GUIDE TO THE MEASUREMENT OF FOREST FUEL QUANTITY

by

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INTRODUCTION

When planning for prescribed burning and fire control operations it is essential to know the quantities of fuels present within the forest area. Litter quantities may often be estimated in the office from records of past burning and forest canopy cover. However litter quantities may have altered due to unforseen factors such as insect infestation of tree crowns, trade cutting and incomplete burning.

Other forest fuel components such as forest understorey vegetation (called scrub) and trash fuels, made up of twigs and dead scrub, cannot be calculated in the office from maps or records.

The need for an objective field checking and fuel quantity assessment method has led to the development of rapid and reliable sampling techniques based on direct measurements of litter depth, trash height and scrub density and height.

The assessment techniques are designed to enable two assessors to cover an average size aerial-burning block (10,000 acres) in two to four days depending on the forest types of the area.

For pine plantations and other valuable, high risk areas, a system of mapping litter depths has been developed which provides a quantitative measure of risks from changes in fuel and provides a basis for deciding correct conditions for lighting.

These notes describe sampling and mapping techniques for ground and scrub fuels and provide an example of field sheets, fuel quantity tables and appropriate assessment aids.

GUIDE FOR MEASURING FOREST FUEL QUANTITY

A. AERIAL PRESCRIBED BURNS

I. Assessing Litter Quantity by Depthing

Litter depthing is conducted with a litter depth gauge which consists of a wooden slide between metal rails attached to a scaled stand. The instrument is used by inserting the slide into a small hole made in the litter bed, and reading off the depth on the rule. It is essential that the base does not rest on twigs, stones and other debris and that there is no disturbance or mounding of the surrounding litter.

A reliable depth estimate is obtained by taking twelve measurements in a line at ten-yard intervals.

Space is provided on the Fuel Assessment Sheet No. 1 (Appendix 4) to record these depths, and to calculate the totals and the mean depth.

Convert depth to weight (tons per acre) by referring to Table 1 and 2 (Appendix 1).

To ensure that the assessment line is in the correct fuel type and age, it is advisable to "walk in" another 5-10 chains from the line and inspect the surrounding area.

N.B. Locate line well in from edges of roads or compartments as these edge zones often receive different fire treatment to the internal areas.

II. Assessing Trash Quantity by Heighting

"Trash" is the term given to the Stick layer present in nearly all karri and mixed karri forests. The trash consists of dead branch and stem debris of trees and understorey shrubs.

A rough relationship exists between trash weight and top height, which is the general trash ceiling level,

and which excludes irregularities caused by the occasional tall, upright branch of dead scrub.

An average trash top height is determined from 24 height measurements per line, preferably one on either side of the 12 sites selected for depthing. The trash contains a large proportion of heavy sticks and scrub stems; sparse trash usually consists of lighter tree and scrub debris.

Convert to tons per acre by referring to Table 3 (Appendix 2). This table also includes the weights of the trash portion with a diameter less than ½ inch, which is the fraction burnt under normal prescribed burn conditions.

III. Scrub Type and Quantity Assessment

Estimates of scrub weight are obtained by classifying the scrub into one of six recognized scrub structural types. These types are identified according to their density profiles and top heights. Each structural type may have a variety of dominant species types, but these must have a similar height-density profile in order to belong to that structural type. That is, scrub classification is based on structural rather than botanic differences.

Each type covers a range of cover densities rated as either sparse, medium or dense. Appendix 5 shows the six types in histogram form, and which, with practice, can be used to classify scrub by appearance only.

Before the assessor can utilize these histograms, it is necessary for him to conduct a small point-sampling trial each time he encounters a new scrub type. The trial requires twenty point-sample observations to be made in both the sparse and dense communities within the type. It is suggested that these be taken along a line at ten (10) feet intervals.

Point sampling is simply the recording of the number of contacts and the height at which the shrub foliage make with a tall (up to 13 ft.) thin, rod marked at one-foot intervals. The rod is carefully inserted vertically in

the scrub at each site. The scrub top height and the species type are also recorded on Field Sheet No. 2 at each site (See Appendix 4).

