	26.7
7	15.2	18.7	20.7	24.7	29.2
8	17.0	20.3	22.5	26.7	31.5
9	18.5	22.5	24.5	29.0	33.7
10	20.2	24.2	26.2	31.0	36.0
15	25	29	34	41	46
20	30	35	40	47	52
25	35	40	44	53	58

5.4.1P. Available Fuel Factor for Pine Litter

Minimum surface moisture content %	Minimum profile moisture content, %								
	30 to 35	36 to 40	41 to 50	51 to 60	61 to 80	81 to 100	101 to 120	121 to 150	151 to 200
	Available fuel factor (pines)								
5-9	1·0	0·9	0·8	0·8	0·8	0·7	–	–	–
10-14	1·0	0·9	0·8	0·7	0·7	0·6	0·5	0·4	0·4
15-19	1·0	0·8	0·7	0·6	0·6	0·5	0·4	0·3	0·3
20-24	1·0	0·8	0·6	0·5	0·5	0·4	0·3	0·3	0·3
25-29	0·9	0·7	0·5	0·4	0·4	0·3	0·2	0·2	0·2
30-35	0·8	0·6	0·4	0·3	0·3	0·2	0·1	0·1	–
36 +	0·8	0·5	0·2	0·2	0·1	0·1	–	–	–

1. Enter table with minimum surface and profile moisture contents for either *Pinus pinaster* or *Pinas radiata* fuels.
2. Read off the available fuel factor (A.F.F.)

N.B. The A.F.F. indicates the portion of the needlebed that is readily available to burn. Thus:

Total fuel quantity x A.F.F. = Available fuel quantity.

Safe and satisfactory prescribed burns in pine litter are achieved when the A.F.F. occurs within the 0.3 to 0.6 range.

5.5. The Soil Dryness Index (S.D.I.)

S.D.I. Estimation

The S.D.I. is a numerical value reflecting the dryness of soils, deep forest litter, logs and living vegetation. It ranges from 0, when soils are saturated, to 2000 when soils are dry to a depth of 200 mm. The S.D.I. estimates the amount of effective rainfall required to saturate the soil profile to a depth of 200 mm.

The S.D.I. rises with soil moisture loss from evapotranspiration and falls with moisture gain from effective rainfall. Calculations involve:

(a) estimating soil moisture loss from evapotranspiration, which is a function of the daily maximum temperature (°C)

(b) estimating rainfall loss from canopy interception and run-off. This is determined from the 24 hour rainfall (mm), vegetation type and soil type.

The S.D.I. can be started at 0 when at least 200 mm of rain has fallen in the past 30 days. It is recommended that the index be maintained throughout the year.

Evapotranspiration tables have been developed for different forest zones to account for variations in forest vegetation cover and soil types. These tables are available from Protection Branch.

Burning Limits

The S.D.I. reflects the quantity of fuel available for burning, particularly the quantity of deep forest litter, logs and tree bark. When the index is high, a greater proportion of these fuels will be dry enough to burn.

The S.D.I. limits shown in the table below are the recommended conditions for safely and effectively carrying out various fire operations. Burning outside these conditions will:

(i) increase the risk of fire escape and potential property damage

(ii) increase the level of tree damage and topsoil exposure

(iii) increase the unit cost of burning, as extra mop-up and patrols will be required.