The number of contacts are totalled and an average value determined for each one-foot height interval. A density profile is drawn up for both scrub density extremes, and these are matched with one of the six standard types provided. Future classification may be done visually by reference to these density profile histograms.

Assessment of scrub is carried out simultaneously with litter and trash a sessments. At each of the twelve (12) observation points on the line, the following scrub features must be recorded; structural type, density rating, average top height, dominant species and an estimate of the percentage of scrub dead or cured. Scrub fuel loadings are determined from Table 4 in Appendix 3. Added to this table is the list of weights of foliage below four (4) feet. This is the amount usually burnt in mild prescribed burns.

Because scrub inflammability varies with species, it is necessary to introduce an inflammability factor which is directly related to the foliage dimensions and the estimated percentage of dead foliage. Table 5 (Appendix 3) lists the multiplicative factors for the common scrub communities.

The following is an example of how to calculate scrub fuel loading.

Consider a Structural Type 5 of medium density and with an average top height of 14 ft., with nectic (Bossiae aquilfolium) as a dominant species. Netic is considered to be relatively highly inflammable.

If prescribing for an all-foliage consuming burn, then foliage weight (Table 4) = 2.0 tons per acre. If foliage is 20 per cent dead, then inflammability factor for a high scrub is 1.5

Therefore, scrub fuel loading = 2.0 x 1.5 = 3.0 t.p.a.
For total scrub consuming burn, loading = 7.0 x 1.5 = 10.5 t.p.a.

IV. Location of Plot Lines

A stratified random sampling is employed in locating plot lines within large aerial burns. The office procedure is as follows:

(i) From past burning plans trace the areas of Same age burns onto the A.P.I. map of the proposed area. Label with the year and season of last burn.

(ii) Outline the major forest types within the areas of same burning age.

(iii) Select the upper and lower extremes of tree canopy cover in each forest type within each burn.

(iv) Randomly select sites for two sample lines within each canopy extreme for each forest type.

If there are more than three ages of burning or more than three major forest types, the number of sampling lines may be reduced to one line for each canopy extreme.

Locate the lines no closer than five chains from the edge of roads or compartments as these edge zones often receive different fire treatment to the internal areas.

(v) From the fuel accumulation tables (Peet 1970), determine the litter quantity in tons per acre for each sample site. This calculated value is compared with the field estimate as a check of the information provided from burning plans and A.P.I. maps.

(vi) The litter, trash and scrub fuel quantities at each site are added together, the values of which may be used to determine the range of expected fire behaviour within forest type and burning age classes. The prescriptions are then drafted indicating the number and sequence of lightings required to burn the area within acceptable fire intensity limits.

B. VALUABLE, HIGH RISK STANDS

High risk areas such as pine plantations and young regrowth stands require more accurate assessment of fuels present within individual compartments. A fuel mapping technique was developed which provides a quantitative measure of risks from change in fuel.

Pine Plantations

Litter depthing is conducted on a grid basis the spacing of which depends on uniformity of fuels. Most stands are measured on a 3 chain x 3 chain grid. Edges of compartments are measured more intensively, i.e. at $1\frac{1}{2}$ chain spacing, because of the heavier fuel accumulation in these zones.

Mapping is done directly on the field sheet (Field Sheet No. 3) which is ruled into $\frac{1}{2}$ inch x $\frac{1}{2}$ inch squares. The field sheet is orientated to the planting line and the north-directing arrow marked in. Depths are recorded in each square commencing at the appropriate corner of the sheet.

Also recorded within each square is the scrub types present, their top heights, and estimated percentage ground cover. Space is also provided to record details about the stand, thinning and pruning history, and period since last burn.

In the office, the fuel contours at selected depth or fuel quantity intervals are shaded in and scrub areas marked in. Areas requiring attention are noted for possible exclusion or special treatment.

In thinned stands it is necessary to assess the needle fuel present on thinning tops. The method developed requires a butt girth measurement of 50 thinning crowns throughout the compartment. The mean girth value is read into Table 6 (Appendix 6) which gives the tonnage of needles and twigs per 100 tops. The number of tops present is equal to the number of trees thinned. The calculated weights of thinning tops are added to the weight of available litter fuel for burning prescription purposes.