6.14.2. Southern Forest Fuel Corrected Rate of Spread and Scorch Height

Maximum Scorch Height (metres)	Total Available Fuel Quantity (tonnes/ha)						
	5-9	10-14	15-19	20-27	28-35	36-44	45+
	Rate of Forward Spread (metres/hour)						
			"Standard"				
					10	10	10
			10	11	12	13	12
		11	12	13	14	16	15
	11	12	14	15	17	18	18
	13	14	16	18	19	21	21
4m	14	16	18	20	22	23	24
	16	18	20	22	24	26	27
	18	19	22	24	26	28	30
	FOUR	SIX		NINE	TWELVE	FIFTEEN	33
	19	21	24	26	29	31	36
	21	23	26	29	31	34	39
	22	25	28	31	34	36	42
	24	27	30	33	36	39	45
	25	29	32	35	38	42	48
	27	31	34	37	41	44	51
	29	32	36	40	43	47	54
6m	30	34	38	42	46	50	57
	32	36	40	44	48	52	60
	34	38	42	46	50	55	63
	35	40	44	48	53	57	66
	37	41	46	50	55	60	69
	38	43	48	53	58	63	72
	40	45	50	55	60	65	75
	42	47	52	57	62	68	78
		NINE	TWELVE	FIFTEEN		TWENTY PLUS	
	43	49	54	59	65	70	81
	45	50	56	61	67	73	84
9m	46	52	58	63	70	76	87
	48	54	60	66	72	78	90
	50	56	62	68	75	81	93
	51	58	64	70	77	83	96
	53	59	66	72	79	86	99
	54	61	68	75	82	89	102
	56	63	70	77	84	91	105
	58	65	72	79	86	94	108
12m	59	66	74	81	89	96	112

Locate the calculated karri R.O.S.I. (table 6.12.) in the standard fuel column (15-19 tonne/ha available fuel). Determine the fuel-corrected rate of spread by horizontal reference to adjacent column with actual fuel quantity.

Read off the maximum scorch height (metres) for spring season (S.D.I. 800).

For autumn conditions, multiply spring scorch height by factor of 1.8.

6.14. RELATIONSHIP BETWEEN R.O.S., FUEL QUANTITY AND SCORCH HEIGHT

6.14.1. Jarrah and Pine Forest (Mild Intensity Fires)

Maximum Scorch Height (m) for Spring* or SDI = 800	TOTAL AVAILABLE FUEL QUANTITY (Tonnes/ha)						
	16.0+	14.0	12.0	10.0	STANDARD 8.0	6.0	4.0
	No. of Leaf Falls (years) - Applies to 50-70% Canopy						
	16-20	12-15	9-11	7,8	5,6	3,4	2
	Rate of Forward Spread (metres/hour)						
4.0	14	12	10	8	8		
	18	16	14	12	10	8	
5.0	20	18	16	14	12	10	
	24	20	18	16	14	12	10
6.0	28	24	20	18	16	14	12
	30	28	24	20	18	16	12
	Six		Five			Four	
8.0	34	30	26	22	20	18	14
	38	34	28	24	22	18	16
	40	36	32	28	24	20	16
	44	40	34	30	26	22	18
10.0	48	42	36	32	28	24	20
	52	46	40	34	30	26	22
	54	48	42	38	32	28	22
12.0	58	52	44	40	34	28	24
	62	54	48	42	36	30	26
	Twelve		Ten	Eight		Six	Five
	64	58	50	44	38	32	26
	68	60	52	46	40	34	28
		64	54	48	42	36	30
		68	58	50	44	38	30
			60	52	46	40	32
			62	54	48	42	34
			66	58	50	44	36
			68	60	52	46	36
				62	54	48	38
				66	56	48	40
					58	50	40
					60	52	42
					64	54	44
					68	58	48

Enter table with calculated jarrah R.O.S. index in the standard fuel (8.0 tonnes/ha) column.

Determine the fuel corrected R.O.S. by horizontal reference to adjacent column with the actual fuel quantity.

Read off the maximum scorch height for spring season (SDI ≤ 800).

* Scorch height in autumn conditions (SDI ≥ 800) is approximately 1.8 times greater than scorch height in spring conditions.

5.6. Recommended S.D.I. Limits for Various Fire Control Operations in Forested Areas

S.D.I. Upper Limits		Fire Operations
Spring	Autumn	
250	S.D.I. to fall by 500 units	Tops disposal, flammable flats, under pine burning, jarrah edging
600	S.D.I. to fall by 500 units	Fuel reduction burning - northern and eastern jarrah forests and wandoo forest
700	S.D.I. to fall by 400 units	Fuel reduction burning - southern jarrah forest, karri forest types 3 and 6
800	S.D.I. by fall by 400 units	Fuel reduction burning - karri types 1, 2, 4 and 5. Karri regrowth stands (12-20 yrs) dry enough to burn

WARNING - Autumn Condition

The S.D.I. must be interpreted differently for spring and autumn conditions (as shown in Table). In spring, soils dry from the top, but in autumn soils dry from both the top and the bottom of the profile. The S.D.I. does not account for soil drying from below. Due to rapid drying from above and below in autumn, the S.D.I. must fall by the given amount from its summer maximum, in NOT LESS THAN 4 DAYS. Heavy and brief downpours in autumn may not effectively wet the soil and fuel profile.

Where the S.D.I. is still above 1000 units in the autumn, there is high potential for re-ignition which could result in damage from excessive fire behaviour or uncontrolled fires, particularly from edging operations.

6. RATE OF FORWARD SPREAD OF HEADFIRE

6.1. METHOD - JARRAH FOREST

6.1.1. Select appropriate wind ratio for forest type under consideration. Table 6.5.

6.1.2. Select appropriate slope correction if applicable. Table 6.6.

6.1.3. Where jarrah litter beds exceed 20 mm in depth, calculate available fuel quantity from:

Available fuel factor (A.F.F.) x Total litter quantity = Available litter fuel quantity.

6.1.4. Enter table 6.7 with S.M.C., wind velocity and wind ratio to obtain rate of forward spread index (m/hr) in 7.6 to 8.5 tonnes/ha of litter fuel (R.O.S.I.).

6.1.5. Adjust rate of spread from table 6.7 for available fuel quantity by correction factor (C.F.) from table 6.8; i.e.

R.O.S.I. x C.F. = R.O.S. adjusted for fuel quantity.

6.1.6. Multiply rate of spread adjusted for fuel quantity by slope correction factor for actual rate of spread.

6.2. EXAMPLE - JARRAH FOREST

6.2.1. Data

S.M.C. = 15 per cent (from S.M.C. daily record).

Wind 18 km/hr in 60 per cent canopy cover on ridge topography measured at 30 m above canopy.

Total litter fuel = 10 tonnes/ha.

Slope = +10°.

6.13. KARRI FUEL QUANTITY CORRECTION

Select known total available fuel quantity (include litter, trash and scrub fuel components) and the appropriate surface moisture content range. Read off the fuel correction factor in body of table.

Total Available Fuel Quantity tonnes/ha	Surface Moisture Content Range		
	19-26%	10-18%	3-9%
5 - 9	0.2	0.2	0.2
10 - 14	0.5	0.5	0.5
15 - 19	1.0	1.0	1.0
20 - 27	1.2	1.3	1.4
28 - 35	1.4	1.6	1.8
36 - 44	1.6	1.9	2.3
45 - 54	1.8	2.2	2.8
55 +	2.0	2.5	3.4

Adjusted Rate of Spread = Rate of Spread Index (Table 6.12) x Fuel Correction Factor.

6.5. WIND RATIO TABLE

Select appropriate wind ratio for table 6.7 from topography, forest canopy, and height of tower reading above the general forest canopy.

Forest Type & Canopy	Height of Tower above Canopy (metres)		
	0	15	30
(a) Jarrah/Wandoo			
(i) 60 per cent canopy			
Ridge	3:1	4:1	5:1
Lower Slopes	4:1	5:1	6:1
(ii) 30 per cent Canopy			
Ridge	2:1	3:1	4:1
Lower Slopes	3:1	4:1	5:1
(iii) Flats	1:1	2:1	2:1
(b) Pine Plantation			
Dense Stands	5:1	6:1	6:1
Thinned Stands	3:1	4:1	5:1

6.6. McARTHUR SLOPE CORRECTIONS

Slope in degrees	Spread factor
−10	0·6
− 5	0·8
Level	1·0
+ 2	1·1
+ 4	1·3
+ 6	1·5
+ 8	1·7
+10	2·0
+15	2·8
+20	4·0

The factor is 1·0 for level ground and doubles for every 10° increase in slope.

6. Rate of Spread of Headfire *(continued)*

6.10. METHOD - SOUTHERN FOREST TYPES

6.10.1. Enter table 6.12. with S.M.C. and wind velocity for particular fuel type and obtain R.O.S.I. for 15-19 tonne/ha of available fuel.