Hardwood Regrowth Stands

It is not necessary to assess fuel quantity within regrowth stands to the same degree as pine plantations. This plus the fact of limited access within these stands make it necessary to reduce sampling somewhat.

The overall area should be divided into convenient blocks of about 200 to 300 acres, bounded by roads. Measurements of litter depth, trash height and scrub type, height and density are conducted at ten-chain intervals one chain in along the perimeter. Two lines either parallel to, or bisecting each other are also taken through the heart of each block.

After litter, trash and scrub fuels have been converted to tons per acre, these can be mapped on A.P.I. base plans showing forest type and canopy. Topographic features such as ridges and gullies should be marked in as these help to define boundaries of scrub and forest types. From these well-defined zones become evident which give guidelines to the probable fire behaviour and the number and sequence of lightings required to burn the area within acceptable scorch and butt damage limits.

APPENDIX 1 Table 1 7 (a)

Fuel Depth - Weight Table for Hardwood Forest Types

Litter Depth inches	Karri (K, KM, KMJ)	Jarrah (J, JM)	Marri near Karri (MK)	Marri near Jarrah (MJ)
	Tons per acre (O.D. Wt.)			
0.1	0.7	0.7	0.7	0.7
0.2	1.3	1.3	1.2	1.2
0.3	2.0	1.8	1.7	1.7
0.4	2.6	2.3	2.2	2.1
0.5	3.3	2.8	2.7	2.5
0.6	3.9	3.3	3.2	3.0
0.7	4.5	3.8	3.7	3.4
0.8	5.2	4.4	4.1	3.7
0.9	5.8	4.9	4.7	3.9
1.0	6.5	5.4	5.2	4.2
1.1	7.1	5.9	5.7	4.4
1.2	7.8	6.4	6.3	4.6
1.3	8.4	6.9	6.8	4.8
1.4	9.1	7.4	7.4	5.1
1.6	10.4	8.4	8.2	5.5
1.8	11.7	9.5	8.8	6.0
2.0	13.0	10.5	9.4	6.5
2.2	14.3	11.5	10.0	7.0
2.4	15.6	12.5	10.6	7.5
2.6	16.9	13.5	11.2	7.9
2.8	18.2	14.5	11.8	8.4
3.0	19.5	15.5	12.4	8.9
3.2	20.8			
3.4	22.1			
3.6	23.4			
3.8	24.7			
4.0	26.0			
4.5	29.3			
5.0	32.5			

APPENDIX 1 Table 2. 7 (b)

Fuel Depth -Weight Table for Needle Litter Types

Litter Depth Inches	Monterey Pine (P.radiata)	Maritime Pine (P.pinaster)	Karri-oak (Casuarina decussata)
	Tons per acre (O.D. Wt.)		
0.2	0.9	1.5	1.3
0.4	1.7	2.5	2.6
0.6	2.5	3.4	3.7
0.8	3.2	4.2	4.7
1.0	3.9	5.0	5.6
1.2	4.6	5.6	6.1
1.4	5.2	6.3	6.6
1.6	5.8	6.9	7.1
1.8	6.3	7.6	7.5
2.0	6.8	8.2	7.9
2.2	7.3	8.9	8.3
2.4	7.7	9.5	8.7
2.6	8.1	10.2	9.0
2.8	8.4	10.8	9.4
3.0	8.7	11.5	9.7
3.5	9.4	13.1	10.5
4.0	10.0	14.7	11.2
4.5		16.3	11.9
5.0		17.9	12.5
5.5		19.6	13.1
6.0		21.1	13.7

APPENDIX 2 Table 3. 7 (c)

Trash Weight Tables

Depth feet	Dense (heavy sticks) Total	Dense (heavy sticks) Less than ½" diam.	Sparse (old dead scrub) Total	Sparse (old dead scrub) Less than ½" diam.
	tons per acre			
0.5	3.8	2.2	2.4	1.0
1.0	7.5	4.4	4.7	2.1
1.5	11.3	6.7	7.1	3.1
2.0	15.0	9.1	9.5	4.2
2.5	18.8	11.3	11.8	5.2
3.0	22.5	13.6	14.2	6.3
3.5	26.3	15.8	16.0	7.3
4.0	30.0	18.0	18.0	8.4