6.10.2. Determine the total fuel quantity from the litter, trash and scrub fuel measurements (tables 7.2.1., 7.3.1. and 7.4.1. respectively.)

6.10.3. Obtain the fuel quantity correction from table 6.13. using the total fuel quantity and surface moisture content.

6.10.4. Adjust the R.O.S.I. for fuel quantity by multiplying the R.O.S.I. for 15-19 tonne/ha by the fuel corrector.

6.10.5. Adjust the R.O.S.I. for slope with the slope factor obtained in table 6.6.

6.11. WORKED EXAMPLE - SOUTHERN FOREST TYPES

6.11.1. Data for Karri Scrub Type (open karri-marri fuels)

S.M.C. (karri 3) = 14 per cent (from S.M.C. record)
P.M.C. (karri 3) = 50 per cent
Therefore A.F.F. = 0.4 (Table 5.4.1 H)
Total fuel quantity (litter, trash and scrub) = 22 tonne/ha
Slope = +6°

6.11.2. Calculations

R.O.S.I. (for 15-19 tonne/ha available fuel) = 50 m/hr (Table 6.12.)
Fuel corrector = 1.3 (Table 6.13.)
Fuel corrected R.O.S.I. = 50 x 1.3 = 65m/hr
Slope factor = 1.5
R.O.S.I. x Slope factor = 65 x 1.5 = 98m/hr

6.12. KARRI RATE OF SPREAD

1. Enter table with surface moisture content (%) and tower (or ground) wind velocity for appropriate fuel.
2. Read off the rate of spread index for standard karri fuel of 15-19 tonnes/ha available fuel quantity.
3. Apply Karri Fuel Correction Factor for non-standard fuel loads (Table 6.13.).

Fuel Types	Tower and wind velocity (kilometres per hour)									
South Jarrah	0-4	5-8	9-12	13-17	18-21	22-26	23-30	31-35	36-39	40-50
Karri 3 and 6	0-4	5-9	10-14	15-19	20-24	25-28	29-32	33-36	37-41	42-55
Karri 4 and 5	0-5	6-10	11-16	17-22	23-27	28-33	34-38	39-43	44-48	49-60
Karri 1 and 2 and Karri Regrowth	0-6	7-13	14-20	21-28	29-35	36-42	43-49	50-56	57-63	64-75

All Fuel Types	Ground wind velocity (1.2 metres above ground) kilometres per hour									
	0.0-0.7	0.8-1.5	1.6-2.3	2.4-3.1	3.2-3.9	4.0-4.7	4.8-5.5	5.6-6.3	6.4-7.1	7.2+

S.M.C. %	Headfire rate of spread (metres per hour)									
26+	—	—	—	—	—	—	—	—	—	—
25	—	8	10	12	15	20	28	38	52	70
24	—	9	10	13	16	22	30	41	56	77
23	—	9	11	14	17	24	32	45	62	85
22	8	10	12	15	18	25	35	49	68	94
21	8	11	13	16	20	27	38	54	76	105
20	9	11	14	17	22	30	42	60	84	115
19	9	12	15	18	25	34	48	68	94	135
18	10	13	16	20	27	38	52	76	105	140
17	11	14	17	22	30	42	58	85	115	160
16	12	15	18	24	32	46	64	95	130	180
15	13	16	20	27	35	50	70	105	150	210
14	14	17	22	29	40	56	80	120	170	230
13	15	19	24	32	45	64	90	135	185	255
12	16	20	26	34	50	72	100	155	215	300
11	17	21	28	38	56	80	115	180	260	360
10	18	23	30	42	62	90	130	205	290	410
9	20	25	33	47	70	105	150	240	340	490
8	22	27	35	52	80	120	175	280	410	580
7	24	30	38	58	90	140	210	340	500	720
6	27	34	43	70	105	165	250	405	620	900
5	30	38	50	80	125	200	300	510	800	1150
4	38	50	68	105	185	260	400	670	1000	1500
3	50	65	90	150	240	380	600	1000	1600	2300