APPENDIX 3 Table 4. 7 (d)

Scrub Weight Tables

Scrub Structural Type	Ave. Top Ht. (Ft)	Total Live Scrub Wt. (t.p.a.)			Total Foliage Wt. (t.p.a.)			Foliage Wt. Below 4ft. (t.p.a.)		
		D	M	S	D	M	S	D	M	S
1	25	16.5	14.0	12.5	3.5	3.0	2.8	0.2	0.3	0.4
	20	14.0	12.5	10.5	3.2	2.8	2.5	0.2	0.3	0.4
	18	12.0	11.0	9.0	2.7	2.5	2.2	0.3	0.3	0.3
	16	9.0	8.0	7.0	2.1	2.0	1.8	0.3	0.3	0.3
2	25	19.5	17.0	15.5	3.8	3.5	3.2	1.2	1.0	0.6
	20	17.0	15.0	13.0	3.5	3.2	2.8	1.2	0.9	0.5
	18	15.0	13.5	11.5	3.2	2.8	2.5	1.2	0.8	0.5
	16	13.0	11.5	10.0	2.8	2.5	2.2	1.0	0.7	0.4
3	10	7.5	5.0	3.0	2.0	1.6	1.2	0.6	0.5	0.4
	8	5.5	3.5	2.2	1.6	1.2	1.0	0.6	0.5	0.4
	6	3.0	2.2.	1.6	1.2	1.0	0.8	0.8	0.6	0.5
	4	2.0	1.5	0.8	1.0	0.8	0.5	1.0	0.8	0.5
4	18	12.5	10.0	8.0	3.5	2.8	2.2	0.6	0.5	0.5
	16	10.5	8.0	6.0	3.0	2.5	1.8	0.6	0.5	0.5
	14	9.0	6.5	4.0	2.5	2.0	1.5	0.5	0.4	0.4
	12	7.5	5.0	2.5	2.0	1.5	1.0	0.5	0.4	0.4
5	20	14.0	11.0	8.0	3.0	2.5	2.0	0.4	0.3	0.3
	16	11.0	8.5	6.5	2.8	2.2	1.8	0.4	0.3	0.3
	14	8.5	7.0	5.5	2.5	2.0	1.6	0.5	0.4	0.4
	12	7.0	5.5	4.5	2.2	1.8	1.4	0.6	0.5	0.4
	10	5.5	4.5	3.5	1.8	1.5	1.2	0.6	0.5	0.4
6	5	3.0	2.0	1.8	1.6	1.2	1.0	1.5	1.2	1.0
	4	2.2	1.8	1.5	1.4	1.0	0.8	1.4	1.0	0.8
	3	1.5	1.2	1.0	1.2	0.8	0.6	1.2	0.8	0.6
	2	1.0	0.8	0.6	0.8	0.6	0.5	0.8	0.6	0.5

APPENDIX 3 Table 5 7 (e)

Scrub Inflammability Factors

Scrub Communities	Type Nos.	Young Green	Percentage Dead 20	50	80+	Examples
Heath (up to 4ft.)	6					
High inflammability		1.0	1.5	3.0	5.0	
Low inflammability		0.2	1.0	2.0	3.0	
Ti-tree types		0.5	1.5	3.0	5.0	Agonis parviceps
Medium Scrub (4-12 ft.)	3,5					
High inflammability		0.3	1.5	2.5	4.0	Prickly Moses, Netic Karri wattle.
Low inflammability		0.1	1.0	1.5	2.0	
High Scrub (12-25 ft.)	1,2, 5					
High inflammability		0.5	1.5	3.0	4.0	Casuarinas
Low inflammability		0.1	0.5	1.0	2.0	Hazel
Grasses High Inflam	6	1.0	2.0	3.0	4.0	Kero Grass
Low Inflam.		0.1	0.5	1.0	2.0	Rushes

Multiply Scrub Weight (Table 4) by Inflammability Factor to determine Scrub Fuel Loading.