6.2.2. Calculations

Wind ratio	= 5:1		(Table 6.5)
Slope factor	= 2.0		(Table 6.6)
Available litter quantity	= 10.0 tonnes/ha		
Fuel corrector	= 1.1		(Table 6.8)
Rate of spread index	= 23m/hr		(Table 6.7)
R.O.S.I. x Fuel corrector	= 23x1.1	=	25m/hr
R.O.S. x Slope factor	= 25x2.0	=	50m/hr

6.3. METHOD - PINE FOREST

6.3.1. Use 6.1 wind ratio for dense stands and 4.1 for open stands.

6.3.2. Select slope, S.M.C. and A.F.F. as for jarrah.

6.3.3. Calculate available litter quantity as for jarrah (see 6.1.3.)

6.3.4. Enter table 6.7 with pine S.M.C. (from S.M.C. record), wind ratio, and wind velocity. Calculate R.O.S. for 7.5 to 8.5 tonnes/ha of litter fuel.

6.3.5. Multiply R.O.S.I. from table 6.7 by fuel quantity correction factor from table 6.9.

6.3.6. Multiply rate of spread adjusted for fuel quantity by slope correction if applicable, to give actual rate of spread.

6.4. EXAMPLE - PINE FOREST

6.4.1. Data (*P. pinaster*)

Litter depth	= 40 mm	
Total litter quantity	= 20 tonnes/ha	(Table 7.2.1.)
Pine S.M.C.	= 22 per cent	
Pine P.M.C.	= 95 per cent	
Therefore A.F.F.	= 0.4	(Table 5.4.1P)
Tower wind speed	= 21km/hr, 6:1 ratio	
Slope	= 0°	

6.4.2. Calculations

Available litter quantity	= 20x0.4	=	8 tonnes/ha
R.O.S. index	= 13m/hr		(Table 6.7)
Fuel correction factor	= 1.5		(Table 6.9)
Slope correction factor	= 1.0		(Table 6.6)
R.O.S. corrected for fuel quantity and slope	= 13x1.5x1.0	=	19.5m/hr

6.8 JARRAH - FUEL QUANTITY CORRECTION FACTORS

Select appropriate S.M.C. percentage class. Read off fuel correction factor opposite relative fuel weight or fuel age.

Fuel age falls (years)	Available fuel quantity (tonnes/ha)	Surface moisture content		
		19-26%	10-18%	3-9%
2	2.5-4.0	0.1	0.1	0.1
3	4.1-5.5	0.2	0.2	0.2
4	5.6-7.0	0.5	0.5	0.6
5	7.1-8.5	1.0	1.0	1.0
6	8.6-10.0	1.0	1.1	1.2
7	10.1-11.5	1.1	1.2	1.3
8	11.6-13.0	1.1	1.3	1.6
9-10	13.1-15.0	1.2	1.5	1.8
11-12	15.1-17.5	1.3	1.7	2.1
13-15	17.6-20.0	1.4	1.9	2.4
16-20	20.1-22.5	1.5	2.1	2.7
21+	22.6-25.0	1.6	2.3	3.0

Adjusted rate of spread = R.O.S. index x fuel correction factor.

6.9. PINE-FUEL QUANTITY CORRECTION FACTORS

Select appropriate S.M.C. class for either *P. pinaster* or *P. radiata*. Read off the fuel quantity correction factor opposite the relevant available fuel quantity. Multiply this factor by the rate of spread index obtained from the Jarrah Rate of Spread table (table 6.7.) to determine the corrected rate of spread for pine fuel on level ground.

Available fuel quantity* tonne/ha	Surface moisture content classes, %							
	Pinus pinaster 35-40	30-34	26-29	22-25	18-21	13-17	8-12	3-7
	Pinus radiata 30-35	25-29	20-24	16-19	12-15	9-11	6-8	3-5
4-9	1·0	1·1	1·2	1·5	1·9	2·2	2·5	2·7
10-14	1·0	1·2	1·5	1·8	2·4	2·8	3·2	3·5
15-20	1·2	1·5	1·8	2·2	3·0	3·5	4·0	4·4
21 +	–	–	2·0	3·0	4·0	4·8	5·5	6·0

* Available fuel quantity = Total fuel quantity x A.F.F.