APPENDIX 4

FUEL ASSESSMENT SHEET NO. 1

AREA LOCATION ..... DATE.....
LINE NO..... FOREST TYPE .....
AV. TREE HT. (FT)..... CANOPY COVER .....%
YEAR OF LAST BURN..... SEASON.....
MAJOR SCRUB SPECIES.....

OBSERV. NO.	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL	AVER.
Litter Depth (ins)														
Trash Ht.														
(FT.)														
Scrub No.														
Density														
Top Height														
% Foliage Dead														

Litter Wt. (K, M or J) = T.P.A. Trash Wt. = T.P.A.
Total Live Scrub Wt. = T.P.A. Foliar Wt. = T.P.A.
Wt. of Foliage Below 4 ft. = T.P.A. Grass Dens.

LINE NO..... FOREST TYPE.....
AV. TREE HT. (FT)..... CANOPY COVER.....%
YEAR OF LAST BURN..... SEASON.....
MAJOR SCRUB SPECIES.....

OBSERVE. NO.	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL	AVER.
Litter Depth (ins)														
Trash Ht.														
(FT.)														
Scrub No.														
Density														
Top Height														
% Foliage Dead														

Litter Wt. (K, M or J) = T.P.A. Trash Wt. = T.P.A.
Total Live Scrub Wt. = T.P.A Foliar Wt. = T.P.A.
Wt. of Foliage Below 4 ft. = T.P.A. Grass Dens. =

APPENDIX 4 FIELD SHEET NO. 2

SCRUB POINT SAMPLING LOCATION: DATE:

HEIGHT INTERVALS

NO. OF RODS	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12 to 14	14 +	SCRUB TYPES
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
TOTALS															
AVERAGE															

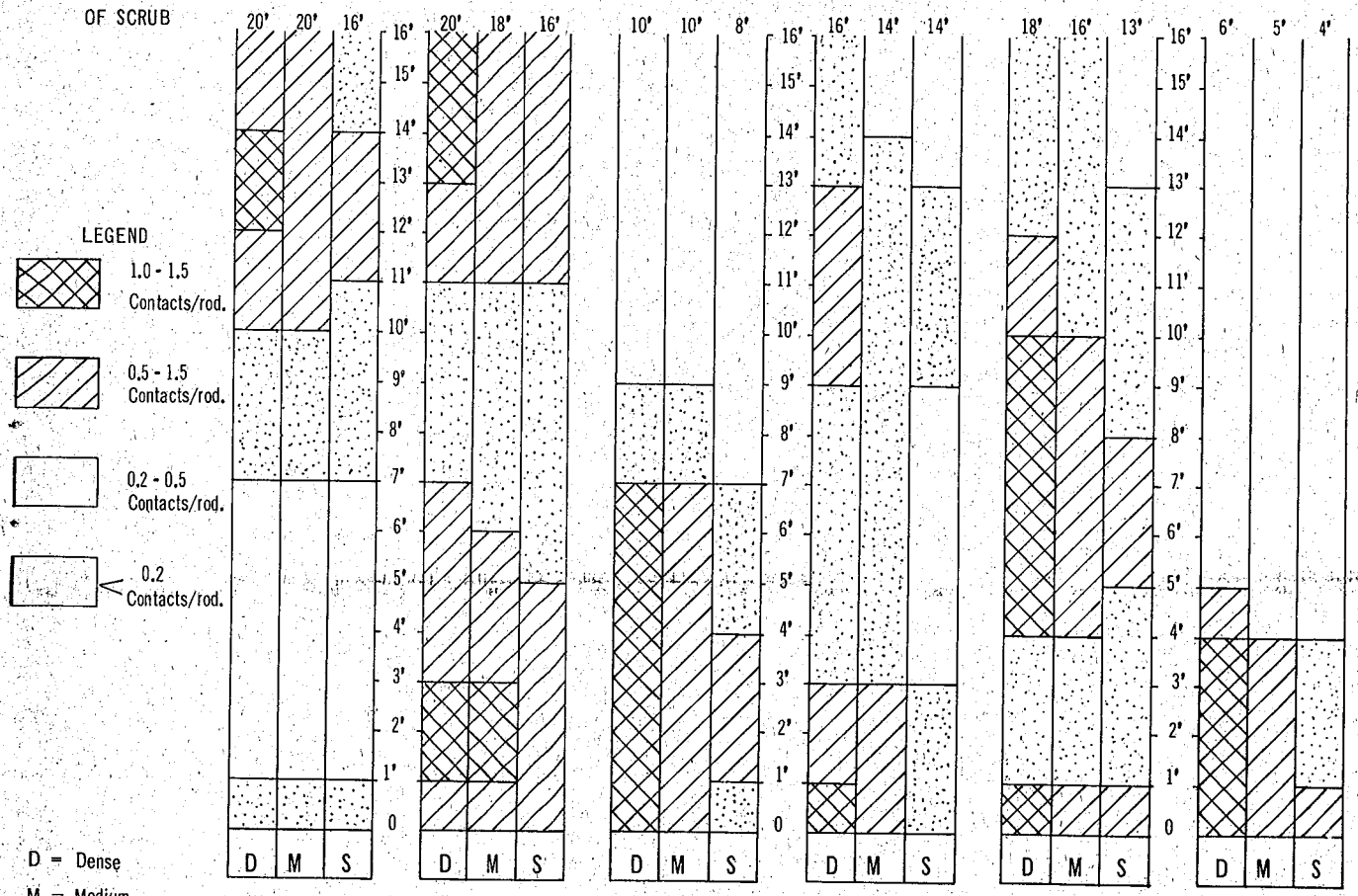
DOMINANT SCRUB TYPES:

STRUCTURAL TYPE:

APPENDIX 5

7 (h)

SCRUB DENSITY PROFILES OF SIX COMMON STRUCTURAL TYPES



TYPE 1
HAZEL
MOCK-OAK
KARRI-WATTLE
NETIC
NO GRASS

TYPE 2
HAZEL
MOCK-OAK
BRACKEN
RUSHES
GRASS

TYPE 3
HOVEA
KARRI-WATTLE
PRICKLEY-MOSES
RUSHES
GRASS

TYPE 4
TI-TREE
KARRI-WATTLE
CASUARINA
MOCK-OAK
GRASS

TYPE 5
NETIC
KARRI-WATTLE
HAZEL
SHARK-TOOTH
PRICKLEY-MOSES

TYPE 6
SCRUB FUELS OF THE JARRAH & MARRI FORESTS

APPENDIX 6 Table 6 7 (i)

P. pinaster Thinning Crown Weights in Tons per acre (O.D. Wt.) per 100 tops

Crown Butt Girth ins.	Foliage Weight T.P.A.	Twigs Weight T.P.A.	Crown Butt Girth	Foliage Weight T.P.A.	Twigs Weight T.P.A.
6.0	.17	.04	13.5	.95	.23
6.5	.22	.05	14.0	1.00	.24
7.0	.27	.07	14.5	1.07	.26
7.5	.32	.08	15.0	1.11	.27
8.0	.38	.09	15.5	1.16	.28
8.5	.43	.10	16.0	1.21	.29
9.0	.48	.11	16.5	1.27	.30
9.5	.53	.13	17.0	1.31	.31
10.0	.59	.14	17.5	1.37	.33
10.5	.63	.15	18.0	1.42	.34
11.0	.69	.17	18.5	1.47	.36
11.5	.74	.18	19.0	1.53	.37
12.0	.79	.19	19.5	1.58	.38
12.5	.85	.20	10.0	1.63	.39
13.0	.90	.21	20.5	1.68	.40

Enter Table 3 with mean butt girth of thinning crowns (from 50 measurements) and read off Foliage and Twigs weight in T.P.A per 100 tops. To derive at total tons per acre multiply the table value by the number of trees thinned per acre, divided by 100.