6.7. JARRAH RATE OF SPREAD INDEX

Apply the surface moisture content and open wind velocity (tower wind). Read off the rate of spread index for 7.6-8.5 tonnes/ha of litter fuel - fuel quantity and slope corrections should be applied where appropriate by referral to Tables 6.8. and 6.6. respectively.

Wind rates	Tower Wind Velocity (kilometres/hour)													
1:1	0.0	1.0	1.7	2.5	3.3	4.1	4.9	5.7	6.5	7.3	8.1	8.9	9.7	10.5
	0.9	1.6	2.4	3.2	4.0	4.8	5.6	6.4	7.2	8.0	8.8	9.6	10.4	11.2
2:1	0.0	1.7	3.3	4.9	6.5	8.1	9.7	11.3	12.9	14.5	16.1	17.7	19.3	20.9
	1.6	3.2	4.8	6.4	8.0	9.6	11.2	12.8	14.4	16.0	17.6	19.2	20.8	22.4
3:1	0.0	2.5	4.9	7.3	9.8	12.1	14.5	16.9	19.3	21.7	24.1	26.3	28.9	31.3
	2.4	4.8	7.2	9.7	12.0	14.4	16.8	19.2	21.6	24.0	26.2	28.8	31.2	34.0
4:1	0.0	3.3	6.5	9.7	12.9	16.1	19.3	22.5	25.7	28.9	32.1	35.2	38.5	41.7
	3.2	6.4	9.6	12.8	16.0	19.2	22.4	25.6	28.8	32.0	35.2	38.4	41.6	45.0
5:1	0.0	4.1	8.1	12.1	16.1	20.1	24.1	28.1	32.1	36.1	40.1	44.1	48.1	52.1
	4.0	8.0	12.0	16.0	20.0	24.0	28.0	32.0	36.0	40.0	44.0	48.0	52.0	56.0
6:1	0.0	4.9	9.7	14.5	19.3	24.1	28.9	33.7	38.5	43.3	48.1	52.9	57.7	62.5
	4.8	9.6	14.4	19.2	24.0	28.8	33.6	38.4	43.2	48.0	52.8	57.6	62.4	67.2

Surface M.C.%	Jarrah Rate of Spread Index (F.D.I.) m/hour													
27+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	10	12	14	17	20	23	28	32	38	45
24	2	4	7	9	12	14	17	20	26	32	38	47	58	72
22	5	6	8	10	13	16	20	25	32	40	50	62	78	100
20	7	8	9	11	15	18	23	30	38	47	60	76	96	125
19	8	9	10	12	16	20	26	33	43	55	70	88	115	150
18	9	11	12	14	18	23	30	38	50	63	80	100	130	170
17	10	11	12	15	19	25	32	42	54	70	90	115	145	190
16	11	12	13	17	21	27	36	47	62	78	100	130	170	220
15	12	13	14	18	23	30	39	51	68	88	115	145	190	250
14	13	15	16	20	26	34	43	57	75	95	125	165	215	285
13	15	16	17	22	28	37	48	62	83	105	140	180	235	310
12	16	17	18	23	31	40	55	68	92	120	155	200	265	350
11	18	19	20	26	35	46	60	80	105	140	180	240	310	420
10	20	22	23	30	39	53	68	92	125	160	210	280	370	500
9	22	24	26	34	45	60	80	110	145	190	250	330	450	600
8	26	28	30	40	53	72	95	130	175	230	310	410	550	760
7	31	34	37	48	66	90	120	160	220	290	400	530	720	1000
6	37	40	43	58	80	110	145	200	280	370	500	680	940	1300
5	45	48	53	72	100	130	185	240	360	480	660	900	1250	1600
4	55	62	68	94	130	180	240	330	480	620	900	1250	1660	2300
3	75	82	90	120	170	240	320	450	650	880	1200	1650	2300	3200

LOW
MOD
HIGH
VERY HIGH
EXTREME
V. HIGH