APPENDIX 6 PINE FUEL DATA SHEET No.3. 7 (j)

Date: 6/9/71 Location: Ludlow Compt. 48 Date Planted: 1936 Spacing: 8 x 6

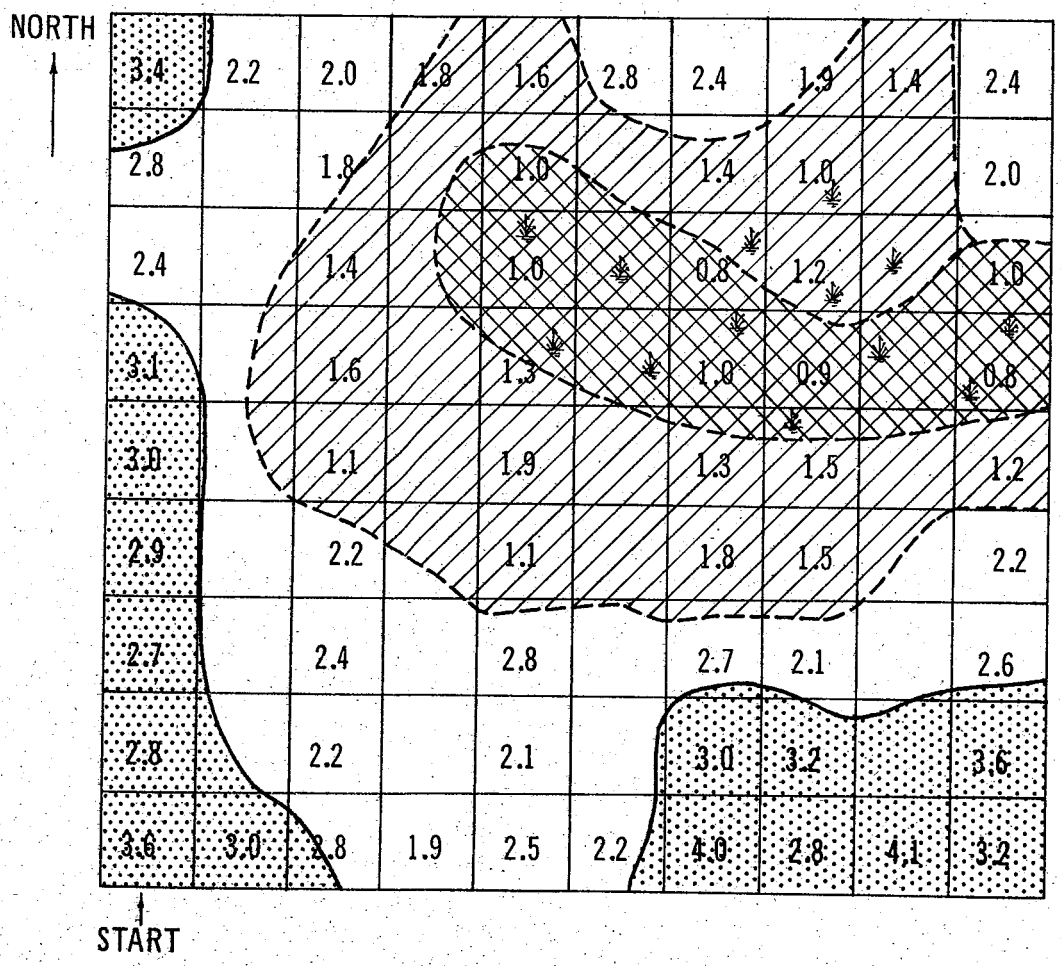
Fuel Type: Needles pruned: yes tops: No Co-dom height: 45′

Stocking: 450 Green crown height: 25′ Scrub type: Hib. hypericoides Height: 2′ - 3′

Density: Med. Slope: 2° Aspect: North Area: 18 ac.

Date thinned: 1950 Date previously burned: 1968 Type of burn: edge only

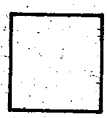
Scale: 1" = 3 chain



LEGEND


< 1.0"


1.0" to 2.0"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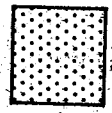
> 3.0"


Swamp